Framework Soil Management Plan:

Westhide Solar Farm, Herefordshire

Prepared for:
Ersun (Westhide SPV) Limited

Prepared by:
R W Askew BSC(Hons) MSc F.I. Soil Sci CSci
Askew Land & Soil Limited

Date:

21st October 2022

Project Number:
C923

Contract/Proposal No:	C923
Issue:	1
Author:	Rob Askew
Date:	21st October 2022

Our interpretation of the site characteristics is based on available data made during our desktop study. This desktop study has assessed the characteristics of the site in relation to the soil for soil management purposes. It should not be relied on for alternative end-uses or for other schemes. This report has been prepared solely for the benefit of Ersun (Westhide SPV) Limited.

Version Control Record			
Issue	**Description of Status**	**Date**	**Initials**
A	First draft	20/10/2022	RWA
1	First issue to Client	21/10/2022	RWA

CONTENTS

1 INTRODUCTION

1.1 Background

1.1.1 This Framework Soil Management Plan (FSMP) was commissioned by Ersun (Westhide SPV) Limited to set out a methodology for identifying and safeguarding the soil resources (topsoil and subsoil) on land required for the construction, operation and decommissioning of the proposed Westhide Solar Farm, Herefordshire ('the Site'), as shown on **Appendix 1**. The approximately 61.7 hectare (ha) Application Site is as shown on **Figure 1**. The approximate centre of the Site is located at British National Grid (BNG) reference SO 57726 44495.

1.1.2 It should be noted that only 24ha is proposed to locate the solar infrastructure, as shown on Figures 1-3. The remainder of the agricultural land within the Application Site does not have solar infrastructure located on it, and the land is being retained in its former agricultural use.

1.2 Competency

1.2.1 This FSMP has been prepared by a Chartered Scientist (CSci), who is a Fellow (F.I. Soil Sci) of the British Society of Soil Science (BSSS). The author meets the requirements of the BSSS Professional Competency Standard (PCS) scheme for '*Soil Science in Soil Handling and Restoration*', which is endorsed, amongst others, by the Department for Food and Rural Affairs, Natural England, the Science Council, and the Institute of Environmental Assessment and Management (IEMA) (see BSSS PCS Document 4)[1].

1.3 Aims and Objectives

1.3.1 The aim of the FSMP is to maintain, and where possible improve, the quality and quantity of soil resources (i.e., topsoil and subsoil) at the Site in its current physical condition (e.g., soil depth, soil texture, soil structure, soil drainage status), chemical condition (e.g., pH level, nutrient status of available phosphorus, available potassium, available magnesium, total nitrogen, and potentially toxic elements (PTE)) and soil organic matter (SOM) content, in order to maintain soil functions (see Section 1.4 below) during (i) the construction, (ii) operational, and (iii) decommissioning phases of the proposed solar farm.

1.3.2 Post-consent, the FSMP Plan will require updating in accordance with approved documentation by the appointed contractor prior to any construction commencing onsite. A detailed **Construction Phase Soil Management Plan** would be submitted to the Local Planning Authority (LPA) for approval prior to the start of construction and this will sit alongside the Construction Environmental Management Plan (CEMP), or similar. Prior to decommissioning, a final **Decommissioning Soil Management Plan** would be submitted to the LPA for approval and this would sit alongside the Decommissioning Plan. Prior to the end of

[1] British Society of Soil Science. Professional Competency Standard Scheme Document 4 'Soil Science in Soil Handling and Restoration'. Available online @ WWS-Complete-Competencies.pdf (soils.org.uk) Last accessed October 2022

decommissioning works, an **Aftercare Soil Management Plan** would be submitted to the LPA for approval. The 'Aftercare period' means a period of five years from compliance with the decommissioning condition or such other maximum period after compliance with that condition as may be prescribed by the LPA.

1.3.3 The objective of this FSMP is to set out appropriate methodology to:

(i) Determine the location, extent and quality of in-*situ* soil resources (topsoil and subsoil) at the Site prior to construction (i.e., baseline soil status) by carrying out a desk-based assessment of published information on climate, geology, soils, and Agricultural Land Classification (ALC), and by carrying out a detailed Soil Resource Survey (SRS) on Site prior to the commencement of construction;

(ii) Determine types (units) of soil according to their resilience to damage (e.g., compaction) during soil handling prior to the commencement of construction;

(iii) Produce maps showing the location and extent of soil resources (topsoil and subsoil) in separate units identified in (ii) prior to the commencement of construction;

(iv) Ensure vehicular traffic over the land is restricted to farm tracks, haul roads or on agricultural land in appropriate weather conditions and soil-wetness state during the construction, operational and decommissioning phases;

(v) Where necessary, to strip, store and respread soil resources in appropriate weather conditions and soil-wetness state during the construction and decommissioning phases;

(vi) Produce a plan for an appropriate level and period of Aftercare following decommissioning of the soil panels and infrastructure. This is to help ensure the agricultural land is reinstated and handed back to the landowner/farmer in its former quality, i.e., a similar condition to the baseline soil conditions to be determined by a SRS prior to commencement of construction of the proposed solar farm.

1.4 Soil Functions

1.4.1 Following an Ecosystem Services[2] approach, soil functions[3] are general capabilities of soils that are important for various agricultural, environmental, nature protection, landscape architecture and urban applications. Six key soil functions are:

1. Food and other biomass production;
2. Environmental Interaction: storage (including carbon sequestration), filtering, and transformation;
3. Biological habitat and gene pool;
4. Source of raw materials;
5. Physical and cultural heritage; and

[2] Department for Environment, Food and Rural Affairs (Defra)(2013) 'Ecosystem Services' . Available online @ https://www.gov.uk/guidance/ecosystems-services Last accessed September 2022

[3] ISRIC World Soil Information. Available online @ http://www.isric.org/about-soils/functions-soil Last accessed October 2022

6. Platform for man-made structures: buildings, highways.

1.5 Soil Receptor Sensitivity/Resilience

1.5.1 When considering soil as a growing medium for food and biomass production (i.e., the land at the Site is currently in agricultural production), and a habitat which supports microbial, plant, and animal life, its sensitivity to change is largely dependent on its **resilience to structural damage** during cultivation and soil handling (i.e., soil stripping, storing in stockpiles, and re-spreading). As detailed in numerous guidelines for soil handling, including the Code of Practice for Sustainable Management of Soil on Construction Sites (2009)[4], the key to understanding soil resilience to structural damage during soil handling is the interaction between **soil texture** and **soil moisture,** and the effect of this interaction on **soil structure**.

I. Soil Texture

1.5.2 Soil texture describes how the mineral element of soil comprises a mixture of mineral particles of different size, and a different **texture class** can be ascribed according to the proportion of (according to the British Standards Institution):

- clay (<0.002mm);
- silt (0.002mm to 0.06mm);
- sand
  - fine sand (0.06mm to 0.2mm);
  - medium sand (0.2mm to 0.6mm); and
  - coarse sand (0.6mm to 2.0mm).

II. Soil Moisture

1.5.3 The amount of moisture in the soil is known to affect key soil properties[5], including:

- **soil strength** (i.e., cohesion, internal friction). This is an important feature of soils in relation to their response to soil handling, and importantly to their resistance to fracture, compression, smearing, moulding and compaction; and

- **soil consistency**. This is commonly used to describe the 'feel' of the soil and includes properties such as friability, plasticity, stickiness and resistance to compression and shear. Changes in consistence are sometime described in terms of various limits (for which there are British Standard Institute (BSI) methodologies):

  - The Plastic Limit (or Lower Plastic Limit), i.e., the moisture content at which the soil changes from friable to plastic and is taken to be the minimum moisture content at which the soil can be puddled. This can be measured in a laboratory under

[4] Department for Environment, Food and Rural Affairs (2009). 'Code of Practice for the Sustainable Management of Soil on Construction Sites'. Available online @ https://www.gov.uk/government/publications/code-of-practice-for-the-sustainable-use-of-soils-on-construction-sites Last accessed October 2022

[5] Landon, J. R (Editor) (1991). Chapter 6 'Soil Physics' in 'Booker Tropical Soil Manual'. Longman Scientific & Technical

BS1377:1990 ‘*Methods of test for soils for civil engineering purposes’* by rolling threads of soil that shear longitudinally and transversely at approximately 3mm diameter; and

- The Liquid Limit (or Upper Plastic Limit), i.e., the water content at which soil cohesion is so reduced that the soil mass will flow when a force is applied

III. Soil Structure

1.5.4 The most important structural features of soils are the size, shape, and stability of the peds (soil aggregates), which influences how the soil is penetrated by water, air and roots. In general terms, a soil with a good structure is well drained and well aerated and are conducive to soil flora and fauna.

1.5.5 When a soil is handled when it is too wet (i.e., the moisture content is at or exceeds the lower plastic limit), then soil strength is reduced, and it becomes prone to structural damage, i.e., it has less resistance to compression and shear. By introducing a force, such as a mechanical excavator, the wet (or plastic) soil can lose its structure and become compacted.

1.5.6 In the worst-case scenario, a well-structured and aerated soil can become poorly structured (even massive) by soil handling when it is too wet (plastic). If it is stored in this state it can become anaerobic, with distinctive grey colouration and associated ‘sour’ smell. Poor drainage and anaerobic conditions cause stress and often death to plants (crops) and soil fauna.

1.5.7 The Ministry of Agriculture, Fisheries and Food (MAFF) ‘*Agricultural Land Classification (ALC) of England and Wales*’ system has developed a methodology for assessing the interaction between soil texture and soil moisture, and, in part, classifies agricultural land quality according to soil wetness, i.e., the interaction between soil topsoil texture, soil wetness class (WC)[6], and the number of days that the soil profile is predicted to be at field capacity (which is the amount of soil moisture or water content held in the soil after excess water has drained away).

1.5.8 For the purpose of the FSMP, the methodology for assessing soil wetness should be utilised to place the different soil types at the Site into one of three soil handling units which have different resilience (i.e., high resilience, medium resilience and low resilience) to structural damage according to their respective soil cohesion and soil strength and resistance to compression and smear at different soil moisture contents. These three categories of resilience should be related to the prevailing climate, namely Field Capacity Days (FCD), as set out in the Table 1.1 below.

[6] The Wetness Class (WC) of a soil is classified in Appendix II of Hodgson, J.M. (1977), The Soil Survey Field Handbook. Soil Survey and Land Research Centre, Technical Monograph No.5, according to the depth and duration of waterlogging in the soil profile and has six bands ranging from Wetness Class I (well drained) to Wetness Class VI (permanently waterlogged).

Table 1.1: Soil Handling Units		
Soil Handling Unit/Sensitivity	**Resilience to structural damage during soil handling**	**Soil Texture Class**
A (Green) – Low Sensitivity	High	Light textured soils: sand (S), loamy sands (LS), sandy loam (SL), sandy silt loams (SZL); where fewer than 225 Field Capacity Days (FCD) (Average Annual Rainfall (AAR) less than 1000mm).
B (Orange) – Medium Sensitivity	Moderate	Above textures where there are 225 FCD or more (AAR 1000mm or greater). Medium textured soils with less than 27% clay content: silt loam (ZL), medium silty clay loam (MZCL), medium clay loam (MCL), sandy clay loam (SCL); where there are 225 FCD or fewer (AAR 1000mm or less). Heavy textures below (i.e., more than 27% clay content) where fewer than 150 FCD (AAR less than 700mm).
C (Red) – High Sensitivity	Low	Medium textures above where there are more than 225 FCD (AAR greater than 1000mm). Heavy textures soils with more than 27% clay content: heavy silty clay loams (HZCL), heavy clay loam (HCL), sandy clay (SC) silty clay (ZC) clay (C); where FCD are 150 or more (AAR 700mm or greater). Organic and peaty soils.

1.6 Soil Health

1.6.1 As described in Section 2.3 in '*Agricultural Land Classification: 'Westhide Solar Farm, Herefordshire*' (Askew Land & Soil Project C790_v3, dated 26th November 2021), the installation of a solar photovoltaic (PV) array is a reversible, i.e., the agricultural land can be returned to its former agricultural productivity once the generation of renewable electricity has ceased, and the solar panels and associated infrastructure is removed. The agricultural land at the Site is currently used mainly for producing arable crops. In many respects, the management of the land under solar PV panels as grassland can benefit soil health, as described in detail in **Appendix 2**.

1.7 Structure of the Remainder of this Report

1.7.1 The remainder of this report is structured as follows:

- Section 2 – Preliminary Soil Resource Assessment;
- Section 3 – Framework Soil Management Plan – Construction, Operation and Decommissioning Phases; and
- Section 4 – Outline Aftercare Scheme.

2 PRELIMINARY SOIL RESOURCE ASSESSMENT

2.1 Background

2.1.1 Part 1 of this section of the FSMP sets out the findings of a desktop study of relevant published information on climate, topography, geology, soil, and Agricultural Land Classification information. This information below is summarised from a separate report '*Agricultural Land Classification: 'Westhide Solar Farm, Herefordshire*' (Askew Land & Soil Project C790_v3, dated 26th November 2021)

2.1.2 Part 2 sets out an appropriate Soil Resource Survey (SRS) which should be carried out prior to commencing the construction of the solar farm.

2.2 Desk-based Assessment of Site Characteristics and Soil Resources

2.2.1 This part of the report describes site characteristics which are pertinent to soil management, as follows:

- Climate (e.g., opportunity for soil handling in suitably dry conditions);
- Topography and gradient (e.g., to help identify potential risks of soil erosion by wind and/or water); and
- Information on geology and soils.

I. Climate

2.2.2 Interpolated climate data relevant to the determination of the Agricultural Land Classification (ALC) grade of land at the Site is given in Table 2.1.

Table 2.1: Interpolated ALC Climate Data for Westhide Solar Farm, Herefordshire

Climate Parameter	National Grid Reference SO 574 445	National Grid Reference SO 576 442	National Grid Reference SO 576 442
Average Altitude (m)	59	59	62
Average Annual Rainfall (mm)	676	677	678
Accumulated Temperature above 0˚C (January – June)	1451	1451	1447
Field Capacity Days (FCD)	145	145	146
Moisture Deficit (mm) Wheat	107	107	107
Moisture Deficit (mm) Potatoes	99	99	99
Best ALC Grade According to Climate	1	1	1

2.2.3 Of relevance to soil management, it is clear the Site receives relatively low levels of rainfall over the year, i.e., **Average Annual Rainfall (AAR) of between 676mm and 678mm**. The AAR is comparable to central lowland England, which is approximately 625-700mm[7].

2.2.4 In addition, the soil is predicted to be at field capacity (i.e., the amount of soil moisture or water content held in the soil after excess water has drained away) for between **145 and 146 Field Capacity Days (FCD) per year**. These values are comparable to central lowland England (i.e., 126-150 FCD)[8].

II. Topography and Gradient

2.2.5 The study area is gently undulated, at an elevation of between 70 metres (m) Above Ordnance Datum (AOD) at the highest point in the north-eastern region, and 57 mAOD at the lowest elevation in the west and centre regions of the Site. Gradient is not a limiting factor to agricultural land quality at this Site as gradient does not exceed 7° (re Table 1 of the ALC Guidelines). Likewise, micro-relief, i.e., complex changes in slope angle and direction over short distances, is not limiting to agricultural land quality at the Site.

III. Published Geology/Soil Parent Material

2.2.6 British Geological Survey (BGS) information available online[9] has been utilised to identify the Bedrock underlying the Site and any Superficial (Drift) Deposits over the Bedrock. This information helps to determine the parent material[10] from and within which a soil has formed.

2.2.7 The BGS information (1:50,000) describes how the Site is underlain mainly by the Raglan Mudstone Formation (siltstone and mudstone, interbedded) with a small band sandstone in the Raglan Mudstone Formation (sandstone) in the centre of the Site.

2.2.8 The bedrock is covered Head (clay, silt, sand and gravel) and Alluvium (clay, silt, sand and gravel) in the north and western regions of the Site. There are no superficial deposits in the south-eastern parts of the Site, where the soils are developed from mudstone.

IV. Published Information on Soil

2.2.9 The Soil Survey of England and Wales (SSEW) Provisional information for soils at the Site was gathered from the Soil Survey of England and Wales (SSEW) soil map of Midland and Western England (Sheet 3) at a scale of 1:250,000 and accompanying Bulletin '*Soils and their Use in Midland and Western England* (J. M. Ragg *et al,* Harpenden, 1984). This provisional soil map indicates that land at the Site is covered soils grouped in the Bromyard Association and Middleton Association.

[7] J.M. Ragg *et al* (1984). Page 20 in 'Soils and their use in Midland and Western England', Soil Survey of England and Wales Bulletin No.12, Harpenden
[8] J.M. Ragg *et al* (1984). Page 25 in 'Soils and their use in Midland and Western England', Soil Survey of England and Wales Bulletin No.12, Harpenden
[9] British Geological Survey 'Geology of Britain Viewer'. Available online @ http://www.bgs.ac.uk/discoveringGeology/geologyOfBritain/viewer.html Last accessed September 2022
[10] British Geological Survey. A 'parent material' is a soil-science name for a weathered rock or deposit from and within which a soil has formed. In the UK, parent materials provide the basic foundations and building blocks of the soil, influencing their texture, structure, drainage and chemistry. Available online @ Soil Parent Material Model - British Geological Survey (bgs.ac.uk) Last accessed September 2022

2.2.10 As described by the SSEW, the Bromyard Association consist of reddish fine silty soils over silty shales and soft siltstones and occasionally coarse loamy soils over sandstones. In dry districts, these soils, with moderate permeability, are waterlogged for short periods only in winter, the duration depending on slope or long-term land use (Wetness Class I to II).

2.2.11 The Middleton Association consist of reddish fine silty and fine loamy soils on soft red Devonian silty shales and siltstones. These soils are seasonally waterlogged (Wetness Class III) but respond well to artificial drainage.

V. Detailed Soil Resource Survey (SRS) and Agricultural Land Classification (ALC)

2.2.12 A detailed Soil Resource Survey (SRS) and Agricultural Land Classification (ALC) was carried out across the whole application area (Study Area) in June 2021. The SRS/ALC survey involved examination of the soil's physical properties at 60 auger-bore locations on an approximate 100 m grid pattern, at a sampling density of approximately 1 auger bore per ha. A log of the soil profiles recorded on Site is given as Appendix 1, and a description of one soil pit (soil Pit 1) is given as Appendix 2, in Askew Land & Soil Limited's Agricultural Land Classification (C790_v3, dated 26th November 2021).

2.2.13 The texture of the topsoil was determined by hand-texturing, as described in Natural England's Technical Information Note 037 'Soil Texture'[11], and by laboratory particle size analysis (see below).

VI. Topsoil Particle Size Analysis

2.2.14 To substantiate topsoil texture determined during the SRS/ALC survey by hand-texturing, two samples of topsoil were collected over the Site (i.e., auger bore locations 4 and 56, as shown in **Figure 1**. The two topsoil samples were sent to an accredited laboratory for analysis of particle size distribution (PSD), based on the British Standard Institution particle size grades. The certificate of analysis is provided as Appendix 3 in Askew Land & Soil Limited's Agricultural Land Classification (C790_v3, dated 26th November 2021). The findings of the PSD analysis are reproduced in Table 2.1 below:

Table 2.1: Topsoil Texture (re Table 10, ALC Guidelines)

Topsoil Sample Location (See Fig. 1)	% sand 0.063-2.0 mm	% silt 0.002-0.063 mm	% clay <0.002 mm	ALC Soil Texture Class
AB4	8	32	60	Clay
AB56	34	46	20	Medium Clay Loam

[11] Natural England's Technical Information Note 037 'Soil Texture'. Available online at http://publications.naturalengland.org.uk/publication/32016

VII. Soil Handling Units

2.2.15 By applying the criteria set out in Table 1.1 ‘*Soil Handling Units*’ against the climate data (i.e., 145-146 FCD and 676mm-678mm AAR) and soil textures, the topsoils and subsoils at Westhide Solar Farm may be assigned to Soil Handling Units as shown on **Figure 3**.

Unit 1

2.2.16 The part of the Application Area which will be covered by solar infrastructure measures approximately 24.0ha, as shown on **Figure 1**. This area, which correlates with agricultural land predominantly in Subgrade 3b (see **Figure 2**) has medium clay loam or medium silty clay loam topsoil and subsoil (<27% clay). Therefore, in a climate area with an Average Annual Rainfall (AAR) of between 676mm and 678mm between 145 and 146 Field Capacity Days (FCD) per year, these soils may be grouped into a single soil handling unit (i.e., Unit 1). This soil handling unit is assessed as being of **medium sensitivity**, with **moderate resilience to structural damage** during soil handling, as coloured orange on **Figure 3**, following the criteria in Table 1.1.

3.0 FRAMEWORK SOIL MANAGEMENT PLAN

3.1 Introduction

3.1.1 This section outlines general requirements for vehicular traffic over agricultural land, and where necessary soil handling, i.e., soil stripping, storage and placement/re-spreading, during the construction, operational and decommissioning phases of the proposed solar farm.

3.1.2 Best practice for solar farm design and layout and good practice in construction set out in the BRE National Solar Centre's (2014) 'Agricultural Good Practice Guidance for Solar Farms' (Editor J Scurlock) should be followed (available online @ https://www.bre.co.uk/filelibrary/nsc/Documents%20Library/NSC%20Publications/NSC_-Guid_Agricultural-good-practice-for-SFs_0914.pdf).

3.2 General Requirements for Soil Handling

3.2.1 The quality and quantity of soil resources (topsoil and subsoil) within the Site shall be maintained by following the approach of the DEFRA '*Code of Practice for the Sustainable Management and Use of Soil on Construction Sites*' (Defra, September 2009) (available online @ https://www.gov.uk/government/publications/code-of-practice-for-the-sustainable-use-of-soils-on-construction-sites). This is to achieve the following principal objectives:

(i) The avoidance of unnecessary damage to all soil layers, especially by compaction and smearing;

(ii) The maintenance of a reasonable degree of fissuring, drainage and aerobic conditions in stored soils;

(iii) The reasonable replication of the original sequence of textural horizons and permeability of the soil profile when the materials are reinstated, based on a target restoration profile (i.e., the original/baseline soil profile determined in the SRS prior to commencement of construction);

(iv) The preservation of soil biodiversity and Soil Organic Matter (SOM).

3.2.2 All soil and soil forming materials shall be handled in accordance with the Institute of Quarrying's Good Practice Guide for Handling Soil (2021), Sheets A – E (handling soil using backacters and dumptrucks). As per https://www.quarrying.org/soils-guidance

3.2.3 Where relevant, handling peaty/organic soils should aim to maintain peatland ecosystem services (such as carbon sequestration), minimise risks to ecosystem services (such as the loss of habitat, water quality, storage or ground stability, and retain excavated peat in storage as close to the point of extraction as practicable.

3.2.4 As described in Section 1.5, when a soil is handled when it is too wet (i.e., the moisture content is at or exceeds the lower plastic limit), then soil strength is reduced, and it becomes prone to structural damage, i.e., it has less resistance to compression and shear. By introducing a force, such as a mechanical excavator, the wet (or plastic) soil can lose its structure and become compacted. As described in Best Practice produced by the Institute of Quarrying12 (see '*Supplementary Note 4 – Soil Wetness'* given as **Appendix 4**),

'…*The degree of effect due to soil handling is likely to vary between the soil textural class, structural condition, and organic matter content, the local climate and daily weather conditions, but also between the types and size of machinery used and handling practice adopted. The primary cause of compaction arises from the compression caused by trafficking by the machinery and stockpiling of soil in storage*. *Whilst some degree of remedial actions might be possible, experience has demonstrated that minimising compaction by handling soil in a dry condition is the more effective and reliable, and likely most cost-effective option.'*

3.2.5 Advice is given in **Appendix 4** on the general timing of operations. A field-based determination of when the actual operations should start, cease or restart based upon actual soil wetness is provided. The SMP should carefully consider the timing of (i) vehicles trafficking over the land and soil, and (ii) land-work and soil handling operations. The SMP should provide mitigation measures to avoid or reduce damage to soil structure, especially when the soil is wet, including a method for determining when land-work and soil handling operations should start, cease and restart based upon actual soil wetness. This may include determination of the Plastic Limit (see Section 1.5 (III) above) of the different soil types/units should be determined in a laboratory to British Standard 1377: 1990 '*Methods of test for soils for civil engineering purposes*'.

3.2.6 From an '*Indicative on-average months when vegetated mineral soils might be in a sufficiently dry condition according to geographic location, depth of soil and clay content*' (Table 4.1, **Appendix 4**), the soil at Westhide Solar Farm is predicted to be in a sufficiently dry condition as follows (Note: this is a predicted period over the year when the soil is most likely to be suitable for handling. However, guidance in paragraph 3.2.5 (above) for ceasing and restarting work during this period):

(i) Soil Handling Unit 1 (Moderate Resilience): Less than 27% clay in Climatic Zone 2 = Early May to Early November.

3.2.7 Throughout the period of working, restoration and Aftercare, the operator shall take all reasonable steps to ensure that drainage from areas adjoining the Site is not impaired or rendered less efficient by the permitted operations.

3.2.8 The operator shall take all reasonable steps, including the provision of any necessary works, to prevent damage by erosion, silting or flooding and to make proper provision for the disposal of all water entering, arising on or leaving the Site during the permitted operations.

[12] Dr R N Humphries (2021) 'Good Practice Guide for Handling Soils in Mineral Workings'. Institute of Quarrying. Available online @ https://www.quarrying.org/soils-guidance Last accessed October 2022

3.2.9 Any oil, fuel, lubricant, paint or solvent within the site shall be so stored as to prevent such material from contaminating topsoil, subsoil, soil forming material, or reaching any watercourse.

3.2.10 Throughout the period of working, restoration and aftercare, the operator shall have due regard to the need to adhere to the precautions for preventing the spread of plant and animal diseases', published by the Government (available online @ https://www.gov.uk/guidance/prevent-the-spread-of-harmful-invasive-and-non-native-plants).

3.3 Ground Preparation

3.3.1 Prior to stripping agricultural topsoil (e.g., access roads, inverters, cable-routes and the sub-station), all above-ground vegetation should be cleared off Site in the areas to be stripped, so that the amount of vegetation within the topsoil strip is minimised (this is to minimise the amount of anaerobic decomposition of vegetation / organic matter that will occur within the topsoil stockpiles).

3.4 Haul Roads

3.4.1 Vehicles, e.g., heavy goods vehicles (HGV) delivering construction materials should not be permitted to traffic over agricultural land and be restricted to public highways, farm tracks, haul roads and storage compounds.

3.4.2 Construction machinery such as piling machines and telehandlers should not traffic over agricultural land which is left in-situ (i.e., where the topsoil has not been stripped) when the soil is too wet. This is to avoid causing soil structural damage by compaction and smearing, and to avoid creating ruts/vehicle wheelings at the ground surface. See 'General Requirements for Soil Handling' above for guidance on appropriate soil moisture content for soil handling.

3.4.3 It is recommended using temporary haul road systems for installing the solar panels to minimise structural damage to the soil. This could involve the a heavy-duty composite plastic trackway system on a thin layer of stone, or no stone, e.g., GroundGuards Xtreme Mats 4mx2m Large Mats (online @ https://www.ground-guards.co.uk/product/xtreme-4m-x-2m-mat/), or SignaRoad 3mX2m Large Mats (online @ https://www.ground-guards.co.uk/product/signaroad/) or other similar geotextile material.

3.4.4 Where a peaty/organic layer is present, construction machinery, e.g., piling machines and telehandlers, should not traffic directly over agricultural land in any weather. In this case, a temporary haul road system is required to prevent structural damage, shrinkage, or erosion of the peat/Soil Organic Matter (SOM).

3.5 Soil Stripping

3.5.1 Before any part of the Site is excavated or is built upon, or used for the stacking of topsoil, subsoil or overburden, or as a machinery dump or plant yard, or for the construction of a road, all available topsoil and subsoil shall be stripped from that part.

3.6 Soil Storage

3.6.1 Bunds for the storage of soils shall conform to the following criteria:

(i) Topsoil and subsoil (referred to as overburden) in the different soil handling units shall be stored separately.

(ii) Where continuous bunds are used, dissimilar soils shall be separated by a third material.

Soil with Medium Sensitivity/Moderate Resilience (coloured orange on **Figure 3**)

(iii) Topsoil and subsoil with medium sensitivity/moderate resilience shall be stored in bunds which do not exceed 4m in height.

(iv) Materials shall be stored like upon like, so that topsoil shall be stripped from beneath subsoil bunds.

(v) All storage bunds containing soils which are intended to remain in situ for more than 6 months or over the winter period are to be grassed over and weed control and other necessary maintenance carried out. The seed mixture and the application rates are to be set out in the SMP.

(vi) All topsoil and subsoil shall be retained on the Site.

4.0 OUTLINE AFTERCARE SCHEME

4.1.1 Following the decommissioning of the solar farm, removal of the solar panels and associated infrastructure, and restoration of land and soil to agriculture, there shall be a period of Aftercare. The Operator shall prepare a schedule of Aftercare maintenance, to include soil testing, appropriate to the target for soil restoration for a period up to five years.

4.1.2 On completion of the restoration works the restored soils will be in a fragile condition. The objectives of the Aftercare period are to:

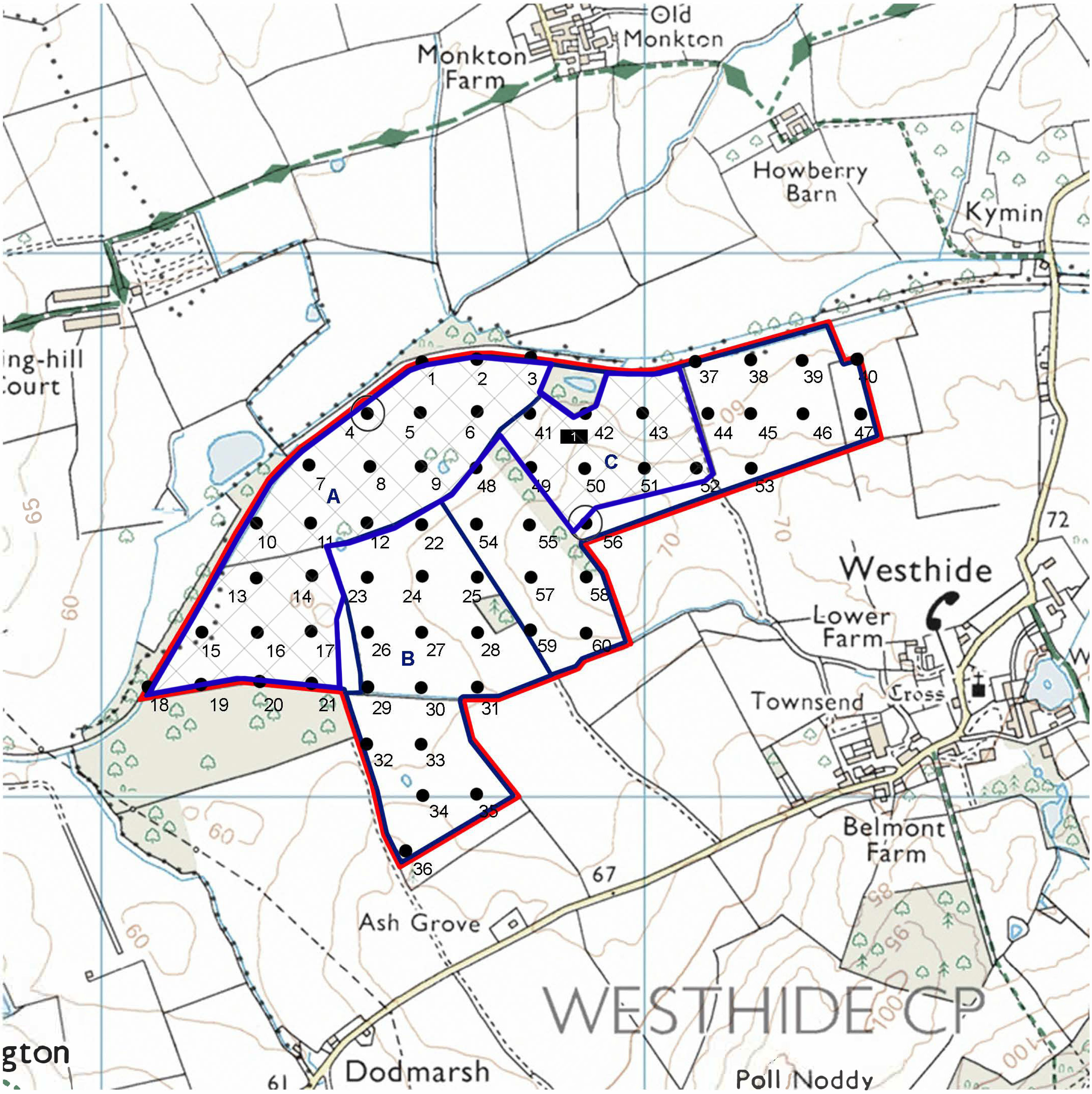
(i) Soil cultivation and establishment of vegetation cover with a good rooting system such as grass as soon as possible after reinstatement of the soils (year 1);

(ii) At the end of year 1, the land should be checked for settlement and any hollows should be infilled by scraping back the topsoil and infilling with subsoil compatible with the subsoil beneath, before reinstating the topsoil;

(iii) Soil cultivation and vegetation management (year 2-5). This is to check the condition of the soil and grass (or other crop); and amelioration work is undertaken as necessary, e.g., infilling of settlement hollows, subsoiling to improve soil structure and to correct any patchy areas of poor growth; and

(iv) Consideration of the drainage of the restored agricultural land to prevent flooding.

Figures



Site Parcel

Area covered by solar infrastructure

Study Area

Auger location

Topsoil Sample

Soil Pit

N

Client

Ersun (Westhide SPV) Ltd

Project No C923

Dwg. No 01

Scale NTS

Date 21/10/2022

Drawn By ELA

Figure 1

Sample Locations

Project Name

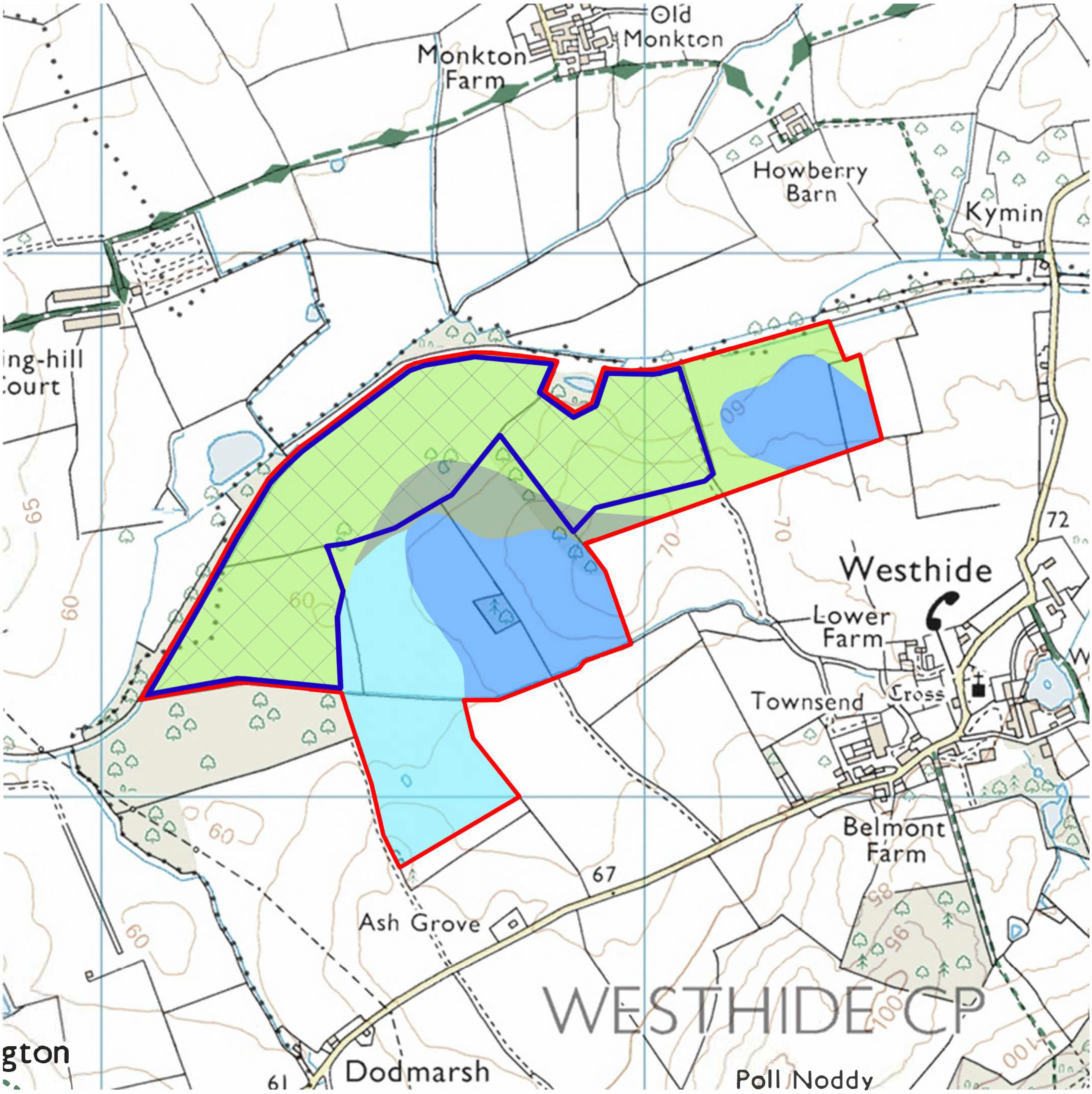
Westhide, Herefordshire

R W Askew BSc(Hons) MISoilSci MSc CSCi

The Old Stables, Upexe, Exeter, EX5 5ND

Tel: 07753 227 224

Email: rw.askew@btinternet.com



ALC Grade

- Grade 1
- Grade 2
- Subgrade 3a
- Subgrade 3b
- Grade 4
- Grade 5
- Non-agricultural

- Study Area
- Area covered by solar infrastructure

N

Client

Ersun (Westhide SPV) Ltd

Project No C923

Dwg. No 01

Scale NTS

Date 21/10/2022

Drawn By ELA

Figure 2:

Agricultural Land Classification

Project Name

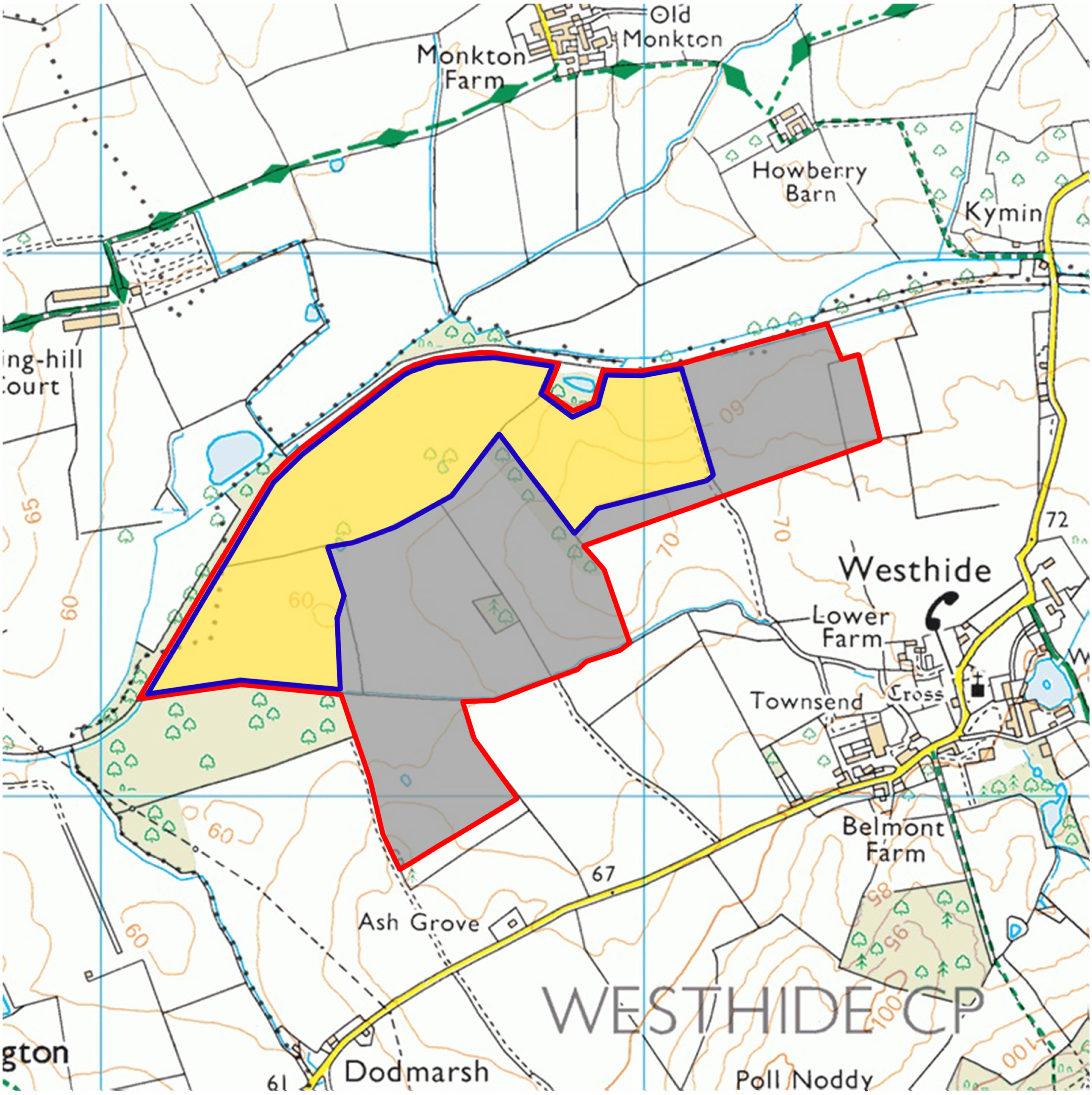
Westhide, Herefordshire

R W Askew BSc(Hons) MISoilSci MSc CSci

The Old Stables, Upexe, Exeter, EX5 5ND

Tel: 07753 227 224

Email: rw.askew@btinternet.com



Soil Handling Units:

- High Resilience (Unit 2)
- Medium Resilience (Unit 1)
- Low Resilience
- Land to be retained in its former agricultural use
- Study Area
- Area covered by solar infrastructure

N

Client

Ersun (Westhide SPV) Ltd

Project No C923
Dwg. No 01
Scale NTS
Date 21/10/2022
Drawn By ELA

Figure 3:

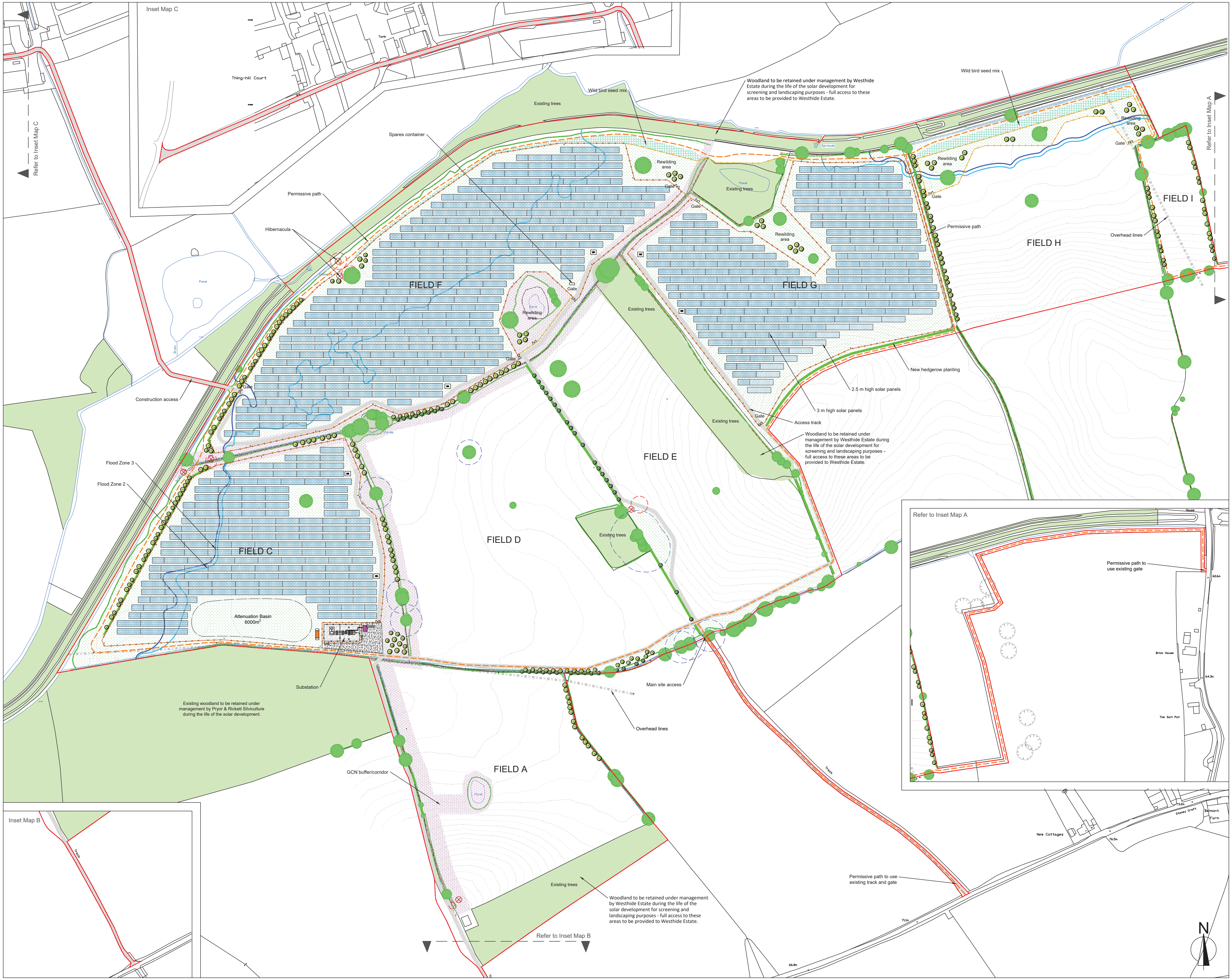
Soil Handling Units (Topsoil)

Project Name:

Westhide, Herefordshire

R W Askew BSc(Hons) MISoilSci MSc CSci
The Old Stables, Upexe, Exeter, EX5 5ND
Tel: 07753 227 224
Email: rw.askew@btinternet.com

Appendix 1: Masterplan



GENERAL NOTES:

1. ALL DIMENSIONS AND LEVELS SHALL BE CHECKED ON SITE PRIOR TO CONSTRUCTION WORK COMMENCING.
2. ALL LANDSCAPE DRAWINGS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ENGINEER'S AND ARCHITECT'S DRAWINGS AND SPECIFICATIONS.
3. ALL DRAWINGS TO BE READ IN CONJUNCTION WITH THE LANDSCAPE SPECIFICATION.
4. ANY DISCREPANCY CONCERNING THE DRAWINGS SHOULD BE REFERRED TO THE CA IMMEDIATELY.
5. ALL DIMENSIONS IN MILLIMETRES UNLESS NOTED OTHERWISE.
6. ALL LEVELS IN METRES.
7. DO NOT SCALE OFF THIS DRAWING.
8. EXISTING SERVICE ALIGNMENTS SHALL BE CHECKED ON SITE BY THE CONTRACTOR PRIOR TO CONSTRUCTION WORK COMMENCING.

Site boundary

Existing
- **Existing woodland**
- **Existing tree (surveyed)**
- Existing hedgerow (surveyed) all to be retained and enhanced to 3m high winter cut height
- **Existing overhead utility/electricity lines** (surveyed)
- **Existing water course / pond**
- Existing tree planting retained and enhanced
- Buffer zone for ancient and veteran trees
- Flood zone 2
- Flood zone 3

Proposed
- Proposed tree planting (*Indicative - refer to Landscape Mitigation and Enhancement Plans*)
- Poor quality trees to be removed (please refer to arb survey, drwg # 210409-WSS-SP-AM)
- New species-rich hedgerow planting
- Proposed species-rich grassland
- Proposed wild bird seed mix grassland (0.5 ha total)
- Great Crested Newt (GCN) ecological buffer
- Hibernacula
- 2.5 m high post and wire fencing to have mammal gates for mammal access
- 2.4 m high palisade fencing *(around DNO customer substation)*
- 1.2 m high timber post and rail fencing *(to rewilding areas)*
- Access track
- CCTV camera
- Inverter transformer unit
- DNO switch housing
- Customer substation
- Substation hardstanding
- Proposed solar panels 2.5 m high
- Proposed solar panels 3 m high
- Permissive path

DRAWING NOTES:

Field G to have 2.5 m high solar panels along the southern edge. 3m high solar panels to be used elsewhere.

During the design development process Field B was removed from the proposals and, therefore, it is not shown or referred to on the Masterplan.

Rev:	Date:	Description:	Drawn	Ch'd
A	21/09/2021	Ecology and landscape additions as per comments	GS	JH
B	04/10/2021	Site access and permitted path amended as per comments	GS	JH
C	01/11/2021	Contours added	GS	JH
D	16/11/2021	Substation relocated and redline boundary updated. Minor amendments as per comments	JH	AS
E	18/11/2021	Redline boundary update	JH	AS
F	23/11/2021	Redline boundary update	JH	AS
G	14/06/2022	Updates as per local authority comments	JH	AS
H	20/06/2022	Minor amendments as per comments	JH	AS
I	23/06/2022	Amendments to GCN corridor	JH	AS
J	26/09/2022	Removal of panels in Fields H and I	JH	AS
K	26/09/2022	Updated mitigation and permissive path	JH	AS
L	27/09/2022	Updated mitigation and permissive path	JH	AS
M	11/10/2022	Removal of panels in Fields A, D and E	JH	AS
N	18/10/2022	Updated panel layout	JH	AS
O	20/10/2022	Updated panel layout - Attenuation basin added	JH	AS

THE Landmark PRACTICE
1 Theynes Court
Long Ashton Business Park
Yanley Lane
Bristol BS41 9LB
United Kingdom

Tel: +44 (0)117 923 0455

enquiries@thelandmarkpractice.com
www.thelandmarkpractice.com

CLIENT
ERSUN (WESTHIDE SPV) LTD

PROJECT
WESTHIDE SOLAR

TITLE
MASTERPLAN

Status:	Drawn:	Checked:
PLANNING	GS	JH
Scale: 1:2,000@A1	Date: 20.07.21	Approved: GM
Drawing Number: 3352_L_GA_0_01		Rev: O

Appendix 2: Soil Health

Soil Health

[1]**Soil Health**

Soil health can be defined as a soil's ability to function and sustain plants, animals and humans as part of the ecosystem. There are five main factors that impact the health of the soil and can have a large influence over its capability and resilience to function, they are:

1. Soil structure
2. Soil chemistry
3. Organic matter content
4. Soil biology
5. Water infiltration, retention and movement through the profile

A healthy soil will have a good combination of all these factors, whilst an unhealthy soil will have a problem with at least one of these. A healthy soil has plenty of air spaces (voids) within it, maintaining aerobic (oxygenated) conditions. A healthy soil will provide a buffer to extremes in temperature (as it allows movement of gases between the soil and the air above) and rainfall (as the soil is well drained). This helps to reduce the impact of extreme weather events.

When a soil has limited air spaces, anaerobic conditions (i.e. oxygen depleted) dominate, leading to waterlogging and stagnation of roots and the proliferation of anaerobic microbes and denitrification (i.e. the loss of nitrogen from the system). A healthy soil will filter water slowly, retaining the nutrients and plant protection products (PPP) applied to the crop. If rainfall moves through the soil profile too quickly, or if it is prevented from entering the soil through compaction or soil sealing, surface runoff increases, taking soil, nutrients and PPP with it. This also increases the risk of flooding.

Summary: A healthy soil has a well-developed soil structure, where soil particles are aggregated into soil peds (structural units) separated by pores or voids. This allows the free movement of water (precipitation) through the soil and facilitates gaseous exchange between the plant roots and the air. These soils are well aerated (oxygenated), which encourages healthy plant (crop) growth and an abundance of soil fauna and aerobic microbes. These soils often have high amounts of soil organic matter (SOM), associated with an accumulation of plant and animal matter, and thus are a good store of soil organic carbon (SOC).

[2]**Soil Organic Matter (SOM)**

Soil carbon is predominantly derived from carbon fixed by plants. This enters the soil as litter or dung, root tissue turnover, root exudates and carbon allocated to mutualistic fungi. Carbon is mixed into the soil and transformed by biological processes, but some is also carried down the profile by downward movement of rainwater. Where these biological processes are retarded, and mixing does not occur, soils can develop organic layers on their surface, and in waterlogged conditions these become deep peat deposits. Soils on limestone and chalk may also contain inorganic carbon as carbonate compounds. Some ammonia oxidising bacteria also fix carbon.

In all habitats, most carbon is stored in soils in the form of soil organic matter (SOM), and peaty soils in particular, are major stores of carbon (Natural England, 2012). Globally, soils contain more organic carbon than the vegetation and atmosphere combined (Swift, 2001). Ten billion tonnes of organic carbon are estimated to be stored in United Kingdom (UK) soils, with over half stored in peat. Soils in England and Wales store 2.4 billion tonnes of carbon of which 58% is in the top 30 cm of soil

(Department for Environment and Rural Affairs (Defra), 2011). Soil carbon is stored in fresh and decomposing litter and as longer-lasting material stored in soil particles, in a complex with clays or in anaerobic waterlogged conditions. England's deep and shallow peaty soils are estimated to contain over 580 million tonnes of carbon (Natural England, 2010), but in surface layers, denser mineral soils contain more carbon than peaty soils (Emmett et al, 2010). In peat, anaerobic conditions caused by waterlogging prevent the breakdown of phenols, which build up and inhibit other decomposition enzymes, while plants producing tannins also inhibit enzyme activity (Defra, 2010A). In lowland fens where waterlogging is due to groundwater, peat can be formed from a wide range of plants that are found in waterlogged conditions. In bogs, where water supply is derived from precipitation only, peat is predominantly formed from Sphagnum mosses and Cotton-grass (Eriophorum spp.), with minor components of other plants reflecting past drier conditions or periods (Natural England, 2013).

Cultivation of soils promotes the release of stored soil carbon by mineralisation of soil organic matter to carbon dioxide (CO^2) (Lal, 2004). The conversion of grassland to arable cropland was the largest contributor to soil carbon losses from land use change in the UK between 1990 and 2000 (Ostle et al, 2009). Carbon in the subsoil (below 15 cm for grassland or 30 cm plough layer for arable) is more stable and less influenced by surface processes (Defra, 2011A).

On mineral soils, Environmental Stewardship is estimated to have reduced England's agricultural greenhouse gas (GHG) emissions by around 11% a year (Defra, 2007), mainly through increases in soil organic carbon delivered by options such as buffer strips that take land out of cultivation.

The greatest benefits in terms of increase in soil carbon can be realised through land use change from intensive arable to grasslands (Conant et al, 2001), woodlands or some biofuels (Defra, 2003). Avoiding disturbance of undisturbed soils, and changing land use to grassland, heathland, woodland or wetland is likely to deliver carbon storage benefits (Natural England, 2012A), including on organo-mineral soils (Defra, 2011B). Conversion from arable to grassland may, however, be offset to some extent by methane emissions associated with livestock production.

There is ongoing research into how grasslands can be managed to increase carbon storage. Defra Project BD5003 (Ward et al, 2006) found that older, and particularly semi-improved grasslands are important carbon stores compared to intensively managed, improved grasslands.

Soil organic matter is a key indicator of many desirable soil functions. It helps to maintain soil structure, provides and stores nutrients, supports biological activity, increases water retention and stores carbon (Gobin et al, 2011). Early results from Natural England's project BD5001 (Natural England, 2016) indicate that grassland soils in good structural condition tend to have more organic matter than soils in moderate or poor condition. Soils with more organic matter tend to be more resistant and resilient to damage, with this effect interacting with soil texture and biological properties (Defra, 2010C).

The best opportunities to increase carbon storage come from planting perennial crops, returning crop residues to the soil and application of organic manures (Defra, 2014).

In the short to medium term (up to 10 years) zero tillage does not result in increased levels of soil carbon compared to conventional tillage (Defra, 2014), but global data suggests that zero tillage results in more total soil carbon storage when applied for 12 years or more (Steinbach and Alvarez, 2006).

Summary: The greatest benefits in terms of increase in soil organic matter (SOM), and hence soil organic carbon (SOC), can be realised through land use change from intensive arable to grasslands. Likewise, SOM and SOC are increased when cultivation of the land for crops (tillage) is stopped and the land is uncultivated (zero tillage). Global evidence suggests that zero tillage results in more total soil *carbon storage when applied for 12 years or more. Therefore, there is evidence that conversion of land from arable to grassland which is uncultivated over the long-term (>12 years), such as that under solar PV arrays, increases SOC and SOM.*

[3]**Biodiversity in the Soil**

Biological function of soils can be enhanced by simple approaches that can be integrated into real farm systems, including adapting organic matter management, cultivation approaches and cropping, with likely benefits to both farming and the environment (Natural England, 2012B).

Soils are habitats for millions of species, ranging from bacteria, fungi, protozoa, and microscopic invertebrates to mites, springtails, ants, worms and plants. It is estimated that more than 1 in 4 of all living species in earth is a strictly soil-dwelling organism (Decaens et al, 2006).

A single gram of soil can contain a billion bacterial cells from up to 10,000 species (Torsvik et al, 1990, 2002).

Soil biota are strongly influenced by land management. Modern farming has sought to replace many soil biota functions with less sustainable technological solutions, which lead to loss of soil biodiversity (Stockdale et al, 2006; Defra 2010c). For example, changes in land management practice and land use can have large effects on soil biodiversity over relatively short-time scales. Reducing the intensity of management, introducing no-tillage management and converting arable land to pasture usually has substantial beneficial effects (Spurgeon et al, 2013).

Microbial diversity in the UK reflects soil conditions, especially pH, but also vegetation, climatic and other environmental factors. Distinct specialist communities occur in more extreme soils with low diversity (Griffiths et al, 2012).

Current levels of understanding of soil biodiversity is low. Out of approximately 11 million species of soil organisms, an estimated 1.5% have been named and classified (Turbé et al, 2010) and most ecological roles are understood only at a general level.

Summary: Soils are habitats for millions of species, ranging from bacteria, fungi, protozoa, and microscopic invertebrates to mites, springtails, ants, worms and plants. Soil biota are strongly influenced by land management. Modern farming has led to the loss of soil biodiversity. Changes in land management practice and land use can have large effects on soil biodiversity over relatively short-time scales. Reducing the intensity of management, introducing no-tillage management, and converting arable land to pasture, such as grassland under solar PV arrays, has substantial beneficial effects.

[4]**Soil Structure**

Soil structure is defined by the way individual particles of sand, silt, and clay are assembled. Single particles when assembled appear as larger particles, called aggregates or peds. Soil structure is most usefully described in terms of grade (degree of aggregation), class (average size) and type of aggregates (form), or shape. The degree of aggregation ranges from structureless, through weak and moderate structure to strong structure. The shape of soil aggregates/peds is often describes as platy, prismatic/columnar, angular/subangular, or granular/crumb structure (Farming and Agriculture Organisation, FAO).

Soil structure refers to the way that soils are bound together. In a well-structured soil, water and air can move freely through cracks and pores. But a poor soil structure prevents water and air movement, and increases the risk of runoff (Defra, 2008). Soil structure can be improved by increasing soil organic matter (SOM) (Cranfield University, 2001).

The Game and Wildlife Conservation Trust's Allerton Project (Game and Wildlife Conservation Trust, 2020) has been involved in investigating the sustainable intensification of agriculture through different experiments. Some research has focused on moving away from conventional agricultural practice, with greater emphasis on no-tillage ('no-till'). One of the fields at the Allerton Project has not been ploughed for the last 14 years and the soil structure is visibly different compared to other soils on the farm. No-till systems can help improve soil fertility, create changes to the structure and properties of the soil due to the stability of the environment, and enhance soil biology. Over time the no-till field has had the highest yields compared to the conventional field equivalent on the farm.

Summary: In a well-structured soil, water and air can move freely through cracks and pores. But a poor soil structure prevents water and air movement, and increases the risk of runoff. Soil structure is improved when the land is uncultivated over time (no tillage), and when soil organic matter content (SOM) is increased through the accumulation of plant material, such has roots, in the soil. The aerobic (oxygenated) decomposition of SOM helps to bind soil particles together into aggregates (peds). Therefore, the conversion of land which is tilled for arable to long-term grassland (no tillage), such as that under solar PV arrays, improves soil structure over time.

References

CONANT, R. T., PAUSTIAN, K., & ELLIOTT, E. T., (2001). Grassland Management and Conversion into Grassland: Effects On Soil Carbon, Ecological Applications, 11(2), 343–355

CRANFIELD UNIVERSITY. 2001. A Guide to Better Soil Structure. Available online @ http://adlib.everysite.co.uk/resources/000/094/894/soilstructure_brochure.pdf Last accessed July 2020

DECAENS, T., JIMENEZ, J.J., GIOIA, C., MEASEY, G.J. & LAVELLE, P. 2006. The values of soil animals for conservation biology. European Journal of Soil Biology, 42, 23-38.

DEFRA. 2003. Development of economically & environmentally sustainable methods of C sequestration in agricultural soils - SP0523. Available online @ http://randd.defra.gov.uk/Default.aspx?Module=More&Location=None&ProjectID=10946 Last accessed in July 2020

DEFRA. 2007. Research into the current and potential climate change mitigation effects of Environmental Stewardship - BD2302. Available online @ http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=%200&ProjectID=14413 Last viewed July 2020

DEFRA. 2008. Maintaining and improving soil structure. Available online @ http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=2RRVTHNXTS.7P2ROC7MW33Z8 Last accessed July 2020

DEFRA. 2010A. To evaluate the potential of technologies for increasing carbon storage in soil to mitigate climate change. Sub-project A of Defra project SP1605: studies to support future soil policy. Available online @ http://randd.defra.gov.uk/Document.aspx?Document=SP1605_9702_FRP.pdf Last accessed July 2020

DEFRA. 2010B. Soil Functions, Quality and Degradation – Studies in Support of Implementation of Soil Policy - SP1601. Subproject A: Review of current knowledge on the impacts of climate change on soil processes, functions and biota. Available online @ http://randd.defra.gov.uk/Document.aspx?Document=SP1601_9491_FRP.pdf Last accessed July 2020

DEFRA. 2010C. Review and initial assessment of what makes some soils more resilient to change and how this resilience can be conferred to other soils. Sub-project D of Defra Project SP1605: Studies to support future Soil Policy. Available online @ http://randd.defra.gov.uk/Document.aspx?Document=SP1605_9702_FRP.pdf Last accessed July 2020

DEFRA. 2011A. Review of the evidence base for the status and change of soil carbon below 15 cm from the soil surface in England and Wales. Sub-Project iii of Defra Project SP1106: Soil carbon: studies to explore greenhouse gas emissions and mitigation. Department for Environment, Food and Rural Affairs, Research project final report. Available online @ http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=17323 Last accessed July 2020

DEFRA. 2011B. Assessment of the response of organo-mineral soils to change in management practices Sub-Project ii of Defra Project SP1106: Soil carbon: studies to explore greenhouse gas emissions and mitigation. Department for Environment, Food and Rural Affairs, Research project final report. Available online @ http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=%200&ProjectID=17323 Last accessed July 2020

DEFRA, 2014. Capturing cropland and grassland management impacts on soil carbon in the UK Land Use, Land Use Change and Forestry (LULUCF) inventory - SP1113. Available online @ https://core.ac.uk/display/33450527 Last accessed July 2020

EMMETT, B.A., REYNOLDS, B., CHAMBERLAIN, P.M., ROWE, E., SPURGEON, D., BRITTAIN, S.A., FROGBROOK, Z., HUGHES, S., LAWLOR, A.J., POSKITT, J., POTTER, E., ROBINSON, D.A., SCOTT, A., WOOD, C. & WOODS, C. 2010. Soils report from 2007, CS Technical Report No. 9/07. Available online @ http://www.countrysidesurvey.org.uk/outputs/soils-report-from-2007 Last accessed July 2020

FARMING AND AGRICULTURE ORGANISATION. Soil structure. http://www.fao.org/fishery/static/FAO_Training/FAO_Training/General/x6706e/x6706e07.htm Last accessed July 2020

GAME AND WILDLIFE CONSERVATION TRUST. Allerton Project. Available online @ https://www.gwct.org.uk/allerton/ Last accessed July 2020

GOBIN, A., CAMPLING, P., JANSSEN, L., DESMET, N., VAN DELDEN, H., HURKENS, J., LAVELLE, P., BERMAN, S. 2011. Soil organic matter management across the EU – best practices, constraints and trade-offs, Final Report for the European Commission's DG Environment, September 2011. Available online @ http://ec.europa.eu/environment/soil/pdf/som/full_report.pdf Last viewed July 2020

LAL, R. 2004. Soil carbon sequestration to mitigate climate change. Geoderma, 123, 1-22.

NATURAL ENGLAND. 2012A. Carbon Storage by Habitat: Review of the evidence of the impacts of management decisions and condition of carbon stores and sources. Natural England Research Report 043. Available online @ http://publications.naturalengland.org.uk/publication/1412347 Last accessed July 2020

NATURAL ENGLAND. 2012B. Managing soil biota to deliver ecosystem services (NECR100). Available online @ http://publications.naturalengland.org.uk/publication/2748107?category=23033 Last accessed July 2020

NATURAL ENGLAND. 2010. England's Peatlands: Carbon Storage and Greenhouse Gases. Natural England Research Report NE257. Sheffield: Natural England. Available online @ http://publications.naturalengland.org.uk/publication/30021 Last accessed July 2020

NATURAL ENGLAND, 2016. BD5001: Characterisation of soil structural degradation under grassland and development of measures to ameliorate its impact on biodiversity and other soil functions (RP00359). Available online @ http://publications.naturalengland.org.uk/publication/5089918056398848 Last accessed July 2020

OSTLE, N., LEVY, P.E., EVANS, C.D. & SMITH, P. 2009. UK land use and soil carbon sequestration. Land Use Policy, 26, S274–S283.

SPURGEON, D.J., KEITH, A. M. SCHMIDT, O., LAMMERTSMA, D. & FABER, J. H., 2013. Land use change and management effects on soil diversity and regulation of water flows in soil. BMC Ecology. 13, 46.

STEINBACH, H.S and ALVARAZ, R. (2006). Changes in Soil Organic Carbon Contents and Nitrous Oxide Emissions after Introduction of No-Till in Pampean Agroecosystems. *Journal of Environmental Quality* January:3–13. Available online @ https://acsess.onlinelibrary.wiley.com/doi/abs/10.2134/jeq2005.0050 Last accessed July 2020

STOCKDALE, E.A., WATSON, C.A., BLACK, H.I.J. & PHILIPPS, L. 2006. Do farm management practices alter below-ground biodiversity and ecosystem function? - Implications for Sustainable Land Management. JNCC report No. 364. Peterborough: JNCC. Available online @ http://jncc.defra.gov.uk/page-3934 Last accessed July 2020

SWIFT, R.S. 2001. Sequestration of Carbon by Soil. Soil Science, 166, 858-871.

TORSVIK V., GOKSOYR, J. & DAAE, F. 1990. High diversity in DNA of soil bacteria. Applied and Environmental Microbiology, 56, 782-787.

TORSVIK, V., ØVREÅS, L., THINGSTAD, T. F. 2002. Prokaryotic diversity - magnitude, dynamics, and controlling factors. Science, 296, 1064-1066.

TURBÉ, A., DE TONI, A., BENITO, P., LAVELLE, P., LAVELLE, P., RUIZ, N., VAN DER PUTTEN, W.H., LABOUZE, E. & MUDGAL, S. 2010. Soil biodiversity: functions, threats and tools for policy makers. Bio Intelligence Service, IRD, and NIOO, Report for European Commission.

WARD, S.E, WILBY, A and BARDGETT, R (2016) 'Managing grassland diversity for multiple ecosystem services.' Final report, Defra project BD5003. Available online @ https://eprints.lancs.ac.uk/id/eprint/125014/ Last accessed July 2020

Appendix 3:
NSRI Soil Site Report: Westhide Solar Farm

Soil Site Report

Soil Report

Westhide Solar Farm

Easting: 357690
Northing: 244575
Site Area: 1km x 1km

Prepared for: Robert Askew, PERSONAL USE
Date: 21 Oct 2022

Citation

Citations to this report should be made as follows:

National Soil Resources Institute (2022) Soils Site Report for location 357690E, 244575N, 1km x 1km, National Soil Resources Institute, Cranfield University. Accessed via: https://www.landis.org.uk/sitereporter

Disclaimer

The report, modules and risk maps have been prepared by Cranfield University for you, the client. Whilst every care has been taken by Cranfield University to ensure the accuracy and completeness of the reports, modules and risk maps, the client must recognise that as with any such reports, modules and risk maps errors are possible through no fault of Cranfield University and as such the parties give no express or implied representations or warranty as to:

(i) the quality or fitness for any particular purpose of the report, modules or risk maps contained herein or of any design, workmanship, materials or parts used in connection therewith or correspondence with regard to any description or sample;
or
(ii) the accuracy, sufficiency or completeness of the report modules or risk maps provided herewith. In particular, there are hereby expressly excluded all conditions, warranties and other terms which might otherwise be implied (whether by common law, by statute or otherwise) as to any of the matters set out in paragraphs (i) and (ii) above.

Cranfield University, its employees, servants and agents shall accept no liability for any damage caused directly or indirectly by the use of any information contained herein and without prejudice to the generality of the foregoing, by any inaccuracies, defects or omissions in the report, modules or risk maps provided.

Cranfield University and the environment

Cranfield University is a truly unique learning environment. The only wholly postgraduate University in the UK, our world-class programmes, unrivalled facilities, close links with business, industry and governments and an international outlook all combine to attract students and teaching staff from around the globe. We offer a range of specialist full- and part-time Masters Courses, research programmes and short courses for environment professionals and graduates interested in careers in the sector. This includes key areas such as water sciences, water management, waste, land, soil, sports surfaces and energy. Funding is available to suitably qualified candidates.

Masters programmes

Full and part-time

Many of our taught programmes are professionally accredited and include a group and individual project which expose you to cutting-edge projects with industry and commerce. Funding may also be available for full-time students. Details are available on application.

Environment MSc courses (https://www.cranfield.ac.uk/themes/environment-and-agrifood/environment-courses):

- Geographical Information Management (GIM)
- Global Environmental Change (GEC)
- Environmental Engineering (EE)
- Environmental Management for Business (EMB)

Agrifood MSc courses (https://www.cranfield.ac.uk/themes/environment-and-agrifood/agrifood-courses):

- Applied Bioinformatics (AB)
- Future Food Sustainability (FFS)
- Food Systems and Management (FSM)

Research opportunities: For details about our funded research opportunities visit: https://www.cranfield.ac.uk/themes/environment-and-agrifood/research-degrees

Short courses: For details about our intensive short course programmes aimed at busy professionals working in the environment sector please visit: https://www.cranfield.ac.uk/themes/environment-and-agrifood/cpd

Contact

For further information and for application forms please contact:
Phone: +44 (0) 1234 758008 Email: enquiries@cranfield.ac.uk

About this Report

This Soils Site Report aims to support the teaching of soil science at undergraduate (BSc, NVQ etc.) or equivalent level. If you are a researcher, we suggest you contact us for access to more comprehensive Soils Site Reports and their underlying data.

This Soils Site Report identifies and describes the properties and capacities of the soil at your specified location as recorded in the National Soil Map for England and Wales. It has been produced by Cranfield University's National Soil Resources Institute.

The National Soil Map represents the most accurate and comprehensive source of information about the soil at the national coverage in England and Wales. It maps the distribution of soil mapping units (termed soil associations) which are defined in terms of the main soil types (or soil series) that were recorded for each soil association during field soil survey. Each soil association is named after its principal soil series and these bear the location name from where they were first described (e.g. Windsor). Each of these soil associations have differing environmental characteristics (physical, chemical and biological) and it is by mapping these properties that the range of thematic maps in this report have been produced.

Soil types and properties vary locally, as well as at the landscape scale. It is not possible to identify precisely the soil conditions at a specific location without first making a site visit. We have therefore provided you with information about the range of soil types we have identified at and around your selected location. Schematic diagrams are also provided to aid accurate identification of the soil series at your site.

Whilst an eight-figure national grid reference should be accurate to within 100m, a single rural Postcode can cover a relatively large geographical area. Postcodes can therefore be a less precise basis for specifying a location. The maps indicate the bounded area the reports relate to.

Your Site Soil Report will enable you to:

- identify the soils most likely to be present at and immediately around your specified location;
- understand the patterns of soil variation around your location and how these correlate with changes in landscape;
- identify the nature and properties of each soil type present within the area;
- understand the relevant capacities and limitations of each of the soils and how these might impact on a range of factors such as surface water quality.

Provided that this Soils Site Report is not modified in any way and it is used in the context of your undergraduate course work, you may reproduce it for a third-party.

Table of Contents

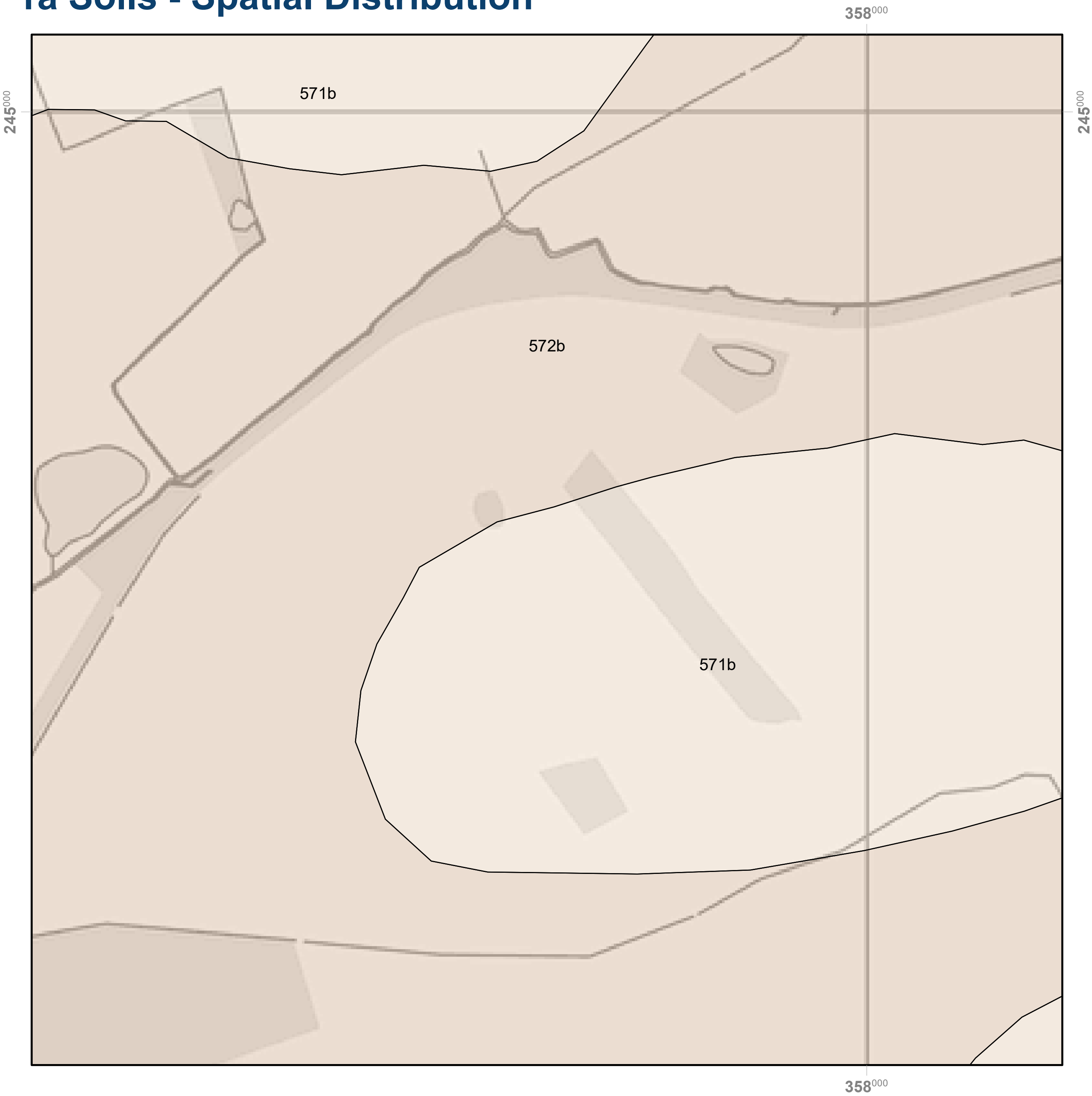
1. Soil Thematic Maps

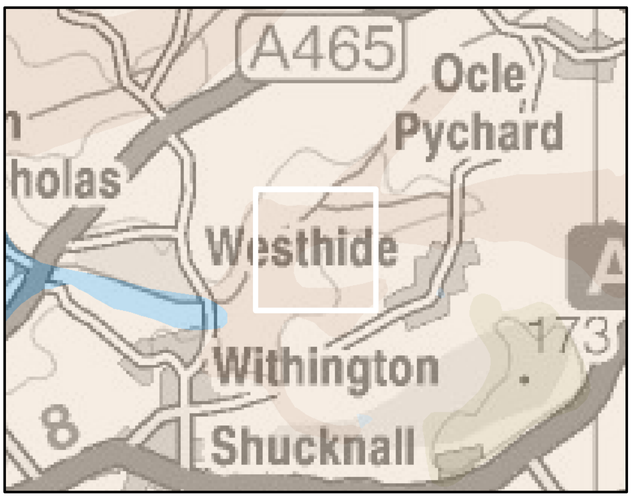
This section contains a series of maps of the area surrounding your selected location, presenting a number of themes relating to the characteristics of the soils. These provide an overview of the nature and condition of the local soil conditions. It is these conditions that may be used to infer the response of an area to certain events (with the soil as a receptor), such as pollution contamination from a chemical spill, or an inappropriate pesticide application and the likelihood of these materials passing though the soil to groundwater. Other assessments provide an insight into the way a location may impact, by corrosive attack or ground movement, upon structures or assets within the ground, for example building or engineering foundations or pipes and street furniture.

Soil is a dynamic environment with many intersecting processes, chemical, physical and biological at play. Even soils 'sealed' over by concrete and bitumen are not completely dormant. The way soils respond to events and actions can vary considerably according to the properties of the soil as well as other related factors such as land-use, vegetation, topography and climate. There are many threats facing our national soil resource today and importance should be given to identifying the best measures aimed towards soil protection and ensuring the usage of soils in the most sustainable way. This report is therefore a useful snapshot of the soil properties for your given area, providing a summary of a broad range of ground conditions

Figure 1: Location of study area

1a Soils - Spatial Distribution





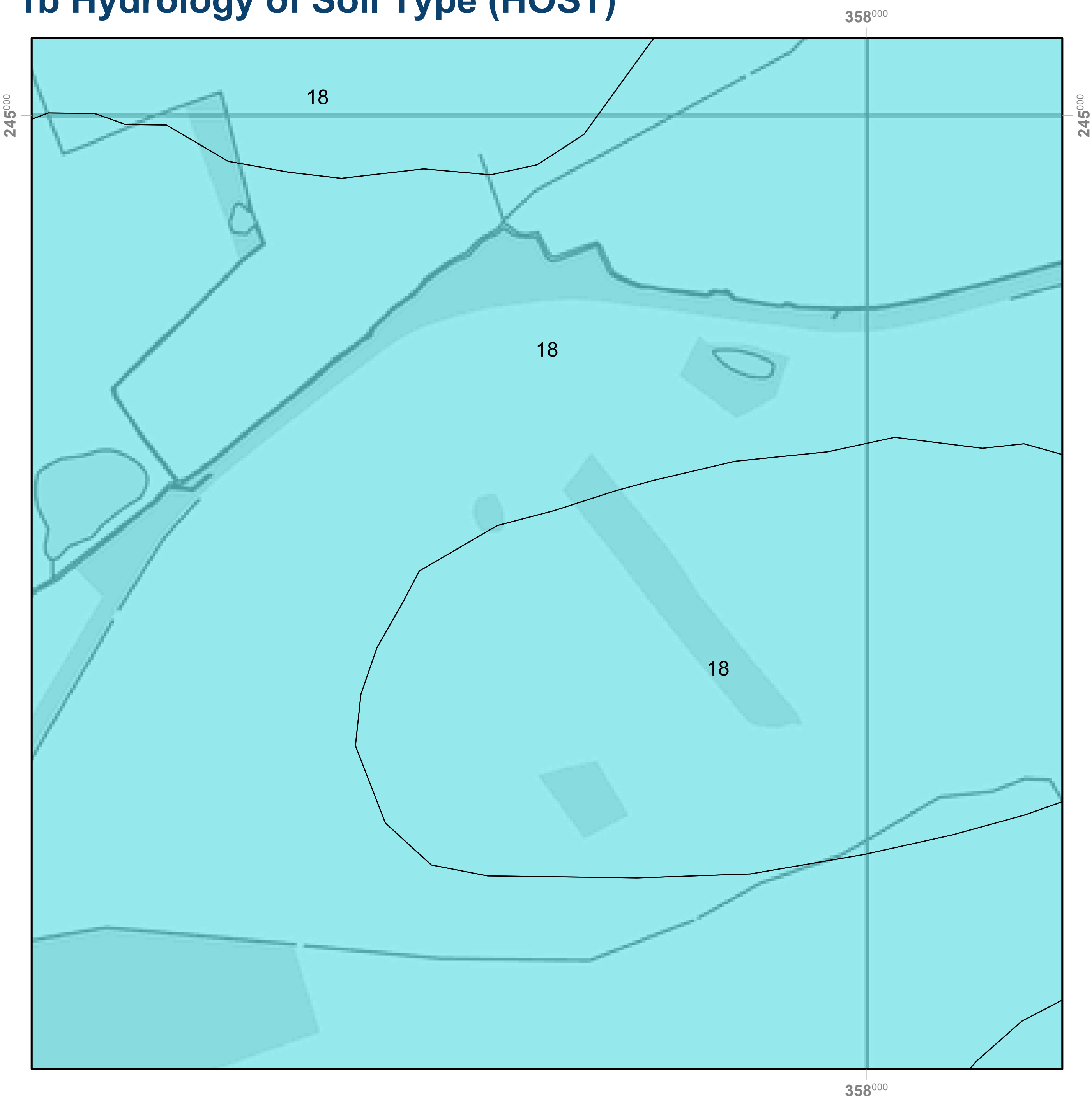
Soils - Spatial Distribution Key

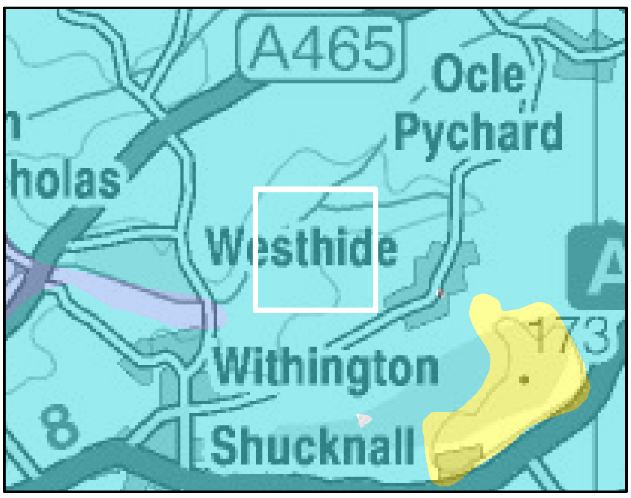
- 571b BROMYARD
  Well drained reddish fine silty soils over shale and siltstone.
- 572b MIDDLETON
  Reddish fine silty soils with slowly permeable subsoils and slight seasonal waterlogging over shale and siltstone.

SOIL ASSOCIATION DESCRIPTION

Soil associations represent a group of soil series (soil types) which are typically found occurring together, associated in the landscape (Avery, 1973; 1980; Clayden and Hollis, 1984). Soil associations may occur in many geographical locations around the country where the environmental conditions are comparable. For each of these soil associations, a collection of soil types (or soil series) are recorded together with their approximate proportions within the association. Soil associations have codes as well as textual names, thus code '554a' refers to the 'Frilford' association. Where a code is prefixed with 'U', the area is predominantly urbanised (e.g. 'U571v'). The soil associations for your location, as mapped above, are described in more detail in Section 2: Soil Association Descriptions.

1b Hydrology of Soil Type (HOST)





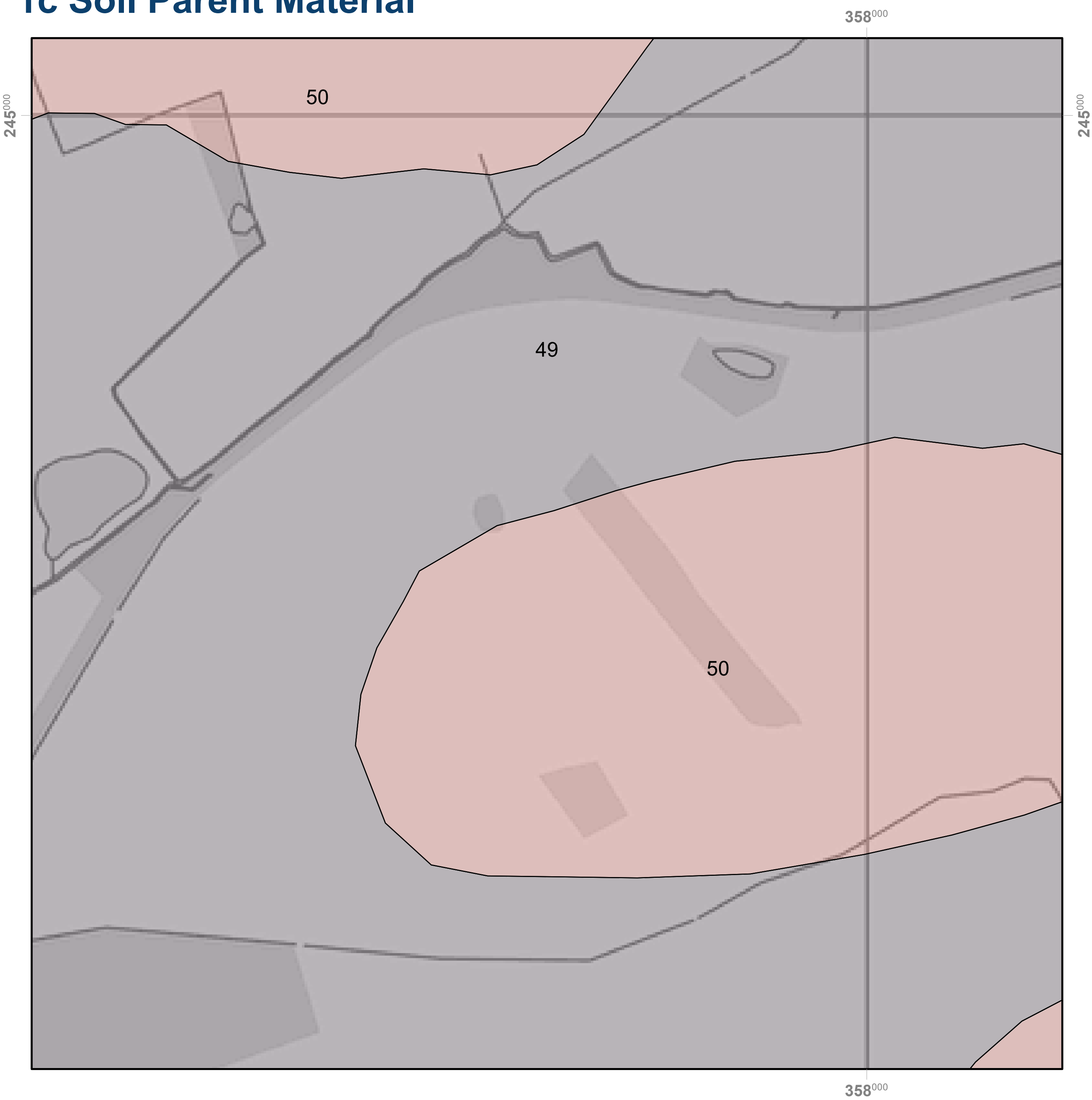
Hydrology of Soil Type (HOST) Key

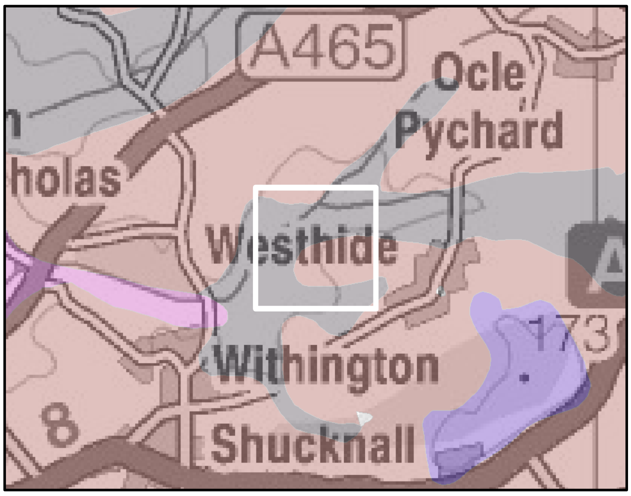
18 Slowly permeable soils with slight seasonal waterlogging and moderate storage capacity over slowly permeable substrates with negligible storage

HOST CLASS DESCRIPTION

The Hydrology of Soil Types (HOST) classification describes the dominant pathways of water movement through the soil and, where appropriate, the underlying substrate. Eleven drainage models are defined according to the permeability of the soil and its substrate and the depth to a groundwater table, where one is present (Boorman et al,1995). These are further subdivided into 29 HOST classes to which all soil series have been assigned. These classes identify the way soil water flows are partitioned, with water passing over, laterally through, or vertically down the soil column. Analysis of the river hydrograph and the extent of soil series for several hundred gauged catchments allowed mean values for catchment hydrological variables to be identified for each HOST class, The HOST classification is widely used to predict river flows and the frequency and severity of flood events and also to model the behaviour of diffuse pollutants (Hollis et al, 1995).

1c Soil Parent Material





Soil Parent Material Key

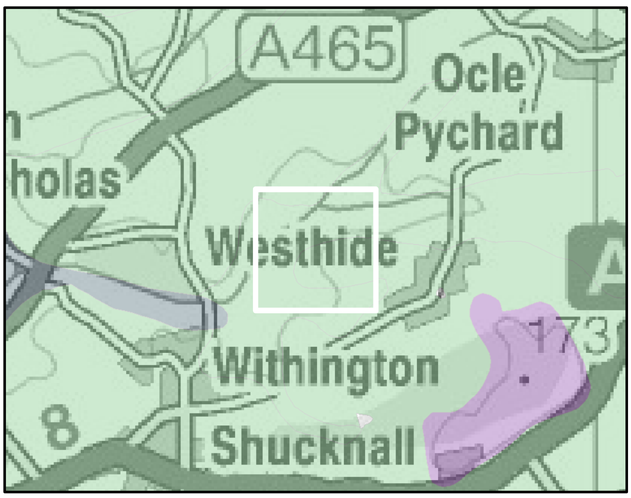
49 Devonian reddish silty shale and siltstone

50 Devonian reddish silty shale. siltstone and sandstone

SOIL PARENT MATERIAL DESCRIPTION

Along with the effects of climate, relief, organisms and time, the underlying geology or 'parent material' has a very strong influence on the development of the soils of England and Wales. Through weathering, rocks contribute inorganic mineral grains to the soils and thus exhibit control on the soil texture. During the course of the creation of the national soil map, soil surveyors noted the parent material underlying each soil in England and Wales. It is these general descriptions of the regional geology which is provided in this map.

1d Natural Soil Fertility



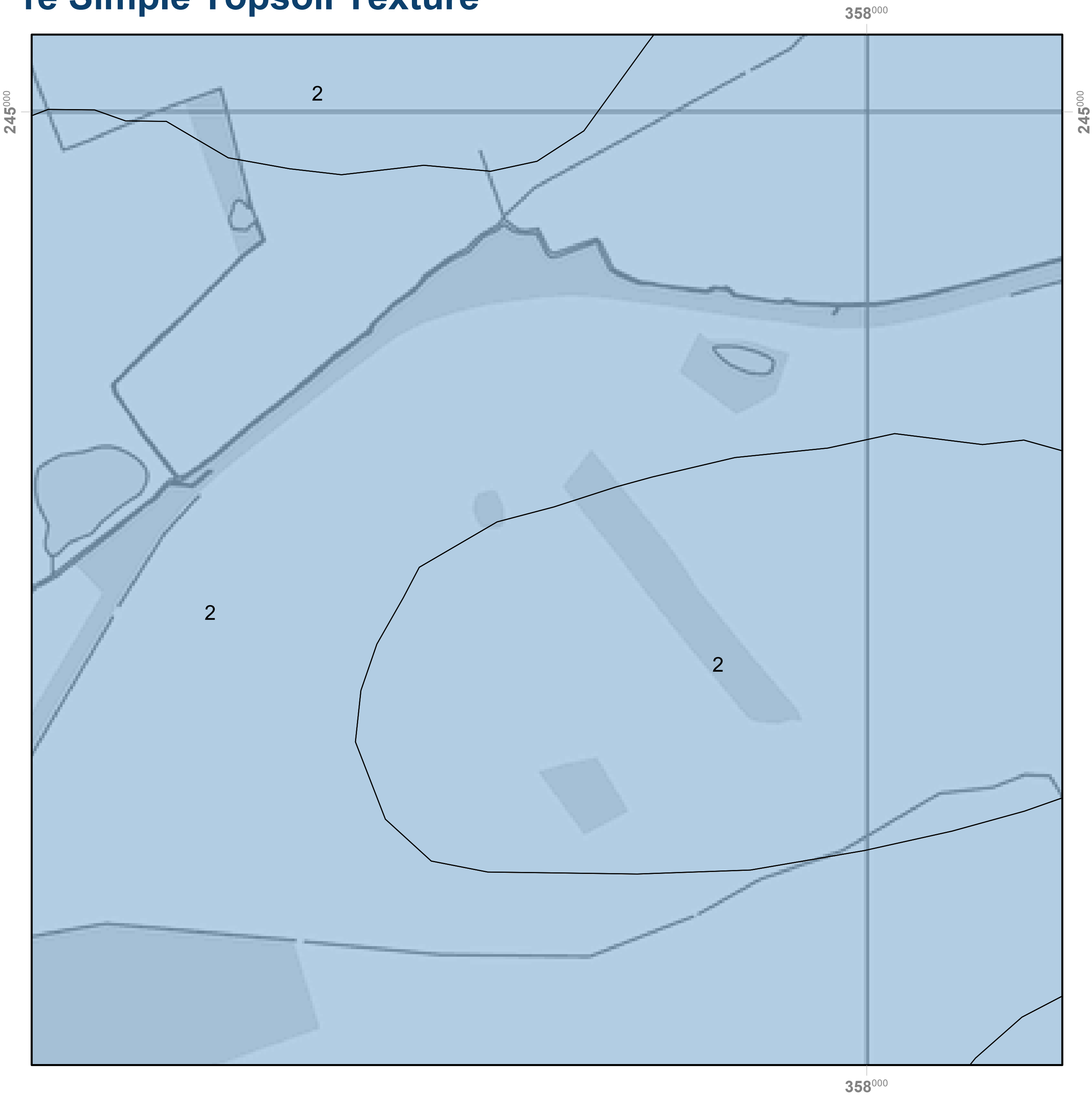
Natural Soil Fertility Key

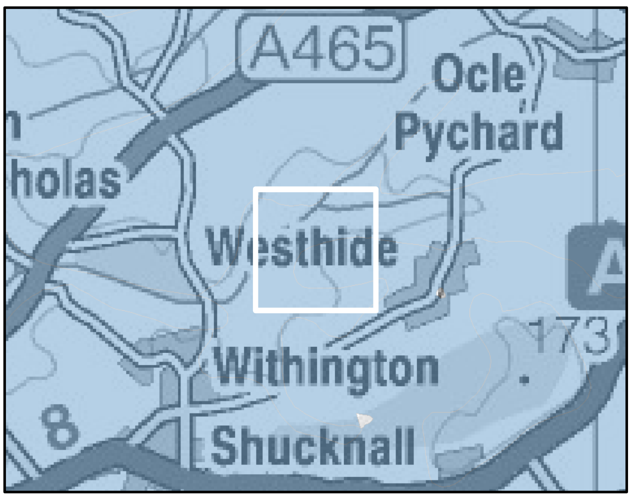
11 Moderate to high

NATURAL SOIL FERTILITY DESCRIPTION

Soil fertility can be greatly altered by land management especially through the application of manures, lime and mineral fertilisers. What is shown in this map, however, is the likely natural fertility of each soil type. Soils that are very acid have low numbers of soil-living organisms and support heathland and acid woodland habitats. These are shown as of very low natural fertility. Soils identified as of low natural fertility are usually acid in reaction and are associated with a wide range of habitat types. The moderate class contains neutral to slightly acid soils, again with a wide range of potential habitats. Soil of high natural fertility are both naturally productive and able to support the base-rich pastures and woodlands that are now rarely encountered. Lime-rich soils contain chalk and limestone in excess, and are associated with downland, herb-rich pastures and chalk and limestone woodlands.

1e Simple Topsoil Texture





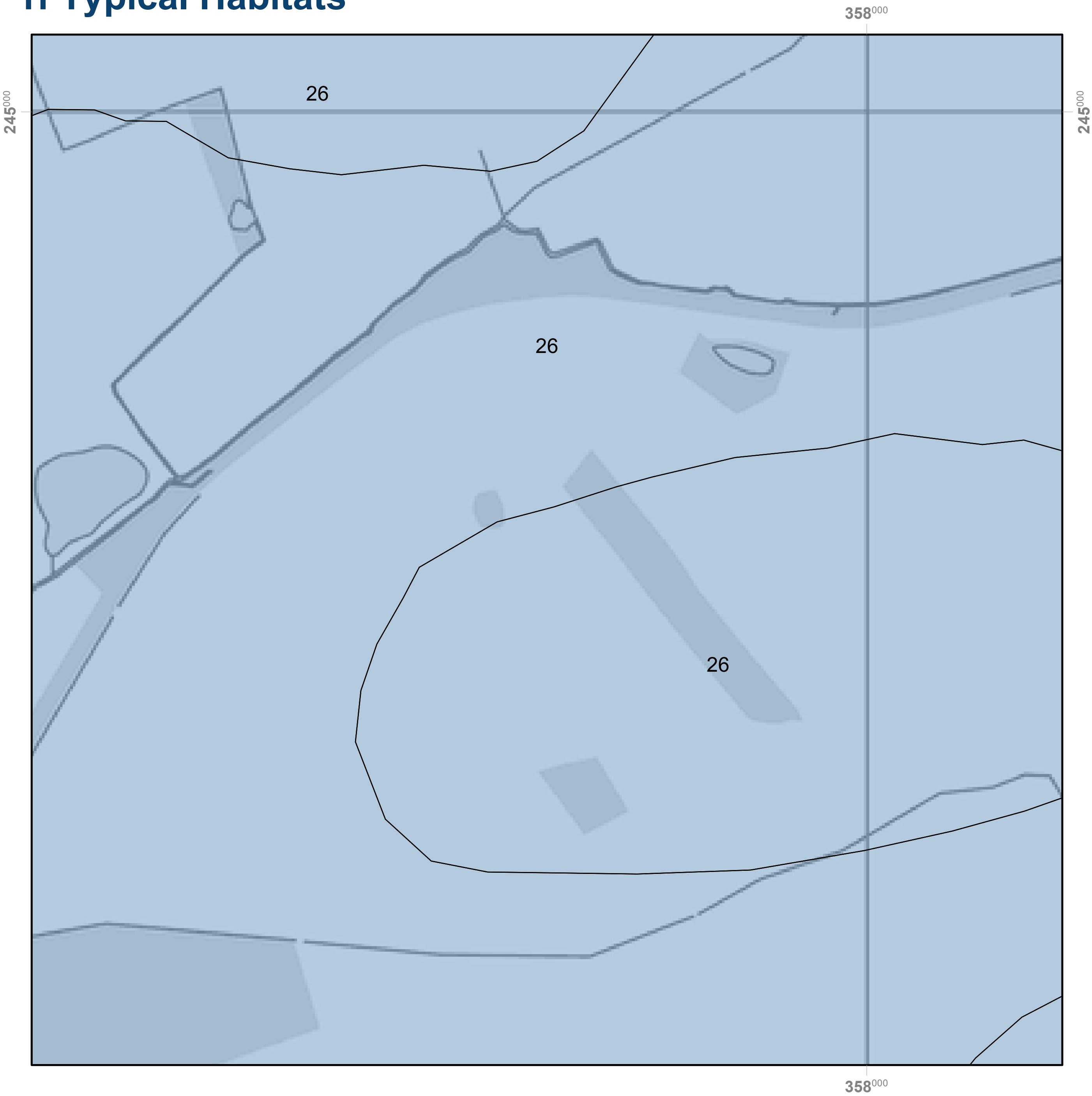
Simple Topsoil Texture Key

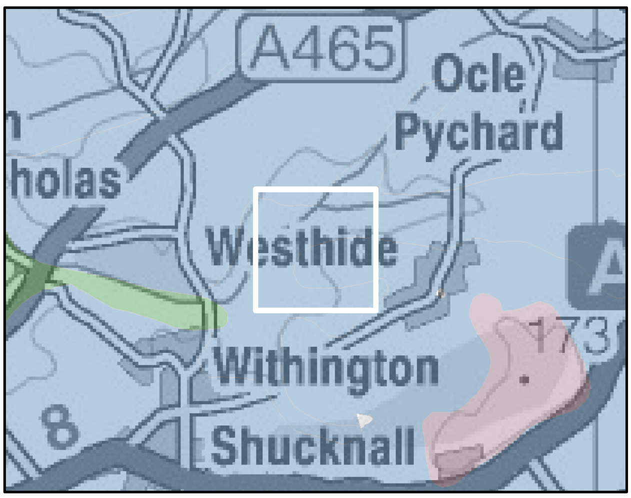
2 Loamy

SIMPLE TOPSOIL TEXTURE DESCRIPTION

Soil texture is a term used in soil science to describe the physical composition of the soil in terms of the size of mineral particles in the soil. Specifically, we are concerned with the relative proportions of sand, silt and clay. Soil texture can vary between each soil layer or horizon as one moves down the profile. This map indicates the soil texture group of the upper 30 cm of the soil. Loamy soils have a mix of sand, silt and clay-sized particles and are intermediate in character. Soils with a surface layer that is dominantly organic are described as Peaty. A good understanding of soil texture can enable better land management.

1f Typical Habitats





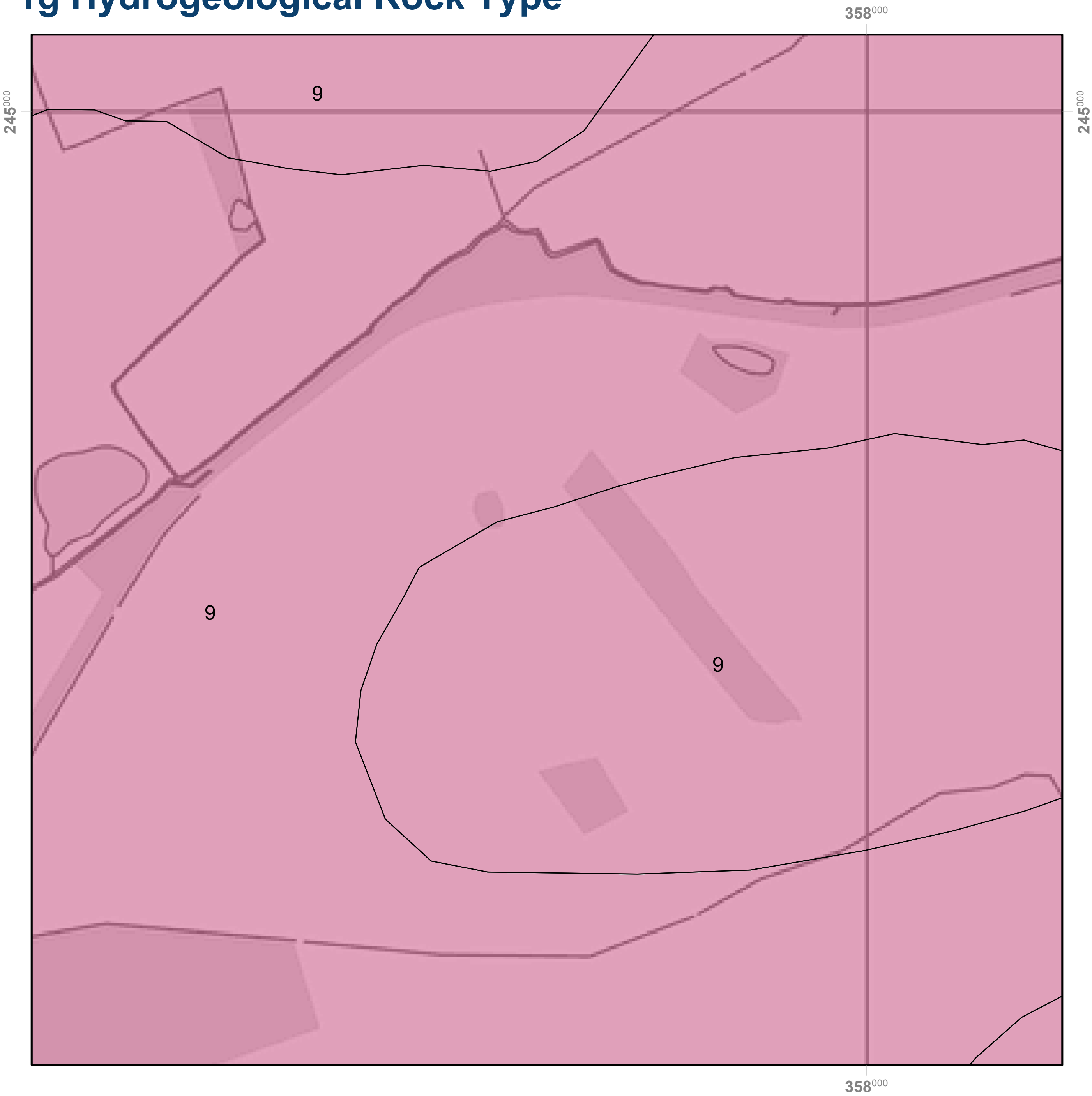
Typical Habitats Key

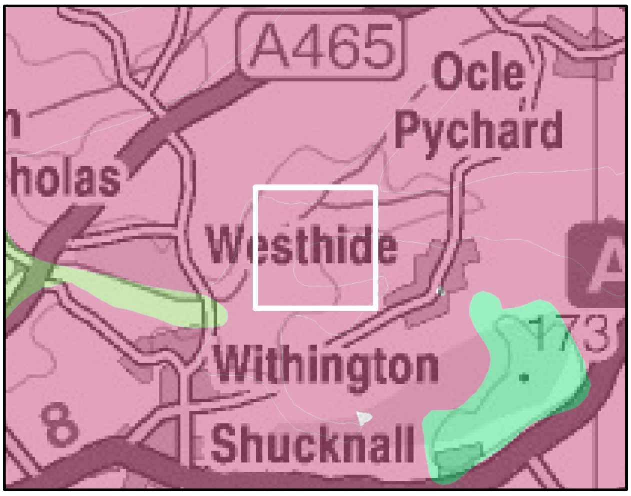
26 Wide range of pasture and woodland types

TYPICAL HABITATS DESCRIPTION

There is a close relationship between vegetation and the underlying soil. Information about the types of broad habitat associated with each soil type is provided in this map. Soil fertility, pH, drainage and texture are important factors in determining the types of habitats which can be established. Elevation above sea level and sometimes even the aspect, the orientation of a hillslope, can affect the species present. This map does not take into account the recent land management, but provides the likely natural habitats assuming good management has been carried out.

1g Hydrogeological Rock Type





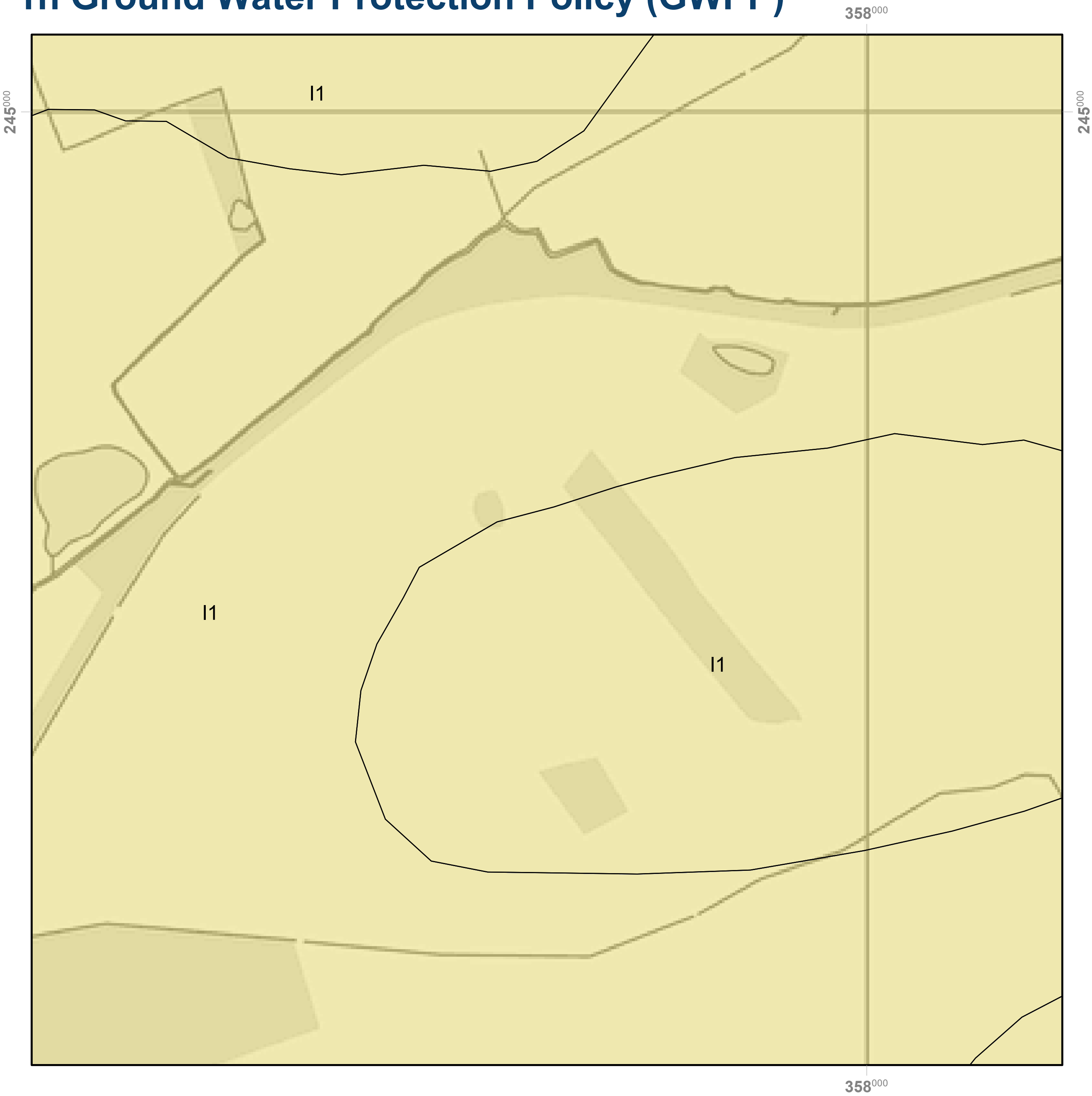
Hydrogeological Rock Type Key

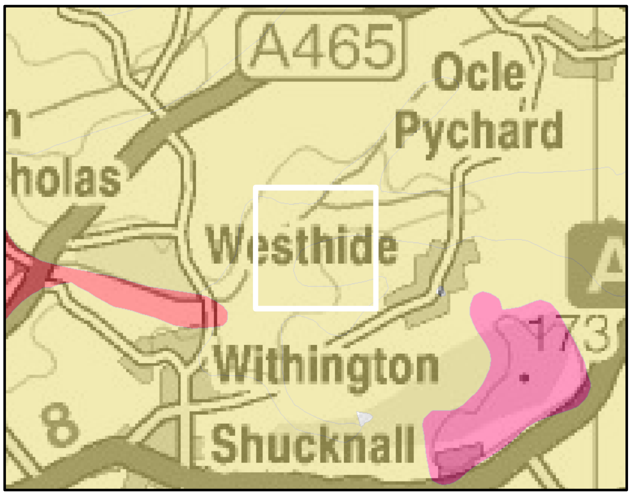
9 very soft reddish blocky mudstones (marls)

HYDROGEOLOGICAL ROCK TYPE DESCRIPTION

The hydrogeological classification of the soil parent materials provides a framework for distinguishing between soil substrates according to their general permeability and whether they are likely to overlie an aquifer. Every soil series has been assigned one of the 32 substrate classes and each of these is characterised according to its permeability (being characterised as permeable, slowly permeable or impermeable). For further information, see Boorman et al (1995).

1h Ground Water Protection Policy (GWPP)





Ground Water Protection Policy (GWPP) Key

I1 Soils of intermediate leaching potential which have a moderate ability to attenuate a wide range of diffuse source pollutants but in which it is possible that some non-adsorbed diffuse source pollutants and liquid discharges could penetrate the soil layer

GWPP LEACHING CLASS DESCRIPTION

The Ground Water Protection Policy classes describe the leaching potential of pollutants through the soil (Hollis, 1991; Palmer et al, 1995). The likelihood of pollutants reaching ground water is described. Different classes of pollutants are described, including liquid discharges adsorbed and non-adsorbed pollutants.

2. Soil Association Descriptions

The following pages describe the following soil map units, (soil associations), in more detail.

BROMYARD 571b
Well drained reddish fine silty soils over shale and siltstone.

MIDDLETON 572b
Reddish fine silty soils with slowly permeable subsoils and slight seasonal waterlogging over shale and siltstone.

The soil associations are described in terms of their texture and drainage properties and potential risks may be identified. The distribution of the soils across England and Wales are provided. Further to this, properties of each association's component soil series are described in relation to each other. Lastly, schematic diagrams of each component series are provided for greater understanding and in-field verification purposes.

BROMYARD (571b)

Well drained reddish fine silty soils over shale and siltstone.

a. General Description

Well drained reddish fine silty soils over shale and siltstone.Some similar soils with slowly permeable subsoils and slight seasonal waterlogging. Some well drained coarse loamy soils over sandstone.
The major landuse on this association is defined as Cereals and short term grassland with stock rearing, some hops; deciduous woodland on steep slopes.

b. Distribution (England and Wales)

The BROMYARD association covers 1485 km² of England and Wales which accounts for 0.98% of the landmass. The distribution of this association is shown in figure 2. Note that the yellow shading represents a buffer to highlight the location of very small areas of the association.

c. Comprising Soil Series

Multiple soil series comprise a soil association. The soil series of the BROMYARD association are outlined in Table 1 below. In some cases other minor soil series are present at a particular site, and these have been grouped together under the heading 'OTHER'. We have endeavoured to present the likelihood of a minor, unnamed soil series occuring in your site in Table 1.

Schematic diagrams of the vertical soil profile of the major constituent soil series are provided in Section D to allow easier identification of the particular soil series at your site.

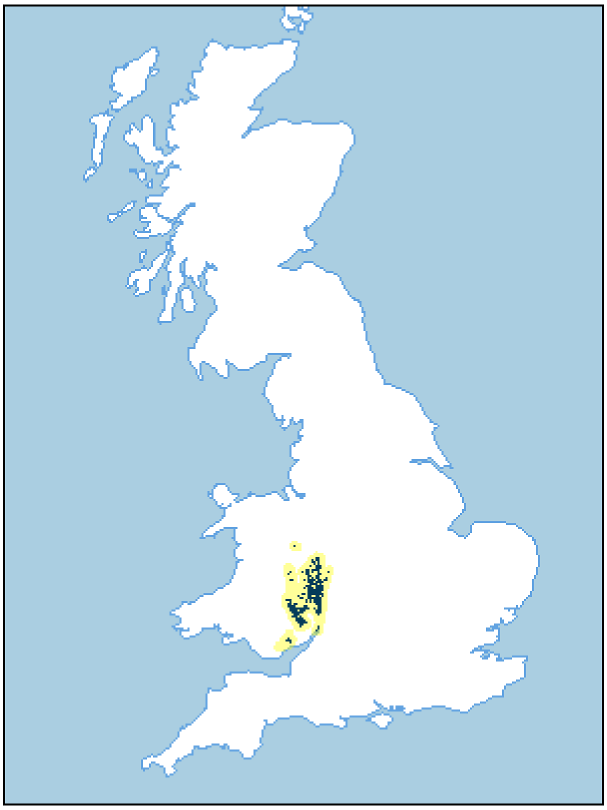


Figure 2: Association Distribution

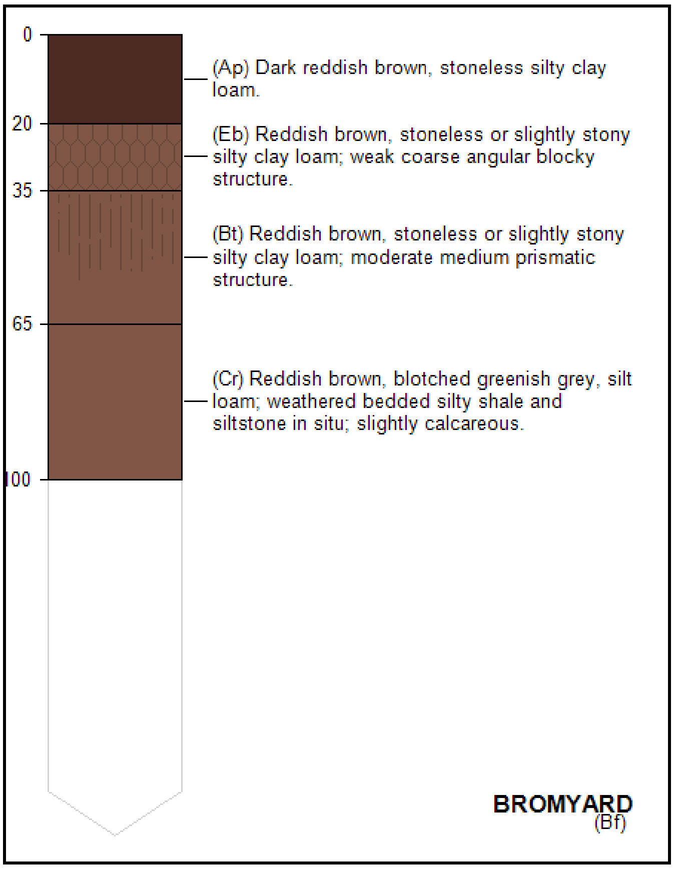
Table 1: The component soil series of the BROMYARD soil association. Because absolute proportions of the comprising series in this association vary from location to location, the national proportions are provided.

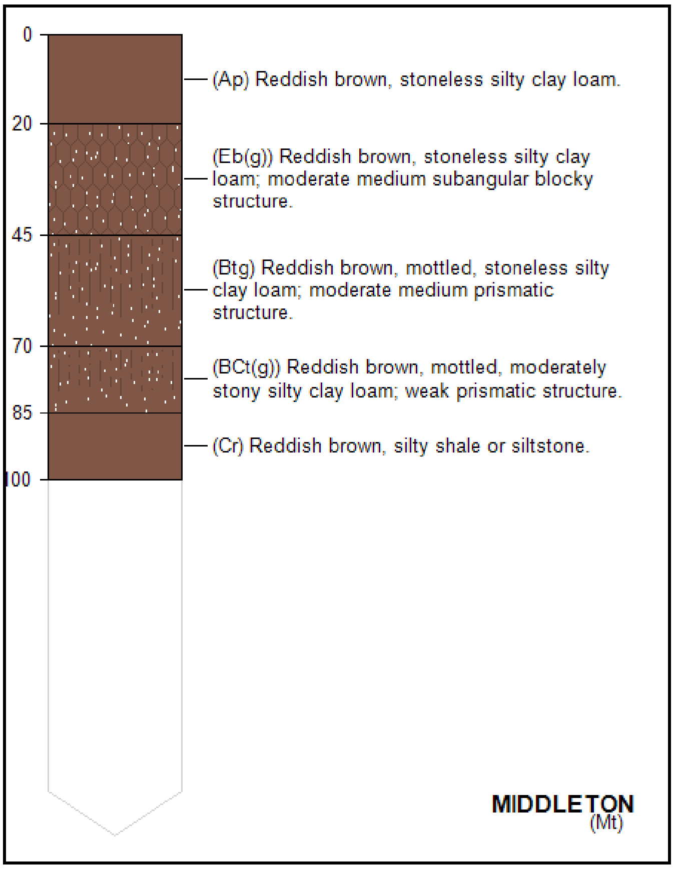
Soil Series	Description	Area %
BROMYARD (Bf)	reddish medium silty material passing to soft siltstone or shale	50%
MIDDLETON (Mt)	reddish medium silty material passing to soft shale or siltstone	15%
EARDISTON (Es)	reddish light loamy material over lithoskeletal sandstone	12%
OTHER	other minor soils	23%

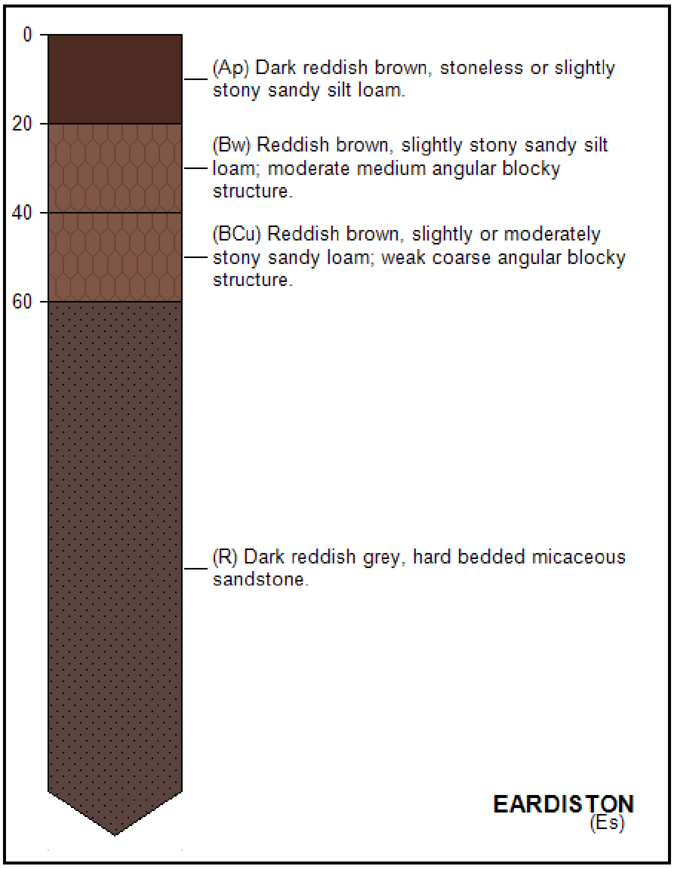
BROMYARD (571b)

Well drained reddish fine silty soils over shale and siltstone.

d. BROMYARD Component Series Profiles







MIDDLETON (572b)

Reddish fine silty soils with slowly permeable subsoils and slight seasonal waterlogging over shale and siltstone.

a. General Description

Reddish fine silty soils with slowly permeable subsoils and slight seasonal waterlogging over shale and siltstone.Some similar fine loamy soils slowly permeable seasonally waterlogged fine silty soils in places.

The major landuse on this association is defined as Stock rearing on permanent and short term grassland; some cereals.

b. Distribution (England and Wales)

The MIDDLETON association covers 113 km² of England and Wales which accounts for 0.07% of the landmass. The distribution of this association is shown in figure 3. Note that the yellow shading represents a buffer to highlight the location of very small areas of the association.

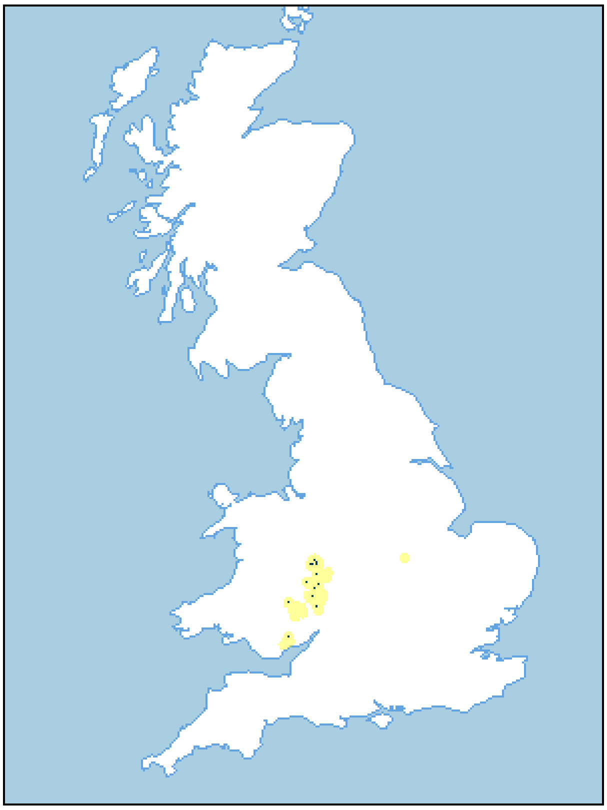


Figure 3: Association Distribution

c. Comprising Soil Series

Multiple soil series comprise a soil association. The soil series of the MIDDLETON association are outlined in Table 1 below. In some cases other minor soil series are present at a particular site, and these have been grouped together under the heading 'OTHER'. We have endeavoured to present the likelihood of a minor, unnamed soil series occuring in your site in Table 2.

Schematic diagrams of the vertical soil profile of the major constituent soil series are provided in Section D to allow easier identification of the particular soil series at your site.

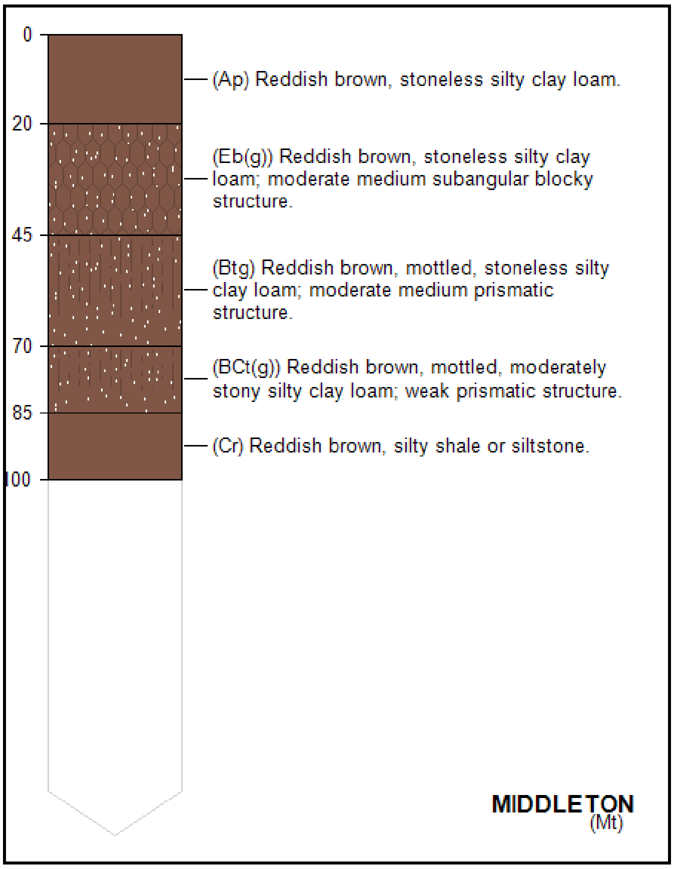
Table 2: The component soil series of the MIDDLETON soil association. Because absolute proportions of the comprising series in this association vary from location to location, the national proportions are provided.

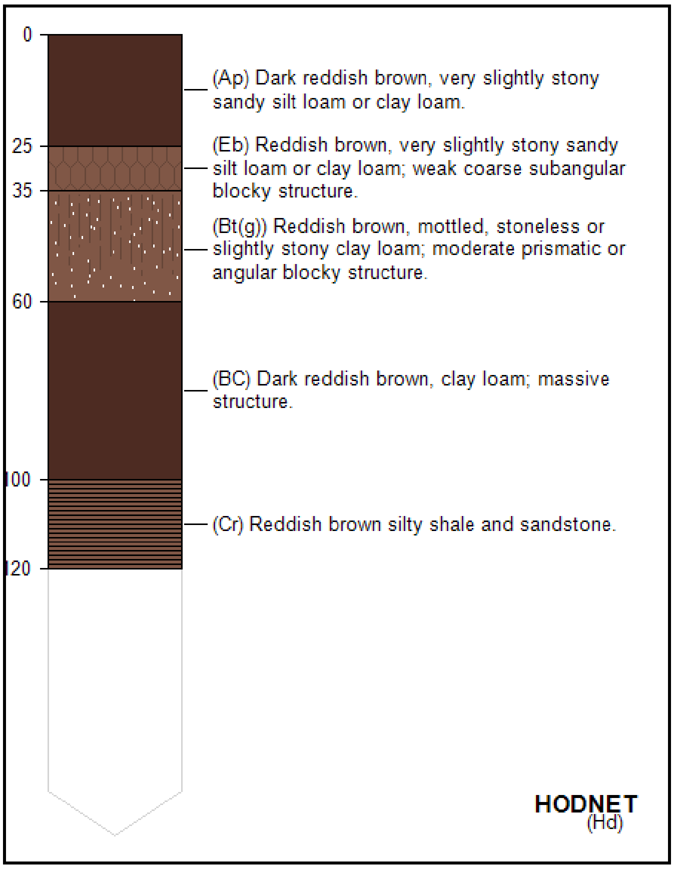
Soil Series	Description	Area %
MIDDLETON (Mt)	reddish medium silty material passing to soft shale or siltstone	55%
HODNET (Hd)	reddish medium loamy material passing to soft siltstone and sandstone	18%
NETCHWOOD (Nw)	reddish medium silty material passing to soft shale or siltstone	12%
OTHER	other minor soils	15%

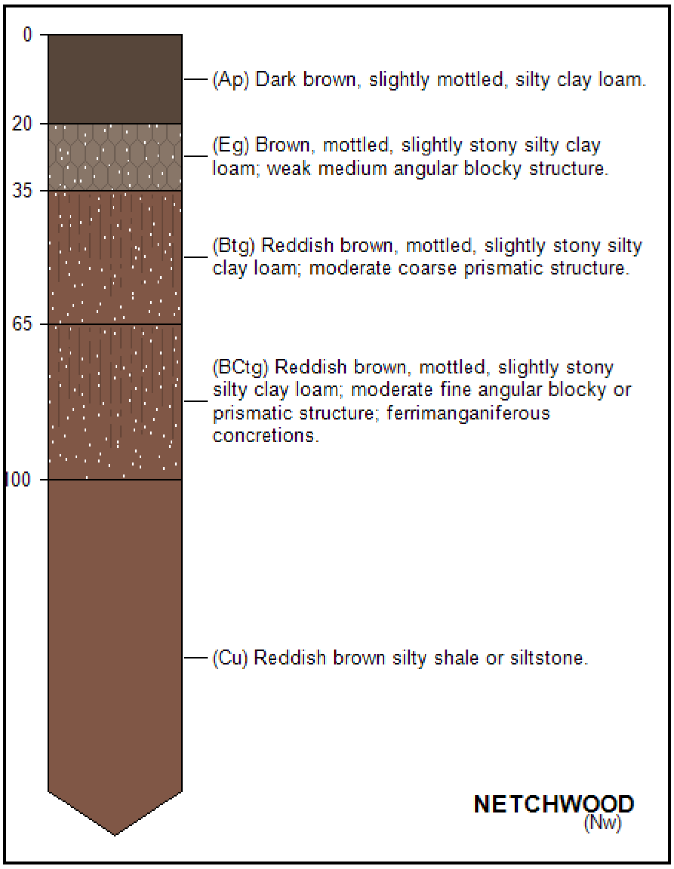
MIDDLETON (572b)

Reddish fine silty soils with slowly permeable subsoils and slight seasonal waterlogging over shale and siltstone.

d. MIDDLETON Component Series Profiles







REFERENCES

AVERY, B.W. (1973). Soil classification in the Soil Survey of England and Wales. Journal of Soil Science, 24, 324-338.

AVERY, B.W., (1980). Soil classification for England and Wales. Soil Survey Technical Monograph No.14, Harpenden, UK.

BOORMAN, D.B, HOLLIS, J.M. and LILLEY, A. (1995). Hydrology of Soil Types: a hydrologically-based classification of the soils of the UK. Institute of Hydrology Report No.126, Wallingford, UK.

CLAYDEN, B and HOLLIS, J.M. (1984). Critieria for Differentiating Soil Series. Soil Survey Technical Monograph No.17, pp159. Harpenden, UK.

HALLETT, S.H., KEAY, C.A., JARVIS, M.G. and JONES, R.J.A. (1994). INSURE: Subsidence risk assessment from soil and climate data. Proceedings of the Association for Geographic Information (AGI). National Conference Markets for Geographic Information. Birmingham. 16.2.1 - 16.2.7.

HOLLIS, J.M. (1991). Mapping the vulnerability of aquifers and surface waters to pesticide contamination at the national and regional scale. In: Pesticides in Soils and Water, BCPC Monograph No.47, 165-174.

HOLLIS, J.M., KEAY, C.A., HALLETT, S. H., GIBBONS, J.W. and COURT, A.C. (1995). Using CatchIS to assess the risk to water resources from diffusely applied pesticides. In: British Crop Protection Council monograph No. 62: Pesticide movement to water, 345-350

JARVIS, M.G and HEDGES, M.R. (1994). Use of soil maps to predict the incidence of corrosion and the need for iron mains renewal. Journal of the Institution of Water and Environmental Management 8, (1) 68-75.

PALMER, R.C., HOLMAN, I.P., ROBINS, N.S. and LEWIS, M.A. (1995). Guide to groundwater vulnerability mapping in England and Wales. National Rivers Authority R and D Note 578/1/ST.

Appendix 4:
Institute of Quarrying
Good Practice for Soil Handling
Supplementary Note 4
Soil Wetness

Supplementary Note 4
Soil Wetness

Soil wetness is a major determinant of land use, and environmental and ecosystem services in the UK. It is also a factor in the occurrence of significant compaction arising from handling soils with earth-moving machines and the practices used (Duncan & Bransden, 1986).

Relative soil wetness can range from the waterlogged to moist (mesic) or dry (xeric) depending on rainfall distribution and depth to a water-table and duration of waterlogging. In the UK, soil wetness is largely seasonal with higher evapo-transpiration rates potentially exceeding rainfall in the summer resulting in the soil profile becoming drier where there is vegetation. Whilst soil wetness is largely weather system and equinox (climate) driven, it varies with geographical and altitudinal locations, and importantly the physical characteristics of the soil profile, such as texture structure, porosity, and depth to the water-table and topography including flood risk (MAFF, 1988). The Soil Wetness Class is based on the expected average duration of waterlogging at different depths in the soil throughout the year (days per year), and can be determined by reference to soil characteristics and local climate (MAFF, 1988). The likely inherent wetness and resilience status of a soil should be indicated in the SRMP (see **Part 1, Table 2 & Supplementary Note 1**), reflecting potential risks for soil handling such as low permeability, permanently high groundwater, or a wet upland climate.

Wet soils can also be a result of other circumstances. For example, the interception of water courses, drainage ditches and field land drains. Where these occur, the provisions are to be made in the SRMP to protect the soils being handled and the operational area.

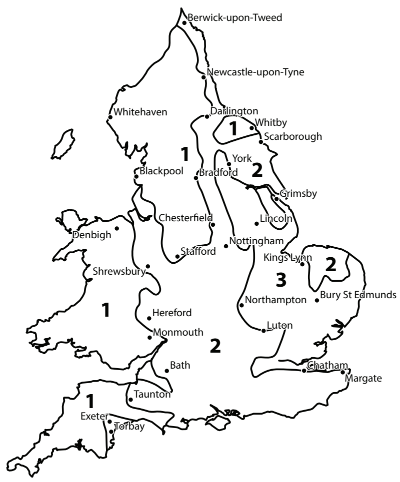
Soils, when in a wet condition generally have a lower strength and have less resistance to compression and smearing than when dry. Lower strength when soils are wet also affects the bearing capacity of soils and their ability to support the safe and efficient operation of machines than when in a dry state.

In terms of resilience and susceptibility to soil wetness, the clay content of the soil largely determines the change from a solid to a plastic state (the water content at which this occurs is called the 'plastic limit' (MAFF, 1982)). This is the point at which an increasing soil wetness has reduced the cohesion and strength of the soil and its resistance to compression and smearing.

Whilst coarse textured sandy soils are not inherently plastic when wet, they are still prone to compaction when in a wet condition. Hence, handling all soils when wet will have adverse effects on plant root growth and profile permeability, which may be of significance for the intended land use and the provision of services reliant on soil drainage and plant root growth. It may be less so in other circumstances where wet soil profiles, perched water tables and ponding are the reclamation objectives, though drainage control, for example to control flooding, may still be important in these contexts.

In cases of permanently wet soils, such as riverine sites, upland or deep organic soils where there is a persistent high water-table throughout the seasons within the depth of soil to be stripped and/or the soil profile remains too wet, a strategic decision has to be made to be able to proceed with the development of the mineral resource. This may mean alternative and less favourable soil handling practices have to be agreed with the planning authority.

Predicting & Determination of Soil Wetness
There are well established methods to predict and determine soil wetness of undisturbed and restored soil profiles (Reeve, 1994). The challenge has been the prediction of the best time for soil stripping. Models based on soil moisture deficits and field capacity dates for a range of soil textures can provide indicative regional summaries (**Table 4.1**) that can help with planning operations at broad scale but cannot be relied upon in practice for deciding operationally whether to proceed on the ground given the actual variation in weather events from year to year and within years.



	Climatic Zones		
Soil Clay Content	**1**	**2**	**3**
Soil Depth <30cm			
<10%	Mid Apr - Early Oct	Late Mar – Early Nov	Late Mar – Early Dec
10 -27%	Late May - Early Oct	Early May – Early Nov	Early Apr – Early Dec
Soil Depth 30-60cm			
<10%	Late Apr - Early Oct	Mid Apr – Early Nov	Early Apr – Early Dec
10-27%	Late May - Early Oct	Early May – Early Nov	Early Apr – Early Dec
>27%	Late June – Early Oct	Early June – Early Nov	Late May – Early Dec
Soil Depth >60cm			
<10%	Late Apr - Early Oct	Mid Apr – Early Nov	Early Apr – Early Dec
10-18%	Late May - Early Oct	Early May – Early Nov	Early Apr – Early Dec
18-27%	Late June – Early Oct	Early June – Early Nov	Late May – Early Dec
>27	Mid July – Mid Sept	Early July – Mid Oct	Late June – Mid Oct

Table 4.1: Indicative on-average months when vegetated mineral soils might be in a sufficiently dry condition according to geographic location, depth of soil and clay content

The timing of most soil handling operations takes place between April and September. Although in western (Zone 1) and central (Zone 2) areas it typically can be a later start in May with an earlier termination in August. Whilst the return to climatically 'excess rainfall' is later in the eastern counties (Zone 3) and can be as late as November/early December, there is a need to maintain transpiring vegetation to keep the soils being handled in a dry as possible condition and to establish new vegetation covers as soon as possible (on replaced soils and storage mounds). Hence, soil handling operations generally need to be completed no later than the end of September (Natural England, 2021), unless appropriate provisions can be assured.

Where data is available, more realistic local and real-time predictions can be made, however, because weather patterns and events differ between and within years, and soils can be vary locally in their condition. Experience has shown that the most practical approach for operations is to inspect the site and soils in question near to/ at the time when soil handling is to take place. Professional soil surveyors can advise on the best time for soil handling (stripping, storage & replacement) and carry out site assessments of soil wetness condition prior to the start of operations.

A Practical Method for Determining Soil Wetness Limitation

During the soil handling season (see Table 4.1 above), prior to the start or recommencement of soil handling soils should be tested to confirm they are in suitably dry condition (**Table 4.2**). The 'testing' during operations can be done by suitably trained site staff and reviewed periodically by the professional soil surveyors.

The method is simply the ability to roll intact threads (3mm diameter) of soil indicating the soils are in a plastic and wet condition (MAFF, 1982; Natural England, 2021). Representative samples are to be taken through the soil profile and across the area to be stripped. It is the best available indicator of soils being too wet to be handled and operations should be delayed until a thread cannot be formed. For coarse textured soils which do not roll into threads, a professional's view as to soil wetness and the risk of compaction may have to be taken.

Table 4.2: Field Tests for Suitably Dry Soils

Soil tests are to be undertaken in the field. Samples shall be taken from at least five locations in the soil handling area and at each soil horizon to the full depth of the profile to be recovered/replaced. The tests shall include visual examination of the soil and physical assessment of the soil consistency.

i) Examination

- If the soil is wet, films of water are visible on the surface of soil particles or aggregates (e.g. clods or peds) and/or when a clod or ped is squeezed in the hand it readily deforms into a cohesive 'ball' means **no soil handling to take place.**
- If the samples is moist (i.e. there is a sligh dampness when squeezed in the hand) but it does not significantly change colour (darken) on further wetting, and clods break up/crumble readily when squeezed in the hand rather than forming into a ball means **soil handling can take place.**
- If the sample is dry, it looks dry and changes colour (darkens) if water is added, and it is brittle means **soil handling can take place.**

ii) Consistency
First test
Attempt to mould soil sample into a ball by hand:

- Impossible because soil is too dry and hard or too loose and dry means **soil handling can take place.**
- Impossible becuase the soil is too loose and wet means no soil handling to take place.
- Possible - Go to second text.

Second test
Attempt to roll ball into a 3mm diameter thread by hand:

- Impossible because soil crumbles or collapses means soil handling can take place.
- Possible means no soil handling can take place.

N.B.: It is possible to roll most coarse loamy and sandy soils into a thread even when they are wet. For these soils, the Examination Test alone is to be used.

A Rainfall Protocol to Suspend & Restart Soil Handling Operations

Local weather forecasts of possible rainfall events during operations and the occurrence of surface lying water have been used to advise on a day-to-day basis if operations should stop (Natural England, 2021). Single events such as >5mm/day in spring and autumn months, and >10mm/day in the summer have been suggested as more precise triggers for determining soil handling operations (Reeve, 1994). However, in practice the following generic guidelines are often used:

- In light drizzle soil handling may continue for up to four hours unless the soils are already at/near to their moisture limit.
- In light rain soil handling must cease after 15 minutes.
- In heavy rain and intense showers, handling shall cease immediately.

In all of the above it is assumed that soils were in a dry condition. These are only general rules, and it is at the local level decisions to proceed or stop should be based on the actual wetness state of the soils being handled. After the above rain event has ceased, the soil tests in **Table 4.2** above should be applied to determine whether handling may re-start, provided that the ground is free from ponding and ground conditions are safe to do so.There can be extreme instances where soil horizons have become very dry and are difficult to handle resulting in dust and windblown losses. In these conditions the operation should be suspended. The artificial wetting of extremely dry soils is not usually a practice recommended but has been successful in some cases.

References

Duncan N A and Bransden B E, 1986. The effects on a restored soil caused by soil moving under different moisture contents. Applied Geography, 6, 3, pp 267-273

MAFF, 1982. Reference Book 441: Techniques for measuring soil physical properties. Her Majesty's Stationery Office, London

MAFF, 1988. Agricultural Land Classification Of England and Wales

Natural England, 2021. Planning and aftercare advice for reclaiming land to agricultural use

Reeve M J, 1994. Improving land restoration in Britain by better timing of soil movement, pp 28-37. In, Proceedings American Society of Mining and Reclamation. DOI: 10.21000/JASMR94030028