Amberley Wild Brooks Eco-Hydrology and Peat Assessment Report

A report into the investigation of Amberley Wild Brooks Site of Special Scientific Interest

May 2025

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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 Amberley Wild 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 Amberley'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.

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Executive summary

Background

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 Amberley Wild Brooks Site of Special Scientific Interest (SSSI). This will hereby be referred as the site.

Soil conditions were investigated by means of a desk study and field investigation. Boreholes were advanced to obtain samples of the soil profile. 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. Water chemistry was monitored using hand-held equipment.

This report provides a factual summary of this work.

Results

Geology

The ground conditions encountered typically comprised of clay over gravel deposits, over a bedrock of sandstone. Peat deposits were found in discrete areas along the northern and eastern edges of the site and in an area of the central eastern portion of the site. Peat distribution appears to be controlled by the presence of a former channel of the River Arun, which crosses the site and is naturally infilled. Peat was absent within the footprint of the channel's meander. The northern and eastern peat lies between the adjacent higher ground off-site, to the north and east, and the relic river channel. The central-eastern area of peat lies in the former channel's course, within the inside of the meander.

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 in the best condition was found in the north-west of the site and in the centre of the bend in the former channel's course. 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.

Hydrology

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

Springs and seeps from the slopes surrounding the site are considered to have been important in peat generation along the northern and eastern edge of the site, as well as groundwater feeding in the subsurface.

Conclusion

A conceptual model has been produced that provides a summary of the hydrology mechanisms and peat conditions beneath the site. A high-level assessment of the implications for the ecosystem services from 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.

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, such as gathering further knowledge and working towards pilot intervention measures.

Contents

Abbreviations

Term	Definition
AOD	Above Ordnance Datum
BGL	Below Ground Level
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
STW	Sewage Treatment Works
SWT	Sussex Wildlife Trust
UXO	Unexploded Ordnance
WETMEC	Wetland Functional Mechanisms

1. Introduction

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 in Appendix 1) within part of a larger nature reserve, owned and operated by the Sussex Wildlife Trust (SWT), the Royal Society for the Protection of Birds (RSPB) and private landowners. The whole Site is designated as Amberley Wild Brooks Site of Special Scientific Interest (SSSI). It also forms part of the Arun Valley Special Protection Area (SPA), the Arun Valley Special Area of Conservation (SAC) and Arun Valley Ramsar site. The site is also 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 in both the site itself and in the surrounding area.

The purpose of the project is to review the ecohydrological status of Amberley Wild Brooks to understand its development and unmodified state, looking at the potential for its restoration to a more natural state. Amberley Wild Brooks has a relict lowland peat bog on site, mentioned in the SSSI citation as an area of peat in the north, which represents the only sizeable example of a relict raised bog in the southeast.

Key drivers of changes in peatland hydrology are climate, land use, groundwater or surface water abstraction and drainage, input of nutrients and pollutants from atmosphere or external water sources.

A number of parties are currently investigating and assessing the hydrological and hydrogeological status of the site. In parallel with this investigation, Atkins are also being employed by Natural England to investigate and assess the nutrient balance within the watercourses and ditches on the site. A third project is also ongoing, 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 Pulborough.

1.1 Scope

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

The combined scope of works comprised of:

- 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 Natural England 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 focussed specifically on the Natural England brief, 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, 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.

Figures A to M provide further context on the site and are provided in Appendix 1. They are referred to in the text alongside Figures 1 to 25,

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.

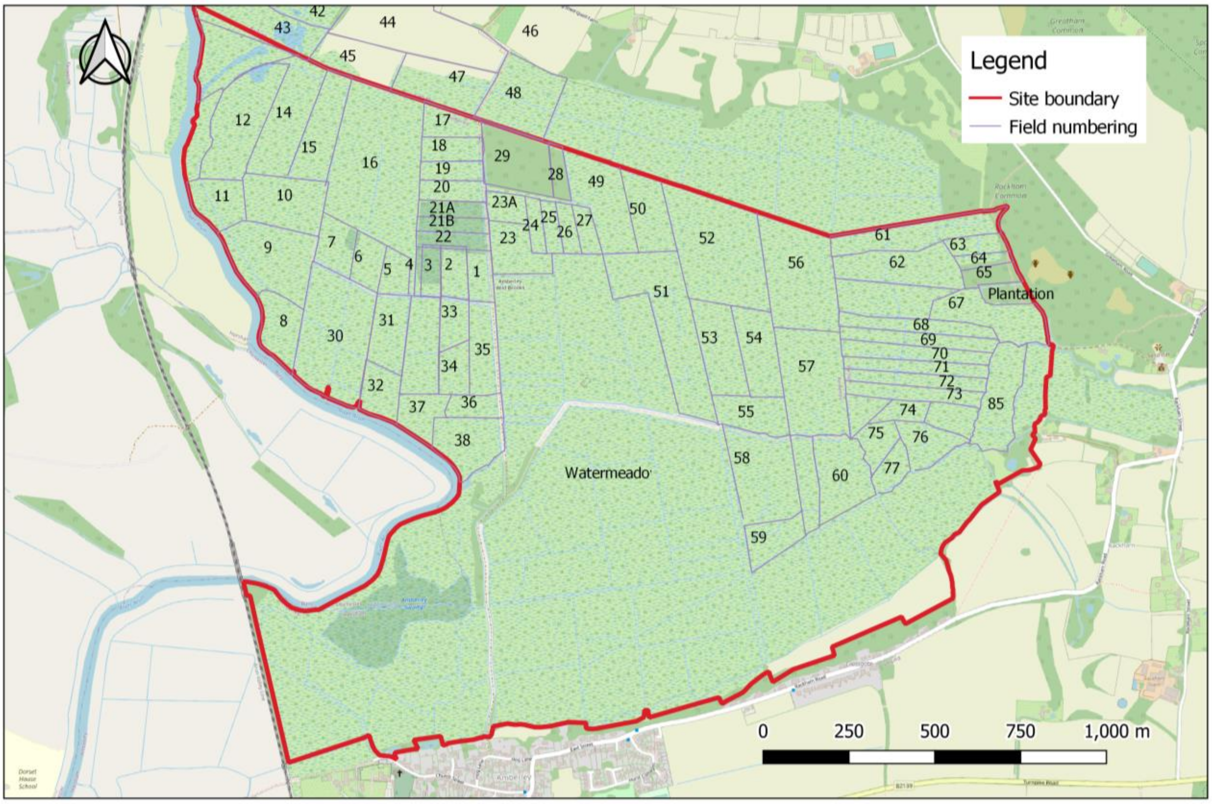
2. Desk Study

2.1 Site description and topography

A summary of the site setting is provided in Annex 1 at the end of this report.

Amberley Wild Brooks is situated regionally on the southern slope of the Greensand ridge, low-lying within the flood plain of the River Arun. The site location and fields names are shown in Figure 1 below.

Figure 1 Amberley Wild Brooks field numbering created using Map data © Google 2024



The site is bounded by the River Arun to the west. On all other sides, the site is surrounded by higher ground, with steep scarp slopes along parts of the eastern edge and along the southern edge, above which the village of Amberley sits. It is considered likely that this scarp slope was formed by erosion by the River Arun, which is anticipated to have once migrated across the floodplain. The change to higher ground along the northern edge of the site is less marked. There is an apron of slightly higher ground along the foot of this slope, raised 1 to 2m above the floodplain. There is then a more marked change in slope to steeper ground as you move northwards, towards Quell Farm. The area of higher ground to the north (around Quell Farm) forms a westerly extending ridge that separates the Amberley site to the south from a similar area of floodplain to the north known as Pulborough Brooks. 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.

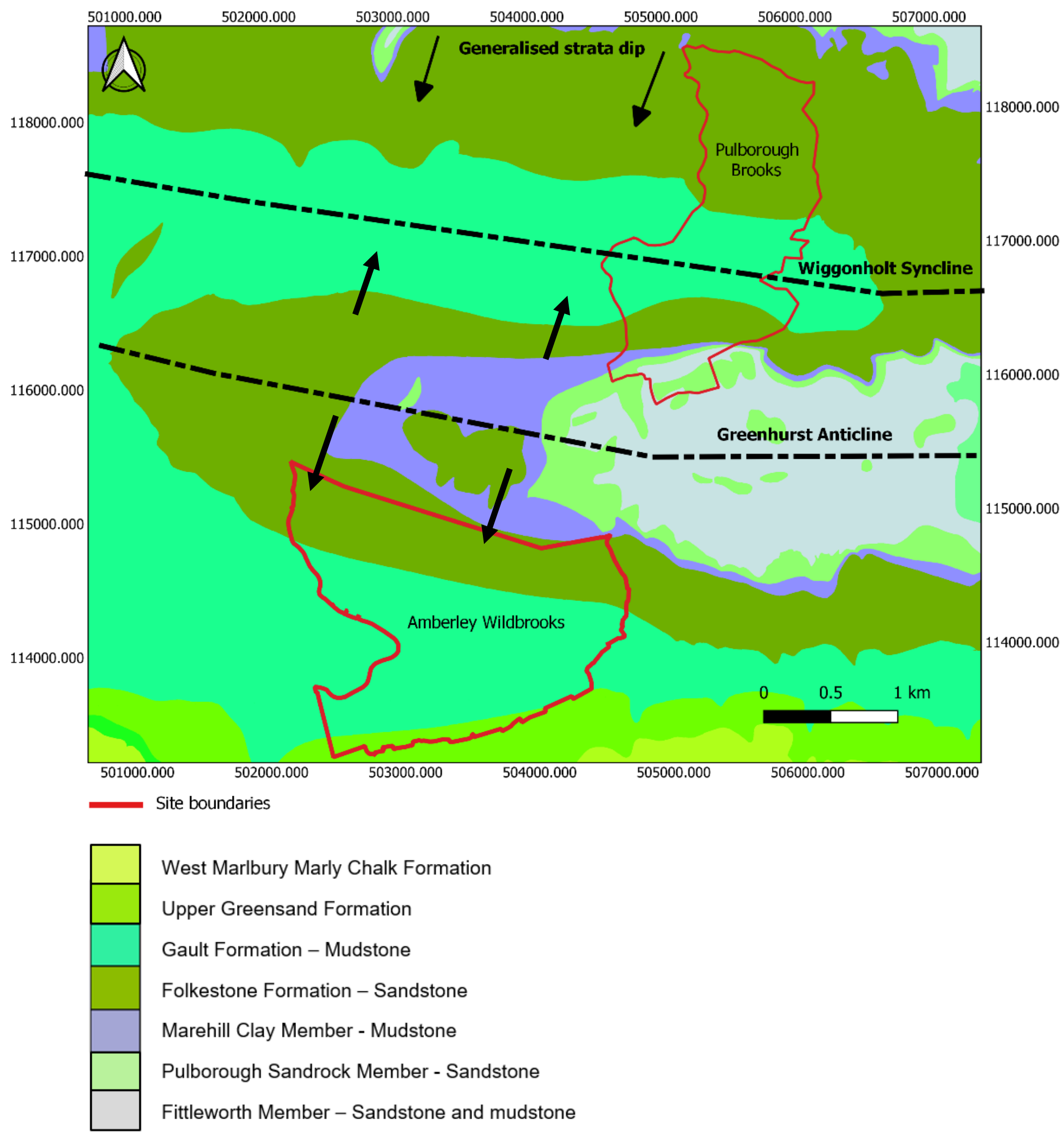
Within the floodplain of the site itself, the ground is predominantly low lying and of a similar elevation throughout, at around 2m Above Ordnance Datum (AOD). This places the ground level within the tidal range (0.1 to 2.8m at Arundel). Subtle changes in elevation can be seen within the site, and these are picked out in the LiDAR image of the site in Figure B. The LiDAR image clearly picks out a former channel of the River Arun, forming a large relic meander that crosses the site from a loop, leaving the current course of the Arun in the centre of the western boundary, heading north-eastwards towards Glebe Farm before forming a large arcuate meander through the eastern portion of the site, and returning to the current Arun course in the area of Amberley Swamp in the far south-west corner of the site. This relic meander feature forms a distinct area of lower ground. There is a pronounced area of higher ground within this relic meander, which can be clearly seen by eye when on site.

Flood embankments (levees) approximately 1 to 2m high run along the eastern boundary of the site separating it from the Arun River. Drainage ditches running across the 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

Amberley 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 2 below:

Figure 2 Regional structural geology adapted from Bristow and Wyatt, 1983



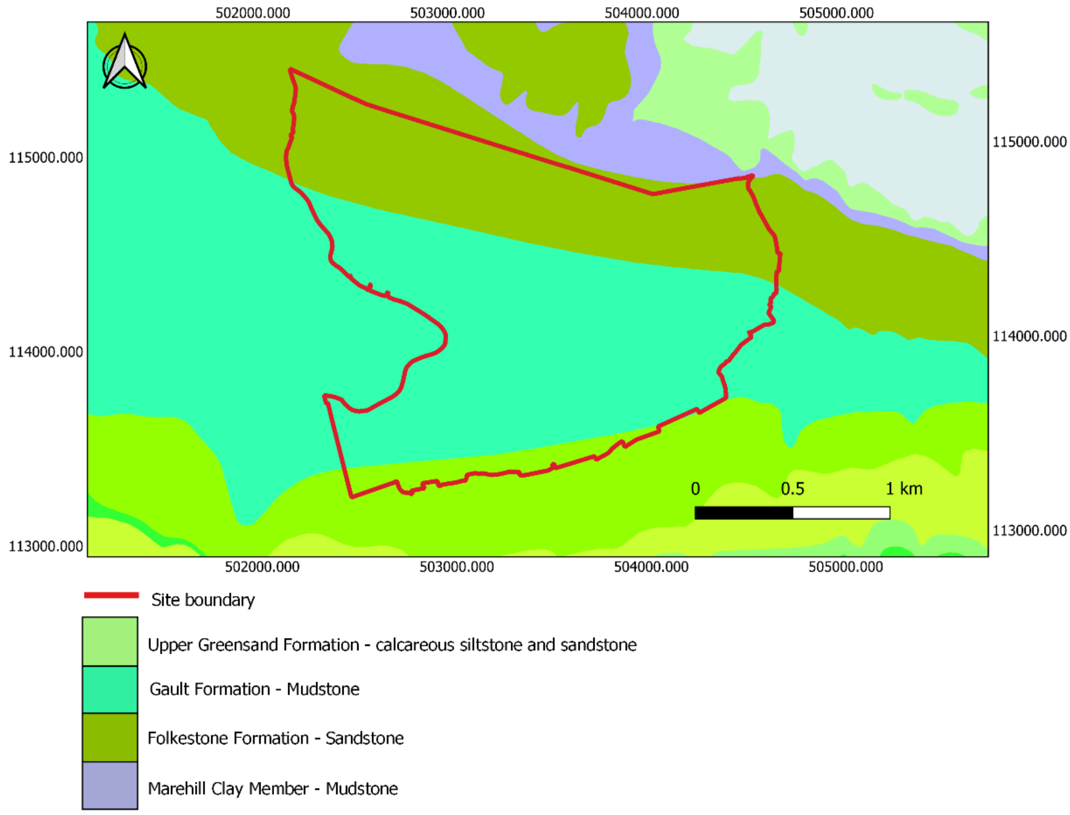
According to the British Geological Survey (BGS) 1:50,000 mapping, the bedrock geology comprises (Figure 3):

- Upper Greensand Formation – Sandstone and Siltstone
- Gault Formation - Mudstone
- Folkestone Formation – Sandstone
- Marehill Clay Member – 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

Figure 3 Bedrock geology from BGS 50K mapping



Nearby historical borehole logs recorded from the BGS Geoindex online portal, confirm the above succession and record the following (Table 1):

Table 1- Strata encountered in example nearby historical borehole logs, with depth defined as metres Below Ground Level (BGL) (Contains British Geological Survey materials © UKRI 2024)

Borehole ref.	Stratum	Maximum depth (m bgl)
TQ01SW28 Easting: 503100 Northing: 114170 Near Field 38	Clay Silty Clay Silty Clay with some Sand Silt Silty Sand Silty Sand Silty Sand Silt with Gravel Clay Silt	0.4 1 1.3 2 2.5 2.6 8.9 9.6 10.5
TQ01SW27	Topsoil Sand	0.2 0.5

Borehole ref.	Stratum	Maximum depth (m bgl)
Easting: 503110 Northing: 114130 Near Field 38	Sandy silt with peat Silt Sandy Silt Gault Clay	1.5 3 3.6 4.8
TQ01SW32 Easting: 503800 Northing: 114130 Field 58	Sandy Clay with Chalk Silty Clay Clay Sand Clay Sand	0.4 0.8 1 1.4

2.2.1 Upper Greensand Formation – sandstone and siltstone

Mapped by the BGS to the southern boundary of the site, the Upper Greensand Formation consists of fine-grained, glauconitic, shelly sand and sandstone. The Upper Greensand Formation is underlain by the Gault Formation and overlain by the Chalk Group. Typical thicknesses of the unit are 55m with a full thickness of the formation shown up to 60m in the cliffs of the Isle of Purbeck. The sandstone is thought to be deposited in a marine, shallow water environment. Within the area, the Upper Greensand Formation forms an escarpment which is dwarfed by the adjacent chalk scarp.

2.2.2 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. Typically comprising 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 penetrated the entire succession of Gault clay with a thickness of 91.6m. Red cementitious Iron grit occurs locally within the Gault formation typically at the sharp junction to the Folkestone Formation below.

2.2.3 Folkestone Formation – sandstone

The Folkestone Formation 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.

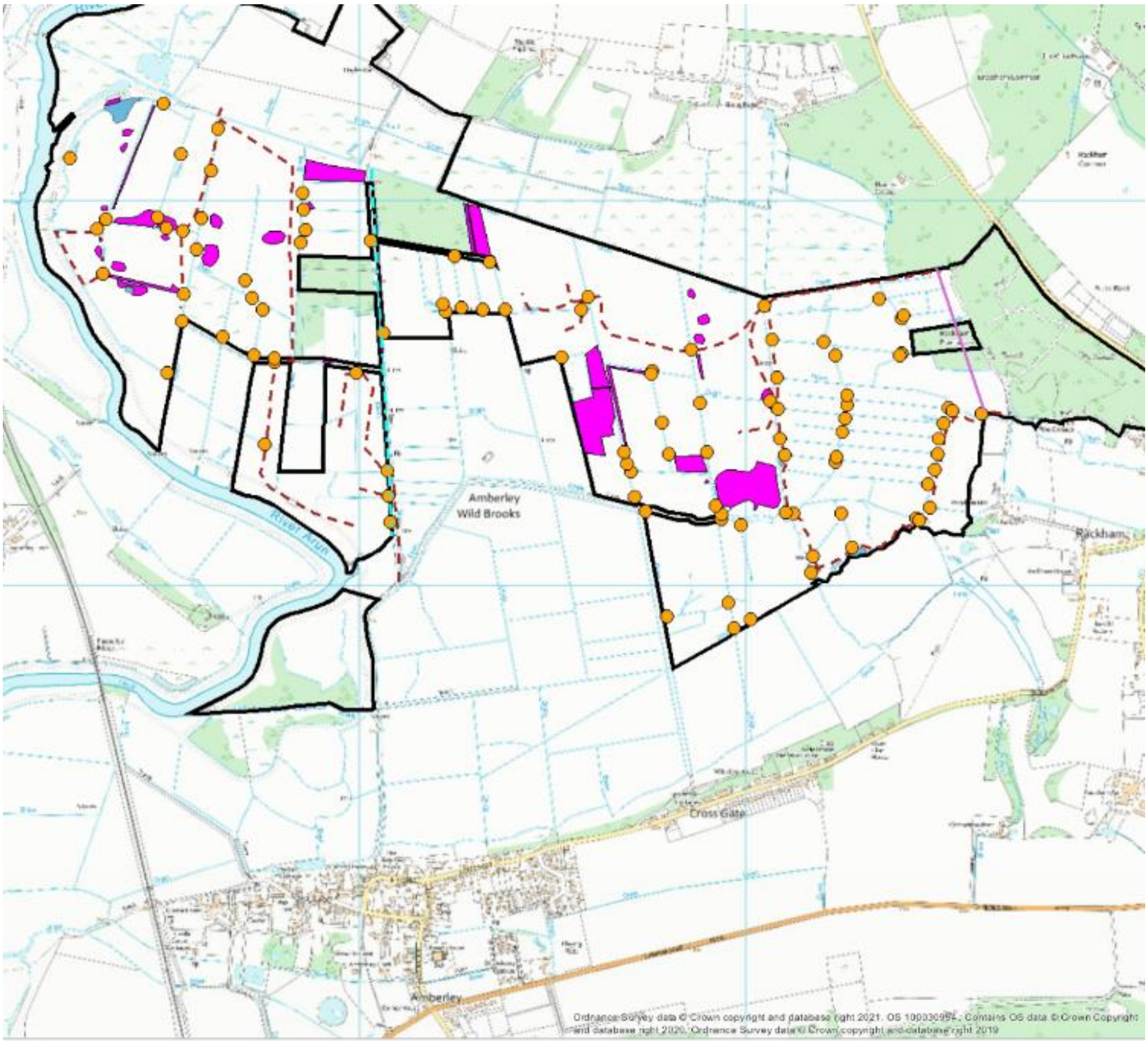
2.2.4 Marehill Clay Member – mudstone

Mapped running along the northern site boundary, the Marehill Clay Member underlies the Folkestone Formation Comprising a dark grey, locally glauconitic silty clay. The clay has blocky weathering and in has been used historically for brick making. The outcrop varies in thickness between 50 - 100m.

2.2.5 Peat

Peat deposits have been mapped in the northern extent of site with a small section to the east. RSPB hazard maps show soft peat in small areas across northern and central regions of the site in fields 11, 12, 14, 15, 10, 9, 17, 20, 61, 54, 56 and 57 (Figure 5). The northern extent of field 12 is also flagged as unsafe areas to drive on. These areas are shown in Figure 5.

Figure 4 RSPB Hazard Map of Amberley Wild Brooks. Produced by the RSPB.



Legend:

PROW | Powerline | Tractor access routes | Crossing

Soft peat | Do not drive on! | RSPB Reserves – Public (UK)

Acknowledgements & Notes:

Created by RSPB

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 at Amberley with peat overlying the Arun River Terrace Deposits (RTD) and Folkestone Formation bedrock, development of the peat bog relies on a consistent water supply such as springs.

Peat rests of gravelly sands of the Arun member 1 gravels and sands in the north of Amberley, in the south they can be traced intermittently as a thin bed below the topmost alluvial clays. 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 Wild Brooks was undertaken from peat overlying alluvial clay at a depth of 1.5m bgl. The peat was dated 2620 +/- 10 years ago.

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 is pore size and hydraulic conductivity ensuring a high-water table is maintained.

2.2.6 Alluvium – clay, silt, sand and gravel

Alluvium is mapped across the entirety of the site consisting 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.

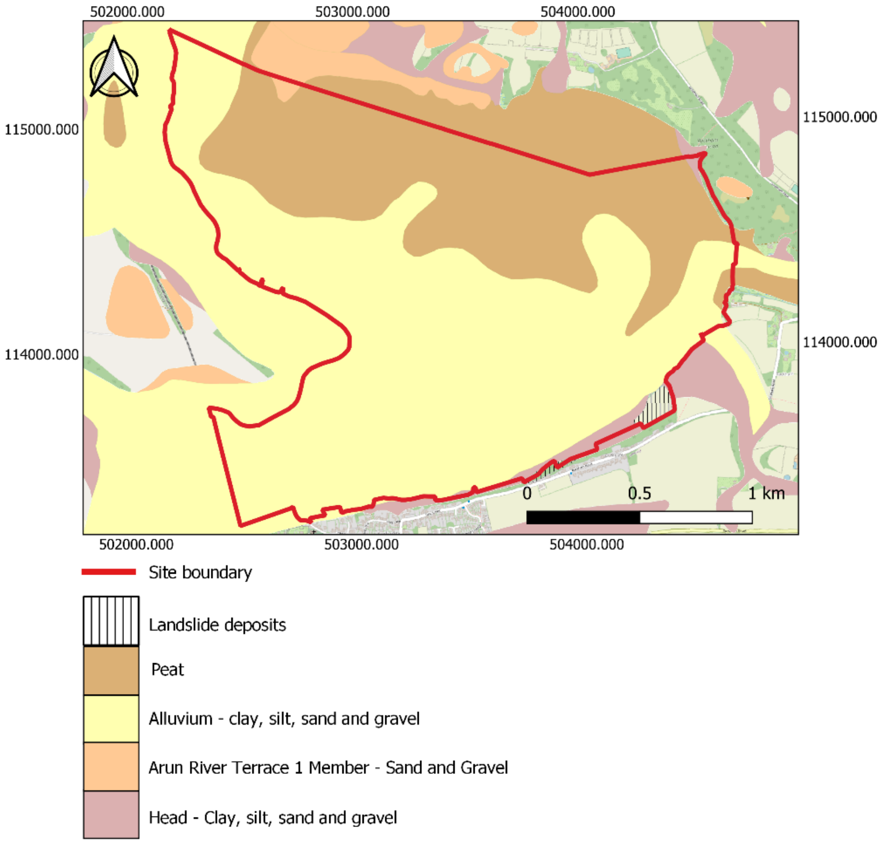
2.2.7 Arun River Terrace Deposits – sand and gravel

A small area of Arun RTDs Member 1 is mapped in the northern extent of the site. 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.

2.2.8 Head – clay, silt, sand and gravel

Head deposits are mapped underlying the Alluvium 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. Landslides were noted on the southern edge of the site, shown in Figure 4, associated with the over steepened slope due to the river paleochannel.

Figure 5 Superficial geology and mass movement from BGS 50K mapping



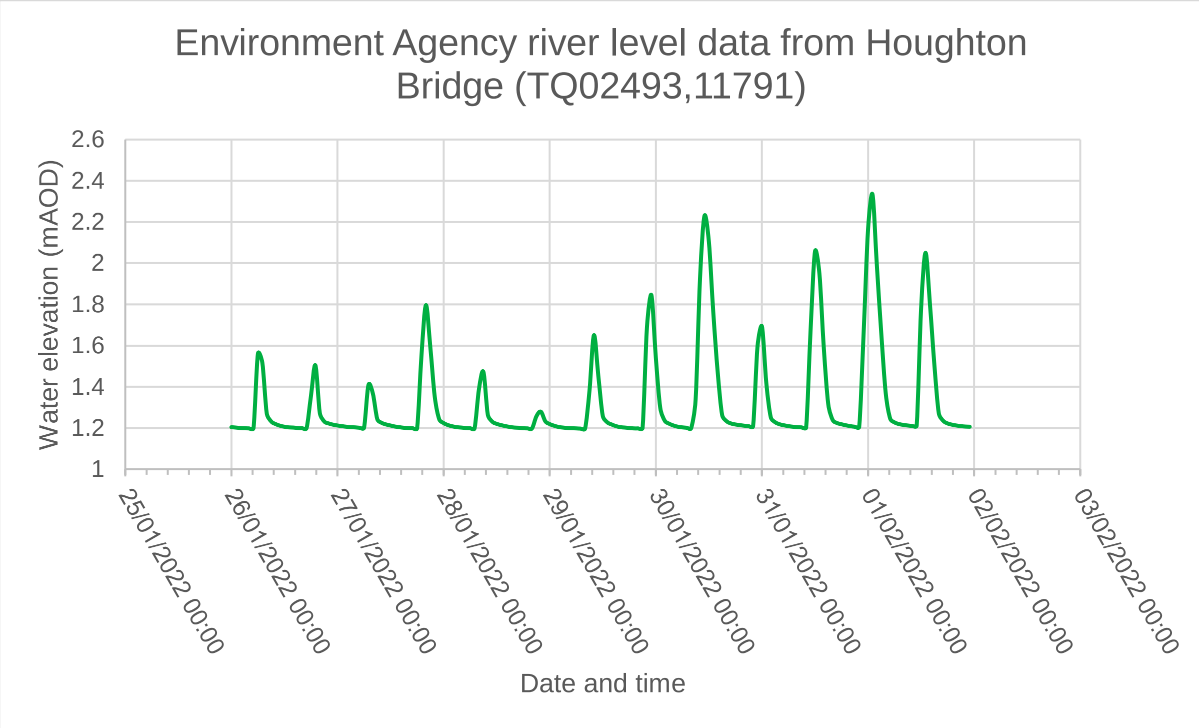
2.3 Hydrology

2.3.1 Surface water

2.3.1.1 Rivers and streams

The site is bound by the River Arun to the west. The River Arun has flood embankments along its course with a series of flap sluices in place along the embankment. The Ordnance Survey map 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 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 (Figure 6).

Figure 6 River Arun level data, Houghton Bridge sourced from the Environment Agency (Contains public sector information licensed under the Open Government Licence v3.0 © Crown Copyright 2024)



The site lies further upstream than this, with approximately 4.5 km of river channel between Houghton Bridge and the southern edge of the site. 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.

A tributary of the Arun flows across the site from east to west, named Amberley Wildbrook. This stream rises from springs in the chalk escarpment in the area of Parham Park. It flows along the valley bottom in Parham Park, where peat is also mapped by the BGS. It then enters the site between Rackham Mill and Rackham Plantation between fields 67 and 85 (Figure 1). It flows within an isolated channel, which has no surface water connection to other ditches monitored on site, however connections with other unmonitored ditches may exist. This channel turns southwards and then westwards, flowing around the southern edge of Fields 77 and 75 before following alongside the north of the main access track from track Field 55 westwards (Figure 1). It flows into the Arun via a tidal flap to the north of Amberley Swamp.

2.3.1.2 Ditch network

The site is reclaimed land from the floodplain of both bordering rivers. The area has been artificially separated from the River Arun 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 in excess of 10 km in length. Larger ditches are typically 8-10m wide and 2m deep (Gasca & Ross, 2009). Minor ditches are smaller in size 4m wide and 1.5m deep.

Information on ditch flow direction, inlet structures and outlet structures has been provided by the RSPB, as discussed in more detail in Section 6.5 and shown in Figure C.

2.3.1.3 Springs and seepages

Spring lines can be found along the eastern boundary of the site, with ochreous discharges emanating from the Folkestone Beds in several locations here, including near Rackham Mill, in the woodland south of Rackham Mill and near Pine Cottage to the north of Rackham Mill. Springs are also noted along the northern boundary of the site, both on the track from Quell Farm and in the area of Glebe Farm. These are captured by perimeter ditches as the enter the site. Figure C provides 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) of fluvial flooding from the River Arun. 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 not located within a Source Protection Zone however land off-site to the north-west and north of site is located with Flood Zone 3.

2.4.1 Superficial hydrogeology

Superficial Alluvium and Arun RTDs are classified by the Environment Agency (EA) as a Secondary A 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.

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. 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 that 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 within transmissivity thought to be a function of aquifer thickness. Measured transmissivity in the beds range from 150m2 d-1 to 1200m2 d-1 with a geometric mean of 260m2 d-1 (Allen and others, 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 the 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.

Amberley Wild Brooks is located approximately 2km away from a groundwater abstraction from the Folkestone Formation, 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 & Ross in 2009. It is currently unknown if a link lies between the groundwater abstraction and the shallow hydrogeology and hydrology of Amberley Wild Brooks, 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 the nearby 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; Hulme and others, 2012). The Folkestone Formation contributes spring flow to the site from the higher ground to the north and east. There is potential for this inflow to be affected by the abstraction.

2.5 Site history

A review of historical Ordnance Survey (OS) mapping and Google Earth imagery of the site was undertaken. The results of this review are shown in Table 2.

Table 2- Site history obtained from OS mapping and Google Earth Imagery

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 layout as the present day. A railway runs west of the River Arun named the Mid Sussex line. Drainage channels across the site in the same layout as present day however, a lot less in number. A lock later named Coldwaltham lock is marked on the Arun Canal which branches off from the River Arun north-east of the site.
1888-1913 (OS six-inch mapping)	Further drainage ditches have been added to the site in nearly identical alignment to present day mapping. A few drainage ditches have since been infilled, notably three cross-cutting diagonal ditches in Fields 35, 36 and 37, the nameless field above Fields 16, 37 and 49 and below Fields 23 and 60. Several areas of site are now marked as 'liable to floods'. A spring is marked to the east of site by Rackham Mill. A Sand Pit is marked further east off-site by the Rackham plantation (woods).
1937-1961 (OS 1:25,000 mapping	Amberley swamp and middle gutter is marked just below Field 39 off-site. A sand pit and a sand and gravel pit have been mapped north of the site boundary. Arun lock to the north-east of site is now marked as Old Canal and has been infilled. The lock remains.
2001 (Google Earth, 2001)	December aerial mapping shows virtually no surface flooding in any of the fields. Several curving paleochannels in below Fields 23, 31, 32, 30, 37, 34, 61, 62 and 57.
2009 (Google Earth, 2009)	December aerial mapping once again shows minimal surface water bar a few small ponds to the southwest, Fields 51, 57 and 60 appear to have been ploughed. A paleochannel has appeared crossing Fields 68-72.
2012 (Google Earth, 2012)	January mapping shows flooding in the southwestern corner of the site, the remainder of the site appears to be dry. By September mapping of the same year this flooding has dried up. October

Epoch	Details
	mapping one month later shows increased surface water in the north-eastern extent of site in the fields bordering the woodland. The paleochannel formed in Fields 68-72 has spread out further.
2013 (Google Earth, 2013)	June aerial mapping shows the majority of the site to be dry. Extensive criss-crossing paleochannels channels are shown in Fields 61 and 62.
2015 (Google Earth, 2015)	April aerial mapping shows surface water in Field 9. This has dried up by September mapping of the same year. The aerial photography from this year is particularly good at highlighting both the palaeochannel meander of the River Arun, but also a series of smaller sinuous relic channels that meander across the site, superimposed on top of the Arun palaeochannel, as shown in below.
2018 (Google Earth, 2018)	August aerial mapping shows a lack of surface water across the whole site.
2020 (Google Earth, 2020)	Small, ponded areas of water are shown in fields 8 and 9*.
2021 (Google Earth, 2021)	No discernible changes shown.

Source: OS Mapping and Google Images

Note 1: See Figure 1 for field numbers.

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. Banks of rivers have been raised and sluices installed in ditches to speed drainage of water during floods. The natural hydrology of the area has been significantly altered by a man-made drainage network, groundwater abstractions and construction of flood banks.

Figure 7 shows white arrows which denote large-scale palaeochannels associated with the former meander of the River Arun. A younger generation of small-scale palaeochannels can be seen as sinuous features, over which is superimposed the modern geometric field drain network.

Figure 7 2015 aerial imagery showing two epochs of palaeochannels (Google Earth, 2024)

2.6 Environmental designations

Envirocheck mapping indicates there are multiple environmental designations both on site and in the surrounding local area. These designations are comprised of:

- Site of Special Scientific Interest (SSSI) - Previous assessment indicated that 98.05% of Amberley Wild Brooks was in unfavourable condition but recovering.
- Special Protection Area (SPA) - Lies within the Arun Valley SPA of European importance under articles 4.1 of the Directive (79/409/EEC) Annex I with over winter Bewick’s swans and under article 4.2 by regularly supporting at least 20,000 wildfowl.
- Special Area of Conservation (SAC) - Designated an SAC due to the significant aquatic plant and invertebrate assemblage 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 - The 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.

2.7 Unexploded Ordnance (UXO) risk assessment

Following an assessment by Zetica UXO the site has been deemed to be at a Low Risk from all forms of Unexploded Ordnance. 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;

- 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 and depth of peat.

Distribution of peat is shown along the northern portion of the site and in the north-east of the site in BGS mapping (Figure 4). RSPB hazard mapping indicates peat present in the north-west, central-north and central-east part of the site. The ground investigation therefore aimed to characterise the depth of peat deposits across the site and to provide transects across the peat and the drift/solid boundary at the edge of the reserve. This was in order to provide data on comparative geology and groundwater conditions along floodplain and peat margins.

The ground investigation on site also aimed to characterise the depth of peat deposits as well as constructing a series of groundwater monitoring well installations. The 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 and others, 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 and Sussex Wildlife Trust and was facilitated by the numerous private landowners and stakeholders of the site. 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 11th of January 2022 to assess current site conditions. During this walkover exploratory hole locations were agreed between RSPB, Sussex Wildlife Trust, Natural England, Atkins, Southern Water and Yellow Sub representatives.

3.4 Service clearance

Yellow Sub Geo 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 1.2m bgl where possible, to provide confirmation of clearance.

3.5 Fieldwork undertaken

Fieldwork was undertaken on the 19th, 20th, 21st and 24th of January 2022. The works comprised:

- Hand pitting using insulated hand tools to 1.2m bgl to confirm the absence of services in all locations;
- A series of eleven boreholes (WS-A-01 to WS-A-10 and WS-A-18, Figure D drilled with a Crawler Mounted Terrier Rig to a maximum depth of 8 metres below ground level (m bgl);
- A series of twenty-four exploratory holes (HA-A-01 to HA-A-24, Figure D) excavated using a hand auger to a maximum depth of 2.5m bgl;
- 14 Installations of groundwater monitoring wells (50 and 35mm internal diameter HDPE pipework) across the site;

- 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;
- logging of all boreholes and the trial pit in accordance with Industry Standards (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 14 installations across the site;
- Construction of a series of fences around the installations;
- Installation and set-up of data loggers within 14 installations to provide continuous groundwater elevation monitoring over the period of five weeks in selected boreholes; and,
- Installation of three slotted standpipe wells into a series of drainage ditches.

With the exception of WS-A-18, which was added as an additional locality during the SI, 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. 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 is shown on Figure D and 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 superficial head deposits, Upper Greensand Formation, Gault Formation nor Marehill Clay Member were encountered during the site investigation.

4.1 Strata encountered

The strata encountered in the exploratory holes advanced during the fieldwork are summarised in the Table 3 below:

Table 3- Strata encountered during field work

Strata	Description	Depth range encountered (m bgl)	Top and bottom m bgl (typical thickness, m)
Topsoil	Encountered across most of the site; absent at two locations, HA-A-03 and HA-A-18 (Figure D) where peat is present at ground level. Typically thin (<0.2m) it comprises a soft to firm brown organic-rich silty slightly sandy to sandy clay, generally with rootlets.	GL-0.9	0.05-0.9 (0.1)
Peat	Encountered across the majority of site, absent in WS-A-07, WS-A-09 and WS-A-18. Variable in composition, ranging in type in accordance with Von Post scaling (von Post and Granlund, 1926) from H3 to H9, typically H5. Water levels in the peat are typically confined by the overlying clay-rich topsoil. Moisture content of the peat encountered typically increases with depth, with a trend of desiccated low	GL to 2.10	0.15-2 (0.5)

Strata	Description	Depth range encountered (m bgl)	Top and bottom m bgl (typical thickness, m)
	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. (Section 5 talks about the peat deposits on site in more detail).		
Alluvium	Encountered across the site beneath the Topsoil and 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. Occasionally 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. Increased thicknesses of alluvium were encountered in WS-A-09 and WS-A-10 in the east of the site at the base of the woodland and elevation rise.	0.1-8	0.1-7 (1.4)
Arun River Terrace Deposits	Encountered in the northern and central area of site only in WS-A-04, HA-A-01, HA-A-04, WS-A-04 WS-A-05, WS-A-06, WS-A-07, WS-A-08 and WS-A-18. 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.	0.35-6	0.2-3.2 (2.5)

Strata	Description	Depth range encountered (m bgl)	Top and bottom m bgl (typical thickness, m)
Folkestone Formation	Proven in only two localities WS-A-01 and WS-A-02, Folkestone Formation bedrock consists of yellowish occasionally orangeish slightly gravelly to slightly clayey SAND. Sand is well sorted and unfirmly graded.	1.2-4	2.8+ (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 River Terrace Deposits 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 contamination was recorded during the fieldwork.

4.5 Groundwater

Groundwater was encountered in the majority of the exploratory holes during the drilling works at relatively shallow depth. Details of the groundwater strikes in metres below ground level (m bgl) are given in Table 4 below. Groundwater well localities are indicated on Figure D.

Table 4- Groundwater strike details

Locality	Depth (mbgl)	Depth after 20 minutes	Strata
HA-A-02	0.5	No change	Peat
HA-A-03	0.2	No change	Peat
HA-A-03	0.2	No change	Peat
HA-A-04	0.1	No change	Peat
HA-A-08	0.65	No change	Peat
HA-A-10	0	0.1	Peat
HA-A-11	0	0.3	Peat
HA-A-11	1.3	No change	Peat
HA-A-12	0.4	No change	Peat
HA-A-14	0.75	No change	Peat
HA-A-15	0.6	No change	Peat
HA-A-16	0.45	0.1	Topsoil/peat
HA-A-17	0.05	No change	Topsoil
HA-A-18	0	No change	Peat
HA-A-18	0.3	No change	Peat
HA-A-19	0	No change	Peat
HA-A-20	0.2	No change	Peat
HA-A-20	0.6	No change	Peat
HA-A-23	0.4	No change	Peat
HA-A-24	0.5	No change	Peat

Locality	Depth (mbgl)	Depth after 20 minutes	Strata
WS-A-01	1.2	No change	Folkestone Formation
WS-A-01	2	2.1	Folkestone Formation
WS-A-01	0.1	No change	Peat
WS-A-02	2	2.2	Peat
WS-A-02	0.05	No change	Peat
WS-A-03	0.4	No change	Peat
WS-A-04	1	No change	Peat
WS-A-04	3	3.5	Arun RTD
WS-A-05	2.5	3	Alluvium
WS-A-05	0.2	No change	Peat
WS-A-06	0.4	No change	Peat
WS-A-07	1.2	2.5	Peat
WS-A-07	5	5.4	Alluvium
WS-A-08	1	No change	Peat
WS-A-09	1.3	No change	Alluvium
WS-A-10	0.5	No change	Peat
WS-A-18	2	3	Peat
WS-A-18	3.1	3.2	Folkestone Formation
WS-A-18	2	3	Folkestone Formation

Groundwater levels were recorded on a return visit on the 16th of February 2022. The range of water levels are shown in Table 5, with groundwater well localities shown on Figure D.

Table 5- Rest groundwater levels in boreholes 16th to 18th of February 2022

Exploratory Hole	Groundwater level mbgl	Groundwater level m AOD
HA-A-01	0.06	2.825
HA-A-02	0	2.852
HA-A-09	0	2.675
HA-A-10	0.95	1.475
HA-A-14	0.23	1.951
HA-A-20	0.04	1.948
HA-A-21	0.1	1.242
HA-A-23	0.27	1.932
HA-A-24	0.096	1.58
SW-A-01	0.17	2.643
SW-A-02	0.07	2.374
SW-A-03	0.13	1.452
SW-A-04	0.15	1.552
SW-A-05	0.66	0.742
WS-A-01	0.23	2.622
WS-A-02	0	2.832
WS-A-03	0.55	2.285
WS-A-04 [note 1]	+0.3	2.713
WS-A-05	0.74	0.803
WS-A-06	0.25	1.618
WS-A-07 [note 1]	+0.37	1.824
WS-A-08 [note 1]	+0.28	2.216
WS-A-09	0.78	0.801
WS-A-10	0.935	0.733
WS-A-18	1.77	4.464

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. Manual dips were also taken at the beginning and end of the period. Comparison of these depths to water is provided in Table 6.

Table 6- Groundwater monitoring manual dip results

Exploratory Hole**	16th – 18th Feb 2022 groundwater level (m bgl)	16th – 18th Mar 2022 groundwater level (m bgl)	March groundwater level m AOD	Screened Strata
HA-A-01	0.06	0.18	2.705	Alluvium
HA-A-09	0	0.13	2.545	Peat
HA-A-10	0.95	0.7	1.725	Peat
HA-A-14	0.23	0.3	1.881	Peat
HA-A-24	0.096	0.17	1.506	Peat
SW-A-01	0.17	0.21	2.603	Surface Water
SW-A-02	0.07	0.1	2.344	Surface Water
SW-A-04	0.15	0.11	1.592	Surface Water
WS-A-01	0.23	0.28	2.572	Folkestone beds
WS-A-03	0.55	0.27	2.565	Alluvium
WS-A-04 [note 1]	+0.3	+0.3	2.713	RTD
WS-A-10	0.935	0	1.668	Alluvium
WS-A-18	1.77	0.73	5.504	Folkestone beds

Note 1: Indicates boreholes with Artesian conditions, dip is above ground level

Note 2: Exploratory positions shown on Figure D

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 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 (Figure 8). Graphs for each strata type and paired installations are plotted in Figures 9 to 16.

Figure 8 Barometric data recorded over a 1-month period on site

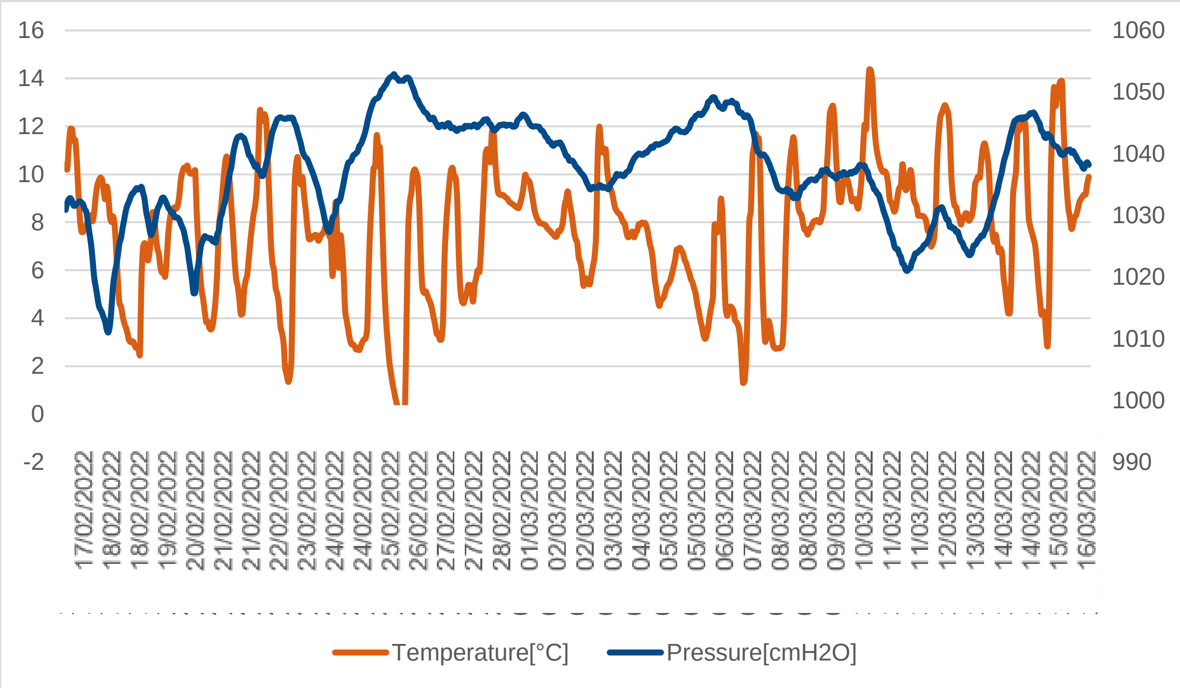
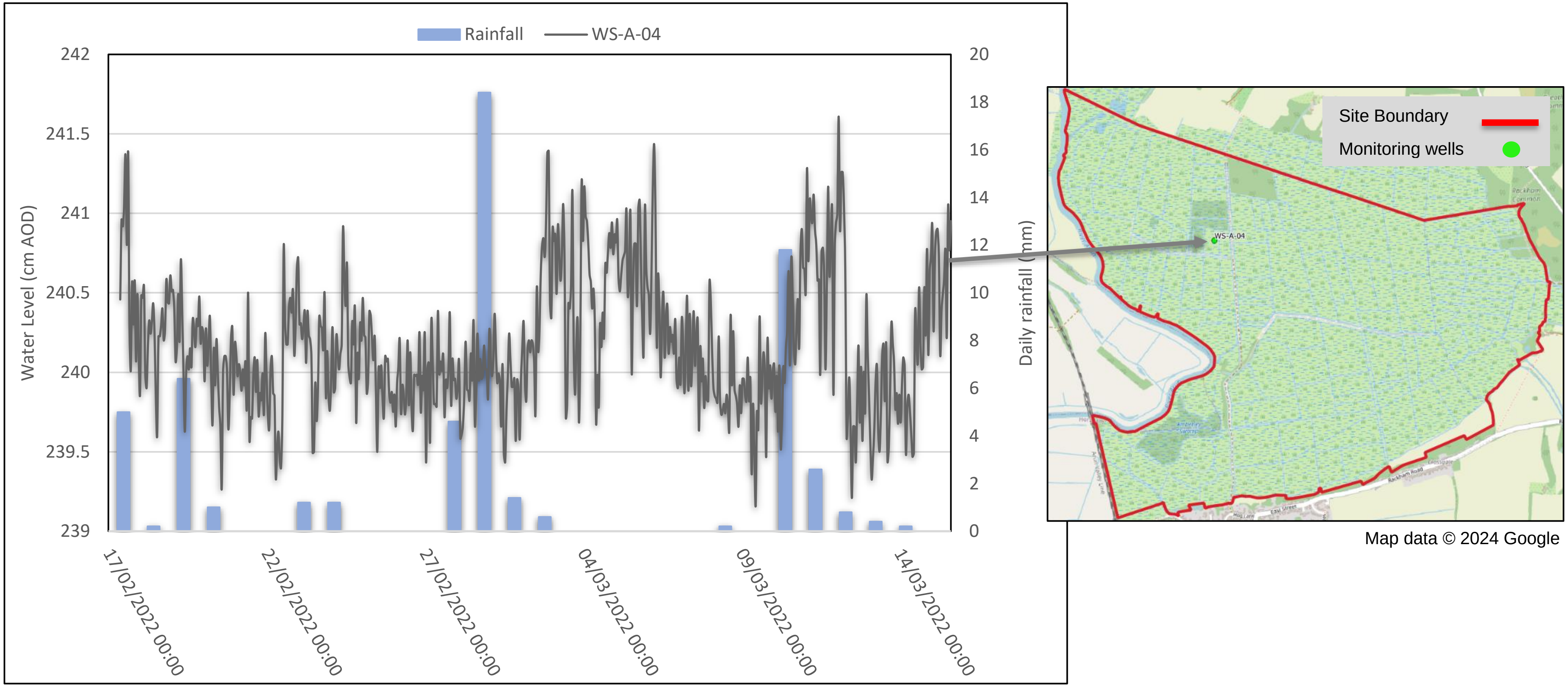
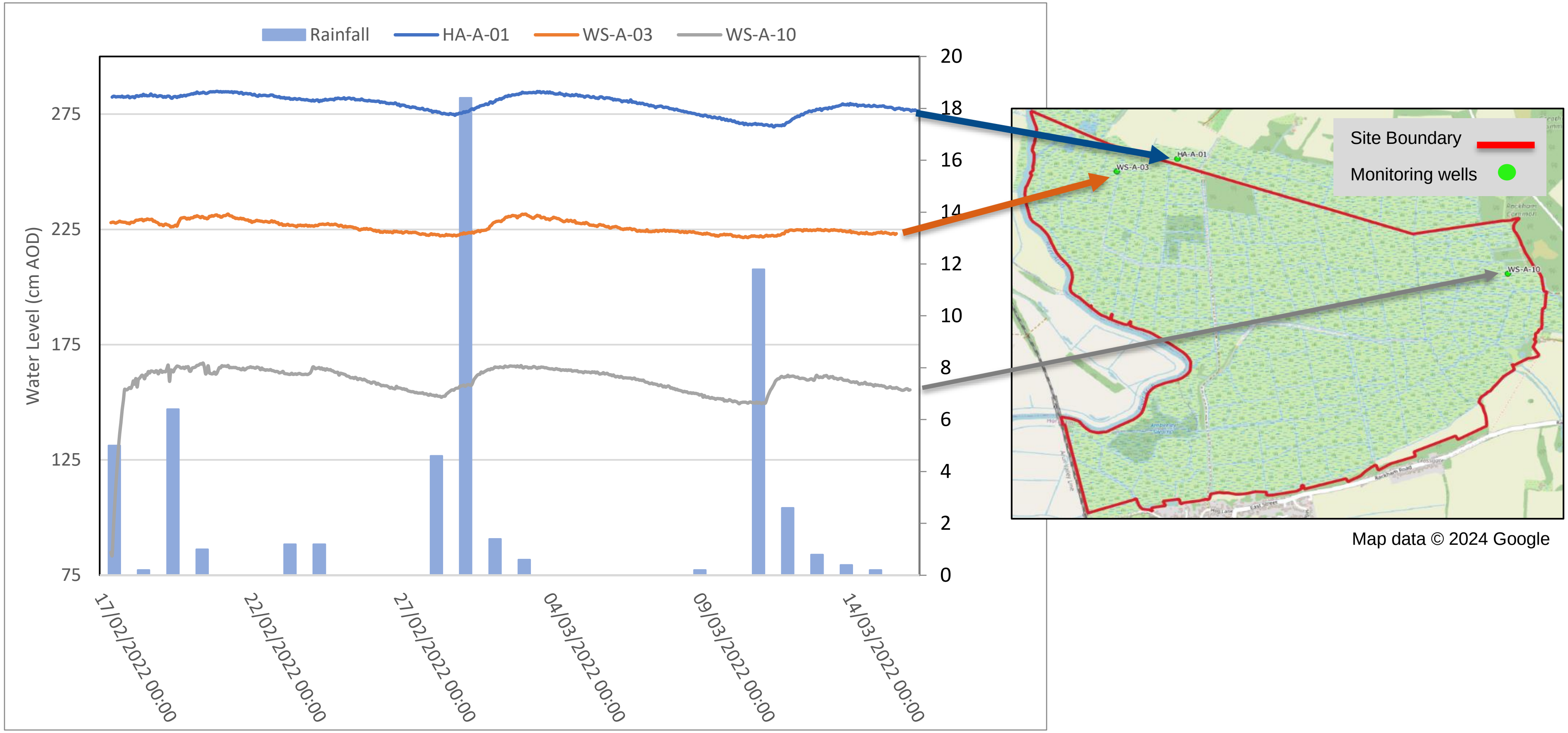


Figure 9 Water levels observed for wells with Arun River Terrace Deposits over a 1-month period on site



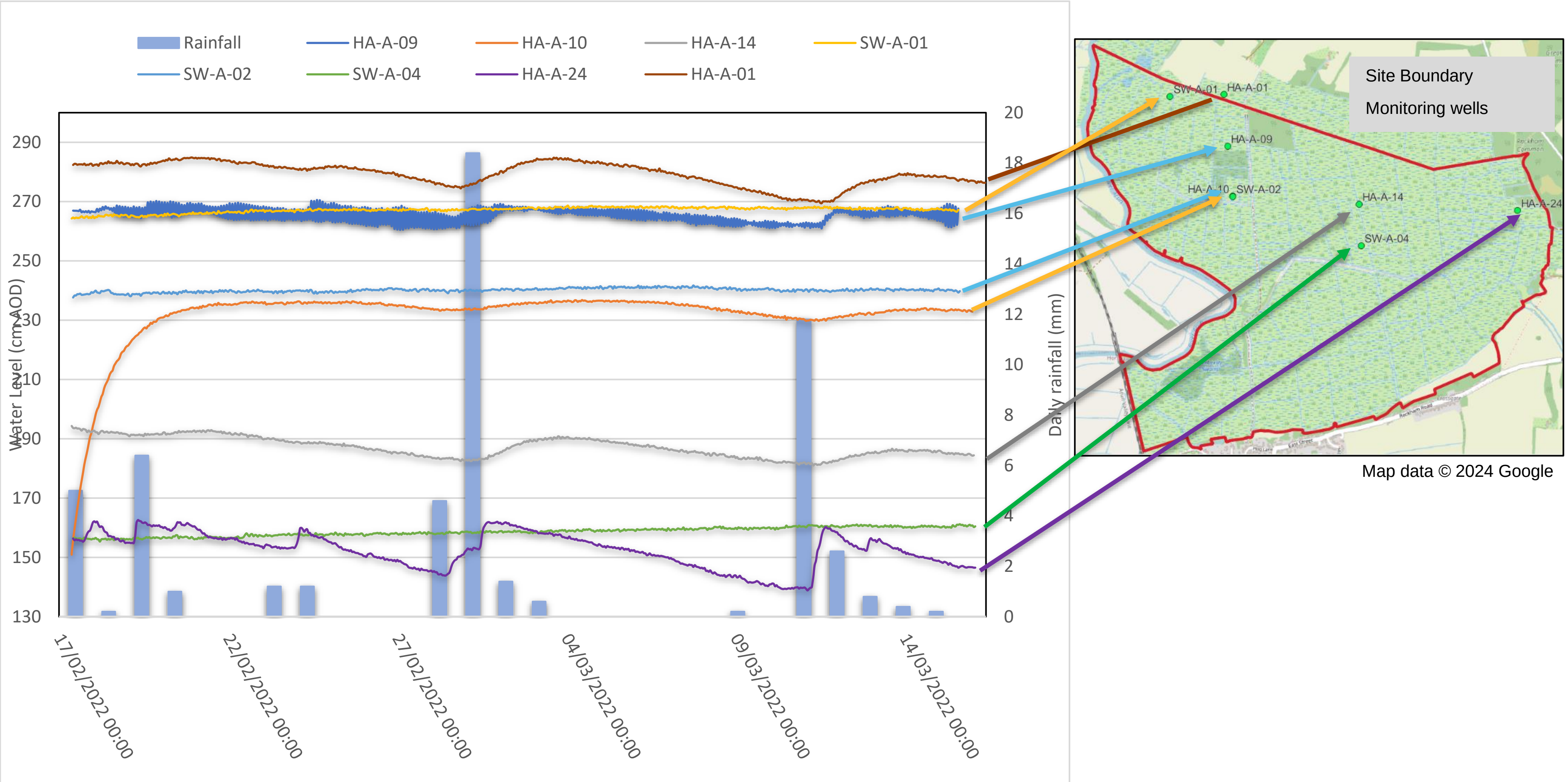
There is a single well within the RTD deposits. The response to rainfall events shows a degree of delay, with an approximate 2-day delay between rainfall event and hydrograph peak on 29th February, and a 2-day delay on 11th March. However, the change is small in amplitude (3 to 4 cm). This suggests the response delay is associated with recharge of the RTD aquifer from the surrounding area, where it is not confined by the overlying alluvium as it is at WS-A-04.

Figure 10 Water levels observed for wells with Alluvium over a 1-month period on site



The hydrograph within WS-A-10 has a rising trend following installation, indicating that groundwater levels within the well were equilibrating with the surrounding ground. This early period of data for this well is not considered representative of actual groundwater conditions. From approximately 25th February onwards, this well then has a similar hydrograph to the other two installations within the alluvium, showing a fairly rapid response to rainfall, but of limited amplitude. Peaks are typically one day after the rainfall event.

Figure 11 Water levels observed for wells with peat over a 1-month period on site



HA-A-10 has a rising trend for the first five days of the monitoring period, suggesting that water within the well is equilibrating with the groundwater in the surrounding peat over this period. After 20th February, this well then has a similar patter to the hydrographs of HA-A-01, HA-A-09 and HA-A-14. These all show a low amplitude, delayed response to rainfall, with a 1-to-4-day lag between rainfall event and hydrograph peak. HA-A-09 is the most flashy of these four wells, with a one-day delay in the peak and with a more pronounced rise.

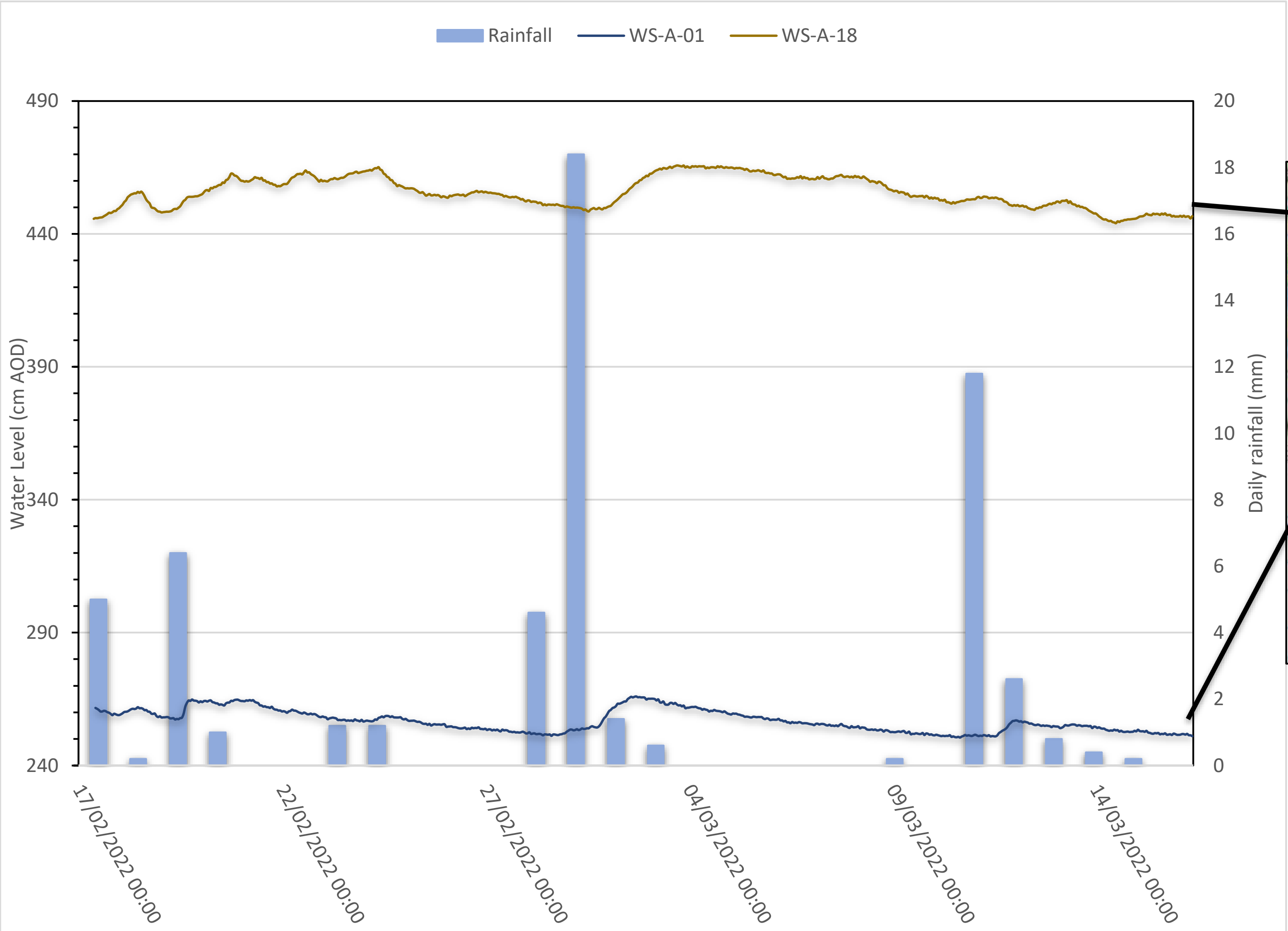
(The broad trend in HA-A-09 is overlaid by an hourly oscillation in the data, suggesting that there may be an issue with the logger in this installation).

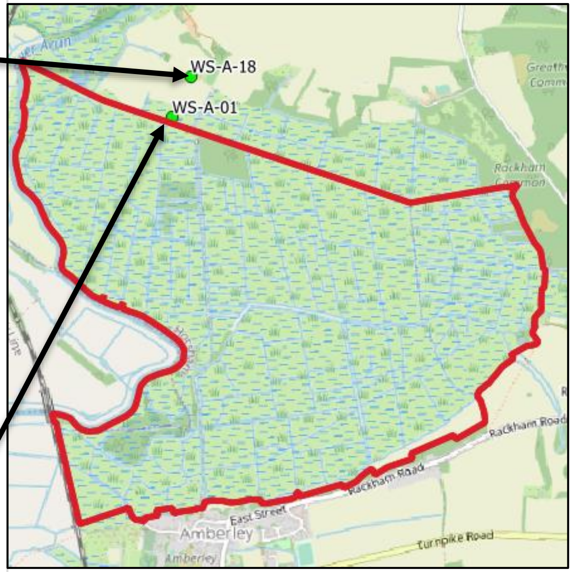
This low amplitude, long wavelength response to rainfall events may indicate a degree of groundwater baseflow control to the groundwater within the peat, may be indicative of very low permeability within the peat or, more likely, a degree of both factors. It certainly suggests an isolation from ground surface and meteoric waters.

HA-A-24 has a very different pattern, with a marked and rapid, higher amplitude, lower wavelength response to rainfall more indicative of a rainwater-controlled system in greater connectivity to ground surface.

The three surface water wells all show a slowly rising trend over the monitoring period, but with no response to rainfall notable. This slowly rising pattern may reflect the ongoing equilibration of water within the monitoring pipe with the ground surface around, with the protective metal well cover potentially isolating the logger from actual surface (ponded) water on the surrounding ground.

Figure 12 Water levels observed for wells with Folkestone Formations over a 1-month period on site

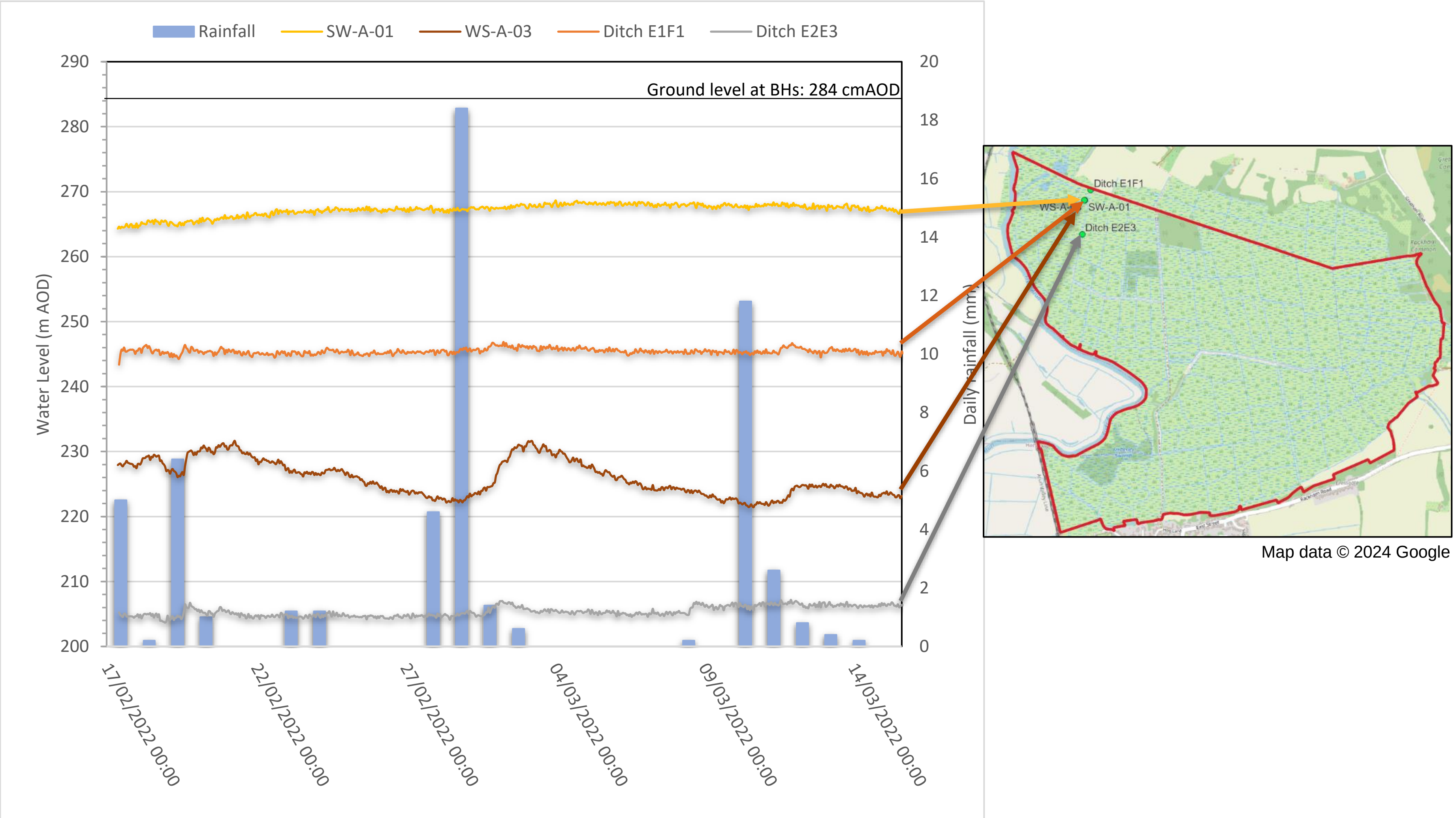




Map data © 2024 Google

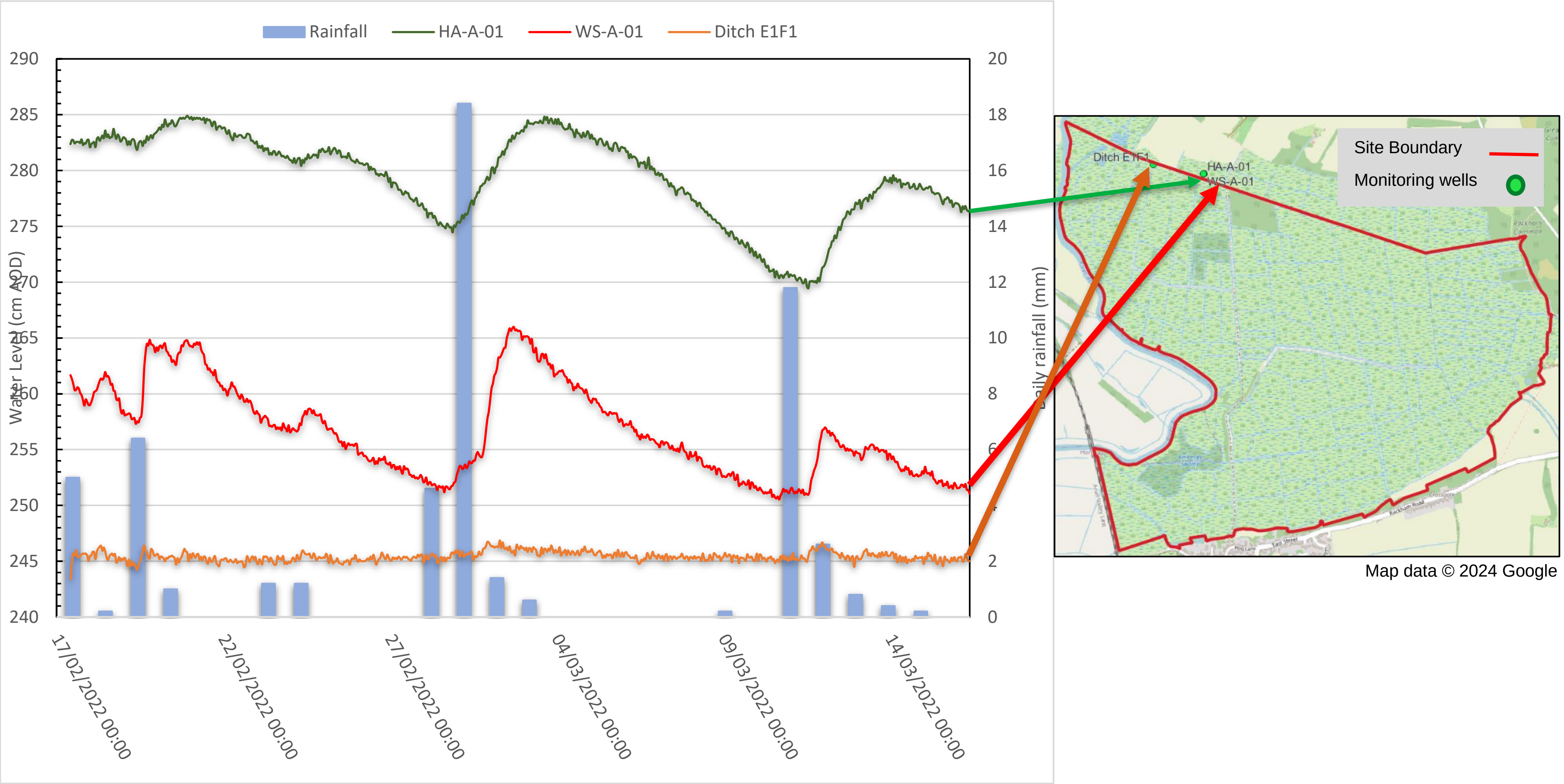
The two wells within the Folkestone Beds are in a similar location in the north of Amberley. WS-A-18 is further upslope, at the base of the gently sloping apron of higher ground. WS-A-01 lies at the lower edge of this apron, near to the commencement of floodplain deposits. The hydrographs show much similarity in shape, with levels decreasing with topographical elevation (i.e. groundwater surface reflects topographical surface, as might be expected in a highly permeable and porous sandstone aquifer). The wells show an approximate 1-day delay between rainfall and hydrograph peak, with a slow and steady decline in elevations in drier periods.

Figure 13 Water levels observed for E2 paired wells with Alluvium and surface water over a 1-month period on site



There is a marked difference in elevation of ponded surface water (SW-A-01) and ditch levels. The two ditches show a small response to rainfall events, with the muted response likely attributable to the large storage capacity of the ditch network. The groundwater within the alluvium in WS-A-03 can clearly be seen to be isolated from the ditch water, with very different elevations. At present the comparative elevations would suggest that the perimeter ditch (E1-F1) may contribute water to the groundwater, whereas the groundwater may then be losing water to the north-south trending Ditch E1. These observations are made based on the period of time monitored, i.e. in cold, early spring conditions. Typically, monitoring at this time of year would be representative of wet conditions, although February and March 2022 were drier than average.

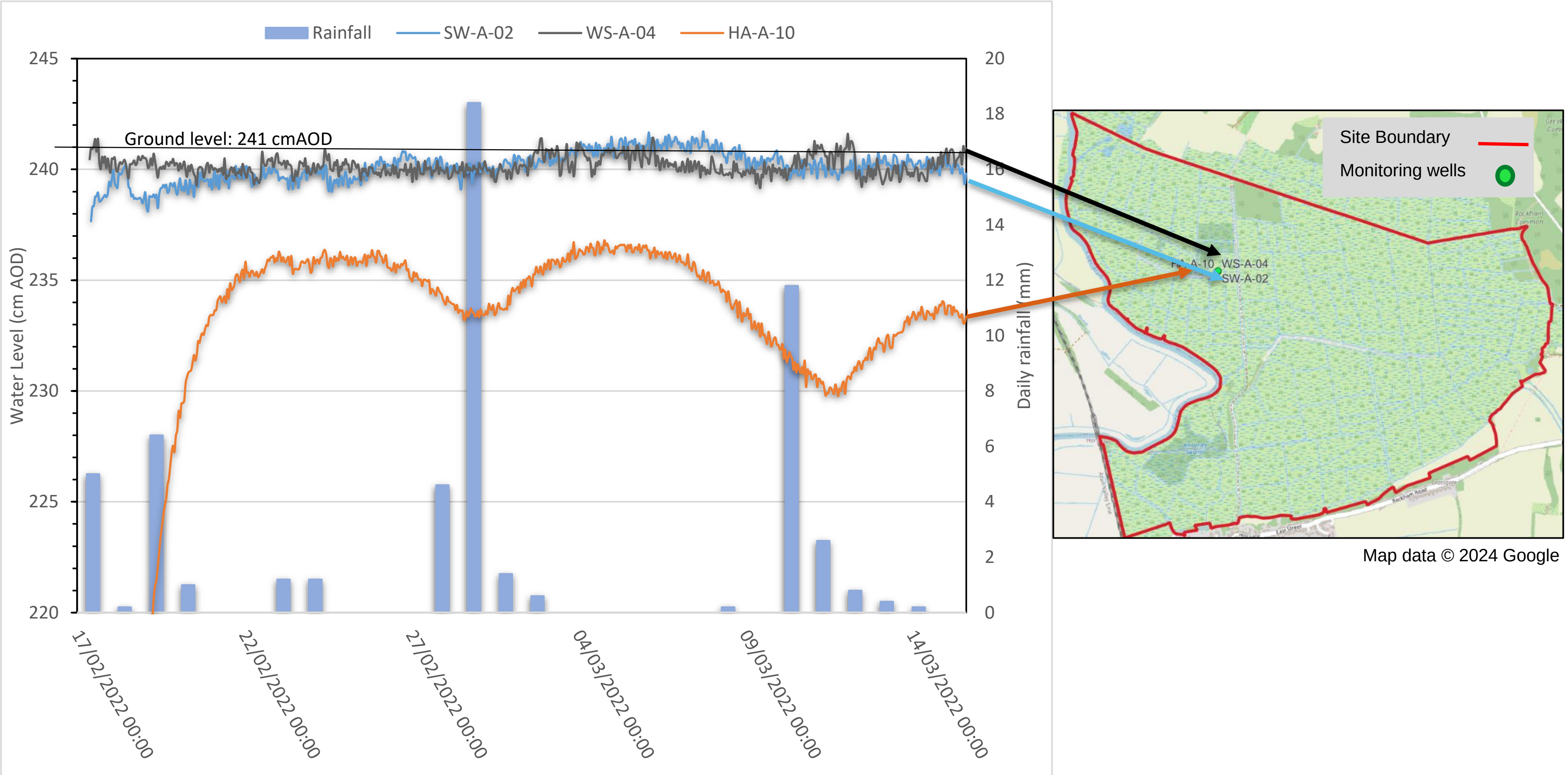
Figure 14 Water levels observed for the F1 paired wells with Folkestone formation (WS-A-01) and Alluvium (HA-A-01) over a 1-month period on site



The groundwater in the alluvium and underlying Folkestone Beds show a very similar response to rainfall, suggesting a commonality of response that may be attributable to hydraulic connection. However, the difference in elevation indicates that there is a local downwards head gradient between the alluvium and Folkestone. The groundwater table in both units is above that of the Ditch E1-F1. This must be viewed in the context of location however, as on-site constraints necessitated the placing of the ditch installation some 100m or so to the west. This stretch of ditch visually seems to have a constant water elevation due to the blockage downstream of it, so the ditch water levels are considered likely representative of the ditch near to the boreholes, but this has not been confirmed.

Assuming that the ditch elevation is representative, its lower elevation would make it a sink for groundwater from both strata, if there is hydraulic connection (e.g. in the event that ditch clearance and casting removes any silt lining that the ditch may have). Recent ditch casting in the area was noted to include sandy and gravelly material, suggesting that the depth of clearance does indeed extend down beneath the base of the alluvium in the area. Ochreous groundwater seeps were noted in the ditch to the east of Field 16 during the fieldwork. Ochreous water is typical of seeps and springs from the Folkestone Beds aquifer, and so this would seem to corroborate the movement of groundwater from aquifer towards the ditches.

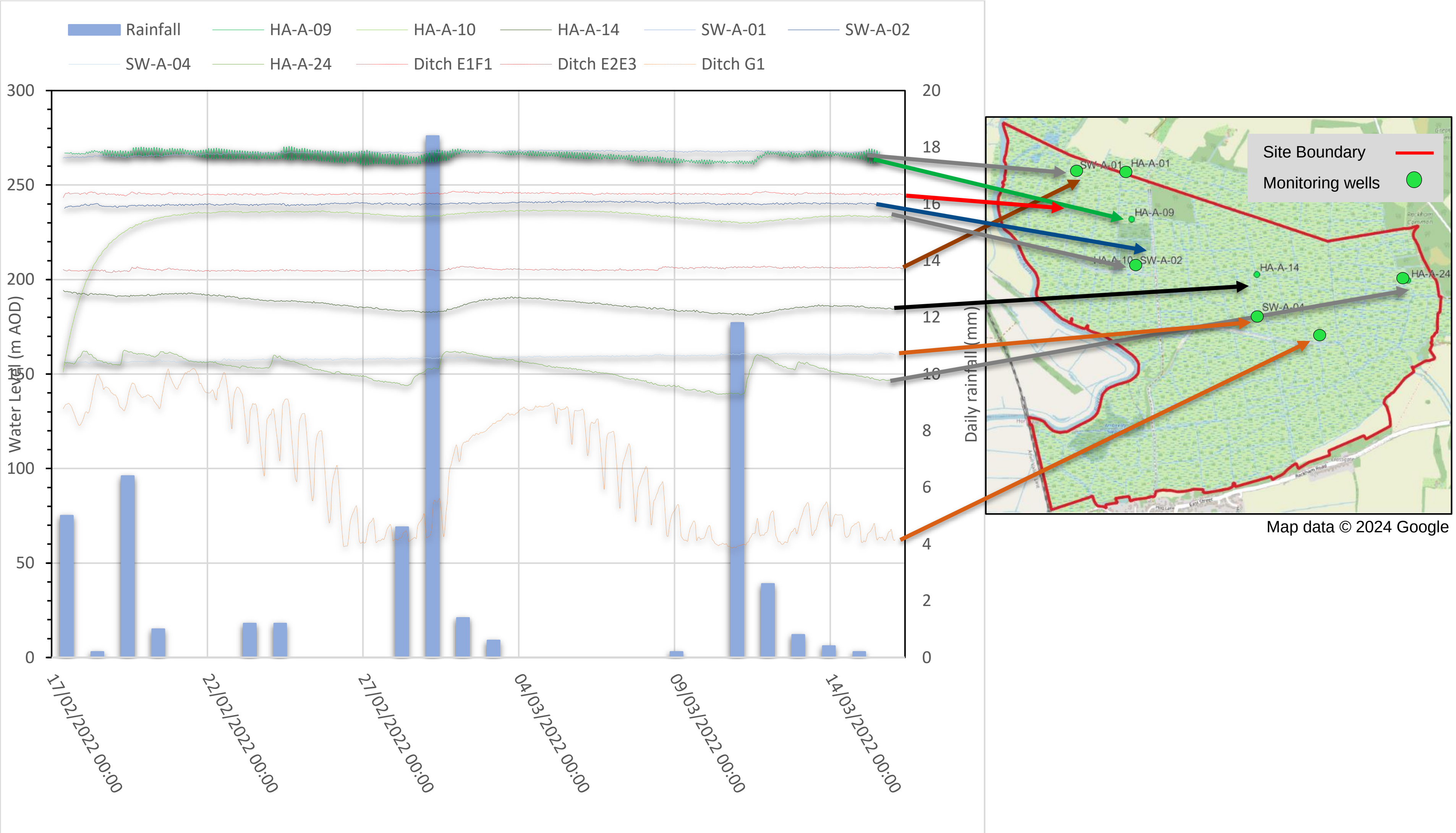
Figure 15 Water levels observed for the F2 triple wells with RTD and peat over a 1-month period on site



This triple install of wells are all located within 2 m of each other. Following an initial period of equilibration, the groundwater within HA-A-10 in the peat can be seen to have a laggy response to rainfall, with an amplitude of approximately 5-6cm. Water in the peat is between 5cm and 13cm beneath ground surface. Ponded water on the ground surface (SW-A-02) can be seen to respond to rain events but is completely isolated from the water within the peat below. The 10cm layer of organic rich clay topsoil and the upper drier hydrophobic peat appear to act to isolate the ponded surface water from the peat.

The deeper groundwater within the RTD can be seen to be artesian/ sub-artesian and this is corroborated by site observations of water filling and overtopping the metal protective cover and ochreous staining forming at the point of overflow. This groundwater body shows very little, if any reaction to rainfall, suggesting it is significantly isolated from meteoric waters. The higher head elevation of this deep groundwater suggests an upwards head gradient between the deep superficial deposits and the shallower peat.

Figure 16 Water levels observed for the ditches and wells with peat over a 1-month period on site



As discussed in Figure 11, there are differences within those wells installed in the peat, with HA-A-10 and HA-A-14 showing a more muted response to rainfall typical of low permeability/ groundwater influence, whereas HA-A-24 shows a spikier response typical of rainwater influence. HA-A-09 shows an element of both. All the surface water wells show no discernible response to rainfall with the exception of SW-A-02. The distinct differences between surface water hydrograph and peat hydrograph supports the hypothesis that peat is largely isolated from ponded surface water by the intervening layer of clay-rich topsoil and/ or hydrophobic dry peat.

The hydrograph for ditch G1 is markedly different to the other two ditches. This ditch is part of the Amberley Wild Brook stream. There is a clear tidal signal to the water elevation in this stream, and it is clearly separate from the rest of the ditch system based on these data. The tidal signal is considered likely to be due to the indirect effect of tides in the River Arun, rather than representative of tidal flow within the stream. Whether this tidal signal is due to the direct backing up of stream water at high tides, or due to the backing up of water behind the sluice at Ham Sluice is not clear.

The lower end of the tidal curves are truncated consistently at approximately 0.6 mAOD. This is possibly representative of the sluice elevation at the lower sluice on the Wild Brook.

5. Peat

5.1 Formation of Amberley 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. 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 coastline such as the Arun valley. The Arun valley is estimated to have excavated 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). 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 ago (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 Amberley Wild Brooks low-lying floodplain, with the River Arun meandering across. The eroded scarp slope around the eastern and southern edges of the site was likely due to this low sea level. The floodplain was initially saltmarsh but became freshwater dominated by approximately ago 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 Wild Brooks 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 the site has formed from accumulated organic matter outweighing decomposing 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 no more than 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. 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 decomposition depends on the peat's composition and degree of waterlogging. A peat bog is usually described at 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 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 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 mm or cm per day. It can vary by the physical property of peat including vegetation compositions, compaction, decomposition, presence of macropores (pipes) and entrapped gas bubbles

Peat soils typically contain very high moisture contents in the range 600-1800% compared to the mass of dry material in the same volume. Bogs remain wet because peat generally has a low hydraulic conductivity even when there is a relatively high hydraulic gradient. The brown peaty water squeezed out of some peat deposits is dissolved organic carbon.

5.1.3 Wetland Functional Mechanisms (WETMECs)

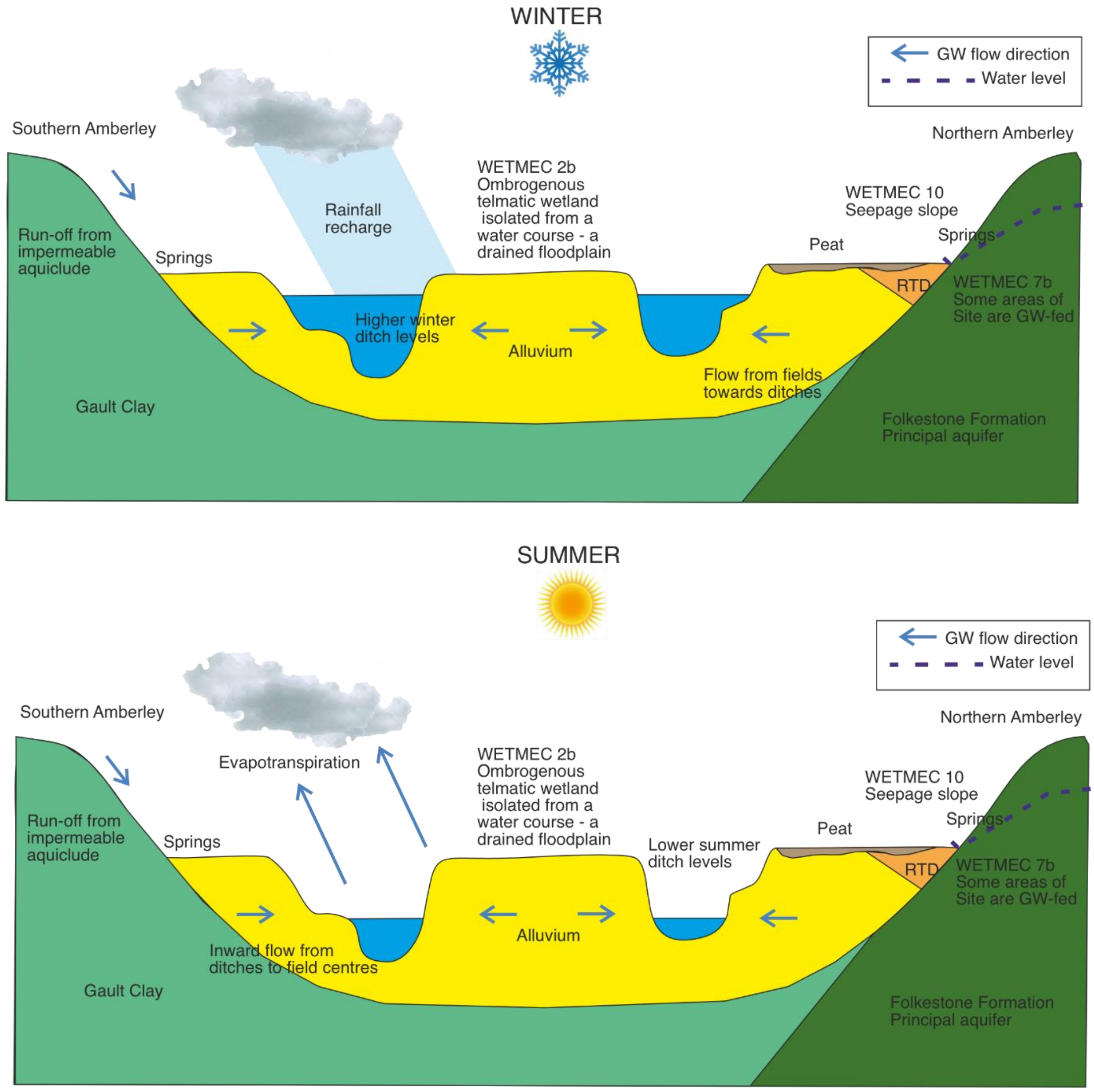
WETMECs represent a simplification of the somewhat complex mechanisms and wetland classifications but provide a useful guide to clarify fundamental drivers of peat formation. The peat on site is fed both by precipitation and the underlying Secondary A and Principal aquifers in conjunction with springlines. The WETMEC classification of the site is likely to be 7b or 2b shown in Figure 17.

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 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 17 Schematic cross section of WETMECs on Amberley



5.2 Peat deposits across the site

Peat was logged across the site using the Von Post scale as described in Table 7 below:

Table 7- Von Post Humification Scale sourced from Damman and French, 1987

Scale	Peat Characteristics
H1	Completely undecomposed peat; only clear water can be squeezed from peat

Scale	Peat Characteristics
H2	Almost undecomposed; mud free peat; water squeezed from peat is almost clear and colourless
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

Peat was found in northern, central and eastern areas of Amberley during the site investigation concurrent with BGS mapping. Peat was located outside of (to the north and east of) the northern-eastern bend of the palaeochannel. It was also found within the inside of the meander loop, in the central-eastern part of the site. A limited number of exploratory holes (4) were advanced within the meander footprint itself, and no peat was present.

Peat thickness across the site is shown in Figure 5 and Figures E and F. The thickest concentrations of peat were found in the north-western region of the site to the north and south of the wooded area (Fields 2 and 19, with in excess of 1.5 m of peat). The deposits thinned towards the north and west from here.

A significant thickness of peat was found in the central-eastern region too, with between 1 and 2 metres of peat recorded in the area of Fields 52 and 57 (Figure 1). A single auger undertaken within the palaeochannel between this location and the peat encountered in the far east of the site suggests that the intervening river palaeochannel is devoid of peat, and hence the two peat bodies are unlikely connected.

In the east of the site, the peat is recorded as between 0.4m and 1.2m thick (Figure F).

Some uncertainty remains as to the lateral extent of peat, due to the access constraints that wet ground conditions placed on the investigation. Of particular note is the lack of data in Fields 23 to 29 and Fields 49 & 50 (Figure 1) and also in fields around Rackham Plantation.

Peat is underlain by alluvium in the majority of localities across the site. Alluvium acts as an aquiclude forming a silty clayey impermeable layer that confines the RTD and Folkestone Formation below the peat. Figure G shows a north-south cross-section through Amberley.

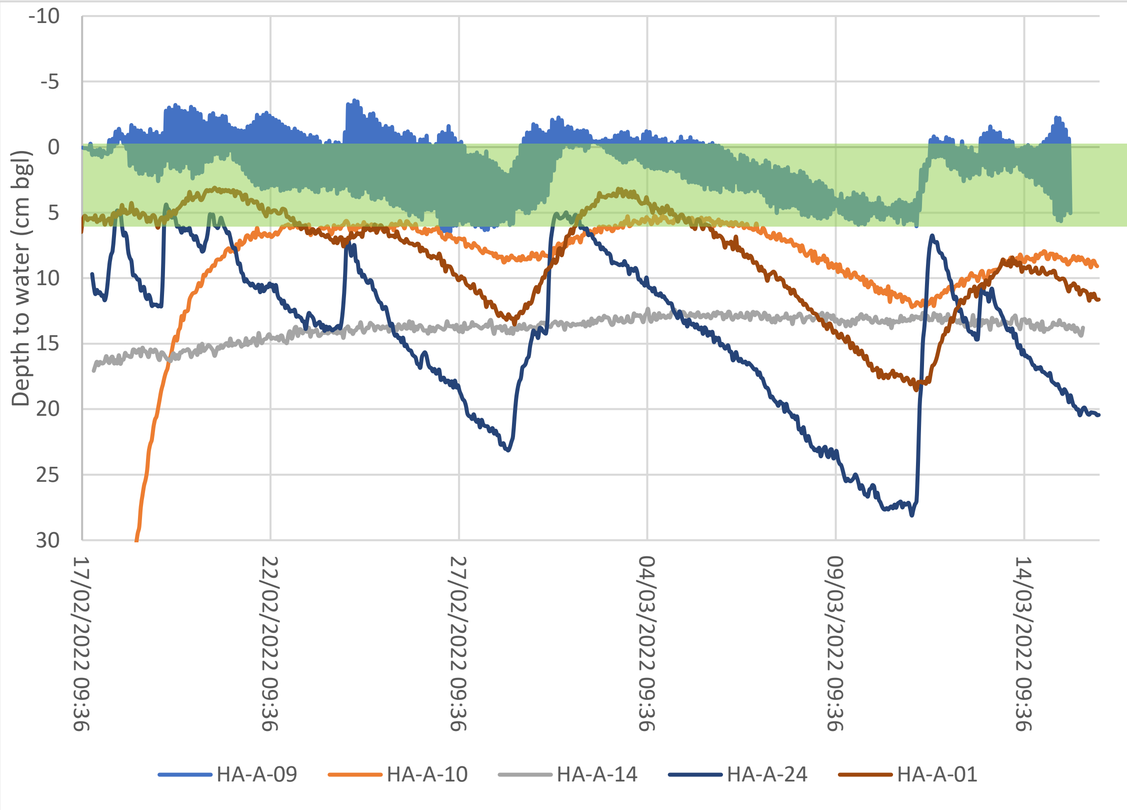
Topsoil was found overlying many of the peat deposits forming a clay-rich impermeable layer reducing the amount of surface run-off and infiltration into the peat below. This clayey topsoil layer has likely formed from a combination of sediment accumulation settling out of flood water during fluvial flood events (which would provide the input of sediment) and due to the preferential formation of soil during periods of drier conditions (which would occur in preference to ongoing peat formation when 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, groundwater abstraction, 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 opposed to a sink.

Peat mapped on site appeared to be in relatively poor condition with some areas of healthier deposits. Water levels in the peat ranged from surface level to 1.5m bgl with an average depth of 0.55m bgl. During the groundwater monitoring, only HA-A-09 of the monitored wells displayed water levels that consistently fell within the 0-5cm healthy peat bracket as shown in Figure 18. The monitoring occurred in late winter/ early spring conditions. Summer conditions and dry weather may exacerbate this further.

Figure 18 Water level fluctuations in peat at or near ground surface in cm bgl. The green band between 0-5cm bgl depth to water indicates the healthy bracket for peat.



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 of already decomposed peat. The drainage ditches also divert water emitting from springs mapped around site flowing 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 50100cm 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 increase 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. 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, which was encountered on site, varied in its condition. Desiccated peat with a low recorded moisture content is listed in Table 8. Figure 19 also shows an image of desiccated peat that was observed during fieldwork.

Table 8- Peat condition recorded during fieldwork

Exploratory hole	Von Post Peat condition	Water Content	Depth (mbgl)
HA-A-11	H3	Low	0.1-1.3
HA-A-11	H5	High	1.3-1.4
WS-A-06	H5	Low	0.4-0.6
WS-A-08	H5/6	Low	0.1-1.2
HA-A-01	H4	Low	0.1-0.25
HA-A-04	H7	Low	0.2-0.35
HA-A-04	H7	High	0.1-0.2
HA-A-05	H6	Low	0.15-0.35
HA-A-05	H6	High	0.35-0.85
HA-A-06	H6	Low to Medium	0.45-0.9
HA-A-07	H7/8	Low	0.45-0.95
HA-A-09	H4	Low	0.15-0.45
HA-A-09	H7	High	0.45-1.6
HA-A-10	H5	Low	0.1-1.4
HA-A-12	H4	Very low	0.2-0.4

Exploratory hole	Von Post Peat condition	Water Content	Depth (mbgl)
HA-A-13	H3/H4	Very low	0.1-0.35
HA-A-14	H5	Low	0.35-0.75
HA-A-14	H7/H8	High	0.75-1.75
HA-A-15	H3	Low	0.15-0.6
HA-A-15	H7/H8	High	0.6-1.7
HA-A-17	H5	Very low	0.4-0.8
WS-A-10	H5	Low-medium	0.3-0.5

Figure 19 Image of Desiccated Peat at Exploratory Hole HA-A-10, taken by surveyors during fieldwork

As seen in Table 8, 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

The River Arun flows along the western boundary of Amberley Wild Brooks passing through farmland and populated areas that have been affected by flooding in recent years. The river is tidally influenced, with management controlled via embankments, water level and ditch management. This is controlled in accordance with the Water Level Management Plan (WLMP) for the SSSI, which was agreed in 2006.

6.1 River Arun catchment

6.1.1 Surface water bodies (Figure M)

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 3km north of the site however the sinuous nature of the River Arun from the major confluence means the river travels a considerable distance past the confluence before reaching the site. Between the confluence of the Western Rother and the site the River Arun is joined by the River Stor, outfalls from Pulborough Brooks SSSI, the Pulborough Brooks Catchment (separate to the outfalls from the SSSI) and passes Coldwaltham Sewage Treatment Works (STW) outflow and Hardham Water Abstraction point. This section details the catchment data for the five local watercourse catchments immediately upstream of the site obtained from the Environment Agency Catchment Data Explorer, 2022) which describes the physical and chemical characteristics of the appropriate River Catchment which is used to determine its ecological status. It should be noted due to the tidal nature of the Lower Arun it is classified as a tidally influenced watercourse.

6.1.1.1 Upper Arun to Pulborough

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

The EA describe the Upper Arun catchment as ‘predominately the non-tidal reach rising to the north-east 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.'

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 status 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 hydromorphological regime also able to support a good classification.

6.1.1.2 Western Rother

Also forming a part of the Upper Arun catchment the EA description is 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 20132019 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 has 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

6.1.1.3 River Stor

The Stor catchment contains the entirety of the town of Storrington to the north-east of the site, flowing along the northern extent of Pulborough Brooks SSSI before joining the River Arun 4km north of Amberley Wild Brooks, 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 20132019.

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.

6.1.1.4 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 STW, and slightly upstream of the site but is likely to represent conditions of the Arun as it passes adjacent to Amberley Wild Brooks.

The ecological status of the catchment is classed as moderate due to moderate classifications of the supporting elements (surface water) mitigation measures assessment, from 20132019.

With the reasons for not achieving good in this catchment due to physical modifications.

There are also some failures of priority hazard substances:

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

It is worth noting that this tidally influenced section of River Arun is treated as a transitional water body and therefore will have saline Water Framework Directive objectives rather than freshwater (which are more stringent for these substances).

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).

6.1.1.5 Pulborough Brooks Catchment

Located immediately to the south-west of Pulborough Brooks SSSI, the catchment is 1.7km² in area and encapsulates some of the higher ground to the north of the site around Fangrove Hill before flowing northward and joining the Arun approximately 2.5km. The ecological status of this catchment is determined as moderate (from 2015-2020 upstream of the site). 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)

6.1.2 Groundwater bodies

6.1.2.1 Lower greensand Arun & western streams groundwater body

This groundwater body reflects the Folkestone Beds as well as the wider Greensands aquifer which extends from beneath the northern extents of Pulborough and is the bedrock which forms much of the higher ground around the north and east of 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 source associated with agriculture and land management.

6.1.2.2 Worthing chalk groundwater body

This groundwater body reflects the Upper Cretaceous chalk aquifer that forms the scarp slopes and downs between the site and the English Channel to the south. This compartment of the chalk aquifer extends as far south as Worthing, and as far east as Steyning. The Arun forms the western boundary of the groundwater body, suggesting that it is a hydrogeological divide between this compartment and the continued chalk aquifer to the west.

The Amberley Wildbrook that flows through the centre of the site derives the majority of its flow from springs emanating from this chalk aquifer, in Parham Park.

It is assessed to have poor overall status. This is driven by two factors:

- Poor nutrient management which is ascribed to diffuse source associated with agriculture and land management.
- Groundwater abstraction impacting quantitatively on the flow available for groundwater dependent water bodies.

6.1.3 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)

6.1.4 Abstractions

Approximately 2.5km north of the site the Pulborough Water Supply Works, which supplies water to 100,000 households, abstracts water from the River Rother and from the Folkestone Beds groundwater aquifer beneath 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 river ecological communities more vulnerable to a reduction in flow (Gasca & Ross, 2009).

A further surface water abstraction, also connected to the Pulborough Water Supply works, abstracts water from the River Arun at Churchland Farm approximately 2km north 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 Pulborough 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 Amberley Wild Brooks current state

Amberley Wild Brooks has experienced modification from anthropogenic pressure. Prior to the earliest Ordnance Survey mapping, humans have significantly modified the landscape with the introduction of ditches in order to drain the land to an extent that provides better grazing for livestock. More recently, some interventions have been made to land management practices in order 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 & Ross (2009); the methodology links regional hydrogeological processes to wetland hydrology and ecology which are affected by processes that take place of a reduced spatial scale. 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. It should be noted that although the modelling has been derived for the northerly Pulborough Brooks, the hydrogeological setting of the site is extremely similar, and general concepts are transferable between the Pulborough Brooks and Amberley Wild Brooks.

6.3.1 River Arun

Inflows from the River Arun throughout the site are limited by flood embankment which run along the entire length of the site which are interspersed with active and redundant water control features.

It is not known whether there are any historical water inlet sluices present in the north of the site. On the nearby Pulborough Brooks, outlet sluices are occasionally used to feed water to the ditches in times of water scarcity, 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). It is not known whether a similar practice has occurred historically on Amberley, but anecdotal information from the RSPB suggests that this operation has not been undertaken on either site in recent years.

Overtopping used to occur on rare occasions providing a mechanism for floodwater to enter the site from the West. This phenomenon may now be more frequent. It is uncertain what impact this is having on existing flora, and this is part of the remit provided by Natural England to Atkins on their parallel nutrient budget study.

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.

Multiple boreholes installed in deeper Arun RTDs (WS-A04, 07 and 08) showed artesian conditions after installation. These boreholes were located a considerable distance toward the centre of the site, both in the east and the west. This is evidencing the head of water does extend a considerable distance under 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-A-01, HA-A-10 and HA-A-14 (delayed response to rainfall suggestive of low permeability/ groundwater influence) and HA-P-24 (rapid response suggestive of more rainwater fed)). HA-A-09 shows a response to rainfall with elements of both low permeability/ groundwater (low amplitude, long wavelength) and meteoric water (rapid response after rainfall event) influence.

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 and with the abstraction in place.

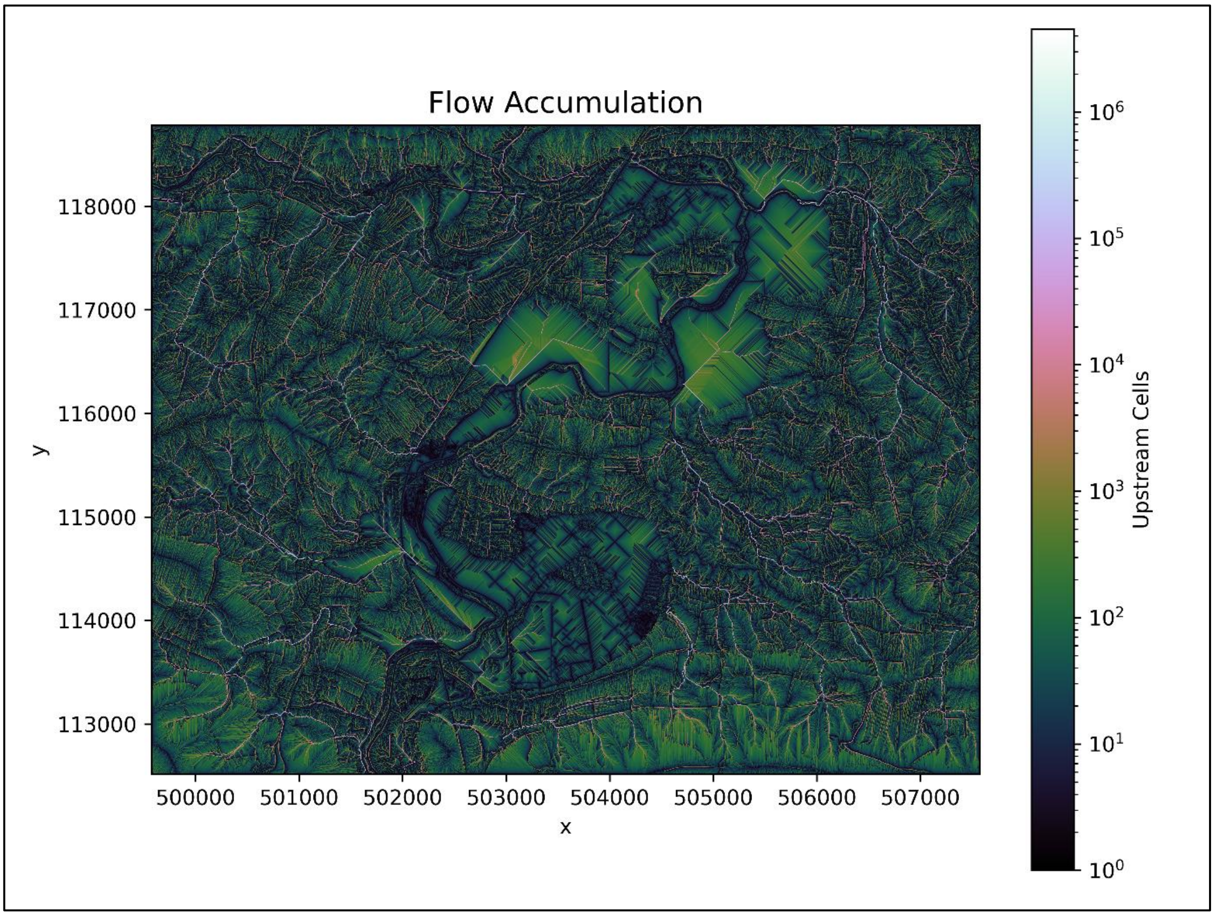
6.3.3 Meteorological

The site is 280 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, 12km 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 or the subsequent evapotranspiration of surface water directed to the ditch system.

6.3.4 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 20 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, Amberley is denoted by the large green areas crossed by dark blue lines in the central and southern area of the map, due to the very flat terrain, flow path calculations were not possible for the majority of on-site locations.

Figure 20 LiDAR imaging detailing flow accumulation



As can be seen in Figure 20 there is an abundance of very small catchments, rising at the head of the raised ground along the northern and southern site boundary. 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 along the northern site and boundary and east of the site where the Folkestone beds are not confined by aquicludes. These springs and seeps, due to the small area they are fed from are likely to be ephemeral and 'flashy' and may not represent a baseflow to the reserve during the summer months.

In the east of the site, there are slightly elongated catchments when compared to the extremely small catchments that surround the majority of the site. These larger catchments tend to originate from the large chalk ridgeline to the south-east of the site (feeding into the Amberley Wildbrook stream).

In the centre of the site there is a slightly raised area of ground where the lidar data has detailed the typical flow path of incident rainfall when it falls on the reserve itself. The flow paths themselves are very short before being collected by the ditch system indicating the low residency time of incident rainfall before entering the ditch system.

6.3.5 Wildbrook stream

The Wild Brook Stream discharges into the River Arun via the Ham Sluice outfall. The Wildbrook stream enters Amberley Wild Brooks SSSI from the eastern site boundary, and is fed by the 'Springhead Farm' chalk feeder stream (located within the grounds of Parham House) (adapted from WLPM, 2006)

6.4 Water level Management Plan

Yellow Sub Geo have been provided with a copy of the water level management plan for the Amberley site. This 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.

In order to achieve these objectives, there are target sluice levels for the site, as detailed in Table 9, extracted from the WLMP Table 9 WLMP target elevations for ditch water impoundment sluice.

Table 9- Target sluice levels for the Amberley site

	Location	Level / m AOD	Timing
Low Brook Sluice A (outfall to R. Arun)	TQ 0265 1430	0.84	Mid-April to early November
Low Brook Sluice B (outfall to Wildbrook stream)	TQ 0305 1420	0.84	Mid-April to early November
Wildbrook stream lower	TQ 0310 1420	0.75	Late June to early November. Aim is to maintain water level at 0.9

	Location	Level / m AOD	Timing
			OD at junction of Smooth Ditch & Smith's Ditch
Wildbrook stream upper	TQ 0420 1400	1.22	Late June to early November
Middle Gutter	TQ 0305 1365	0.6 1.4	Mid-April to late June Late June (or after haymaking) to early November

Reference is also made in the document to a spring water level of 0.3m AOD for Wildbrook stream (lower) in order to minimise the effect of spring flooding.

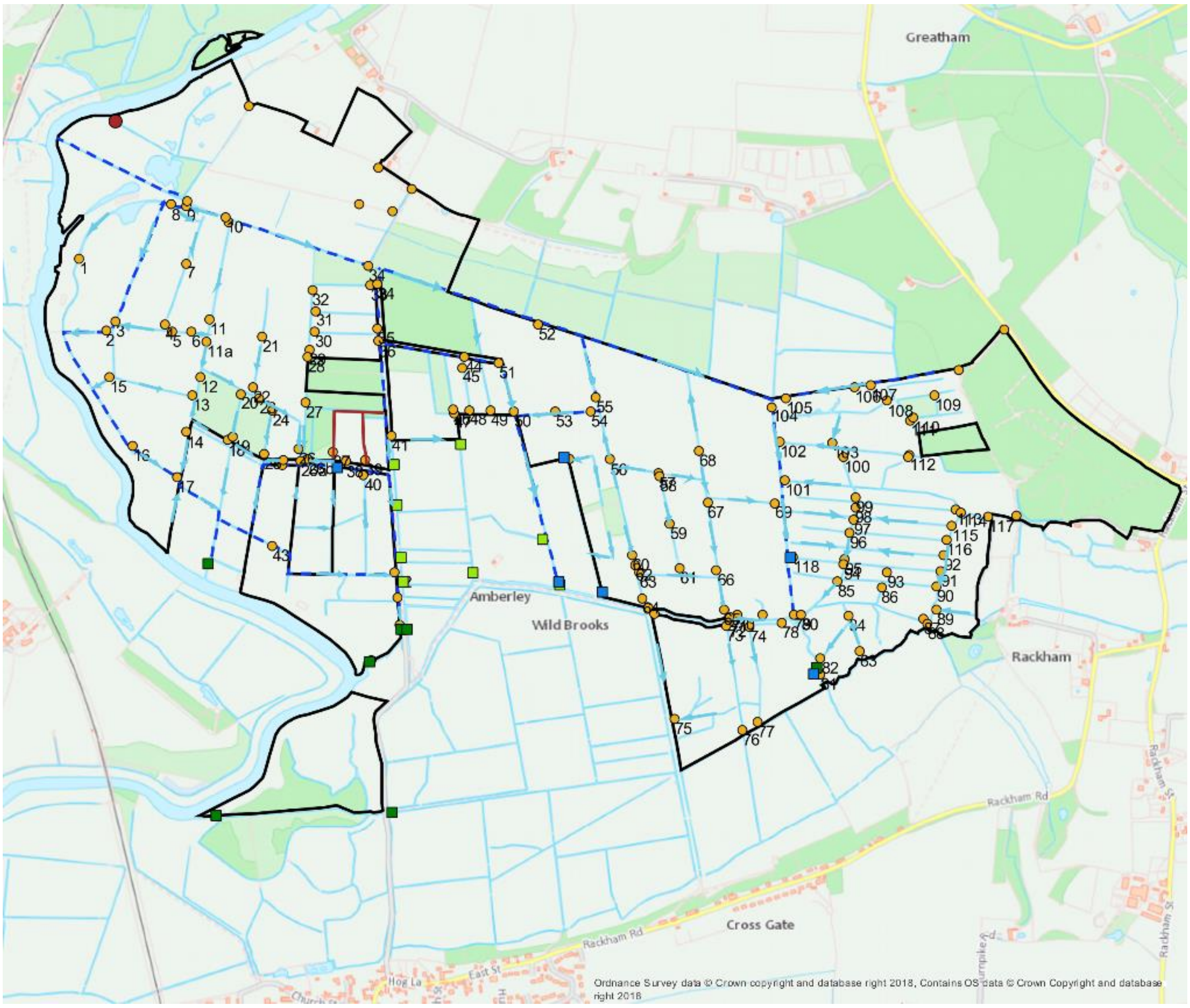
It is understood from anecdotal evidence from the RSPB that these elevations are targets, and that in some cases decisions are made to depart from these targets by the various stakeholders on site for land management reasons.

6.5 Water movement on site

The main control of water flow on site is the ditch drainage system. An extensive ditch system throughout the site, 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 to the Wildbrook and to the River Arun. There are extensive marginal ditches especially across the northern boundary of the site to capture the seepages known to originate in this area. In the north-east, marginal capture ditches are typically more absent with the ditch system often running parallel to the springs and seeps in this area.

Figure 21, produced by the RSPB shows the movement of water in the ditch system across the site.

Figure 21 LiDAR imaging detailing flow accumulation



Legend:

Flow direction | IDB | EA Water Control Structure | Tilting Weir

WSPB Water Control Structure | RSPB & SWT Crossing/Culverts/Elbows | RSPB Reserves (UK) – Public

Acknowledgements & Notes:

Created by RSPB

The Wildbrook stream that flows onto the site from the east is immediately captured as it enters the site and is directed across the centre of the site from east-to west in a large ditch. It is effectively isolated from the rest of the site, as evidenced by the distinct difference in hydrograph seen in Figure 16.

6.5.1 Outfalls

As can be seen in the water features plan (Figure C) and in Table 10 above there are three main outfalls for the site at Middle Gutter Outfall, at Wildbrook Lower Sluice and at the two Low Brook Sluices. The site can be split into three large compartments with respect to outfalls:

6.5.1.1 South of the Wildbrook

The Middle Gutter outfall sluice controls the base elevation within the ditch network to the south of the Wildbrook stream. These ditches appear to be entirely isolated from the Wildbrook stream.

6.5.1.2 North-western compartment

The two Low Brook outfall sluices control the base elevation of ditches to the north of the Wildbrook stream in the north-west of the site. These two sluices appear to drain all of the ditches to the west of the public right of way that crosses the site from north to south.

6.5.1.3 North-eastern compartment

To the east of this public right of way, the ditches appear to drain into the Wildbrook stream in its section between the Lower and Upper sluices. These connections into the Wildbrook are typically controlled by elbows – pipes at right angles beneath culvert crossings, which provide an isolation between the impounded ditch water upstream of the elbow, and the Wild Brooks water downstream of it. It is not known whether an elbow is present on every feed into the Wildbrook, and so the tidal pressure signal on the Wildbrook may also be seen in some of the ditches on site, if elbows are not present. The base elevation of water in this compartment is controlled by the Lower Sluice on the Wildbrook, but elbows will provide an additional control to water elevations where present.

6.5.2 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 Environment Agency quoting the study on 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. For example, it may impact the water level, but the overall health of the peat may be related to other long-term factors, such as base level of ditch water, degree of groundwater feeding. 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.

6.6 Water quality

A considerable amount of water quality monitoring has taken place across Amberley Wild Brooks. Table 10 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. Monitoring points A, B, C and D were chosen by NE (Figure 22) to take into consideration differences in ecological diversity and where certain notified interest features were known to be present. For example, rare aquatic plant species and the SAC feature, Anisus vorticulus. This was part of the objective for NE; 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 for the sites.

Of these, monitoring points A, B and C were chosen for review in this study to represent a range of locations and settings across Amberley Wild Brooks. The sampling locations are detailed in Figure 22. Point B is used as it is representative of the conditions in the centre of the ditch system of Amberley Wild Brooks and has inflows from ditches from the north and east. Location C is chosen as it is relatively close to the eastern margin and will reflect water conditions closer to the margins of the systems and therefore marginal inputs. Location A is chosen as it close to the outfall in the South of Amberley Wild 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 using the EA database. The Greatham Bridge and Downstream Coldwaltham STW monitoring points were selected. Both points lie upstream of Amberley Wild Brooks; Greatham Bridge is 1.3km upstream and Downstream Coldwaltham is located in the northern corner of the site (Table 10).

Figure 22 Long term water quality monitoring plan, created by Natural England using information supplied by Ordnance Survey © Crown copyright and database rights 2021. OS 10022021.

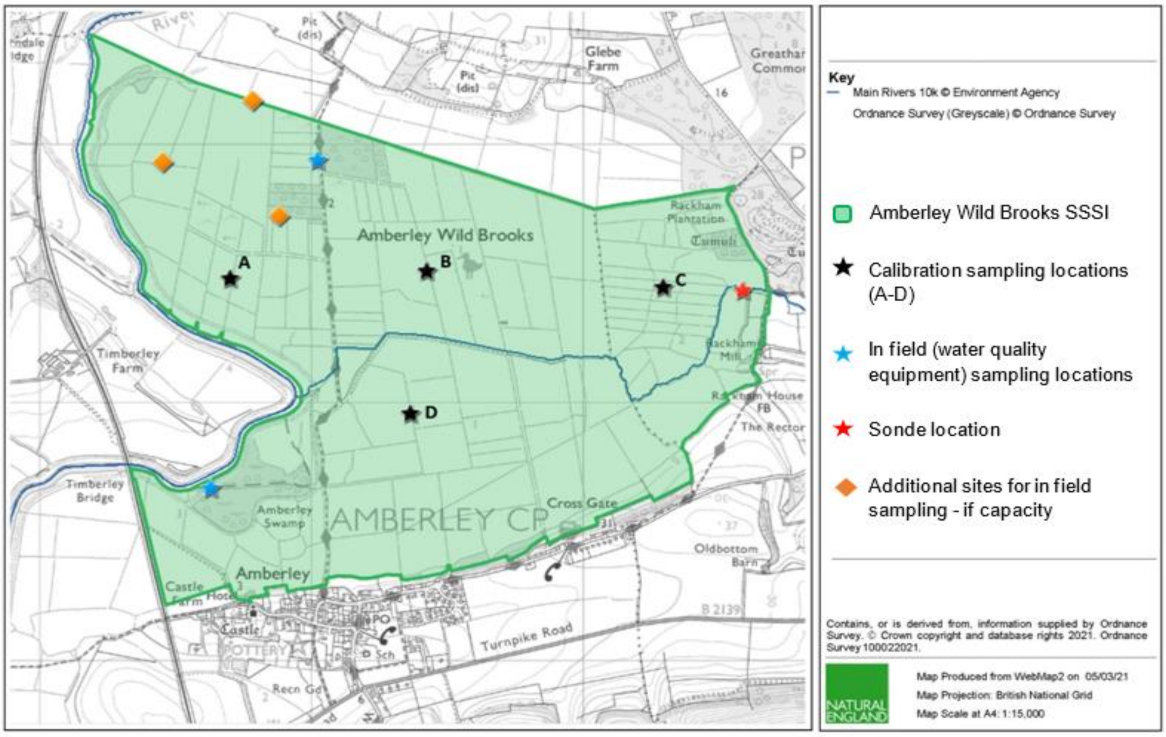


Table 10- Water quality collected at sampling points during fieldwork across Amberley Wild Brooks

Location	A	B	C	A	B	C
Sample Date	20/06/2021	20/06/2021	20/06/2021	05/12/2021	05/12/2021	05/12/2021
Season	Summer	Summer	Summer	Winter	Winter	Winter
pH	7	6.7	7	7.1	7	6.9
Temp °C	20.6	21.5	19.2	5.6	5.1	5.1
DO %	103.4	59.4	70.7	77.3	67.6	75
Conductivity SPC	320.5	272.7	274.4	303.3	292	298.5
Salinity psu	0.15	0.13	0.13	0.14	0.14	0.14
Turbidity NTU	5.77	16.9	10.3	17.6	72.4	94.1
T Phosphorus mg/l	0.11	0.12	0.036	0.066	0.17	0.46
Phosphate mg/l	0.073	0.056	<0.02	0.058	0.13	<0.02
T Nitrogen mg/l	0.9	1	0.5	0.4	1.7	0.5
Ammonia N mg/l	0.18	0.59	0.18	0.031	0.47	0.031
Nitrate as N mg/l	0.13	0.5	0.59	0.21	0.34	0.47
Nitrate mg/l	1.3	0.298	0.298	0.125	0.127	0.127
Nitrite mg/l	0.0046	0.054	0.037	<0.001	0.012	0.0011

As expected, the oxygen demand on the water within the ditch system is higher in summer than it is in winter at point B and C, shown by considerably lower dissolved oxygen values in summer. The opposite is seen at monitoring point A, where summer dissolved oxygen is considerably higher than in the winter and indeed all other points. The pH of the sampling locations does show a broad pattern of elevated readings during winter, with the exception of point C. Turbidity in winter point B and C considerably higher than point A as well their corresponding summer measurements. Phosphate is depressed at point C across both winter and summer and raised phosphate at points A and B, may indicate elevated phosphate levels from the River Arun into the system (Table 10). This is supported by elevated phosphate and total phosphorus at both monitoring points on the River Arun respectively. In addition, the pH at Coldwaltham is notably higher than that recorded across Amberley Wild Brooks (Table 11).

Table 11- Water quality data for the River Arun for two EA monitoring points

Location	Downstream Coldwaltham STW	Downstream Coldwaltham STW	Greatham Bridge
Sample Date	05/06/2018	17/12/2018	24/10/21
Season	Summer	Winter	Autumn
pH	7.82	7.57	-
Temp °C	16.7	6.6	11.6
DO %	57.3	71.6	70.3
Conductivity SPC	-	-	274.2
Salinity psu	-	-	0.13
Turbidity NTU	12.2	60.8	36.2
T Phosphorus mg/l	0.254	0.229	-
Phosphate mg/l	-	-	0.23
Ammonia N mg/l	0.08	0.075	0.07
Nitrate as N mg/l	4.6	3.87	
Nitrate mg/l	-	-	1.04
Nitrite as N mg/l	00543	0.0222	0.017

6.7 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 water quality sampling locations are shown on Figure H.

6.7.1 pH and Electrical Conductivity

Tables 12 and 13 summarise the readings taken from a variety of locations including directly from aquifers across Amberley Wild 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 12- pH readings summary from Amberley Wild Brooks

Localities	pH			
	Count	Min	Max	Average
Alluvium	4	5.8	7	6.48
Ditches	6	6.5	6.9	6.65
Folkestone	3	6.4	6.6	6.50
Wildbrook	1	7.2	7.2	7.20
Peat	4	6.2	6.9	6.63
River Terrace Deposits	4	6.5	6.6	6.55
Seeps and Spring Inflows	7	6.2	7.3	6.69
Surface Water	6	6.3	6.7	6.52

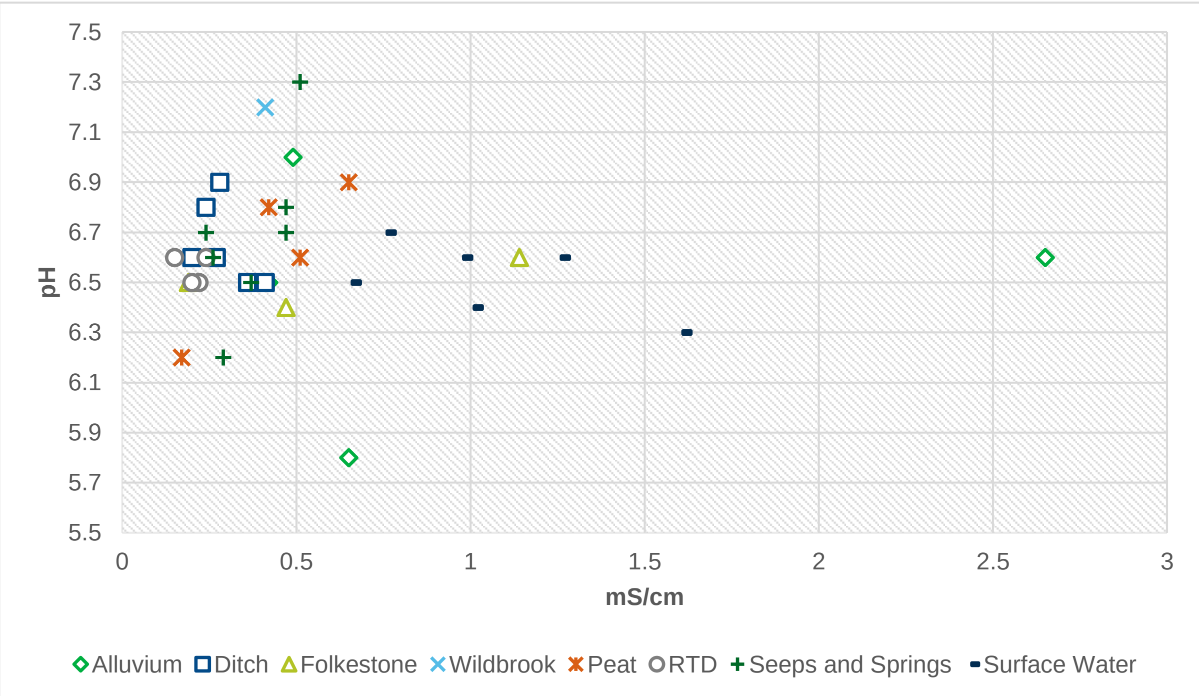
Table 13- Summary of electrical conductivity at Amberley Wild Brooks

Localities	Electrical Conductivity mS/cm			
	Count	Min	Max	Average
Alluvium	4	0.42	2.65	1.05
Ditches	6	0.2	0.41	0.29
Folkestone	3	0.19	1.14	0.60
Wildbrook	1	0.41	0.41	0.41
Peat	4	0.17	0.65	0.44
River Terrace Deposits	4	0.15	0.24	0.20
Seeps and Spring Inflows	7	0.24	0.51	0.37
Surface Water	6	0.66	1.61	1.05

6.7.2 Summary

Figure 23 highlights the relationship between electrical conductivity in mS/cm and pH across Amberley Wild Brooks.

Figure 23 Graph of pH versus Electrical Conductivity Amberley Wild Brooks



The highest pH readings were pH 7.2 at Wildbrook Stream as it flows onto the site and pH 7.3 at the spring close to Quell Farm. Wildbrook stream catchment originates in the chalk uplands to the south-east of the site and this chalk is likely the cause of the elevated pH. Quell farm has deposits of Marehill Clay upgradient which can have a significant glauconitic component, this glauconite may be elevating the pH in the spring at Quell Farm. The springs and seeps that form a large inflow component to the system have an average electrical conductivity when compared to the other localities sampled and also have a relatively low pH with the exception of the previously mentioned Quell Farm Spring. 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 Amberley. Peat ranged from relatively low pH values at 6.2 to relatively high at pH 6.9, 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 EC within peat, with lower pH associated with lower EC, the mechanism behind this is not currently clear.

The Folkestone Beds show little variation in pH, with all points remaining around pH6.5 and generally less than 0.5mS with a single outlier with a high electrical conductivity. River Terrace Deposits and the Ditch system also show low electrical conductivity and relatively average pH when compared to the larger population.

Alluvium readings vary greatly in both pH and electrical conductivity, with three very large outliers and a single reading in the average population centre. WS-A-03 showed 2.65mS/cm and when sampled this water was observed to have a distinct 'peaty' hue. HA-A-01 also had a similar hue when sampling with the influence of peat in the local area potentially reducing the pH.

The surface water readings show a consistently very high electrical conductivity when compared to all other localities sampled although limited variation in pH when compared to the rest of the sample group. This high conductivity 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.

6.8 Naturalised state

In its naturalised state, Amberley would have a considerably different hydrological regime than 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 Amberley (Figure B), there are a number of relic sinuous channels which historically drained the site. Remnants of these relic channels can still be seen on site as shown in Figure 20 and as picked out by the LiDAR image. 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.

Notably, on Amberley there is the large sinuous relic former channel of the river which can be seen on LiDAR data (Figure B) heading down along the west of the site before curving to the north-east across the site. Once it reaches the north-eastern boundary of the site it curves down to the south before fading out of existence in the far south of the site. Figure 24 shows an image of this sinuous channel.

Due to its lower lying nature, this relic river meander was flooded with water during the January 2022 site visit, and hence the initial exploratory holes were positioned to avoid this area. The drier conditions in March 2022 enabled the advancement of four hand augers within the footprint of the former meander. No peat was found in any of these hand augers (HA-A-42 to HA-A-45).

This lack of peat within the relic river meander footprint may suggest that peat formation was contemporaneous with the river meander, forming on the flat bankside floodplain on the northern edge of the river (the peat seen in HA-A-09, HA-A-10 and other holes in the north-west of the site) and within the apex of the meander (e.g. HA-A-14).

The area of peat to the north of the relic river meander lies between the river and the higher ground of the Folkestone Beds to the north. It is possible that groundwater seeps and springs sustained the peat in its natural state in this area, in addition to rainwater and overtopping river waters.

Given that the area of peat within the apex of the meander is isolated from the higher ground around the margin of the site by the relic meander, it is unlikely that this peat deposit received direct feeding from groundwater. The artesian groundwater conditions seen in this area within the deep alluvium/Arun RTD deposits does suggest an upwards head gradient from beneath however, and this may have helped to maintain peat wetness. Water feeding the peat would likely be dominated by rainwater and river overtopping in this area.

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.

Figure 24 An image showing an example of the current sinuous channel on the site, taken during fieldwork by surveyors.

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 of oligotrophic. The site's hydrological regime can be defined as stable if fed by a constant water supply, for example 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 25, mapping out water movement and the overall hydrological regime.

7.1 Acidity

Peat ranged from lower pH values at 6.2 to relatively high at 6.9, 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 and others (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 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 focussed 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 on-site management as much as external inputs of water, for example 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 channels supplying the submerged ground conditions needed for peat accumulation; and,
- The site’s current state as a managed wetland with a series of drainage ditches which are essentially draining the peat of water over time.

7.3.1 Groundwater

Peat has been encountered in the north, east and central-east areas of the site. The limited data available at present suggests that peat is absent within the footprint of the river meander. Hence the relic meander footprint separates the peat in the northern and eastern margin from the area of peat in the central-eastern area.

The area of peat to the north of the relic river meander lies between the river and the higher ground of the Folkestone Beds to the north. It is possible that groundwater seeps and springs sustained the peat in its natural state in this area, in addition to rainwater and overtopping river waters. Data gathered during this study suggests a degree of connectivity between the Folkestone Beds aquifer and the superficial deposits, and there is a potential groundwater baseflow element to hydrographs for wells within the peat in HA-A-09 and HA-A-10 in this area.

Given that the area of peat within the apex of the meander is isolated from the higher ground around the margin of the site by the relic meander, it is unlikely that this peat deposit received direct feeding from groundwater. However, there are artesian groundwater conditions seen in this area within the deep alluvium/ Arun RTD deposits, suggesting an upwards head gradient from beneath which may have helped to maintain peat wetness.

Given this conclusion that groundwater likely impacts the hydrology of the peat across the northern and eastern areas of the 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 possible that the nearby abstraction may have some effect on peat health and hydro-ecology. However, the increased distance between the abstraction and Amberley Wildbrooks (i.e. this site is further from the abstraction than Pulborough Brooks) means that the potential for this impact to occur is currently unknown.

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, particularly in HA-A-24 and, to some degree in HA-A-09. In the area of peat within the relic river meander's apex, the water within the peat would likely be dominated by rainwater and river overtopping due to the area's isolation from any direct groundwater sources.

Hence 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. This isolation due to an upper less permeable layer may explain the lack of rapid rainfall signal seen in many of the peat hydrographs.

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 Wildbrook 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 northern and eastern margins. Groundwater seepages are also anticipated to be contributing water to the system around these margins.

In its naturalised state it is likely spring lines fed the peat along the northern and eastern margins. This groundwater-driven water source likely promoted the development of peat along these margins. The influence of groundwater is anticipated to have been limited by the presence of the relic river meander. The meander therefore likely represents the boundary at which the effect of direct groundwater feeding of peat via seeps and springs ceases.

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 Brooks area. Whilst the site is more distant from the abstraction than Pulborough Brooks, this may also have led to a reduction in seepage from this aquifer, particularly along the northern margin of the site. Secondly, the peat has been cut off from the seeps and springs by the fact that they are captured by, or drain directly into a perimeter ditch and the general ditch network.

7.3.5 Naturalised state mechanisms

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

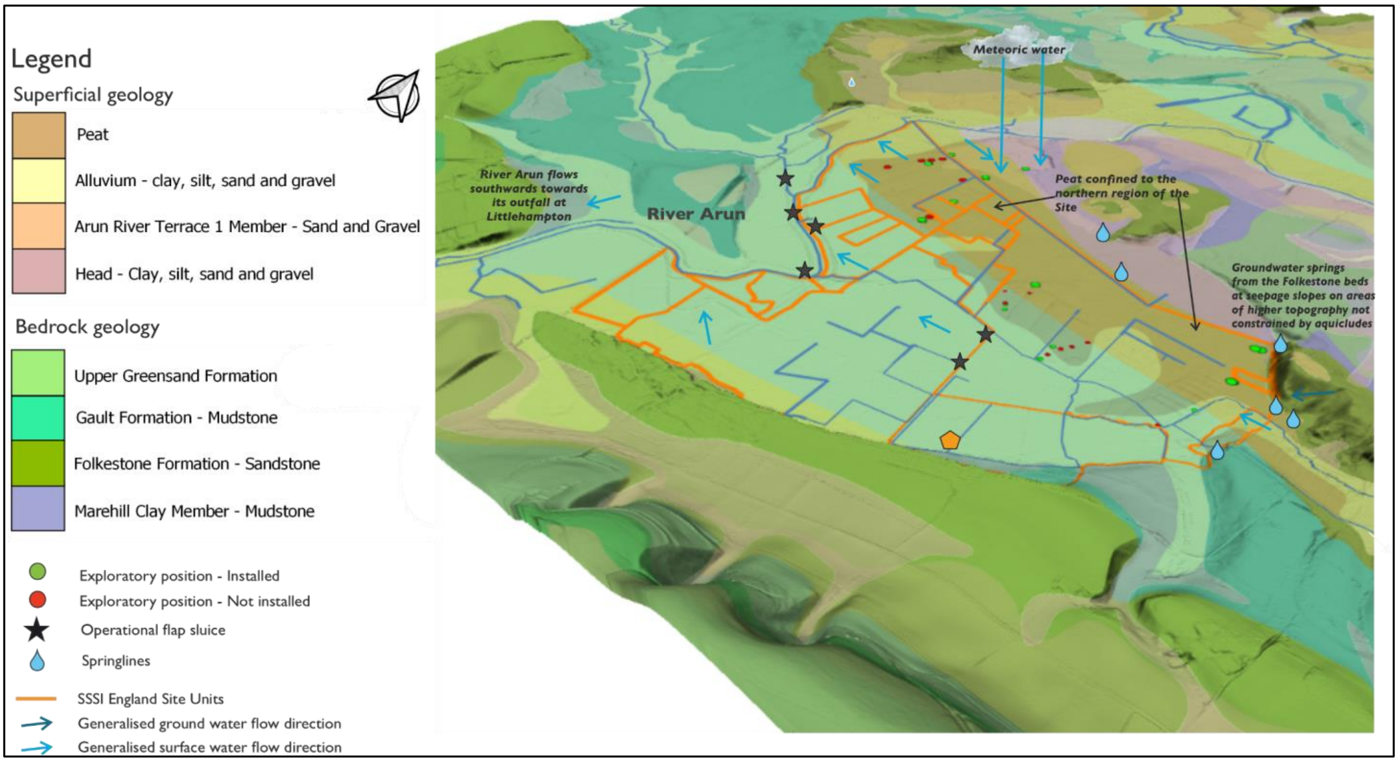
1) A good input of telluric water, mostly from springs and seeps on margins (northern and eastern margins only), but also some upwards from below (across all areas, particularly the central-eastern area).
2) Very flat topography with little drainage, and in sinuous natural channels
3) Meteoric water, which was largely captured and infiltrated to the peat.

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

7.3.6 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 (Figure 25). 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 25 Conceptual Model of Amberley Wild Brooks



8. Conclusion

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 Amberley Wild Brooks that are currently likely of declining quality and require action to help them start to recover towards their natural state. This section describes a series of practical solutions, generally focussed 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.

8.1.1 Ditch maintenance

Currently many ditches, both minor and major across Amberley Wild 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, for example 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 build 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 in WS-A-04, HA-A-01, HA-A-04, WS-A-04 WS-A-05, WS-A-06, WS-A-07, WS-A-08 and WS-A-18 the shallowest depth encountered was at 0.35m bgl, 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-A-04, 07 and 08 indicating a high hydraulic head within the Arun Terrace Deposits. It should also be noted in areas of Amberley 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 the ditches that 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.

This is of particular note in the northern portion of Amberley Wild Brooks, in the region of Fields 14 and 15 (Figure 1). In this region, the material laid on ditch margins from the casting operation includes a significant proportion of sand and (particularly) flint gravel. This suggests that the depth to which the ditch has been cast is below the base of the peat and alluvium sequence. This potential interaction between ditches and the underlying aquifer is further supported by the presence of ochreous seeps in the base of a ditch adjacent to Field 16. Ochreous water is common within the Folkestone Beds aquifer and indicative of waters flowing from the basal bedrock aquifer direct into the ditch system (or indirectly via the RTD deposits). In its natural state (without ditches), this water would be helping support a higher water table within the wetland system.

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/ SWT) and represent a low cost low-impact solution to raising water levels across large swathes of Amberley (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 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 across the two decades 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. For example, 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 and a control section where current practices are continued and monitored over the course of a year to assess the impacts to both water levels but also flora and fauna prior to rolling out across the site.

In the north-western area of the site the peat thickness, aerial extent and comparatively thin layer of overlying topsoil suggests that this may be a good area to trial such an approach. The area of HA-A-09 in the centre of this area is also the only area on site where groundwater is currently near the ideal elevation of within 5cm of ground surface. This location is highlighted in Figure I.

8.1.2 Ditch modification

8.1.2.1 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 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 surface levels to attempt to ensure as much of the extant peat deposits are hydrated as possible.

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 Figure I, Figure J and Figure K and focus on raising water levels in the north-western, central-eastern and north-eastern areas where the largest peat deposits are shown. This would likely have far reaching effects on water level throughout these areas of the site.

8.1.2.2 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. This process however will remove all of the habitat currently associated with the ditches and banks themselves in areas chosen for ditch removal. Therefore, targeted locations for ditch infilling must consider impact to flora and fauna with potential target areas in the north-west located away from protected species.

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 I, Figure J and Figure K. 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 I, Figure J and Figure K. As can be seen, ditches along northern and eastern boundary and in the central-eastern area are targeted, designed to increase the retention time of water close to the boundary of the site. To raise water levels at the large deposits in the centre of the site would require infilling of impractical amounts of ditches, as these would need to extend to all areas upstream of these locations as if upstream ditches were left open they would capture water that would flow to the targeted peat areas.

Areas in the east are considered unsuitable due to the presence of protected species and the loss of habitat would outweigh any potential benefits.

8.1.2.3 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. Whilst modification of ditches may increase the water table in target areas, there may be a corresponding lowering in other areas. Ditch infilling and altering of water levels may also impact on SAC, Ramsar and SSSI features, both directly (by loss of habitat) or indirectly (by alteration to habitat wetness).

8.1.3 Modifying marginal seeps

Across Amberley Wild Brooks, there are seeps or isolated springs issuing from the north and east of the site. Typically, along the northern boundary 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. Seeps in selected locations in the east do have the ability to advance onto the site before being 'caught' by the ditch system. In the north especially 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.

8.1.3.1 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 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 seeps. The potential locations are shown on Figure D, these are in the east of the site where the perimeter ditches are infrequent and peat deposits limited. Therefore, the efficiency of this system may not be particularly effective at Amberley.

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. This also represents a more altered, less naturally functioning system.

8.1.3.2 Medium intervention spring diversion – cut off trench

Across Amberley 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, for example, away from footpaths and fences etc. The issues at Amberley are generally across a large horizontal distance and would likely require a large amount of earthworks for a limited return. It should be noted that the piping system is entirely passive and other than installation would only require maintenance and upkeep.

8.1.3.3 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. Ditches that could be removed to facilitate this are shown in Figure I, Figure J and Figure K. As discussed in the previous sections, ditch removal comes with potentially severe impacts to the local flora and fauna, and it is acknowledged that the infilling of ditches (because of the most potential benefit with respect to providing improved water feed to peat bodies) would severely impact those rare and special aquatic species within them, even if translocation were possible. 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.

8.1.3.4 Considerations

Water derived from the margins of the site was often noted to have an ochreous hue, with 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 8.1.3.4 modification of marginal ditches may impact the current transfer of water from margins to further into the site.

Clearly the infilling of ditches is contrary to the conservation objectives for improving the site from the perspective of its protected aquatic species.

8.1.4 Sluice management

Manipulation of water levels happens consistently throughout the year by RSPB operatives and other stakeholders using sluices at various points across the site as shown in Figure 5. The Water level Management Plan provides the framework for water level management on the site. To increase retention time and water levels throughout Amberley Wild 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 Amberley, 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 Amberley.

This inundation, especially in the summer months, will increase evapotranspiration and may alter other conservation efforts across the site. Figure L provides an indication of the degree of inundation that may be expected by raising water levels to 1.3m AOD across the entire site (i.e. approximately 0.5 and 0.6m above current summer impoundment levels at Wildbrook Lower and Low Brook sluices respectively). Clearly this will lead to flooding of large areas of land. Whether such large-scale inundation is beneficial to wildlife conservation objectives will require a consideration of the balance between competing interests, which is outside of the scope of this study. Thus, such an approach may be more viable when focussed on discrete areas of the site only, such as in the north-western portion of the site (around Fields 14, 15, 16), in the central section of the site (around Field 55) and in the far north-east (Fields 63 to 65) (Figure 1). It is considered the best location to trial this method would be in the north-west or north-east, where peat deposits are located within relatively discrete drainage sub-compartments and inundation if it occurs will be kept to a limited area that already involves artificial scrapes which would likely cope with further inundation.

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. Similarly, the impact on aquatic species and SAC interests within the ditches will be of critical consideration, particularly as some areas identified as of greatest potential for intervention (in the north-east of the site in particular) are also those areas where the greatest concentrations of rare and threatened species have been recorded. Hence, there is likely to be some potential conflict with regards to different conservation objectives in this respect.

8.1.5 Remove flood defences

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. 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.

8.1.5.1 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 have limited impact in increasing 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. It is also worth noting that the flows and water quality in the Arun are not themselves in a naturalised state.

To reinstate the initial conditions that the peat in Amberley 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 along its old alignment. 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.

8.1.5.2 Ecology

Although currently seasonal variations in water level are commonplace regardless of the water level management that occurs on site. Currently 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 Amberley stretch of the Arun (and the lower portion of the Wildbrook) is under tidal influence but does not have a saline wedge. For instance, 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. This would affect adversely the currently existing ecological regime.

8.1.5.3 Considerations

There are a number of problems that may result in large scale modification of flood defences in Amberley. Initially, there would require considerable consultation with the relevant statutory bodies including the Environment Agency. 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.

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 Amberley Wild 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.

8.1.6 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. Some hydrographs within the peat deposits appeared to show an element of groundwater baseflow, and artesian wells installed within the Folkestone Beds confirmed an upwards hydraulic gradient in parts of the site.

This groundwater influence is concluded to be via both 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 Amberley 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 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 northern and eastern southern margins of Amberley Wild Brooks, and in an area in the central-east of the site.

Water levels in the majority of these peat deposits are below that which is expected in a healthy peat body (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 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 much of Amberley Wild Brooks is likely to be an 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.

8.2.2 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 Amberley Wild Brooks 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 that will be the condition of the peat.

8.2.3 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, alterations to the ditch systems will clearly have some impact on the aquatic species and special interests within these ditches. 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. Similarly, the ideal water levels to sustain healthy peat (circa 5cm below ground level) will likely be lower than the ideal water level for wintering wildfowl and waders (which may need to be at, or just above ground level). Conversely, summer nesting species may benefit from intervention measures to improve conditions for peat. 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 14 provides a list of unanswered questions and 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 14- 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 between groundwater body and chemistry. A more detailed or long-term approach may provide a better indication of water source within peat, and so enable differentiation	Water quality sampling and laboratory analysis over a prolonged period of time.	££	2

Uncertainty	Possible next steps	Anticipated cost	Priority
between meteoric and telluric sources of water.			
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 [Note 1]	££	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 year of data in hand	£	5
Can a detailed water balance be constructed for the areas of peat in Amberley, to aid in the modelling of degree to which groundwater/ rainwater/ evapotranspiration dominate?	Gather permeability data through in situ testing.	£	4
Can a detailed water balance be constructed for the areas of peat in Amberley, to aid in the modelling of degree to which groundwater/ rainwater/ evapotranspiration dominate?	Construct water balance model, calibrate and use as tool to model system inputs/ outputs and model future interventions	£££	3
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

Uncertainty	Possible next steps	Anticipated cost	Priority
What is the extent of peat outside of those areas already investigated? Does the relic meander consistently represent an area with no peat? What is the extent and nature of peat in Parham Park?	Selected peat augering to confirm presence/ absence in selected areas, with targeted transects across river meander and (access allowing) in Parham Park.	£££	3
How far eastwards does the peat body in the north-western portion of the site extend?	Peat depth probing in Fields 23 to 29, Field 49 and 50. Produce contour plotting.	££	5
To what degree is the Pulborough 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
To what degree would climate change associated with anthropogenic global warming affect the aims to restore peat on the site?	Review of climate projections for the area, undertake qualitative assessment.	£	4
To what degree would climate change associated with anthropogenic global warming affect the aims to restore peat on the site?	Build upon water balance model to model climate change scenarios	£££	3
How is the peat currently behaving with respect to carbon cycle – net sink/ neutral/ net emitter?	Desk based research in peat carbon balance. Potential for field tests/ sampling and lab testing? Research project as potential academic project?	££	3

Note 1: 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

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12. 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.
Barometric	Atmospheric pressure, used especially in forecasting the weather and determining altitude.
Bog	Acidic (pH < c. 5.5) mires (mainly on peat, but some mineral soils)
Carr	Tree-covered fen

Term	Definition
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.
Cretaceous	The youngest period of the Mesozoic, 251 – 66 million years ago.
Epoch	A particular period of time in history
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.
LiDAR	Lidar is a technology that uses laser beams to measure distances and create 3D maps of the Earth's surface or objects
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.

Term	Definition
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.
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
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.

Term	Definition
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
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 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 are nationally designated protected sites which are management by Natural England
Stand	A relatively uniform patch of vegetation of distinctive species composition and appearance. Can vary in size from very small (in m^2) to very large (in ha).
Strata	A layer or a series of layers of rock in the ground
Swamp	Wetlands with summer water table typically > c. 25cm above ground level
Superficial deposits/ superficial geology	Superficial deposits refer to geological deposits typically of Quaternary age (less than 2.6 million years old). These geologically recent unconsolidated sediments may 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.

Term	Definition
Telluric water	Water that has had some contact with mineral ground
Topogenous	Wetness induced by topography and poor drainage (such as hollows)
Upper Greensand Formation	A glauconitic shelly sandstone with subsidiary conglomerate mudstone and siltstone Cretaceous formation found within the Wessex and Weald basins.
Unexploded Ordnance	Unexploded ordnance (UXO) is any **explosive device** that failed to detonate as intended, such as bombs, shells, grenades, or mines
Water Framework Directive (WFD)	An EU directive which commits European Union member states to achieve good qualitative and quantitative status of all water bodies (including marine waters up to one nautical mile from shore) by 2015. It is a framework in the sense that it prescribes steps to reach the common goal rather than adopting the more traditional limit value approach.

Annex 1: Site setting

Site Address /location	The Site is located in Amberley Wild Brooks Nature Reserve within the South Downs National Park, West Sussex.
NGR	NGR at the centre of the Site is TQ 03331 14654.
Area	The Site area is approximately 322.6 ha comprising the whole nature reserve, specific Site exploratory locations were focussed across the northern, eastern and central regions of the reserve.
Current Site Use and Context	The Site is jointly owned and managed by RSPB, Sussex Wildlife Trust and private landowners. The land use comprises a mixture of grazing land, wet grassland and woodland with open water lagoons and scrapes, within a series of fields divided by artificial linear ditches. The Site supports extensive alluvial grazing marsh bisecting by a series of artificial ditches that support a wide variety of flora and fauna. Recreational visitors to the Site are restricted to the Wey South path due to the sensitivity of the area.
Site Access	Site access was provided by RSPB from four separate points of access, in order from north to south: • Via access track off Brooks Lane from the north. • Via access track off Greatham Road from the east. • Via driveway off Rackham Street. • Via access track Wey South off Hog Lane from the south.
Surrounding Land Use - North	Brooks Lane and the River Arun lie to the north of the Site. Pulborough Brooks SSSI lies to the north-east of the Site.

Surrounding Land Use - South	Amberley village lies to the South of the Site sitting at a distinctly higher elevation than the floodplain.
Surrounding Land Use - East	Rackham woods lie the east of Site, with Parham Park SSSI extending across land further to the east.
Surrounding Land Use - West	The River Arun lies west of the Site with associated floodplain and agricultural land. Waltham Brooks SSSI lies to the west, as does the Arun Valley railway line.
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 (An invasive non-native species) to the Site.

Appendix A: Figures A to M

Figure A – Site location plan: Amberley Wild Brooks

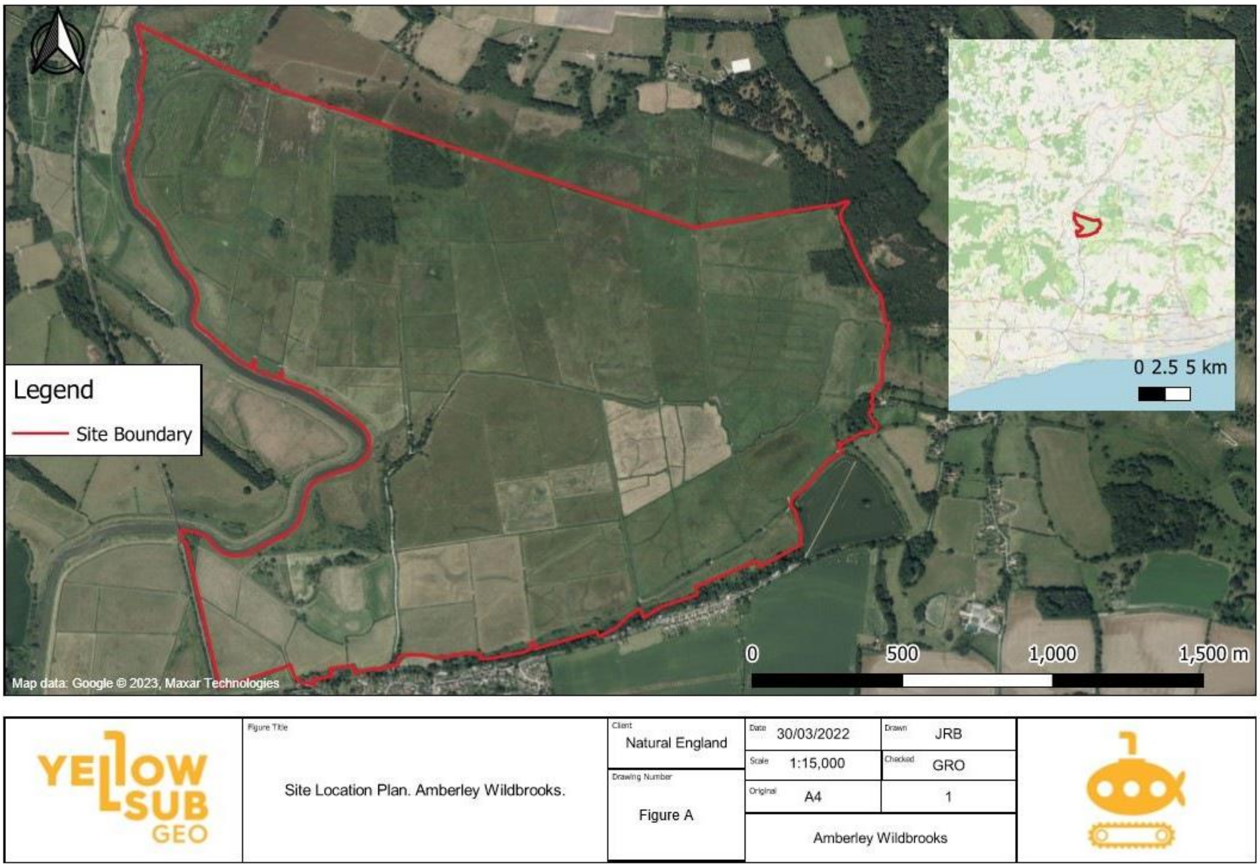
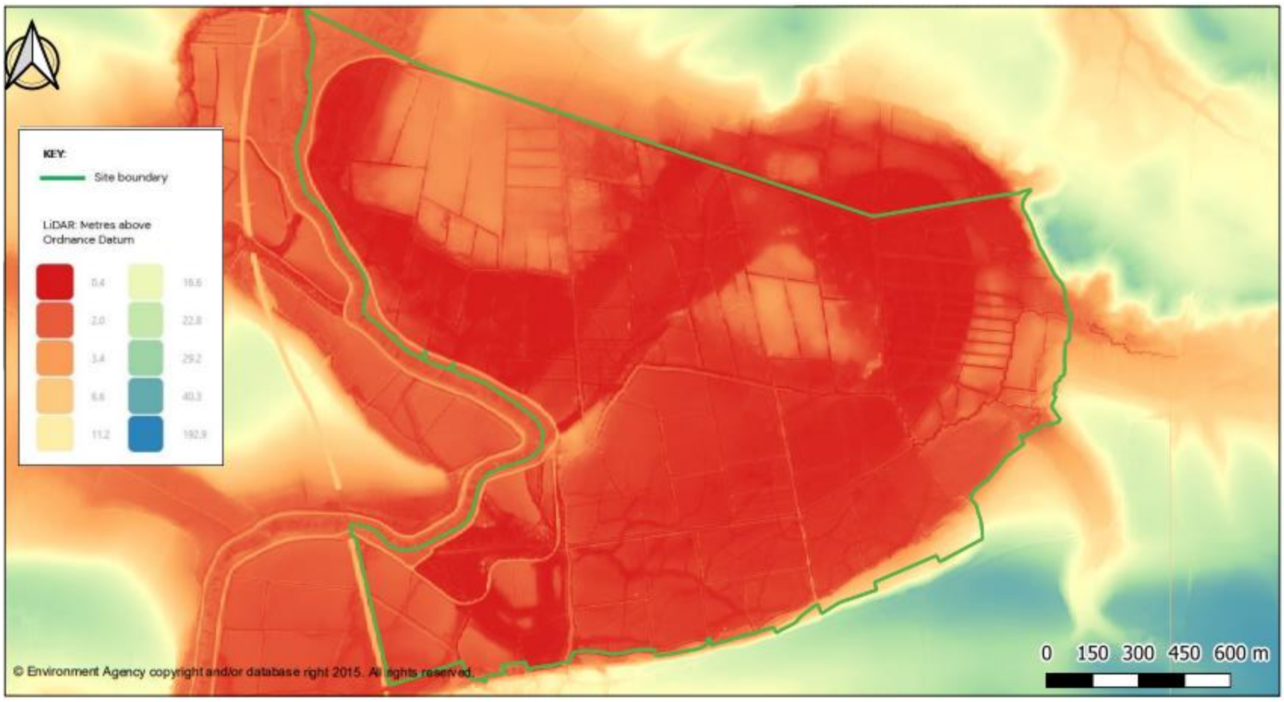


Figure B – Lidar at 25cm resolution, Amberley Wildbrooks



YELLOW SUB GEO	Figure Title: Lidar at 25cm resolution, Amberley Wildbrooks	Client: Natural England	Date: 30/03/2022	Drawn: JRB
			Scale: 1:15,000	Checked: GRO
		Drawing Number: Figure B	Original: A4	1
			Amberley Wildbrooks	

Figure C – Springs, seeps, inflows and outflows, Amberley Wildbrooks

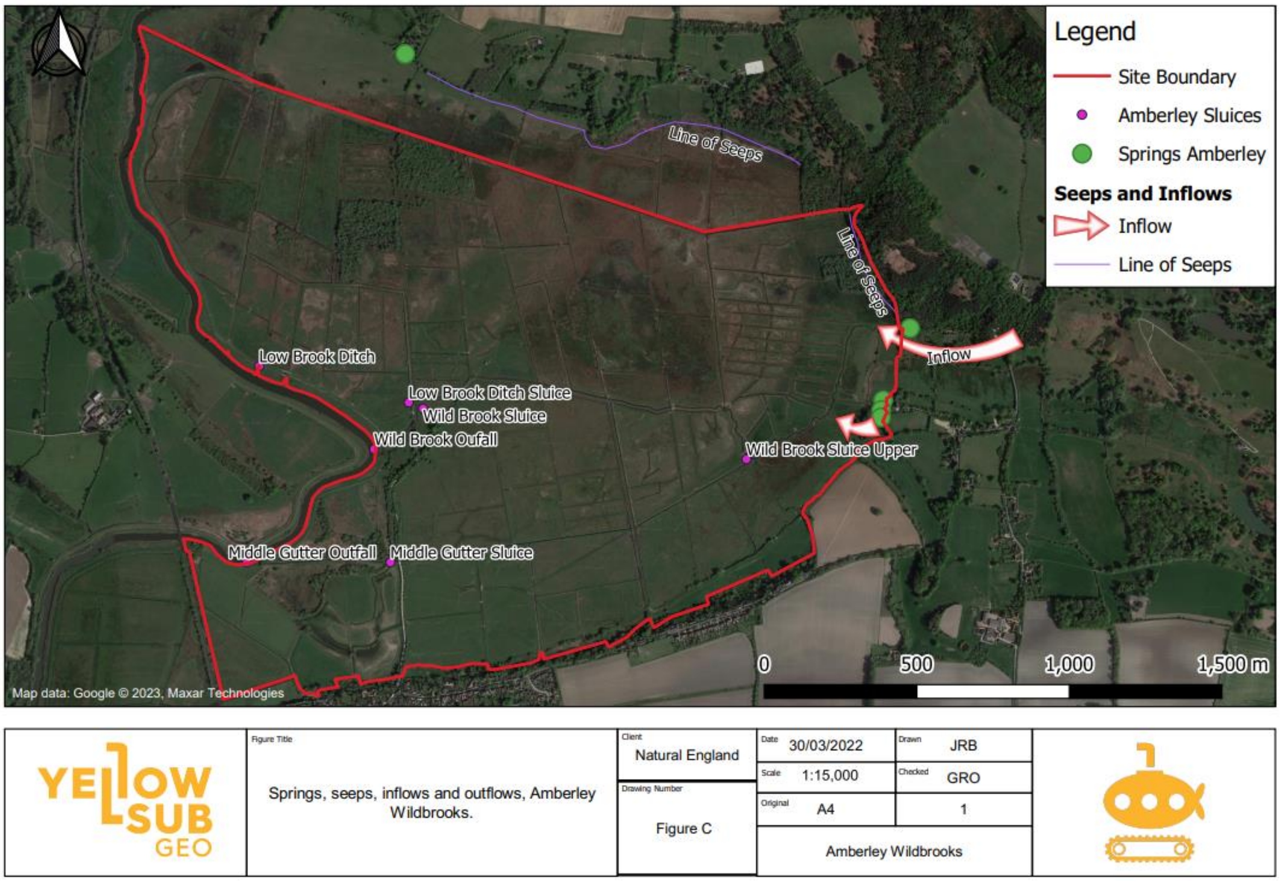
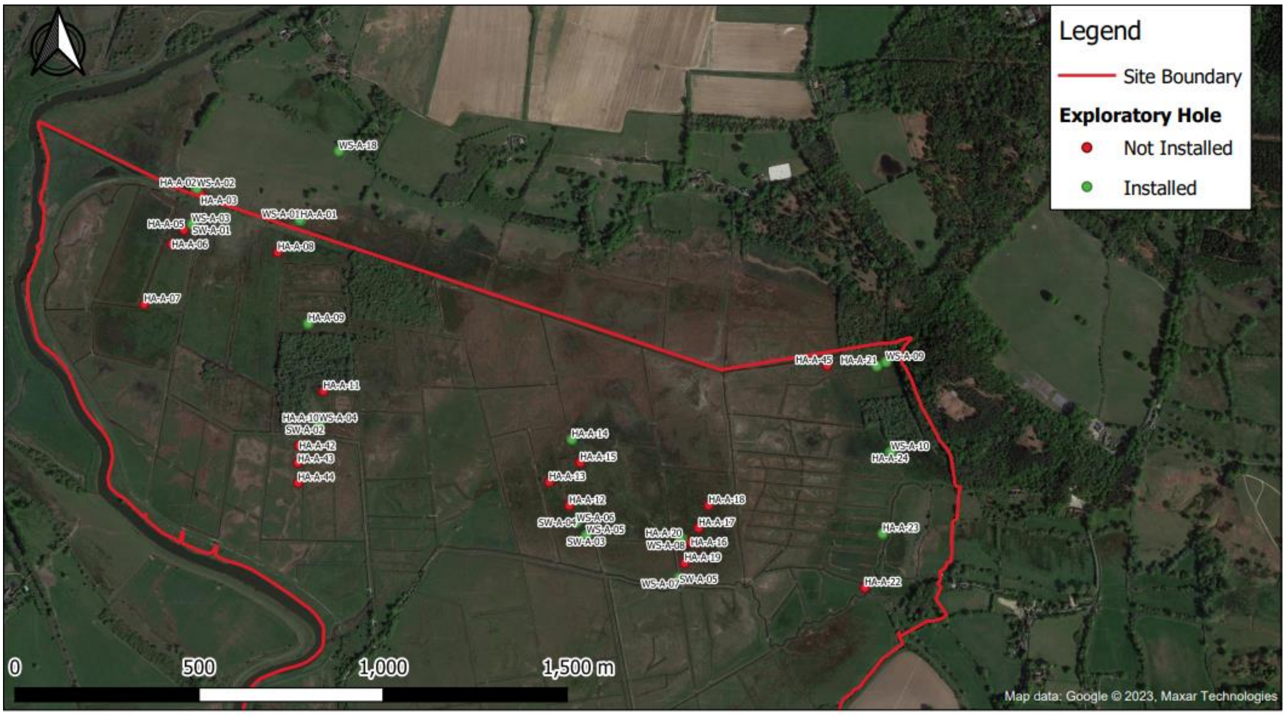


Figure D – Exploratory Hole Location Plan, Amberley Wildbrooks



YELLOW SUB GEO	Figure Title: Exploratory Hole Location Plan, Amberley Wildbrooks.	Client: Natural England	Date: 30/03/2022	Drawn: JRB
			Scale: 1:12,500	Checked: GRO
		Drawing Number: Figure D	Original: A4	1
			Amberley Wildbrooks	

Figure E – Depth to peat labelled with peat thickness, Amberley Wildbrooks West

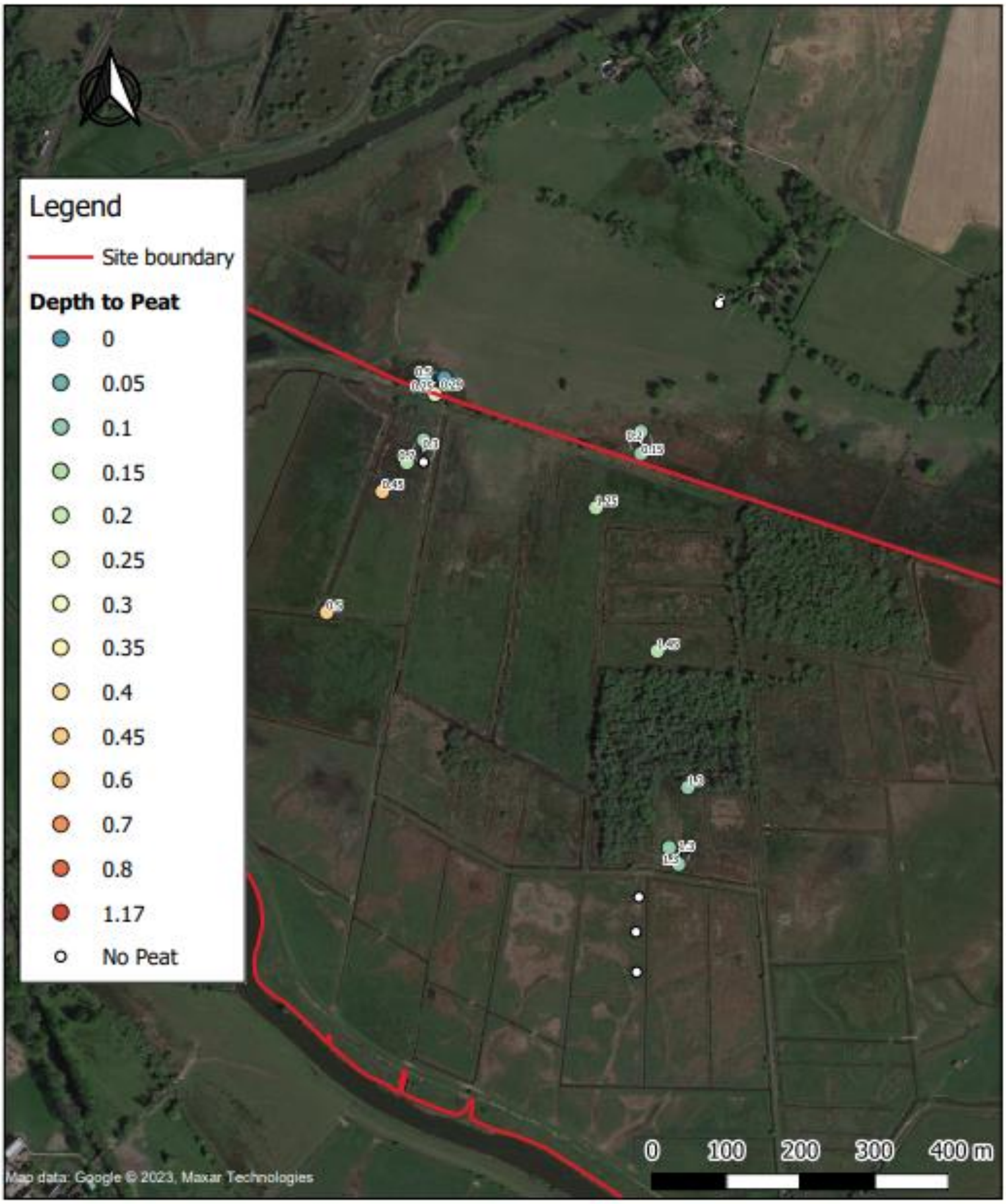


Figure Title	Client	Date	Drawn
Depth to peat labelled with peat thickness, Amberley Wildbrooks West.	Natural England	30/03/2022	JRB
	Drawing Number	Scale 1:7,000	Checked GRO
	Figure E	Original A4	1
		Pulborough	

YELLOW SUB GEO

Figure F – Depth to peat labelled with peat thickness, Amberley Wildbrooks East

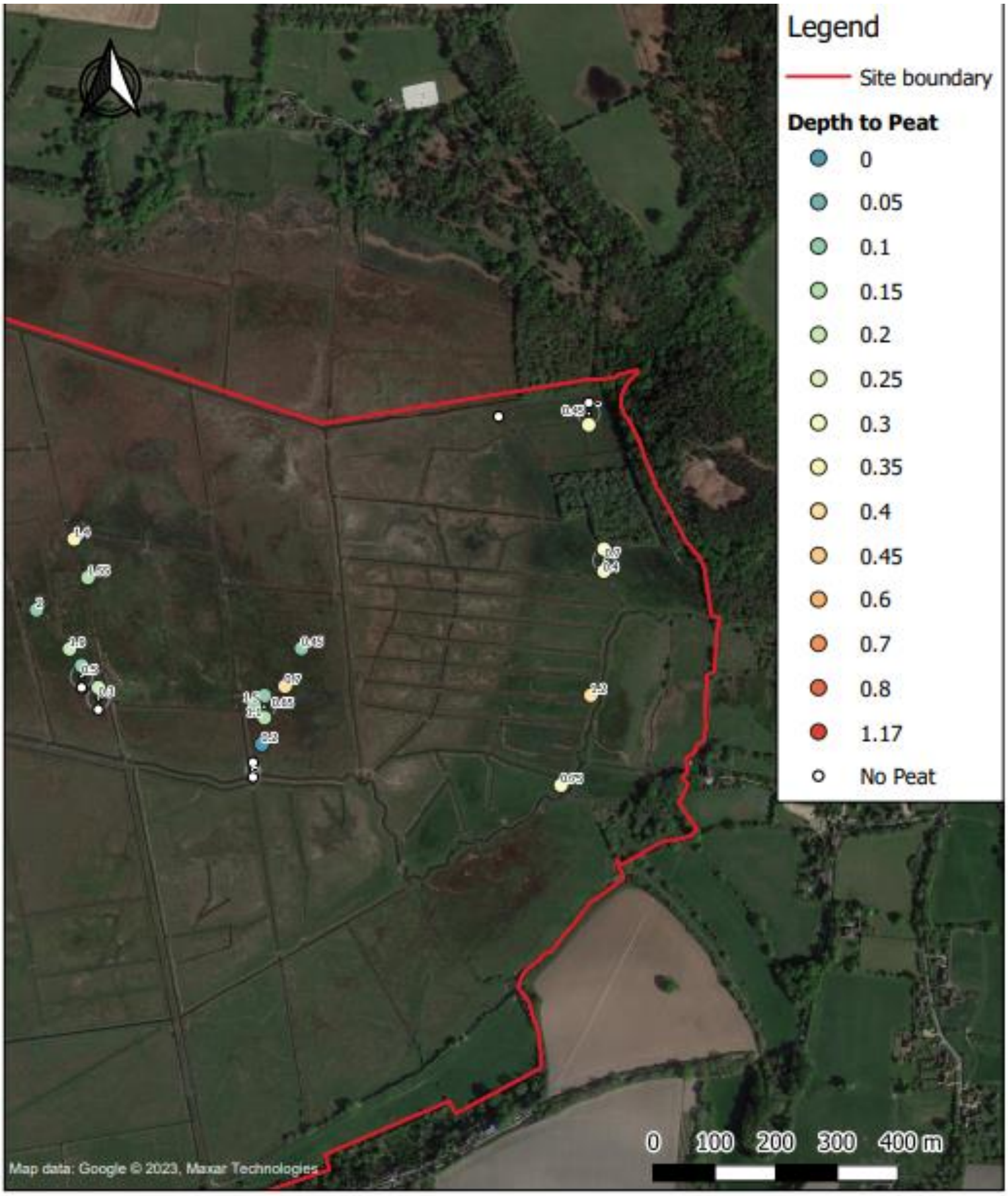


	Figure Title: Depth to peat labelled with peat thickness, Amberley Wildbrooks East.	Client: Natural England	Date: 30/03/2022	Drawn: JRB	YELLOW SUB GEO
		Drawing Number: Figure F	Scale: 1:8,500	Checked: GRO	
			Original: A4	1	
			Pulborough		

Figure G – Stylised cross section, north-west of Amberley Wild Brooks. Looking West

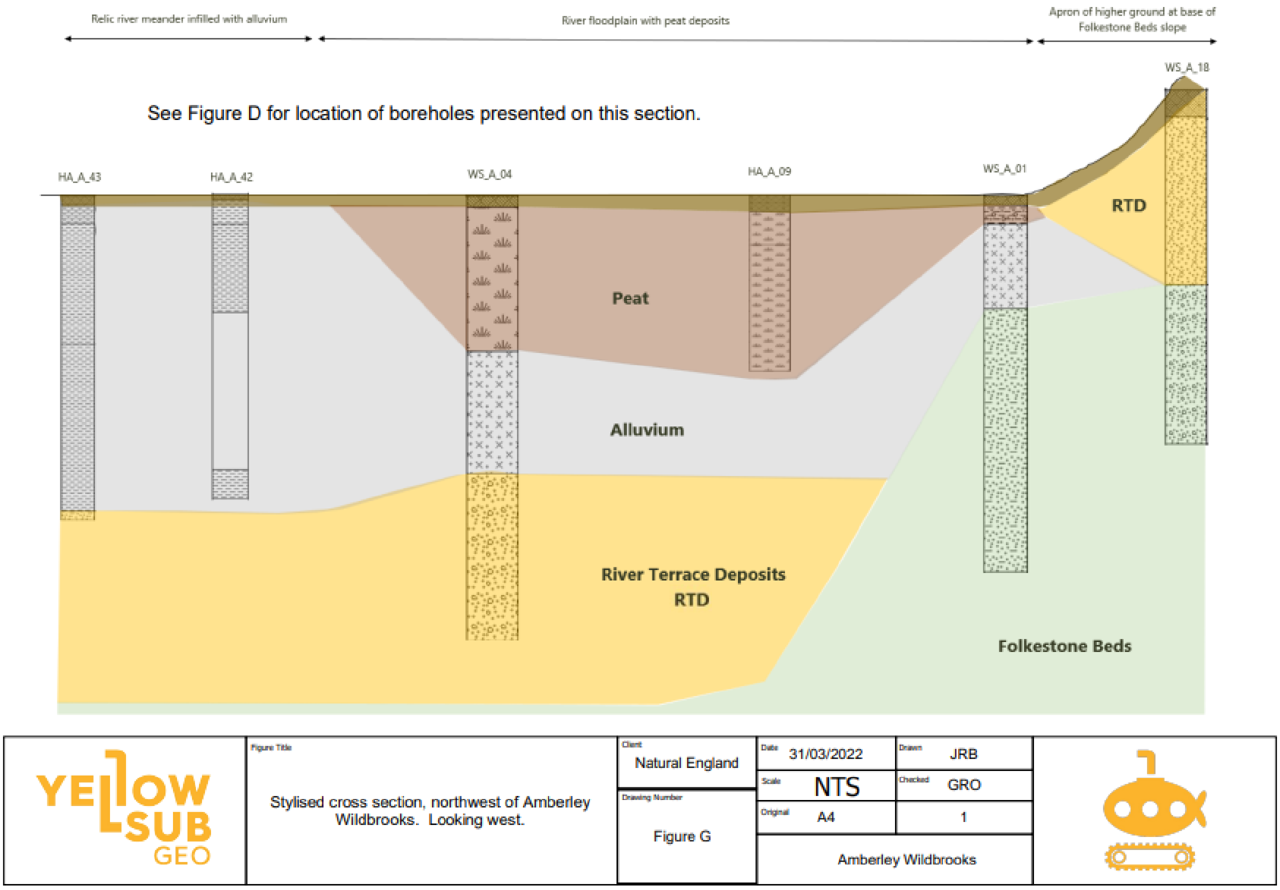


Figure H – Water Quality Sampling Location, Amberley Wildbrooks

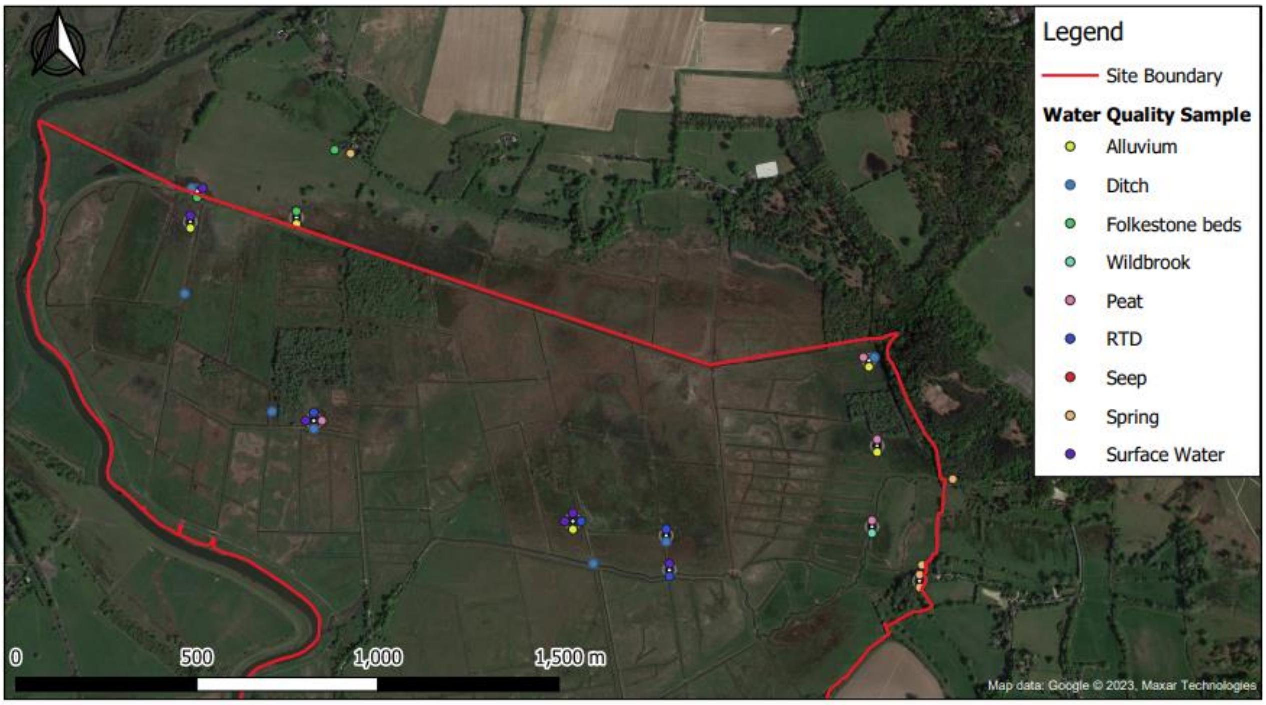
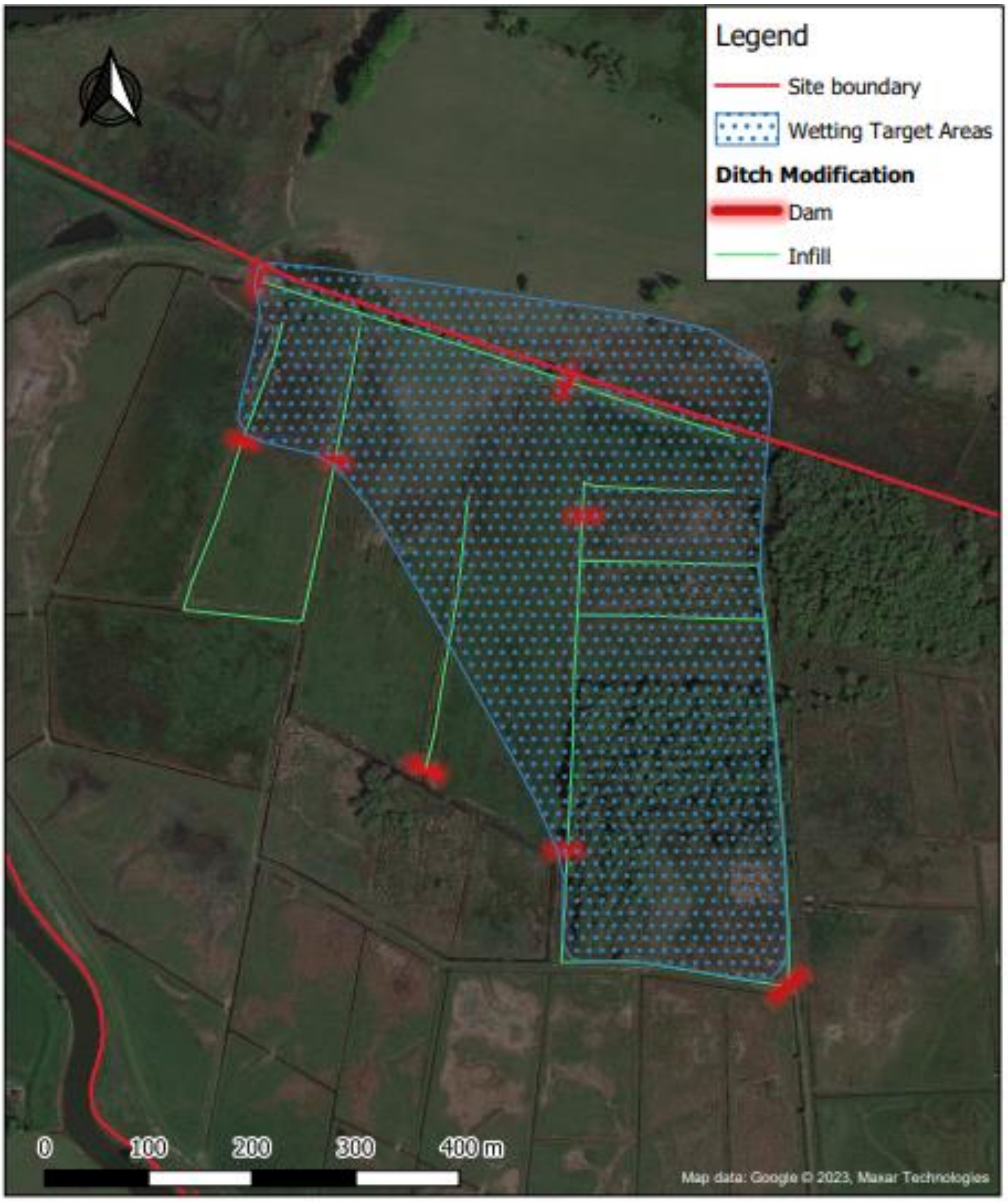


Figure Title	Client	Date	Drawn
Water Quality Sampling Location Plan, Amberley Wildbrooks.	Natural England	30/03/2022	JRB
	Drawing Number	Scale 1:12,500	Checked GRO
	Figure H	Original A4	1
		Amberley Wildbrooks	

Figure I – Wetting target areas and ditch modifications, Amberley Wildbrooks North-West



Wetting target areas and ditch modifications, Amberley Wildbrooks North West.	Natural England	30/03/2022	JRB	
		1:5,000	GRO	
	Figure I	A4	1	
		Pulborough		

Figure J – Wetting target areas and ditch modifications, Amberley Wild Brooks Central

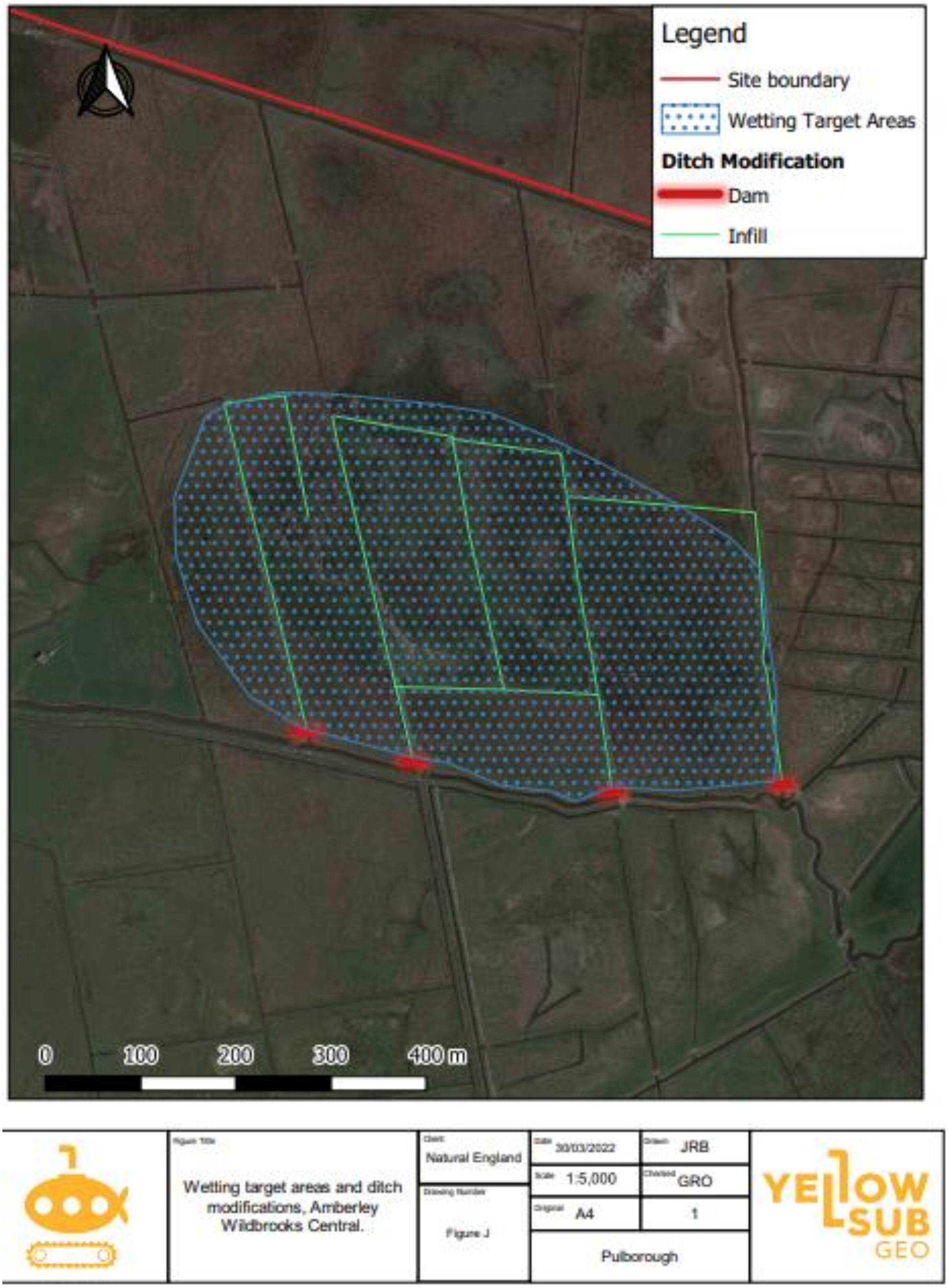
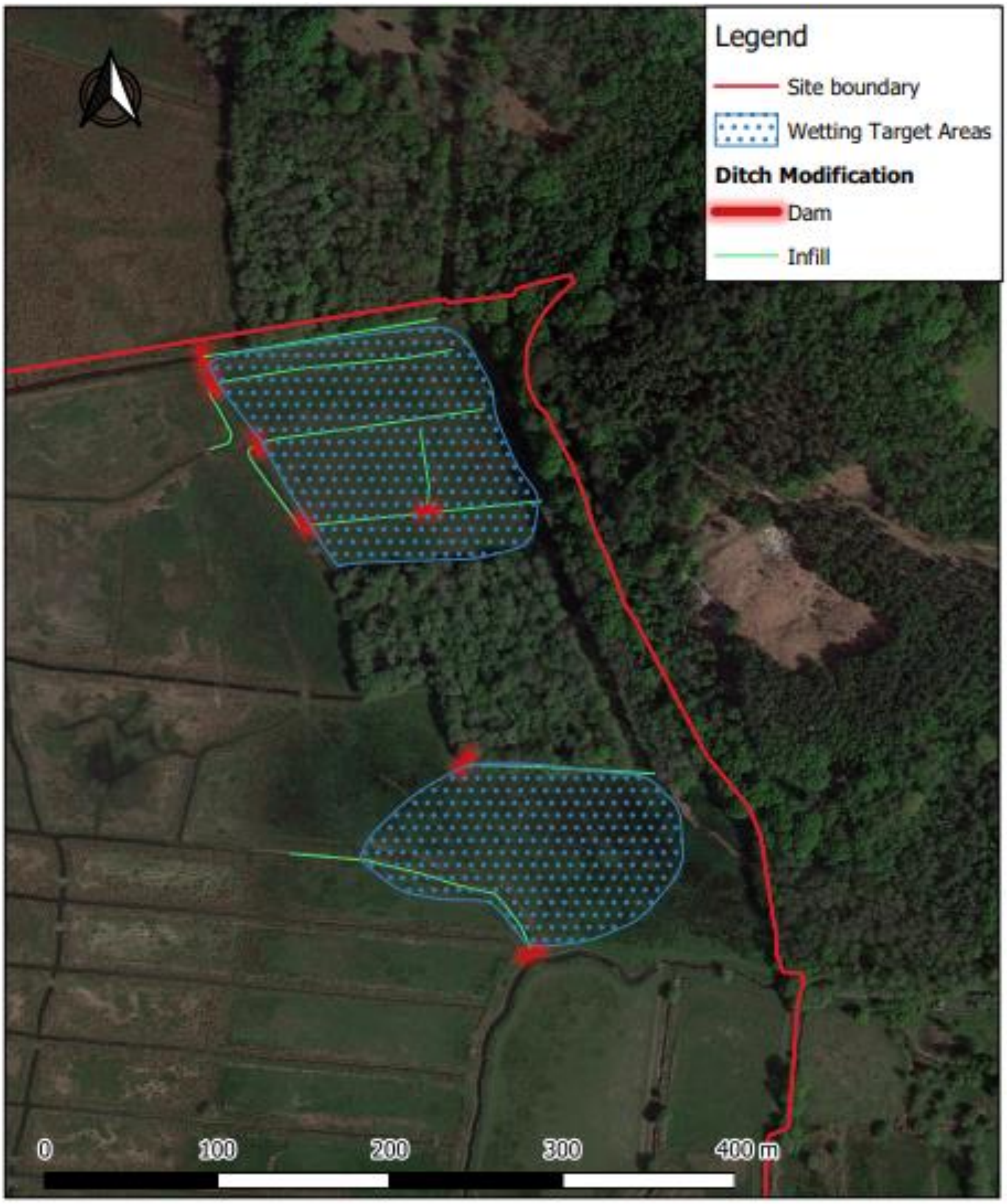


Figure K – Wetting target areas and ditch modifications, Amberley Wildbrooks North-East



	Wetting target areas and ditch modifications, Amberley Wildbrooks North East.	Natural England	30/03/2022	JRB	YELLOW SUB GEO
		Figure K	1:3,000	GRO	
			A4	1	
			Amberley		

Figure L – Amberley Wildbrooks. Lidar at 25cm resolution, providing indication of areas of inundation with sluice height = 1.3m AOD

Figure M – Catchments feeding the Arun. Amberley Wildbrooks