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Small wetlands: identification, significance and threats to their loss. A review of the literature

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SUMMARY
Small wetlands (<10 hectares) – past and present – can be important archives of palaeoenvironmental and archaeological remains. Yet this 'historic environment' potential is not always recognised or realised, especially in a context of different land-use pressures and land management priorities acting on the sites. This document describes a range of small wetland types – both natural and artificial – that might be encountered within England, with indications of their geographical spread and limits provided where appropriate. Specific examples and case studies are used in order to illustrate the range and wealth of palaeoenvironmental and archaeological information that such features can provide, in the anticipation that the deposits which they contain are recognised for their inherent value, particularly before any maintenance/clearance/'restoration' works are carried out.

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Cover image: Kettle hole feature at Sizergh Park, Cumbria. Photo: Z. Hazell © Historic England.

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1 INTRODUCTION

1.1 Project background

The importance of large wetlands as archaeological and palaeoecological archives – due to the exceptional preservation of organic remains in waterlogged conditions – has long been recognised. Such preservation is well demonstrated at sites in the Somerset Levels, SW England, such as Glastonbury Lake Village (Iron Age) (National Heritage List for England (NHLE) ref. 1006156) and The Sweet Track (Neolithic) between Westhay and Shapwick in the Brue Valley (NHLE ref.s 1014440, 1014831, 1014439 and 1014438), where a series of excavations recovering archaeological remains, together with associated palaeoenvironmental studies, was carried out as part of the *Somerset Levels Project* (see work led by Coles and Coles, published in the Somerset Levels Papers series). Furthermore Historic England (formerly as English Heritage) has funded studies that have focussed on large-scale lowland and upland wetlands such as the *Humber Wetlands Project* (Van der Noort 2004), the *North West Wetlands Survey* (eg Hodgkinson *et al* 2000) and the *Upland Peats* project (Oxford Archaeology North, 2011).

However, it is increasingly being recognised that small, discrete wetlands can also be important archives of archaeological and palaeoenvironmental deposits. In 2011 Historic England's (then as English Heritage) *National Heritage Protection Plan* (NHPP) specifically identified that these types of deposit are insufficiently understood, and that because they are potentially at risk of loss, they need to be highlighted in terms of their heritage value and significance[1]. As a result of this, NHPP Project 3A5.203 '*Small wetlands: their definition, potentials and threats*' was set up (see project design document by Hazell (2012))[2]. The overarching aim of the project was to inform the public, professionals, and stakeholders (such as land owners and land/site managers) about the types of small wetland features found and their importance in terms of their palaeoenvironmental and archaeological potential. It was considered

1 It was NHPP Measure 3 'Recognition and Identification of the Resource' that focused on identifying nationally significant heritage landscapes and assets in order to enhance their protection. Within this Measure, Activity 3A5 'Identification of wetland/waterlogged sites' the requirement to assess 'the distribution and heritage value of small wetlands' was identified as a necessary component.

2 The project also fell under: i) English Heritage's revised wetland strategy Theme 1 'Understanding the distribution, character and value of wetland and waterlogged archaeology', section 1.1 'Bring knowledge of under-represented wetland/waterlogged categories to levels comparable *with lowland peatlands and alluviated lowlands, prioritising those under particular pressure*' (Heathcote 2012), and ii) SHAPE sub-programme 11111.140 '*Understanding place: assessing the national resource*' (English Heritage 2008).

important to describe and illustrate clearly the types of features that might be encountered, so that they might be recognised more-readily on site.

1.2 Scope of this document

This report is the first stage in addressing the requirement outlined above, by reviewing the literature available to i) describe the formation, characteristics and age of multiple types of both natural and artificial small wetlands (defined here as <10 hectares) found within England (to match Historic England's area of responsibility), using examples, ii) explain and describe their palaeoenvironmental and archaeological potential and iii) highlight the potential threats to the survival of these deposits.

The review here has been written with the next stage of this project in mind; it will be used to inform a shorter document summarising the characteristics, research potential of and threats to small wetlands, aimed specifically at raising their profile and highlighting their importance to land managers and land owners to help guide small wetland management practices in terms of historic environment considerations. For this reason, focus has been placed on good case studies that will help illustrate the subsequent document.

Features included here focus on extant wetlands[3], as these are features that are often at risk of being drained or cleared out for water and/or wildlife management purposes. They include features that are open waterbodies and those that are permanently- and intermittently-waterlogged at the surface. It should be noted that extant wetland sites might be significantly reduced in area compared with their previous extent, and so their associated waterlogged sediments might still be present elsewhere at depth. The same applies to now extinct wetlands; where examples of these have been included, it is to help demonstrate the potential of these deposits, and their usefulness even if they have become dry/covered at the surface. Where extinct features are discussed, this is because there might be a lack of extant examples; including them also highlights the importance of today's wetlands in terms of preserving their records for future investigation.

Where possible, the sites included focus on those that contain evidence of past environmental and landscape change and of human activity – directly (eg archaeology) or indirectly (eg indicators of agriculture, industrial activity). Only examples from England have been included.

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3 According to Ramsar, wetlands are "areas where water is the primary factor controlling the environment and the associated plant and animal life. They occur where the water table is at or near the surface of the land, or where the land is covered by water" (Ramsar 2009).

1.3 Explanatory notes

All site locations are reported where available, and follow the National Grid Reference scheme. Where given in the original texts, site locations are reported in parentheses (…) and where locations have had to be derived from maps or other sources they are reported in square brackets [...]. In some reports, no indication of location (either map or grid reference) was provided. Site names are given in **bold** and terms that appear in the glossary are given in ***bold italics*** at their first use. A table of the geological and equivalent archaeological time periods is in Appendix 1.

The document has been laid out according to feature types (and thus, formation processes), because it is important that they can be recognised in the field. Although they have been grouped this way, many have the potential to contain the same types of remains and for the application of the same investigative techniques, for example, a lake whether it has been formed through natural or artificial processes. Also, some features could have a complex history; for example natural hollows that have been excavated subsequently eg for watering stock.

The type and formation processes of a particular wetland feature might not be known before it is investigated on-site, and therefore it might only be labelled on Ordnance Survey maps as a broadly termed feature such as ‘marsh’, ‘reedswamp’, ‘pool’, ‘pond’, ‘mire’, ‘common’ or ‘withy’. Only with detailed investigations might it be possible to determine its type.

A map showing the main sites referred to in the text is presented in Section 3.2.

2 SMALL WETLANDS – THEIR ARCHAEOLOGICAL AND PALAEOENVIRONMENTAL SIGNIFICANCE

Given the potential for organic remains within small wetland sites to be extremely well-preserved, a wide range of palaeoecological techniques can be applied to infer past human activities and/or to reconstruct former vegetation and palaeo-environmental/climatic conditions. Commonly-used palaeoenvironmental ***proxy*** methods include i) pollen and plant macrofossil remains (leaves, seeds, wood etc) for vegetation histories, ii) insects, particularly beetles , iii) ***molluscs***, iv) ***ostracods***, v) ***chironomids***, vi), ***Cladocera*** vii) ***testate amoebae***, viii) ***diatoms*** and ix) ***isotopes.*** Reconstruction of past environments/environmental conditions is based on our understanding of the proxies' current ecological requirements, which are measured and modelled first. The most appropriate techniques used will depend on the characteristics of the site itself; factors such as geology, site formation processes and constituent sediments will influence what occurs – from what was originally present, and what has been preserved. The relevant methods can be applied equally to natural and artificial features to reconstruct site histories, examples of which include a) ***anthropogenic*** effects on the vegetation eg 'exotic' introductions, forestry (pine) plantations, b) erosion events in the catchment (climatic or anthropogenic), c) industrial activities eg ***retting***, mineral extraction, and d) pollution events and site 'recovery' (returning to conditions prior to such an event). Using a multi-proxy approach (a combination of different lines of evidence) produces a more reliable site record.

As well as the types of archaeobotanical and palaeoenvironmental remains (outlined above) that will inform on human activities and uses of small wetland sites and their immediate vicinity, artefactual and structural remains (eg timbers of watermills and bridges) can be exceptionally well preserved too.

The variability in form and formation processes of the features themselves, has meant that this literature review has drawn on multidisciplinary information sources; including those from ***Quaternary*** science, archaeology, palaeoclimatology, palaeoecology and geomorphology (***glacial*** and ***periglacial***).

2.1 Natural Features

2.1.1 Glacial

This section describes features that have formed as a result of a direct presence of ice. Whilst high in terms of palaeoenvironmental potential, the oldest deposits often lack archaeological remains. Within the British Isles, such features are most common north of the most southerly limits of the main late ***Devensian*** ice sheet (see Section 3.2), although Dartmoor, on the south-west peninsula, away from the main ice cover, was covered by a discrete ice mass, resulting in the presence of glacial features further south than would otherwise be expected (see Evans *et al* 2012).

2.1.1.1 Kettle holes/kettle lakes

As a glacier retreats, large blocks of ice become detached and are incorporated into the glacial ***till***, buried by debris produced from ***glacial ablation*** and outwash processes. When these 'dead ice' masses melt, the debris resting on top slumps relative to the ground level around it, forming a 'kettle hole' (Anderson 2004). In England these can occur anywhere within the limits of the main late Devensian ice advance (Goudie 1990); although there are particular concentrations on the Shropshire-Cheshire Plain and in East Yorkshire. Frequently these depressions fill with rainwater, to become 'kettle lakes', which gradually infill with lake silts, ***gyttja*** and peat sediments, providing valuable continuous palaeoenvironmental sequences from the ***late glacial*** period onwards. Some East Yorkshire sites with late glacial-early ***Holocene*** deposits include more obvious infilled kettle hole features, for example that of Dishforth Bog, North Yorkshire (Giles 1992), and remains of (possible) kettle hole deposits exposed during quarry works eg Gransmoor Quarry (TA 113 597) (Walker *et al* 1993) and Routh Quarry (TA 087 437 to TA 097 435) (Gearey and Lillie 2001; Gearey 2008). An example of a site where the palaeoenvironmental record extends further into the Holocene and where archaeological remains have also been found is that of Skipsea Withow ***Mere***, Holderness (Gilbertson 1984; Gilbertson *et al* 1987).

At **Dishforth Bog** (Figure 1) (SE 3768 7361) (*c* 10 ha) (Giles 1992) (one of a group of three proximal kettle holes) pollen and mollusc remains were analysed from Late Devensian and early Holocene silt and peat deposits (>3m thick). The record demonstrated the shift to an ameliorating climate at the start of the Holocene (with increased vegetation cover), interrupted by a decline in *Betula* (birch) aligned with a temporary return to more-open conditions. A similar vegetation record was reconstructed from the site of what was considered to be a former kettle hole, near **Kildale Hall**, NE Yorkshire (NZ 609 097) (Kildale Hall ***Site of Special Scientific Interest*** (SSSI) ref. 1005709) where Late Devensian and early Holocene sediments were analysed for molluscs and ostracods (Keen *et al* 1984) and compared to the pollen and plant macrofossil records (Jones 1971; 1976; 1977a). Previously, an almost complete disarticulated *Bos primigenius* (aurochs) skeleton had been found at the site (reported in Jones 1977b, 354), who postulated that this was linked to Mesolithic hunting activities occurring at the wetland and maintenance (through grazing) of more-open vegetation.

Figure 1. Aerial view over Dishforth Bog (the triangular depression slightly above the centre of the photo), September 2016. Photo: M. Oakey © Historic England (ref. 28930_022).

Skipsea Withow Mere (TA 185 545) (Withow Gap, Skipsea SSSI ref. 1003207) (Figure 2) on the Holderness coast contains a palynological record that provides clear evidence for human activity during the Neolithic (Gilbertson *et al* 1987); mixed woodland of oak, alder, elm and lime which was present in the mid Holocene seems to have been largely cleared some time during the Neolithic. Multiple timbers found at the site were interpreted as piles and pegs for structures around the former lake (Gilbertson 1984). Although Gilbertson (1984) also interpreted working markings on early Neolithic alder timbers as strongly indicative of ***coppice*** management of alder ***carr*** woodland (indicating exploitation of the wetland margins of the site), later excavations at the site recovered several pieces of timber with clear beaver tooth marks and Taylor (2009) suggests that the 'coppiced' fragments from earlier excavations might in fact have been felled by beavers. It would appear from historical evidence that Skipsea Withow Mere continued to be important until the late Medieval period, when it was breached and drained by coastal erosion (Gilbertson *et al* 1987). The archaeological remains recovered include an early Mesolithic bone harpoon, flint tools and remains of elk, reindeer, red deer and pike (Armstrong 1922; 1923). Some of these were exposed in the cliff face following a phase of coastal erosion noted by Armstrong (1923), processes that are ongoing today.

Figure 2. Skipsea Withow Mere: (a) the exposed section (Photo: © P. Murphy), and (b) showing the high degree of preservation of the organic remains, notably the hazel nuts (Photo: © J. McCarroll).

(a)  (b) 

Blelham Tarn is a well-studied lowland lake *c* 0.1sq km in the Lake District area of Cumbria, associated with the adjacent Blelham Bog – described as a double 'kettle-hole'-like feature by Evans (1970), who also reported that the area of the tarn is smaller than it once was (Evans 1970, 849 and fig 4). Together they are Blelham Tarn and Bog SSSI (ref. 1002887) (NY 365 005) and Blelham Bog is also a National Nature Reserve (NNR) (ref. 1006018). Multiple pollen and diatom studies have been carried out at the site, including Evans' (1970) Late Devensian and Holocene record, as well as a study of Cladocera and Chironomids (Harmsworth 1968). There is also evidence for an anthropogenic ***eutrophication*** signal commencing *c* 1926-1930 as a result of land use changes including sewage disposal and the use of agricultural fertilisers (see Pennington 1991, 16). A more-recent study of its sediments revealed an exponential increase in soil erosion within the catchment over the last 40 years, interpreted as a direct response to increased pressure from sheep grazing (Van der Post *et al* 1997). Oldfield (1970) considers the site's more-recent vegetation development (over the last 200 years) with respect to the rationale for its purchase for protection in 1954. He concluded that all the changes in vegetation within that time could be related to human activities (including: peat cutting, and lowering Blelham Tarn's lake level) (Oldfield 1970, 156) rather than ***hydroseral succession***.

A multi-proxy palaeoenvironmental investigation of late Devensian and early Holocene deposits within a kettle hole – a *c* 150m diameter wetland – at **Lilburn South Steads** [NU 0280 2340[4]], near Wooler, NE Northumberland was carried out by Jones *et al* (2000). Pollen, molluscs and ostracods were used to reconstruct past vegetation of the environs, the kettle hole's hydroseral succession and changes in lake levels. From these, past climatic conditions were

4 Note that the grid reference NU 4028 6234 stated in the original publication is incorrect.

inferred. Problems of 'old carbon' contamination possibly affecting radiocarbon dating results were highlighted here, as radiocarbon ages were older than their respective pollen signal indicated.

Work by Oxford Archaeology North (OAN) at the National Trust property **Sizergh Park**, Cumbria has investigated the palaeoenvironmental record of waterlogged kettle hole deposits (*c* 150x70m) (SD 500 875) (Figure 3). Stratigraphical and palynological investigations of the peat and the underlying mineral deposits suggest that the earliest sediments are typical of the late glacial/early Holocene (OAN 2014). Radiocarbon dating of the overlying peat indicates that it extends from the early Mesolithic to late Roman/early medieval period (although the upper peat could have been truncated) (OAN 2014). On top sits a burnt mound, previously radiocarbon dated to the Late Neolithic/Early Bronze Age (OAN 2013).

Figure 3. Looking south west across the marshy kettle hole feature at Sizergh Park (a National Trust property). Photo: Z. Hazell © Historic England.

Norton Farm Pit, **Condover**, Shropshire (SJ 494 073), found during quarrying works, is an important site due to the discovery there between 1986-1988 of woolly mammoth bones (*Mammuthus primigenius*) from multiple individuals (Coope and Lister 1987; Scourse *et al* 2009). Palaeoenvironmental work that put the mammoth in their landscape context was carried out on the kettle hole infill deposits (Allen *et al* 2009) and the bones themselves are described by Lister (2009).

2.1.1.2 Tarns

Strictly, tarns are lakes that have formed in the glacial features known as ***corries***, found on upland slopes (although many lakes in upland areas are called 'Tarn'). If they are within the limits of the most recent ice advances, then they are unlikely to contain pre-glacial deposits. Tarns are frequent features within the English Lake District (Cumbrian massif) region in north-west England.

Angle Tarn, Bowfell, Cumbria [NY 417 143] is a 3.4ha upland lake situated within a corrie, sited in the path of the former ***Loch Lomond Stadial*** (readvance) glacier. Importantly, it contains what is thought to be a complete ***post-glacial*** record – something that other tarn sediments often lack. The pollen records show upland forest clearance *c* 5000 years BP in an area where soils had already begun to acidify (see Pennington 1991, 18-19).

2.1.1.3 Other

Embleton's Bog, on the coastal plain near Bamburgh, Northumberland [NU 16500 29600] is an area of peatland located near Bradford Kaims [***kame***] (possibly an ***esker***[5]). Although the area of peat preserved at depth is larger than 10ha, this site is included here because of the readily-observed smaller areas that are waterlogged at the surface. Coring has identified that this area was once part of a larger lake (Bartley 1965) that was itself part of a lake system (see Gething *et al* 2013, fig 1). The sediments transition from (late-glacial) lake clays and ***marls***, to reedswamp and then to *Sphagnum* bog (Bartley 1965). More-recently palaeoenvironmental and archaeological investigations have taken place as part of the '*Bradford Kaims Wetland Heritage Project*' (see Gething *et al* 2013; Dixon *et al* 2015). Archaeological features discovered at the site include a complex of burnt mounds – one of which sits on a promontory of higher ground between two waterlogged depressions (see Figure 4) – and waterlogged artefacts including a Neolithic paddle on a brush wood platform (Bamburgh Research Project 2013). ***Pollen analysis*** from the area has shown the *Ulmus* (elm) decline (Bartley 1965; Gething *et al* 2013) and the rise of cereal cultivation (Gething *et al* 2013; Dixon *et al* 2015).

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5 Although the ridge appears to be an esker, the sediments are unsorted which is not typical of eskers (Bartley 1965).

Figure 4. Aerial view of burnt mound excavations at Bradford Kaims, showing waterlogged depressions separated by the higher promontory. Photo: courtesy of T. Gardner © Bamburgh Research Project.

Bartley (1965) compared Embleton's Bog record with that from a small, higher altitude wetland site (a possible kettle hole) on **Longlee Moor**, Northumberland (NU 156 195) – a 40m wide depression containing 3m of sediments. Despite their close proximity (*c* 11km) differences between the records, in particular their asynchronies, likely reflect their difference in altitude (Bartley 1965, 149).

Crag Lough, Northumberland (NY 766 680) (Figure 5) is a lake within a glacially-eroded hollow at the foot of a line of crags (Whin Sill) upon which sits Hadrian's Wall. Pollen, charcoal and sedimentological analyses showed that there was a vegetation mosaic of woodland, heather moorland, pasture and arable land by the time of Roman occupation (Dark 2005). It seems that the local section of Hadrian's Wall was constructed in an area that was already largely cleared of woodland. Evidence for a decline in local land management practices involving fire following the establishment of the Hadrianic frontier is interpreted as possibly reflecting the removal of some native settlements (Dark 2005). Local cultivation of *Secale cereale* (rye) seems to have been introduced by the Romans, and this appears to have ceased at the end of the Roman period with a shift towards greater pastoralism. There are indications that some areas were abandoned and colonised by birch woodland, but the scale of land abandonment appears to be smaller than that suggested by other palynological investigations in the area (Dark 2005). Cultivation and/or retting of *Cannabis sativa* (hemp) is also inferred at the site during the medieval and early post-medieval (Dark 2005).

Figure 5. View over Hadrian's Wall to Crag Lough, September 2006. Photo: J. Davies © Historic England (ref. DP034772).

Further south, the low-lying plain of Holderness (between Flamborough Head in the north and the Humber Estuary to the south) was once scattered with numerous lakes of various sizes in the till. The origins of many are uncertain; some are likely to be remains of kettle holes, and others might have formed in depressions within the till (the underlying geology (Flenley 1987)). Many of these are now infilled, but some are still wetlands, for example: **The Bog,** Roos (TA 274 289) (Roos Bog SSSI ref. 1001457) (a possible kettle hole 200x120m, containing sediments extending back to the late glacial, which were subjected to pollen analysis) (Beckett 1975, 60-88), **Bittern Boom Mere** (TA 157 399) (a 2.8ha probable kettle hole) and **Gilderson Marr/Gill's Mere** (TA 299 331) (*c* 3ha), plus the much larger (230ha) SSSI (ref. S1002380) **Hornsea Mere** [TA 190 470[6]] (see Dinnin and Lillie 1995, 49). Multiple mere sites were surveyed and assessed for their palaeoenvironmental potential as part of the Humber Wetlands Project by Dinnin and Lillie (1995).

Another feature of glacial origin is the infilled hollow (a former lake) known as **King's Pool** (Figure 6), at Kingsmead Marsh ***Local Nature Reserve*** (LNR

6 The grid reference quoted in the original publication (TA 210 475) does not align with the modern mere.

ref. 1082932) (SJ 926 234), Stafford. It contains up to 21m of organic deposits that extend back to the late glacial period. Multiple palaeoenvironmental investigations have studied the pollen and plant macrofossils; see Bartley and Morgan (1990), Colledge and Greig (1991) and Pearson *et al* (1999). The sequences show multiple episodes of woodland clearance and one of possible woodland regeneration continuing into the Dark Ages. Saxon deposits are associated with rye pollen, and medieval deposits with that of Cannabaceae (probably hemp) and flax.

Figure 6. Aerial view over King's Pool, August 2016. Photo: D. Grady © Historic England (ref. 29978_002).

2.1.2 Periglacial

Originally, the term 'periglacial' was used to refer to areas peripheral to glaciers, but its usage no longer requires the presence of ice (Matthews and Shakesby 2014). These areas have ***permafrost*** and/or undergo repeated freeze-thaw cycles (French 2014), resulting in features characteristic of these cold-climate environmental conditions.

2.1.2.1 Relict cryogenic mounds

This group (also known as 'ramparted ground-ice/cryogenic depressions') includes the periglacial features 'pingos' and 'palsas' and all those on the probable continuum in between (Gurney 2000). The relict features are characterised by a circular-to-oval raised rampart (often 2-3m high) completely or partially enclosing a central depression that is usually filled with peat deposits. They often occur as clusters within gently sloping valleys. Most are between 40-120m in diameter (Bryant and Carpenter 1987) although pingos are generally the larger. They form as a result of former below-ground perennial ice masses. When frozen, the ice pushes up the ground surface leading to an accumulation of soil and other debris around the margins (Bryant and Carpenter 1987). When the ice melts, the inner area sinks relative to the surroundings, resulting in the encircling rampart/ringwall. Because the formation processes and resultant morphological characteristics are similar, often it can be difficult to distinguish between the two forms in the field (Sparks *et al* 1972); in fact some have been reclassified, for example those in mid and west Wales from hydraulic pingos to mineral-cored palsas on the basis of their sediment fills and their sedimentary and geological settings (Gurney 1995). Although differentiation of the types is necessary to understand their morphological development, their specific formation processes will not have implications for the types of archaeological and palaeoenvironmental remains that they might contain.

Although the distribution of ramparted ground ice depressions in Britain is incompletely documented (Ballantyne and Harris 1994) concentrations of these features are known to occur in north-west England (the Whicham Valley in Cumbria and the Shropshire-Cheshire Plain) and in south/-eastern England (East Anglia and Surrey) (Goudie 1990).

Pingos (hydro-laccoliths)

Active pingos are considered 'true' permafrost features as they are an integral part of the permafrost, forming below the active layer (Gurney 1998). They are large, roughly circular mounds (the term 'pingo' derives from the Inuit meaning 'hill') up to 50m high and 600m long (Ballantyne and Harris 1994). They have an ice core that is fed from a pressure gradient-driven water supply. As this ice centre enlarges, the overlying sediment is forced upwards (Anderson 2004). There are two[7] main types of pingo: hydraulic and hydrostatic (formerly known as 'open system' and 'closed system' respectively). Hydraulic pingos are often found in groups, forming at locations where groundwater rises (eg via faults in the rock) through the permafrost due to artesian pressure. Hydrostatic pingos are often solitary. Their formation is associated with the presence of deep lakes (>3m deep) that do not freeze to their depth in winter. The insulating effect of such a lake results in the formation of a ***talik*** (a layer of unfrozen ground) below it. When the lake level falls – either as the lake infills over time, or more commonly if there is a sudden emptying of the lake eg by erosion – its

7 Although this two-group categorisation is common, some modern, active pingos do not fit into either, thereby having implications for the interpretation of some relict features; therefore Gurney (1998) proposes a third 'polygenetic'/'mixed' category.

shallowing means that it will freeze completely in winter, so that the talik becomes completely surrounded by frozen ground (Gurney 1998). Pressure from the encroaching permafrost causes water in the sediment to concentrate beneath the former lake bed, and this trapped body of groundwater eventually freezes to form a mass of segregated ice that pushes up the overlying sediment to form a pingo (Anderson 2004). When the ice within a pingo melts, the top collapses leaving a depression surrounded by ramparts, in which ponds can sometimes develop (Anderson 2004).

Within England pingos are frequently recorded in East Anglia and have been the subject of a detailed survey by Walmsley (2008) of the Norfolk Wildlife Trust (NWT) – the '*The Norfolk 'pingo' mapping project*'. Often, pingo basins are protected nature conservation sites, such as Thompson Common (Figures 7 and 8), part of Thompson Water, Carr and Common SSSI (ref. 1000249) managed by the NWT. Their high conservation value is due to their high biodiversity; Norfolk pingos are important habitats for many ***Red List*** invertebrates, particularly beetles – many of which are thought to have been extant in the region since early post-glacial times.

Figure 7. Pingos on Thompson Common, showing a range of surface water conditions and vegetation cover, 2014: (a) open water, (b) open water with vegetation, (c) no open water, and (d) ponding at the site of a ploughed pingo feature. Photos: © M. Farrell.

(a)

(b)

(c)

(d)


Figure 8. Aerial view over Thompson Common, October 2016. Photo: D. Grady © Historic England (ref. 29969_045).

Pollen analysis on a core from a depression on **Thompson Common** (TL 934 967) was found to contain almost 50% Cannabaceae pollen in sediments thought to date from the 18th century. This was interpreted as evidence for hemp retting on site (Bradshaw *et al* 1981) (the Holocene sediments are thought to have been removed by dredging in order to clear the pond to make it suitable for retting). The pollen was interpreted as *Cannabis sativa* (hemp) rather than *Humulus lupulus* (hop), on the basis that: i) there were no corresponding high Cannabaceae pollen levels in other sequences from elsewhere on the Common, ii) the pingo was too wet at the time of the sediment's deposition for either plant to be growing *in situ*, iii) tree pollen levels were low indicating that hop was unlikely to have been growing in the immediate vicinity of the pingo (as it is a climbing plant) and iv) the presence of trampled or disturbed ground indicator taxa suggested human activity consistent with hemp being brought to the site to be retted (Bradshaw *et al* 1981).

Further south, a pingo remnant at **Elstead Bog**, Surrey (SU 899 422) is thought to be the most southerly example of a relict cryogenic mound in the UK, and is one of a few clustered in the River Wey valley (Ballantyne and Harris, 1994). It was *c* 100x60m, surrounded by a rampart up to 1m high in places. It has been the subject of several palaeoenvironmental investigations by Seagrief and Godwin (1960), Carpenter and Woodcock (1981) and Farr (2008). The sequences recovered from this site provide a rare record of environmental conditions during the late Devensian and early Holocene (Upper Palaeolithic and Mesolithic periods) (Branch and Green 2004).

In north-west England, in the **Whicham Valley**, south-west Cumbria [*c* SD 154 840], the study of pingo scars near Beckside included stratigraphical and palynological analyses (see Bryant *et al* (1985) and Ridge (1980)). They are 65m in diameter, with ramparts up to 2m high and with 3m depth of infill sediments, and tend to have higher ramparts due to their glacio-***lacustrine*** clay substrate (resulting from the glacial Lake Whicham), making them better defined than their sandy Surrey equivalents (Bryant and Carpenter, 1987). Pollen recovered from the basal infill of one of the ramparted pingos – that is referred to as Grass Guards (SD 158 844) – shows a characteristic late glacial–early Holocene flora.

Palsas

Active palsas are low circular-oval mounds which can reach 10m high and 100m long and most often occur in groups (Gurney 2001). They result from the formation of a perennially frozen core of ice that draws in water to enlarge the ice mass. They form in peat bogs within areas of permafrost, where the fine-grained peat and underlying mineral sediments are frost-susceptible. Where the peat is thin and the palsa is predominantly composed of mineral deposits (albeit with an overlying peat layer) it is often referred to specifically as a 'mineral palsa' (although it should be noted that there is some debate over the use and applicability of palsa terminologies (see Gurney 2001)). Ultimately relict palsas form when the ice core melts and the centre collapses relative to the surroundings. This can happen through a variety of processes, for example, exposure of the ice core at the margins of the palsa where pooling water is a common feature, loss of – or changes in – the vegetation cover, or degradation of a mineral palsa's thin peat cover.

A group of enclosed depressions (up to 60m diameter, with *c* 2m of sediment infill) near **Brent Tor** (SX 466 803) (Figure 9) on Dartmoor have been interpreted as collapsed mineral palsas (Miller 1990, chapter 5; and referred to in Ballantyne and Harris 1994), but this is questioned by Gurney (2000) on the basis that geological conditions there would favour formation processes of a hydraulic pingo instead. Pollen analysis of the basal organic silts within one of the depressions was undertaken by Gotts (in Miller 1990).

Figure 9. The palsa/pingo depressions at Brentor, Devon, July 2016: (a) looking approximately south-east from the top of Brent Tor (note the water-filled feature in the centre of the photograph) and (b) how they look at ground level. Photos: Z. Hazell © Historic England.

(a) 

(b) 

Gurney and Worsley (1996) interpret a series of such features at **Owlbury**, Shropshire (*c* SO 312 919) as being mineral palsas (Figure 10). Excavations during pond clearance works in one of them revealed peat containing birch branches with evidence of gnawing by beaver (Gurney and Worsley 1996). Subsequently, a trial trench uncovered a *c* 1m thick woody peat deposit, from which samples were analysed for their pollen content by Watson (1995); from this it was inferred to be of ***Boreal age***.

Figure 10. Examples of palsas at: Owlbury, Shropshire (a) Feature 3 that underwent archaeological excavations and (b) Feature 7; and at Letton, Herefordshire (Gurney *et al* 2010) [*c* SO 33970 47900] (c) Feature 21 and (d) Feature 30 that has been dug out to form a pond; some of the Letton features sit within The Sturts SSSI (ref. 2000205). (All photos: © S. Gurney).

(a)

(b)


(c)

(d)


Sparks and West (1970) and West *et al* (1974) investigated sections of a terrace of the River Wissey at **Wretton**, west Norfolk [*c* TL 686 991] that were exposed during construction of a flood management channel. The older ***Ipswichian*** interglacial deposits are presented by Sparks and West (1970) and the younger Devensian sediments are reported in West *et al* (1974). The latter describe the remains of small peat-filled, enclosed hollows that were encountered, interpreted as being the remains of former ground-ice (palsa) mounds. It has been recognised as an important site (now Wretton SSSI ref. 1003441) on the basis of its rich and diverse Devensian microfossil and vertebrate remains (Natural England 1985).

2.1.2.2 Other ground-ice features

Near Thelnetham, on the floodplain of the Little Ouse river, Suffolk, Coxon (1978) investigated the sediments within a ***spring***-fed depression (fen), 50-60x350m in size. It is known as **Bugg's Hole** (TM 005 793) and is a SSSI (ref. 1003517). Due to a combination of factors, notably the presence of a water source (the spring and/or an adjacent palaeochannel) and the absence of a rampart, it was interpreted it to be a *naled* – an elongated periglacial feature resulting from the repeated formation of sheet ice. Because naleds are shallow features (1-10m thick), they are often not preserved and are at particular risk of being ploughed over (Coxon 1978) – it is thought that this particular feature was preserved because the constant water input prevented its drainage. The naled at Bugg's Hole was 1.8m deep, lined with sand and gravel deposits and contained organic sediments overlying grey clays. Investigative coring indicated that it was originally slightly larger (60x500m). From pollen analysis, the basal sediments were inferred to be Late Devensian. Although the upper 0.7m of sediment was disturbed, it contained high frequencies of *Cannabis* pollen, thought to relate its cultivation up until the 1800s as indicated by documentary records from the area (Coxon 1978).

2.1.3 Alluvial

This section refers to deposits laid down in settings associated with rivers, focussing on floodplains and former river channels. See Lewin and Macklin (2003) for a discussion on the potential of Quaternary riverine ***alluvial*** deposits to be preserved and Brown (1997a, 128-145; 1997b) for an outline of their palaeoenvironmental and archaeological investigation, respectively.

2.1.3.1 Floodplain deposits

Floodplains are broad, low-gradient plains, adjacent to a river, formed by material deposited when the river floods (Huggett 2003). Low magnitude, high frequency floods cover only a small part of the floodplain, but during rare major floods the whole floodplain might be submerged (Summerfield 1991). Floodplains are often poorly drained (Mayhew 2004) and therefore their deposits are likely to be waterlogged, meaning that the preservation potential of sediments suitable for palaeoenvironmental reconstructions is high. The appeal of floodplains as areas for settlement (flat, with fertile sediments and near a source of water) means that archaeological remains can be well preserved too. Today the flooding regimes of rivers can be highly managed (particularly restricted in built-up areas) but although floods might occur less often, if at all, remains within these settings are still preserved.

Two studies have been carried out in East Sussex; at Pannel Bridge and at Brede Bridge (Waller 1993; Waller and Marlow 1994). The sequence from **Pannel Bridge** (TQ 8822 1523) contained a full Holocene record of sea-level change, vegetational succession and human activity (Waller 1993), while the **Brede Bridge** profile (TQ 829 175) was interpreted as showing an expansion in human settlement during the late Neolithic and early Bronze Age, with the suggestion that lime forest was preferentially exploited at this time (Waller and Marlow 1994).

Floodplain deposits can also provide rare evidence of past vegetation cover in chalkland areas, as at the **Caburn** in East Sussex [TQ 4440 0842] where deposits indicated the presence of chalk grassland in the area throughout the mid-Holocene (Waller and Hamilton 2000). The waterlogged sediments associated with floodplains can also preserve organic archaeological remains, for example i) at **Silvertown** in London (TQ 4077 8020) where a timber trackway dated to the Early Neolithic was uncovered within the floodplain of the Thames (Crockett *et al* 2002) and ii) **Fiskerton** near Lincoln in the Witham Valley, Lincolnshire (TF 0495 7158) (Figure 11) where an Iron Age timber causeway and abundant associated metalwork was excavated (Field and Parker Pearson 2004).

Figure 11. Aerial view towards Lincoln along the River Witham valley, with Fiskerton in the front right of the photograph, June 2003. Photo: © Historic England (ref. NMR 17822/02).

In Kingsdale Valley, N Yorkshire (within Whernside SSSI ref. 1004533), there is evidence of human occupation from as early as the Mesolithic (see Howard, 2007). It is postulated that there was once a short-lived lake there, created as a result of ponding by the Raven Ray ***moraine*** at Kingsdale Head – the end of the valley (Waltham *et al* 2010; Waltham and Batty 2012). Work by Ingleborough Archaeology Group at **Sandymire** (SD 696 763) (Figure 12) – now an area of *Juncus*-dominated marshland crossed by palaeochannels at the southeastern end of the valley – recorded a series of wooden timbers and branches (hazel, willow and alder) that had been exposed in the eroding banks and riverbed of Kingsdale Beck (Batty, 2008). The remains showed evidence of being worked (some were radiocarbon dated to the Bronze Age) and of beaver gnawing, but it was not possible to interpret definitively whether the features were created by natural/anthropogenic/beaver formation processes.

Figure 12. Looking northeast across Kingsdale Valley, June 2014. Photo: © Z. Hazell.

2.1.3.2 Palaeochannel deposits

As rivers migrate laterally across their floodplains, abandoned channels are preserved and can become infilled. These features are known as palaeochannels and can become buried by younger deposits, thereby preserving a sediment archive. They are most commonly preserved as exposed cross-sections, abandoned surface features or buried channels (Knighton 1998). During periods of higher water tables, areas of standing water can form, helping identify palaeochannels that might have little/no obvious surface topographical expression (at least at ground-level[8]). Based on empirical relationships

8 Often, features are recognised and mapped using aerial survey techniques, such as photographs and Light Detection and Ranging (LiDAR). The latter is able to detect small scale topographical features and is increasingly being used successfully to identify palaeochannels.

established for modern rivers, the dimensions of palaeochannels can be used to estimate other palaeochannel features and former flow conditions, known as palaeohydrology (Knighton 1998). The sediments contained within palaeochannels can be used in palaeoenvironmental, palaeomagnetic and palaeoclimatological studies to analyse spatial patterns of hydrological change, which might have been caused by changes in climate, sea-level, tectonics and vegetation (Mayhew 2004). Their extensive, meandering, ribbon-like character means that the cumulative area of relict features often is much larger than the 'small' wetland category (<10ha) used here.

Moores *et al* (1999) describe a series of palaeoenvironmental investigations at various sites within the Tyne Basin, notably a series of palaeochannels just south-east of **Brownchesters Farm** (NY 889 922) associated with the River Rede. These become visible in flood waters due to ponding (see site photograph in Moores *et al* 1999, 293). They are notable for their thick, highly-organic deposits that are uncommon in upland river valleys. Two cores from channel fill sediments were subject to pollen analysis, and showed a clear, sustained influence of anthropogenic activity in the valley since the late Mesolithic.

Palaeochannels at **Sutton Common**, near Askern, South Yorkshire (Gearey *et al* 2009) (***Scheduled Monument*** (SM) ref. 1004816) [SE 56400 12100] also become waterlogged at the surface during particularly wet conditions (see Figure 13). At this site, a Bayesian approach was used to determine that archaeological 'events' – namely the construction of an Iron Age timber enclosure palisade (descriptively termed a 'marsh-fort') and a Bronze Age mortuary enclosure (together with associated cremation burial activities) – did not seem to have been coincident with local vegetation changes, as reconstructed from the pollen evidence.

Figure 13. Aerial view eastwards over the Sutton Common site, showing localised waterlogged patches within the palaeochannels, February 2008. Photo: D. MacLeod © Historic England (ref. 20741_044).

Other studies that demonstrate the archaeological relevance and significance of palaeochannels have been carried out at the sites of: i) **Eton Rowing Lake** site, Dorney, Middle Thames Valley, Buckinghamshire [SU 92800 78000] (see Allen and Welsh (1996) for an outline of the archaeological remains) where sedimentological and palaeoecological analyses of an infilled palaeochannel revealed periods of active channel flow, phases of channel 'ponding', and alluviation that took place from the Late Bronze Age through to the medieval period. This sequence of events appears to have developed in response to anthropogenic activity including deforestation, changes from pastoral to arable agriculture, and burning, which resulted in destabilisation and inwash of soils into the channel (Parker and Robinson 2003; Parker *et al* 2008); ii) **West Cotton**, near Raunds, Northamptonshire (Ruiz *et al* 2006; Campbell and Robinson 2010) (SM ref. 1003636; SP 97549 72538) (Figure 14) a multi-period settlement site with evidence for Saxon flax retting (plant remains), sheep husbandry (***sheep ked*** puparia) (Figure 15) and bee-keeping (remains of worker honey bees) (Campbell and Robinson, 2010) and possible deteriorating water quality (nutrient enrichment; inferred from the chironomid record) that may have been associated with the Saxon settlement activities (Ruiz *et al* 2006), and iii) at **Must Farm Quarry**, near Whittlesey, Cambridgeshire (TL 23342 96718), where multiple prehistoric logboats – together with other wooden artefacts including weirs and fish traps – were recovered from deposits associated with a former channel of the River Nene during the recent phase of excavations (see Murrell 2012). Since then, the 2015-2016 excavations by Cambridge Archaeological Unit (Figure 16) have uncovered multiple hut features and associated household goods destroyed during a single catastrophic fire event; the high level of preservation gives an unprecedented insight into Bronze Age life (see the Must Farm blog archives for further details of this on-going work http://www.mustfarm.com/progress/).

Figure 14. Large palaeochannel adjacent to the village of West Cotton, Northamptonshire. Anglo-Saxon activity there included flax-retting. Photo: G. Campbell © Historic England.

Figure 15. A sheep ked (left) and puparium (right). Photo: © M. Robinson.

Figure 16. The Must Farm excavations, 2015-2016. Photo: Z. Hazell © Historic England.

Work funded by the Aggregates Levy Sustainability Fund (ALSF) included larger, landscape-scale studies on former river system complexes, such as that of the **River Trent**. See the project reports – particularly Havelock *et al* (2002) which presents the results of multi-proxy palaeoenvironmental investigations (assessment of pollen, plant, insect and mollusc remains) and radiocarbon dating of sediments from coring multiple palaeochannels – and associated publications, for example Baker (2007), Brown *et al* (2001), Howard *et al* (2007) and Smith and Howard (2004) for further information. This project was an important early application of the use of LiDAR for mapping palaeochannels. Studies in the west of England include the early work on alluvial deposits of the **River Severn** (Brown 1983) and more recently the ALSF-funded *Severn Geoarchaeology Project* (outlined in Jackson *et al* (2012) that identified and mapped areas of organic (palaeoenvironmental) potential (see Figure 17 as an example) using LiDAR and historic maps (see Jackson *et al* (2011) for more detail).

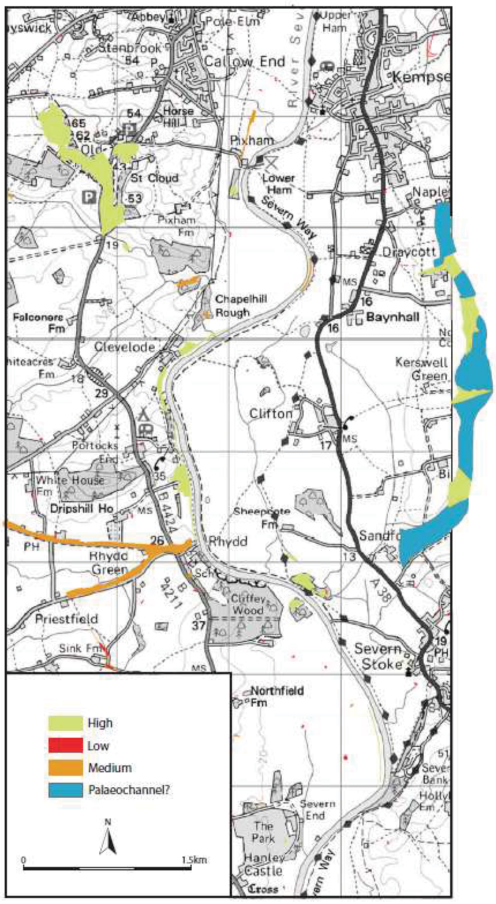


Figure 17. Map showing the areas of varying organic potential for a section of the River Severn (image from Jackson *et al* 2011) (Base mapping © Ordnance Survey).

2.1.3.3 Oxbow lake/meander cut-off deposits

Smaller, discrete sections of former channels – known as oxbow lakes (or meander cut-offs) – are the abandoned loops of rivers. As rivers cross flat, low-lying plains they tend to form wide meanders, or bends, which gradually become more acute. After a period of time (from a few years to several decades) the narrow strip of land between the two banks is breached, forming a new straighter river channel and the abandoned, cut-off meander loop.

Oxbow lakes tend to be small in area and so the accumulated sequences are more suited for reconstructing local-scale past environments. Analyses of the pollen, insect and macroscopic plant remains from a 'wood peat'-filled palaeochannel of the River Irwell – which is thought to have developed as an oxbow lake – from **Burrs Countryside Park**, Bury, Greater Manchester (SD 796 127) revealed evidence of environmental conditions during the Middle to Late Bronze Age, a period for which this type of information is extremely rare in this region. The record contains few signs of human activity, suggesting that occupation of this area began with the construction of the Iron Age hillfort of Castle Steads immediately adjacent to the site (Smith *et al* 2010).

2.1.3.4 Meander loops and movements

Distinct from the 'relict' oxbow lake features, ***meander loops*** and meander movements refer to river meanders that have not been 'cut-off' yet. Baker (2003) describes the undulating topography of the alternating 'ridges' (raised bars) and 'swales' (depressions)[9] that formed parallel to the meander bend as the river channel migrated (Figure 18). The latter hollows are potential locations of sediments suitable for palaeoenvironmental analyses. It is sometimes possible to track historical shifts in channels by comparing their routes with parish boundaries on maps.

Figure 18. Aerial photo of part of the River Trent, showing ridge and swale topography (in the bend of the river in the left side of the image) at **Foremark**, Derbyshire [SK 3367 2788], 1971. Photo: © Simmons Aerofilms Ltd (ref. 7145/11/959). Reproduced under NCAP Licence number IMSL-IR-105449.

2.1.4 Karstic

'Karst' is defined by Mayhew (2004, 286) as '*any area of limestone which is dominated by underground streams, and hollows and pits usually caused by subsidence into underground channels*'. Well known areas of karst geology in England include north-west Yorkshire, Derbyshire, the Morecambe Bay area, the Mendips and south Devon (Goudie 1990).

Three main processes are responsible for the creation of karst scenery: rock solution, cave collapse and subsidence (Huggett 2003). As running-water flows across the landscape, its acidity dissolves the calcareous rock and forms a variety of features characteristic of karst scenery, most spectacularly,

9 'Ridge and swale' in this setting can be also known as 'scroll bars' or 'meander scrolls'.

underground cave systems. Of particular relevance here though, are a specific group of circular/oval depressions known as dolines described below. Also discussed are 'poljes'; larger karstic features which contain wetlands.

2.1.4.1 Dolines

Dolines are sub-circular depressions typically 10s-100s of metres in diameter (Williams 2004), with no surface stream associated with them. Not all dolines infill subsequently, but where they do, the sediments within them can yield useful palaeoenvironmental data from areas of calcareous bedrock geology where pollen is often otherwise poorly preserved.

Waton (1983) successfully carried out pollen analysis on two peat-filled dolines on Bryants Puddle Heath, south-central Dorset; Rimsmoor and Okers. Within this area, dolines are on average 10-20m diameter and 1-2m deep (see Waton, 1983, 134), densely concentrated and because most are free-draining they are not sediment-filled. At **Rimsmoor Pool** (SY 8142 9218) (within Oakers Bog SSSI ref. 1000356 and the much larger Dorset Heathlands Ramsar site ref. 964) (Figure 19(a)) 18m of sediment was recovered from the bog (60x90m); it is thought that its drainage must have been impeded thereby facilitating peat growth (see Waton 1983, 136). Six bulk radiocarbon dates spanned from 5150±70 years BP (HAR-3919) (at 11.25-11.50m) to 610±60 years BP (HAR-3924) (at 1.50-1.75m). This dated section of profile incorporated *Ulmus* (elm) and *Tilia* (lime) declines and subsequent clearance and cultivation signals, as shown by the pollen record. At **Okers** (SY 8127 9221) (Figure 19(b)) 4m of sediment was recovered from the smaller (35x50m), shallower feature, and rather than being directly dated, its profile was compared to that at Rimsmoor.

Figure 19. Peat-filled dolines on Bryants Puddle Heath, Dorset, 2015: (a) Rimsmoor Pool and (b) Okers Pool. Photos: © Z. Hazell.

(a) 

(b) 

Common within Norfolk are lakes that are thought to have formed in hollows created by solution of the chalk bedrock, The Brecklands[10] ***National***

10 This area is also known as the Brecks.

Character Area (NCA 85) (crossing the Norfolk-Suffolk-Cambridge county boundaries) is distinctive for its dense pattern of waterlogged depressions, some of which are thought to be dolines whose water levels fluctuate greatly because they are groundwater fed. A well known example is the **Devil's Punchbowl** (TL 87790 89200) (*c* 100m diameter). As part of an archaeological survey of the Brecklands by Sussams (1996), Murphy (1996a; 1996b) investigated the potential of waterlogged deposits at a selection of features (meres and a medieval moat). Only one of these was still wet; an isolated, small open-water mere (*c* 30m across) at **Rymer Point**, Little Livermere, Suffolk (TL 8667 7577) thought to have been a valuable site for watering stock. Although samples from the feature's margins did not recover any peat, the potential for the site's centre was highlighted (Murphy 1996b, 210).

Examples of similar sites where multiproxy palaeoenvironmental histories have been reconstructed, are Diss Mere and Quidenham Mere. **Diss Mere** (Figure 20) is a small lake (*c* 3ha/0.03sq km) [TM 11600 79800] that has been the subject of much research. It contains 17m of organic sediments representing the entire Holocene (Peglar *et al* 1984a). 3m of sediments towards the base of the profile (spanning *c* 2500 to 5500 years BP) are laminated (layered) and have been shown to represent seasonal sediment deposition cycles (Peglar *et al* 1984b). High resolution pollen analysis by Peglar (1993a) showed a rapid (7-year) mid-Holocene *Ulmus* (elm) decline. The drivers of the decline are discussed by Peglar and Birks (1993) who concluded that it was a pathogenic attack on an already anthropogenically-altered woodland. Historic pollution as a result of human activity has also been recorded in the mere's sediments, in the form of elevated mercury (Hg) levels. Levels started to increase from background levels in the 11th century, but peaked to extremely high values in the mid 19th century (Yang 2010). This was attributed to local *Cannabis sativa* (hemp) cultivation and the traditional weaving industry, in which mercury was used as a component of pesticides and dyes (Yang 2010).

Figure 20. Diss Mere, 2014. Photo: © M. Farrell.

Quidenham Mere (Kenninghall and Banham Fens with Quidenham Mere SSSI, ref. 1000583) (TM 040 875) is a small lake (200x300m) set within the parkland of Quidenham Hall (Figure 21). Pollen analysis of the upper 8m of sediment (spanning the last *c* 8000 years) by Peglar (1993b) indicates Anglo-Saxon woodland clearance, hemp retting taking place over the last 1500 years (peaking in the post-medieval) and the planting of native and exotic tree taxa (including *Aesculus* (horse-chestnut), *Castanea sativa* (sweet chestnut), *Juglans* (walnut) and *Platanus* (plane) with the creation of the parkland *c* 200 years ago. Cheng *et al* (2007)[11] present chironomid evidence for eutrophication of the lake during the post-medieval period, which they attribute to increased input of nutrients due to hemp-retting.

11 Because Cheng *et al* (2007) do not clearly describe the methods and dating, nor do they adequately cite previous work, this article is not discussed here in detail.

Figure 21. Aerial view over Quidenham Mere, October 2016. Photo: D. Grady © Historic England (ref. 29969_048).

Comparing records between sites can also give indications as to the location of industrial processes. From a comparison of the Cannabaceae (Hop family) components of the Diss and Quidenham Mere pollen records, it was concluded that the much higher pollen abundances at Quidenham Mere suggested that hemp-retting took place within the lake itself. At Diss Mere the steep sides of the lake may have prevented this and necessitated the use of separate hemp-retting pits in the locality (Peglar 1993b).

Vincent (1985, 174-175) outlines the pre-glacial karst features of the Silverdale Peninsula, Lancashire; one of the dolines is **Hawes Water** (Figure 22), a hardwater lake *c* 225x400m set within Hawes Water SSSI (ref. 1001594) and Gait Barrows NNR (ref. 1006058) [SD 477 766]. It has been investigated by: Oldfield (1960) (pollen), Bedford *et al* (2004) (chironomids) and Marshall *et al* (2002) (oxygen isotopes). More recently, Jones *et al* (2011) reconstructed its Holocene lake level record, suggesting that a rise in lake level *c* 6000 years BP was driven by a period of rising sea-level affecting the local water table. They also discuss intensification in human activity (as inferred from their pollen record) after that time, suggesting that this was linked to the rising sea-level and people moving into the area surrounding the lake.

Figure 22. Hawes Water, February 2016. Photo: Z. Hazell © Historic England.

2.1.4.2 Swallets

Strictly speaking, these features (also known as sink-holes, swallow-holes, and ponors) differ from dolines in that sink-holes are a surface feature (a 'stream-sink') where water sinks underground down a fissure (Bonacci 2004a, entry for 'ponor'). However, in England the terms are often used interchangeably (Huggett 2003).

A series of small depressions was mapped in the vicinity of the Neolithic henge monuments at **Priddy**, Somerset by Stanton (1986) who reinterpreted them as being of natural origin (rather than the previously-assumed mine workings as per Tratman (1967)). Within Circle 3, Tratman (1967, plate 14) had mapped ponds (that he inferred to be recent) and an area of marsh, but Stanton (1986) suggests that these could have been ***swallets*** (although it is not clear if this term was used in the strict sense) that were more recently filled-in with clay to even the land surface, and therefore resulting in waterlogging. More recent coring investigations associated with excavations by Lewis and Mullin (2011) took place within infilled swallets[12] adjacent to Circle 1 (see examples in Figure 23). Within multiple features, infill sediments of 3m were typically recorded (Allen and Scaife 2011, 150). Palaeoenvironmental samples (cores and monoliths) were recovered from the longest of these profiles 4.25m deep [*c* ST

12 It is not clear whether any of these swallets were waterlogged at the surface at the time of sampling; it is assumed not, given that it is not specified.

5404 5256], described as "*moist sediments*". The upper levels provided what has been interpreted as a medieval and post-medieval palynological record from the area (Allen and Scaife 2011) (although it should be noted that no samples from this feature were directly dated).

Figure 23. Swallet holes adjacent to Priddy Circle 1 in 2014, showing examples: (a) waterlogged (centre) and vegetated (left back), and (b) dry. Photos: R. Pelling © Historic England.

(a) 

(b) 

2.1.4.3 Poljes

Generally, 'poljes' are flat-bottomed, steep-sided, elliptical features, fed by temporary/permanent springs/rivers (Bonacci 2004b). As a result of their poor drainage, they are waterlogged and therefore their palaeoenvironmental potential is high. Polje-like features occur on the Silverdale Peninsula (see Vincent 1985, 174-175), although some of these sites are large in size, for example the pre-Devensian Leighton ***Moss*** (Figure 24) (a SSSI ref. 1001669 and Ramsar site ref. 11035 owned and managed by the Royal Society for the Protection of Birds (RSPB)) (SD 483 749).

Figure 24. View over Leighton Moss, February 2016. Photo: Z. Hazell © Historic England.

2.1.5 Coastal

2.1.5.1 Lagoons

Coastal lagoons are areas of relatively shallow water that have become partially or completely cut off from the sea by sand and shingle spits or barriers (Bird, 2000), themselves formed as a result of ***longshore drift***. In sheltered areas with low-energy waves, sediment accumulation exceeds depletion and results in the formation of long, narrow deposits of material known as spits, with one end joined to the mainland and extending part way across a bay. If these features develop in a bay into which no major river flows it could eventually extend across the entire width of the bay, linking two headlands and forming a bar, thereby straightening the coastline and trapping water in a lagoon on the landward side. In England, areas of coastline suitable for the formation of spits and bars, and therefore lagoons, include east Norfolk and large areas of the south coast. Examples of English back-barrier coastal lagoons are i) Loe Pool, Cornwall, ii) Slapton Ley, Devon and iii) the Fleet, Dorset, all of which are too large for discussion here.

Swanpool (SW 803 313) (see Figure 25), a SSSI (ref. 2000095) and LNR (ref. 1009181) in Falmouth, Cornwall is a coastal lagoon separated from the sea by a sand and shingle bar. It formed after the last glaciation, when rising sea-levels pushed bars of sand and/or shingle landwards until they met the coastline. When the barrier joined the land, cutting off the area behind from the influence of the sea, it resulted in the formation a freshwater lake (see Natural England 2013). The lake, now 5.5ha, is thought to have originally been double that size. Although once freshwater, it is now brackish due to marine incursions over the bar at spring high tides, and was deliberately connected to the sea in AD1826 via a tunnel through the barrier (lowering the lake's level and reducing its size). Sediments recovered from a 4.5m core were analysed by Henon *et al* (1999). A sharp sediment transition at *c* 1.5m, together with changes from freshwater to brackish conditions (as demonstrated by the pollen and diatom records) acted as a good chronological marker of the lake's connection to the sea[13]. The sequence also records evidence, in the form of enhanced levels of heavy metals, of the impact of the Swanpool Mine on the lagoon and surrounding area (Henon *et al* 1999).

13 No direct dating was undertaken on the sediment profile.

Figure 25. Looking down over Swanpool coastal lagoon, Falmouth, January 2018. Photo: © Phoebe Herring.

2.1.5.2 Natural wetlands on shingle

Natural gravel pits – manifest as small wetland sites – can be found within gravel barrier complexes (large, coastal shingle expanses), notably at Dungeness, Kent. They originally formed as a result of beach/barrier migration processes; the recurved end of a spit would enclose an area of water (the 'pit'), which then would become progressively land-locked as subsequent spits 'overtook' and built the shoreline further out (Eddison *et al* 1983; Ferry and Waters 1988). The pits – which on Dungeness become younger further east as that is the direction of longshore drift in the region – would begin saline and then shift to freshwater, as seen from analysis of the sediments (often silts and organic muds) preserved within them.

As well as all the pits showing their developmental shift from brackish to freshwater conditions, other natural and anthropogenic events affecting the features were observed. At **Wickmaryholm Pit**, a return to clastic sediments above the organic deposits is thought to result from erosion events. Long and Hughes (1995) attributed this to an increase in storm incidence 700-800 years BP which is also historically-documented. At **Muddymore Pit** (Figure 26) large amounts of *Cannabis* pollen were inferred to be evidence for hemp retting at the site, in turn related to the maritime rope- and sail-cloth industries at Lydd during the period AD 1000-1400 (Schofield and Waller 2005; Waller *et al* 2007).

Figure 26. Muddymore Pit, Dungeness Foreland, Kent: (a) general site view and (b) core section showing the sediments changing from the clastic basal sediments (left) to the overlying organic sediments (right). Photos: © Martyn Waller.

(a) 

(b) 

Three of the pits from the Dungeness foreland, Kent were studied in order to reconstruct palaeoenvironmental conditions of the sites (Waller *et al* 2007): i) Muddymore Pit (TR 0620 1760) (currently a *c* 50x75m *Phragmites australis* reedswamp) (also see Schofield and Waller (2005)), ii) Wickmaryholm Pit (TR 0344 1722) (*c* 75x50m) (also see Long and Hughes (1995)) and iii) Open Pit 1 (TR 0735 1845) (a 200x100m water-filled pit – one of a group of four). Inter-site comparisons were made of the reconstructed pollen, diatom and plant macrosfossil records.

2.1.6 Mires

The palaeoenvironmental potential of peat (within bogs, fen and marshland) is well recognised due to the likelihood of waterlogged, anaerobic conditions. Whilst many deposits are large in area (beyond the scope of this document), smaller discrete patches can be found; either where local site conditions have allowed their formation, or where small remnants remain. Here they are divided into i) peat, ii) fen and iii) marsh sites, and no further subdivisions are considered relevant.

2.1.6.1 Peat

Investigation of large peatland sites is an already well-established research discipline. Well-studied examples of larger sites (>10ha) include **Coom Rigg Moss** (40ha) (NY 692 796) and **Felecia Moss** (33ha) (NY 721 777), Northumberland (Mauquoy and Barber 1999) and **Tor Royal Bog** (58ha) (SX 605 722), Dartmoor (Amesbury *et al* 2008) (Figure 27). The palaeoenvironmental records can provide information on the character of the landscape in order to understand the setting of archaeological features and sites over time, for example, during their construction, use and abandonment (see Amesbury *et al* 2008).

Figure 27. View looking northerly across Tor Royal Bog, near Princetown, Dartmoor, November 2016. Photo: Z. Hazell © Historic England.

Fyfe (2012) reconstructed the vegetation histories of three small peat deposits (***soligenous*** wetlands) on Exmoor (Somerset and Devon) (**Comerslade** (SS 738 372), **Twitchen Springs** (SS 723 369) (Figure 28) and **Moles Chamber** (SS 718 393) (Figure 29)) set within the upland peat landscape in order to investigate the degree of landscape 'openness' contemporaneous with a Bronze Age ceremonial complex comprising a series of ***barrow*** cemeteries there. Contrasting with previous assumptions about the nature of the landscapes in which such burial features were constructed (that is, open landscapes for high site visibility), the pollen evidence suggested semi-open woodland at the time of the monuments' construction in the Early Bronze Age (Fyfe 2012).

Figure 28. Aerial view of the landscape showing the line of barrows (centre) with Comerslade to the north (left of the photo) and Twitchen Springs to the west (lower left of the photo), January 2017. Photo: D. Grady © Historic England (ref. 33021_023).

Figure 29. Aerial view of Moles Chamber, January 2017. Photo: D. Grady © Historic England (ref. 33021_006).

On Bodmin Moor, Cornwall is **Dozmary Pool** mire (SX 192 744) (which, together with the adjacent spring-fed pool, forms part of Dozmary Pool SSSI (ref. 1050105)) that was studied by Brown (1977) and Kelly *et al* (2010). Pollen analysis by Kelly *et al* (2010) on late Devensian sediments spanning 25,416±672 and 17,569±523 cal years BP (earlier than those analysed by Brown (1977)) recorded both conifer and deciduous tree and shrub taxa. This has been an important study contributing to the understanding of glacial-interglacial vegetation changes in the region; contrary to the accepted view that the area was treeless tundra-steppe during the ***Last Glacial Maximum*** (LGM), this work suggests that an area of woodland persisted throughout (a 'glacial refugium').

Taw Marsh, north Dartmoor (SX 623 906) is a large, flat basin across which the River Taw flows. It contains silty sediments thought to have been deposited under lacustrine conditions, after a lake formed by the damming of the area by a terminal moraine barrier consisting of rounded boulders 12ft (*c* 3.7m) high (Pickard 1943, 31-33). Palaeoenvironmental investigation of a peaty hollow in the south-east of the basin was undertaken by Simmons (1964). Pollen analysis of the (undated) sediments – a mineral soil immediately underlying a blanket peat – was interpreted together with a number of other pollen records from small peaty sites within the region, in order to reconstruct post-glacial forest development.

2.1.6.2 Fen

A fen is a peat-forming wetland that is influenced by water from beyond its own limits, such as groundwater and surface runoff (Charman 2002). Fens differ from bogs in that they are usually less acidic and have higher nutrient levels, although in reality there is huge variation in the trophic status of fens. The term oligotrophic is used to describe nutrient-poor fens while eutrophic refers to more alkaline, calcium-rich fens (Charman 2002). Different types of fen include basin mires, which are restricted to topographic hollows and are fed by surface runoff and groundwater; valley mires, where peat is restricted to the valley bottom and receives water from surface runoff, groundwater and stream flow; and floodplain mires, where water supply comes from river floods, surface runoff and/or groundwater (Charman 2002).

Several fens have yielded complete or partial Holocene palaeoecological records from areas often regarded as being devoid of suitable sites for palaeoenvironmental reconstruction, such as **Sidlings (Sydlings) Copse** (SP 556 096) (Day 1991; Day 1993; Preece and Day 1994), **Cothill Fen** (SU 461 998) (Day 1991) and **Daisy Banks Fen** (SU 512 981) (Parker 1997), all in Oxfordshire. Fen sedimentary sequences are also important for archaeological interpretation, with Wells and Wheeler (1999) suggesting that widespread human interference and control of fen vegetation in the **Norfolk Broadland** could be a relatively recent phenomenon, beginning fewer than 400 years ago.

2.1.6.3 Marsh

'Marsh' is defined as a fen that supports tall herbaceous vegetation, often with a mineral substrate (Keddy 2000; Charman 2002) and often characterised by their dominant vegetation type. Salt marshes are located in the intertidal zone and are regularly flooded by the tides. Freshwater marshes occur inland in areas of low drainage, such as low-lying depressions, and adjacent to lakes and river channels.

Areas of marsh tend to be large in size, so smaller site examples are few; an example of a palaeoenvironmental study of a small freshwater marsh is that at **Slapton Sewage Works marsh**, Slapton Ley, Devon [SX 8205 4434]. The relative roles of climate and land-use changes in influencing Holocene erosion rates were investigated; a period of increased sedimentation that post-dated agricultural intensification (and its associated within-catchment land clearance and soil erosion) was demonstrated to coincide with a medieval climatic deterioration (Foster *et al* 2000) (albeit acting on an already altered landscape).

Similar to waterlogged floodplain deposits, organic archaeological remains can also be preserved within marshes, with examples provided by i) the pointed oak stakes used in the construction of the Saxon shore fort of **Pevensey Castle** (*Anderitum*) in East Sussex (Salzmann 1908) (NRHE ref. 411896, NMR ref. TQ 60 SW 16) (TQ 6444 0477) and ii) the Bronze Age SM (ref. 1400780) timber platform and causeway preserved at **Shinewater** (TQ 61485 02940) (formerly on the Willingdon Levels) also in East Sussex (Woodcock 1998) (NRHE ref. 1212067, NMR ref. TQ 60 SW 61), found during the construction of flood alleviation ponds.

Near Dadlington, Leicestershire, palaeoenvironmental investigation of organic deposits (**Fen Hole** (SP 381 985) and **Fen Meadow** (SP 397 982)) was employed in an attempt to locate the 'marsh' believed to be the site of **Bosworth Battlefield**. Whilst truncation of the record due to alluvial and agricultural processes prevented a precise interpretation of ground conditions at the time of the battle, the results of the investigation did provide a wider landscape context and demonstrated the presence of local wetlands that persisted into the medieval period (Wheeler *et al* 2010).

2.2 Artificial Features

This section discusses features that have been created artificially, for a specific purpose. It also includes features that might have initially formed naturally, but have more-recently been altered for user requirements – sometimes the degree of alteration is such that the original form and character is hard/impossible to determine reliably. Depending on their settings and uses, these features can provide information on the local landscape and human activities.

2.2.1 Moats

A moat is a water-filled ditch surrounding a structure or settlement, usually built to i) fulfil a defensive function, ii) drain the inner area, and/or iii) provide a supply of fish and waterfowl (Darvill 2002). As well as naturally-accumulating sediments, moat fill deposits frequently also contain purposely-dumped waste and accidentally lost remains, providing environmental and archaeological data relating to the site's period of use as well as to the post-abandonment phase. Waterlogged deposits within moats are particularly prone to destruction by activities such as dredging, most often to clear out and 'restore' the moat.

At the scheduled moated royal manor house **King's Manor** (Figure 30), just south of West Cowick, Yorkshire (SM ref. 57939; NHLE ref. 1015307; SE 6520 2055), the moat was dredged to enable conversion to a fish farm. Analysis of pollen, plant macrofossils and insect remains from sediments recovered from the moat prior to dredging provided rare environmental evidence from a well-dated rural medieval site (Hayfield and Greig 1989). Pollen and beetle remains indicated the presence of local woodland, correlating well with documentary evidence that the site was a hunting lodge, perhaps being surrounded by parkland with mature trees. The surrounding area also appears to have supported arable land, hay meadow and pasture, with evidence for the cultivation of wheat, rye, oats, flax, broad bean, brassicas and hemp (Hayfield and Greig 1989). Stones and pips of damson, apple and sour cherry were also recovered and are thought to have been grown in a nearby orchard. Seeds of fig, grape and fennel, unusual finds from a rural site such as this, probably arrived in the moat deposits in the form of domestic waste or human excrement, and are thought to represent imported foodstuffs. Pollen from walnut, a non-native tree, indicates that this species grew locally, and the occurrence of privet and box pollen perhaps suggests the presence of a formal garden enclosed by the moat (Hayfield and Greig 1989).

Figure 30. Aerial view over King's Manor, May 2012. Photo: M. Oakey © Historic England (ref. 28301_005).

Deposits recovered from the moat of **Hall Garth**, Beverley (Dobney *et al* 1994) (NHLE ref. 1008122; TA 0375 3912) provided evidence of domestic and commercial refuse, used to reconstruct activities associated with the (wider) site's abandonment and post-abandonment phases. Medieval and post-medieval remains (primarily from vertebrates) from after the manor's decline were interpreted as tanning waste (***metapodials*** from unimproved breeds of sheep) and possibly the presence of a knacker or ***fellmonger*** at the site (horse bones). Horse and dog bones were also recovered from 12th to 17th century moat deposits at **Witney Palace** (the Bishop of Winchester's Palace), Oxford (Wilson and Edwards 1993) (NHLE ref. 1018654; SP 357 093) – giving insights into the slaughter and use of their meat and skins. At this site horsemeat was fed to hunting dogs of the high-status household.

Organic remains found preserved within moat sediments can give information about the cultivation of plants – often 'exotic' – for ornamental purposes. For example, at **Hampton Court Palace**, London (TQ 1577 6862) (see Keevill and Bell 1996), the waterlogged basal (primary) fills of the moat – thought to date from the early 17th century – contained pollen and/or plant macrofossils of *Tilia* sp (lime) (dominant), *Aesculus* sp (horse chestnut), *Buxus* (box) and *Acer* (maple), suggesting their ornamental cultivation in the vicinity (see Robinson 1996; Scaife 1996). Pollen taxa also indicated nearby grassland and pasture (Scaife 1996), and from the seeds of *Leontodon* sp (hawkbit) and *Bellis perennis* (daisy) it was suggested that this might have been scythe-mown lawn (Robinson 1996). Although the pollen record showed no evidence of standing water present in the moat during its earliest phase, a subsequent presence of water is inferred from the good preservation of the organic remains (Scaife 1996). At the **Tower of London** moat [TQ 3362 8055], London (Figure 31), palynological evidence of 'exotic' introduced tree species, including *Picea* (spruce) and *Juglans* (walnut), was recovered (Scaife 2004); these investigations were part of excavations associated with assessing the feasibility of re-flooding the moat.

Figure 31. Aerial view looking south over the Tower of London, August 2002. Photo: © Historic England (ref. 21766_19).

Excavations at **Old Abbey Farm**, Risley, Cheshire (SJ 6624 9355) (Heawood *et al* 2004) – a moated farmhouse – were carried out as part of its controlled demolition prior to the extension of an adjacent landfill site. At the time of investigation, the northern section of moat still contained water. Results – which included investigation of insect and plant remains from the moat infill (Kenward *et al* 2004) – showed that it had been more-or-less continuously occupied for over 700 years. Characteristic of the site was a lack of medieval remains, which is reported as being typical of other moated sites in the region (Heawood *et al* 2004, 160). As well as the palaeoenvironmental remains preserved within the moat, other organic remains, including wooden timbers and artefacts and leatherwork (predominantly shoes), were recovered.

2.2.2 Ditches

Ditches are narrow linear features created to channel water, typically to drain water away from low-lying areas although they may also be constructed to bring water into drier areas for irrigation. They are a common source of palaeoenvironmental data on archaeological sites, and occasionally contain sedimentary archives of sufficient quality to contribute to wider debates within palaeoecology and archaeology. At the Roman fort of **Vindolanda**, Northumberland (NY 771 663), two ditch fills dating to the periods *c* AD 85-92 and *c* AD 160-180 yielded palaeoecological data which have helped to establish the impact of Roman settlement on the environment around Hadrian's Wall. The relatively precise dating of these ditch fills gave insights into the timing of a major deforestation event in northern England at a resolution which has been lacking from more loosely radiocarbon dated sequences from natural features (Manning *et al* 1997). Pollen spectra from the earliest ditch fill indicate that the landscape was already largely open some 40 years prior to the construction of Hadrian's Wall, contrasting with previous suggestions that deforestation in this area occurred primarily for military purposes. Instead, it is suggested that clearance was carried out to create land suitable for agriculture, as in other parts of northern England and southern Scotland (Manning *et al* 1997).

2.2.3 Ornamental gardens and features

Ornamental lakes have been important elements of parks and gardens since at least medieval times and were often constructed purely for aesthetic purposes (Currie 2005). Water gardens, where artificial lakes and other water features are the main focus of the garden, have been popular throughout history (Currie 2005), illustrated by the early 17th century water garden at Tackley, Oxfordshire (Whittle and Taylor 1994).

Examples of palaeoenvironmental studies from these features appear few. The potential to reconstruct garden plantings is large, with the comparison with planting records providing timeframes for the schemes.

As part of a wider archaeological project on the 18th century **Stourhead Gardens**, Stourton, Wiltshire (on the *Register of Historic Parks and Gardens of special historic interest in England* ref. 1000471; ST 777 343) sediment cores were recovered from the ornamental lake (Figure 32) in order to compare their pollen content with historical records. The lake was formed by damming the River Stour in the AD 1750s but before then it was a series of inter-connecting, probable fishponds (see Johnston 2006a, 79). Estate records contain information on the site's development (see Johnston 2006b), significant phases of which were carried out by Henry Hoare II (AD 1705-1785) and subsequently his grandson Sir Richard Colt-Hoare (AD 1758-1838); detailed plant lists were compiled by Woodbridge (1970; [1971]; [1982])[14]. Analysis of the pollen by B Silva (see Johnston 2006a, 86) identified pollen grains of multiple taxa that had been detailed in the estate's records, in particular: *Acer* (maple), *Alnus* (alder), *Castanea* (sweet chestnut), *Fagus* (beech), *Fraxinus* (ash), *Quercus* (oak), *Betula* (birch), *Crataegus* (hawthorn), *Ilex* (holly), *Prunus* (cherries), *Tilia* (lime), *Salix* (willow) and *Pinus* (pine).

Figure 32. Ornamental lakes at Stourhead. Photo: © Nautical Archaeology Society.

Lyveden New Bield, Northamptonshire (SP 982 856) (Figure 33) is a National Trust-owned property consisting of a roofless Elizabethan lodge, together with its associated gardens that are Grade 1 listed (ref. 1001037) on the *Register of Historic Parks and Gardens*. In 2000, in order to 'restore' the water-filled moats within the gardens it was proposed that they should be dredged. However, before any works took place, a series of sediment cores was taken and analysed by Hunt and Rushworth (2000) (also see Newman 2002). Examination of the sediments indicated that much of the original infill, from the Elizabethan period onwards, remained, thereby potentially providing a landscape and garden history since that time. Examples include: i) various peaks in cereal pollen (possibly corresponding with an early 19th century and then with the WWII agricultural boom) and ii) the garden's planting history (for

14 Johnston (2006b: 79) recommends that both the first and second editions of Woodbridge's National Trust guide book are consulted, as the later one removed references to plants that are no longer present at the site. NB It seems that both editions have had multiple reprints.

example *Salix* (willow) plantations). Further palaeoenvironmental sampling and investigations – that seem to chart the decline of the garden – took place in 2012 (Figures 33(b) and (c)) (Rackham and Jefferson 2013).

Figure 33. Lyveden New Bield in 2012, showing: (a) the moat sampled for palaeoenvironmental investigation, (b) coring in progress with the house in the background and (c) sampling in progress. Photos: R. Hall © National Trust.

(a) (b) (c)

2.2.4 Industrial, transport and water supply

2.2.4.1 Millponds and hammerponds

Millponds and hammer ponds are artificial ponds used as reservoirs to ensure a regular water supply and energy source for mills and for iron furnaces and forges, respectively. Sediments that have accumulated in water features constructed/adapted for industrial purposes can be important sources of information regarding the impact of industrial sites on the local environment, for example Evans' (1991) study of the impact of the post-medieval iron industry on the woodland of the western Wealden district of West Sussex. Palynological analysis of sequences recovered from a series of five hammer ponds – **Burton Mill Pond** (SU 977 178) (part of Burton Park SSSI ref. 1000222 and Burton and Chingford Ponds LNR ref. 1008020) (Figure 34(a)); **Hammer Pond**, near Chithurst (SU 847 238) (Figure 34(b)); **Combe Pond**, near Rake (SU 814 269) (Figure 35); **Furnace (Wood) Pond**, near Fernhurst (SU 879 282) (Figure 34(c)); **Ebernoe** [Furnace] **Pond**, near Ebernoe (SU 975 277) (part of Ebernoe Common SSSI ref. 1000229 and NNR ref. 1007232) (Figure 34(d)) – revealed that the hypothesis that the iron industry caused large-scale deforestation in the Wealden district is largely unsupported, and it seems more likely that fuel was obtained from sustainable sources such as coppiced woodland (Evans 1991).

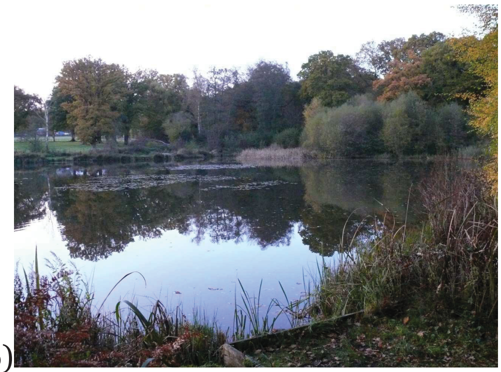
Figure 34. Aerial views over a selection of hammer ponds, September 2016: (a) Burton Mill Pond. Photo: D. Grady © Historic England (ref. 29942_011), (b) Hammer Pond. Photo: D. Grady © Historic England (ref. 29945_018), (c) Furnace (Wood) Pond. Photo: D. Grady © Historic England (ref. 29945_017), and (d) Ebernoe Pond. Photo: D. Grady © Historic England (ref. 29945_003).

(a)

(b)


(c)  (d) 

Figure 35. Combe Pond: (a) aerial view, September 2016. Photo: D. Grady © Historic England (ref. 29945_046) and (b) at ground level, November 2016. Photo: Z. Hazell © Historic England.

(a)  (b) 

Samples recovered from the millpond and ***leat*** system associated with the late Saxon watermill at **West Cotton**, near Raunds, Northamptonshire, contained evidence for the possible cultivation of *Reseda luteola* (weld), commonly used as a dye plant, and *Papaver somniferum* (opium poppy), which may have been grown as a garden crop for its oil or as a spice (Campbell and Robinson 2010).

At **Bordesley Abbey**, Redditch, Worcestershire (SM ref. 1005304) (SP 04880 68726) features associated with Medieval metal-production and -working were excavated (see Astill 1993). Waterlogged remains from the mill pond and its water channels were well preserved indicating multiple phases of its use and remodelling. Examples include wooden structural remains, for example i) the wooden millpond drain, ii) the channel lining planks and wattle revetment of the mill race and iii) a wooden sluice from an abandoned bypass channel/ditch. The latter feature also contained waste from cobbling, textile- and leather-working industries (Astill 1993, 33). With particular relevance to textile processing are the remains of flax – interpreted as flax retting in the ditch – and fuller's teasel, possibly for 'fulling' (felting woollen cloth) at the site (Carruthers 1993).

2.2.4.2 Canals and reservoirs

A canal is an artificial watercourse or extensively modified natural channel used for inland navigation or for the control and diversion of water for drainage or irrigation (Darvill 2002). The earliest artificial water channels in England were constructed by the Romans (Smith 2011). An example is the **Car Dyke** (Figure 36) which follows the western edge of the fens from Lincoln [TF 0215 7082] to Peterborough [TL 2945 8786] and may have been used for navigation (Simmons and Cope-Faulkner 2004; Smith 2011). Suggestions as to the function of the Car Dyke include drainage (Simmons 1979; Hall 1985) as well as transport (eg Clark 1949). More recently it has been recognised that the Dyke may have had a dual function, and that the southern sections may have served a navigational purpose while the primary function of the section north of Peterborough may have been drainage of the fens (Macauley and Reynolds 1993; Simmons and Cope-Faulkner 2004). An alternative function as a boundary controlling access to and activity in the fens, particularly in relation to salt production, has also been suggested (Simmons and Cope-Faulkner 2004).

Figure 36. Aerial view looking south along Car Dyke at Martin, Lincolnshire, July 2003. Photo: © Historic England (ref. NMR 17893/13).

The **Foss Dyke** (ref. 1034549), which runs for around 18km between the River Witham at Lincoln [SK 9735 7114] and the River Trent at Torksey [SK 833 781], is thought to have been created in the medieval period in order to facilitate the shipment of stone to Lincoln for the construction of the cathedral there (Smith 2011). Other early artificial waterways include the **Monk's Lode** at Sawtry, Cambridgeshire [c TL 210 857] associated with the Cistercian Sawtry Abbey (NHLE ref. 1013280) and the '**Saxon Canal**' at Glastonbury in Somerset

(Hollinrake and Hollinrake 1992) [ST 4900 3826[15]] (Figure 37). At these sites the artificial channels linked medieval religious sites to rivers and hence to towns for supply (Smith 2011). Canals became an important mode of transport in England in the late 18th century due to the poor condition of many roads, but as roads improved and railways were built, many canals later fell out of use (Mayhew 2004). Because the maintenance of canals has been somewhat neglected since they ceased to be used for trade, it is possible that some may contain palaeoenvironmental archives relating to the past few centuries.

(b)

Figure 37. Saxon Canal, on the outskirts of Glastonbury, November 2016, looking: (a) west along the feature itself, and (b) north east down on the feature (marked by the line of trees). Photos: Z. Hazell © Historic England.

(a)

Whilst the following sites have not undergone palaeoenvironmental/ archaeological investigation of their sediments, they have been recognised for their palaeoenvironmental potential. **Woodall Pond** [SK 47670 81050] and **Killamarsh Pond** [SK 47250 80920] in Derbyshire are adjacent reservoir ponds of the Norwood Canal section of the Chesterfield Canal, to which they are joined by a leat. A desk-based assessment of the canal's archaeology and heritage as part of proposed restoration works of part of the canal (by the Chesterfield Canal Partnership (CCP)) identified Woodall and Killamarsh Ponds as having the potential to provide records of pollution since the canal's construction (Coles *et al* 2010, 5). The feeder leat itself is described as infilled in

15 Also referred to as Abbot's Canal (NRHE ref. 193906).

places (CCP 2008) potentially containing sediments of palaeoenvironmental interest. There are plans to clear it in order to partially drain the ponds. Today, Killamarsh Pond is used for fishing and there are similar proposals for Woodall Pond (CCP 2008).

2.2.4.3 Reservoirs

A reservoir is a natural or, more commonly, artificial lake, often impounded by a dam, used for water storage. Reservoirs have occasionally been utilised as palaeoenvironmental archives, in particular of industrial pollution, although caution must be exercised as not all sites may be suitable for this purpose. The suitability of **March Haigh Reservoir** [SE 01580 12960] (Figure 38) (within the South Pennine Moors SSSI ref. 1006648) (originally constructed as a water source for the Huddersfield Narrow Canal) as an archive of recent industrial pollution and vegetation change was assessed by Yeloff *et al* (2005), who compared the sedimentary record from the reservoir with that of a local blanket peat. It was found that large variations in lead influx to the reservoir took place during periods of increased erosion recorded in the peat profile, suggesting that the record of aerial pollution input may have been obscured by terrestrial inputs. Yeloff *et al* (2005) conclude that reservoirs in the south Pennines, where extensive areas of blanket peat are severely denuded, as well as in other regions where erosion and sediment influx are high, are unsuitable for producing accurate records of aerial pollen and industrial pollutant deposition.

Figure 38. View over March Haigh reservoir, February 2016. Photo: Z. Hazell © Historic England.

Other reservoirs, however, have been found to contain useful records of recent industrial pollution. Chemical and palaeoecological analyses of sediments recovered from four reservoirs in the English Midlands by Foster *et al* (1991) produced records of atmospheric pollution for both inner city and rural areas over the last 150 years. One urban site was highly contaminated with lead, copper, nickel, zinc and cadmium, severely limiting options for restoration of this reservoir as a recreational feature. All sites showed evidence of increased eutrophication in the recent past (Foster et *al* 1991).

2.2.5 Animal management

The primary function of fishponds, dewponds and decoy ponds relates to the management of animals, both wild and domesticated.

2.2.5.1 Fishponds

Fishponds were artificial freshwater pools constructed for the purpose of breeding, raising and storing fish. They were typically triangular or rectangular in plan with a complex layout involving groups of ponds and several water channels (Alexander 2011). Romano-British fishponds are known, although restricted to villa sites, and medieval fishponds are very common although their distribution tends to be concentrated in central, eastern and southern England. In upland and coastal areas where other sources of fish were readily available, fishponds are less common (Alexander 2011). Fishponds have been known to accumulate valuable palaeoenvironmental archives, as for example at **Higher Lane** in Fazarkerley, Merseyside [SJ 38000 96400], where a radiocarbon dated sequence covering the period from the end of the 12th century to the 18th century provided evidence for the prevailing environmental conditions in the vicinity of the fishpond, though few signs of human activity associated with the nearby settlement were recorded (Dobney *et al* 1995; Hall *et al* 1996). At **Hailes Abbey**, Gloucestershire (SP 05026 30010) a sequence of monoliths recovered from a presumed former fishpond (Figure 39) were analysed for their plant macrofossils, pollen and diatoms (Robinson and Forster 2009; 2012).

Figure 39. The profile through the infill deposits of a former fishpond at Hailes Abbey, subsequently sampled using a series of monolith tins, for palaeoenvironmental analyses. Note the rubble layer half-way. Photo: © Historic England (ref. 5115-128-B1).

Analysis of pollen and fish remains from a feature at **Owston Abbey**, Leicestershire (SK 7743 0796) (Figure 40) confirmed the identification of the feature as a fishpond. The study also provided insights into the management of fishponds as well as into the fish species kept by a medieval monastic foundation, which included pike, roach, perch, rudd, bream and chub (Shackley *et al* 1988). The sequence recovered from this former fishpond also contained evidence for the abandonment of pond management between AD 1536 and 1793, presumably related to the systematic enclosure of the abbey lands and a gradual shift towards greater pastoral farming (Shackley *et al* 1988).

Figure 40. Aerial view looking northwards over the partially water-filled former fishponds at Owston Abbey (running slightly diagonally across the photo towards the bottom righthand corner), August 2016. Photo: D. Grady © Historic England (ref. 29948_023).

Features such as these could be reused, as indicated at the 'fish pond' feature at **Ellerton Priory**, North Humberside (SE 701 398), where abundant (97% of ***Total Land Pollen***) *Cannabis*-type pollen in the upper sediment levels suggest that hemp was retted there (Lillie and Gearey 1999; Gearey *et al* 2005).

2.2.5.2 Dewponds

Dewponds are artificial ponds with a watertight lining, often of clay mixed with straw. They were constructed to provide a water supply in areas of permeable geology such as chalk or limestone (Darvill 2002). One region where these features are particularly common is on the chalk Wolds of the East Riding of Yorkshire, where a major feature of late 18th century enclosure in this area was the construction of hundreds of dewponds, since the process of enclosure restricted access to scarce natural water supplies (Hayfield and Wagner 1995; Hayfield *et al* 1995). Natural hollows which became lined with clay following deglaciation, very similar in form to the artificially constructed dewponds, have been an important source of water and therefore a focus for anthropogenic activity since prehistoric times on the East Yorkshire Wolds (Hayfield *et al* 1995). Although it is possible that these features may accumulate useful palaeoenvironmental and/or archaeological archives, estate records from Yorkshire suggest that artificial dewponds were regularly cleaned out, and Hayfield *et al* (1995) stress that this may well have removed any palaeoenvironmental evidence. Care is clearly required if interpreting sequences recovered from such features. The establishment of modern water supply systems has led the East Yorkshire dewponds to be neglected and many are now dry and overgrown by vegetation (Hayfield and Wagner 1995).

2.2.5.3 Decoy ponds

Decoy ponds are another form of artificial or modified freshwater pool, used for attracting and trapping wildfowl (Darvill 2002). They consist of a central pond with a number of gradually narrowing channels (‘pipes’) leading off it (Alexander 2011) (see Figure 41). The ponds were usually surrounded by trees to provide seclusion, encouraging wildfowl to land, and the pipes would have been enclosed by nets. Birds that landed on the ponds were lured up the pipes where they could be trapped. Most decoy ponds were constructed in the post-medieval period, with the earliest examples dating to the 17th century, although it is known that ducks were trapped in medieval times (Alexander 2011). The ponds tend to occur in low-lying areas, away from settlements, and their present distribution is concentrated in the eastern counties (Alexander 2011). Although many of these features are now visible only as earthworks, they have significant archaeological and palaeoecological potential since they are found in low-lying situations and may still contain waterlogged deposits.

Figure 41. Duck decoy on **High Halstow** marshes (TQ 7827 7778), Hoo Peninsula, north Kent, March 2011. Photo: D. Grady © Historic England (ref. 26889_038). See Carpenter (2014).

2.2.6 Marl and clay pits

Marl has been used in the past to improve the texture and water-retaining capacity of light soils (Mayhew 2004) and a place from which it is extracted is known as a marl pit. Likewise, a clay pit is a quarry or mine from which clay is excavated for use in the manufacture of pottery and bricks. Abandoned marl and clay pits may fill with water and accumulate sedimentary archives.

A palynological sequence recovered from an infilled clay pit on **Ashtead Common**, Surrey [*c* TQ 1789 6020] was analysed by Waller (2010). The pit is one of a series of interconnecting pits through which there is a flow of water; within the pit itself grows *Salix cinerea* (grey willow), together with other moist-loving taxa, including *Juncus effusus* (soft-rush) and *Callitriche* spp (water-starworts). It began to infill following the abandonment of the Roman industrial complex (a villa, bath house and tile kilns) on the common, and is therefore thought to have been related to Roman clay extraction. The palynological sequence provides a record of landscape history from the Roman to the modern period, and the palaeoecological data are consistent with archaeological evidence for continuity of settlement and land-use at the boundary between the Roman and Saxon periods (Waller 2010). The palaeoenvironmental data generally fit well with the archaeological and documentary evidence for land-use, and serve as an excellent example of the advantages of studies which use a multidisciplinary approach to the reconstruction of vegetation change in the historic period (Waller 2010).

2.2.7 Osier/withy beds

An osier (or ***withy***) bed is a site where willows were grown and coppiced to produce withies, to make, for example, baskets, wattle fences and fish-traps (see Figure 42). Since willow prefers to grow on damp ground, natural waterlogged features (such as marshy ground or old river channels) were often exploited as sites for its cultivation. As a result, osier beds are a potential source of waterlogged archaeological remains and palaeoenvironmental information.

Figure 42. Peeling withies on a river near Oxford, 1860-1922. Photo: Henry W. Taunt © Historic England (ref. cc97_02900).

Gatcombe Withy Bed [SZ 50155 85720], in the valley of the River Medina, on the Isle of Wight was maintained as an osier bed until relatively recently. It was protected from peat cutting as it provided other useful resources and thus has preserved one of the most complete palaeoenvironmental records (namely pollen) for this part of southern England, extending from the late Devensian to the 20th century AD (Scaife 1980).

Many other osier beds may contain similarly valuable sedimentary archives. Current examples demonstrating their character and form include: i) **Lower Astley Wood**, Worcestershire [SO 81190 67140] and ii) **Pavenham** near Bedford (SP 990 551) (Figure 43) on the banks of the Great Ouse river, where the osier beds (1.38ha) are currently managed as a nature reserve by the Wildlife Trust for Bedfordshire, Cambridgeshire and Northamptonshire.

Figure 43. Osier beds (currently undergoing restoration) at Pavenham, Bedfordshire, 2015. Photo: © Z. Hazell.

2.2.8 Wells

Wells are shafts or pits, often lined with stone or wood, dug from the ground surface down to a point below the water table, allowing the bottom of the well to fill with water so as to act as a water supply accessible by lowering a bucket down from above (Darvill 2002). Due to the waterlogged nature of these features they often preserve environmental remains and organic artefacts associated with archaeological sites. The problems of interpreting palaeoenvironmental data from well fills have been discussed by Hall *et al* (1980), who stress that extreme caution must be exercised when dealing with assemblages recovered from wells since it is necessary to establish their age, mode of entry and relationships to the stratigraphy and archaeology before any meaningful interpretations can be made. Well fills may not be an ideal source of information about past environments and anthropogenic activity, but Hall *et al* (1980) point out that good preservation of organic remains on Roman and earlier settlement sites is rare and in some instances wells may be the richest, or even only, source of palaeoenvironmental material. This was the case at **Skeldergate**, York (Hall *et al* 1980) [SE 60190 51435], where excellent preservation of plant and insect remains occurred in the fills of a timber-lined Roman well, allowing the previously unknown flora and fauna of the *colonia* (city) to be compared with that of the fortress and later periods of civilian occupation. The remains of several food and medicinal plants were recovered, along with hemp and flax. Large quantities of ancient peat were present within the well fills, and it is suggested that this material was probably imported for use as fuel (Hall *et al* 1980).

Well fills also preserve organic archaeological artefacts, for example at **Dalton Parlours**, West Yorkshire (SM ref. 1017560; SE 4025 4454), where a well associated with a Roman villa was found to contain large numbers of wooden coopered buckets, some made of silver fir which must have been imported from central or southern Europe either as raw material or as complete objects. A series of wooden objects interpreted as part of the lifting mechanism associated with the buckets was also recovered, along with a number of leather objects including shoes and sandals (Wrathmell and Nicholson 1990).

Valuable archaeological and palaeoenvironmental evidence was also recovered from **Wilsford Shaft**, Wiltshire (SU 1086 4148) – a Bronze Age structure interpreted as having either a purely practical function, primarily to water stock (Bell 1989a), or a ritual purpose (Ashbee 1989a). In terms of archaeological remains recovered from the fill of the feature, parts of stave-built containers with inserted bases, possible shovels and the remains of wickerwork, probably from baskets, provided evidence for prehistoric woodworking technology (Ashbee 1989b). A huge range of environmental evidence was also obtained from the fills, including fungi, moss, pollen, seeds, wood, bud scales, rope, plant fibres, insects, molluscs, domestic animal bones, remains of small vertebrates, animal fibres and dung. This is an extremely valuable palaeoenvironmental archive in an area of permeable chalk geology where delicate biological remains such as non-carbonised plant remains and insect remains are rare (Bell 1989b). The environmental evidence indicates that the surrounding vegetation at the time the shaft was dug was largely dominated by chalk grassland, with arable cultivation also nearby, in an area where the nearest '***Celtic***' ***fields*** are around 400 yards (366m) away. This evidence serves to demonstrate the point that the surviving record of prehistoric fields does not necessarily reflect their former extent (Bell 1989a). There are suggestions from the plant remains that flax and opium poppy may have been cultivated alongside cereal crops (Robinson 1989).

3 SUMMARY AND CONCLUSIONS

3.1 Types of records

Although the site formation processes of the features discussed are very diverse, the range of methods which can be applied to them in terms of palaeo-investigations is the same. What does differ is the length and age of the sedimentary archives and the particular site records and histories that they can produce, ranging from, for example, a climate-driven post-glacial vegetation record, through to prehistoric human impacts on the landscape to evidence of more-recent industrial activities. Even though in some cases it may be hard to reliably determine how a feature was formed, or if it has been subsequently modified, the deposits it contains can still provide valuable waterlogged remains.

The types and applications of the archaeological and palaeoenvironmental records are broad, and often sites will include a combination of multiple record-types. Examples of those covered include:

- human activities and their settings, such as:

  i) forest clearances
  ii) agriculture eg Roman rye introductions at Crag Lough,
  iii) textile manufacture eg hemp processing at Diss Mere
  iv) garden plantations eg Quidenham Mere, Stourhead, Hampton Court Palace and the Tower of London
  v) pollution eg mercury from textile industries at Diss Mere
  vi) settlements and associated activities eg Sutton Common
  vii) the landscapes surrounding burial features

- environmental changes

  i) glacial and post-glacial vegetation changes
  ii) natural climatic changes
  iii) sea-level histories
  iv) storm events
  v) tracing the same or similar events across England eg the elm decline

- chronologies, through:

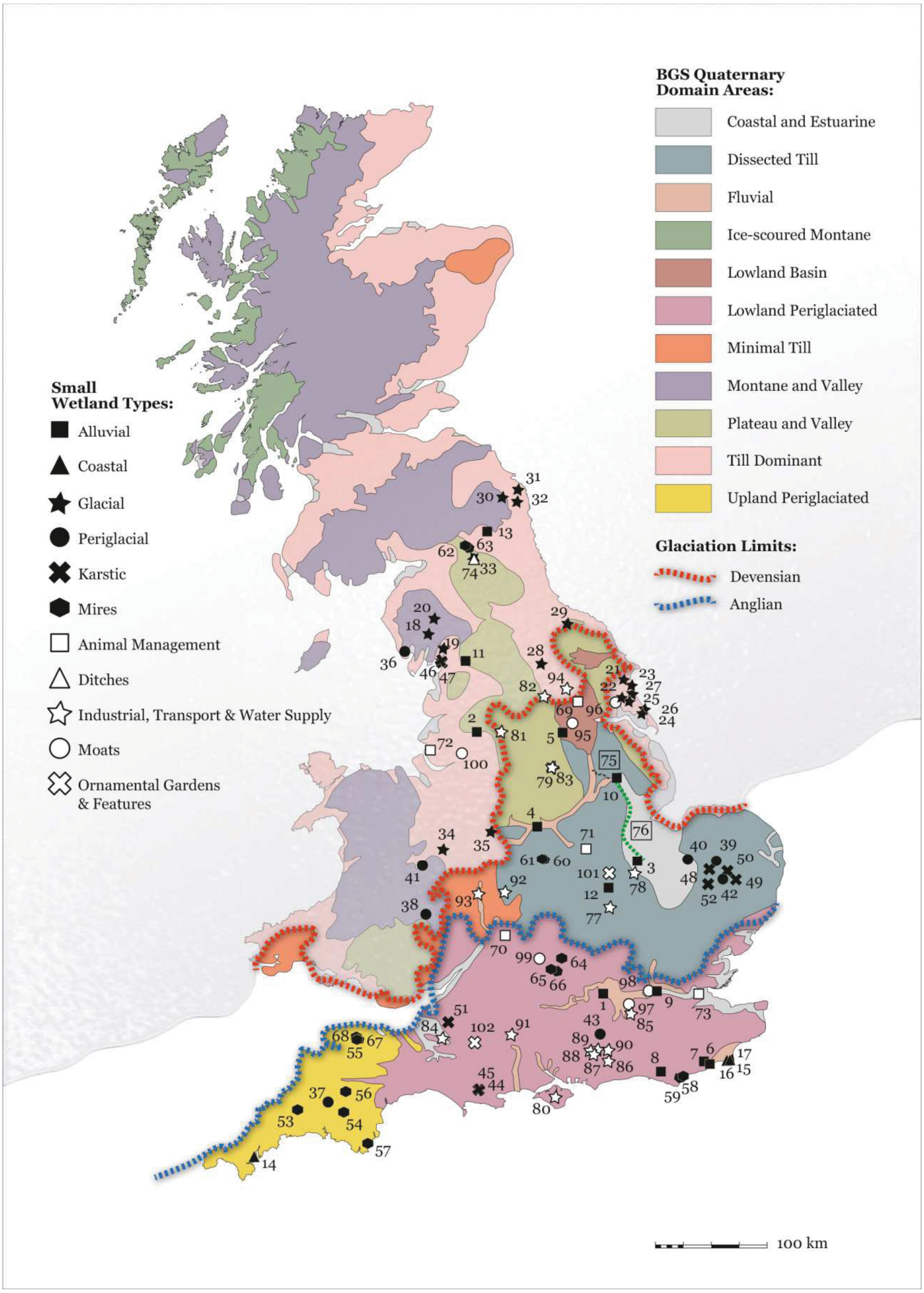
  i) the direct dating of sediment contents or sediments themselves eg radiocarbon
  ii) comparisons with historical documentary records

3.2 Distribution of features

Certain site-types are associated with particular landscape features and geomorphologies, and some of these are limited in their geographical extent across England (see Figure 44):

- features associated with previously-glaciated landscapes will occur within the limits of the last glaciation, generally in northern England. Tarns are found in upland regions where active glaciers produced a particular feature-type – corries – and so are found in northwest England's Lake District. Other features are associated with glacial debris eg till deposits, with lakes/bogs forming in depressions (notably kettle holes) created within it. An area of particular note is that of the Holderness coastal plain, East Yorkshire.
- periglacial features will be present beyond the limit of previous glaciations, and so generally in southern England, for example fossil pingo and palsa features in Surrey
- karstic features (eg dolines, poljes) are constrained to areas of underlying limestone and chalk geologies. Limestone areas include northwest England, such as the Silverdale Peninsula, and chalk-land areas include southern England and East Anglia.
- river palaeochannels are associated with broad floodplain settings, and so tend to be in middle and lower reaches of rivers. Larger river systems include that of the River Trent.
- areas of discrete peat/marsh/fen can form wherever the hydrological conditions are conducive (for example the presence of springs), so they are more geographically widespread nationwide.

Figure 44. Map showing the sites referred to in the main text (see following page for key). The British Geological Survey (BGS) Quaternary domains were redrawn from the BGS map available on the webpage https://www.bgs.ac.uk/research/climatechange/quaternaryDomains/home.html. Also see Booth *et al* (2015).



Small Wetland Types (Natural)

Alluvial

1 Eton Rowing Lake
2 Burrs Countryside Park
3 Must Farm Quarry
4 Foremark
5 Sutton Common
6 Pannel Bridge
7 Brede Bridge
8 Caburn
9 Silvertown
10 Fiskerton
11 Sandymire
12 West Cotton
13 Brownchesters Farm

Coastal

14 Swanpool
15 Muddymore Pit
16 Wickmaryholm Pit
17 Open Pit 1

Glacial

18 Blelham Tarn
19 Sizergh Park
20 Angle Tarn
21 Gransmoor Quarry
22 Routh Quarry
23 Skipsea Withow Mere
24 The Bog, Roos
25 Bittern Boom Mere
26 Gilderson Marr/Gill's Mere
27 Hornsea Mere
28 Dishforth Bog
29 near Kildale Hall
30 Lilburn South Steads
31 Embleton's Bog
32 Longlee Moor
33 Crag Lough
34 Norton Farm Pit, Condover
35 King's Pool

Periglacial

36 Whicham Valley
37 Brent Tor
38 Letton
39 Thompson Common
40 Wretton
41 Owlbury
42 Bugg's Hole
43 Elstead Bog

Karstic

44 Rimsmoor Pool
45 Okers
46 Hawes Water
47 Leighton Moss
48 Devil's Punchbowl
49 Diss Mere
50 Quidenham Mere
51 Priddy
52 Rymer Point

Mires

53 Dozmary Pool mire
54 Tor Royal Bog
55 Twitchen Springs
56 Taw Marsh
57 Slapton Sewage Wks Marsh
58 Pevensey Castle
59 Shinewater
60 Fen Hole
61 Fen Meadow
62 Coom Rigg Moss
63 Felecia Moss
64 Sidlings Copse
65 Cothill Fen
66 Daisy Banks Fen
67 Comerslade
68 Moles Chamber

Small Wetland Types (Artificial)

Animal Management

69 Ellerton Priory
70 Hailes Abbey
71 Owston Abbey
72 Higher Lane
73 High Halstow

Ditches

74 Vindolanda

Industrial, Transport & Water Supply

75 Foss Dyke
76 Car Dyke
77 Pavenham
78 Monk's Lode
79 Killamarsh Pond
80 Gatcombe Withy Bed
81 March Haigh Reservoir
82 Dalton Parlours
83 Woodall Pond
84 Saxon canal
85 Ashtead Common
86 Burton Mill Pond
87 Hammer Pond
88 Combe Pond
89 Furnace (Wood) Pond
90 Ebernoe Pond
91 Wilsford Shaft
92 Bordesley Abbey
93 Lower Astley Wood
94 Skeldergate

Moats

95 King's Manor
96 Hall Garth
97 Hampton Court Palace
98 Tower of London
99 Witney Palace
100 Old Abbey Farm

Ornamental Gardens & Features

101 Lyveden New Bield
102 Stourhead Gardens

3.3 Threats

Threats to waterlogged deposits are varied, but include:

- loss through *drainage* of the land for agriculture and construction purposes
- loss through *coastal erosion*; eg the cliff erosion of Skipsea Withow Mere that led to its drainage, but meant that Armstrong (1923) could recover artefactual remains. The cliff section containing the mere is still being eroded today
- loss or damage to small wetland features adjacent to watercourses through erosion resulting from *flooding*
- loss through removal of sediment by *quarrying* works, although by its nature this has uncovered deposits that would otherwise be buried; eg Routh Quarry and Must Farm
- loss through removal for *aesthetic reasons*. For example, remains of the 17th century water gardens at Tackley Abbey, Bicester, Oxfordshire (SP 480 205) (SM ref 1007716) and a *Historic Park and Garden* (ref 1001109)) were cleared out and '*restored'* in the 1960s by the owner at the time (see the site's list entry). They consisted of a series of geometrical ornamental ponds (with islands) that also functioned as fishponds (see Whittle and Taylor 1994). In addition, 'restoration' (ie clearance) of the feeder leat at Norwood (see CCP 2008) will result in draining and lowering the water levels of the feeder ponds upstream
- loss of fills through *clearance* to rejuvenate ponds and create small wetland habitats as part of environmental stewardship schemes and initiatives
- drying out through *water abstraction* lowering water tables
- loss for *leisure*-related activities eg for fishing, water sports
- *nature conservation* considerations being prioritised, for example, pingos in Norfolk are important Red Data Book sites and so their management priorities might not align with those of the historic environment. Multiple wetland partnerships and schemes have biodiversity-led habitat 'restoration' (creation) visions and targets eg the Wetland Vision 50-year Vision, and Local Nature Partnerships (LNP) eg Gloucestershire's LNP (http://www.gloucestershirenature.org.uk/index.php) that do not always include representation of the historic environment.
- *agriculture* eg ploughing. Subtle, shallow features are particularly susceptible eg naleds. A dew pond at Normanton Down, Wiltshire, that was visible on aerial photos from the 1940s and 50s, has now been ploughed out (see Barrett and Bowden 2010).

- *land levelling* (ie flattening) by filling in, resulting in the loss of a feature's identifiable form in the field eg the land levelling at Priddy reported by Tratman (1967) based on historical records

This document has demonstrated the importance of small wetlands in terms of their palaeoenvironmental and archaeological deposits. In order to minimise their loss, it is imperative that they are recognised from the outset as archives of such remains, and that appropriate advice is sought in advance of any proposed works. Methods for prospecting and modelling organic deposits (see Hurst *et al* 2014; Droitwich) and for identifying and mapping small wetlands and assessing them for their palaeoenvironmental potential (see Pearson 2014; Worcestershire) have been developed to facilitate this.

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5 GLOSSARY

Anthropogenic = resulting from human action.

Alluvial = relating to flowing water in a non-marine setting.

Barrow = a prehistoric, raised burial mound.
https://content.historicengland.org.uk/images-books/publications/iha-prehistoric-barrows-burial-mounds/prehistoricbarrowsandburialmounds.pdf/

Boreal Age = a stage from the Scandinavian Blytt-Sernander climatic classification scheme, based on their work in the late 1800s/early1900s. The Holocene was divided into stages, each distinguished by their distinctive pollen assemblages; the Boreal Age itself was inferred to be a period of relatively warm and dry conditions. These terms are no longer commonly used.

Carr = a type of wetland, supporting woody vegetation (typically alder, hazel and/or willow).

'Celtic' fields = prehistoric agricultural field systems; typically their arrangement is coaxial and the fields tend to be small and rectangular.

Chironomids = non-biting midges that live in aquatic habitats, members of Insecta: Diptera. The subfossil head capsules of their larvae are well preserved due to their chitin content and are diagnostic to genus level (sometimes to species). They are used to reconstruct former lake water temperatures, depths and quality.

Cladocera = microscopic crustaceans, generally less than 1mm in size. They inhabit a wide variety of freshwater habitats and their shells, head-shields, post-abdomens and claws are frequently preserved in sedimentary deposits. They are used to reconstruct a range of events that impact on lakes, including climatic changes, trophic oscillations, acidification and changes in water levels.

Coppice (coppicing) = a woodland management technique which involves cutting young tree stems down to ground level to encourage the growth of multiple new shoots. The regrowths were used for a range of purposes including fuel, animal fodder, structures.

Corrie = cirque/cwm = an armchair-shaped hollow on a mountain side formed by the erosive action of a glacier. Following glaciation the hollow may be filled by a small lake.

Devensian = the last glacial (cold) period within the British Isles. At its maximum, sea-levels were so low that a land-bridge joined mainland Britain to the rest of Europe.

Diatoms = single-celled, microscopic algae that live in aquatic environments. They are used to reconstruct water temperatures, pH and trophic status.

Esker = a sinuous raised, ridge of sediment deposited by glaciofluvial processes; from sediment deposited by water flowing through sub-glacial tunnels ie underneath the glacier itself. The sediments (sands and gravels) are often stratified.

Eutrophication = nutrient enrichment of a lake or other water body.

Fellmonger = a dealer in animal skins and hides, who also might prepare them for tanning.

Glacial = a cold period when ice cover expanded and sea-levels were lower.

Glacial ablation = refers to various processes by which snow and ice are removed from the surface of a glacier, including melting and evaporation.

Gyttja = organic lake muds formed mainly under anaerobic conditions.

Holocene = the current, warm period (not technically an interglacial yet) which began *c* 11,700 years ago (Walker *et al* 2009). Within Britain, this is known also as the Flandrian, although increasingly the term Holocene (as used on mainland Europe) is being used for terminological consistency.

Hydroseral succession = a plant succession which develops in aquatic environments, resulting in the waterbody becoming infilled with sediment and culminating in a raised bog or dry woodland habitat.

Interglacial = a warm period between two glacial (cold) periods.

Ipswichian = the interglacial period that occurred prior to the Devensian glacial, from *c* 130,000 to 115,000 years ago.

Isotopes = several common elements (eg oxygen, carbon, hydrogen) naturally exist in different isotopic states, reflecting different numbers of neutrons in the nuclei. Each isotope of an element exhibits different physical and chemical behaviours, and variations in isotope ratios in sediments can provide information on the environmental conditions under which the sediments accumulated, as well as forming a proxy record for climate change.

ka = abbreviation for thousand years

Kame = a steep-sided mound of sediment deposited by glaciofluvial processes; deposited by meltwater from the margins of a glacier. Between the raised deposits – in the relative depressions – lakes would form, such as kettle lakes which are often found associated with kames.

Lacustrine = relating to a lake.

Last Glacial Maximum (LGM) = the period during the Devensian glacial when the earth's ice sheets were at their greatest extent. The age of the LGM is not formally defined, but it is generally accepted to have occurred *c* 21,000 years ago (Mix *et al* 2001).

Late glacial = a term used generally for the Last Glacial-Interglacial Transition (LGIT); the period of climatic fluctuations during the deglaciation at the end of the Devensian and the start of the Holocene. It is often reported as spanning *c* 15 to 9ka, starting with the rapid warming Late Glacial Interstadial event identified in the GRIP ice core isotope record at 14.7ka.

Leat = an artificial channel dug as a water supply route.

Local Nature Reserve (LNR) = a statutory designation within England, administrated by Natural England. They are protected for their wildlife and/or their geology and are of local importance. http://www.naturalengland.org.uk/ourwork/conservation/designations/lnr/.

Loch Lomond Stadial = a brief period of colder conditions that occurred from *c.* 12,900 to 11,700 years ago and led to the readvance of many glaciers in northern Britain; equivalent to the Younger Dryas Stadial of the European mainland.

Longshore drift = littoral drift = a term used to describe the movement of sediment along the coast by wave action.

Ma = abbreviation for million years

Marl = mud rich in calcium carbonate or lime and containing varying amounts of silt and clay.

Meander loop = a pronounced stream/river bend.

Mere = waterbodies that are commonly shallow and broad, with steep sides.

Metapodial = toe (or finger) bone.

Molluscs = comprise a large phylum of invertebrates. They tend to live in aquatic or damp environments and can be either terrestrial, freshwater or marine. They have soft, unsegmented bodies and most have a hard calcareous shell eg univalves (snails) and bivalves (mussels, clams).

Moraine = accumulations of sediment deposited by glaciers, for example, at the end (snout) of the glacier at its maximum extent (a terminal moraine), the sides of a glacier (a lateral moraine) or as a glacier recedes (a recessional moraine).

Moss [as part of a place name] = a site where peat cutting took place, often named after the place the peat supplied eg Leighton Moss would have supplied Leighton (Rotherham 2011, 16-7)

National Character Area (NCA) = an area of distinctive landscape, biodiversity, geodiversity and cultural and economic activity, within England, as identified by Natural England. There are currently 159 NCAs. See http://www.naturalengland.org.uk/publications/nca/

Ostracods = small, bivalved crustaceans that live in aquatic environments (marine and freshwater). Their calcite shells can be preserved in the sedimentary records, and they have been used to reconstruct water temperature, salinity, chemistry and nutrient status.

Periglacial = an area which, although not ice covered, is subjected to repeated freezing and thawing.

Permafrost = subsurface rock, sediment or soil that remains frozen for at least two consecutive years.

Pollen analysis = the study of pollen grains preserved in sediments in order to reconstruct vegetation and landscapes.

Post-glacial = the period of time following the last glacial.

Proxy = something that is counted/measured in place of a variable of interest, because it responds to that variable in a known way; and that variable can no longer be measured because it happened in the past. A proxy provides an indirect measure of past climates or environments.

Quaternary = the geological Period covering the last 2.8/2.4Ma, and divided into the two Epochs: the Pleistocene and the Holocene.

Red List = a set of criteria set by the International Union for Conservation of Nature (IUCN) that is used to classify and highlight rare and/or threatened flora and fauna; those identified as such are put on the '*IUCN Red List of Threatened*

Species'. The Red Lists were previously known as (and are still often referred to as) Red Data Book (RDB).

Retting = softening and rotting fibrous plant stems such as hemp (*Cannabis sativa*) and flax (*Linum usitatissimum*) by soaking them in water. The purpose of this exercise is to cause the majority of the non-vascular plant material to decay, so that the stems can then be beaten in order to detach the fibres from the woody core (Darvill 2002).

Scheduled Monument = a site under the highest level of historic environment statutory protection (the Ancient Monuments and Archaeological Areas Act of 1979), recognised for its national and/or international importance.

Sheep ked = blood-feeding parasites (*Melophagus ovinus*) that complete their entire life cycle in the wool of sheep.

Site of Special Scientific Interest (SSSI) = a statutory designation within England, administrated by the governmental organisation Natural England. Such sites are protected for their wildlife and/or their geology and are of national importance. See http://www.sssi.naturalengland.org.uk/Special/sssi/index.cfm

Soligenous = refers to peatland sites where the water movement is mainly lateral eg valley mires. They are often <5ha in size.

Spring = a place where water naturally flows out of the ground due to pressure in underlying aquifers, forcing water up through permeable sediments and/or soils.

Swallet = swallow hole/ponor = a feature in limestone areas through which surface water flows underground (Goudie 1994).

Talik = a pocket of unfrozen ground occurring either above or within permafrost eg beneath a lake (Holden 2008).

Testate amoebae = single-celled, microscopic organisms characterised by the presence of a test (shell). For peatland palaeoenvironmental studies they are used as indicators of past hydrological changes, as they are sensitive to moisture content and water table levels.

Till = a generic term for glacially deposited sediments.

Total Land Pollen = a conventional way of presenting pollen data by totalling all pollen from land taxa (so not including aquatics).

Withy = a rod of coppiced wood, suitable for bending and weaving to make structures (eg hurdles, baskets etc).

6 APPENDIX 1

Table A1. The main stratigraphical divisions of the British Quaternary period, showing their equivalent marine oxygen isotope stages (MOIS) and archaeological periods, derived from a combination of Wenban-Smith *et al* (2007, tables 2 and 3) and AHOB (2009). The stages between 10 to 5e were previously grouped together as the Wolstonian Complex; but since the identification of discrete stages within that timeframe, the name has become redundant. The timing of the boundary between the Lower Palaeolithic and Middle Palaeolithic is currently debated (hence the hashed line used here). The early Middle Palaeolithic and late Middle Palaeolithic are separated by a period of human absence.

Epoch	**Stage**	**Main climate characteristics**	**MOIS equivalent**	**Approximate start (1,000 years BP)**	**Archaeological divisions (approximate start; 1,000 years BP)**
Holocene	Holocene (Flandrian)	Warm	1	11.5	Mesolithic to modern (11)
Late Pleistocene	Devensian	Mainly cold	4-2	70	Upper Palaeolithic (40)
		Temperate	5d-a	110	Late Mid Pal.
	Ipswichian	Warm	5e	120	
Middle Pleistocene		Cold	6	190	Early Mid Pal.
	Aveley	Warm	7	240	Middle Palaeolithic (250)
		Cold	8	300	
	Purfleet	Warm	9	340	
		Cold	10	380	
	Hoxnian	Warm	11	425	
	Anglian	Cold	12	480	
	Cromerian complex; Beestonian glaciation	Cold and warm cycles	19-13	780	
Early Pleistocene		Cool and warm cycles	64-20	1,800	Lower Palaeolithic (950)

Table A.2 Details of sites mentioned in the text, ordered by county or district (as appropriate).

	County/district	Site name	Grid reference	References	Site type
1	Bedford	Pavenham	SP 990 551		Osier/withy bed
2	Buckinghamshire	Eton Rowing Lake	SU 92800 78000	Allen and Welsh (1996); Parker and Robinson (2003); Parker et al (2008)	Palaeochannel
3	Bury	Burrs Countryside Park	SD 796 127	Smith et al (2010)	Oxbow Lake
4	Cambridgeshire	Must Farm Quarry	TL 23342 96718	Murrell (2012)	Palaeochannel
5		Monk's Lode	TL 210 857	Smith (2011)	Canal
6	Cornwall	Swanpool	SW 803 313	Henon et al (1999)	Coastal lagoon
7		Dozmary Pool mire	SX 192 744	Brown (1977); Kelly et al (2010)	Spring-fed mire
8	Cumbria	Blelham Tarn	NY 365 005	Evans (1970); Harmsworth (1968); Pennington (1991); Van der Post et al (1997); Oldfield (1970)	Kettle hole
9		Sizergh Park	SD 500 875	OAN (2013, 2014)	Kettle hole
10		Angle Tarn	NY 417 143	Pennington (1991)	Tarn
11		Whicham Valley	SD 154 840	Ridge (1980); Bryant et al (1985)	Pingo
12	Derbyshire	Killamarsh Pond	SK 47250 80920	Coles *et al* (2010)	Canal reservoir pond
13		Foremark	SK 3367 2788	(None used)	Meander feature
14	Devon	Brent Tor	SX 466 803	Miller (1990); Gotts, in Miller (1990); Gurney (2000)	Pingo (or palsa)
15		Tor Royal Bog	SX 605 722	Amesbury et al (2008)	(ombrotrophic raised bog)
16		Twitchen Springs	SS 723 369	Fyfe (2012)	Soligenous
17		Taw Marsh	SX 623 906	Pickard (1943); Simmons (1964)	Peat-filled hollow
18		Slapton Sewage Works Marsh	SX 8205 4434	Foster et al (2000)	Marsh
19	Doncaster	Sutton Common	SE 56400 12100	Gearey et al (2009)	Palaeochannel
20	Dorset	Rimsmoor Pool	SY 8142 9218	Waton (1983)	Doline

21		Okers	SY 8127 9221	Waton (1983)	Doline
22	East Sussex	Pannel Bridge	TQ 8822 1523	Waller (1993)	Floodplain
23		Brede Bridge	TQ 829 175	Waller and Marlow (1994)	Floodplain
24		Caburn	TQ 4440 0842	Waller and Hamilton (2000)	Floodplain
25		Pevensey Castle	TQ 6444 0477	Salzmann (1908)	Marsh
26		Shinewater	TQ 61485 02940	Woodcock (1998); English Heritage (2012)	Marsh
27	East Yorkshire	Gransmoor Quarry	TA 113 597	Walker et al (1993)	Kettle hole
28		Routh Quarry	TA 092 436	Gearey (2008); Gearey and Lillie (2001)	Kettle hole
29		Skipsea Withow Mere	TA 185 545	Gilbertson (1984): Gilbertson et al (1987); Taylor (2009); Armstrong (1922, 1923)	Kettle hole
30		The Bog, Roos	TA 274 289	Beckett (1975)	Kettle hole
31		Bittern Boom Mere	TA 157 399	Dinnin and Lillie (1995)	Kettle hole
32		Gilderson Marr/Gill's Mere	TA 299 331	Dinnin and Lillie (1995)	(mere)
33		King's Manor	SE 6520 2055	Hayfield and Greig (1989)	Moat
34		Hall Garth	TA 0375 3912	Dobney *et al* (1994)	Moat
35		Ellerton Priory	SE 701 398	Lillie and Gearey (1999); Gearey *et al* (2005)	Fish pond; hemp retting
36		Hornsea Mere	TA 190 470	Dinnin and Lillie (1995)	(mere)
37	Gloucestershire	Hailes Abbey	SP 05026 30010	Robinson and Forster (2009, 2012)	Fish pond
38	Greater London Authority	Silvertown	TQ 4077 8020	Crockett *et al* (2002)	Floodplain
39		Hampton Court Palace	TQ 1577 6862	Keevill and Bell (1996); Robinson (1996); Scaife (1996)	Moat
40		Tower of London	TQ 3362 8055	Scaife (2004)	Moat
41	Herefordshire	Letton	SO 33970 47900	Gurney et al (2010)	Palsa
42	Isle of Wight	Gatcombe Withy Bed	SZ 50155 85720	Scaife (1980)	Osier/withy bed
43	Kent	Muddymore Pit	TR 0620 1760	Waller *et al* (2007); Schofield and Waller (2005)	Natural gravel pit (coastal)
44		Wickmaryholm Pit	TR 0344 1722	Waller *et al* (2007); Long and Hughes (1995)	Natural gravel pit (coastal)
45		Open Pit 1	TR 0735 1845	Waller *et al* (2007)	Natural gravel pit (coastal)

46	Kirklees	March Haigh Reservoir	SE 01580 12960	Yeloff *et al* (2005)	Canal reservoir
47	Lancashire	Hawes Water	SD 477 766	Oldfield (1960); Bedford et al (2004); Marshall et al (2002); Jones et al (2011)	Doline
48		Leighton Moss	SD 483 749	(None used)	Polje
49	Leeds	Dalton Parlours	SE 4025 4454	Wrathmell and Nicholson (1990)	Well
50	Leicestershire	Fen Hole	SP 381 985	Wheeler *et al* (2010)	Floodplain mire
51		Fen Meadow	SP 397 982	Wheeler *et al* (2010)	Floodplain mire
52		Owston Abbey	SK 7743 0796	Shackley *et al* (1988)	Fishpond
53	Lincolnshire	Fiskerton	TF 0495 7158	Field and Parker Pearson (2004)	Floodplain
54		Foss Dyke	SK 833 781 to SK 9735 7115	Smith (2011)	Canal
55	(and Cambridgeshire)	Car Dyke	TF 0215 7082 to TL 2945 8786	Simmons and Cope-Faulkner (2004); Smith (2011); Simmons (1979); Hall (1985); Clark (1949); Macauley and Reynolds (1993)	Canal
56	Liverpool	Higher Lane	SJ 38000 96400	Dobney *et al* (1995); Hall *et al* (1996)	Fish pond
57	Medway	High Halstow	TQ 7827 7778	Carpenter (2014)	Duck decoy
58	Norfolk	Thompson Common	TL 934 967	Bradshaw *et al* (1981)	Pingo
59		Wretton	TL 686 991	Sparks and West (1970); West *et al* (1974)	Palsa
60		Devil's Punchbowl	TL 87790 89200	NONE USED	Doline
61		Diss Mere	TM 11600 79800	Peglar *et al* (1984a,b); Peglar (1993a); Peglar and Birks (1993); Yang (2010)	Doline
62		Quidenham Mere	TM 040 875	Peglar (1993b); Cheng et al (2007)	Doline
63	North Yorkshire	Dishforth Bog	SE 3768 7361	Giles (1992)	Kettle hole
64		near Kildale Hall	NZ 609 097	Keen *et al* (1984); Jones (1971, 1976, 1977a,b)	Kettle hole
65		Sandymire	SD 696 763	Waltham *et al* (2010); Waltham and Batty (2012); Batty (2008)	Floodplain
66	Northamptonshire	West Cotton	SP 97549 72538	Ruiz *et al* (2006); Campbell and Robinson (2010)	Palaeochannel; millpond and leat
67		Lyveden New Bield	SP 982 856	Hunt and Rushworth (2000); Newman (2002); Rackham and Jefferson (2013)	Ornamental moat
68	Northumberland	Lilburn South Steads	NU 028 234	Jones *et al* (2000)	Kettle hole

69		Embleton's Bog	NU 16500 29600	Bartley (1965); Gething et al (2013); Bamburgh Research Project (2013); Paterson et al (2014); Dixon et al (2015)	(peat bog)
70		Longlee Moor	NU 156 195	Bartley (1965)	Kettle hole
71		Crag Lough	NY 766 680	Dark (2005)	Glacial hollow
72		Brownchesters Farm	NY 889 922	Moores *et al* (1999)	Palaeochannel
73		Coom Rigg Moss	NY 692 796	Mauquoy and Barber (1999)	Peatland
74		Felecia Moss	NY 721 777	Mauquoy and Barber (1999)	Peatland
75		Vindolanda	NY 771 663	Manning *et al* (1997)	Ditch
76	Oxfordshire	Sidlings Copse	SP 556 096	Day (1991, 1993); Preece and Day (1994)	Fen
77		Cothill Fen	SU 461 998	Day (1991)	Fen
78		Daisy Banks Fen	SU 512 981	Parker (1997)	Fen
79		Witney Palace	SP 357 093	Wilson and Edwards (1993)	Moat
80	Rotherham	Woodall Pond	SK 47670 81050	Coles *et al* (2010)	Canal reservoir pond
81	Shropshire	Norton Farm Pit, Condover	SJ 494 073	Coope and Lister (1987); Scourse et al (2009); Allen et al (2009); Lister (2009)	Kettle hole
82		Owlbury	SO 312 919	Gurney and Worsley (1996); Watson (1995)	Palsa
83	Somerset	Priddy	ST 5404 5256	Stanton (1986); Lewis and Mullin (2011); Allen and Scaife (2011)	Swallet
84		Comerslade	SS 738 372	Fyfe (2012)	Soligenous
85		Moles Chamber	SS 718 393	Fyfe (2012)	Soligenous
86		Saxon canal	ST 4900 3826	Hollinrake and Hollinrake (1992); Smith (2011)	Canal

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