Pulborough Brooks Nature Reserve eco-hydrology and peat assessment report

A report into the investigation of Pulborough Brooks Site of Special Scientific Interest.

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Foreword

Peatland is an important habitat for wildlife, people and planet covering just under 11% of England's land area. It is England's largest carbon store even when degraded, is rich in wildlife and provides a range of ecosystem services including cultural through the effective preservation of archaeological remains. Peatlands that are healthy can sequester carbon, help flood management and act as natural water filters.

Unfortunately, over 80 % of all peatland is considered degraded and the environmental benefits can be significantly impacted or even reversed by this degradation. For example, degraded peatland can act as a carbon equivalent source rather than a carbon sink. The supporting habitat wildlife benefits as peat degrades can also be reduced, including for its ability to support some wetland habitats and plant communities. Therefore, Natural England commissioned Yellow Sub Geo to undertake a programme of study and produce this report, investigating the condition of peat and associated hydrology of Pulborough Brooks Site of Special Scientific Interest (SSSI), part of the Arun Valley Special Area of Conservation (SAC), Special Protection Area (SPA) and Ramsar.

This report increases the understanding of Pulborough's ecohydrology, its development over time in comparison to an unmodified state and identifies any evidence gaps. The report also assesses options to improve the status of peatland to aid in further conservation and move to more natural functioning.

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Executive summary

Yellow Sub Geo undertook a programme of desk study, fieldwork, and groundwater monitoring in order to investigate the peat and hydrology conditions at play beneath Pulborough Brooks SSSI (the site).

Soil conditions were investigated by means of desk study and by field investigation. Groundwater monitoring wells were installed and automatic dataloggers used to monitor the behaviour of groundwater, ponded surface water, and ditch water over a one month period.

This report provides a factual summary of this work.

The ground conditions encountered typically comprised of clay over gravels, over a bedrock of sandstone of the Folkestone Beds. Possible Gault Clay bedrock was encountered in a single exploratory hole. Peat deposits were found in discrete areas along the eastern and southern edges of the site, adjacent to the scarp slope that lies immediately outside of the site boundaries.

Peat was typically found to be wet in the lower portions, and dry in the upper portions. Peat was typically overlain by a thin layer of clay-rich topsoil. The deepest peat of best condition was found in the Large Rushy Brook. Elsewhere, peat was encountered in Pete Brook, North Spring, and Penfolds Spring. The occurrence of peat typically tallied with observations made by the Royal Society for the Protection of Birds (RSPB), although it must be borne in mind that the location of exploratory holes was deliberately focused on these areas, and so there is the potential for peat to also be present elsewhere.

Groundwater monitoring results indicate that the peat is fed partly by groundwater seeping from and through the adjacent scarp slope, and partly by rainfall. Groundwater levels in all peat deposits were lower than 5cm below ground level, and hence can be considered deeper than that required to maintain healthy peat.

Springs and seeps from the scarp slopes surrounding the site are considered to have been important in peat generation, as is groundwater feeding in the subsurface.

A conceptual model has been produced that provides a summary of the hydrology mechanisms and peat condition beneath the site. A high-level assessment of the ecosystem services implications of this conceptual model is also provided.

The current conceptual model is heavily modified by the presence of the geometric drainage ditches, particularly the perimeter ditches. It is notable that the healthiest area of peat within the Large Rushy Brook is in the only field where perimeter drainage is not present.

Potential intervention options are discussed to improve the hydrology and health of the peat deposits. The report concludes with an options appraisal of potential next steps in further knowledge and working towards pilot intervention measures.

Contents

Acronyms

Term	Definition
AOD	Above Ordnance Datum measurement
BGL	Below Ground Level measurement
EA	Environment Agency
OS	Ordnance Survey
RSPB	Royal Society for the Protection of Birds
RTD	River Terrace Deposits. River terrace deposits typically comprise sand and gravel with local lenses of silt, clay and/or peat.
SAC	Special Areas of Conservation (SACs) are protected areas in the UK, designated under the Conservation of Habitats and Species Regulations 2017 (as amended) in England and Wales
SPA	Special Protection Areas (SPAs) are protected areas for birds in the UK classified under the Conservation of Habitats and Species Regulations 2017 (as amended) in England and Wales.
SSSI	Site of Special Scientific Interest
DTM	Digital Terrain Model
UXO	Unexploded Ordnance
WETMEC	Wetland water supply mechanisms
LiDAR	Light Detection And Ranging

1. Introduction

Pulborough Brooks SSSI (the Site) comprises a lowland wet grassland forming part of the Arun Valley floodplain. A series of grassland fields are criss-crossed by ditches with areas of scrub and surrounding woodland. The Site is located (see Figure A and Figure B) within part of a larger nature reserve, owned and operated by the Royal Society for the Protection of Birds (RSPB). The whole Site is designated as Pulborough Brooks Site of Special Scientific Interest (SSSI), a Ramsar Site, A Special Protection Area (SPA), and a Special Area of Conservation (SAC), situated within the South Downs National Park. In order to inform works to improve the value of the Site for nature conservation, the investigation involved mapping the depth of peat deposits in select localities across the Site along with investigating surface water and groundwater interactions.

The purpose of the project is to review the ecohydrological status of Pulborough Brooks to understand its development and unmodified state, looking at the potential for its restoration to a more natural state.

Natural England (NE) were alerted to the decline in condition of the nature reserve by Southern Water's 2019 reporting on the changing abstractions at Pulborough to increase supplies to Sussex Water North supply zone, in conjunction with other survey data which suggested there were concerns in relation to the condition of wildlife on the Site (Natural England, 2021). A NE condition assessment was undertaken in 2021 to 2022. This report will support the condition assessment.

A number of parties are currently investigating and assessing the hydrological and hydrogeological status of the Site. In parallel with the report's work, Atkins are also being employed by NE in order to investigate and assess the nutrient balance within the watercourses and ditches on the Site. A third project is also ongoing, also delivered by Atkins, on behalf of Southern Water. This involves the ongoing long-term investigation and assessment of the behaviour of groundwater in the Folkestone Beds aquifer, associated with Southern Water's groundwater abstraction for Public Water Supply at Hardham.

1.1 Scope

The project was augmented in order to take the opportunity to provide additional data on groundwater for the ongoing Atkins study for Southern Water.

The combined scope of works comprised:

- A series of borehole transects providing a cross section of geological sequence and groundwater level through the nature reserve;
- A series of hand augers to investigate the depth of peat across the Site;
- A series of peat probes to investigate the depth of peat across the Site;
- Installation of groundwater monitoring wells in select locations enabling groundwater and gas monitoring.

This report provides a summary of; details of the Site at the time of inspection, including soil and peat sampling; records of fieldwork undertaken; encountered ground conditions, and groundwater monitoring.

Section 2 of this report provides a summary of information collated during desk-based assessment of the Site. Section 3 describes the fieldwork undertaken, and Section 4 the water and ground conditions encountered. Sections 3 and 4 provide a combined record of work undertaken to meet both the NE and Atkins scope, with the data being collated to provide the best dataset upon which to base subsequent interpretation.

Section 5 onwards of the report provides an assessment and interpretation of the peat, hydrology and hydrogeology conditions beneath the Site. These sections are specifically to address the following aspects:

- To develop a conceptual understanding of the hydrogeological and ecohydrological regime at play beneath and within the peat body; both the likely natural regime and the current, anthropogenically altered regime.
- To identify historical modifications to hydrology and their likely impact on ecohydrology and vegetation.
- To identify current ecohydrological pressures and provide a series of possible measures/actions required to restore a more natural hydrological regime. A discussion is provided on the possible effects of such interventions, including consideration of both beneficial and negative effects.

The report culminates in a high-level ecosystem services assessment, discussing the effects on biodiversity, carbon and water services that historical anthropogenic intervention has had, and how these may be impacted by restoration measures.

1.2 Limitations

Due to the wet conditions encountered during the initial site walkover in January 2022, the scope of works for this report was designed as such to avoid flooded areas of the site ensuring safety and access was feasible. This has constrained the location of exploratory holes to select areas of the site.

2. Desk Study

2.1 Site description and topography

Pulborough Brooks is situated regionally on the southern slope of the Greensand ridge, low-lying within the flood plain of the River Arun. Site location and field names are shown in Figure A and Figure B.

The floodplain of the Site is bounded by higher ground to the east and south and by the Rivers Arun and Stor to the west and north. The Site is split into two sections by an area of higher ground protruding westwards to the south of Banks Cottage, separating the reserve into Pulborough North and Pulborough South. A thin area of floodplain connects these two areas, forming the contiguous Pulborough reserve.

Pulborough North is edged by a steep scarp slope on its western and southern edge. It is considered likely that this scarp slope was formed by erosion by the River Arun, which historically will have migrated across the floodplain. In the area of the south-eastern edge of the Site near to Banks Cottage, this scarp slope is particularly over-steepened to the degree of landslip, with a distinctive area of hummocky ground. The landslip is considered likely to be a relic (i.e. no longer active) feature associated with previous erosion of the foot of the slope by the River Arun. On Figure 1 below, mass movement has been mapped on Site showing landslide deposits in this area.

Pulborough South is fringed to the east and south by less steep slopes, although the change from floodplain to slope remains marked. A small valley feature extends southwards from the floodplain in the area of Washingham Farm. The area of higher ground to the south of the Site forms a westerly extending ridge that separates the Pulborough Site to the north from a similar area of floodplain to the south known as Amberley Wildbrooks. These two areas of floodplain are separated by the close proximity of the River Arun to this ridge of higher ground as it flows beneath Greatham Bridge.

Within the floodplain of the Site itself, the ground is predominantly low lying and of a similar elevation throughout, at around 2m AOD (Above Ordnance Datum). This places the ground level within the tidal range (0.1-2.8m at Arundel). There is a gradual but largely imperceptible slope from east to west across the Site towards the River Arun.

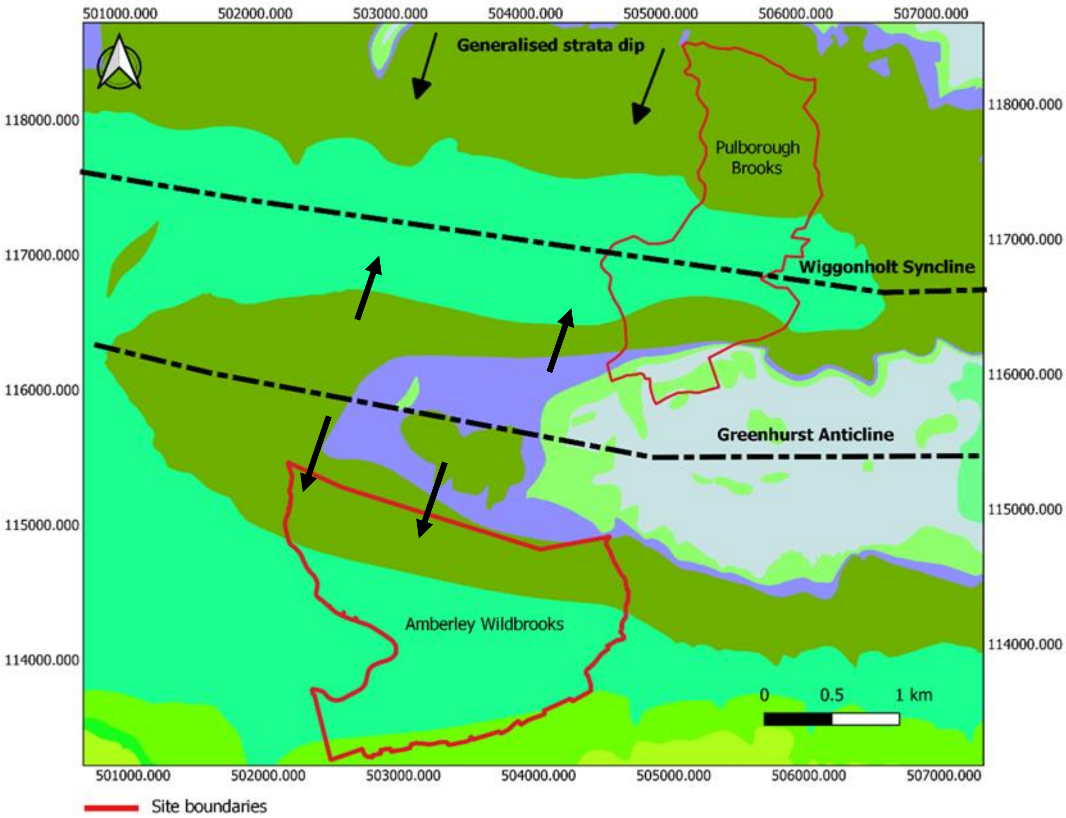
Flood embankments (levees) approximately 1-2m high run along the eastern boundary of the Site separating the Site from the Arun River.

Drainage ditches running across Site form areas of lower elevation. Ditch castings from clearances of the drainage ditches create small ridges of higher ground parallel to ditch alignment.

2.2 Geology

Pulborough lies within the Hardham Basin which is characterised by paired anticline and syncline structures of Cretaceous aquifers and aquicludes. The area lies upon the flank of the Wealden Anticlinorium modified by the Wiggonholt Syncline and the Greenhurst Anticline. Regional structural geology is shown in Figure 1 below:

Figure 1 Regional structural geology adapted from Bristow and Wyatt, 1983



- Gault Formation – Mudstone
- Folkestone Formation – Sandstone
- Marehill Clay Member – Mudstone
- Pulborough Sandrock Member – Sandstone
- Fittleworth Member – Sandstone and mudstone
- West Marlbury Marly Chalk Formation

According to the British Geological Survey (BGS) 1:50,000 mapping (see Figure 2 and Figure 3 below), the bedrock geology comprises:

- Gault Formation - Mudstone
- Folkestone Formation – Sandstone
- Marehill Clay Member – Mudstone
- Pulborough Sandrock Member – Sandstone
- Fittleworth Member – Sandstone and mudstone

In addition, superficial deposits are present comprising of:

- Peat
- Alluvium – Clay, Silt, Sand and Gravel
- Arun Terrace Deposits – Sand and Gravel
- Head – Clay, Silt, Sand and Gravel

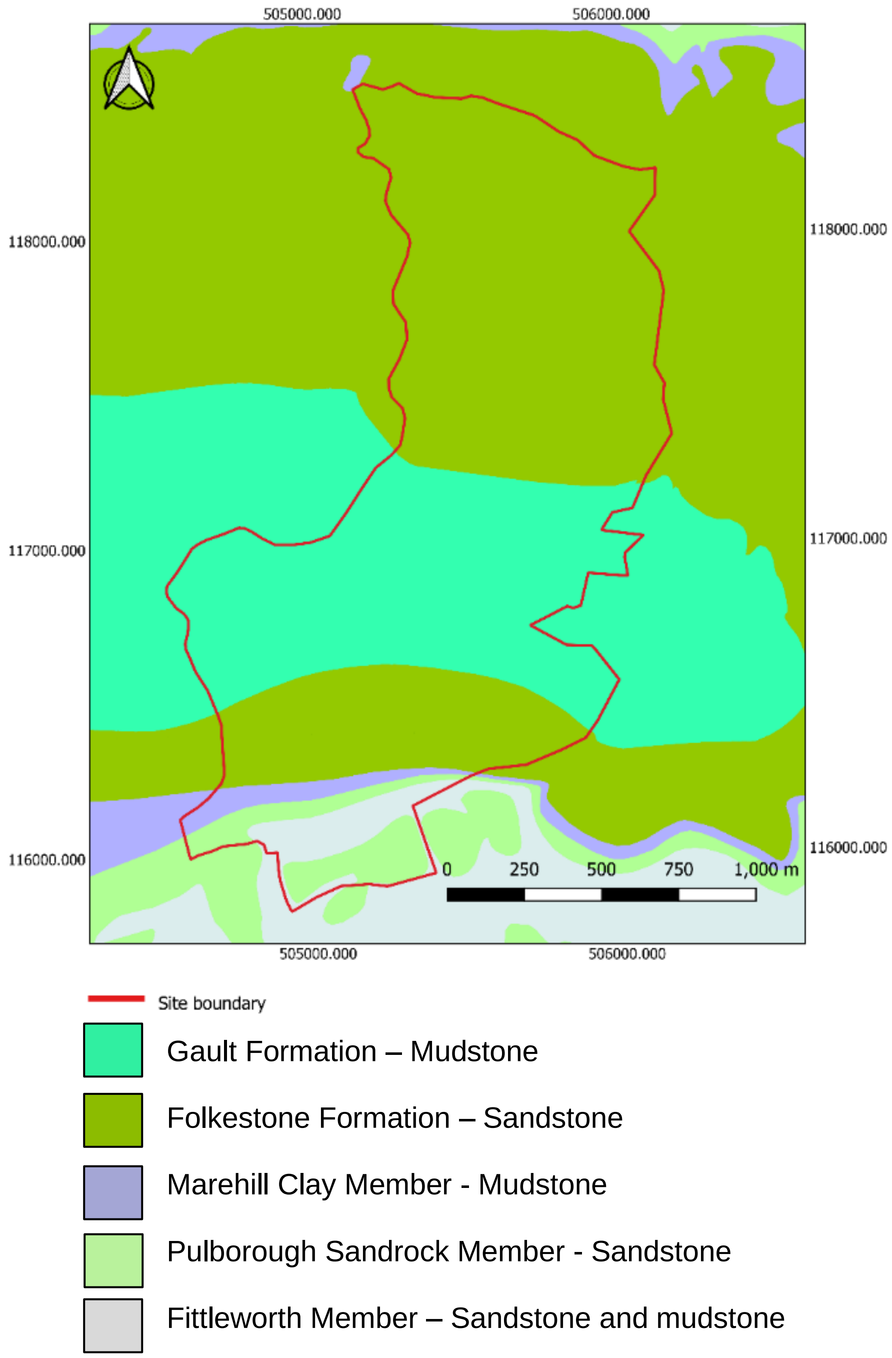
Historical borehole logs on Site recorded from the Atkins/Southern Water Arun Valley SPA Sustainability Study from 2006 (Ref: 5035745/70/DG/26), confirm the above succession of superficial geology and record the following:

Table 1 Strata encountered in nearby historical boreholes logs (mbgl - metres below ground level)

Borehole ref.	Stratum	Maximum depth (mbgl)
PB-GW-01 Eastings 505527 Northings 116552	Topsoil	0.3
	Clayey fine Sand	0.45
	Sandy Gravel	0.5
	Clayey fine Sand	1.1
	Sandy Clay	1.5

Borehole ref.	Stratum	Maximum depth (mbgl)
	Clayey fine Sand Sandy Silt Fine Sandy Silt Mottled Sandy Silt Fine Sand No recovery Stiff Dark Clay	1.8 1.82 2 2.5 3 4 5
PB-GW-02 Eastings 505215 Northings 116319	Topsoil Peat Clay Sandy Clay Clayey Sand Clayey fine gravelly Sand Fine Sand	0.41 0.6 1 1.24 1.35 2.19 3
PB-GW-03 Eastings 504832 Northings 116267	Clay Peat Sand Sandy Gravel Slightly gravelly Sand Sand	4 5 6.3 6.7 7 8
PB-GW-04 Eastings 505417 Northings 117853	Topsoil Clay Silty Clay Peat Gravelly Sand Sandy Gravel Gravelly Sand Gravel/Sand Sand	0.11 0.98 1.81 2.60 2.96 3.58 4 6.86 6.95
PB-GW-05 Eastings 505727 Northings 117876	Clay Sand	6 8.6
PB-GW-06 Eastings 506031 Northings 117919	Topsoil Clay Sand Silty Clay Sand with clayey fine sand laminae Sand Clayey Sand Clay Sand	0.1 1.19 1.4 1.57 1.75 2 2.5 5 6

Figure 2 Site bedrock geology from 50K BGS mapping. Contains British Geological Survey materials © UKRI 2024



2.2.1 Gault Formation – Mudstone

Gault formation mudstone is mapped extending across the central section of the Site, comprising a sequence of clays, mudstone, and thin siltstones from the Cretaceous era. The Gault Formation overlies Jurassic and Triassic strata resting unconformably and becoming more arenaceous as the deposit is traced westwards. It typically comprises a pale to dark grey or blue-grey clay or mudstone with occasional phosphatic, pyritic, and calcareous nodules. Historically the clay was worked on a small scale for brick making. An historic borehole drilled in Amberley (0282 1323) penetrated the entire succession of Gault clay with a thickness of 91.6m. Red cementitious iron-rich grit occurs locally within the Gault formation, typically at the sharp junction to the Folkestone Formation below.

2.2.2 Folkestone Formation – Sandstone

The Folkestone Formation is mapped in the north and south of the Site and comprises the uppermost formation of the Lower Greensands, a medium to coarse-grained, well-sorted, poorly consolidated, cross-bedded quartz sand or weakly cemented sandstone. The formation is considered to be lithologically uniform, however seams of iron-cemented sandstones called capstones and pale grey and green silt and clay occur within the succession. The formation reaches a maximum thickness of 85m at Farnham, thinning towards Eastbourne (3m thick). The formation is thought to be deposited in a shallow marine environment. The cross-stratification of the units in some areas can be up to 5m thick with azimuths indicating a paleocurrent direction of north-west. It is considered that the deposition of the sandstone beds happened via lateral migration of sand waves possibly in shallow tidal conditions. The acid-rich sandy soils of the Folkestone Formation commonly support woodland habitats. Historically, the Folkestone Formation has been worked for building aggregates and tile making.

2.2.3 Marehill Clay Member – Mudstone

Mapped in the south of the Site, the Marehill Clay Member underlies the Folkestone Formation, comprising a dark grey, locally glauconitic silty clay. The clay has blocky weathering and has been used historically for brick making. The outcrop varies in thickness between 50 - 100m.

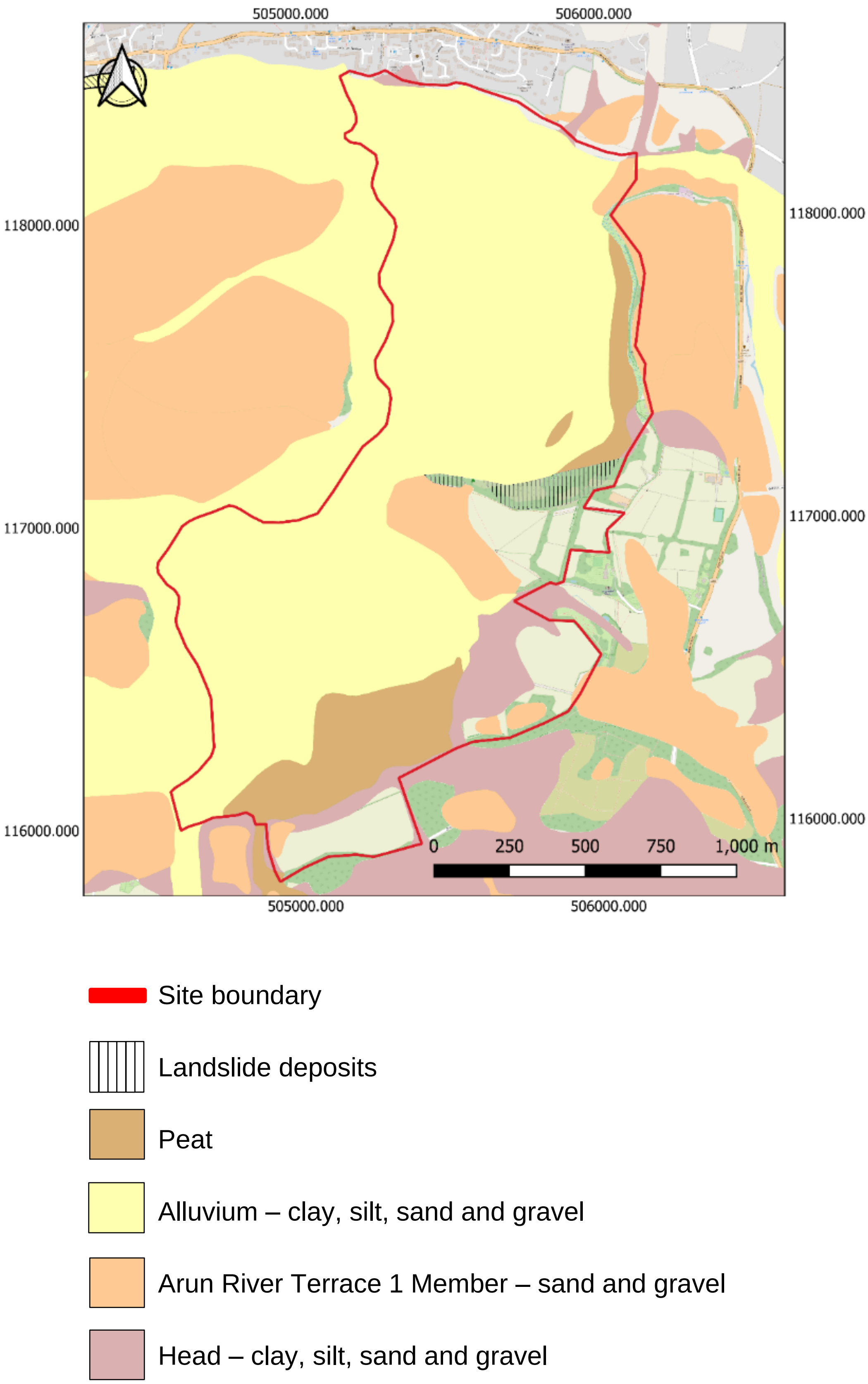
2.2.4 Pulborough Sandrock Member

Mapped by the BGS in the south of the Site, the Pulborough Sandrock Member consists of uniformly fine-grained, friable, well sorted fossiliferous sandstone. The lower boundary is the Fittleworth Member and upper boundary of Marehill Clay Member.

2.2.5 Fittleworth Member

Mapped by the BGS adjacent to the Pulborough Sandrock Member in the south of the Site, consisting of uniformly glauconitic sandy clays and clayey sands. Associated with the Pulborough Sandrock Member and upper boundary of the Eastbourne Member.

Figure 3 Superficial geology and mass movement from BGS 50K mapping



2.2.6 Peat

Peat deposits have been mapped in the northern and south sections of Site. RSPB hazard maps show soft peat in Large Rushey Brook and Pete Brook fields in the south of the Site. Folley Brook, Challens Brook, Ducks Brook, Penfolds Spring and South Langmead fields in the southeast of the Site are all flagged as unsafe areas to drive on. These areas are shown in Figure C.

Peat deposits develop from the accumulated remains of organic matter, forming when the accumulating quantity outweighs the decomposing quantity. Peatland development depends on a somewhat impermeable underlying geology, i.e., clays, to ensure sufficient water retention at ground level. In more freely draining contexts (such as is the case in some of Pulborough, with peat overlying the Arun River Terrace Deposits (RTD) and Folkestone Formation bedrock), development of the peat bog relies on a consistent groundwater supply such as springs and seeps.

In certain localities, in particular at floodplain margins of the deposits, peat is commonly overlain by alluvial clay. In the memoir by Bristow and Wyatt (1983), radiocarbon dating of the peat at Amberley Wildbrooks (near to Pulborough) is referenced, undertaken on peat overlying alluvial clay at a depth of 1.5mbgl. The peat was dated 2620 +/- 10 years B.P.

It can be difficult to estimate the depth of peat deposits as they typically become deeper and denser over time. A peat bog is diplotelmic, consisting of two layers: an acrotelm and catotelm in an idealised scenario (typically in the field it can be more complex than this idealised scenario). Material decomposes within the acrotelm and is added to the catotelm, with a reduction in pore size and hydraulic conductivity ensuring a high-water table is maintained.

2.2.7Alluvium – Clay, Silt, Sand and Gravel

Alluvium is mapped at surface across the majority of the Site, but this surface covering is absent from the eastern and south-eastern margins, furthest from the River Arun. Alluvium consists of unconsolidated detrital material deposited by a river on its floodplain. Typically comprising soft to firm, consolidated compressible silty clay with layers of silt, sand, peat, and gravel. A stronger desiccated surface zone may be present.

2.2.8 Arun Terrace Deposits – Sand and Gravel

A small area of Arun RTD Member 1 is mapped in the central area of the Site, between Pulborough North and Pulborough South. The BGS report that an average thickness of 4m can be expected but may reach 8-10m in some areas, comprising gravel, sand, and sandy gravel formed during the Quaternary era.

2.2.9 Head – Clay, Silt, Sand and Gravel

Head deposits are mapped in the south-eastern sections of the Site. Characterised by poor sorting and stratification, angular gravel and local lenses of silt, clay, peat, or organic material, head is termed a polymict deposit. Head deposits are typically linked to the Pleistocene periglacial solifluction.

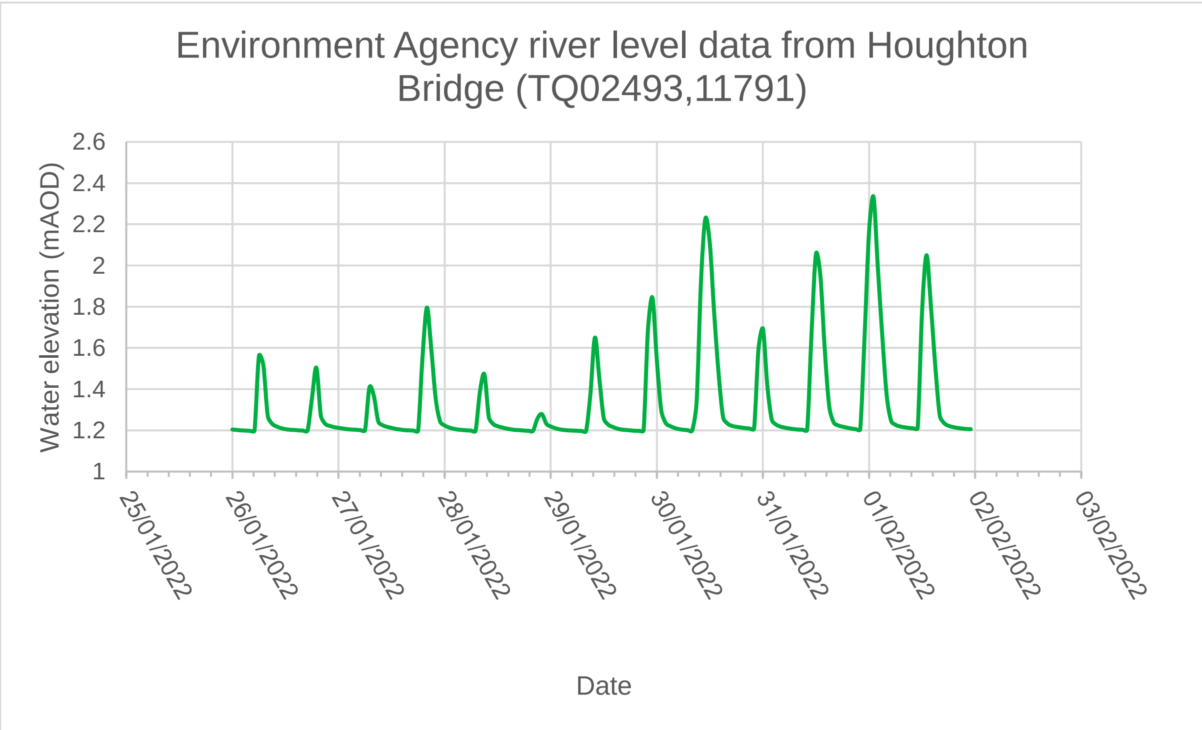
2.3 Hydrology

2.3.1 Surface water

Main rivers

The Site is bound by the River Arun to the west and the River Stor to the North. The River Arun has flood embankments along its course, with a series of flap sluices in place along the embankment. The Ordnance Survey map shows the presence of a Mean High-Water mark as extending upstream from the river mouth to the area of North Stoke, just downstream of Houghton Bridge, Amberley. Environment Agency (EA) data for a permanent river level monitoring point at the bridge has a clear tidal signal, albeit with the lower end of the signal truncated, presumably due to the presence of a structure in the channel retaining river water during the lowest portion of the tide – see Figure 4 below.

Figure 4 River Arun level data, Houghton Bridge (Contains public sector information licensed under the Open Government Licence v3.0 © Crown Copyright 2024)



The Site lies further upstream, with approximately 8 kilometres (km) of river channel between Houghton Bridge and Pulborough. Various sources suggest that the River Arun is tidally affected with a tidal influence detectable in river water levels all the way to its confluence with the River Rother at Pulborough, upstream of the Site. The tidal influence seen along the Arun adjacent to the Site is likely due to the indirect influence of saltwater intrusion/ regression, in the form of the backing up/release of freshwater through the tidal cycle.

Ditch network

The Site is reclaimed land from the floodplain of both bordering rivers. The area has been artificially separated from the River Arun and River Stor by the creation of levees along the entire length of the western and northern site boundary drained. A network of artificial drainage ditches have been created, criss-crossing the Site area. The levees and ditches are present on the earliest Ordnance Survey mapping (albeit there are slightly fewer ditches than at present), indicating that this process of artificially draining the Site predates 1885.

The ditch network comprises 8,143m in length. Larger ditches are typically 8-10m wide and 2m deep (Gasca and Ross, 2009). Minor ditches are smaller in size, typically 4m wide and 1.5m deep, and 7 ponds are seen in the East of the Site.

Information on ditch flow direction, inlet structures and outlet structures has been provided by the RSPB, as detailed in Figure D,

and Figure 22. Two inlet sluices are present in the northern end of the Site, which historically provided inflow from the River Stor. Anecdotal information from the RSPB suggests that neither of these sluices currently function. Three outlet sluices are present along the western edge of the Site, draining to the River Arun. The RSPB report that one of these is redundant. The other two are in use regulating drainage from the Site but are reported to leak.

Springs and seepages

Spring lines can be found along the eastern boundary of the Site near Brooks cottage and at seepage slopes within the Folkestone Formation. Springs are also noted in the south-western corner of the Site.

and

provide an indication of the location of known inflows to the ditch network from the adjacent higher ground.

2.3.2 Flooding

EA mapping indicates the majority of the Site is located in Flood Zone 3 (high risk). The areas of Flood Zone 3 lie either side of the River Arun. Areas along the eastern boundary of the Site lie within Flood Zone 2 and 1 (medium to low risk).

The Site is shown by EA mapping to be a very low risk from surface water (pluvial) flooding.

2.4 Hydrogeology

The hydrogeology of the Site is complex with spatially varying superficial drift deposits overlying a Principal aquifer at depth. Groundwater vulnerability on Site is classed as low to medium. The Site is located within a Zone I and Zone III Source Protection Zone.

2.4.1 Superficial hydrogeology

Superficial Alluvium and Arun Terrace Deposits are classified by the EA as a Secondary A aquifers. These are layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale.

Head Deposits are classified as a Secondary (undifferentiated) Aquifer. These are described by the EA as “aquifers where it is not possible to apply either a Secondary A or B definition because of the variable characteristics of the rock type” (gov.uk, 2017). These have only a minor value.

2.4.2 Bedrock hydrogeology

The Folkestone formation beneath the Site is classified by the EA as a Principal aquifer. These are layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale.

Folkestone beds form the ideal aquifer, sitting within the Wiggonholt syncline with free draining sands 44-71m in thickness, a lack of cement, and fines with a typical uniform coarse grain size. Groundwater flow is principally intergranular with transmissivity thought to be a function of aquifer thickness. Measured transmissivity in the beds range from $150m^2\ d^{-1}$ to $1200m^2\ d^{-1}$, with a geometric mean of $260m^2\ d^{-1}$ (Allen et al., 1997).

The Folkestone beds are part of the upper formation of Lower Greensands Formation, the aquifer is confined by Gault Clay and Marehill Clay aquicludes, hydraulically isolating the aquifer from the other regional principal aquifers; the Hythe Beds and the Chalk/Upper Greensands. On Site, the Folkestone sandstone is confined by the Gault Clay below and alluvial and estuarine deposits above. The presence of low permeability aquicludes limit the interaction between the Principal aquifer and the overlying shallow water table and river system.

Pulborough Brooks is located 2km away from a groundwater abstraction from the Folkestone Formation; the Hardham PWS - a public water supply serving over 100,000 people. This abstraction has led to a regional cone of depression in the centre of the basin modelled by Gasca and Ross (2009). It is currently unknown if a link lies between the groundwater abstraction and the shallow hydrology and hydrogeology mechanisms within the Site. However, connectivity between peat deposits mapped on Site and the aquifers beneath is possible. Southern Water undertook numerical modelling of groundwater within the Folkestone Formation; this model shows groundwater levels in the aquifer can rise and fall by 9m in response to variable rates of abstraction. The model predicted that, without abstraction, groundwater at Pulborough Brooks would be 4-6m above ground level, while with abstraction water levels would likely be at ground level, suggesting abstraction is depressing water levels (NE, 2021 and Hulme et al., 2012).

2.5 Previous site investigation

Groundwater and surface water data is currently being collected using an array of dip wells, piezometers and loggers installed across Site. In a previous Site Investigation (Atkins, 2006), 10 wells were installed across 6 locations to monitor groundwater (Table 2), and 8 surface water monitoring locations were implemented (Table 3). These wells were installed to monitor the interaction/hydraulic continuity between the deeper Folkestone beds and the superficial River Terrace and alluvial clays.

Table 2 Existing groundwater monitoring installations

Name	Type of Installation	Easting	Northing	Ground Level (mAOD)	Depth of Well (m)	Diver Installed
PB-GW-01	Piezometer	505527	116552	2.328	2.89	06/10/2005
PB-GW-02	Piezometer	505215	116319	1.443	2.18	06/10/2005
PB-SGW-03	Dip well	504835	116268	1.61	2.90	06/10/2005
PB-GW-03	Piezometer	504832	116267	1.576	6.85	
PB-SGW-04	Dip well	505418	117856	2.07	1.07	06/10/2005
PB-GW-04	Piezometer	505417	117853	2.062	5.25	
PB-SGW-05	Dip well	505727	117876	1.744	3.00	06/10/2005

Name	Type of Installation	Easting	Northing	Ground Level (mAOD)	Depth of Well (m)	Diver Installed
PB-GW-05	Piezometer	505725	117878	1.751	8.56	
PB-SGW-06	Dip well	506031	117919	2.051	2.34	06/10/2005
PB-GW-06	Piezometer	506031	117919	1.978	5.98	

Note 1: Blank cells within Table 2 indicate that the date is unknown.

Table 3 Existing surface water monitoring installations

Gauge Board	Easting	Northing	Stream Bed Level (mAOD)	Diver Installed
PB-RIV-01	506084.623	117901.965	1.472	06/10/2005
PB-RIV-02	505855.852	117174.198	1.107	06/10/2005
PB-RIV-03	505336.972	117501.555	1.089	06/10/2005
PB-RIV-04	505679.916	117126.675	3.208	06/10/2005
PB-RIV-05	505488.81	117166.003	1.705	06/10/2005
PB-RIV-06	505386.974	117156.808	1.202	06/10/2005
PB-RIV-07	505574.605	116713.187	3.671	06/10/2005
PB-RIV-08	505201.506	116528.41	1.236	06/10/2005

Note 1: Blank cells within Table 3 indicate that the date is unknown.

2.6 Site history

The natural hydrology of the area has been significantly altered by a man-made drainage network, groundwater abstractions, and construction of flood banks.

A review of historical Ordnance Survey (OS) mapping and Google Earth imagery of the Site has been undertaken (Google Earth, 2024a). Salient observations are summarised in Table 4.

Table 4 Site History

Epoch	Details
1885-1900 (OS one inch mapping)	The Site is shown as agricultural fields in the earliest available OS mapping. River Arun flows to the west of the Site in the same channel as the present day. River Stor and River Chilt are shown east of the Site. River Stor confluences with River Arun north of the Site. Field alignment with associated bounding drainage ditches in the northern and southern sections of the Site are identical to present day mapping with a footpath running along the eastern boundary. A small building is shown along the Site's eastern boundary. Heavily coppiced land, delineated as Northpark Wood, lies to the southeast of the Site.
1889-1913 (OS six-inch mapping)	The small building on the eastern boundary is now marked as Banks Cottage. A spring is labelled approximately 50m west of Banks cottage.
1949-1970 (OS 1:10,560 mapping and OS one inch 7th series)	A Roman road is mapped running east-west across the north Site section. A Roman bath house is marked to the east of the northern Site. A High-Water Mark of Medium Tides is marked along the Site's western boundary.
2001 (Google Earth Pro Aerial Mapping)	December aerial mapping shows fields in the south of the northern section of Site are flooded. West Clapham, East Clapham, Roman Road, Ducks Brook, Folley Brook, Challens Brook, Penfolds Spring, South Langmead, Large Square, and North Langmead fields all show surface water flooding.
2009 (Google Earth Pro Aerial Mapping)	December aerial mapping shows significantly reduced surface water from 2001 mapping. Ducks Brook, Roman Road, Folley Brook, Pensfold Spring, and South Langmead fields show surface water flooding.
2012 (Google Earth Pro Aerial Mapping)	September aerial mapping shows even less surface water than 2009 mapping, however this may be due to seasonal variations. Roman Road, Folley Brook, Duck Brook, Penfolds Spring, and South Langmead still show surface water flooding. October mapping of the same year shows a significant increase in surface water, particularly in fields to the north. Additional fields which include North Elbow, Sheep Pen, Small Square, and Kite Brook, along with the fields previously mentioned, show surface water flooding.
2013 (Google Earth Pro Aerial Mapping)	June and August aerial mapping shows the majority of the Site to be dry.

Epoch	Details
2015 (Google Earth Pro Aerial Mapping)	April aerial mapping shows surface water in West Clapham, East Clapham, Roman Road, Folley Brook, Duck Brook, and South Landmead fields. September mapping in the same year shows reduced flooding in Roman Road, Folley Brook and South Langmead fields only. This aerial photograph is particularly clear in picking up sinuous palaeochannels within the Site, which will predate the artificial geometric recent drainage ditches – see **Error! Reference source not found.** and **Error! Reference source not found.**.
2018 (Google Earth Pro Aerial Mapping)	August aerial mapping shows surface water in southern fields only including Folley Brook, Roman Road, Duck Brook, and Penfolds Spring.
2020 (Google Earth Pro Aerial Mapping)	April aerial mapping shows surface water in Roman Road, East Clapham, Folley Brook, Penfold's Spring, South Langmead, and North Langmead.
2021 (Google Earth Pro Aerial Mapping)	No discernible changes shown.

Historic and aerial mapping of the Site shows few changes from the earliest 1880 mapping. Aerial mapping highlights seasonal changes of surface water on the wetlands.

Figure 5 2015 aerial photography with clear sinuous palaeochannels highlighted by vegetation patterns (Pulborough North). Google Earth (2024a).

Figure 6 2015 aerial photography with clear sinuous palaeochannels highlighted by vegetation patterns (Pulborough South). Google Earth (2024b)

2.7 Environmental Designations

There are multiple environmental designations both on Site and in the surrounding local area, a summary of these designations from South Downs National Park Authority (2016) is provided in Table 5 below.

Table 5 Environmental designations within proximity of the site

Designation	Location	Information
Site of Special Scientific Interest	On Site	In the most recent assessment 100% of Pulborough was judged to be meeting the Public Service Agreement (PSA) targets and in favourable condition, however the valley wetlands are deteriorating in part due to drying conditions. Site managers' report ditches in southeast corner of Pulborough Brooks drying out in recent years.
Special Protection Area (SPA)	On Site	Lies within the Arun Valley SPA of European importance under articles 4.1 of the Directive (79/409/EEC) Annex I with over wintering Bewick's swans, and under article 4.2 by regularly supporting at least 20,000 wildfowl.
Special Area of conservation (SAC)	On Site	Designated an SAC due to the significant aquatic plant and invertebrate assemblages present, including the Ramshorn snail *Anisus vorticulus*. The Arun valley is one of the few remaining Sites in the UK to support this species.
Ramsar Site	On Site	Site designed as a Ramsar Site under criterion 2, 3, and 5. The Site supports seven wetland invertebrate species list in the British Red Book and the swollen spire snail *Pseudamnicola confuse* as well as four nationally scare plant species. The Site regularly supports 20,000 or more water birds and the ditches intersecting the Site support five British duckweed species, six out of seven British water dropworts *Oenanthe species* and two thirds of the British *Potamogeton* pondweed species.

2.8 Unexploded Ordnance risk assessment

Following an assessment by Zetica UXO the site has been deemed to be at a Low Risk from all forms of Unexploded Ordinance. With Zetica stating 'No records have been found indicating that the Sites were not bombed, and no other significant military activity has been identified on the Sites'. No specific actions are required when a site is designated a low UXO risk, however industry good practice should be followed during intrusive investigation. This constitutes ‘raising awareness of those involved in excavations so that in the unlikely event that a suspect item is discovered, appropriate action is taken’.

3. Fieldwork

3.1 Rationale

Two key drivers are in place for the undertaking of a ground investigation, namely:

- To provide the ability to monitoring water table fluctuations, as a key to understanding the hydrology of a peatland.
- To provide data on the presence/absence/distribution of peat.

Distribution of peat is shown along the eastern margins of the Site in BGS mapping and in eastern and southern sections on RSPB hazard mapping. The ground investigation on Site therefore aimed to characterise the depth of peat deposits across Site and to provide transects across the peat and the drift/solid boundary at the edge of the reserve, in order to provide data on comparative geology and groundwater conditions along floodplain/peat margins.

The ground investigation also involved constructing a series of groundwater monitoring well installations. A subsequent period of groundwater and surface water monitoring through the use of dataloggers was then proposed to characterise the spatial hydraulic gradients as well as at a point measure of water table depth. Allot et at (2009) suggest 15 dip wells is the minimum required for adequate representation of water table fluctuations at a site.

3.2 Site access

Site access was organised by RSPB. Vehicles were tracked along pre-existing tracks where possible, and livestock grazing was moved to minimise disruption to site.

3.3 Pre-survey site visit

A pre-survey Site visit was undertaken on the 12th of January 2022 to assess current Site conditions. During this walkover exploratory hole locations were agreed between RSPB, Natural England, Atkins, Southern Water, and Yellow Sub representatives.

3.4 Service clearance

Yellow Sub undertook clearance of each exploratory position for underground services in accordance with our common operating procedures, including:

- A review of services plans provided by Yellow Sub

- A survey of the Site with a cable detection tool and signal generator (CAT and Genny) to confirm the absence of underground services
- Hand pitting of each exploratory position to 1.2 metres below ground level (mbgl) where possible, to provide confirmation of clearance.

3.5 Fieldwork undertaken

Fieldwork was undertaken on the 25th, 26th, 27th and 28th of January 2022. The works comprised:

- Hand pitting using insulated hand tools to 1.2 mbgl to confirm the absence of services in all locations;
- A series of eleven boreholes (WS-P-11 to WS-P-22) drilled with a Crawler Mounted Terrier Rig to a maximum depth of 7 mbgl;
- A series of sixteen exploratory holes (HA-P-25 to HA-P-41) excavated using a hand auger to a maximum depth of 2.7 mbgl;
- 18No. Installations of groundwater monitoring wells (50mm internal diameter HDPE pipework) in both WS and HA holes;
- 3No. Surface water monitoring points (slotted 50mm internal diameter HDPE pipe pushed approx. 200m into the soil surface, with upstanding metal borehole cover for protection).
- Peat probing in select localities across the Site using peat probe rod;
- logging of all boreholes and the trial pit in accordance with BS5930:2015+A2 2020.

A second round of fieldwork was undertaken on the 16th, 17th and 18th of February 2022. Works comprised:

- Surveying of all 18No. installations across the Site;
- Construction of a series of fences around the installations;
- Installation and set-up of data loggers within 18No. installed to provide continuous (hourly) groundwater monitoring over a period of five weeks; and,
- Installation of one slotted stilling well into a drainage ditches, with datalogger deployed within.
- Installation of 1No. barologger to provide barometric compensation to datalogger readings.

During the site investigation, all borehole locations were completed as per the original scope. The encountered ground conditions for exploratory holes is discussed in Section 4 – Ground conditions.

3.6 Data limitations

Fieldwork was undertaken in January with subsequent data logger installation and removal in February and March (some data loggers were retained for further monitoring undertaken by Atkins). Monitoring has been undertaken in a small window across winter only. These are typically the coldest and some of the wettest months and can experience the highest groundwater tables. That said, the January and March periods were atypically dry, with precipitation less than the long-term average.

Due to the short-term nature of this monitoring period, it may not be possible to gain a full picture of the peatland hydrogeological interactions across all seasons and temperature/ pressure variations.

4. Ground Conditions

The location of the exploratory positions are shown on Figure E and Figure F, with photographs in Appendix A.

Ground conditions at the site concur with the geological mapping and comprised Peat overlying Alluvium and River Terrace Deposits with Folkestone Formation deposits at depth. Neither Upper Greensand Formation nor Marehill Clay Member were encountered during the Site investigation. The Gault Formation may have been encountered at the very base of one window sample hole, WS-P-16 at 4.5 mbgl.

4.1 Strata encountered

The strata encountered during the field work across all exploratory locations are summarised in the Table 6 below:

Table 6 Strata encountered during field work

Strata	Description	Depth range encountered (mbgl)	Range of Thickness mbgl (typical thickness, m)
Topsoil	Encountered across most of the site; absent at two locations, HA-P-30, HA-P-31, HA-P-32 and HA-P-34 where peat is present at ground level. Typically thin (<0.3m), it comprises a soft to firm brown organic-rich silty slightly sandy to sandy clay, generally with rootlets.	GL-0.8	0. 05-0.8 (0.3)
Peat	Encountered across more than half the localities on Site, absent in WS-P-11, WS-P-12, WS-P-15, WS-P-16, WS-P-19, WS-P-22, HA-P-25, HA-P-26, HA-P-35, HA-P-36, HA-P-40 and HA-P-41. Variable in composition, ranging in type in accordance with Von Post scaling, from H2 to H7, typically H5. Water levels in the peat are typically confined by the overlying clay-rich topsoil. Moisture content of the peat	GL to 1.5	0.1-0.7 (0.5)

Strata	Description	Depth range encountered (mbgl)	Range of Thickness mbgl (typical thickness, m)
	encountered typically increases with depth, with a trend of desiccated low moisture content peat in the upper 0.3m of peat. Peat encountered ranges from fine to coarse fibrous slightly decomposed/ partially decayed to strongly decomposed/ extremely decayed with occasional to moderate fragments of decomposed wood.		
Alluvium	Encountered across the majority of the Site beneath the Topsoil and Peat. In HA-P-37, HA-P-40 and HA-P-39 alluvium is overlying peat. Very soft and soft cohesive deposit. Generally comprising a grey, light blue grey, grey with orange / yellowish mottling silty clay or slightly sandy silt. Frequently forming interbedded layers of slightly gravelly clayey SAND. Organic material is comprising occasional rootlets or decayed fibrous fragments. Organic odour noted in the majority of deposits. Alluvium is noted to be interbedded with Arun River Terrace Deposits in WS-P-20.	0.2-5.5	0.2-2.3 (1.6)
Arun River Terrace Deposits (RTD)	Encountered in the northern and central area of Site only in WS-P-15, WS-P-16, WS-P-17 and HA-P-33. A yellowish/grey/brown mottled red granular deposit with variable proportion of coarse materials. Ranges laterally and vertically between a clayey/silty sand, gravelly sand, and sandy/gravelly clay. Gravel comprises flint and quartzite. Locally occasional shell fragments noted.	1.4-4.8	3.4 (1.5)
Head	Encountered in WS-P-16 only. Comprised a medium orange occasionally grey slightly	1.4-3.0	1.6

Strata	Description	Depth range encountered (mbgl)	Range of Thickness mbgl (typical thickness, m)
	clayey sand. Sand is fine to coarse predominantly coarse.		
Folkestone Formation	Found within WS-P-11, WS-P-12, WS-P-13, WS-P-14, WS-P-15, WS-P-22 and HA-P-29. Folkestone Formation bedrock consists of yellowish occasionally orangeish slightly gravelly to slightly clayey SAND. Sand is well sorted and uniformly graded.	0.2-6	2.5m+ (base not proven)
Possible Gault Clay	Red cementitious sandstone gravel was noted in the base of WS-P-16 at 4.5 mbgl. This coincides with BGS mapped boundary for the Gault Clay.	4.5	0.1+ (base not proven)

4.2 Progress and obstructions

No obstructions to progress were noted in any of the exploratory holes. However, the dense nature of the RTD resulted in lack of progress and refusals in several of the exploratory positions. Running sands from both the RTD and Folkestone beds also resulted in refusals of the sampler rig.

4.3 Stability

All exploratory holes remained stable however water ingress was noted particularly in the Hand Augers into the shallow peat.

4.4 Visual and olfactory signs of contamination

No gross contamination was recorded during the fieldwork.

4.5 Groundwater elevations

Groundwater was encountered in the majority of the exploratory holes during the drilling works at relatively shallow depth. Details of the groundwater strikes are given in Table 7 below.

Table 7 Groundwater strike details

Locality	Depth (mbgl)	Strata
HA-P-25	0.8	Peat
HA-P-26	0.75	Peat
HA-P-27	0.6	Peat
HA-P-27	0.7	Peat
HA-P-28	0.3	Peat
HA-P-29	0	Peat
HA-P-30	0.5	Peat
HA-P-30	0	Peat
HA-P-31	0.55	Peat
HA-P-31	0	Peat
HA-P-31	0.45	Peat
HA-P-32	0	Peat
HA-P-33	1.1	Peat
HA-P-33	1.17	Peat
HA-P-34	0	Peat
HA-P-37	0.85	Peat
HA-P-38	0.8	Peat
HA-P-38	0.8	Peat
HA-P-39	0.9	Peat

Locality	Depth (mbgl)	Strata
HA-P-40	0.77	Peat
WS-P-12	1.4	Folkestone Formation
WS-P-12	2.7	Folkestone Formation
WS-P-13	0.3	Peat
WS-P-14	0.3	Peat
WS-P-15	1	Alluvium
WS-P-15	2	Head
WS-P-15	3	Head
WS-P-15	4	Arun RTD
WS-P-16	2	Head
WS-P-16	3	Arun RTD
WS-P-17	0.6	Peat
WS-P-17	3	Arun RTD
WS-P-20	0.85	Peat
WS-P-21	1.5	Peat
WS-P-21	2.05	Arun RTD

Groundwater levels were recorded on a return visit between the 16th and 18th February 2022. The water levels are shown in Table 8 below.

Table 8 Rest groundwater levels in boreholes 16th to 18th of February 2022.

Exploratory Hole	Groundwater level mbgl	Groundwater level mAOD
SW-P-06	0.22	0
HA-P-28	0.1	1.62
HA-P-33	0.22	1.48
HA-P-37	0.187	1.80
HA-P-38	0.05	1.94
HA-P-40	0	1.69
HA-P-41	0.11	1.57
WS-P-11	1	2.51
WS-P-12	0.32	1.93
WS-P-13	0.89	0.88
WS-P-14	0.11	1.86
WS-P-15	0.35	2.41
WS-P-16	0.86	1.86
WS-P-17	0.15	2.09
WS-P-19	1.155	2.96
WS-P-20	0	2.03
WS-P-21	0.927	1.06
WS-P-22	1.909	2.79

Groundwater levels were monitored in selected wells for an interval of five weeks between 16th of February and 16th March 2022 using data loggers. Water levels were recorded at 60-minute intervals. The range of water levels are shown in Table 9 below.

Table 9 Groundwater monitoring manual dip results

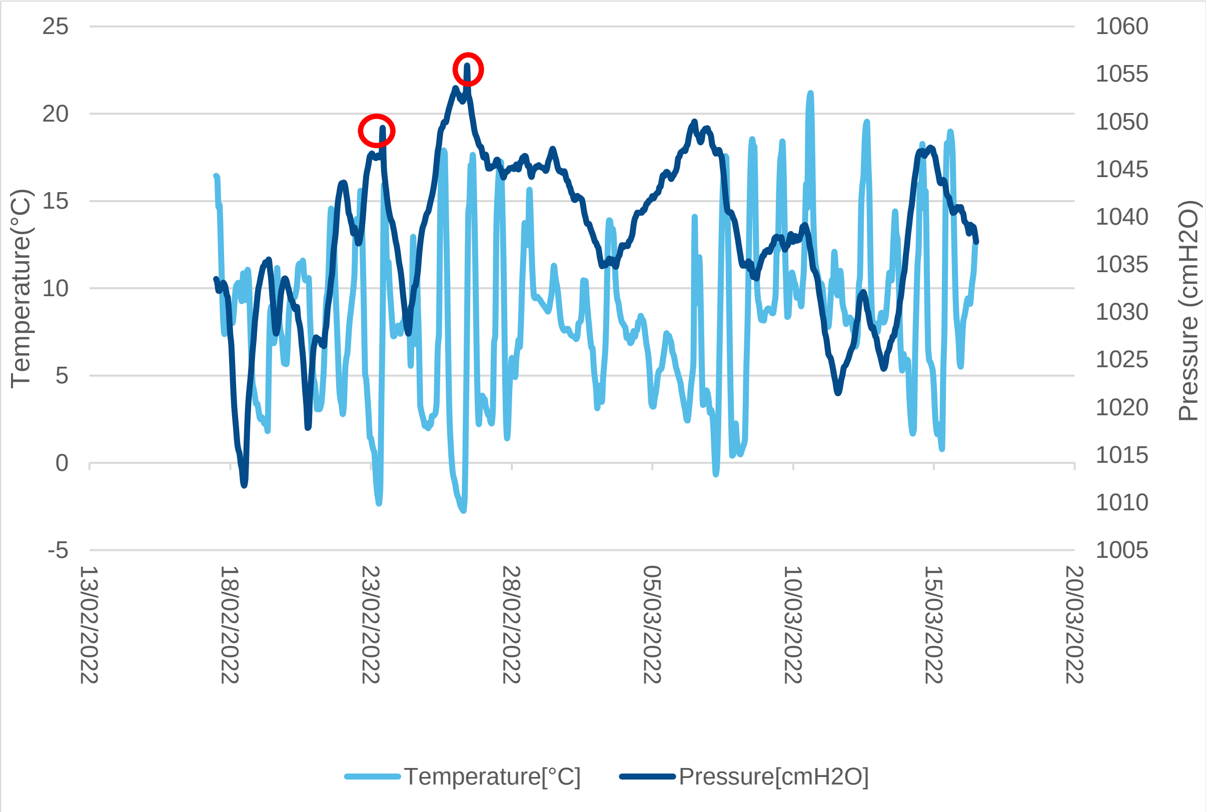
Exploratory Hole	16th - 18th February 2022 Groundwater level mbgl	16th – 18th March 2022 Groundwater level mbgl	March groundwater level cmAOD	Screened Strata
Ditch D3	0.44	0.425	-	Surface water
HA-P-28	0.1	0.24	172	Peat
HA-P-33	0.9	0	169	Peat
HA-P-37	0.187	0.3	199	Peat
HA-P-38	0.5	0.18	199	Peat
HA-P-40	0	0.01	168	Peat
HA-P-41	0.11	0.09	167	Surface Water

Exploratory Hole	16th - 18th February 2022 Groundwater level mbgl	16th – 18th March 2022 Groundwater level mbgl	March groundwater level cmAOD	Screened Strata
SW-P-06	0.22	-	230	Peat / surface water
WS-P-11	1	1.024	350	Folkestone
WS-P-13	0.89	0	177	Alluvium
WS-P-15	0.35	0.396	276	head/ RTD
WS-P-16	0.86	0.33	271	Head
WS-P-17	0.15	0.155	223	RTD
WS-P-19	1.155	1.105	411	Folkestone
WS-P-20	0	0	203	River Terrace Deep
WS-P-21	0.927	0.2	198	River Terrace Upper
WS-P-22	1.909	1.9	469	Folkestone beds
Ditch D3	0.44	0.425	240	Surface water

4.6 Water elevations

Surface water and groundwater elevations were monitored over a 1-month period in selected wells across the Site. Loggers were installed non-sequentially over the three-day period 16th to 18th February 2022 and the data retrieved from them over the three-day period 16th to 18th March 2022. Barometric pressure was also recorded and used to compensate the water level logger data. Graphs for each strata type and paired installations are plotted below.

Barometric data (Figure 7)

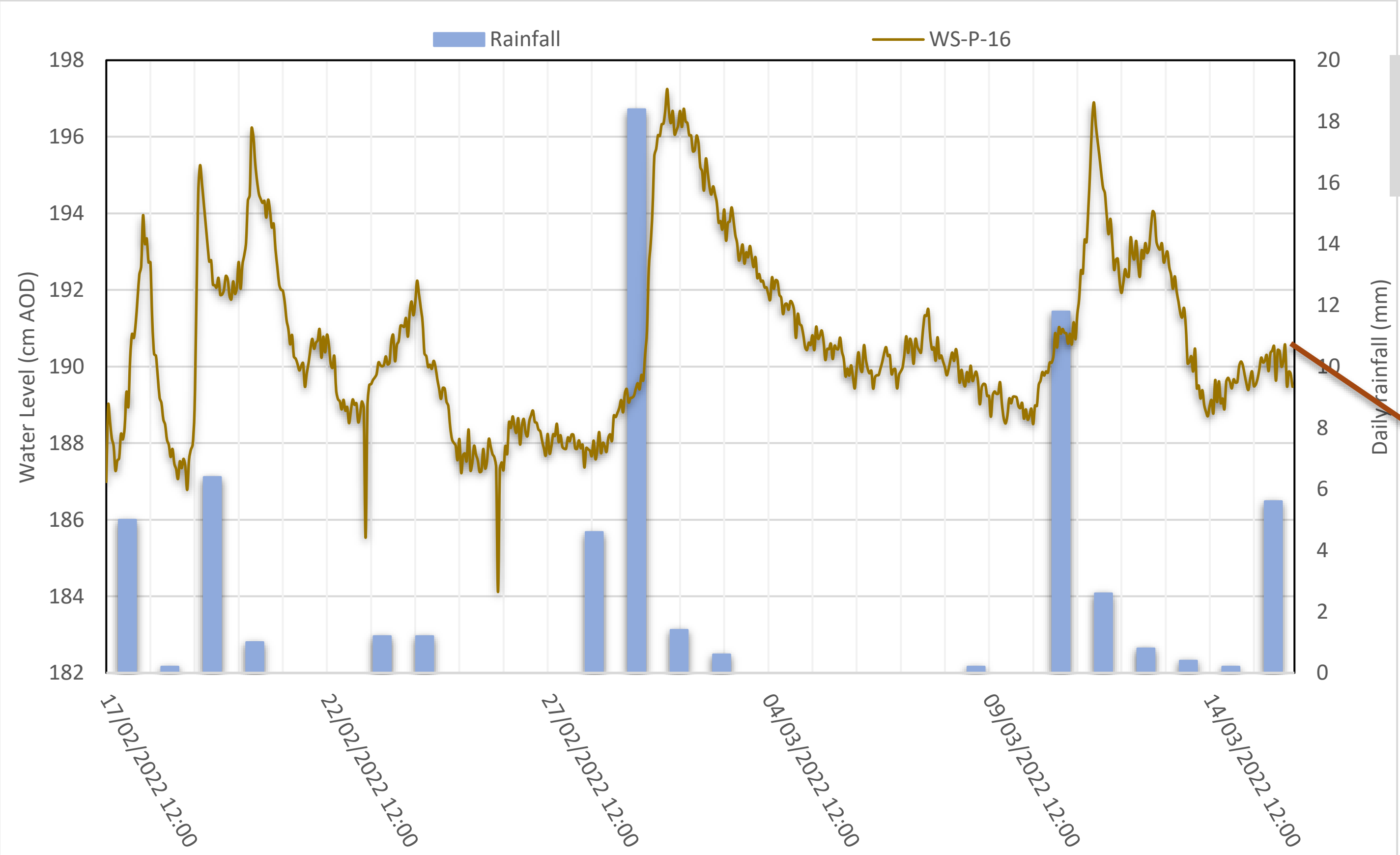


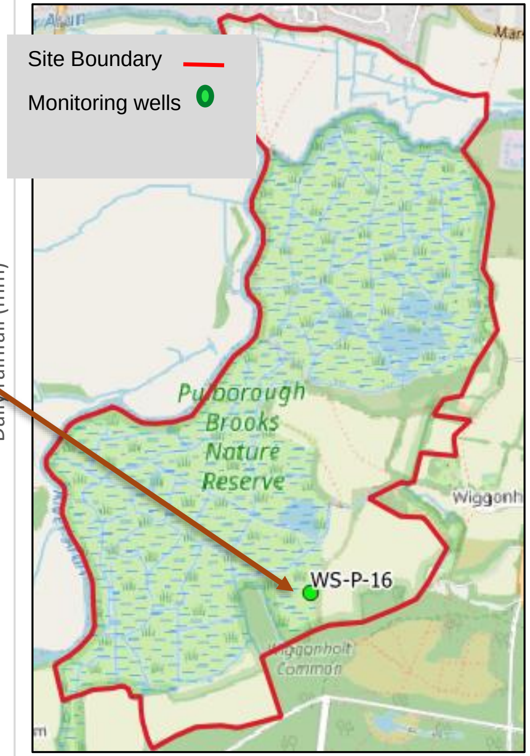
Barometric data has recorded pressure and temperature fluctuations on Site for the monitoring period ranging through February and March 2022. Two distinct peaks of high pressure were noted on the 23/02/2022 and 26/02/2022 with corresponding temperatures falling below freezing on both dates. A period of low pressure was noted on the 18/02/2022 with a slight rising trend to higher pressure throughout the month.

There are two distinct troughs in the temperature data on 23/02/2022 and 26/02/2022, corresponding with two peaks in atmospheric pressure. The two pressure peaks are sustained over a period of hours, but with a single additional spike on each occasion (circled in red in Fig 7). These correspond to anomalous spiked troughs in all of the groundwater and surface water datasets, as displayed on subsequent graphs (fig. Y-Z). The consistency of the presence and marked nature of these troughs in the groundwater/surface water data is such that these are interpreted to be artefacts of the barometric data, rather than representative of troughs in the water level data (i.e. these two instantaneous peaks have provided an artificial corresponding dip in water levels during the compensation process, which is not truly reflective of water levels).

Head

Figure 8 Groundwater hydrographs (head)



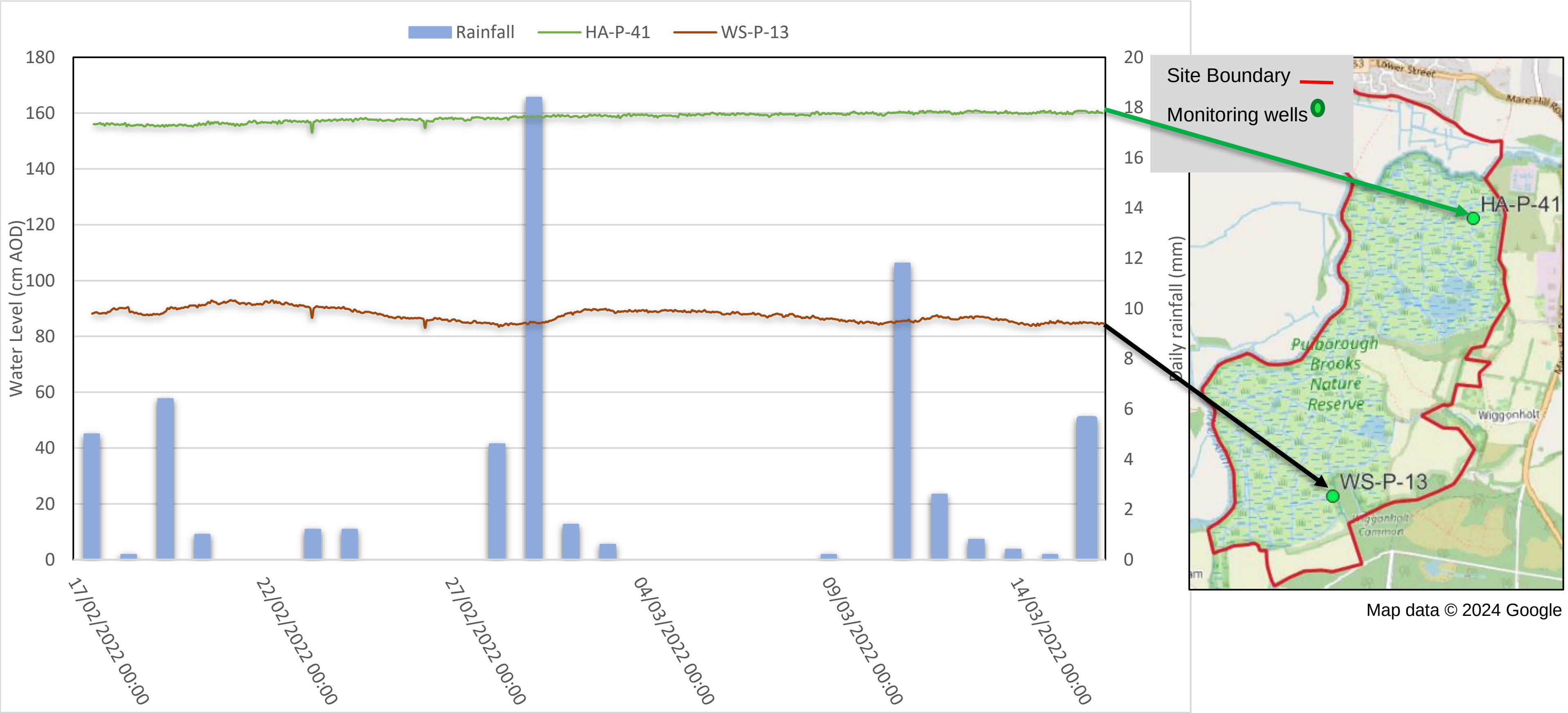


Map data © 2024 Google

Head deposits show a sharp rapid response to rainfall events. The hydrograph is characterised by a rapid response to rainfall, with sharp rise, followed by a slower return to lower water levels over the subsequent days.

Alluvium

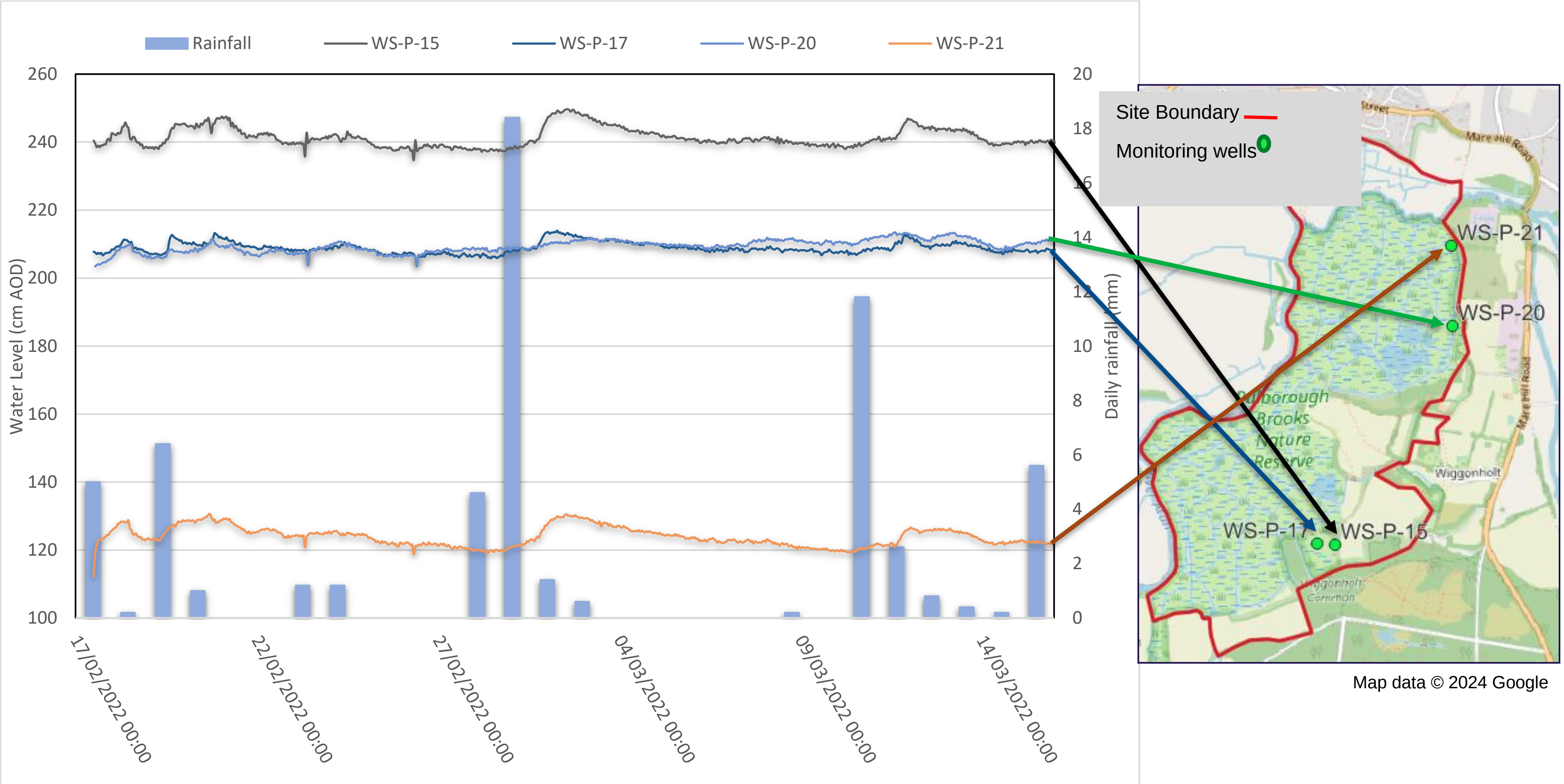
Figure 9 Groundwater hydrographs (alluvium)



Alluvium water levels have remained fairly constant over the monitoring period. Their hydrograph is much more muted in comparison with the head above, with the wavelength of response much longer, albeit with similar amplitude. HA-P-14 sees very little response to rainfall at all, but a gradual increase in levels of over the monitoring period.

Arun River Terrace Deposits

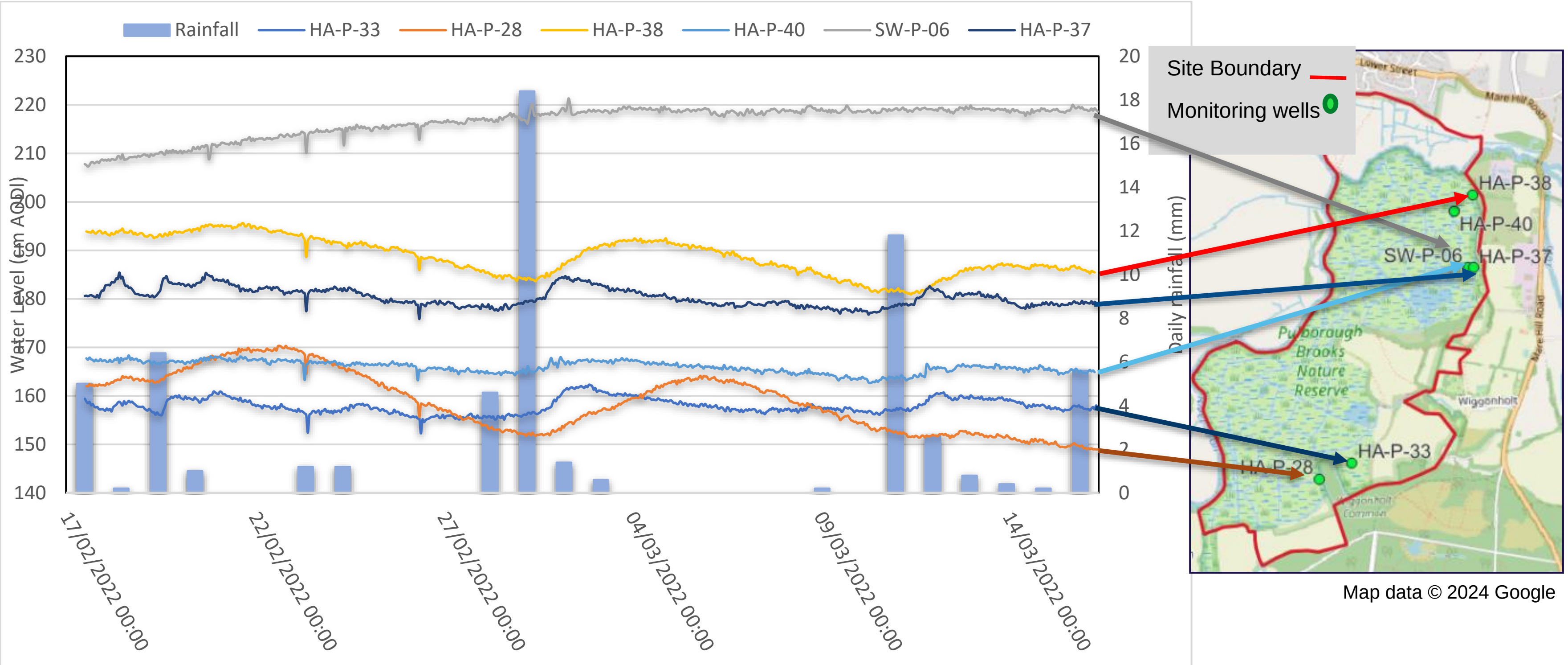
Figure 10 Groundwater hydrographs (river terrace deposits)



Arun RTD deposits show delayed smooth peaks in response to rainfall events. This delayed response hints that groundwater may be the controlling mechanism feeding the water level in this stratum. The RTD shows similar troughs on 23/02/2022 and the 26/02/2022 as seen in the Alluvium. These troughs coincide with two distinct periods of high pressure and low temperatures shown in the barometric graph above.

Peat

Figure 11 Groundwater hydrographs (peat)



SW-P-06 shows anomalous results of the monitoring well filling up and levelling off. This early increase in water levels is considered likely due to the isolating effect that the installation of metal protective cover has had on the monitoring well within. It has therefore taken approximately two weeks to equilibrate with the surrounding ponded surface water. The latter two weeks of data may be more representative of surface water conditions.

The remaining five installations can be separated on the basis of their hydrograph shape. HA-P-33 and HA-P-37 have a smaller amplitude, and a more rapid response to rainfall events, with a peak arriving within 24 hours of rain. In contrast, HA-P-28 and HA-P-38 both have a greater amplitude and a much slower response to rainfall events. In the case of HA-P-38, the hydrograph peak arrives 3 days after the rainfall event. HA-P-28 is delayed still further, with the peak at 5 days subsequent to the rainfall event.

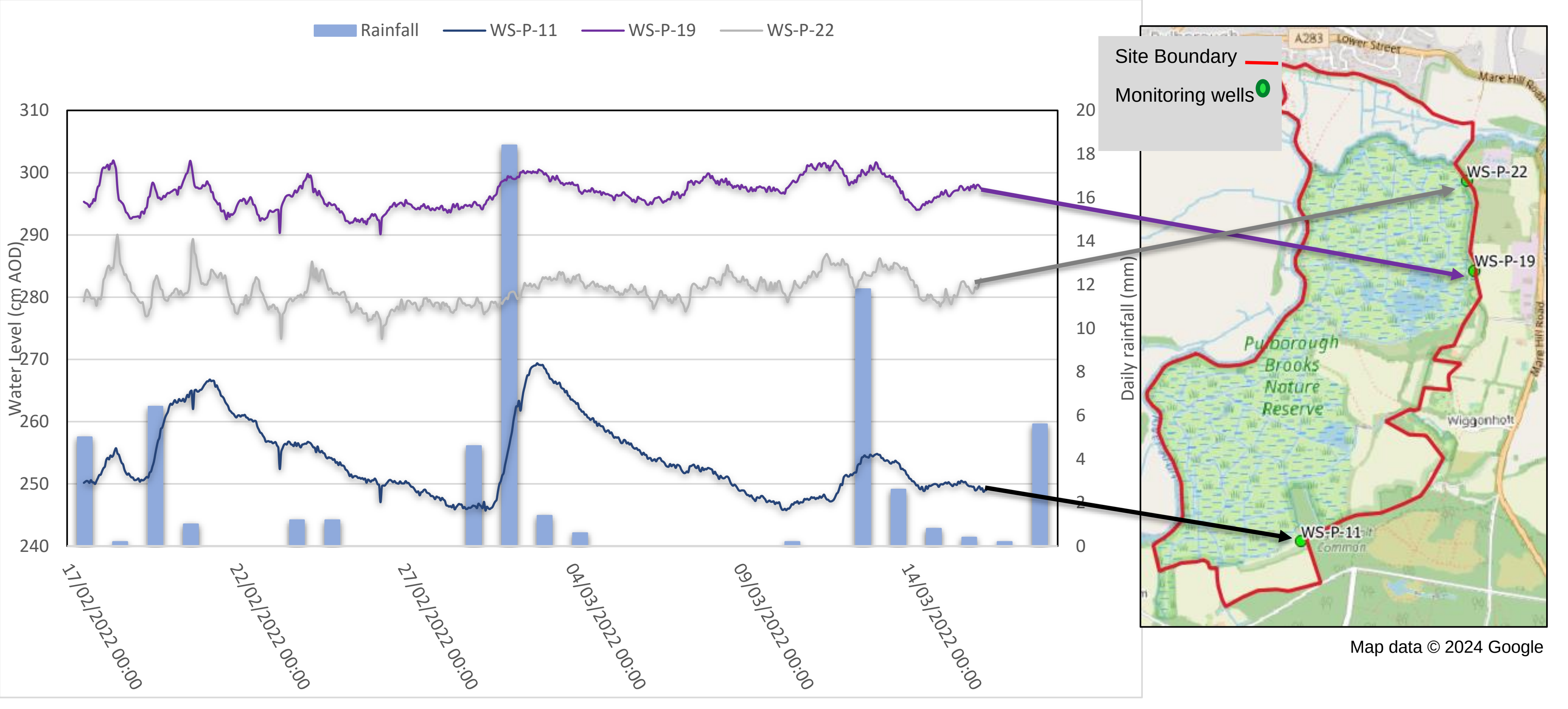
HA-P-40 shows a muted, small amplitude response. However, this peat body is buried beneath 0.8m of alluvial clay, and so any comparison with the other wells must bear this in mind. The small response to rainfall here is likely due to the confining nature of the overlying clay.

This suggests that groundwater within HA-P-33 is more directly linked to, and influenced by, rainfall. In contrast, HA-P-28 and HA-P-38 are more influenced by base flow, either directly from groundwater (as may be the case in HA-P-38, which is situated very close to the Folkestone Beds scarp slope on the east of the Site), or via inflow to the system associated with inflows from the surrounding catchment (as may be the case with HA-P-28, which lies close to the inflowing stream from the higher ground to the south). In both cases, HA-P-28 and HA-P-38 show a groundwater influence, either directly via sub-surface water movement, or indirectly via baseflow to streams and then inflow to the system.

In contrast, the hydrographs for HA-P-33 and HA-P-37 suggest much more of a rainfall-driven influence.

Folkestone Formation

Figure 12 Groundwater hydrographs (Folkestone Formation)

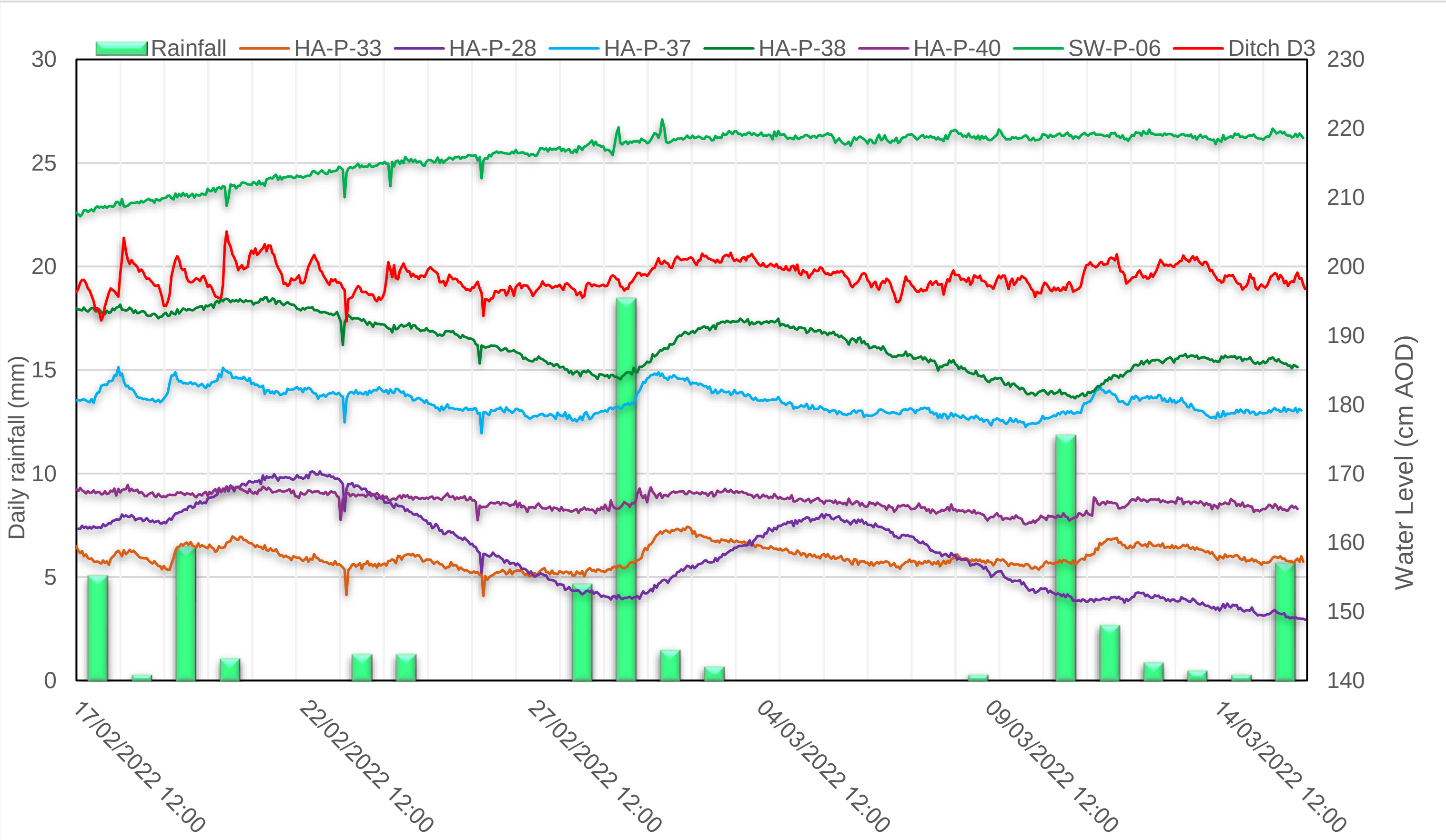


WS-P-19 and WS-P-22 shows similar trends whilst WS-P-11 shows a more marked response to rainfall events. The hydrographs of all three are indicative of an aquifer with high conductivity, with fairly spiky shape. The amplitude of response in WS-P-11 is much greater than in the other two.

The locations of all three wells are mid-slope. The catchment for WS-P-11 is much larger than that for the other two, due to the more gradual slope above and the larger area of higher ground with topographical fall towards the Site.

Peat and ditches

Figure 13 Groundwater hydrographs (peat and ditches)



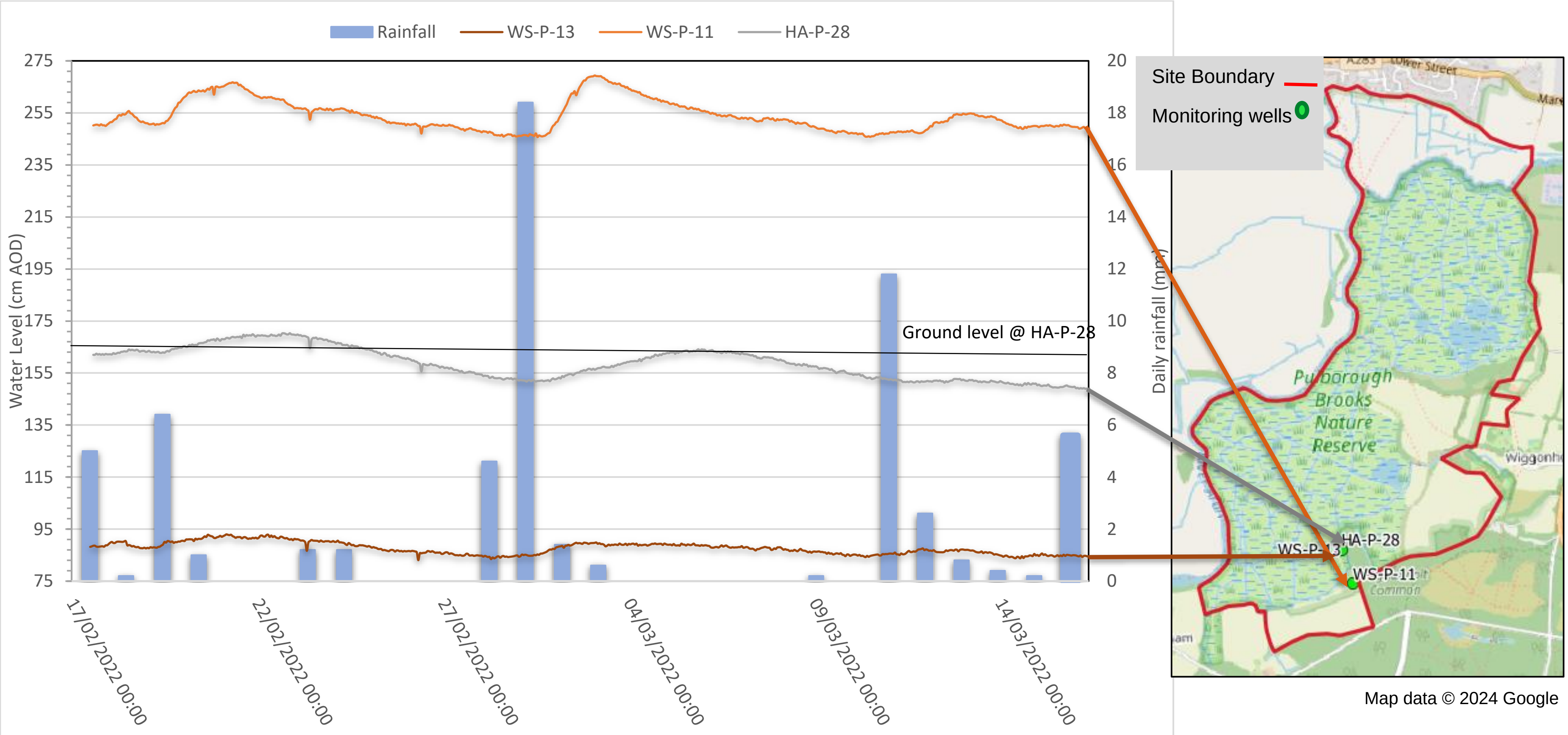
Ditch D3 shows a sharp jagged response to rainfall events, as might be expected of surface water bodies on Site. It also shows a small amplitude, suggestive of a large degree of storage, which may also be expected of the ditch network on site. It is important to note that, due to time constraints on site, an absolute elevation has not been determined for the D3 ditch logger installation. Its estimated elevation has been plotted on the graph above, but must be regarded as provisional until such time as a precise elevation has been surveyed for it.

SW-P-06 shows anomalous results of the monitoring well filling up and levelling off. This early increase in water levels is considered likely due to the isolating effect that the installation of metal protective cover has had on the monitoring well within. It has therefore taken approximately two weeks to equilibrate with the surrounding ponded surface water. The latter two weeks of data may be more representative of surface water conditions.

HA-P-38 and HA-P-28 show high and smooth peaks following a rainfall event. This delay in groundwater level rise shows both these monitoring points have a high groundwater feeding mechanism. HA-P-33 and HA-P-37 show sharper rapid responses to rainfall events than the other monitoring points and are likely less impacted by groundwater, likely ombrogenous.

Pulborough south transect

Figure 14 Groundwater hydrographs (Pulborough South transect)

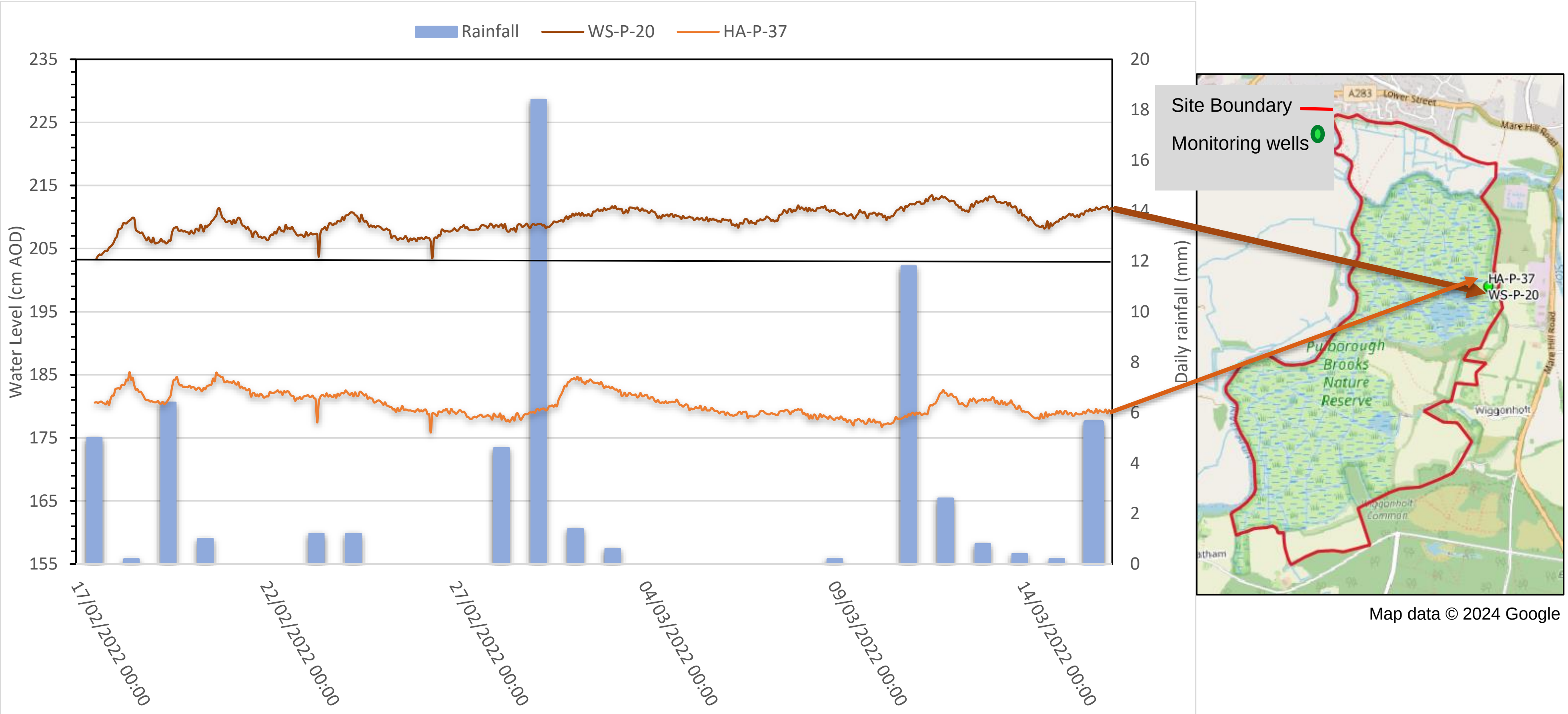


The southern transect has installations in the Folkestone (WS-P-11), alluvium (WS-P-13) and peat (HA-P-28). Folkestone stratum has the greatest response to increased rainfall with the peat and alluvium showing smaller amplitude peaks and troughs. The Folkestone has nearby ridges where precipitation can freely infiltrate while the peat is confined by an upper clay layer. The delay in response of the peat hydrograph is considered likely indicative of a combination of its reliance on groundwater feeding, and/or the low permeability nature of the deposit.

It should be noted that the groundwater elevation in the Folkestone beds is significantly above the ground level at HA-P-28, and above the elevation of the groundwater in the peat. This head difference would drive the upwards migration of water from the Folkestone beds, through overlying superficial deposits, thus providing some degree of baseflow to, or at least support for, groundwater within the peat.

Banks Cottage paired wells

Figure 15 Groundwater hydrographs (Banks Cottage transect)



The paired wells at Banks cottage are within the Arun RTD (WS-P-20) and the peat (HA-P-37). Both installations show similar trends with slightly higher peaks in peat in response to rainfall. The more marked response to the peat water body after rainfall events may indicate a more ombrogenous nature of the peat. Conversely, the groundwater elevations in the river terrace deposits are seen to be above ground level in this location, with this being corroborated by observations of artesian flow during the logger installation and retrieval. This suggests the potential for an upwards head gradient beneath the peat, potentially providing telluric baseflow to, or support of the peat groundwater from beneath.

5. Peat

5.1 Formation of Pulborough peat deposits

5.1.1 Pre-formation

In the last Devensian glacial period the sea level became progressively lower as ice accumulated on the continents. The sea level was approximately 130m lower than present day (Robinson and Williams, 1983). The nearest coastline to Sussex would have likely been southwest of the Scilly Isles 450-500km away. This sea level lowering led to rivers incising their channels particularly in lower valleys near to the (current) coastline such as the Arun valley. The Arun valley is estimated to have eroded its valley down to -36m OD at Arundel. Post-glaciation the sea levels rose rapidly as the ice sheets diminished, rivers infilled their lower valleys with post-glacial sediments including clayey sand and gravels deposited by flood water (River Terrace deposits and Alluvium) (Robinson and Williams, 1983). After this deposition, peaty clays interbedded with fenwood peat began to accumulate in riverside swamps.

Sea level is thought to have inundated the river valleys around 3000 B.P (Robinson and Williams, 1983), turning them into tidal estuaries. The Arun valley is likely to have remained a tidal inlet up until the Norman times as the Domesday Book records numerous salt workings in the area. The marine incursion into the lower Arun valley returned the base level of the river to near to today's levels, possibly slightly higher. This then created Pulborough Brooks low-lying floodplain, with the River Arun meandering across. The eroded scarp slope around Banks Cottage (which has led to the oversteepening and landslip to the south) was likely due to this low sea level. The floodplain was initially saltmarsh but became freshwater dominated by approximately 2600 BP, hence the commencement of peat formation. Peat overlies the marine silts and silty clays and sands, representing the return to freshwater conditions. This concurs with the small shell fragments noted in the Arun River Terrace deposits. Peat at Amberley Wildbrooks nearby has been radiocarbon dated as 2620 B.P suggesting a rapid retreat of the sea from the Arun valley (Shephard-Thorn, 1975).

5.1.2 Formation

Peat on Site has formed from accumulation of organic matter outweighing decomposition of organic matter in anoxic conditions. Peat formation occurs in waterlogged areas such as bogs, mires, swamps and fens in temperate, humid environments where decomposition is slowed. A shallow water table is critical for peatland development because it controls species composition through anoxia at depth, which retards decomposers and enables peat to accumulate. Water table depths are typically 5cm below the surface of a pristine bog. Different plant species have different root systems that can utilise water at varying depths, sphagnum moss is the main vegetation that accumulates across peat deposits. Typically, peatland development depends on a relatively impermeable underlying geology to ensure sufficient water retention on the land surface. In more freely draining contexts, peat development relies on a consistent water supply, such as springs.

Peat layer growth and the degree of humification depends on the peat’s composition and degree of waterlogging. A peat bog is usually described as diplotelmic (two layers of soil with distinct characteristics), with an acrotelm overlying the catotelm, however this is an idealised scenario. A dual acrotelm and catotelm is a simplification of peat properties as severely humified bands of peat may be separated by more fibrous ones. Material is added to the catotelm over time from decompositions within the acrotelm, becoming deeper and denser with a reduction in pore size decreasing the hydraulic conductivity of peat and enabling maintenance of a high-water table. Despite storing large amounts of water, peat covered catchments are typically poor suppliers of baseflow to rivers and streams.

The layer of peat on the surface (the acrotelm) is typically the least decomposed and the most permeable, with a fluctuating water table. Beneath this the peat remains saturated so oxygen cannot penetrate. In the catotelm the plant material decomposes slowly and becomes compact and less permeable to water. The velocity of water flow through peat is determined by its hydraulic conductivity which is typically measured in millimetres or centimetres per day. It can vary by the physical property of peat including vegetation compositions, compaction, decomposition, presence of macropores (pipes), and entrapped gas bubbles. Bogs remain wet because peat generally has a low hydraulic conductivity even when there is a relatively high hydraulic gradient.

5.1.3 WETMEC

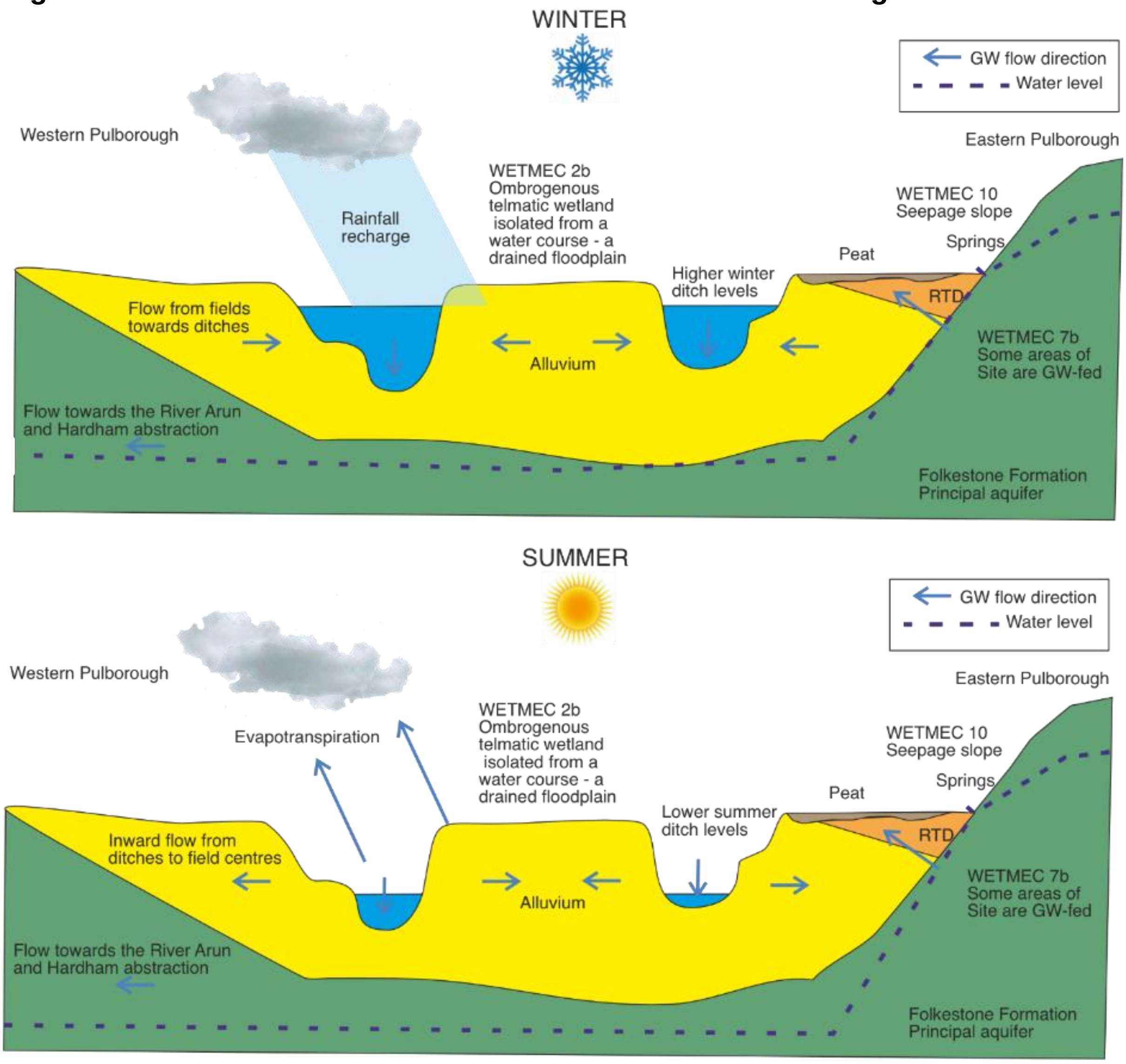
Wetland water supply Mechanisms (WETMECs) represent a simplification of the somewhat complex mechanisms and wetland classifications but provide a useful guide to clarify fundamental drivers of peat formation. The peat on Site is fed both by precipitation and the underlying Secondary A and Principal aquifers in conjunction with springlines. The WETMEC classification of the Site is likely to be 7b or 2b shown in Figure 16.

WETMEC 7b: A groundwater flood plain. Floodplain surfaces alongside groundwater-fed watercourses with water levels related to piezometric head of the source aquifer.

WETMEC 2b: An ombrogenous quag (GW-fed basin). The wetland forms a wet terrestrial ecosystem defined as a telmatic wetland. This wetland has relatively stable vegetation that is not inundated year-round. The water is acidic, so the wetland habitat is termed a ‘bog’. The area is a floodplain surface which is effectively isolated from the water course and is referred to as drained floodplains, drained levels or valley bottoms depending on the context. Some floodplain wetlands may have soligenous margins, but these are small in size in relation to whole unit.

The Site also has some areas that could be classified as WETMEC 10, being fed by seepage slopes, however the marginal ditch around the perimeter of the Site has partially severed this interaction.

Figure 16 Schematic cross section of WETMECs on Pulborough



5.2 Peat deposits across the Site

Peat was logged across the Site using the Von Post scale as described in Table 10 below:

Table 10 Von Post Humification Scale from Damman and French, 1987

Scale	Peat Characteristics
H1	Completely undecomposed peat; only clear water can be squeezed from peat
H2	Almost undecomposed; mud free peat; water squeezed from peat is almost clear and colourless

Scale	Peat Characteristics
H3	Very little decomposition; very slightly muddy peat; water squeezed from peat is muddy; no peat passes through fingers when squeezed; residue retains structure of peat
H4	Poorly decomposed; somewhat muddy peat; water squeezed from peat is muddy; residue is muddy but it shows structure of peat
H5	Somewhat decomposed; muddy; growth structure discernible but indistinct; when squeezed some peat passes through fingers but most muddy water passes through fingers; compressed residue is muddy
H6	Somewhat decomposed; muddy; growth structure indistinct; less than one-third of peat passes through fingers when squeezed; residue very muddy
H7	Well decomposed; very muddy, growth structure indistinct; about one-half of peat passes through fingers when squeezed; exuded liquid has a "pudding-like" consistency
H8	Well decomposed; growth structure very indistinct; about two-thirds of peat passes through fingers when squeezed; residue consists mainly of roots and resistant fibres
H9	Almost completely decomposed; peat is mud-like; almost no growth structure can be seen; almost all of peat passes through the fingers when squeezed
H10	Completely decomposed; no discernible growth structure; entire peat mass passes through fingers when squeezed

During the Site investigation, peat was found on the eastern margins on the Site in both the northern and southern sections in conjunction with the BGS mapping. Peat thickness varied in each of these areas and can be seen in Figure G and Figure H. In the south of the Site there was an obvious trend of increasing peat thickness towards the wooded area where a spring line was mapped and sampled. This area is known to be marshy with stagnant pools of black ponded water noted along the tree line's western boundary. The thickest peat spans 0.7m with thickness shallowing out to 0.1m west of the woodland. Peat east of the woodland ranges from 0.5-0.65 towards the woodland. The area south of this transect was one of the few areas across the whole Site noted to have healthy living sphagnum moss.

Peat thickness in the northern section of the Site ranges from 0.3-0.1m, decreasing in thickness as the transect heads west. This may be somewhat influenced by the increasing distance away from spring lines and seepages that emanate nearby from around Banks Cottage and further north.

Generally, in the central and northern areas of Pulborough the further west, toward the extant river channel, the deposits of Peat not only become thinner, but they are also often overlain by a significant layer of alluvium. Alluvium overlying the peat is often found at floodplain margins.

Figure 16 shows a cross-section through Pulborough North.

Alluvium is typically found beneath the peat for the majority of the exploratory positions, acting as an aquiclude to the permeable RTD and Folkestone beds below. This can be seen in the Pulborough South Transect graph in Figure 14 above.

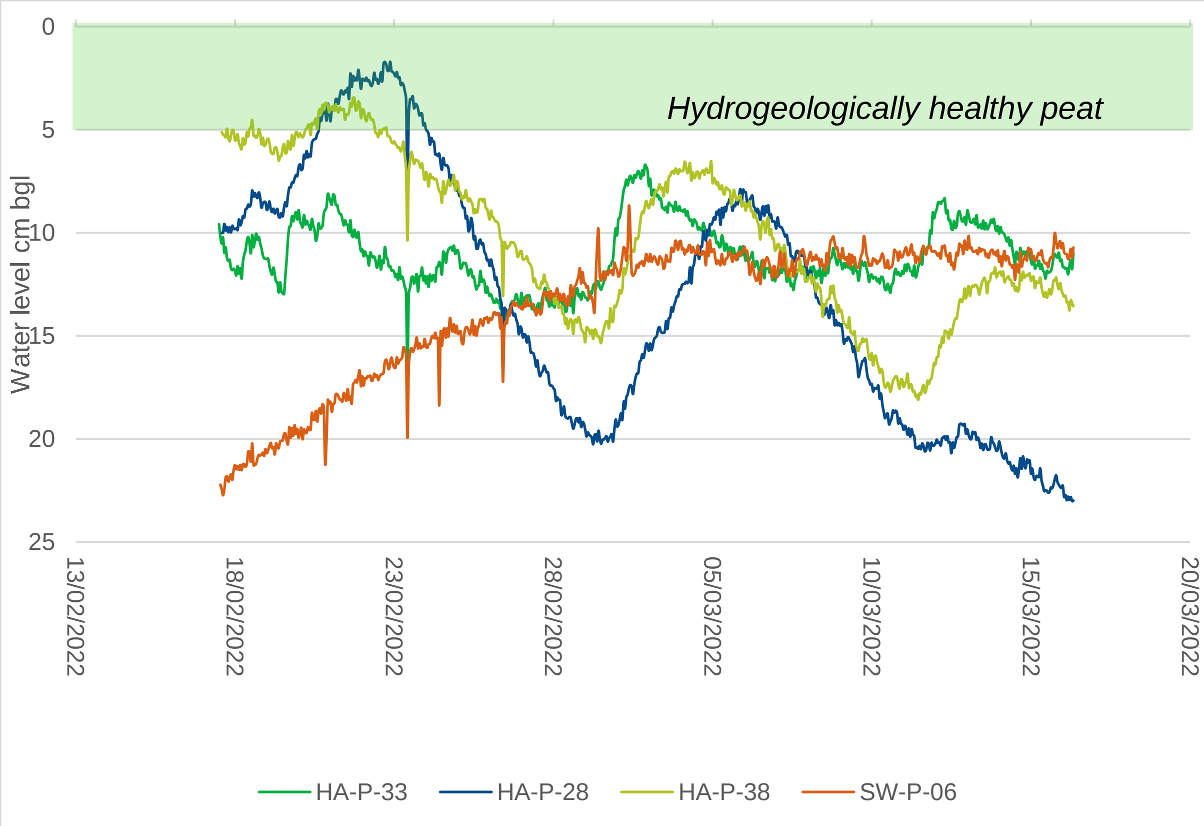
Topsoil was found overlying many of the peat deposits, forming a clay-rich impermeable layer and reducing the amount of surface run-off and infiltration into the peat below. This clayey topsoil layer has likely formed from a combination of sediment accumulation settling out of flood water during fluvial flood events (which would provide the input of sediment) and due to the preferential formation of soil during periods of drier conditions (which would reoccur in preference to ongoing peat formation if water levels within the peat are low enough to promote aerobic, rather than anaerobic degradation of organic matter).

5.3 Health of peat

Anthropogenic activities including burning, peat cutting, construction, drainage, afforestation, and grazing can all impact the health of a peatland. Within a hydrogeologically healthy peat deposit, the water table would lie within 5cm of the surface, enabling over 95% of plant material decomposition to be inhibited. Areas with a lower water table will allow for the aerobic decomposition of plants and a loss of CO_2 to the atmosphere, turning the peat into a carbon source as opposed to a sink.

Peat mapped on Site at or near ground surface appeared to be in relatively poor condition with some areas of healthier deposits. Water levels in the peat ranged from surface level to 1.5 mbgl with an average depth of 0.55 mbgl. During the groundwater monitoring, none of the monitored wells displayed water levels that consistently fell within the 0-5cm healthy peat bracket as shown in Figure 17 below.

Figure 17 Water level fluctuations in peat at or near ground surface in cm below ground level



The creation of drainage channels across Site pre-dating 1800s mapping has helped to accelerate the water outflow from the peatland in both magnitude and speed. Over time on Site more ditches have been added, although the general layout remains similar to the 1800s. Water tables can be drawn down up to 50m away from a ditch in fibrous peat, however drainage ditches have less of an impact on already decomposed peat. The drainage ditches also divert water emitting from springs mapped around Site, which flows through the ditches and off-site rather than across the surface of the peat.

Many lowland peat deposits on floodplains contribute to storing floodwater and slowing down the flow of floodwater to reduce flooding magnitude downstream, however on Site the construction of flood embankments severs this infiltration. Changes in peatland hydrology can lead to degradation of the peat by humification of plant material.

5.3.1 Peat desiccation

Water table instability is a feature in many damaged bogs, with water levels 50-100cm below the surface generating adversely dry conditions for sphagnum establishment. Prolonged desiccation of surface peat layers may lead to a development of a hydrophobic layer which would reduce infiltration capacity of the acrotelm peat and so generate increased occurrence of infiltration excess overland flow.

Run off is likely to be accelerated by the loss of vegetation, increased areas of bare peat, and desiccation which can lead to peat becoming so dry or hydrophobic that water doesn't infiltrate anymore (IUCN UK Peatland Programme, 2010). Conversely, in areas with vegetation cover flow peaks can be reduced and slightly delayed compared to bare peat. Sphagnum is important in reducing flow velocities.

Peat encountered on Site varied in condition. Desiccated peat with a low moisture content has been listed below:

Table 11 Peat condition recorded during fieldwork

Exploratory hole	Von Post Peat condition (see Table 10)	Water Content	Depth (mbgl)
HA-P-27	H6	Low	0.7-0.8
HA-P-29	H5	Low	0.3 – 0.65
HA-P-31	H5/6	Low with high water content peat below	0.15-0.45
HA-P-30	H5	Low	0.1-0.5
HA-P-32	H6/7	Low-med	0.25-0.65
WS-P-20	H5	Low	0.6-0.9
HA-P-37	H5 =	Low	0.6-0.9
HA-P-39	H6/H7	Low water	0.7-0.9
WS-P-17	H5/H7	Low-med	0.2-0.8

Figure 18 WS-P-17 Desiccated Peat

As seen in Figure 18, some of the peat deposits across the Site had a very low water content with discernible levels of decomposing rootlets and wood fragments noted. Many of the peat deposits had standing water at the surface above, a dry upper peat layer and then a wetter lower peat layer. This shows the peat is displaying hydrophobic behaviour described above.

6. Hydrology

6.1 River Arun catchment

The River Arun rises on the Tunbridge Wells Sandstones, although as it runs over Weald Clay the upper reaches tend to be flashy, with rapid run-off and high peak flows in response to rainfall. The River Rother is primarily groundwater fed; the majority of its flow originating from the scarp slope of the Chichester Chalk together with a substantial Sandstone feed from the hydraulically linked Chichester Chalk and Upper Greensand beds. These two, together with the Lower Greensand (mainly Folkstone beds), provide substantial baseflow with significantly less marked seasonal differences (National Rivers Authority Southern Region, 1996)

The confluence of the River Arun and the Western Rother is located approximately 1.8km upstream of the Site to the north-west. The River Arun continues onward and flows from north to south down the western Site boundary. The River Stor flows across the northern end of the Site and joins with the Arun adjacent to the northern extent of the Site. The section below details the catchment data for the three local watercourses immediately upstream of the Site obtained from the EA Catchment Data Explorer (2022), which describes the physical and chemical characteristics of the River that are used to determine its ecological status.

Upper Arun to Pulborough

The Upper Arun catchment is upstream of Pulborough Brooks, with the lower limit noted at the confluence with the Western Rother.

The EA describes the Upper Arun catchment as ‘predominately the non-tidal reach rising to the northeast of Horsham and flowing south until Pulborough at its confluence with the river Rother. Apart from the town of Horsham, the catchment area is largely rural, with most land under agricultural use. The biggest impacts on the water environment in the sub catchment relate to fish and water quality. There are many structures in the Upper Arun which prevent fish movement through the river system, and a number of large sewage treatment works which reduce water quality (EA, 2023).

The closest section of the Upper Arun and that most relevant to the Site is ‘Arun downstream of Pallingham Weir’.

The ecological status of Arun downstream of Pallingham Weir has been classed as Moderate from 2014 to 2019, this is directly due to a poor Phosphate classification with the poor Phosphate caused by a continuous sewage outfall in the catchment. There are also some failures of priority hazard substances:

- Mercury and Its Compounds

- Perfluoro-octane sulphonate (PFOS)
- Polybrominated diphenyl ethers (PBDE)

The majority of the classifications are high or good, with the hydro morphological regime also able to support a good classification.

Western Rother

Also forming a part of the Upper Arun catchment, the EA description is also relevant, with the Western Rother being mainly agricultural in nature with common impediments to fish and a number of sewage outfalls with the catchment area of 132.9km^2.

The ecological status of the Western Rother is classed as Moderate from 2013-2019 generally, due to a continuous moderate classification for Fish and Phosphate.

The hydrological regime in its current state does not support a good classification and there have also been a number of failures of Priority Hazard Substances in the most recent data set in 2019:

- Mercury and Its Compounds
- Perfluoro-octane sulphonate (PFOS)
- Polybrominated diphenyl ethers (PBDE)

These failures are identical to those noted in the Arun suggesting a widespread issue with these contaminants in these catchments.

The reasons for not achieving good in this catchment include:

- Poor soil management, a diffuse source affecting fish and phosphate classification,
- Continuous sewage discharge affecting phosphate classification,
- River alterations creating physical barriers to fish, and;
- Low flows likely as a result of surface water abstractions from the water industry

River Stor

The Stor catchment contains the entirety of the town of Storrington to the East of the Site, flowing along the norther Site extent before joining the River Arun, the size of the catchment is 20km^2.

The ecological status of the catchment is classed as moderate mainly due to a poor phosphate classification from 2013-2019.

The reasons for not achieving good in this catchment are strictly related to phosphate and include:

- Poor nutrient management techniques in agricultural and land management
- Point discharge of sewage from a water treatment works

There are also some failures of priority hazard substances:

- Mercury and Its Compounds
- Polybrominated diphenyl ethers (PBDE)

The majority of the classifications are high or good with the hydromorphological regime also able to support a good classification.

Lower Arun

Below the confluence with the Western Rother the River Arun is tidally influenced, the monitoring point for the classification of the Lower Arun is downstream of Coldwaltham Sewage treatment works located slightly downstream of the Site but is likely to represent conditions of the Arun as it passes adjacent to Pulborough Brooks.

The ecological status of the catchment is classed as moderate, due to the moderate classifications of the supporting elements (surface water) mitigation measures assessment from 2013-2019.

The reason for not achieving 'good' in this catchment is due to physical modifications.

There are also some failures of priority hazard substances:

- Mercury and Its Compounds
- Polybrominated diphenyl ethers (PBDE)

The majority of the classifications are high or good with the hydromorphological regime also able to support a good classification.

River embankments currently run all the way down the river valley to the coast which pushes the saline water higher up the river valley than a more natural estuarine system would. This effect is expected to exacerbate under climate change (Abraham et al., 2019).

6.1.1 Groundwater bodies

Lower Greensand Arun & Western Streams groundwater body

This groundwater body reflects the Folkestone Beds as well as the wider Greensands aquifer, which extends beneath the northern and southern extents of Pulborough and is the bedrock which forms much of the higher ground around the Site, from which springs and seeps flow onto the Site itself.

The Site is towards the eastern extent of the groundwater body, as it extends westwards as far as Petersfield and north from there to Haslemere.

It is assessed to have a poor overall status. This is driven by poor nutrient management which is ascribed to diffuse sources associated with agriculture and land management.

6.1.2 Summary

Overall, the majority of the catchments feeding into the Arun and the Arun itself are of moderate ecological status. The typical reasons behind the moderate classifications are that of poor or moderate phosphates, attributed to both poor land management of agricultural practices including soil run off and separately the discharge of treated water from wastewater treatment works.

There are typical failures of priority hazard substances across the majority of the catchments:

- Mercury and Its Compounds
- Polybrominated diphenyl ethers (PBDE)

6.1.3 Abstractions

In the vicinity of the Site is the Pulborough Water Supply Works (WSW), which supplies water to 100,000 households and abstracts water from the River Rother at Hardham Weir, and from the Folkestone Beds groundwater aquifer beneath the Hardham Site approximately 2km from the Site. The groundwater abstraction well field is licensed for a maximum abstraction of 36.5 megalitres per day (Ml/d), although recharge to the basin means that this rate cannot be sustained all year round. Being able to draw upon the groundwater reserve at high rates to meet peak demands is of strategic importance to the water company and provides a means of reducing the reliance on surface water abstraction from the river when river flows are low and ecological communities more vulnerable to a reduction in flow. (Gasca, Ross, 2009)

A further surface water abstraction also connected to the Hardham Water Supply works abstracts water from the River Arun at Churchland Farm immediately to the West of the Site boundary. This abstraction has been installed to take advantage of the tidal nature of the Arun at this location, to supplement the existing surface water extraction at Hardham during drought conditions, although saline water is not abstracted. Due to the turbidity of the water, abstraction takes place during the 6-hour ebb of every tide. Water is abstracted at a high rate across the ebb portion of the tidal cycle, and some of the abstracted water will be stored in the bankside storage pond and released as necessary to achieve a consistent overall output of 10Ml/d.

6.2 Pulborough Brooks current state

Pulborough Brooks has experienced modification at the hands of humans, generally to modify water levels by draining the land to an extent that provides grazing opportunities for cattle. More recently the RSPB have altered the landscape to make it more amenable to wild birds. In its current state the hydrological regime of the Site is regarded as modified.

6.3 Inflows

Methodology for modelling the wetland water levels has been derived from Gasca and Ross, 2009; the methodology links regional hydrogeological processes to wetland hydrology and ecology which are affected by processes that take place on a reduced spatial scale, requiring consideration of large scale and small-scale processes that influence water levels. This model helps predicts future wetland water levels and assesses how suitable these modelled water levels are for species of ecological significance.

6.3.1 River Arun

Generally, inflows from the River Arun throughout the Site are limited by flood embankment. Inflows from the river are therefore limited to controlled feeds via sluices, and via periodic overtopping during fluvial flood events.

Inlet sluices

Whilst two historical water inlet sluices are present in the north of the Site, it is understood that these are redundant. The intended approach for these sluices is that, during times of water scarcity, sluice B (Figure D) is used to feed the designated Site, by 'chinking' the tidal flap open to drive water into the Site from the River Arun to top up ditch water levels. This will only be done when wetland water levels are low enough to compromise designated species, as concerns have historically been raised regarding water quality in the River Arun. In addition, a sufficient head of water in the River Arun must also be available to drive water into the Site (Gasca, Ross 2009). Anecdotal information from the RSPB suggests that this operation has not been undertaken in recent years.

Occasionally overtopping of the embankments does happen, providing a mechanism for floodwater to enter the Site from the north and west. This floodwater is likely to have a high sediment load.

6.3.2 Aquifer Feeding

As noted during the investigation, there is in places confined water pressure in the underlying aquifer, both in the shallow and deep superficial deposits. The peat deposits on Site often form an aquiclude, with penetration of the peat during the investigation often associated with a water strike which would subsequently rise.

Furthermore, borehole WS-P-20 installed in the deeper Arun Terrace deposits showed Artesian conditions after installation; this was located close to the eastern Site margin, but it is likely the head of water does extend further onto the Site. The results of the Site investigation confirm a proportion of the water balance on Site is derived from the underlying aquifer. This is supported by the artesian conditions recorded (which provides an upwards head gradient from underlying RTD and bedrock towards the overlying peat). Peat hydrographs suggest that some areas of peat may be more groundwater fed than others (as displayed by the difference between HA-P-28/ HA-P-38 (delayed response to rainfall suggestive of groundwater) and HA-P-33/ HA-P-37 (rapid response suggestive or more rainwater fed)).

It should be noted that the investigation took place during winter where the aquifer water table is elevated, and during summer months the reverse may be true, with water leaking from surface and meteoric inputs through the Site into the underlying aquifer.

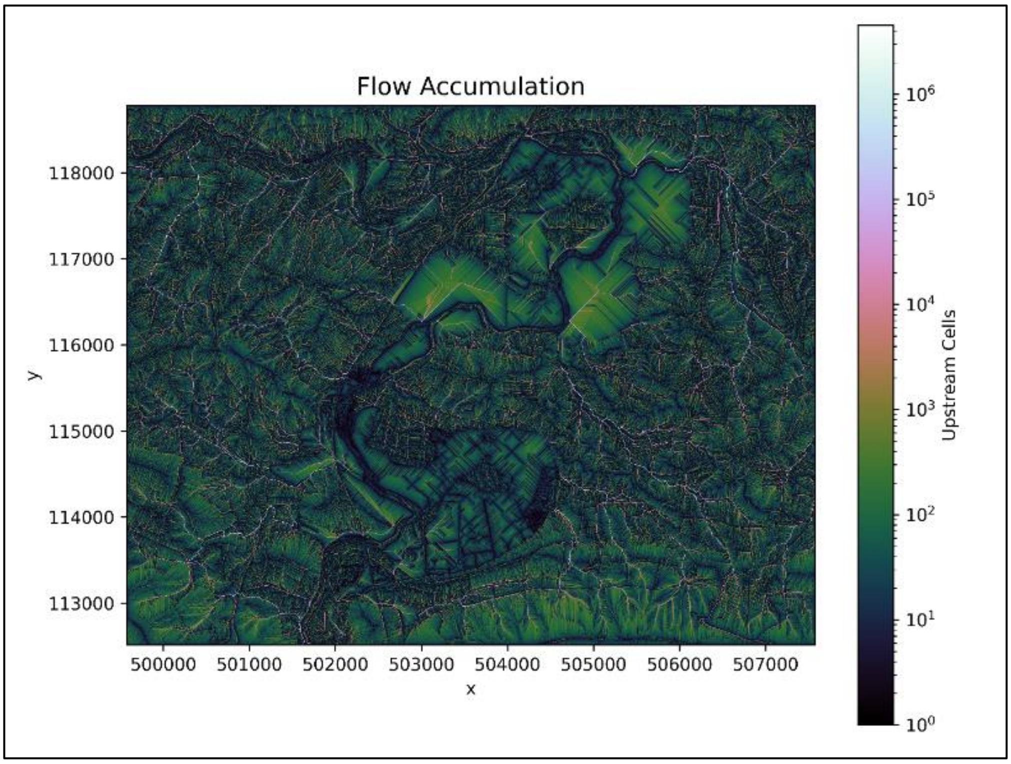
6.3.3 Meteorological

The site is 65 ha with a mean long-term annual regional rainfall of 650 mm/year. Rainfall used within this study has been taken from the Southern Water monitoring station at Kirdford, some 9km north-west of the Site. In the summer months evapotranspiration will have a considerable effect on the proportion of this meteorological water recharging the groundwater table, both from direct evaporation from vegetation, and the subsequent evapotranspiration of surface water directed to the ditch system.

6.3.5 Marginal Feeds; Springs and Seeps

A considerable proportion of the water balance of the Site are springs and seeps from the margins of the Site. Figure 19 details LiDAR derived flow accumulation where the digital terrain model created from the LiDAR is used to calculate the accumulation of flow based on terrain, delineating catchments and showing the predicted path of water. Pulborough Brooks is denoted by the two large green areas in the northeast of the map, due to the very flat terrain, flow path calculations were not possible for the majority of on-site locations.

Figure 19 LiDAR imaging detailing flow accumulation



As can be seen in Figure 19, there is an abundance of very small catchments, rising at the head of the raised ground along the eastern and southern reaches of the Site. Although the typical sandstone geology of these catchments will allow for a large amount of infiltration along these catchments, some water will flow onto the Site from these catchments. In addition to this, there will be a component of incident rainfall that has infiltrated into the underlying aquifer that rises out of the ground at spring and seep lines. The RSPB have identified springs and seeps in the vicinity of Brooks Cottage and again in the extreme south-west of the Site, as shown on in Figure 20 and Figure 21.

Pulborough Brooks Catchment

The closest analogy in terms of water quality for the springs and seeps that feed Pulborough Brooks from the margins is likely to be the Pulborough Brooks catchment. Located immediately to the south-west of the Site boundary the catchment is 3.7km^2 in area and encapsulates some of the higher ground to the south of the Site around Fangrove Hill. The ecological status of this catchment is determined as moderate (from 2015-2019). Driving this classification are moderate ratings for Phosphate and Dissolved Oxygen, and a poor rating for Ammonia. The moderate rating for dissolved oxygen attributed to poor nutrient management and low flows in the catchment. The moderate and poor rating for Ammonia and Phosphate is attributed to poor agricultural soil management. As with other catchments in the region there are typical failures of priority hazard substances of:

- Mercury and Its Compounds

- Polybrominated diphenyl ethers (PBDE)

6.4 Water level Management Plan

Yellow Sub Geo have not seen a water level management plan for the Pulborough Site. However, the Water Level Management Plan for the nearby Amberley Wild Brooks states the following objectives:

The key factor to maintaining and achieving favourable condition is to maintain a high, naturally fluctuating water level during the winter and spring, and to allow splash flooding through the spring and autumn to create a mosaic of conditions. The following water level management objectives have been identified:

1) To maintain a high, naturally fluctuating water level during winter and spring, with a gradual change to a lower stable level in the summer;

2) To allow natural winter flooding, with shallow splash flooding throughout spring and autumn to create a mosaic of conditions to benefit wading birds, wildfowl, and wetland plants (including the grassland communities); and

3) To carry out de-silting and weed cutting operations on a rotational basis in order to retain the diversity of ditch habitats and associated plant and invertebrate communities.

It is considered likely that Pulborough Brooks operates under the same general aims and objectives with regards to water management.

6.5 Water movement on site

The main control of water flow on Site are the ditch drainage system; extensive and throughout the Site, the ditch system captures the inflows from the margins and surface water run-off from the interspersed vegetated ground between the ditches and directs it to the outfalls at the River Arun. The two maps below, produced by the RSPB, show the movement of water in the ditch system across the Site. Naturally, this only accounts for water captured within the ditch flow system and not surface water movement or flows into or out of scrapes across the Site.

Figure 20 North Pulborough Brooks Water Movement

Legend:

Culvert required | Twist pipes/elbows/culverts | Ditch | Flow direction

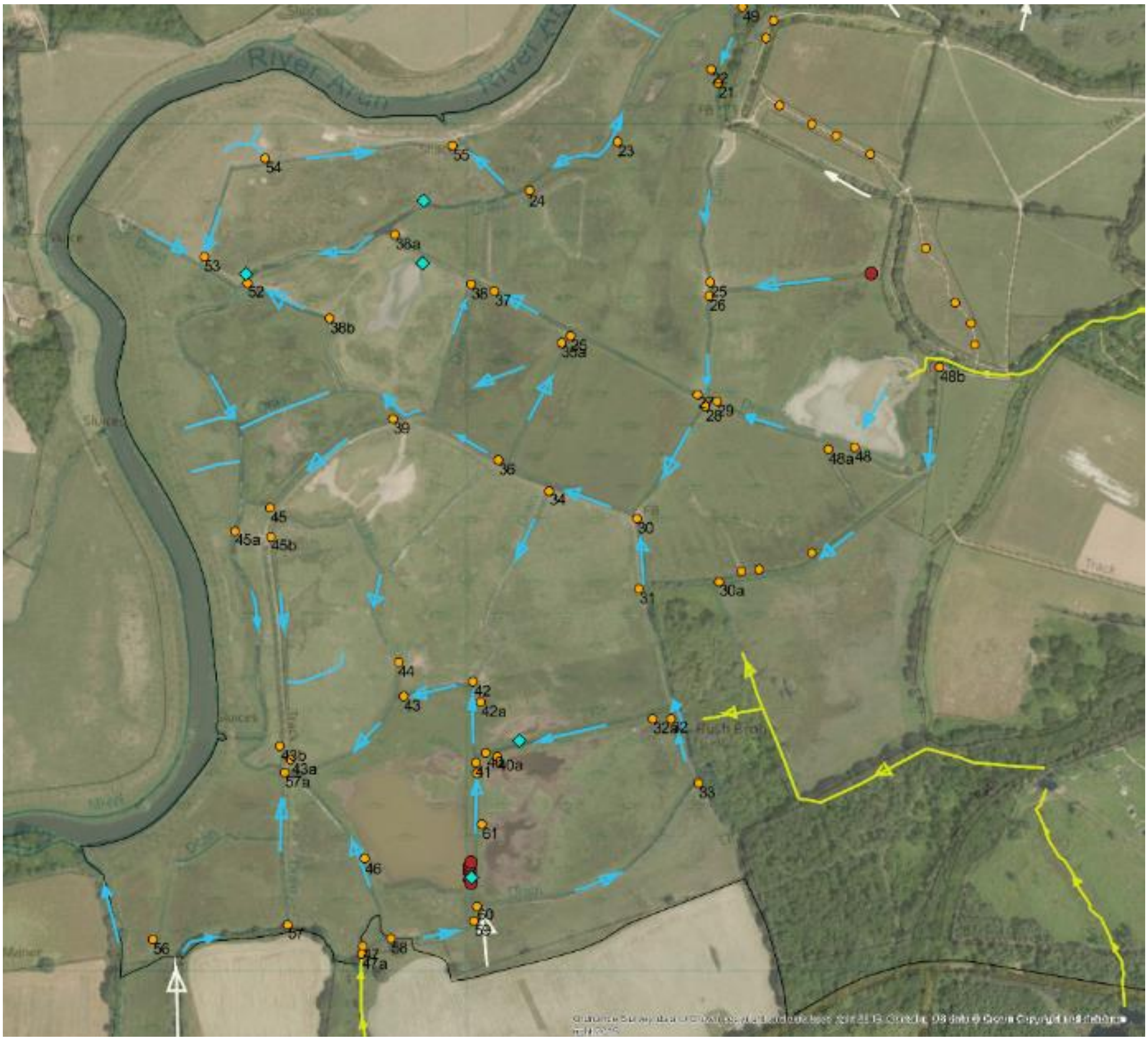
Spring line | n flow | RSPB Reserves – Public (UK)

Acknowledgements & Notes:

Created by RSPB

Water entering the Site from the northern reaches typically flows in a southerly or south-westerly direction across the Site. The further toward the centre of the Site, the more a westerly component of generalised flow begins to dominate. Water entering Site from the southern half typically flows in the north-westerly direction, although some tributary ditches have different alignments.

Figure 21 South Pulborough Brooks Water Movement



Legend:

Culvert required · Twist pipes/elbows/culverts · Ditch · Flow direction

Spring line · In flow · RSPB Reserves – Public (UK) · Build Up

Acknowledgements & Notes:

Created by RSPB

In the south of Pulborough, water enters via a spring line along the southern boundary and discrete inflows, marked with yellow. Flow direction doesn't follow a generalised path in the South of Pulborough, however the ditch that collects the southern marginal inflows flows in an anti-clockwise direction along the margin and then through the centre of the southern Site area before reaching the sluice outfall near 43b.

6.5.1 Outfalls

As can be seen in Figure 20 there are a number of water control features, both intact and defunct. The main outfall for Pulborough's northern section is located in the south-west of this section and is known as Sluice B. In the southern section of Pulborough there are outfalls noted at Sluice C and D, it is not currently known whether sluice C is operational. Sluice D forms the main outfall for the southern area of Pulborough.

Evapotranspiration

Previous work undertaken by ADAS (1995) has concluded that evapotranspiration is likely to form a large component of the water losses from the Site during the summer months, with the EA quoting the study on the nearby Amberley Wild Brooks Water Level Management Plan that 'piezometers recorded a pattern of low levels in the summer and a slow water level rise in the following winter.

This work suggests that the surface hydrology of the Site is controlled in the summer by the development of a soil moisture deficit in response to evapotranspiration, whilst in the winter the main determinant is the water level in the ditches.' (EA, 2006). They go on to state that the summer deficit is likely to be greatest in field centres away from ditches.

Notwithstanding this previous work, there are factors which may suggest that other factors are of importance during summer months, and that not all focus should be placed on evapotranspiration:

- A healthy peat bog relies on water levels within approximately 5cm of ground surface, but not above ground surface. An increase in evapotranspiration may lead to a soil deficit, but this may not necessarily significantly impact on the water table level (i.e. it may impact water level, but the overall health of the peat may be related to other long-term factors (e.g. base level of ditch water, degree of groundwater feeding etc.). Evapotranspiration may be a factor, but may not be the only or most important factor.
- A study on boreal peat bogs by Wu et al (2010) concluded that a tentative correlation between summer evapotranspiration and a reduction in water levels was, in fact, due to the coincidence of naturally falling water levels and increase in evapotranspiration during the period – their statistical analysis suggests that this relationship is coincidental, and not causative. Their study concluded that decreasing rainfall during summer months was the main causative factor in the declining water table. In other words, the change in water feeding was dominant, rather than the change in water loss.

Water quality

A considerable amount of long period water quality monitoring has been undertaken by others across Pulborough Brooks, Table 12 below shows a snapshot of water quality during both the winter and summer extremes at the Site collected during fieldwork undertaken by the authors of this report. The monitoring points B, C and D were chosen to take into consideration differences in ecological diversity and where certain notified interest features were known to be present, e.g. rare aquatic plant species and the SAC feature – *Anisus vorticulus*. This was part of the objective for Natural England; the water quality monitoring was undertaken across representative selection of locations for the Site in order to assess against Common Standards Monitoring Guidance water quality targets set. The sampling locations are detailed in Figure 22 below. Point B is used as it is representative of the conditions in the centre of the ditch system in the north of Pulborough Brooks, point B has inflows from ditches from the north and east, with a defunct sluice located in the far north of the Site and a sewage treatment works to the east but it unlikely that these will impact on the water quality at this point. Location D is chosen as it is relatively close to the margin in Pulborough South and will reflect water conditions closer to the margins of the systems and therefore marginal inputs. Location C is chosen as it close to the outfall in the South of Pulborough Brooks and therefore represents water with a high residency time and may have been affected by inflows of the River Arun at times. Water quality data of the bordering River Arun was also examined, the Greatham Bridge monitoring point was selected, as it lies just 1.5km downstream of the Southern boundary of Pulborough Brooks.

Figure 22 Water monitoring localities Pulborough Brooks created by Natural England using information supplied by Ordnance Survey © Crown copyright and database rights 2021. OS 10022021.

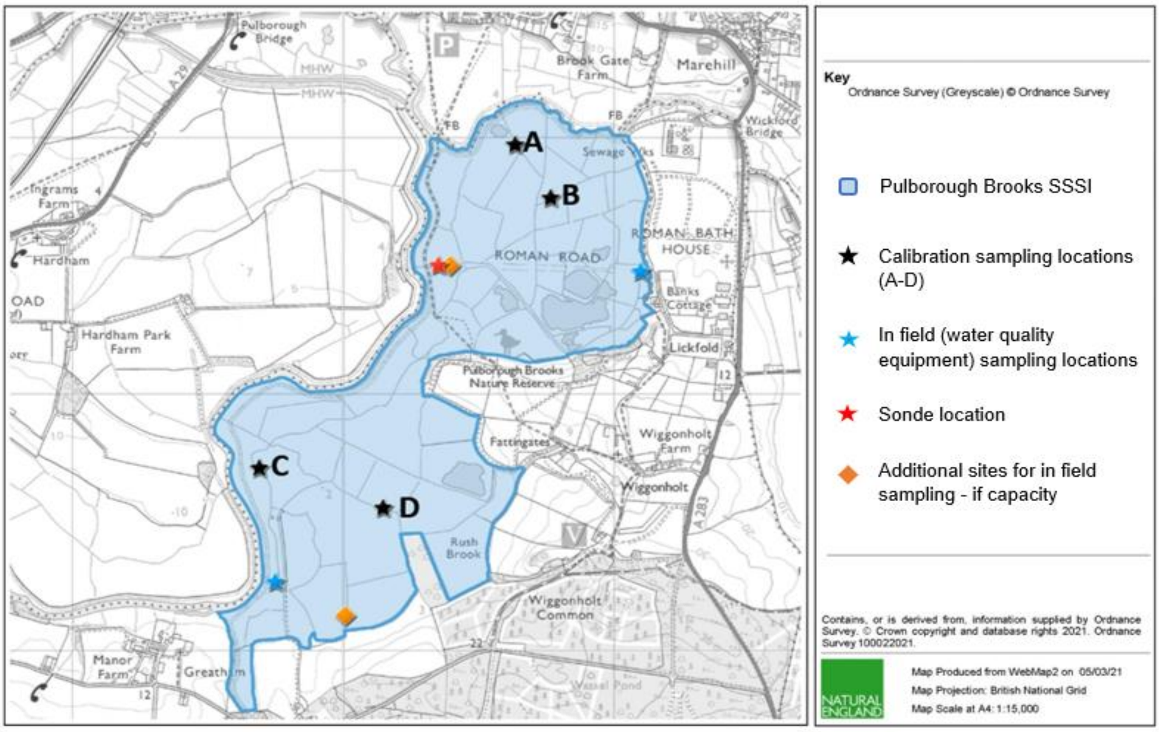


Table 12 Water Quality across Pulborough Brooks

Location	B	C	D	B	C	D	Greatham Bridge
Sample Date	21/06/2021	21/06/2021	21/06/2021	06/12/2021	06/12/2021	06/12/2021	24/10/21
Season	Summer	Summer	Summer	Winter	Winter	Winter	Autumn
pH	7.1	6.5	6.5	7.4	7.2	6.7	
Temp °C	16.6	16.7	16.6	4.8	5.4	5.6	11.6
DO %	21.2	38.8	42.8	80.6	73.4	73.8	70.3
Conductivity SPC	456.4	183.4	184.1	430.1	326.7	171.6	274.2
Salinity psu	0.22	0.09	0.09	0.21	0.16	0.08	0.13
Turbidity NTU	4.31	30.2	31.1	14	30.1	29.5	36.2
T Phosphorus mg/l	0.29	0.21	0.25	0.25	0.18	0.26	
Phosphate mg/l	0.041	0.03	0.081	0.3	0.17	0.25	0.23
T Nitrogen mg/l	0.9	1	1	1.5	2	1.3	
Ammonia N mg/l	0.12	0.49	0.23	0.084	0.31	0.19	0.07
Nitrate as N mg/l	0.11	0.53	0.27	0.27	2.35	0.42	
Nitrate mg/l	0.148	0.346	0.163	0.212	0.65	0.184	1.04
Nitrite mg/l	0	0.049	0.28	0.017	0.045	0.033	0.017

As to be expected, the oxygen demand on the water within the ditch system is considerably higher in summer than it is in winter, shown by considerably lower dissolved oxygen values in summer. The pH of the sampling locations does show a broad pattern of elevated readings during winter. Specifically, sampling point D, closest to the marginal input of the system, shows the lowest readings in both winter and summer, suggesting an acidic component to the water input. Salinity is consistently raised in point B when compared to the other locations, whilst the converse is true for turbidity. Phosphate is also raised in location D across both summer and winter and may indicate elevated phosphate levels from the marginal inputs into the system. This is also reflected in the ecological status of Pulborough Brooks catchment with elevated phosphate levels noted. Elevated phosphorus levels are also seen at Greatham Bridge, with catchment classifications consistently suggesting an issue with Phosphate from agricultural and Sewage Treatment practices. Notably higher turbidity and nitrate are also seen at Greatham Bridge, which may have been contributed to from agricultural runoff.

Water quality monitoring undertaken as part of this study

In order to attempt to identify linkages and patterns across the waterbodies within various strata and their feeding mechanisms, such as springs, seeps and ditches, Yellow Sub Geo undertook a period of spot water quality monitoring across three days from 16th to the 18th of March 2022. This water monitoring was conducted using a field Hanna probe which measured:

- Temperature °C,
- pH,
- Total Dissolved Solids (ppm @0.5),
- Electrical Conductivity (mS/cm)

Water was sampled using either a remote pole sampler for surface water or a bailer to retrieve water from borehole installations, with the probe allowed to sit in the water sample for a number of minutes prior to taking samples to allow the probe to equilibrate. The sampling locations are shown on Figure K. Further data on water quality is available in the condition assessment report.

pH and Electrical Conductivity

Tables 13 and 14 summarise the readings taken from a variety of locations including directly from aquifers across Pulborough Brooks. In order to analyse the data, the readings have been collated into sample 'buckets' dependent on where they were taken. It should be noted that these results indicate a 'snapshot' of water chemistry at the Site and conditions are likely to vary with season and rainfall.

Table 13 pH readings summary Pulborough Brooks

Localities	Count	Min pH	Max pH	Average pH
Alluvium	1	6.6	6.6	6.6
Ditches	6	6.7	6.9	6.77
Folkestone	4	6.6	7.2	6.78
Arun Inflows	3	6.8	7.1	6.93
Peat	5	6.7	7	6.8
River Terrace Deposits	7	6.7	7.3	6.9
Seeps and Spring Inflows	7	6.6	7	6.76
Surface Water	1	6.6	6.6	6.6

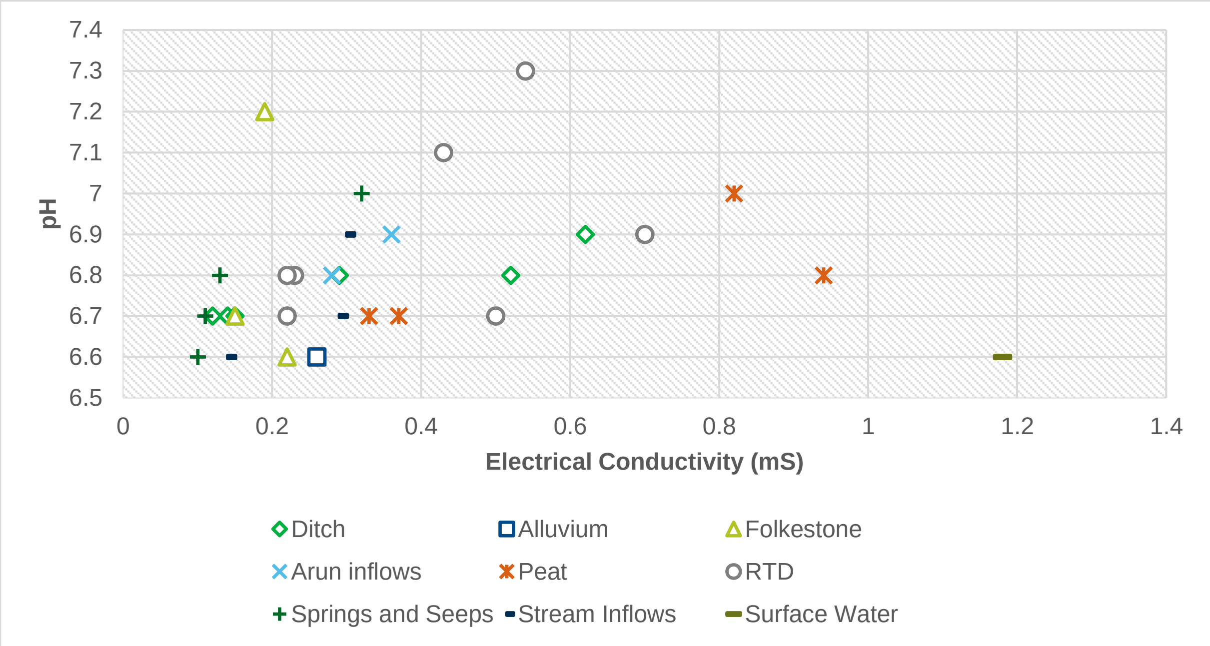
Table 14 Conductivity (mS/cm) summary Pulborough Brooks

Localities	Count	Min conductivity	Max conductivity	Average conductivity
Alluvium	1	0.26	0.26	0.26
Ditches	6	0.12	0.62	0.31
Folkestone	4	0.15	0.22	0.19
Arun Inflows	3	0.28	0.46	0.37
Peat	5	0.33	0.94	0.62
River Terrace Deposits	7	0.22	0.7	0.41
Seeps and Spring Inflows	7	0.1	0.32	0.20
Surface Water	1	1.18	1.18	1.18

Summary

The graph below (Figure 23) highlights the relationship between electrical conductivity in mS/cm and pH across Pulborough Brooks.

Figure 23 Graph of pH versus Electrical Conductivity Pulborough Brooks



Notably, the highest average pH readings were seen in the inflows from the River Arun, likely reflecting the different geology of the catchment of the Arun to that of Pulborough Brooks. Also noted were relatively high pH readings seen within the River Terrace Deposits on Site, however this was part of a wide range of pH values within this strata. With the exception of one outlier pH, the Folkestone Beds showed low pH and were consistently low in electrical conductivity.

The springs and seeps that form a large inflow component to the system generally tend to have a lower electrical conductivity than the other localities sampled and also have a relatively low pH. Conductivity was initially thought to likely be relatively high in these springs and seeps due to the often-observed ochreous hue of the springs seen around Pulborough. The single surface water reading shows a very high electrical conductivity when compared to all other localities sampled. This would likely indicate a limited meteoric water input in the week prior to the sampling round, which was corroborated by rainfall data, with evapotranspiration contributing to the concentration of ions within the remaining surface water.

Peat ranged from lower pH values at 6.7 to relatively high at 7, with higher pH often associated with higher electrical conductivity. Healthy peat has a lower pH derived from natural decomposition and cation exchange (Crum, 1988). There appears to be a relationship between pH and electrical conductivity within peat, with lower pH associated with lower electrical conductivity, though the mechanism behind this is not currently clear.

Naturalised state

In its naturalised state, Pulborough would have a considerably different hydrological regime than in its present state. In terms of input of water components, they would remain broadly similar with the notable exception of the inputs from the River Arun. In its natural state there may have been a limited raised section of flood levees adjacent to the channel but considerably lower than the flood control embankments currently seen. Consequently, the flood events covering the Site would increase in both magnitude and number, especially during Winter, bringing with it a higher sediment load than is currently deposited on Site. As can be seen from the Lidar image of Pulborough (Figure L), there are a number of relic sinuous channels which historically drained the Site. Water draining from the Site, be it from rainfall or marginal inputs, would likely have a considerably higher residence time when draining through the shallow, silty vegetated sinuous channels when compared to the current managed and cleared ditch system. This increased residence time through lower flows would likely have created a low-oxygen environment needed for the creation of peat deposits.

Chemically, the input of water into the system would naturally have lower Phosphate and Ammonia levels with the surrounding land uses not defined by intensive agriculture as they are currently; there would likely remain the potential for low dissolved oxygen due to the slow flow of water across the Site. This low oxygen is typical of peat forming conditions which clearly existed prior to anthropogenic influence at the Site.

7. Conceptual Site Model

A wetland is a complex system resulting from the interaction of an array of mechanisms. Knowledge of how the components interact, combined with a knowledge of the wider area, can help understand how changes may impact upon a wetland. This understanding is typically based on qualitative assumptions with a need for quantitative data to evaluate hypotheses.

Wheeler and Sahe (1995) have identified three main environmental gradients that determine the dynamics of a wetland:

1) Acidity
2) Fertility
3) Hydrological regime.

Acidity can range from base-rich in a chalk aquifer, to the more acidic conditions expected on site. The fertility of the site refers to the abundance of nutrients and whether the site can be classed as eutrophic or oligotrophic. The site's hydrological regime can be defined as stable if fed by a constant water supply, i.e. groundwater, or variable if fed by surface water, such as floodplains in a flashy catchment. A conceptual model of the site is shown in Figure 24, mapping out water movement and the overall hydrological regime.

7.1 Acidity

Peat ranged from lower pH values at 6.7 to relatively high at 7, with higher pH often associated with higher electrical conductivity. These values are towards the upper end of what is typically encountered in a healthy peat body and may indicate poor health of the peat deposits.

7.2 Fertility

Based on the abundance and variety of plant life on site, it is currently classed as eutrophic (although this is currently under review by Natural England due to the presence of certain mesotrophic species which form part of the special interest features of the site).

A study by Abraham et al. (2019) found notable changes in the vegetation community to species with a preference for drier, more saline, habitats, and higher stress tolerance. Floodplains typically perform nutrient retention helping improve overall water quality, however this is often impaired by reducing surface water connectivity, such as the installation of surface water drains and flood embankments such as on site. Reduction of the inundation of floodwater leads to an overall reduction in nutrients in the floodplain. Further study is needed to ascertain the scale to which the site is losing nutrients. A catchment scale nutrient management plan is recommended for the site and is currently being undertaken by Atkins on behalf of Natural England

7.3 Hydrological regime

This report has focused upon the hydrology and hydrogeology of the site in relation to the peat deposits. Groundwater, rainfall, and surface water flow all contribute to the wetland hydrological regime. Wetness can also be controlled as much by onsite management as external inputs of water, i.e. raising and lowering ditch levels. The site has undergone many changes in its history, effectively forming three historical landscapes:

- Pre-peat formation as an inundated tidal inlet;
- Succeeding peat formation as a river floodplain with several dendritic river tributary channels supplying the wet (high groundwater table) ground conditions needed for peat accumulation; and,
- The Site's current state as a managed wetland with a series of drainage ditches which are providing artificial drainage of the Site.

7.3.1 Groundwater

Peat is confined to north and south areas, along the eastern margin of the site and is separated by the underlying bedrock geology of the Marehill Clay Member.

Data from the site investigation suggests that, around the eastern and southern margins of the site, groundwater supply to the peat deposits is an important factor. Hence the peat deposits on site are currently telmatic-fed by the Folkestone formation aquifer in at least some areas. There is currently an upwards hydraulic gradient beneath the site.

Given this conclusion that groundwater likely impacts the hydrology of the peat on site and given that previous studies have indicated a derogation of groundwater levels in the Pulborough area as a result of the Pulborough abstraction, it seems reasonable to assume that this nearby Pulborough abstraction is likely to have some effect on peat health and hydro-ecology.

7.3.2 Rainfall

Meteoric water is likely to have an influence of the area's hydrological regime, and a clear, rapid response to rainfall has been seen in some peat hydrographs. It is likely that meteoric water plays a role in feeding the peat deposits. However, this may have been reduced to some degree by the formation of a hydrophobic upper layer of peat and a clay-rich topsoil cover, which is seen in the majority of exploratory locations. This will provide some isolation of the peat from incident rainfall, and perhaps promote overland flow and evapotranspiration of ponded water, reducing infiltration to the peat itself.

Meteoric water would likely have been a more significant input in the site's naturalised state.

7.3.3 Surface water

Under natural conditions, surface water was likely a partial driver of peat accumulation in the area with flood water from the adjoining River Arun and River Stor overtopping and forming channels which helped provide the submerged anoxic conditions for peat to accumulate. Construction of both drainage ditches and flood embankments on the site has hampered the connection to both Rivers. Any wetland that was historically or is currently fed by surface water will be affected by the use of sluices and weirs to control water level, such as the system of tilting weirs and flap sluices on site.

7.3.4 Seeps, springs, and inflows

Spring flows can be seen to feed the ditches on site from the eastern and southern margins. Groundwater seepages are also anticipated to be contributing water to the system around these margins, as has been recorded near Banks Cottage, for example.

In its naturalised state it is likely spring lines fed the peat along the eastern and southern margins. This groundwater-driven water source likely promoted the development of peat along these margins. Further to the west, the influence of the river increases, and, prior to the creation of the flood banks, regular bank overtopping will have led to the increased accumulation of alluvium westwards. This transition from groundwater dominance to fluvial dominance likely explains the transition westwards from peat at surface, to buried peat, to no peat.

Two factors have developed which will currently inhibit the degree to which these seeps and springs feed the peat hydrology: Firstly, work undertaken by others suggests that the Pulborough abstraction has reduced groundwater elevations in the Folkestone beds in the Pulborough area, and thus a reduction in seepage from this aquifer can be expected. Secondly, the peat has been cut off from the seeps and springs by the fact that they are captured by/ drain directly into a perimeter ditch.

7.3.5 Naturalised state mechanisms

It is likely that the three main mechanisms for the site are in naturalised state consisted of:

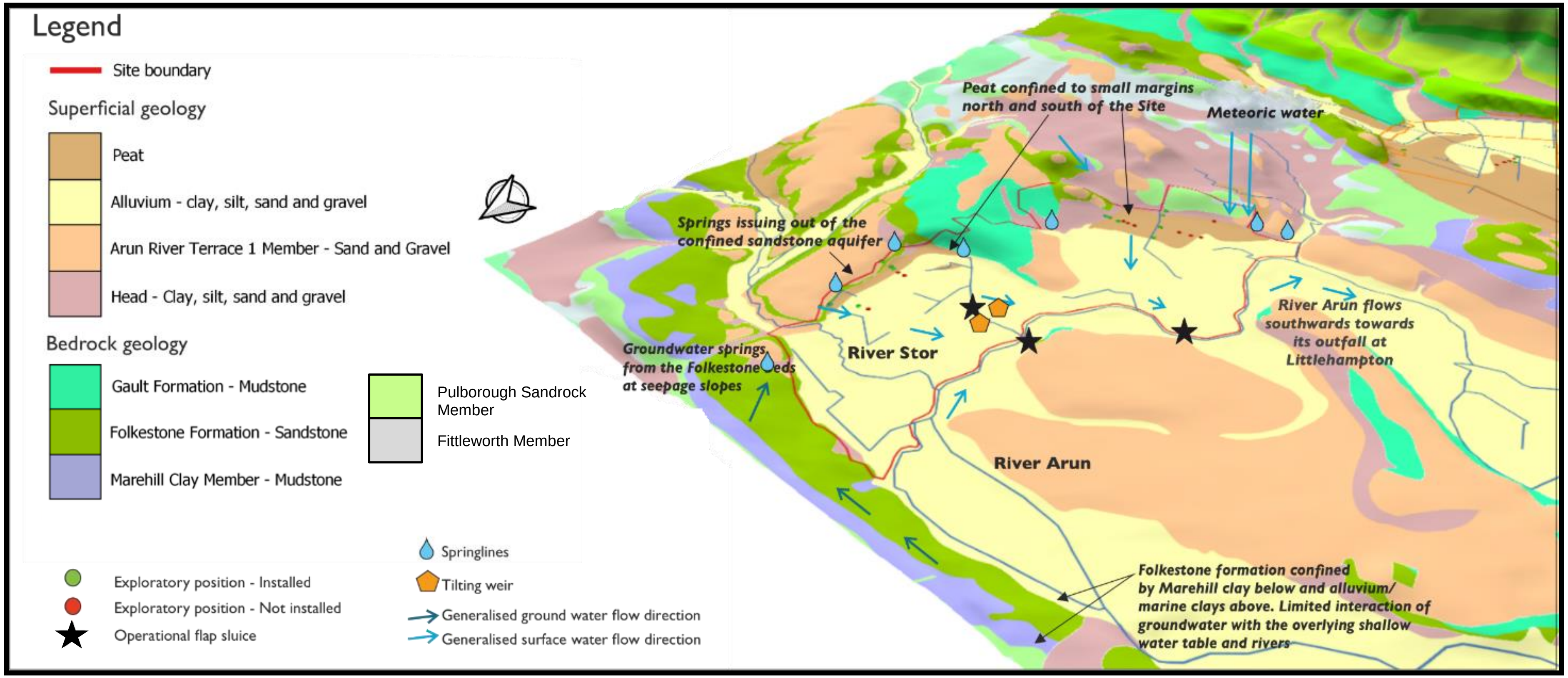
1) A good input of telluric water, mostly from springs/ surface seeps/ subsurface seeps on the eastern and southern margins, but also some upwards from below;
2) very flat topography with impeded drainage, exacerbated by sinuous natural channels, and;
3) Meteoric water, with infiltration greater than currently due to the lack of clay-rich topsoil.

The river inundation was probably a minor additional contributor, but not frequent enough to be the driver. River inundation since the levee construction is probably the source of topsoil and alluvial cover - there was probably a balance between sphagnum and peat growth and alluvial deposition previously.

7.3.5 Potential for further studies

The use of conceptual models within this report have been used to identify the likely hydrological mechanisms that have formed the deposition of peat formations, found present at the site. Further exploratory studies could be undertaken to assess the level of interaction between different groundwater units and the hydrological process that contribute to their distribution.

Figure 24 Site Conceptual Model of Pulborough Brooks SSSI



8. Conclusion and recommendations

8.1 Remediation options

Peat bogs take centuries to millennia to form and are often thousands of years old (in the region of 2,600 years old in the case of Amberley). An area of wild undisturbed habitat that has been converted to some other land use can seldom, if ever, recover in a few decades; it is hard to recover disturbed/ destroyed habitat to revert to a truly natural state.

Notwithstanding the above, there are significant peat deposits located in areas of Pulborough Brooks that are currently likely of declining quality and require action to help them start to recover towards their natural state. The section below describes a series of practical solutions, generally focused on increasing the retention time of both meteoric and spring/seep fed water inputs when crossing the Site, in order to raise water levels in areas of the Site across all seasons.

It should be noted that increasing water levels, especially during summer, may increase overall evapotranspiration, and that there may therefore be a limitation to the degree to which gains are seen. This is one area that exemplifies the current knowledge gaps that remain. Whilst this study has advanced the knowledge of peat hydroecology markedly, there remains some considerable uncertainty as to the current baseline, and some uncertainty as to the pros and cons the various interventions discussed in the subsequent paragraphs. This uncertainty is discussed in Section 8.3 below.

8.1.2 Ditch Maintenance

Currently many ditches, both minor and major, across Pulborough Brooks are maintained practically by means of an excavator to remove excess silt and vegetation build up within the ditches. It is unclear at this moment if there is a specific action level that triggers a ditch maintenance program, nor is it clear if there is specific methodology to the removal of silt and vegetation build up, i.e. whether there are target depths for the ditch to be restored to.

This likely has a two-fold effect on water levels across the Site. Firstly, the removal of vegetation built up within the ditch itself is likely to increase the rate of flow through the ditch system, with heavy vegetation usually impeding flow. In the summer months, shading from vegetation will also have a small effect on limiting evapotranspiration. The removal of silt will also contribute to the increased rate of through flow of water by increasing the channel cross section.

Secondly, the removal of large volumes of material from the base of the ditches may mean the ditches come into hydraulic connectivity with underlying water bearing strata. Although the Arun River Terrace deposits were only encountered in the northern and central area of

Site, (WS-P-15, WS-P-16, WS-P-17, and HA-P-33) the shallowest depth encountered was at 1.4 mbgl, a depth which is likely to be reached during ditch maintenance as minor ditches are typically 1.5m deep. Artesian conditions were also noted within the well of WS-P-20, indicating a hydraulic head within the Arun Terrace Deposits. It should also be noted that in areas of Pulborough the layers of peat appeared to be confining water levels within the alluvium, with water strikes rising after encountering them at depth. As noted above, the lower portion of peat most often had the highest water content.

There is likely a component of peat hydration from the underlying strata. This is significant, as if any of these ditches intersect these underlying strata, they will provide a preferential pathway for any hydraulic pressure in the underlying strata, allowing the water to flow out via the ditch system into the River Arun. This will reduce the component of peat hydration from the underlying water tables, further contributing to the degradation in peat quality. The above scenario is likely typical of winter, when the Site investigation was carried out. There remains a potential for the inverse situation in the summer months with widespread lowering of water tables; the 'maintained' ditches may prove a pathway for any rainfall or surface or spring seeps to flow into the underlying strata of alluvium or the river terrace deposits, artificially lowering water levels over and above that caused by the ditch system itself.

The layer of silt in the base of ditches, if it had been allowed to settle for a number of years, would likely form some impediment to water flow in both summer and winter scenarios described above. In addition to this, the mere increase in the base level of ditches from silt build up will likely contribute to the subsequent increase in water levels in the areas immediately adjacent to the ditch itself. As ditch maintenance removes this important layer of silt, the recommended practical solutions are suggested below:

- Reduction in maintenance schedule, with ditches moved onto a 'rota' based system if it is deemed that it unfeasible to cancel ditch clearing;
- Reduction in depth of maintenance, to avoid penetrating through to underlying geology, and;
- Do nothing; allow ditches to naturally infill, where it is likely that some flow component will limit the ditches becoming redundant.

The advantages of these recommendations are that they don't require any extra work or construction on part of the stakeholders (RSPB) and represent a low-cost low-impact solution to raising water levels across large swathes of Pulborough (depending on the techniques employed and their locality). Discussion with stakeholders would be necessary to identify the most suitable locations for the reduction in maintenance schedule. However, it is assumed that positive benefits from a reduction in the depth of clear-out of the ditches can be employed across the majority of the ditch system where peat is present.

Consideration does need to be given to the effect on sensitive flora and fauna, with studies at the nearby Amberley Wild Brooks indicating; "that management at ditch level is likely to be pivotal to the plant and animal species for which the Site is designated. It seems likely also that some adverse outcomes could be attributed to alterations in management, including overall under-grazing and the recent reduction of early-season grazing, and there may be highly localised effects (e.g. reduction of the open mud habitat along ditch margins, shading and/ or coarsening of marginal vegetation" (Natural England, 2019).

Initial recommendations for this work would include a section of ditches where maintenance was stopped combined with boreholes monitoring ditch water level and water levels in adjacent peat, surface water and underlying aquifers. This could be compared with a separate control section where current practices are continued, and the two areas monitored over a single of multiple maintenance cycles to assess the impacts to both water levels but also flora and fauna.

In the north and the central areas of the Site there are potential areas close to the eastern proximity of the Site which represent the best target areas to reduce maintenance in ditches, due to the largest peat deposits in this area in combination with the smallest layer of topsoil. These locations are highlighted in Figure M. Pulborough has excellent potential for raising water levels close to identified areas of peat, the area in the extreme south east of the Site around WS-P-17 shows significant deposits of peat at a relatively shallow depth, however there are limited ditches that could be targeted in this area with the only ditch slightly north of this location In the Figure N (different to above as shows south) the area of peat is shown to extend relatively close to this ditch, as assessed by peat probe only. It is suggested that, following further investigation to confirm peat does extend close to this ditch, initial trials are conducted in this area. In the south-west of Pulborough by WS-P-14 there are also peat deposits and adjacent ditches that could be targeted, however during Site visits it was noted that these ditches are actively flowing and hence carry significant quantities of water that enter the Site in this vicinity. Altering the ditch set up in this area would need to be considered carefully with respect to the potential for causing unintended flooding issues elsewhere.

8.1.3 Ditch Modification

Targeted Dams

Representing a more active solution than alterations to ditch maintenance, the potential blocking of ditches in key locations is a low cost and rapidly actionable technique to quickly raise water levels in targeted locations.

Blocking ditches with impermeable or very low permeability materials at limited or targeted locations will immediately increase the water levels on the upstream side of the dam to the height of the impediment. This increase in water level will also contribute to increased water levels in the adjacent fields, and an immediate result of this would be the increase in retention time of any water inputs into this area, be that from rainfall or springs, with a lower hydraulic gradient to ditch levels. Heights of impediments can be targeted to just below (circa 5cm below) surface levels to attempt to ensure as much of the extant peat deposits are hydrated as possible.

Again, consideration needs to be given to raising the water level in ditches to the height of surrounding fields as marginal vegetation may be flooded and valuable habitat lost. Potential locations for these dams are shown in Figure M and Figure N, and in the north and central area focus on raising water levels immediately adjacent to the eastern Site boundary where the largest peat deposits are shown. A second advantage of this is that the majority of the northern and central Site could be operated as it is currently with the modification affecting only a small proportion of the Site near the boundary. Damming some ditches may subsequently also cause areas downstream from the dams to suffer from artificially lowered water levels, which should be taken into account when implementing these modifications.

Ditch Infilling

A more active alternative to the creation of selected dams would be the total infilling of ditches to entirely remove the pathway for water in certain areas of the Site. This is a relatively large undertaking when compared to the previously discussed solutions and would require comprehensive earthworks to achieve. However, in many areas of Pulborough Brooks, limited infilling may result in considerable return on investment due to the constrained areas of peat. This process however will remove all of the habitat currently associated with the ditches and banks themselves in areas chosen for ditch removal.

Infilling of ditches removes the historical manmade pathways used to lower and drain water across the Site, the result of this is that water drainage is likely to return to a more natural form, reactivating dendritic drainage channels, remnants of which can be identified from the LiDAR data as detailed in Figure L. These channels will ensure the retention time of water is much higher than the comparative retention time of water in areas where artificial ditch drainage is present, increasing the hydration of peat and potential regeneration of peat forming vegetation.

The dendritic channels will also likely go some way to replacing the lost habitat from the infilling of ditches but there will be a time-lag between the ditch removal and the establishment of these channels.

To return the Site to its most natural state, all ditches on the Site would require infilling, however this is impractical from a number of aspects; including from an ecological perspective and would also require in combination the removal of flood defences along the river. Therefore, the most suitable locations for the infilling of ditches from a practical return on investment are detailed in Figure M and Figure N. As can be seen, ditches along the eastern boundary in the northern and central Site areas are targeted, again due to the large but constrained peat deposits in this section. In the southern areas although infilling of ditches is designed to increase the retention time of water close to the boundary of the Site, this would result in constraining the areas of peat that were identified during the Site investigation. The advantage of these areas being targeted is that the vast majority of the Site can be managed in its current form, and they represent a limited impact on the current Site hydrology and ecology outside of those areas with Peat.

Considerations

In periods of low water levels throughout the summer months, ditches may form an important mechanism of transferring the water supply from the marginal seeps and inflows deeper into the Site. Whist modification of ditches may increase the water table in target areas, there may be a corresponding lowering in other areas.

8.1.4 Modifying Marginal Seeps

Across Pulborough Brooks, there are typically seeps or isolated springs issuing from the elevated ground to the east and south of the Site. Typically, water generated from these seeps is caught by perimeter ditches and channelled into the drainage system straight to the River Arun, having a minimal impact on the Site hydrology other than raising ditch water levels. If these springs were permitted to flow onto the Site without artificial interference, they would contribute to the hydration of peat via infiltration and more widespread increase in water levels, as opposed to the water levels constrained to the ditches themselves.

It is notable that the healthiest area of peat identified during the works was in Large Rushy Brook field, which is also the only part of the Site that does not have a perimeter ditch separating the Site from the higher ground around its margin. Hence this field may be closest to natural state when compared with the other marginal areas.

Low Intervention Spring Diversion - Piping

The most efficient method of taking advantage of the naturally issuing springs and seeps is to directly capture and channel point sources of water onto the critical areas of targeted peat restoration. This would involve identifying springs, such as those located in the vicinity of Banks Cottage, modifying the spring issue to collect into a pipe, and channelling this over and across the perimeter ditches to avoid capture by the drainage system. This technique would only work in locations with clearly defined spring 'point sources' and would not work with large diffuse seeps. The potential location at Banks Cottage is shown on Figure D with further potential locations noted all along the southernmost boundary of Pulborough Brooks.

This represents a low-cost technique with the minimum amount of potential earthworks and is relatively non-intrusive. Unfortunately, capturing point sources is not likely to lead to large scale restoration of Peat and will need to be combined with other methods discussed.

Medium Intervention Spring Diversion – Cut off trench

Across Pulborough, a component of the inflow from the margins is through seepage as opposed to distinct point sources such as springs. In order to maximise the capture and transfer of water from the marginal seepages onto the target areas, there is potential to modify the previously discussed pipe capture technique by adding a clay lined cut off trench along the area of seepage which is subsequently piped through to target areas.

In order to identify the most efficient locations possible, there needs to be surveys conducted during periods of high rainfall to identify seep lines that may be captured. Furthermore, the seeps must be in areas that are conducive to installing a capture trench, i.e. away from footpaths and fences etc. It should be noted that the piping system is entirely passive and other than installation, would only require maintenance and upkeep.

High Intervention Spring Diversion – Trench Infilling

The two previous methods both involve capturing the area of seepage and subsequently piping through water to the target areas, bridging the ditch system itself. Another option in this category, which avoids modifying springs and potentially difficult to install capture methods, would be the removal of the ditches in the vicinity of seeps. This would allow water to directly flow from the seep to the target areas. The ditches to be removed to facilitate this are shown in Figure M and Figure N. As discussed in the previous sections, ditch removal comes with potentially severe impacts to the local flora and fauna. However, the removal of ditches would allow the system to return closest to its most natural state, likely with the reactivation of relic drainage channels over time and the reestablishment of flora and fauna along these channels.

Considerations

Water derived from the margins of the Site (as seen in Figure 25 below) was often noted to have an ochreous hue; the Folkestone Beds from which much of this water is derived is noted to have a high iron content. Consideration should be given to the potential impact of considerably increasing the mineral load on vegetation in relatively limited areas. As discussed in Section 8.1.2, modification of marginal ditches may impact the current transfer of water from margins to further into the Site.

Figure 25 Ochreous spring line in southern Pulborough

8.1.5 Sluice Management

Manipulation of water levels happens consistently throughout the year by RSPB operatives using sluices at various points across the Site as shown in Drawing Figure D. To increase retention time and water levels throughout Pulborough Brooks, it may be possible to raise sluice heights.

It should be noted that closing or raising sluice heights or closing sluices more often in the areas close to the River Arun will initially cause water levels to raise in the ditches close to the sluices. These water level raises will be contained initially to the ditches themselves. With the peat deposits on Pulborough, especially those in the central and northern portions, being located close to the Site perimeter, distal to the River Arun, sluice levels on Site may have to be raised to such an extent that water levels close to sluices may raise above ditch level and inundate areas adjacent to the ditches. This inundation, especially in the summer months, will increase evapotranspiration and may alter other conservation efforts across Pulborough. Therefore, it is considered the best location to trial this method would be in the south of Pulborough, where peat deposits are located relatively close to the River Arun and inundation, if it occurs, will be kept to a limited area that already involves artificial scrapes which would likely cope with further inundation well, as depicted in Figure O. This drawing provides an indication of the impact of raising water levels to 1.7

mAOD across the entire Site. Clearly this will lead to flooding of likely unacceptable areas of land, thus such an approach is much more viable when focussed on discrete areas of the Site only, such as in Large Rushy Brook and Nomans Land.

There are other tipping weirs and sluices present on the interior of Site, with some being shown as out of use. It may be possible to reactivate these sluices to isolate an area upstream of an interior sluice as a trial.

It is important to note here that the ideal water levels to promote healthy peat are likely lower than the ideal water levels to support wildfowl and waders, and hence there is likely to be some potential conflict with regards to different conservation objectives in this respect.

8.1.6 Remove flood defences – more study on this needed

The most comprehensive scheme considered in the potential peat restoration scheme is the alteration of flood defences on the eastern bank of the River Arun. Removal of some or all of these defences would have considerable consequences to the hydrology of the Site. The removal of the flood embankment and related infrastructure could take many forms.

Removal of Defences

Currently, in extreme hydrological conditions, water from the River Arun is used to raise water levels on the Site to ensure protected species are not threated by hydrological extremes. If one were to remove the operational flap sluices that limit the inflow of water from the River Arun, there would be a considerable increase in the rate of inundation from the River.

This would not represent the return to a natural state, with the inflow of water confined to point sources making use of the ditch system to flow back on to Site, and would raise water levels closest to the River Arun initially. Again, this will limit the increase in water levels in targeted Peat areas which remain around the margins, and if these sluices are not closed during summer, it is likely the Site would dry out considerably.

To reinstate the initial conditions under which the peat in Pulborough formed it is likely that the embankments would have to be removed, ditches allowed to infill, and the channel of the River Arun allowed to take a more sinuous route - all large-scale modifications to the current environment at the Site.

Removal of embankments would allow for large scale admission of floodwaters across the Site, one benefit of this would be the reduction in flood risk downstream with the newly created floodplain storage area.

Ecology

Currently seasonal variations in water level are commonplace regardless of the water level management that occurs on Site. Large swathes of the Site are inundated with water during winter, with the removal of flood defences large scale flooding of the Site is also likely during winter periods from flood events. The difference between the two forms of inundation is that the sediment load associated with the flood events will be considerably higher than that which occurs currently. Increased sediment deposition, whilst a natural process, would likely have considerable effects on the existing composition of vegetation which has become accustomed to the currently managed regime.

At present, data sources suggest that the Pulborough stretch of the Arun is under tidal influence but does not have a saline wedge (i.e. the tidal signal seen is due to backing up of freshwater during high tides and release of it in low tides). However, if this is not the case and a saline wedge does reach as far as the Site, removal of the flood defences may potentially add a saline component to the water intruding onto the Site from tidal surges, dependent on how far up the Site the saline intrusion reaches and which defences are removed. Again, this would affect the currently existing ecological regime.

Considerations

There are a number of problems that may result from large scale modification of flood defences in Pulborough. Initially there would require considerable consultation with the relevant statutory bodies including the EA. Although the likely result of removing the flood defences in this area would be the increase in floodplain storage, it is likely that consultations would be an extremely lengthy procedure.

Tidal surges and saline wedges as described above would likely be negated if flood embankments at the southerly Amberley Wild Brooks were also removed, as the tidal influence would likely disperse downstream across the floodplains of Amberley. Consequently, any large-scale modification of flood defences should be cognisant of other modifications of the hydrological regime in the local area.

It is considered that the removal of flood embankments adjacent to Pulborough Brooks is a very large undertaking with many variables that are not currently understood; this large undertaking would not necessarily return better results than more targeted efforts which require much less investment of time and money. Water quality issues for the River Arun are currently an inhibitor for flood embankment removal. Water quality would have to be improved before this modification could be considered further.

8.2 Ecosystem services and intervention impacts

The work undertaken as part of this study has indicated that there is a body of peat at, or close to, ground surface in areas along the eastern and southern margins of Pulborough.

Water levels in these peat deposits are below that which is expected in a healthy peat body (i.e. not within the upper 5cm below ground level). There are indicators that suggest that there is a hydrophobic, dry layer of peat immediately below ground surface, overlying and acting as an aquiclude above a wet, lower portion of peat. In the majority of the peat deposits identified, there is also a thin layer of clay-rich topsoil overlying the peat, which may again suggest that the upper peat is in poor condition, with limited potential for rain infiltration.

The upper layer of peat across the areas investigated has therefore been identified as drier than optimum and in poor condition. This has potential ramifications from an ecosystem services point of view, as discussed below.

8.2.1 Alteration to the abstraction regime

One of the conclusions of this study is that groundwater provides an important source of water required to maintain and improve the health of the peat bogs present on the site. This includes the input of groundwater via seeps and springs from the base of the slopes around the edge of the site, and due to the upwards hydraulic gradient that is seen in the artesian nature of boreholes.

Both of these groundwater recharge mechanisms may be sensitive to changes in the aquifer caused by the public water supply abstraction at Pulborough. Increased pumping rates at the abstraction will lower groundwater elevations within the aquifer, which could impact both springs and seeps and also upwards hydraulic head.

However, the work undertaken in this study is not sufficient to inform whether such an effect (of the abstraction lowering groundwater such that springs, seeps or upwards hydraulic gradients are notably affected) occurs within or around the Pulborough site. Any such assessment would require much longer-term groundwater monitoring, including monitoring within the deeper horizons of the Folkestone Beds aquifer and require detailed quantitative modelling of the water cycle in the area. It is understood that ongoing work by Atkins on behalf of Southern Water is seeking to address some of these aspects.

8.2.2 Carbon storage

Under healthy, high water table conditions, peat is a net sink of carbon. Healthy peat bogs store and sequester a significant amount of global carbon. The UK, amongst other high latitude countries, has a significant amount of carbon storage within peat bogs.

However, dry peat bogs can become a net emitter of carbon, as the carbon stored within them starts to be degraded aerobically, releasing carbon in the form of carbon dioxide. The peat on Pulborough is likely to be a net emitter of caron due to the dry nature of its upper layers. The degree to which this is occurring would require more detailed investigation and assessment outside the scope of this study.

8.2.3 Flood alleviation and water storage

Peat bogs typically provide a buffering service within the water cycle, providing water storage and hence reducing the flashiness of flood responses within water catchments. In order for this to be functioning properly, the peat bog requires connectivity to meteoric waters (rainfall) and requires a healthy degree of saturation (as a wet, healthy peat bog will absorb more water than a dry, hydrophobic peat bog). The upper, drier layer of peat encountered in Pulborough is likely inhibiting the infiltration of rainwater, increasing run-off into the ditches. The presence of a clay-rich topsoil layer is likely also having a similar effect, isolating the potential water storage reservoir of the peat from meteoric waters, and increasing the rate and amount of run-off to ditches.

The degree to which this effect has an impact on flooding downstream in the Arun catchment will be limited by the managed nature of the waters within the Site, with the sluices at outfall to the river providing some management of water discharge from Site.

From a water cycle and flood alleviation perspective, the isolation of the Site from the river by the flood embankments will likely be having a much greater impact on the resilience (or lack of) to flooding in the catchment than will be the condition of the peat.

8.2.4 Biodiversity

As with any landscape, particularly a heavily modified one such as this, there will be competing interest with respect to biodiversity. For example, as discussed above, the ideal water levels to sustain healthy peat (no less than 5cm below ground level) will likely be lower than the ideal water level for wildfowl and waders (which may need to be at, or just above ground level). Similarly, suggested interventions to increase water levels in the peat deposits include the reduction in ditch maintenance, which may well adversely impact some of the species for which the Site is listed as special. Clearly, any intervention to address the poor health of the peat will need to be considered carefully against these sometimes competing interests.

8.3 Uncertainties and proposed next steps

Investigations of ground and groundwater conditions should, by design, be iterative. This piece of work has furthered the knowledge of the peat and peat hydrology conditions beneath the Site considerably. However, in many cases the work has raised further questions as much as it has answers. Table 15 provides a list of unanswered questions/ points of uncertainty, with suggested future work that may be undertaken to address this uncertainty. A degree of options appraisal is then provided with respect to the likely cost and suggested priority of such next steps, with £ = cheap, £££ = expensive and 1= low priority, 5 = high priority:

Table 15 Suggested next steps

Uncertainty	Possible next steps	Anticipated cost	Priority
Chemistry data collected as part of this study was inconclusive in providing a reliable corelation	Water quality sampling and laboratory analysis	££	2

Uncertainty	Possible next steps	Anticipated cost	Priority
between groundwater body and chemistry. Would a more detailed or long-term approach provide a better indication of water source within peat, and so enable differentiation between meteoric and telluric sources of water?	over a prolonged period of time.		
To what degree do perimeter ditches intercept groundwater and/ or seeps?	Topographical and sediment/ geological transect across perimeter ditch(es).	£	4
Data gathered to date is for one month of water levels only – what happens in exceptionally wet winter periods, or in dry summer periods? What impact does amendment to sluice levels have on groundwater elevations?	Continue groundwater and ditch monitoring for at least one calendar year *	££	5
Data gathered to date is for one month of water levels only – what happens in exceptionally wet winter periods, or in dry summer periods? What impact does amendment to sluice levels have on groundwater elevations?	Revisit the conclusions of this report once a year of data is in hand	£	5
Can a detailed water balance be constructed for the areas of peat in Pulborough, to aid in the modelling of degree to which groundwater/ rainwater/ evapotranspiration dominates?	Gather permeability data through in situ testing.	£	4
Can a detailed water balance be constructed for the areas of peat in Pulborough, to aid in the modelling of degree to which groundwater/ rainwater/ evapotranspiration dominates?	Construct water balance model, calibrate and use as tool to model system inputs/ outputs and	£££	3

Uncertainty	Possible next steps	Anticipated cost	Priority
	model future interventions		
What might be the localised impact of increasing impounded water elevations in selected ditch compartments?	Detailed impact assessment using LiDAR/ DTM to model degree of surface inundation and possible impact on depth to groundwater	££	5
What is the extent of peat outside of those areas already investigated?	Selected peat augering to confirm absence along other eastern/ southern margins (Challens Brook, Nettleys Brook, Smiths Triangle, Little Rushy Brook, Horse Brook) (western and central portions can be disregarded for peat potential due to predominance of alluvium in these areas)	£££	3
What is the extent of peat within those areas already investigated?	Peat depth probing in Pete Brook and Naval Brook, North Spring/ NoMans Land/ Penfolds Spring and produce contour plotting similar to that undertaken in Large Rushy Brook (see Figure P)	££	5
To what degree is the Hardham abstraction impacting on the groundwater feed into the peat.	Review of the historical modelling undertaken by Southern Water in light of the new data gathered in this study.	£££	4

*Longer term monitoring of the groundwater supply and associated features is being undertaken as part of Southern Water's Hardham Basin Environmental Studies (HBES) investigation.

9. List of tables

10. List of figures

11. Annex

Table 16 below summarises the key details of the Site and the immediate surrounding area.

Table 16 Site setting

Site Address /location	The Site is located in Pulborough Brooks Nature Reserve, within the South Downs National Park, West Sussex.
NGR	The Site is split into two sections: North and South. NGR in the central northern section is TQ 06034 17580, the central southern section is TQ 05258 16235.
Area	The Site area is approximately 256 ha comprising the whole nature reserve, specific Site exploratory locations were focussed on smaller areas to the north and south of the reserve, within areas mapped as peat by the British Geological Survey.
Current Site Use and Context	The Site is currently owned and managed by RSPB as grazed wet grassland and open water lagoons and scrapes, within a series of fields divided by artificial linear ditches. The Site is used for conservation of a wide range of flora and fauna, in particular wading and ground nesting birds. Several areas of the Site are open to the public with a visitor centre located in between the north and southern localities and a series of public footpaths bisecting areas of the Site, in particular the northern section.
Surrounding Land Use	**North:** the main hub of Pulborough village lies to the north of the Site with the A283 running through the village. The River Stor flows across the Site's northern boundary. **South:** agricultural fields and coppiced land lie to the south of the Site. **East:** Nutbourne and West Chiltington villages lie east of the Site. A water treatment works, vehicle repairs shop and transport hub along with agricultural fields lie along the Site's eastern boundary. **West:** The River Arun lies west of the Site with associated floodplain and agricultural land.

Invasive Species	As the Site is a sensitive environment with respect to biosecurity, a series of precautions were undertaken to prevent the spread of INNS (Invasive non-native species) to the Site.

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13. Glossary

Term	Definition
Acrotelm	The acrotelm is one of two distinct layers in undisturbed peat bogs. It overlies the catotelm. The boundary between the two layers is defined by the transition from peat containing living plants (acrotelm) to peat containing dead plant material (catotelm). This typically coincides with the lowest level of the water table.
Alluvium	Sediment transported and deposited by running fresh water. Can be variable from gravel at its coarsest to clay at its finest, but is typically encountered as a clay rich in decaying organic plant matter.
Anticline	A fold in the rock sequence, in which the older rocks occupy the core.
Anticlinorium	A large composite anticline made up of smaller folds.
Aquiclude	A sediment or rock sequence with low permeability, important in controlling water flow in adjacent overlying and underlying more permeable layers.
Aquifer	Sediment or rock containing sufficient quantities of water within permeable rock to yield supplies of water.
Artesian	Describes an aquifer in which water is under sufficient pressure to drive it to the surface when penetrated by a well.
Arun Terrace Deposits	River Terrace deposits comprising sand, sandy gravel, gravel and occasional clay, Devensian in age.
Bog	Acidic (pH < c. 5.5) mires (mainly on peat, but some mineral soils)
Carr	Tree-covered fen
Catotelm	The catotelm is one of two distinct layers in undisturbed peat bogs. It underlies the acrotelm. The boundary between the two layers is defined by the transition from peat containing living plants (acrotelm) to peat containing dead plant material (catotelm). This typically coincides with the lowest level of the water table.

Term	Definition
Fen	Base-rich (pH > c. 5.5) mires (peat and normally wet mineral soils)
Fold	A curve in the surface of a formerly planar geological surface. Typically used to describe the tilting and curving of sediment layers.
Folkestone Beds/ Folkestone Formation	Part of the Lower Greensand group, a medium and coarse- grained well-sorted sand and weakly cemented sandstone Cretaceous in age.
Gault Formation	Typically a stiff blue/grey clay or sequence of clays, mudstone and thin siltstone, lower Cretaceous in age.
Head	A superficial deposit formed in cold climate, often derived of sediments from further upslope.
Marehill Clay Member	Dark grey locally glauconitic silty clay forming part of the Lower Greensand group which dates to the lower Cretaceous in age.
Marsh	Seasonally dry wetlands on mineral soils
Mass movement	The movement of soil or rock downslope due to inherent instability of the ground.
Meteoric water	Precipitation
Minerotrophic	Surface fed in part by telluric water
Mire	Unconverted permanent telmatic wetlands. Includes wet sites on both peat and mineral soils but excludes former wetlands which have been badly damaged or converted into another habitat.
Ombrogenous	Wetness induced by precipitation
Ombrotrophic	Surface fed directly and exclusively by precipitation
Peat	A soil layer formed of a mass of dark-brown, partly decomposed plant debris.

Term	Definition
Peatland	All areas with peat, including sites with natural or semi-natural vegetation and areas converted to agriculture or forestry or used for peat extraction
Polymict	(of a conglomerate) consisting of fragments of several different rock types
Quaternary	Period of geological time spanning from 2.58 million years ago to the present.
Ramsar Site	a wetland site designated to be of international importance under the Ramsar Convention, [1] also known as "The Convention on Wetlands", an intergovernmental environmental treaty established on 2nd February 1971 in Ramsar, Iran by UNESCO
Relic meander	A meander is a large sinuous bend in a river channel, and a relic meander is the landscape feature created by the change in course of a river such that it no longer flows around the bend (either due to artificial channels being created by humans, or by natural migration of the river channel over its floodplain).
River Terrace Deposits	River terrace deposits typically comprise sand and gravel with local lenses of silt, clay and/or peat. Typically remains of an old floodplain, RTD is Quaternary in age.
RTD	River Terrace Deposits
SAC	Special Area of Conservation
Scarp slope	The steep slope of an asymmetrical ridge of higher ground.
Soligenous	Wetness induced by water supply (such as seepage slopes)
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
Superficial deposits/	Superficial deposits refer to geological deposits typically of Quaternary age (less than 2.6 million years old). These geologically recent unconsolidated sediments may

Term	Definition
superficial geology	include stream channel and floodplain deposits, beach sands, talus gravels and glacial drift and moraine. All pre-Quaternary deposits are referred to as bedrock.
Swamp	Wetlands with summer water table typically > c. 25cm above ground level
Syncline	A fold with younger rocks at its core.
Telmatic wetland	Wet, semi-terrestrial wetlands (non-aquatic wetlands). Subdivided into permanent, seasonal and fluctuating types.
Telluric water	Water that has had some contact with mineral ground
WETMECs	Wetland water supply Mechanisms
Upper Greensand Formation	A glauconitic shelly sandstone with subsidiary conglomerate mudstone and siltstone Cretaceous formation found within the Wessex and Weald basins.

Appendix A: Figures A to P

Figure A – Pulborough Site Location Plan

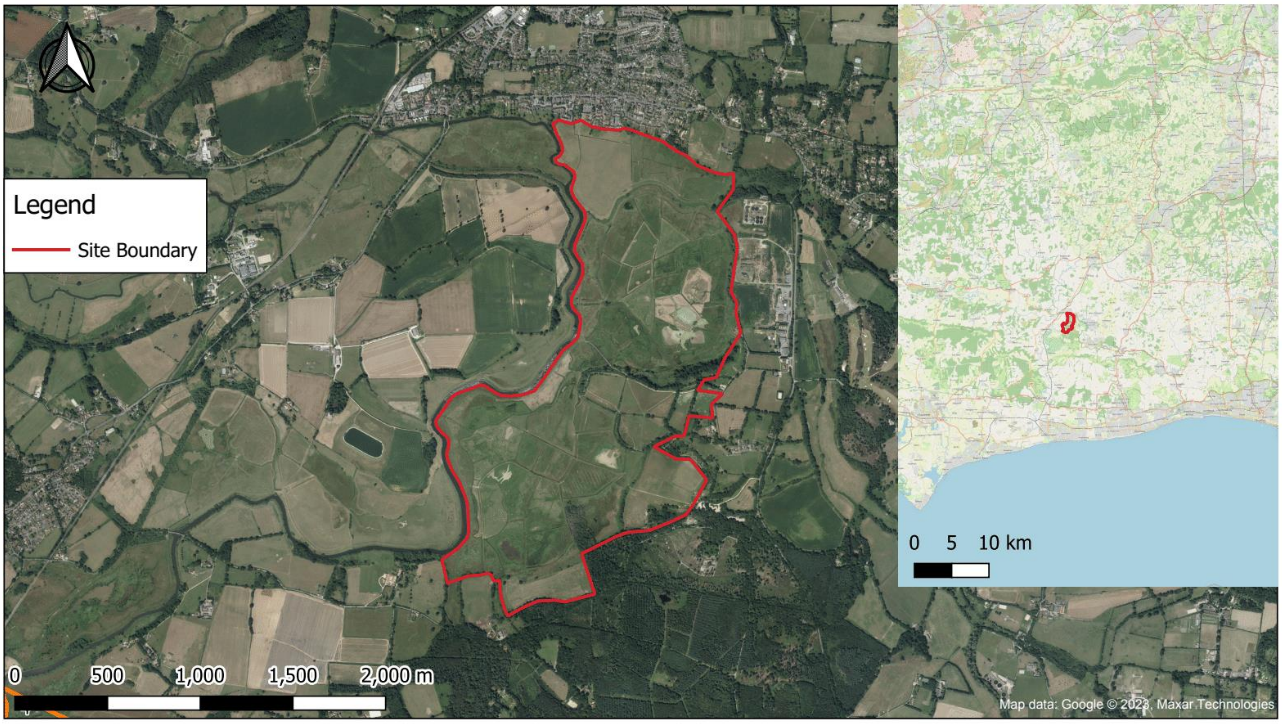

Figure Title	Client	Date	Drawn
Pulborough Site Location Plan	Natural England	30/03/2022	JRB
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		Pulborough North	

Figure B – Field Location Plan, Pulborough Brooks

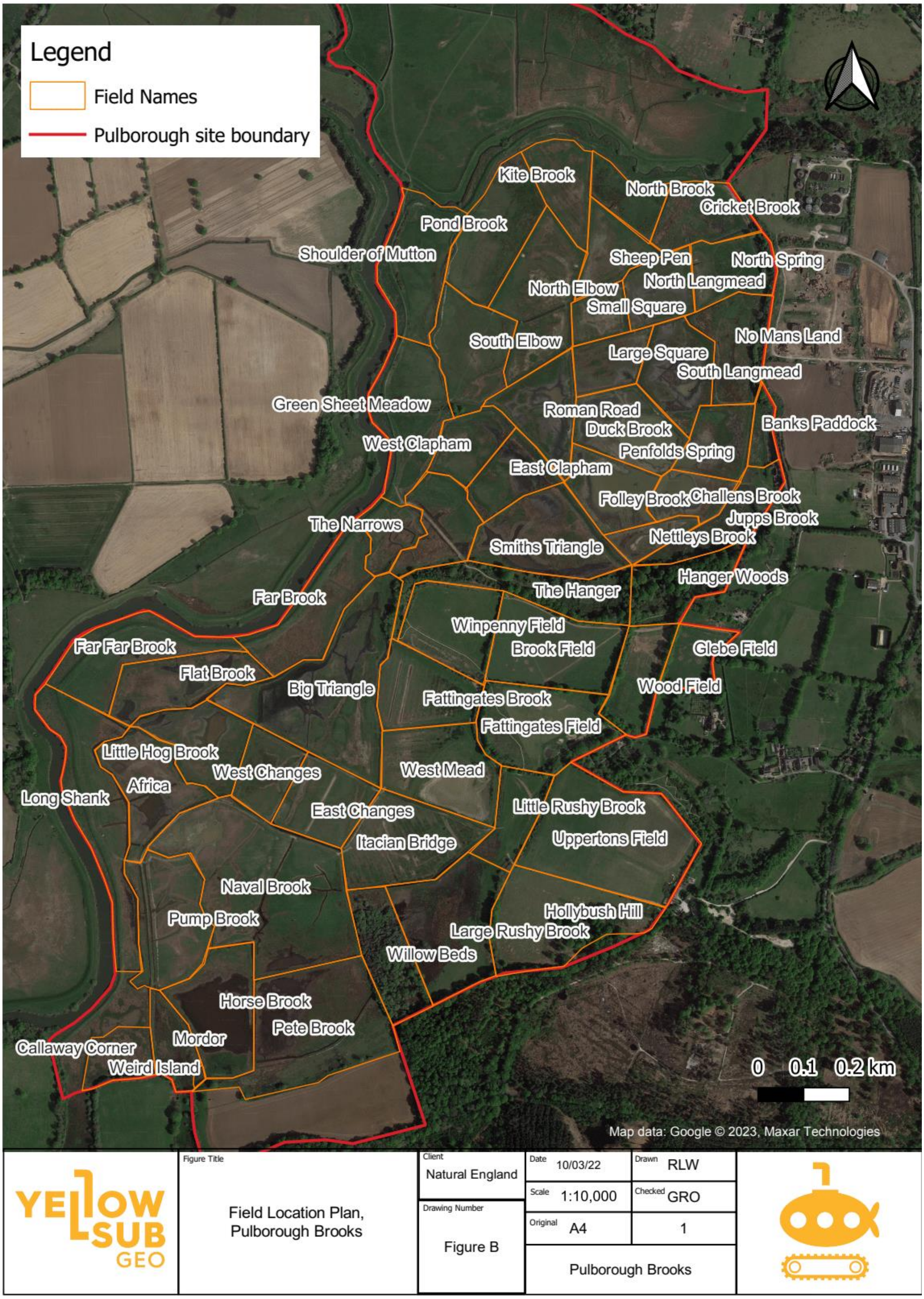


Figure C – RSPB hazard map detailing areas of known peat and compressible ground

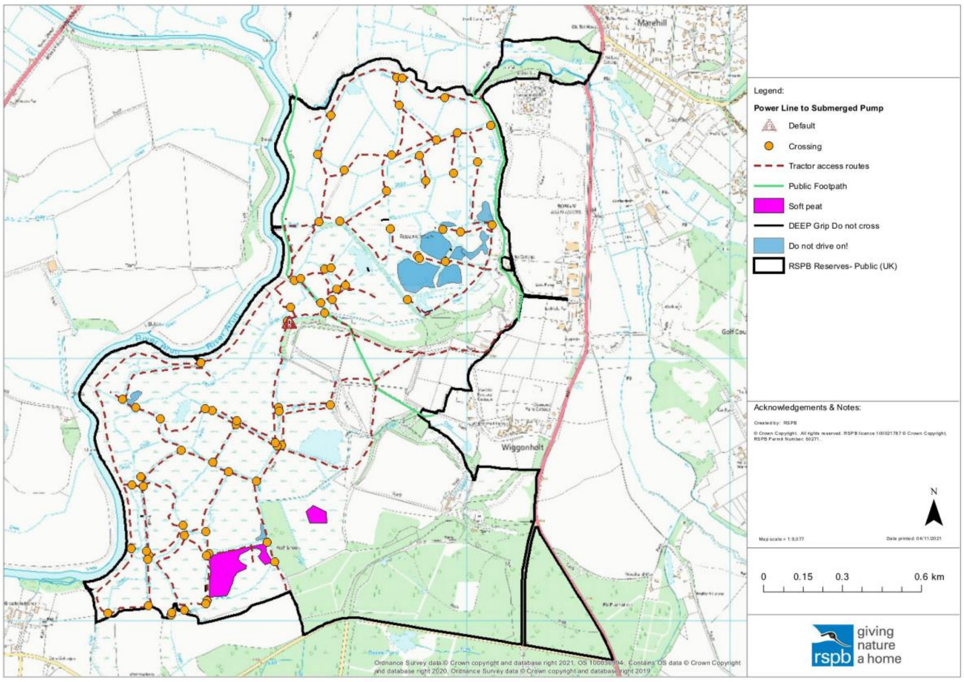
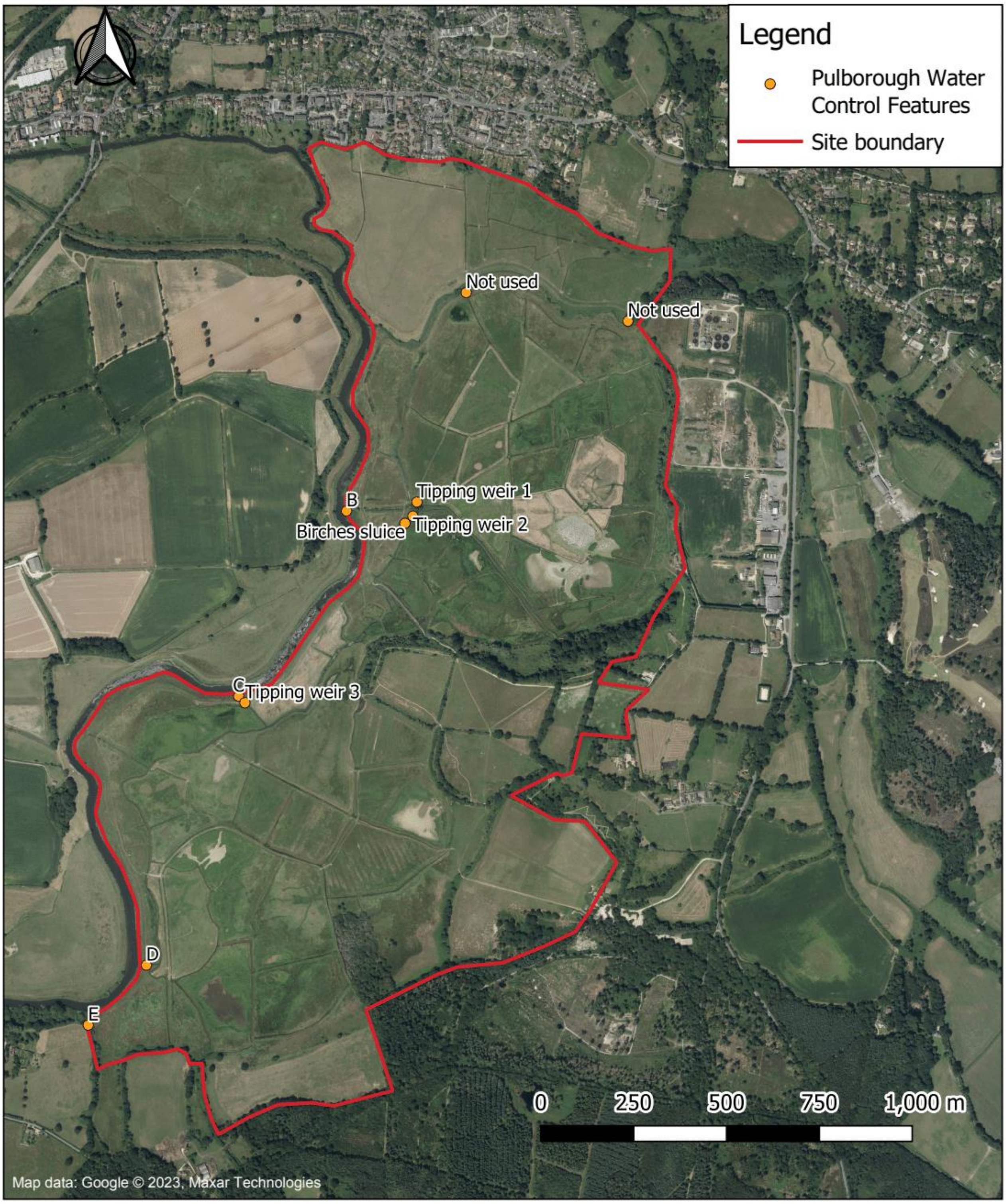


Figure Title	Client	Date	Drawn
RSPB hazard map detailing areas of known peat and compressible ground.	Natural England	30/03/2022	JRB
	Drawing Number	Scale 1:10,000	Checked GRO
	Figure C	Original A4	1
		Pulborough North	

Figure D – Water Control Features, Pulborough Brooks



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			Pulborough	

Figure E – Exploratory Positions, Pulborough Brooks North

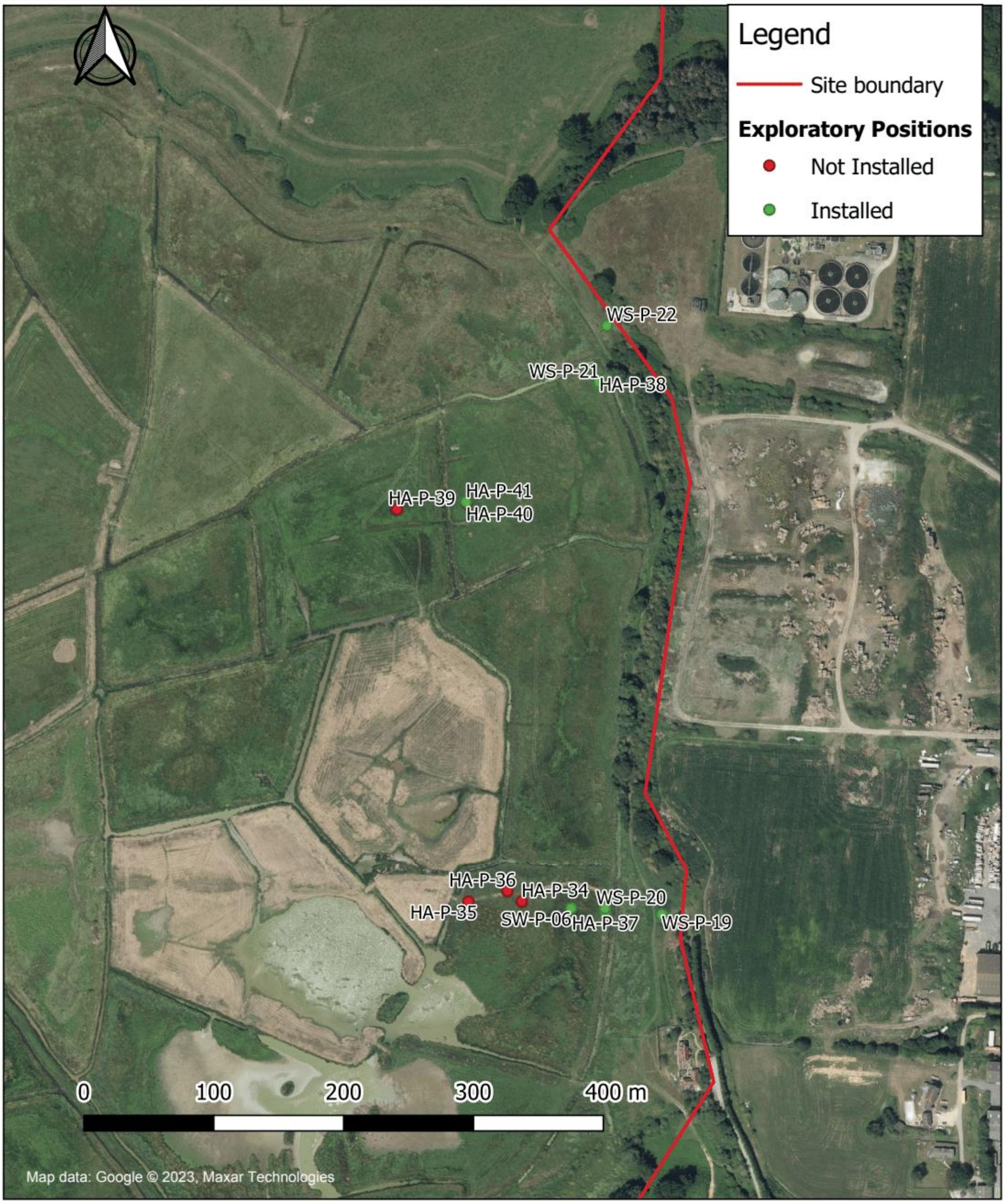

Figure Title	Client	Date	Drawn
Exploratory Positions, Pulborough Brooks North	Natural England	30/03/2022	JRB
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		Pulborough	

Figure F – Exploratory Positions, Pulborough Brooks South

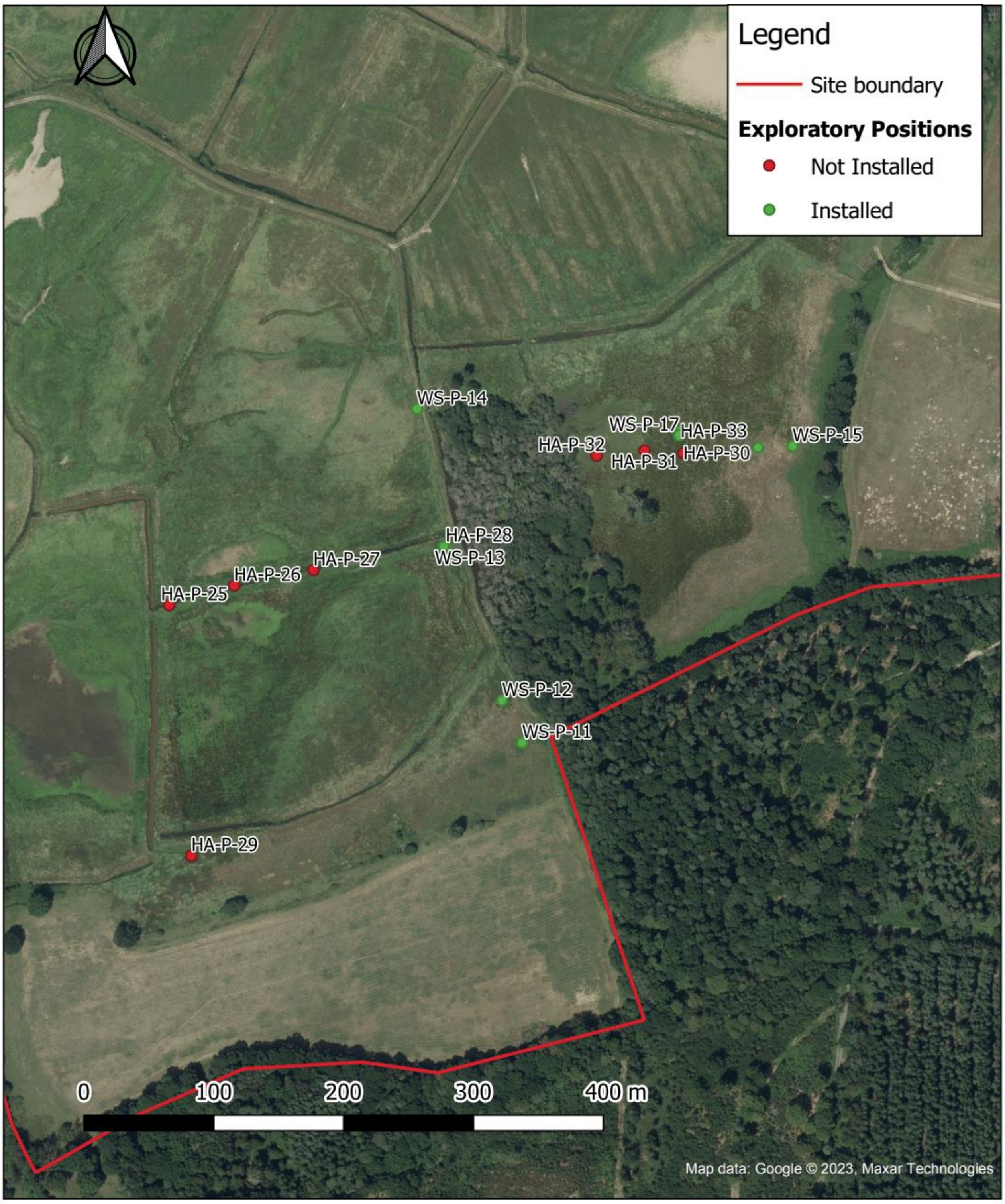

Figure Title	Client	Date	Drawn
Exploratory Positions, Pulborough Brooks South	Natural England	30/03/2022	JRB
	Drawing Number: Figure F	Scale: 1:4,000	Checked: GRO
		Original: A4	1
		Pulborough	

YELLOW SUB GEO

Figure G – Peat depth labelled with peat thickness, Pulborough Brooks North

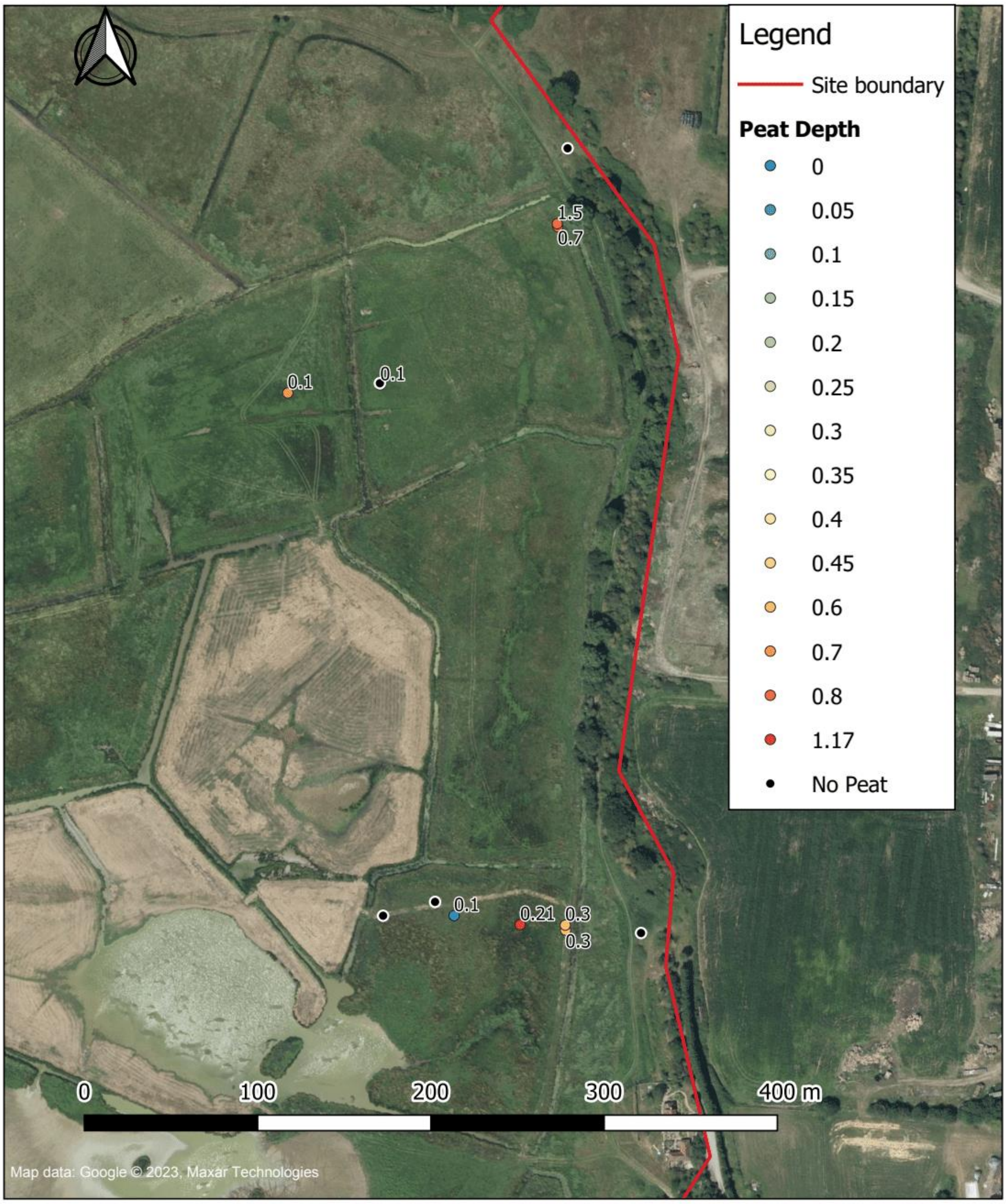

	Figure Title	Client	Date	Drawn	
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		Drawing Number	Scale 1:3,000	Checked GRO	
		Figure G	Original A4	1	
			Pulborough		

Figure H – Peat depth labelled with peat thickness, Pulborough Brooks South

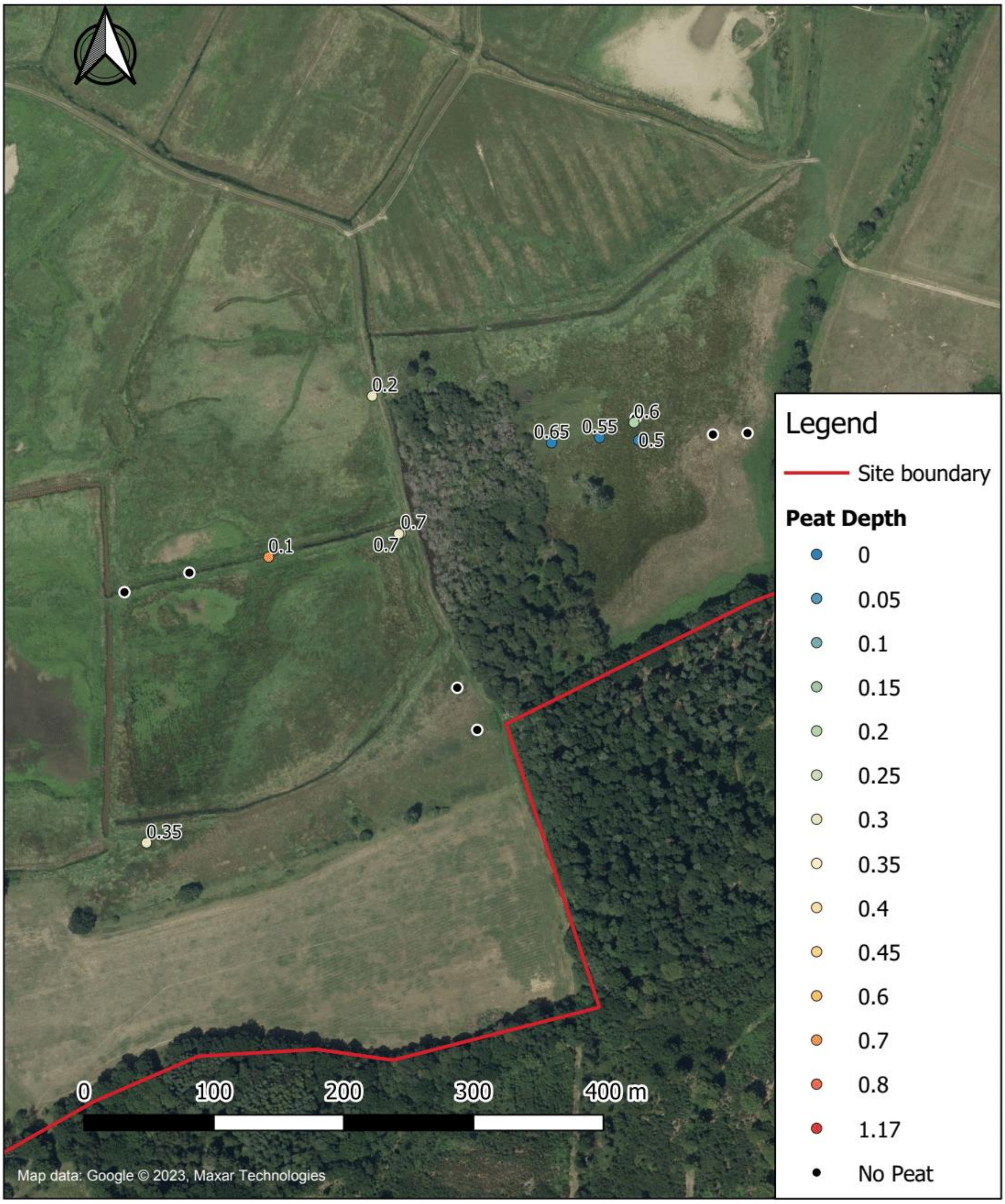
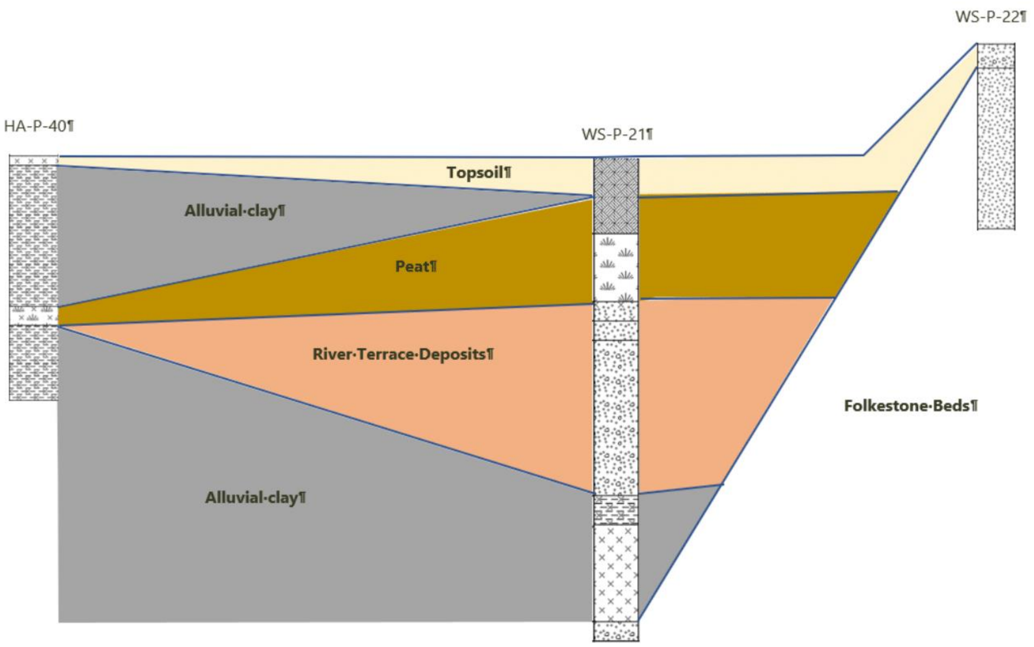


	Figure Title Peat depth labelled with peat thickness, Pulborough Brooks South	Client Natural England	Date 30/03/2022	Drawn JRB	YELLOW SUB GEO
		Drawing Number Figure H	Scale 1:4,000	Checked GRO	
			Original A4	1	
			Pulborough		

Figure I – Stylised cross section, Pulborough North. Looking North



YELLOW SUB GEO	Figure Title: Stylised cross section, Pulborough North. Looking North.	Client: Natural England	Date: 30/03/2022	Drawn: JRB
			Scale: NTS	Checked: GRO
		Drawing Number: Figure I	Original: A4	1
			Pulborough North	

Figure J – Catchments in the vicinity of Pulborough

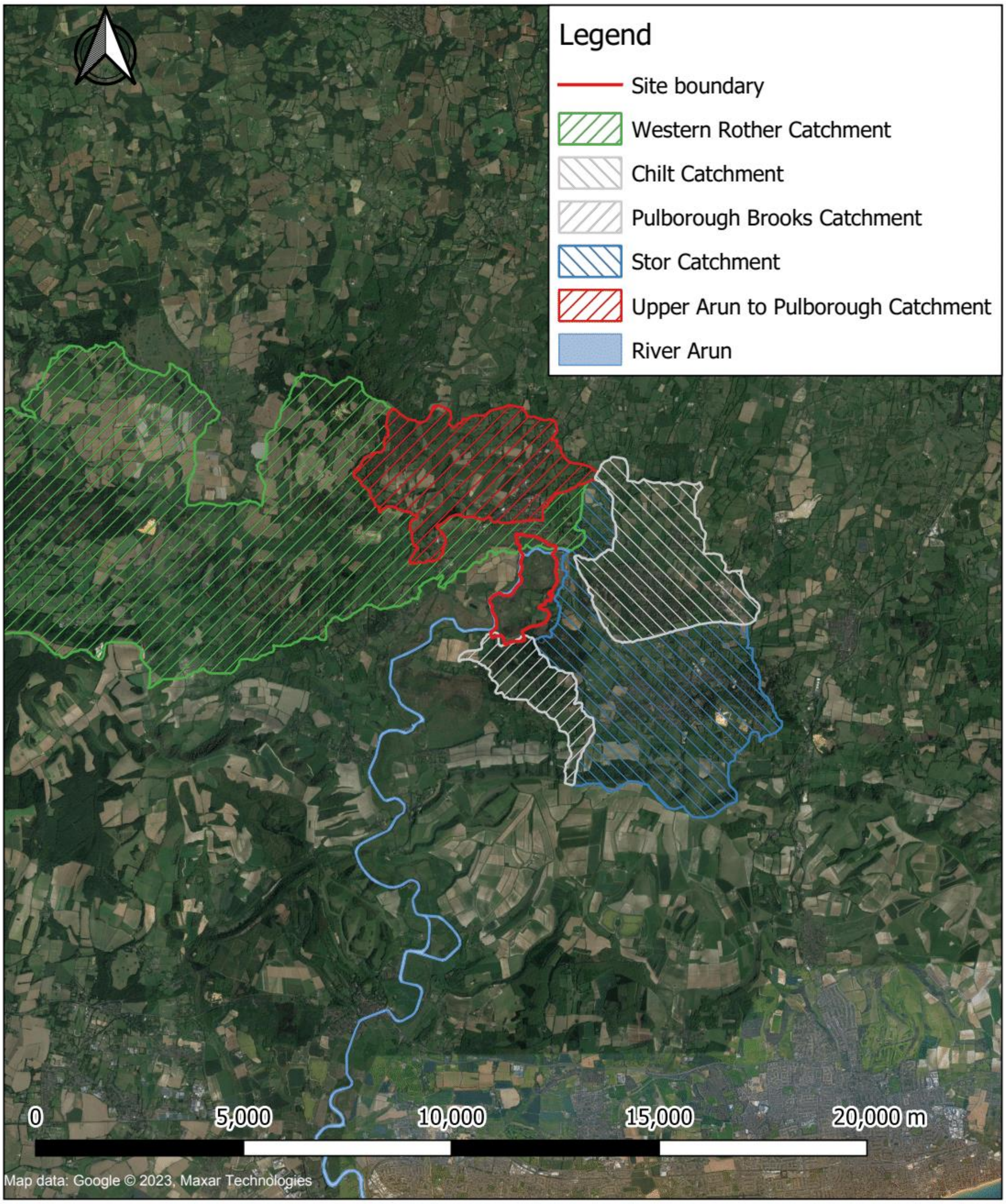


	Figure Title: Catchments in the vicinity of Pulborough	Client: Natural England	Date: 30/03/2022	Drawn: JRB	YELLOW SUB GEO
		Drawing Number: Figure J	Scale: 1:125,000	Checked: GRO	
			Original: A4	1	
			Pulborough		

Figure K – Water Quality Monitoring Points, Pulborough

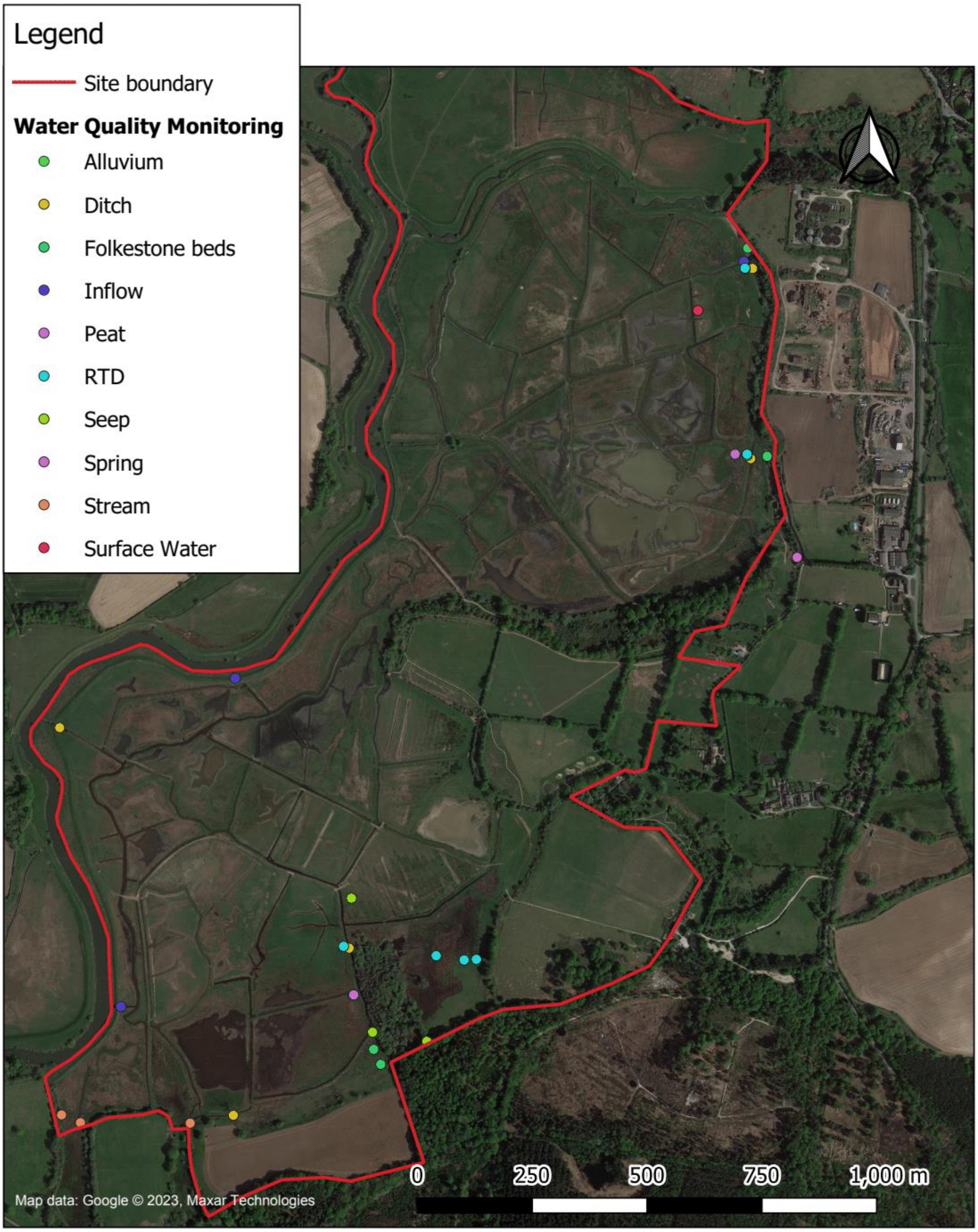


Figure Title	Client	Date	Drawn
Water Quality Monitoring Points, Pulborough	Natural England	30/03/2022	JRB
	Drawing Number	Scale 1:11,000	Checked GRO
	Figure K	Original A4	1
		Pulborough	

Figure L – Lidar at 25cm resolution, Pulborough Brooks

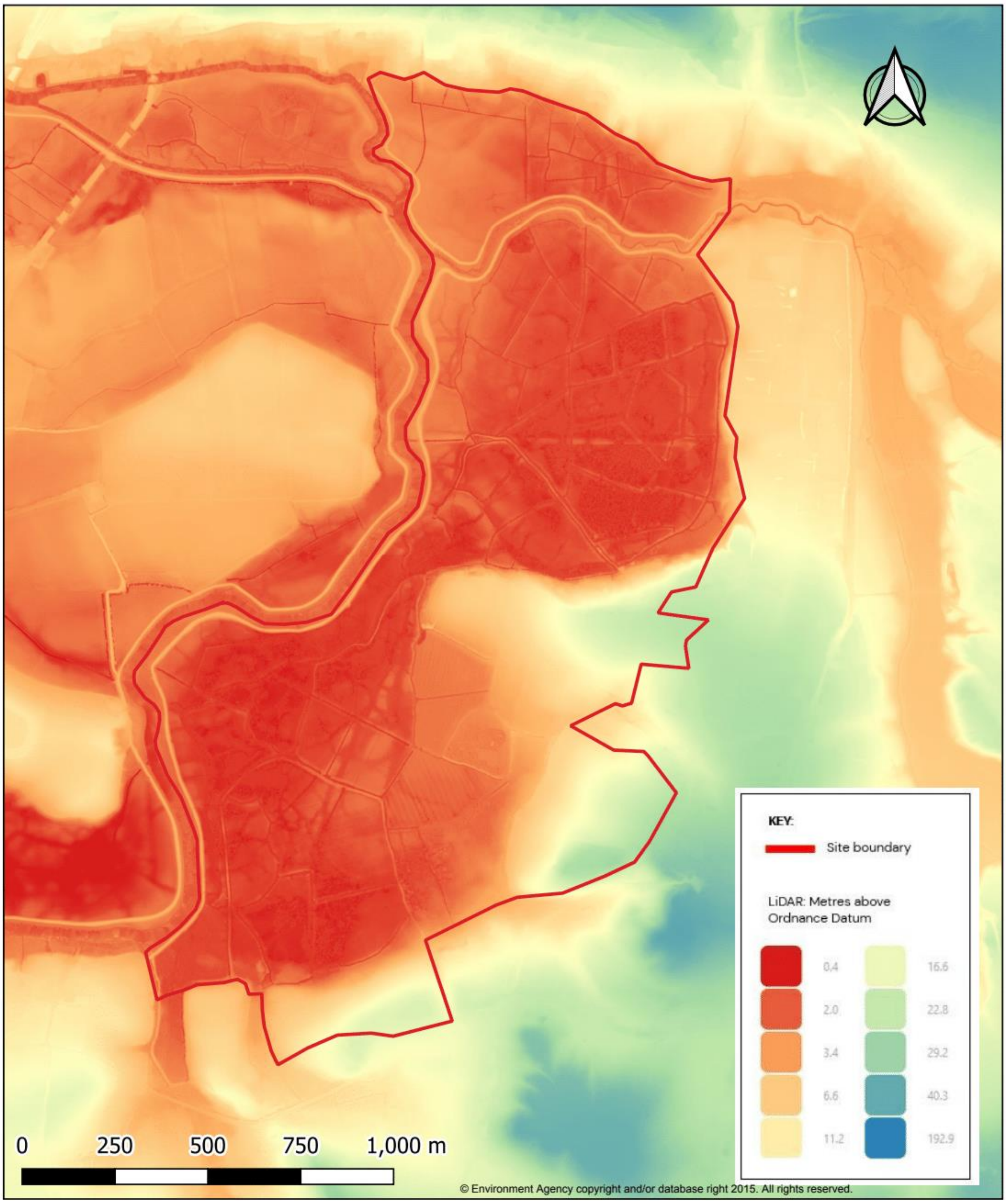


	Figure Title	Client: Natural England	Date 30/03/2022	Drawn JRB	YELLOW SUB GEO
	Lidar at 25cm resolution, Pulborough Brooks	Drawing Number	Scale 1:14,000	Checked GRO	
		Figure L	Original A4	1	
			Pulborough		

Figure M – Suggested Ditch Modifications, Pulborough Brooks North

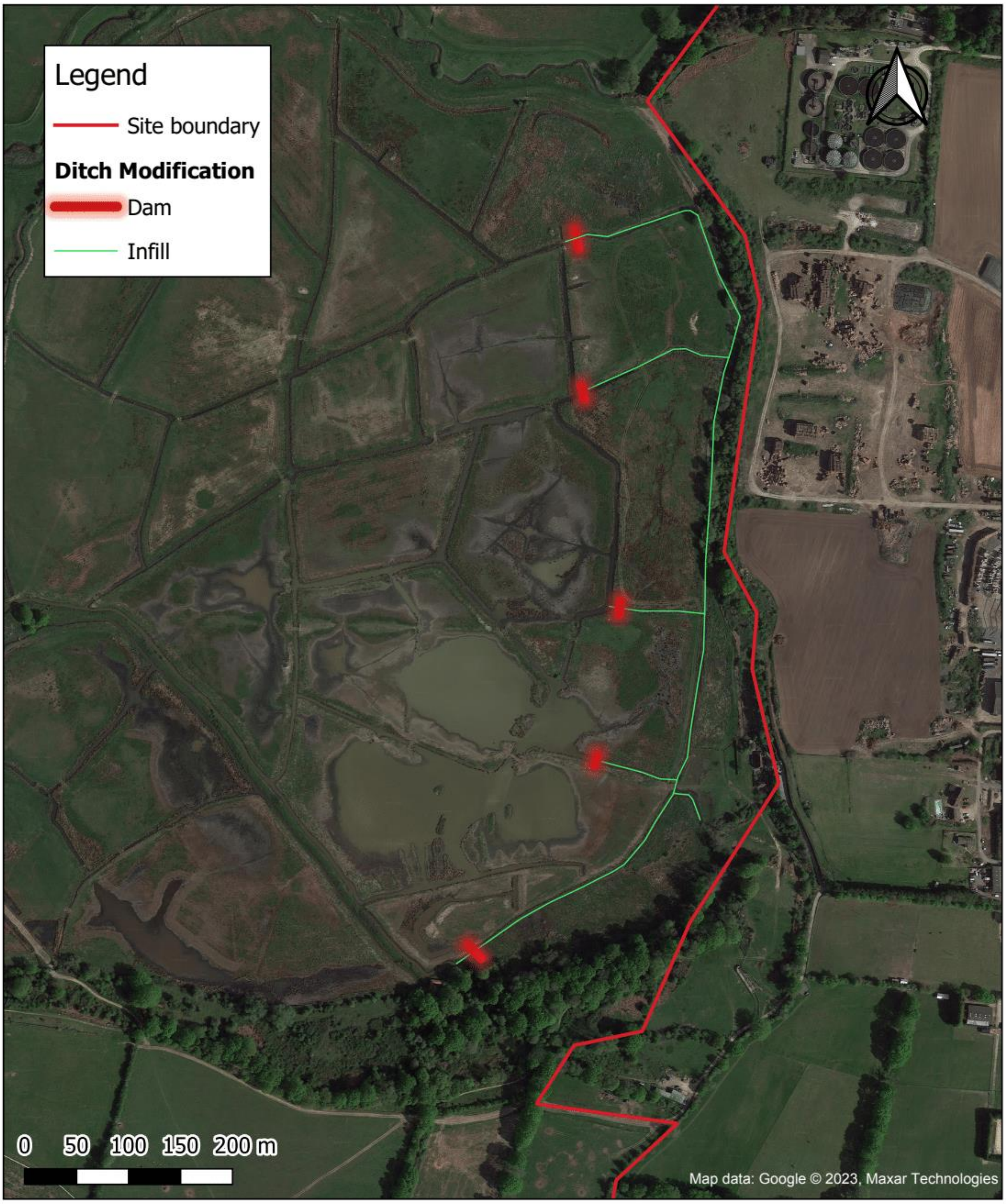


	Figure Title Suggested Ditch Modifications, Pulborough Brooks North	Client Natural England	Date 30/03/2022	Drawn JRB	YELLOW SUB GEO
		Drawing Number Figure M	Scale 1:5,000	Checked GRO	
			Original A4	1	
			Pulborough		

Figure N – Suggested Ditch Modifications, Pulborough Brooks South

Figure Title	Client	Date	Drawn	
Suggested Ditch Modifications, Pulborough Brooks South	Natural England	30/03/2022	JRB	YELLOW SUB GEO
	Drawing Number	Scale 1:5,000	Checked GRO	
	Figure N	Original A4	1	
		Pulborough		

Figure O – Pulborough Brooks: Lidar at 25cm resolution showing areas of inundation at sluice height = 1.7m AOD

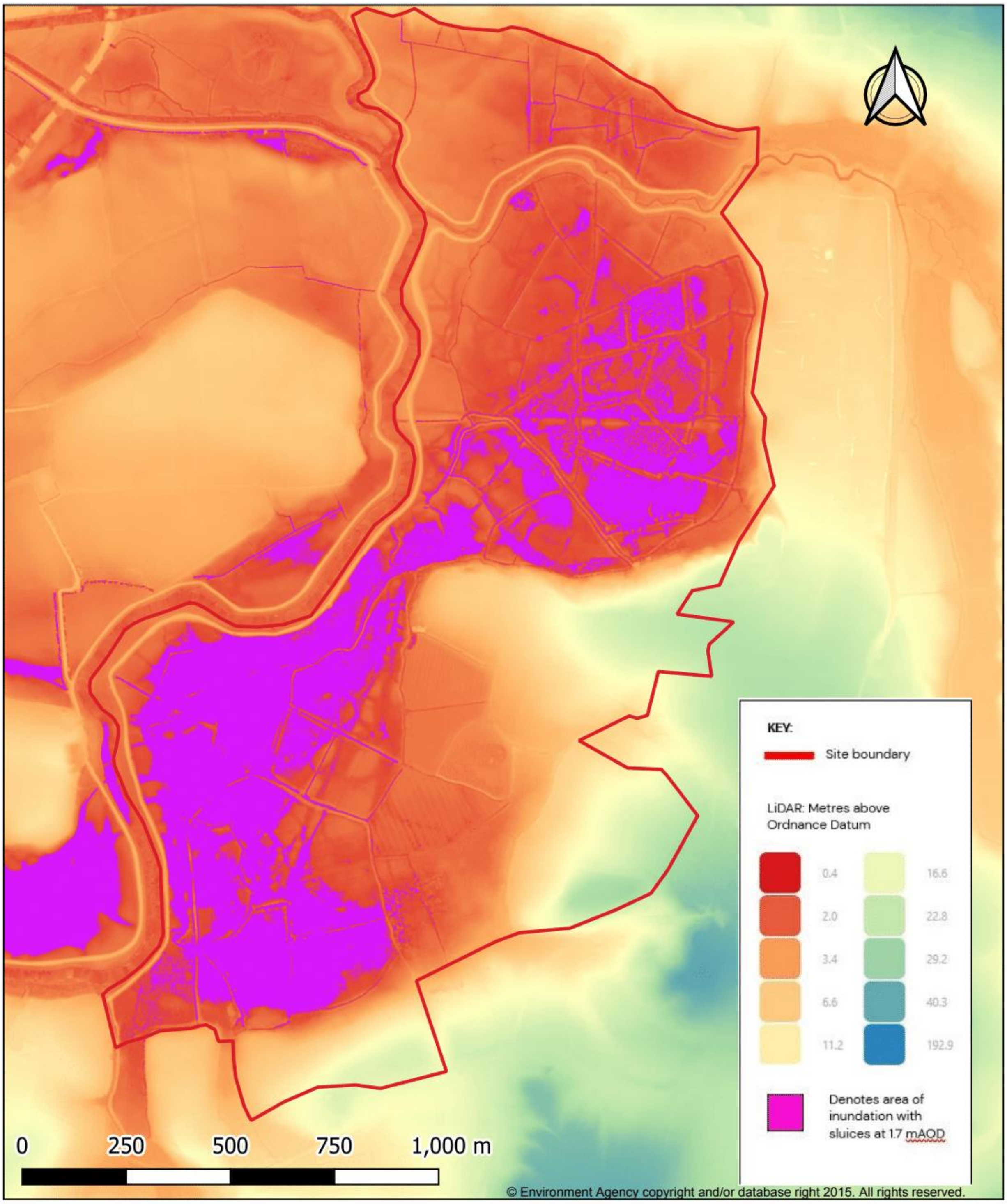


Figure Title	Client	Date	Drawn
Pulborough Brooks: Lidar at 25cm resolution showing areas of inundation at sluice height = 1.7 m AOD	Natural England	30/03/2022	JRB
	Drawing Number: Figure O	Scale 1:12,500	Checked GRO
		Original A4	1
		Pulborough	

Figure P – Peat Probe Countour Plot, Large Rushy Brook. Pulborough Brooks

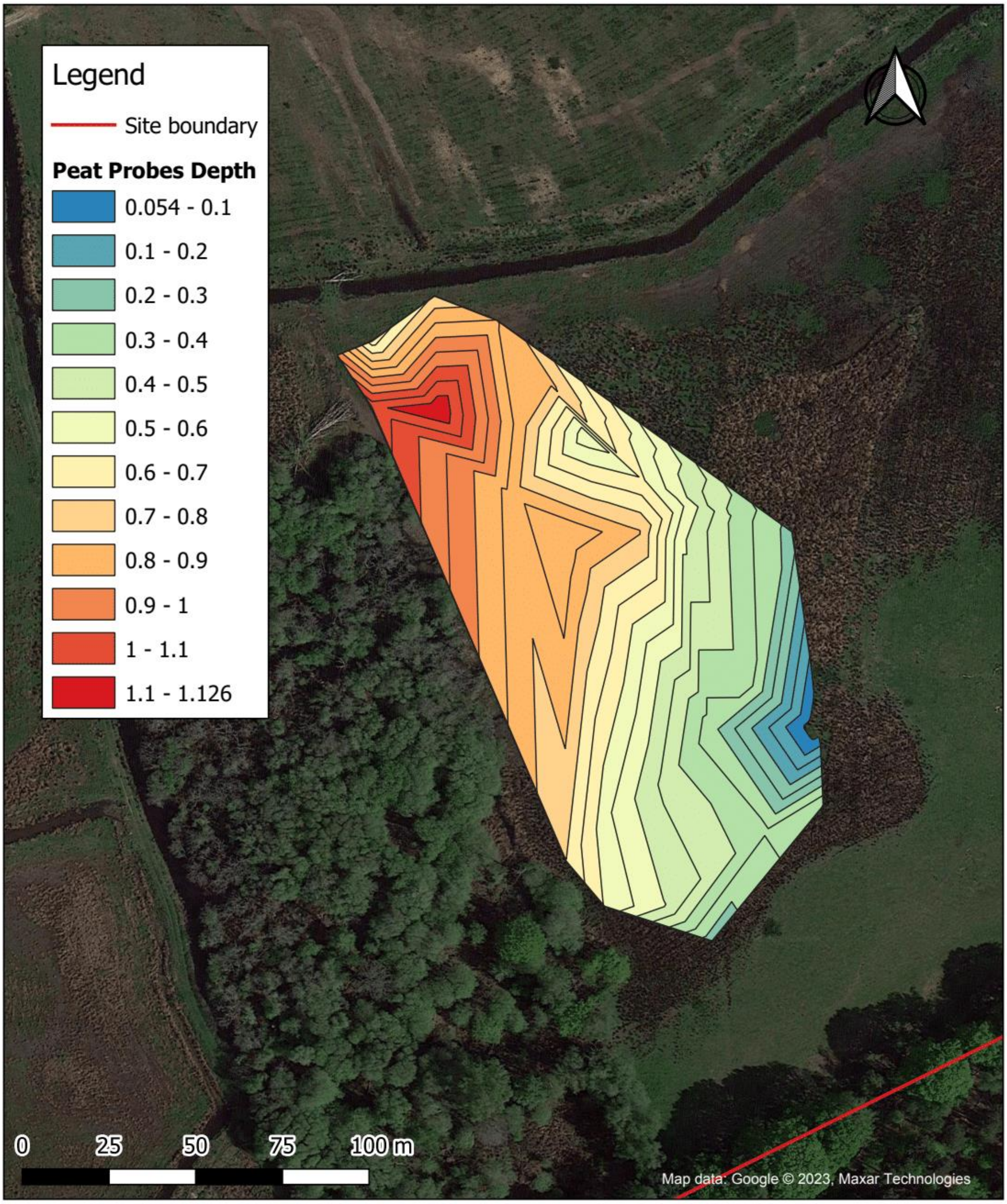


	Figure Title: Peat Probe Contour Plot, Large Rushy Brook. Pulborough Brooks	Client: Natural England	Date: 30/03/2022	Drawn: JRB	YELLOW SUB GEO
			Scale: 1:1,500	Checked: GRO	
		Drawing Number: Figure P	Original: A4	1	
			Pulborough		

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