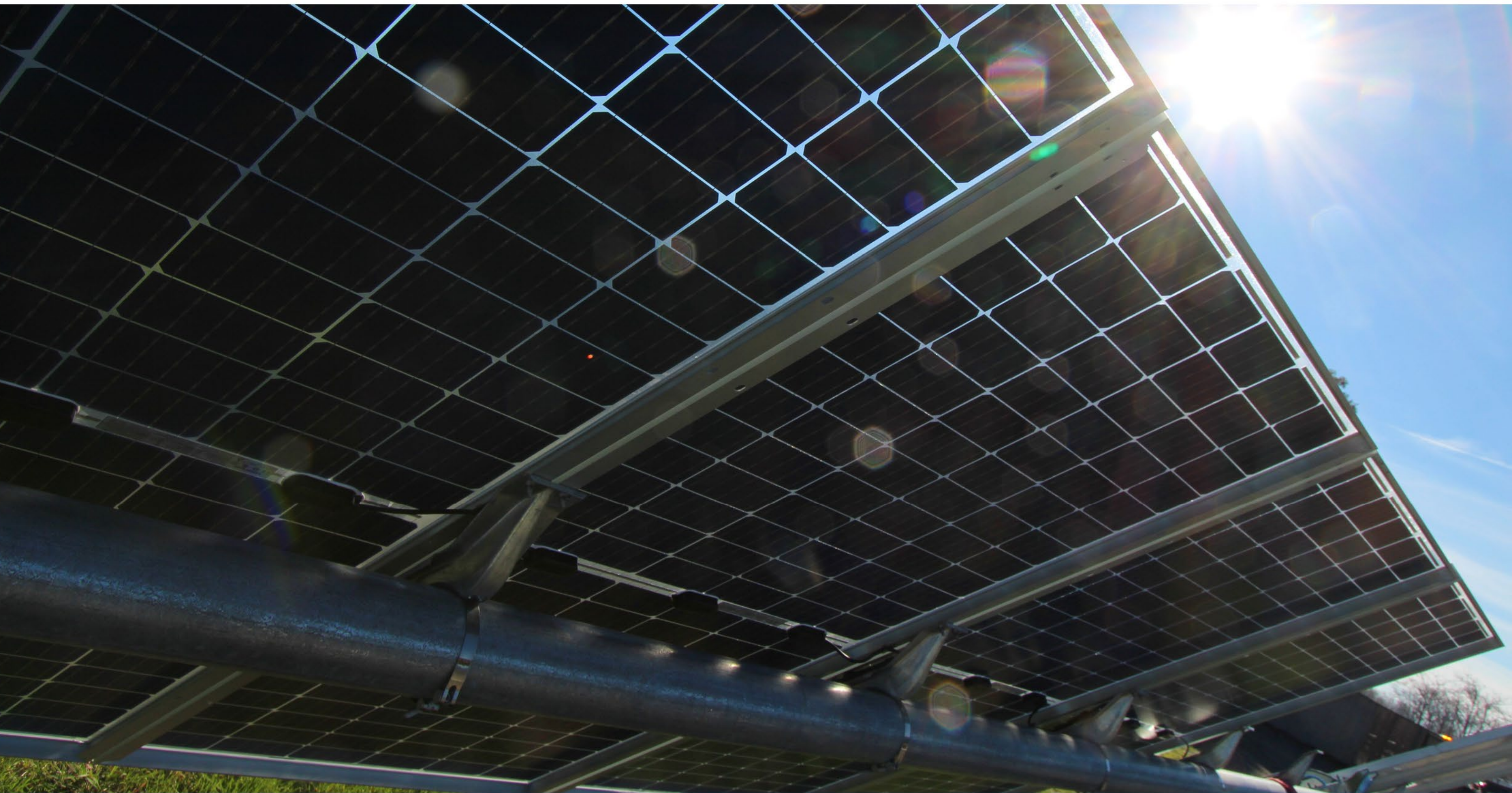
FLOOD RISK ASSESSMENT AND OUTLINE DRAINAGE STRATEGY

SOUTHLANDS SOLAR FARM AND BATTERY STORAGE
LAND SOUTH OF RUNWELL ROAD (A132), RUNWELL, WICKFORD
P19-FRA OCTOBER 2022



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Southlands Solar Farm FRA & Outline Drainage Strategy

Document issue details

WHS1973

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1.0	23/09/2022	Draft	Reuben James *(Consultant)* Sam Pucknell *(Consultant)*	Brett Park *(Principal Consultant)*
2.0	18/10/2022	Final	Sam Pucknell *(Consultant)*	Paul Blackman *(Director)*

For and on behalf of Wallingford HydroSolutions Ltd.

Contents

1 Introduction

1.1 Background

Wallingford HydroSolutions Ltd (WHS) has been commissioned by Enso Green Holdings J Ltd. ("the Applicant") to undertake a Flood Risk Assessment (FRA) and outline drainage strategy for a proposed solar farm located on land south of Runwell Road (A132), Runwell near Wickford, Essex (NGR: 576665, 194589).

This report details the findings of a comprehensive desk-based review detailing flood risk to the site and provides recommendations for the management of surface water runoff on-site, utilising sustainable urban drainage systems (SuDS) options where appropriate.

1.2 Scope

The site is currently a greenfield site, with the proposed works consisting of the construction of a solar farm including panels, transformers and batteries over an area of 58.99ha. Solar farms are defined by the National Planning Policy Framework (NPPF)[1] as being essential infrastructure.

Part of the site is located within Flood Zone 3, defined as an area having less than a 1.0% Annual Exceedance Probability (AEP) of flooding from main rivers. A Flood Risk Assessment (FRA) is required in accordance with the NPPF to demonstrate that flood risk and surface water runoff can be managed sustainably. In summary, this FRA will:

- Introduce the site in terms of its location, topography and the proposed development.
- Assess the flood risk to the site using available data.
- Stipulate national and local sustainable drainage guidance.
- Provide a surface water drainage strategy for the site.

1.3 Sources of Information

- Client supplied drawing[2].
- Environment Agency (EA) National Flood Maps[3].
- British Geological Survey (BGS) Infiltration SuDS GeoReport (attached in Appendix 1).
- CIRIA SuDS Manual[4].
- Publicly available data from the Lead Local Flood Authority (LLFA).

[1] National Planning Policy Framework, July 2018, Ministry of Housing and Local Government, accessed: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/740441/National_Planning_Policy_Framework_web_accessible_version.pdf
[2] Proposed Site Plan. Drawing no. RC3-02-P02 Rev 02 (4th October 2022).
[3] Environment Agency. Available at: https://flood-map-for-planning.service.gov.uk/ Accessed August 2021.
[4] CIRIA SuDS Manual 2015. C753

2 Site Description

2.1 Location

The proposed site is outlined in Figure 1. The 58.99ha site is classified as a greenfield site and lies to the North-East of Wickford at NGR: 576665, 194589. The site spans a number of agricultural fields and has an unnamed watercourse running through it from north to south, in addition to a number of field drains. The River Crouch is located to the south of the site and flows in an easterly direction.

Figure 1 - Site Boundary

2.2 Topography

Figure 2 shows the general ground levels based on 1m LiDAR survey data. The existing site is raised to the north, and the slope declines slightly to the south, with a minimum elevation of approximately 8m AOD. The maximum ground level is approximately 23m AOD and the site is bounded by higher elevations to the northeast and northwest.

For the most part, the site has a slope of less than 2% and consequently is categorised as nearly level. The section of the site sloping from the centre westward towards the unnamed watercourse running through the site is however steeper and is categorised as having a moderate slope.

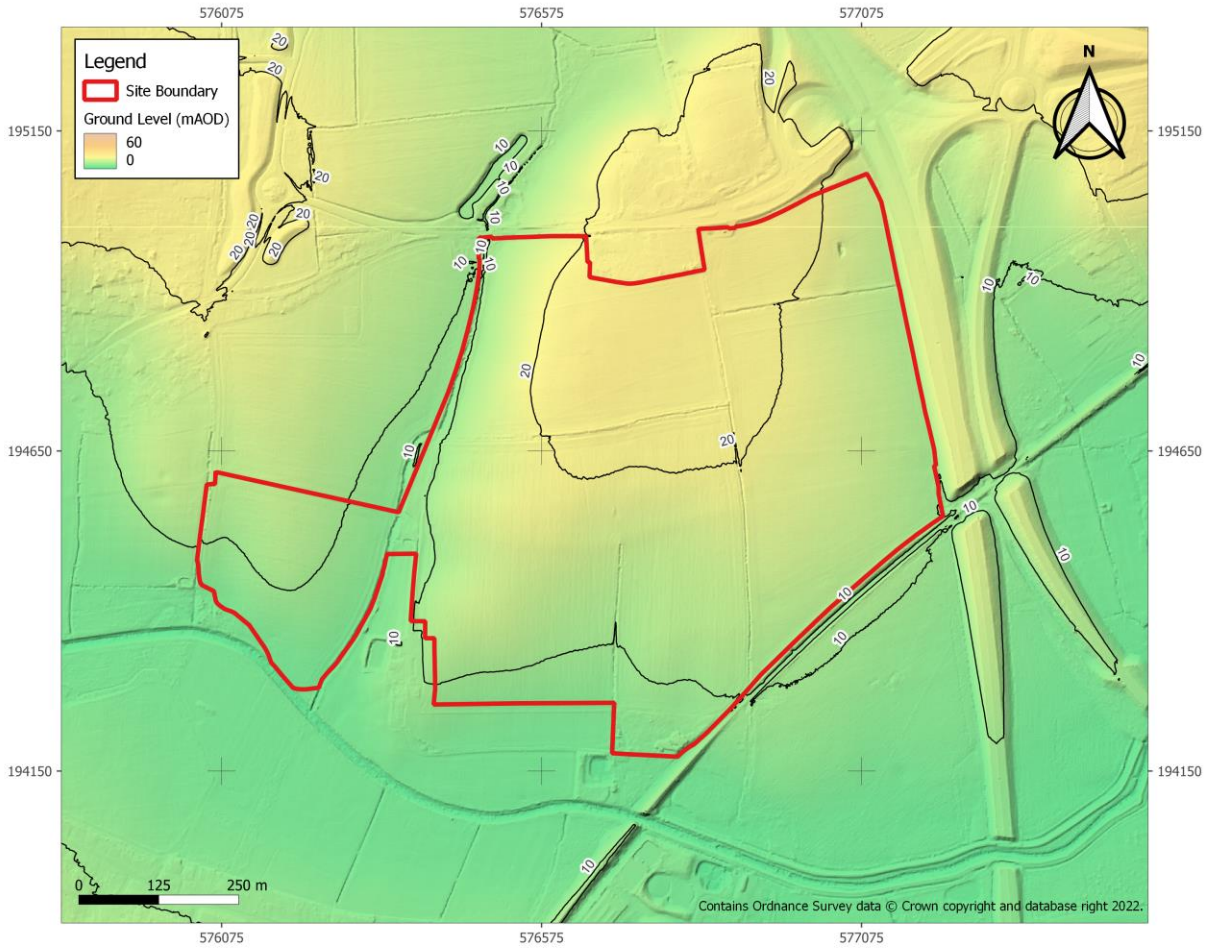


Figure 2 - Site Topography

2.3 Proposed Development

The proposed development is shown below in Figure 3. The development consists of the following:

- solar photovoltaic panels (covering 13.4ha)
- Porous access tracks
- Security fencing
- 24 batteries
- 13 inverters
- 2 storage containers
- 1 transformer
- 1 control building
- 1 substation

The batteries, transformers, storage containers, control building and substation are impermeable areas whilst the track will be porous. The panels will be raised and the surface underneath vegetated.

Figure 3 - Proposed Site Layout

3 Sources of Flood Risk

3.1 Fluvial flood Risk

Flood risk to the proposed development site has been assessed by reviewing the Environment Agency's (EA) online flood maps. The EA flood maps consider the risk associated with fluvial and tidal flood events during an undefended scenario, i.e. the presence of the fluvial or tidal defences are not considered.

The EA flood maps indicate that the majority of the site is located in Flood Zone 1 as shown below in Figure 4. Part of the site is within Flood Zone 3 and is associated with the unnamed watercourse and the River Crouch. The site layout superimposed on the flood maps shows that the design has accordingly placed key infrastructure outside of this zone, only panels and access tracks are located in the flood zones.

Figure 4 - EA Fluvial Flood Map

3.2 Historical Flooding

The EA historic flood map does not show any record of historic flooding at the site. Please note that this dataset only includes flood events known and recorded by the EA.

3.3 Surface Water Flood Risk

The EA surface water flood map is shown in Figure 5 below and displays the depths associated with the 0.1% AEP. Areas of flooding are attributed to the unnamed watercourse (also shown in the fluvial flood map), the field ditches and some minor areas of pooling. Again, critical infrastructure has been located outside of these flood risk areas and where panels are shown to be at risk of flooding in the southwest, during any flood event panels would return to a preprogramed "stowage" height of 2m, which is above the design flood level..

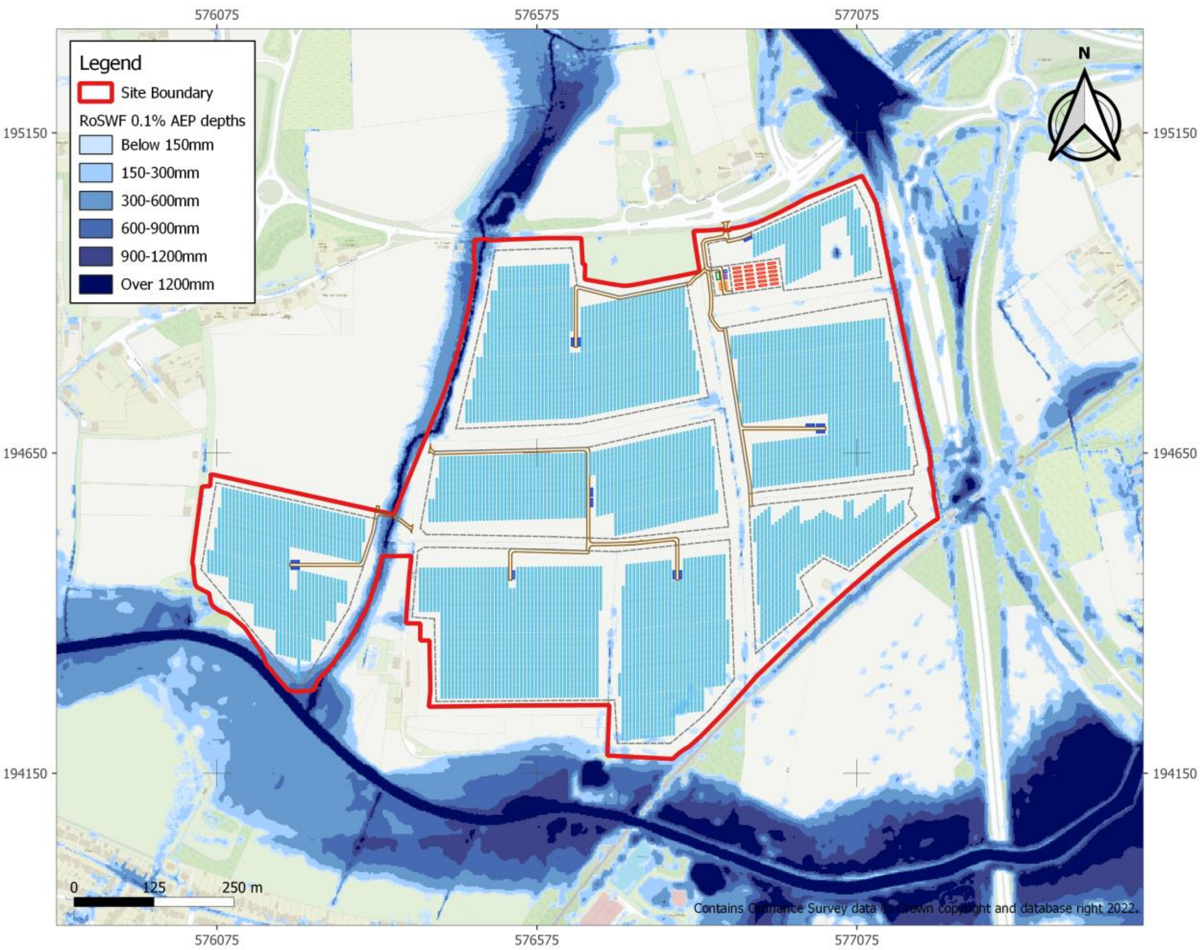


Figure 5 - Surface Water Flood Map

3.4 Groundwater Flood Risk

The BGS SuDS GeoReport (see Appendix 1) indicates that groundwater levels vary across the site, with water levels likely to be less than 3m below the ground surface within the floodplain of the River Crouch and the unnamed watercourse. The flood risk to critical infrastructure associated with groundwater is therefore considered low as they have been placed away from the watercourses.

3.5 Reservoir Flood Risk

The risk of reservoir flooding has been reviewed using the EA's reservoir flood map and indicates that the site is not at risk of flooding from reservoirs.

4 Management of Surface Water Runoff

4.1 Correspondence with the LLFA

Pre-application advice was received from the LLFA[5], Essex County Council. A summary of some of the key requirements are as follows:

- SuDS are required to manage surface water runoff from the site to mitigate against channelised flow and soil erosion.
- Recommend the use of conveyance SuDS such as filter strips, filter drains, check dams and vegetation between the panels.
- Ancillary buildings should be managed using soakaways where possible to provide storage up to the 1 in 100yr + climate change storm event.
- Other small areas can be managed using permeable surfaces with a subbase storage layer.

4.2 Planning Requirements

Based on guidance set out in the NPPF, any development should include measures to manage post-development surface water run-off rates. As the development is currently a greenfield site and within an ecologically sensitive area receiving surface water run-off, effective management of surface water runoff from the proposed development is required to maintain the existing hydrological regime.

The following sections describe how any changes in the surface water will be sustainably managed on-site and provide details of the current greenfield run-off rates.

4.3 Greenfield Run-off Rates

To estimate run-off and determine the drainage requirements for the site, greenfield runoff rates have been calculated. Based upon guidance set out in NPPF the drainage system should be designed for a range of storms up to and including the 1 in 100 year event plus an allowance for climate change. Runoff rates for the existing greenfield land have been calculated using ReFH2, which is the current recommended method outlined in the CIRIA SUDS manual. The rates and volumes have been estimated over 58.99ha, the entire site area.

Table 1 below presents the greenfield runoff rates as the unit rate per hectare and the total rate over the 58.99ha site. The associated calculations are provided in Appendix 2.

Table 1 - Greenfield Runoff Rates

Return Period	Greenfield Runoff Rate (l/s)	Greenfield Runoff Rate (l/s/ha)
1:1	255.07	4.32
1:30	665.57	11.28
1:100	915.84	15.53
1:100 + CC*	1338.33	22.69

*Climate change allowance of 40% as per the recommendations from the LLFA[6]

[5] Essex County Council pre-application response (SUDSPA443648469), August 2022.
[6] https://www.essexdesignguide.co.uk/suds/rates-and-storage/climate-change/

The runoff rates in Table 1 are based on a total area of 58.99ha, a Standard Annual Rainfall (SAAR) of 562, a base flow index (BFIHOST) of 0.3 and a proportion of time soils are wet (PROPWET) of 0.27.

4.4 Post Development Runoff Mitigation

The proposed development is for solar panels which will cover an area of 13.4ha, this equates to 23% of the total site area. As the panels will sit on frames, leaving the natural ground surface below the panels, the amount of permeable land on site is expected to reduce by a negligible amount during the operation of the solar farm compared to pre-development.

The solar panels will intercept rainwater and shed it onto the ground on the lower edge of each array, referred to as the drip line. Gaps within the centre of the panels act to reduce this concentration of water flow towards the drip line providing another route for rainwater to reach the ground. Whilst the panels would result in a concentration of rainwater along the drip-line of each row and in the centre of the panels, water would be intercepted by the vegetation growing in between and underneath the panels. Some of which will infiltrate into the underlying soils and, for more extreme events, some of which will run off through the vegetation, in a similar way to the site response at present.

A study[7] on the hydrological implications of solar farms confirmed this to be the case. Solar panels themselves should not have a significant impact on runoff volumes, peak rates or time-to-peak rates, provided the ground beneath the panels remains vegetated. The study accounted for changes in soil type, slope angle and rainfall intensity, before concluding that ground cover has the most significant impact on runoff rates. On this basis, providing that vegetation cover beneath the solar arrays is maintained, no significant increase in surface water runoff is anticipated as a result of the solar array.

[7] Cook, L. M., & McCuen, R. H. (2011). Hydrologic response of solar farms, *Journal of Hydrologic Engineering,* 18(5), 536-541.

5 Outline Drainage Strategy

5.1 Summary of SuDS Drainage Strategy

The overarching principle for the proposed SuDS scheme is to provide SuDS at source, ensuring that surface water run-off is managed as per existing site conditions. A summary of the SuDS components that are proposed to manage surface water run-off at source are summarised in Table 2 and a detailed discussion of the proposed SuDS scheme is provided in the following sections; along with a plan showing the general arrangement in Figure 6 and Appendix 3.

Table 2 – Summary of Proposed SuDS Scheme

Infrastructure	SuDS Component	Comment
Substation	Soakaway adjacent to the structure	Sized for the 100yr+CC event.
Smaller Ancillary Impermeable Structures	Apron of clean crushed stone	Small impermeable areas are surrounded by clean crushed stone to promote local infiltration.
PV Panels located on nearly Flat Ground	Grassland mix under the panels with wildflower mix around the margins. Filter Strip at the downslope boundary	Increase in the run-off is expected to be negligible due to the nearly flat gradient of the ground. However, a filter strip is added as a precautionary measure.
PV Panel located on Steeper Ground (>5 degrees slope)	Grassland mix under the panels with wildflower mix around the margins. Swale at the downslope boundary	Increase in the run-off is also expected to be negligible, however, a swale on the downslope boundary is included as a precautionary measure.
Access Track	No SuDS required as no increase in impermeable surface	Construction will be a permeable aggregate over a geotextile membrane with an aggregate sub-base layer beneath.

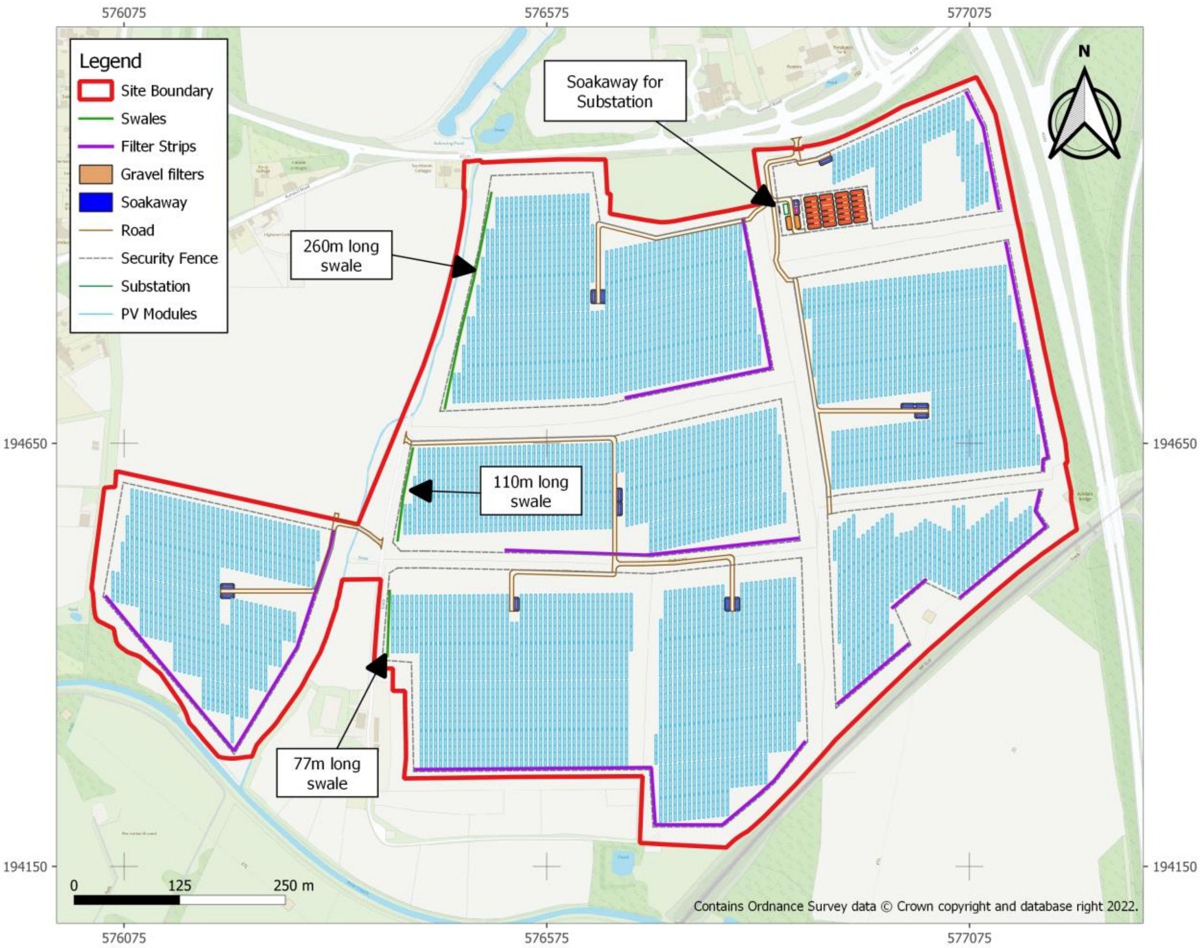


Figure 6 - Outline drainage strategy

5.2 Substation

The BGS SuDS report (Appendix 1) shows that large sections of the site are 'probably compatible for infiltration SuDS' whilst in the vicinity of the River Crouch and the unnamed watercourse there are significant constraints indicated. Infiltration SuDS could therefore be a viable drainage strategy although infiltration testing would be required to confirm the infiltration rate being used in the design of any attenuation feature.

A soakaway is proposed for the substation on the basis that it contributes the largest single increase in the impermeable area within the site. The soakaway is sized to store runoff for storm events up to the 1 in 100 year plus climate change event. At this stage, infiltration testing has not been conducted at the site and as such, an appropriate infiltration rate is assumed ($1x10^{-6}$ m/s minimum as per the LLFA requirements[8]). The calculations for sizing of the soakaway was completed in Causeway Flow and can be found in Appendix 4. The resulting soakaway is 9.0m x 1.5m x 2.0m (length x width x height) with a porosity of 0.30. A minimum clearance of 5m between the building

[8] Essex County Council pre-application response (SUDSPA443648469), August 2022.

and the soakaway is required in compliance with BS8301 1985 & the building regulations 1985 part H. It is proposed that infiltration testing, if required, is completed during the detailed design phase of the project to confirm, and if necessary, update the size of the proposed soakaway.

5.3 Smaller Ancillary Infrastructure

The remaining smaller impermeable areas (batteries, inverters, storage containers, transformer and control room) will have an apron of clean crushed stone to promote local infiltration.

It is proposed that the cursed stone apron will be at least 1m wide and to a depth of at least 300mm, consisting of 40-70mm clean stone.

The use of the clean crushed stone surrounding the ancillary infrastructure is common practice for solar farm developments across the UK and deemed to be an appropriate measure to increase local infiltration at source.

5.4 PV Panels

5.4.1 Landscaping

The majority of the solar farm is situated on a relatively flat site, which results in slower runoff rates in comparison to steep slopes. Consequently, the use of landscaping is largely considered a suitable mitigation measure, including the use of grassland, wildflower mixes, and tree planting where appropriate. These measures, combined with the use of filter strips at the toes of solar panels, act to prevent channelised flow and soil erosion from occurring. Due to the flatness of the majority of the site, these mitigations are considered sufficient to manage run-off from the panels. Swales are proposed as an additional mitigation measure to store runoff where the site is steeper (slope >5 degrees), attenuating water before it enters the water body.

The use of grassland mix underneath solar panels and a wildflower mix surrounding the margins is proposed. This will increase runoff interception and infiltration into underlying soils. As a result of these measures, no significant increase in surface-water runoff is anticipated with the addition of solar panels on site.

5.4.2 Swales

Although the solar panels are not anticipated to significantly increase run-off rates, three unconnected cut-off swales are proposed as a precautionary measure to store the run-off volume adjacent to the steepest sections of the site (where the slope is > 5 degrees). The area of panels served by the swales and the surface water flow direction is shown below in Figure 7. Three drainage zones have been specified on the east side of the unnamed watercourse. These have been numbered from 1 to 3 (north to south) and have areas of 5.8ha, 2.1ha and 1.5ha respectively.

Due to the underlying geology of the site, there is a possibility to allow for infiltration through the proposed swales. Infiltration testing will be undertaken at the detailed design phase to confirm the potential for infiltration and any potential reduction in storage. At this stage and to be conservative, no infiltration allowance has been made.

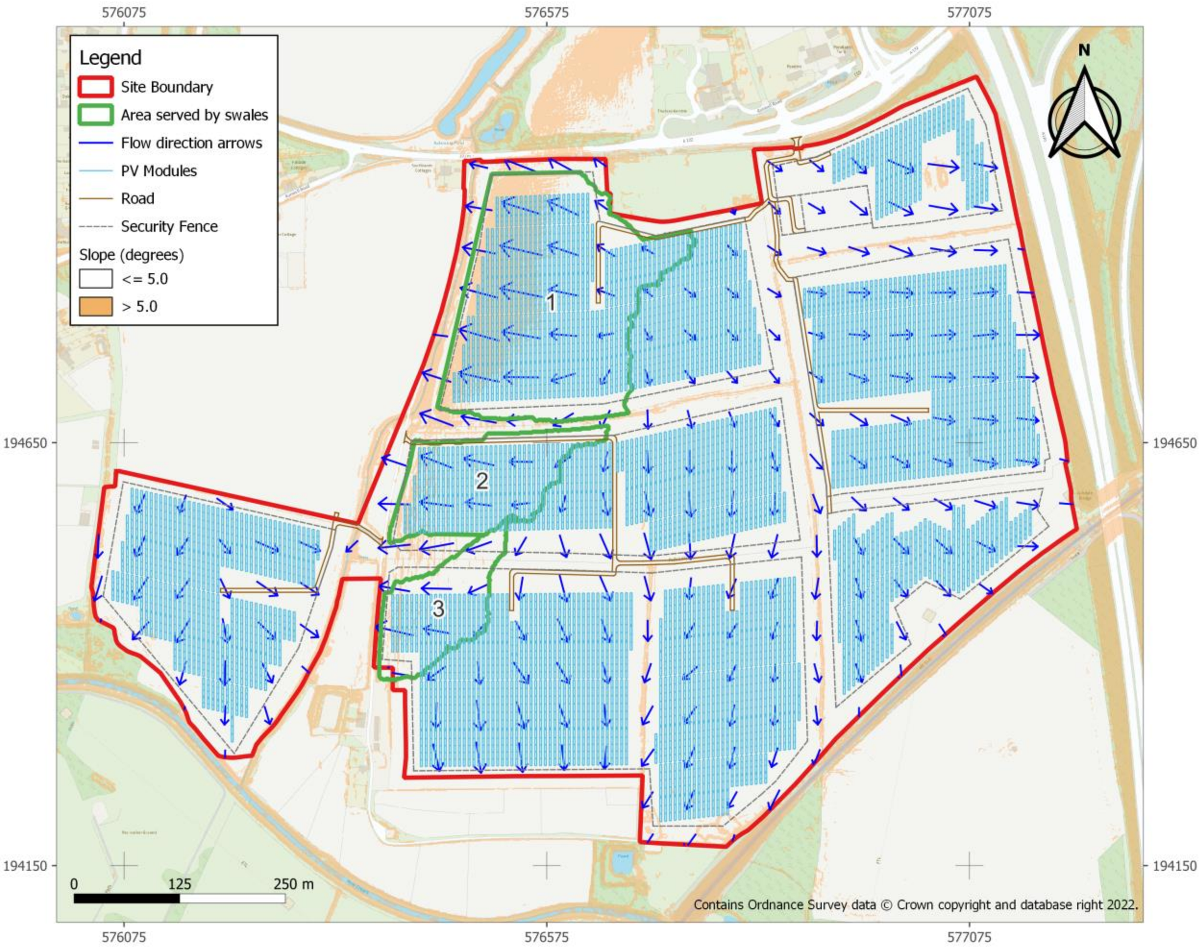


Figure 7 - Swale Drainage Zones

To size the swales, the long-term storage equation was applied to identify the theoretical volume emanating from the site due to the impermeable area of the solar panels. Due to the minor footprint of the panels themselves, i.e. rainwater is still able to drip onto the existing fields, this method was deemed appropriate as it accounts for a nominal increase in the volume of runoff rather than an increase in runoff rate.

A nominal 25% of the total area of the panels was used for the contributing area. This is a conservative assumption as if the area under the panel remains grassed, the only theoretical increase may be the area of the supporting legs. The 25% allowance also allows for the contribution to increased runoff volume during the construction and operational phases of the project. For drainage zones 1, 2 and 3 respectively, 25% of the panels cover 0.43ha, 0.16ha and 0.08ha.

The volume was calculated for the 100yr rainfall event, including a 40% allowance for climate change. The 100 year, 6hr rainfall depth was used in the calculation, this was taken as 78.66mm (110.13mm accounting for climate change).

Drainage Zone 1

The long-term storage calculation equation for Zone 1 of the site is as follows:

$$Vol = 110.13 \times 5.8 \times 10 \left[\frac{7.4}{100}(1 \times 0.8) + \left(1 - \frac{7.4}{100}\right)(1 \times 0.41) - 0.41\right]$$

$$Vol = 185m^3$$

A total additional runoff volume of 185m^3 has been calculated due to the assumed impermeable area of 0.43ha calculated for the drainage zone. To address this potential increase in volume, it is proposed to implement a vegetated swale as a means of storing some of the run-off volume. It is proposed to utilise a swale along the eastern boundary of the unnamed watercourse with a length of 260m, having a cross-sectional area of 0.72m^2, this can be viewed in the drainage strategy drawing available in Appendix 3. The proposed swales are to have a geometry with a base of 0.60m and height of 0.40m with 1 in 3 side slopes as indicated in Figure 8 and Figure *9*. The swales will follow existing contour lines where possible.

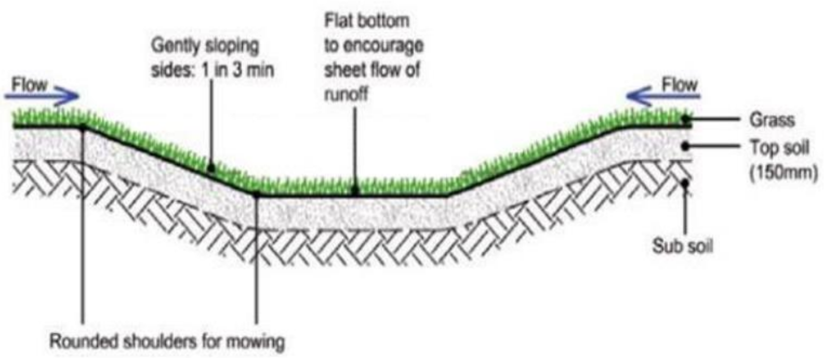


Figure 8 - Typical Swale Cross Section

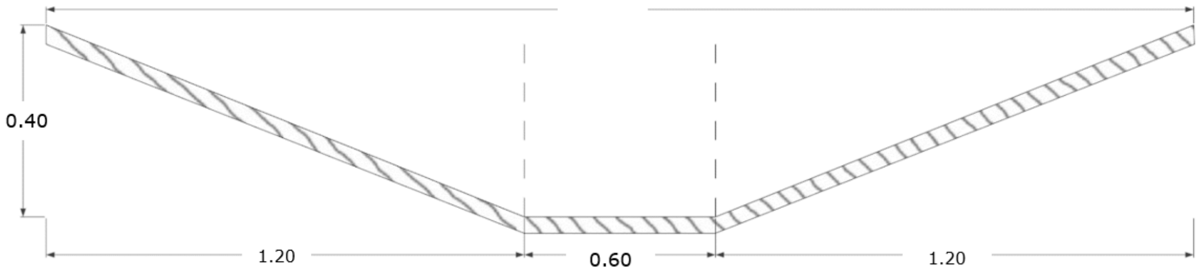


Figure 9 - Proposed Swale Geometry for Zone 1

Drainage Zone 2

The long-term storage calculation equation for Zone 2 of the site is as follows:

$$Vol = 110.13 \times 2.1 \times 10\left[\frac{7.6}{100}(1 \times 0.8) + \left(1 - \frac{7.6}{100}\right)(1 \times 0.41) - 0.41\right]$$

$$Vol = 69m^3$$

A total additional runoff volume of 69m^3 has been calculated due to the assumed impermeable area of 0.16ha calculated for the drainage zone. To address this increase in volume, it is proposed to implement a vegetated swale as a means of storing some of the run-off volume. It is proposed to utilise a swale along the eastern boundary of the unnamed water with a length of 110m, having a cross-sectional area of 0.72m^2, this can be viewed in the drainage strategy drawing available in Appendix 3. The proposed swales are to have a geometry with a base of 0.50m and height of 0.40m with 1 in 3 side slopes as indicated in Figure 10. The swales will follow existing contour lines where possible.

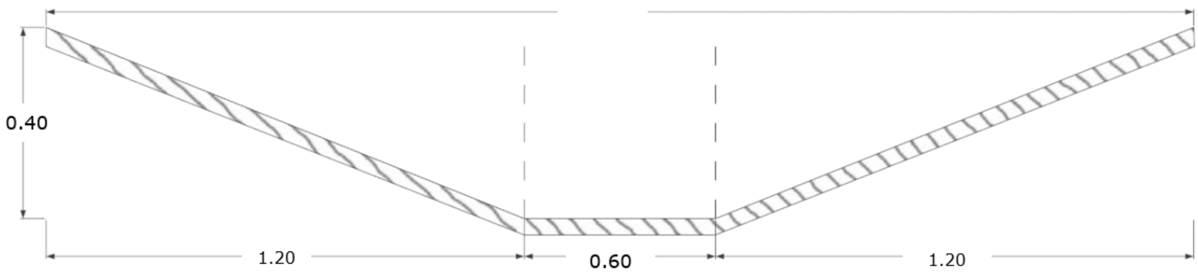


Figure 10 - Proposed Swale Geometry for Zone 2

Drainage Zone 3

The long-term storage calculation equation for the western section of the site is as follows:

$$Vol = 110.13 \times 1.5 \times 10 \left[\frac{5.3}{100}(1 \times 0.8) + \left(1 - \frac{5.3}{100}\right)(1 \times 0.41) - 0.41\right]$$
$$Vol = 34m^3$$

A total additional runoff volume of $34m^3$ has been calculated due to the assumed impermeable area of 0.08ha calculated for the drainage zone. To address this increase in volume, it is proposed to implement a vegetated swale as a means of storing some of the run-off volume. It is proposed to utilise a swale along the eastern boundary of the unnamed water with a length of 77m, having a cross-sectional area of $0.72m^2$, this can be viewed in the drainage strategy drawing available in Appendix 3. The proposed swales are to have a geometry with a base of 0.60m and height of 0.40m with 1 in 3 side slopes as indicated in Figure 11. The swales will follow existing contour lines where possible.

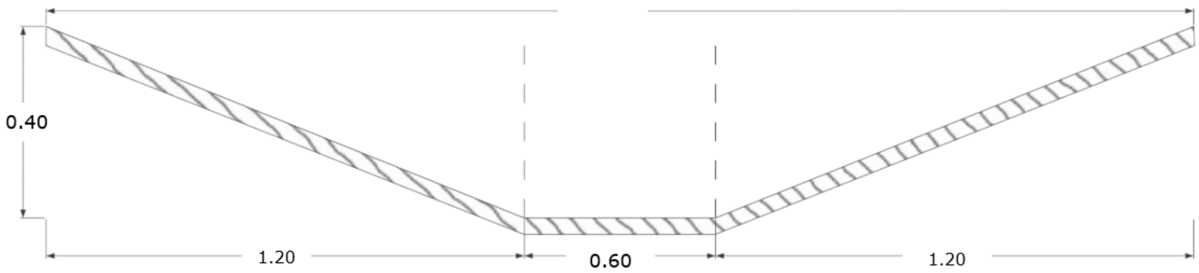


Figure 11 - Proposed Swale Geometry for Zone 3

The swales have been proposed as a precautionary and conservative measure as the solar panels are not expected to significantly alter existing drainage.

The swales will provide a safeguard to manage the runoff volume during both the construction and operational phase of the project in these steeper areas. The swales have been designed in accordance with the CIRIA SUDS manual[9] using the long-term storage equation, which specifically addresses the additional runoff caused by a development. Due to the unverified infiltration rate at the site, the swale has been sized to capture and store all the site runoff, assuming no infiltration.

5.4.3 Filter Strips

Filter strips will be placed downslope of the solar panels (where swales are not proposed) to manage run-off leaving the site. The filter strips are a precautionary measure to help to reduce run-off rates and they can be easily incorporated into the proposed site landscaping.

[9] CIRIA SuDS Manual 2015. C753

5.5 Access Tracks

As the proposed access tracks will be permeable, no additional SuDS measures are required as the access tracks will not increase the impermeable area across the site.

5.6 SuDS Maintenance

This section has been produced as per the guidance provided in the CIRIA SuDS manual.

Swales will require regular maintenance to ensure continuous operation to design performance. Swale maintenance is relatively straight forward and typically, only a small amount of extra work is required over and above the requirements for standard open public space, therefore having only marginal cost implications, assuming that landscape management is already carried out. Adequate access should be provided to all swale areas for inspection and maintenance. Litter and debris removal should be undertaken regularly to ensure that the swale is fully operational. The main requirement for dry swales is mowing. Grass lengths should be retained to 75-150mm to assist in filtering pollutants and retaining sediments. These grass lengths will also reduce the risk of flattening during runoff events. All grass clippings should be disposed of away from the swale to remove any nutrients or potential pollutants. Any sediment deposits within the swale that exceed 25mm should be removed, however, this can be minimised by ensuring that upstream areas are stabilised.

The soakaway will also require maintenance (generally annually or as required) which will include checking any inspection tube for sediment and debris, cleaning the substation gutters and gully pot, trimming any roots that may be causing blockages, replacement of clogged geotextile and replacement of the fill if performance deteriorates.

6 Conclusions

This FRA and drainage strategy outlines how surface water will be managed during operational phases of the development and provides an overview maintenance plan for the key SuDS features proposed. In summary:

- No critical infrastructure has been placed within the mapped flood zones.
- Some PV panels are located within the mapped flood zones; however, this is considered acceptable and in line with current NPPF guidance for Essential Infrastructure.
- New landscaping will improve upon existing farmland by intercepting runoff and promoting sedimentation, filtration and infiltration.
- The proposed solar panels and tracks will not lead to any significant increase in run-off. However, as a precautionary measure, swales are proposed to store run-off from the steepest areas of the site and filter strips are provided for the remainder of the site.
- Ancillary buildings will be surrounded by a crushed stone apron consisting of clean 40-70mm clean stone and the larger substation will be served by a soakaway which has been sized to accommodate the 6hr 100yr + 40% climate change rainfall event.

Appendix 1 BGS SuDS Infiltration Report

GeoReports

British Geological Survey

REUBEN JAMES
WALLINGFORD HYDROSOLUTION
H R WALLINGFORD LTD
HOWBERY PARK
WALLINGFORD
OX10 8BA

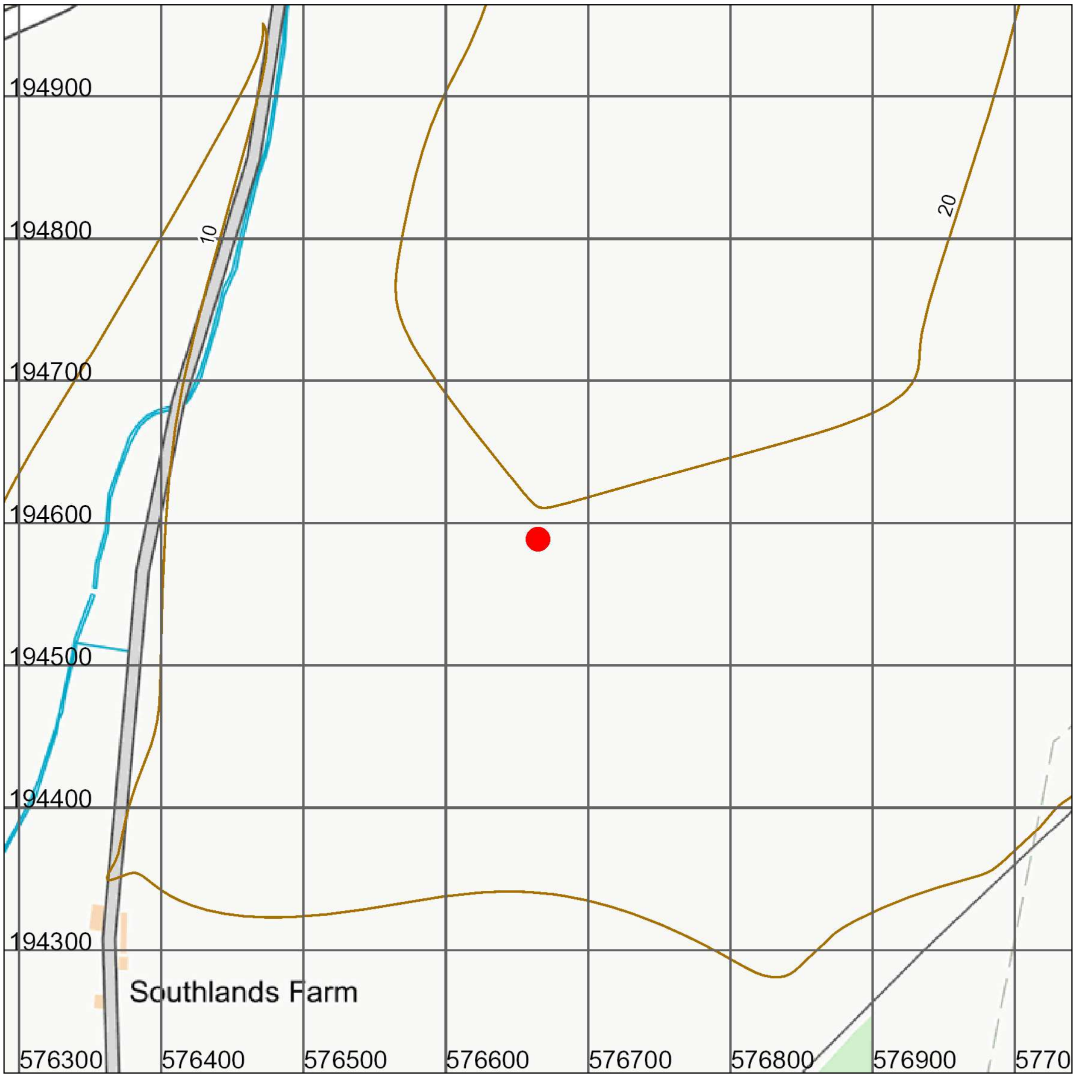
Infiltration SuDS GeoReport:

This report provides information on the suitability of the subsurface for the installation of infiltration sustainable drainage systems (SuDS). It provides information on the properties of the subsurface with respect to significant constraints, drainage, ground stability and groundwater quality protection.

Report Id: ***BGS_327518/36494***

Client reference: WHS1973

Search location



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Search location indicated in red

Point centred at: 576665,194589

Assessment for an infiltration sustainable drainage system

Introduction

Sustainable drainage systems (SuDS) are drainage solutions that manage the volume and quality of surface water close to where it falls as rain. They aim to reduce flow rates to rivers, increase local water storage capacity and reduce the transport of pollutants to the water environment. There are four main types of SuDS, which are often designed to be used in sequence. They comprise:

- **source control:** systems that control the rate of runoff
- **pre-treatment:** systems that remove sediments and pollutants
- **retention:** systems that delay the discharge of water by providing surface storage
- **infiltration:** systems that mimic natural recharge to the ground.

This report focuses on infiltration SuDS. It provides subsurface information on the properties of the ground with respect to drainage, ground stability and groundwater quality protection. It is intended principally for those involved in the preliminary assessment of the suitability of the ground for infiltration SuDS, and those involved in assessing proposals from others for sustainable drainage, but it may also be useful to help house-holders judge whether or not further professional advice should be sought. If in doubt, users should consult a suitably-qualified professional about the results in this report before making any decisions based upon it.

This GeoReport is structured in two parts:

- **Part 1. Summary data**.

  Comprises three maps that summarise the data contained within Part 2.

- **Part 2. Detailed data**.

  Comprises a further 24 maps in four thematic sections:

  - **Very significant constraints.** Maps highlight areas where infiltration may result in adverse impacts due to factors including: ground instability (soluble rocks, non-coal shallow mining and landslide hazards); persistent shallow groundwater, or the presence of made ground, which may represent a ground stability or contamination hazard.
  - **Drainage potential**. Maps indicate the drainage potential of the ground, by considering subsurface permeability, depth to groundwater and the presence of floodplain deposits.
  - **Ground stability**. Maps indicate the presence of hazards that have the potential to cause ground instability resulting in damage to some buildings and structures, if water is infiltrated to the ground.
  - **Groundwater protection**. Maps provide key indicators to help determine whether the groundwater may be susceptible to deterioration in quality as a result of infiltration.

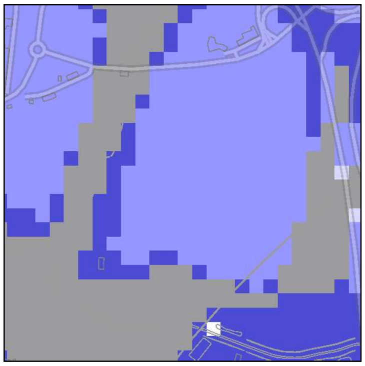
This report considers the suitability of the subsurface for the installation of infiltration SuDS, such as soakaways, infiltration basins or permeable pavements. It provides subsurface data to indicate whether, and which type of infiltration system may be appropriate. It does not state that infiltration SuDS are, or are not, appropriate as this is highly dependent on the design of the individual system. This report therefore describes the subsurface conditions at the site, allowing the reader to determine the suitability of the site for infiltration SuDS.

The map and text data in this report is similar to that provided in the '*Infiltration SuDS Map: Detailed'* national map product. For further information about the data, consult the '*User Guide for the Infiltration SuDS Map: Detailed'*, available from http://nora.nerc.ac.uk/16618/.

PART 1: SUMMARY DATA

This section provides a summary of the data.

In terms of the drainage potential, is the ground suitable for infiltration SuDS?



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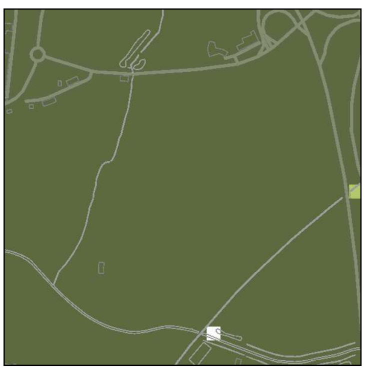
	Highly compatible for infiltration SuDS. The subsurface is likely to be suitable for free-draining infiltration SuDS.
	Probably compatible for infiltration SuDS. The subsurface is probably suitable although the design may be influenced by the ground conditions.
	Opportunities for bespoke infiltration SuDS. The subsurface is potentially suitable although the design will be influenced by the ground conditions.
	Very significant constraints are indicated. There is a very significant potential for one or more hazards associated with infiltration.

Is ground instability likely to be a problem?



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	Increased infiltration is very unlikely to result in ground instability.
	Ground instability problems may be present or anticipated, but increased infiltration is unlikely to result in ground instability.
	Ground instability problems are probably present. Increased infiltration may result in ground instability.
	There is a very significant potential for one or more geohazards associated with infiltration.

Is the groundwater susceptible to deterioration in quality?

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	The groundwater is not expected to be especially vulnerable to contamination.
	The groundwater may be vulnerable to contamination.
	The groundwater is likely to be vulnerable to contaminants.
	Made ground is present at the surface. Infiltration may increase the possibility of remobilising pollutants.

PART 2: DETAILED DATA

This section provides further information about the properties of the ground and will help assess the suitability of the ground for infiltration SuDS.

Section 1. Very significant constraints

Where maps are overlain by grey polygons, geological or hydrogeological hazards may exist that could be made worse by infiltration. The following hazards are considered:

- soluble rocks
- landslides
- shallow mining (not including coal)
- shallow groundwater
- made ground

For more information read 'Explanation of terms' at the end of this report.

<table>
<tr><th colspan="2">Soluble rock hazard</th></tr>
<tr><td rowspan="2">
Contains OS data © Crown Copyright and database right 2022</td><td>Very significant soluble rock hazard.
Soluble rocks are present with a very significant possibility of localised subsidence that could be initiated or made worse by infiltration. The site investigation should consider whether the potential for or the consequences of subsidence as a result of infiltration are significant.</td></tr>
<tr><td>Very significant soluble rock hazards are not present; however this hazard may still need to be considered. See Part 3.</td></tr>
<tr><th colspan="2">Landslide hazard</th></tr>
<tr><td rowspan="2">
Contains OS data © Crown Copyright and database right 2022</td><td>Very significant landslide hazard.
Slope instability problems are almost certainly present and may be active. An increase in moisture content as a result of infiltration may cause the slope to fail. The site investigation should consider whether the potential for or the consequences of landslide as a result of infiltration are significant.</td></tr>
<tr><td>Very significant landslide hazards are not present; however this hazard may still need to be considered. See Part 3.</td></tr>
</table>

Shallow mining hazard (not including coal)

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- [■] Very significant mining hazard.

  Shallow mining is likely to be present with a very significant possibility of localised subsidence that could be initiated or made worse by increased infiltration. Also, infiltration may increase the possibility of remobilising pollutants. The site investigation should consider whether the potential for or consequences of subsidence and/or remobilisation of pollutants as a result of infiltration are significant.
- [ ] Very significant mining hazards are not present; however this hazard may still need to be considered. See Part 3.

Persistent shallow groundwater

Contains OS data © Crown Copyright and database right 2022

- [■] Very high likelihood of persistent or seasonally shallow groundwater.

  Persistent or seasonally shallow groundwater is likely to be present. Infiltration may increase the likelihood of soakaway inundation, or groundwater emergence at the surface. The site investigation should consider whether the potential for or the consequences of groundwater level rise as a result of infiltration are significant.
- [ ] See Part 2 for the likely depth to water table.

Made ground

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- [■] Made ground present.

  Made ground is present at the surface. Infiltration may affect ground stability or increase the possibility of remobilising pollutants. The site investigation should consider whether the potential for or consequences of ground instability and/or pollutant leaching as a result of infiltration are significant.
- [ ] None recorded

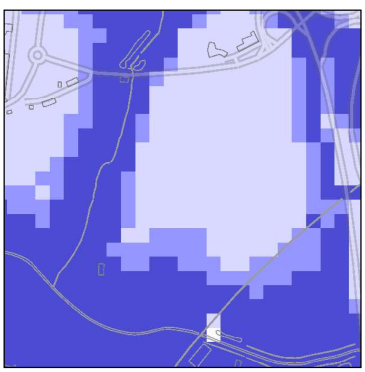
Section 2. Drainage potential

The following pages contain maps that will help you assess the drainage potential of the ground by considering the:

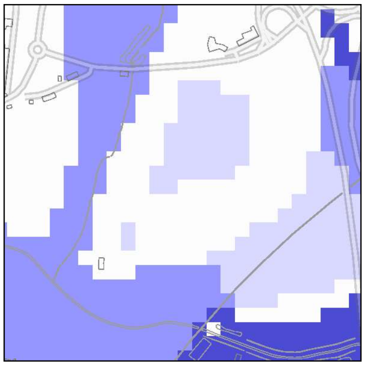
- depth to water table
- permeability of the superficial deposits
- thickness of the superficial deposits
- permeability of the bedrock
- presence of floodplains

Superficial deposits are not present everywhere and therefore some areas of the *superficial deposit permeability* map may not be coloured. Where this is the case, the *bedrock permeability* map shows the likely permeability of the ground. Superficial deposits in some places are very thin and hence in these places you may wish to consider both the permeability of the superficial deposits and the permeability of the bedrock. The *superficial thickness* map will tell you whether the superficial deposits are thin (< 3 m thick) or thick (>3 m). Where they are over 3 m thick, the permeability of the bedrock may not be relevant.

For more information read ‘Explanation of terms’ at the end of this report.

Depth to groundwater table	
 Contains OS data © Crown Copyright and database right 2022	Groundwater is likely to be **more than 5 m** below the ground surface throughout the year.
	Groundwater is likely to be between **3 and 5 m** below the ground surface for at least part of the year.
	Groundwater is likely to be **less than 3 m** below the ground surface for at least part of the year.

Superficial deposit permeability



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Superficial deposits are likely to be **free-draining**.

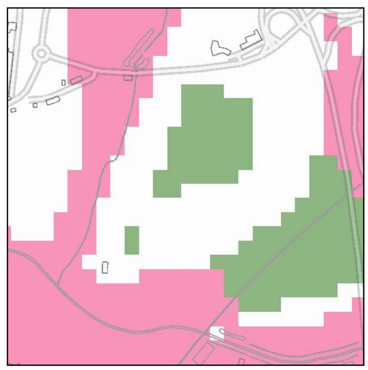
The superficial deposit permeability is **spatially variable**, but likely to permit moderate infiltration.

Superficial deposits are likely to be **poorly draining**.

These maps show the permeability range that is summarised above.

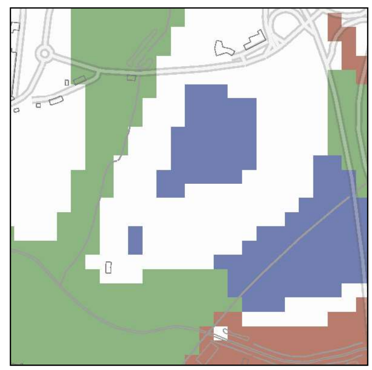
- Very Low
- Low
- Moderate
- High
- Very High

Minimum



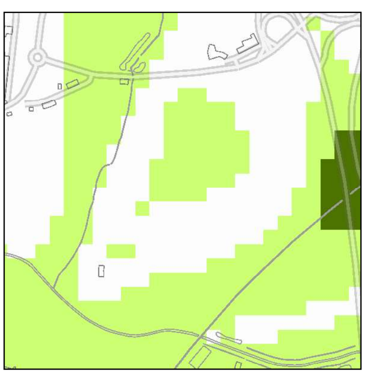
Contains OS data © Crown Copyright and database right 2022

Maximum



Contains OS data © Crown Copyright and database right 2022

Superficial deposit thickness



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The thickness of superficial deposits is **< 3 m** and hence the permeability of the ground may be dependent on both the superficial deposits (where present) and underlying bedrock (see below).

The thickness of superficial deposits is **> 3 m** and hence the permeability of the superficial deposits is likely to determine the permeability of the ground.

Bedrock permeability

Contains OS data © Crown Copyright and database right **2022**

Bedrock deposits are likely to be **free-draining**.

The bedrock permeability is **spatially variable**, but likely to permit moderate infiltration.

Bedrock deposits are likely to be **poorly draining**.

These maps show the permeability range that is summarised above.

Key

- Very Low
- Low
- Moderate
- High
- Very High

Minimum

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Maximum

Contains OS data © Crown Copyright and database right 2022

Geological indicators of flooding

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Superficial floodplain deposits or low-lying coastal areas have been identified. Groundwater levels may rise in response to high river or tide levels, potentially causing inundation of subsurface infiltration SuDS.

Section 3. Ground stability

The following pages contain maps that will help you assess whether infiltration may impact the stability of the ground. They consider hazards associated with:

- soluble rocks
- landslides
- shallow mining
- running sands
- swelling clays
- compressible ground, and
- collapsible ground

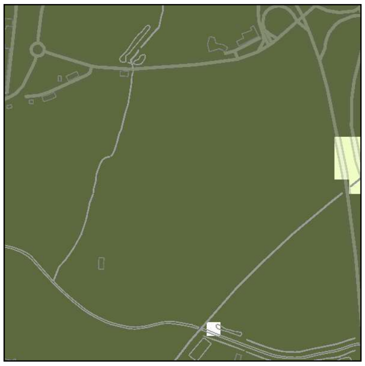
In the following maps, geohazards that are identified in green are unlikely to prevent infiltration SuDS from being installed, but they should be considered during design. For more information read ‘Explanation of terms’ at the end of this report.

Soluble rocks	
 Contains OS data © Crown Copyright and database right 2022	Increased infiltration is unlikely to result in subsidence.
	Increased infiltration is unlikely to cause localised subsidence, but potential impacts should be considered.
	Increased infiltration may result in localised subsidence. The potential for or the consequences of subsidence associated with soluble rocks should be considered.
	Very significant possibility of localised subsidence that could be initiated or made worse by infiltration.

Landslides	
 Contains OS data © Crown Copyright and database right 2022	Increased infiltration is unlikely to lead to slope instability.
	Slope instability problems may be present or anticipated, but increased infiltration is unlikely to cause instability
	Slope instability problems are probably present or have occurred in the past, and increased infiltration may result in slope instability.
	Slope instability problems are almost certainly present and may be active. An increase in moisture content as a result of infiltration may cause the slope to fail.

Shallow mining	
 Contains OS data © Crown Copyright and database right 2022	Increased infiltration is unlikely to lead to subsidence.
	Shallow mining is possibly present. Increased infiltration is unlikely to cause a geohazard, but potential impacts should be considered.
	Shallow mining could be present with a significant possibility that localised subsidence could be initiated or made worse by increased infiltration.
	Shallow mining is likely to be present, with a very significant possibility that localised subsidence may be initiated or made worse by increased infiltration.

Running sand	
 Contains OS data © Crown Copyright and database right 2022	Increased infiltration is unlikely to cause ground collapse associated with running sands.
	Running sand is possibly present. Increased infiltration is unlikely to cause a geohazard, but potential impacts should be considered.
	Significant possibility for running sand problems. Increased infiltration may result in a geohazard.

Swelling clays	
 Contains OS data © Crown Copyright and database right 2022	Increased infiltration is unlikely to cause shrink-swell ground movement.
	Ground is susceptible to shrink-swell ground movement. Increased infiltration is unlikely to cause a geohazard, but potential impacts should be considered.
	Ground is susceptible to shrink-swell ground movement. Increased infiltration may result in a geohazard.

Compressible ground	
 Contains OS data © Crown Copyright and database right 2022	Increased infiltration is unlikely to lead to ground compression.
	Compressibility and uneven settlement hazards are probably present. Increased infiltration may result in a geohazard.

Collapsible ground	
 Contains OS data © Crown Copyright and database right 2022	Increased infiltration is unlikely to result in subsidence.
	Deposits with potential to collapse when loaded and saturated are possibly present in places. Increased infiltration is unlikely to cause a geohazard, but potential impacts should be considered.
	Deposits with potential to collapse when loaded and saturated are probably present in places. Increased infiltration may result in a geohazard.

Section 4. Groundwater quality protection

The following pages contain maps showing some of the information required to ensure the protection of groundwater quality. Data presented includes:

- groundwater source protection zones (Environment Agency data)
- predominant flow mechanism
- made ground

For more information read 'Explanation of terms' at the end of this report.

Groundwater source protection zones	
 Contains OS data © Crown Copyright and database right 2022 Derived in part from Source Protection Zone data provided under licence from the Environment Agency © Environment Agency 2022.	Groundwater is not within a source protection zone. Source protection zone IV Source protection zone III Source protection zone II Source protection zone I
Predominant flow mechanism	
 Contains OS data © Crown Copyright and database right 2022	Water is likely to percolate through the unsaturated zone to the groundwater through either the pore space in granular media or through porespace and fractures; these processes have some potential for contaminant removal and breakdown. Water is likely to percolate through the unsaturated zone to the groundwater through fractures, a process which has little potential for contaminant removal and breakdown.

Made ground	
 Contains OS data © Crown Copyright and database right 2022	Made ground is present at the surface. Infiltration may increase the possibility of remobilising pollutants.

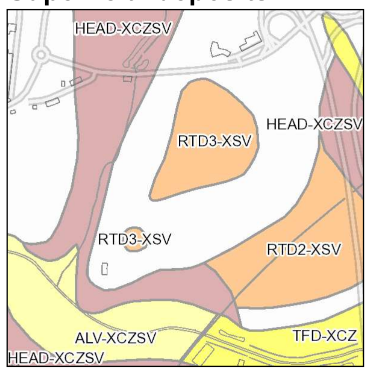
Section 5. Geological Maps

The following maps show the artificial, superficial and bedrock geology within the area of interest.

Artificial deposits

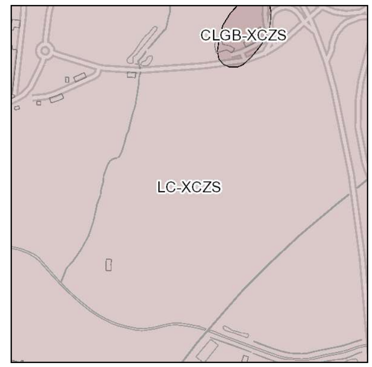
Contains OS data © Crown Copyright and database right 2022

Superficial deposits



Contains OS data © Crown Copyright and database right 2022

Bedrock



Contains OS data © Crown Copyright and database right 2022

Fault

Coal, ironstone or mineral vein

Note: Faults and Coals, ironstone & mineral veins are shown for illustration and to aid interpretation of the map. Not all such features are shown and their absence on the map face does not necessarily mean that none are present

Key to Artificial deposits:
No deposits recorded by BGS in the search area

Key to Superficial deposits:

Map colour	Computer Code	Rock name	Rock type
	ALV-XCZSV	ALLUVIUM	CLAY, SILT, SAND AND GRAVEL
	TFD-XCZ	TIDAL FLAT DEPOSITS	CLAY AND SILT
	HEAD-XCZSV	HEAD	CLAY, SILT, SAND AND GRAVEL
	RTD2-XSV	RIVER TERRACE DEPOSITS, 2	SAND AND GRAVEL
	RTD3-XSV	RIVER TERRACE DEPOSITS, 3	SAND AND GRAVEL

Key to Bedrock geology:

Map colour	Computer Code	Rock name	Rock type
	CLGB-XCZS	CLAYGATE MEMBER	CLAY, SILT AND SAND
	LC-XCZS	LONDON CLAY FORMATION	CLAY, SILT AND SAND

Limitations of this report:

- This report is concerned with the potential for infiltration-to-the-ground to be used as a SuDS technique at the site described. It only considers the subsurface beneath the search area and does NOT consider potential surface or subsurface impacts outside of that area.
- This report is NOT an alternative for an on-site investigation or soakaway test, which might reach a different conclusion.
- This report must NOT be used to justify disposal of foul waste or grey water.
- This report is based on and limited to an interpretation of the records held by the British Geological Survey (BGS) at the time the search is performed. The datasets used (with the exception of that showing depth to water table) are based on 1:50 000 digital geological maps and not site-specific data.
- Other more specific and detailed ground instability information for the site may be held by BGS, and an assessment of this could result in a modified assessment.
- To interpret the maps correctly, the report must be viewed and printed in colour.
- The search does NOT consider the suitability of sites with regard to:
    - previous land use,
    - potential for, or presence of contaminated land
    - presence of perched water tables
    - shallow mining hazards relating to coal mining. Searches of coal mining should be carried out via The Coal Authority Mine Reports Service: www.coalminingreports.co.uk.
    - made ground, where not recorded
    - proximity to landfill sites (searches for landfill sites or contaminated land should be carried out through consultation with local authorities/Environment Agency)
    - zones around private water supply boreholes that are susceptible to groundwater contamination.
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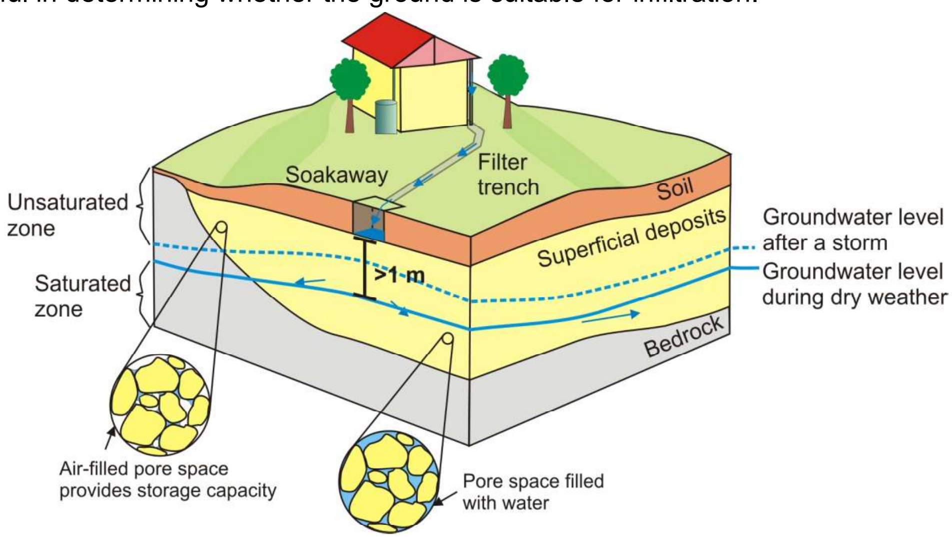
Explanation of terms

Depth to groundwater

In the shallow subsurface, the ground is commonly unsaturated with respect to water. Air fills the spaces within the soil and the underlying superficial deposits and bedrock. At some depth below the ground surface, there is a level below which these spaces are full of water. This level is known as the groundwater level, and the water below it is termed the groundwater. When water is infiltrated, the groundwater level may rise temporarily. To ensure that there is space in the unsaturated zone to accommodate this, there should be a minimum thickness of 1 m between the base of the infiltration system and the water table. An estimate of the *depth to groundwater* is therefore useful in determining whether the ground is suitable for infiltration.



Groundwater flooding

Groundwater flooding occurs when a rise in groundwater level results in very shallow groundwater or the emergence of groundwater at the surface. If infiltration systems are installed in areas that are susceptible to groundwater flooding, it is possible that the system could become inundated. The susceptibility map seeks to identify areas where the geological conditions and water tables indicate that groundwater level rise could occur under certain circumstances. A high susceptibility to groundwater flooding classification does not mean that groundwater flooding has ever occurred in the past, or will do so in the future as the susceptibility maps do not contain information on how often flooding may occur. The susceptibility maps are designed for planning; identifying areas where groundwater flooding might be an issue that needs to be taken into account.

Geological indicators of flooding
In floodplain deposits, groundwater level can be influenced by the water level in the adjacent river. Groundwater level may increase during periods of fluvial flood and therefore this should be taken into account when designing infiltration systems on such deposits. The *geological indicators of flooding* dataset shows where there is geological evidence (floodplain deposits) that flooding has occurred in the past.

For further information on flood-risk, the likely frequency of its recurrence in relation to any proposed development of the site, and the status of any flood prevention measures in place, you are advised to contact the local office of the Environment Agency (England and Wales) at www.environment-agency.gov.uk/ or the Scottish Environment Protection Agency (Scotland) at www.sepa.org.uk.

Artificial ground
Artificial ground comprises deposits and excavations that have been created or modified by human activity. It includes ground that is worked (quarries and road cuttings), infilled (back-filled quarries), landscaped (surface re-shaping), disturbed (near surface mineral workings) or classified as made ground (embankments and spoil heaps). The composition and properties of artificial ground are often unknown. In particular, the permeability and chemical composition of the artificial ground should be determined to ensure that the ground will drain and that any contaminants present will not be remobilised.

Superficial permeability
Superficial deposits are those geological deposits that were formed during the most recent period of geological time (as old as 2.6 million years before present). They generally comprise relatively thin deposits of gravel, sand, silt and clay and are present beneath the pedological soil in patches or larger spreads over much of Britain. The ease with which water can percolate through these deposits is controlled by their permeability and varies widely depending on their composition. Those deposits comprising clays and silts are less permeable and thus infiltration is likely to be slow, such that water may pool on the surface. In comparison, deposits comprising sands and gravels are more permeable allowing water to percolate freely.

Bedrock permeability
Bedrock forms the main mass of rock forming the Earth. It is present everywhere, commonly beneath superficial deposits. Where the superficial deposits are thin or absent, the ease with which water will percolate into the ground depends on the permeability of the bedrock.

Natural ground instability
Natural ground instability refers to the propensity for upward, lateral or downward movement of the ground that can be caused by a number of natural geological hazards (e.g. ground dissolution/compressible ground). Some movements associated with particular hazards may be gradual and of millimetre or centimetre scale, whilst others may be sudden and of metre or tens of metres scale. Significant natural ground instability has the potential to cause damage to buildings and structures, especially when the drainage characteristics of a site are altered. It should be noted, however, that many buildings, particularly more modern ones, are built to such a standard that they can remain unaffected in areas of significant ground movement.

Shrink-swell
A shrinking and swelling clay changes volume significantly according to how much water it contains. All clay deposits change volume as their water content varies, typically swelling in winter and shrinking in summer, but some do so to a greater extent than others. Contributory circumstances could include drought, leaking service pipes, tree roots drying-out the ground or changes to local drainage patterns, such as the creation of soakaways. Shrinkage may remove support from the foundations of buildings and structures, whereas clay expansion may lead to uplift (heave) or lateral stress on part or all of a structure; any such movements may cause cracking and distortion.

Landslides (slope stability)
A landslide is a relatively rapid outward and downward movement of a mass of ground on a slope, due to the force of gravity. A slope is under stress from gravity but will not move if its strength is greater than this stress. If the balance is altered so that the stress exceeds the strength, then movement will occur. The stability of a slope can be reduced by removing ground at the base of the slope, by placing material on the slope, especially at the top, or by increasing the water content of the materials forming the slope. Increase in subsurface water content beneath a soakaway could increase susceptibility to landslide hazards. The assessment of landslide hazard refers to the stability of the present land surface. It does not encompass a consideration of the stability of excavations.

Soluble rocks (dissolution)
Some rocks are soluble in water and can be progressively removed by the flow of water through the ground. This process tends to create cavities, potentially leading to the collapse of overlying materials and possibly subsidence at the surface. The release of water into the subsurface from infiltration systems may increase the dissolution of rock or destabilise material above or within a cavity. Dissolution cavities may create a pathway for rapid transport of contaminated water to an aquifer or water course.

Compressible ground
Many ground materials contain water-filled pores (the spaces between solid particles). Ground is compressible if a building (or other load) can cause the water in the pore space to be squeezed out, causing the ground to decrease in thickness. If ground is extremely compressible the building may sink. If the ground is not uniformly compressible, different parts of the building may sink by different amounts, possibly causing tilting, cracking or distortion. The compressibility of the ground may alter as a result of changes in subsurface water content caused by the release of water from soakaways.

Collapsible deposits
Collapsible ground comprises certain fine-grained materials with large pore spaces (the spaces between solid particles). It can collapse when it becomes saturated by water and/or a building (or other structure) places too great a load on it. If the material below a building collapses it may cause the building to sink. If the collapsible ground is variable in thickness or distribution, different parts of the building may sink by different amounts, possibly causing tilting, cracking or distortion. The subsurface underlying a soakaway will experience an increase in water content that may affect the stability of the ground. This hazard is most likely to be encountered only in parts of southern England.

Running sand
Running sand conditions occur when loosely-packed sand, saturated with water, flows into an excavation, borehole or other type of void. The pressure of the water filling the spaces between the sand grains reduces the contact between the grains and they are carried along by the flow. This can lead to subsidence of the surrounding ground. Running sand is potentially hazardous during the drainage system installation. During installation, excavation of the ground may create a space into which sand can flow, potentially causing subsidence of surrounding ground.

Shallow mining hazards (non coal)
Current or past underground mining for coal or for other commodities can give rise to cavities at shallow or intermediate depths, which may cause fracturing, general settlement, or the formation of crown-holes in the ground above. Spoil from mineral workings may also present a pollution hazard. The release of water into the subsurface from soakaways may destabilise material above or within a cavity. Cavities arising as a consequence of mining may also create a pathway for rapid transport of contaminated water to an aquifer or watercourse. The mining hazards map is derived from the geological map and considers the potential for subsidence associated with mining on the basis of geology type. Therefore if mining is known to occur within a certain rock, the map will highlight the potential for a hazard within the area covered by that geology.

For more information regarding underground and opencast **coal mining**, the location of mine entries (shafts and adits) and matters relating to subsidence or other ground movement induced by **coal mining** please contact the Coal Authority, Mining Reports, 200 Lichfield Lane, Mansfield, Nottinghamshire, NG18 4RG; telephone 0845 762 6848 or at www.coal.gov.uk**.** For more information regarding other types of mining (i.e. non-coal), please contact the British Geological Survey.

Groundwater source protection zones

In England and Wales, the Environment Agency has defined areas around wells, boreholes and springs that are used for the abstraction of public drinking water as source protection zones. In conjunction with Groundwater Protection Policy the zones are used to restrict activities that may impact groundwater quality, thereby preventing pollution of underlying aquifers, such that drinking water quality is upheld. The Environment Agency can provide advice on the location and implications of source protection zones in your area (www.environment-agency.gov.uk/)

Contact Details

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- The data, information and related records supplied in this Report by BGS can only be indicative and should not be taken as a substitute for specialist interpretations, professional advice and/or detailed site investigations. You must seek professional advice before making technical interpretations on the basis of the materials provided.
- Geological observations and interpretations are made according to the prevailing understanding of the subject at the time. The quality of such observations and interpretations may be affected by the availability of new data, by subsequent advances in knowledge, improved methods of interpretation, and better access to sampling locations.
- Raw data may have been transcribed from analogue to digital format, or may have been acquired by means of automated measuring techniques. Although such processes are subjected to quality control to ensure reliability where possible, some raw data may have been processed without human intervention and may in consequence contain undetected errors.
- Detail, which is clearly defined and accurately depicted on large-scale maps, may be lost when small-scale maps are derived from them.
- Although samples and records are maintained with all reasonable care, there may be some deterioration in the long term.
- The most appropriate techniques for copying original records are used, but there may be some loss of detail and dimensional distortion when such records are copied.
- Data may be compiled from the disparate sources of information at BGS's disposal, including material donated to BGS by third parties, and may not originally have been subject to any verification or other quality control process.
- Data, information and related records, which have been donated to BGS, have been produced for a specific purpose, and that may affect the type and completeness of the data recorded and any interpretation. The nature and purpose of data collection, and the age of the resultant material may render it unsuitable for certain applications/uses. You must verify the suitability of the material for your intended usage.
- If a report or other output is produced for you on the basis of data you have provided to BGS, or your own data input into a BGS system, please do not rely on it as a source of information about other areas or geological features, as the report may omit important details.
- The topography shown on any map extracts is based on the latest OS mapping and is not necessarily the same as that used in the original compilation of the BGS geological map, and to which the geological linework available at that time was fitted.
- Note that for some sites, the latest available records may be historical in nature, and while every effort is made to place the analysis in a modern geological context, it is possible in some cases that the detailed geology at a site may differ from that described.

Report issued by
BGS Enquiry Service

Appendix 2 Greenfield Runoff Rates

WHS

Site Name	Southlands Solar Farm
Site Location	Runwell
X (Eastings)	576665
Y (Nothings)	194589
Engineer	Sam Pucknell
Checked by	Daniel Hamilton
Reference	WHS1973
Revision	2
Date	05-Oct-22

ReFH2 Greenfield Runoff Estimate
Calculation Sheet

Site Description

Total Area (ha)	58.99
Existing Developed area (ha)	0
SAAR (mm)	562
PROPWET(mm)	0.27
BFIHOST19	0.3

Rainfall Parameters

Duration (hh:mm:ss)	04:30:00
Timestep (hh:mm:ss)	00:30:00
SCF (Seasonal correction factor)	0.62
ARF (Areal correction factor)	1 [0.98]
Seasonality	Winter

Loss Model Parameters

Cini (mm)	137.89
Cmax (mm)	257.05

Routing Parameters

Tp (hr)	2.87
Up	0.65
Uk	0.8

Baseflow Parameters

BF0 (m^3/s)	0.02
BL (hr)	31.82
BR	0.6

Growth Curves and Discharge rates

Event	*Q/Qmed*	*Q (l/s)*	*Q (l/s/ha)*
Q1	**-**	**255.07**	**4.32**
Q2	1.00	293.73	**4.98**
Q30	**2.27**	**665.57**	**11.28**
Q100	**3.12**	**915.84**	**15.53**
Q100(CC)	**4.56**	**1338.33**	**22.69**
Q1000	6.03	1772.20	30.04

Appendix 3 Outline Surface Water Strategy

576075
576325
576575
576825
577075
194900
194650
194400
Legend
Site Boundary
Swales
Filter Strips
Gravel filters
Soakaway
Road
Security Fence
Substation
PV Modules
Soakaway for Substation
260m long swale
110m long swale
77m long swale
N
0
125
250 m
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Appendix 4 Causeway Flow Calculations

Design Settings

Rainfall Methodology	FEH-13	Minimum Velocity (m/s)	1.00
Return Period (years)	2	Connection Type	Level Soffits
Additional Flow (%)	0	Minimum Backdrop Height (m)	0.200
CV	0.750	Preferred Cover Depth (m)	1.200
Time of Entry (mins)	5.00	Include Intermediate Ground	✓
Maximum Time of Concentration (mins)	30.00	Enforce best practice design rules	✓
Maximum Rainfall (mm/hr)	50.0		

Nodes

Name	Area (ha)	Cover Level (m)	Depth (m)
1	0.005	8.000	2.000

Simulation Settings

Rainfall Methodology	FEH-13	Analysis Speed	Normal	Additional Storage (m³/ha)	0.0
Summer CV	0.750	Skip Steady State	x	Check Discharge Rate(s)	x
Winter CV	0.840	Drain Down Time (mins)	240	Check Discharge Volume	x

Storm Durations

15	60	180	360	600	960	2160	4320	7200	10080
30	120	240	480	720	1440	2880	5760	8640	

Return Period (years)	Climate Change (CC %)	Additional Area (A %)	Additional Flow (Q %)
2	0	0	0
10	0	0	0
30	0	0	0
100	0	0	0
100	40	0	0

Node 1 Soakaway Storage Structure

BRE-365: Volume (m^3)	0.100	Side Inf Coefficient (m/hr)	0.00360	Pit Width (m)	1.000
BRE-365: Area (m^2)	0.100	Safety Factor	1.5	Pit Length (m)	9.000
BRE-365: Time (hrs)	200.000	Porosity	0.30	Depth (m)	
BRE-365: Inf Coef (m/hr)	0.00500	Invert Level (m)	6.000	Inf Depth (m)	
Base Inf Coefficient (m/hr)	0.00360	Time to half empty (mins)	2207	Number Required	1

Results for 2 year Critical Storm Duration. Lowest mass balance: 100.00%

Node Event	US Node	Peak (mins)	Level (m)	Depth (m)	Inflow (l/s)	Node Vol (m³)	Flood (m³)	Status
600 minute winter	1	405	6.365	0.365	0.1	0.9842	0.0000	OK

Link Event (Velocity)	US Node	Link	Outflow (l/s)
600 minute winter	1	Infiltration	0.0

Results for 10 year Critical Storm Duration. Lowest mass balance: 100.00%

Node Event	US Node	Peak (mins)	Level (m)	Depth (m)	Inflow (l/s)	Node Vol (m^3)	Flood (m^3)	Status
240 minute winter	1	228	6.654	0.654	0.3	1.7671	0.0000	OK

Link Event (Velocity)	US Node	Link	Outflow (l/s)
240 minute winter	1	Infiltration	0.0

Results for 30 year Critical Storm Duration. Lowest mass balance: 100.00%

Node Event	US Node	Peak (mins)	Level (m)	Depth (m)	Inflow (l/s)	Node Vol (m³)	Flood (m³)	Status
360 minute winter	1	328	6.866	0.866	0.3	2.3392	0.0000	OK

Link Event (Velocity)	US Node	Link	Outflow (l/s)
360 minute winter	1	Infiltration	0.0

Results for 100 year Critical Storm Duration. Lowest mass balance: 100.00%

Node Event	US Node	Peak (mins)	Level (m)	Depth (m)	Inflow (l/s)	Node Vol (m³)	Flood (m³)	Status
480 minute winter	1	456	7.316	1.316	0.3	3.5527	0.0000	OK

Link Event (Velocity)	US Node	Link	Outflow (l/s)
480 minute winter	1	Infiltration	0.0

Results for 100 year +40% CC Critical Storm Duration. Lowest mass balance: 100.00%

Node Event	US Node	Peak (mins)	Level (m)	Depth (m)	Inflow (l/s)	Node Vol (m³)	Flood (m³)	Status
720 minute winter	1	690	7.922	1.922	0.3	5.1890	0.0000	OK

Link Event (Velocity)	US Node	Link	Outflow (l/s)
720 minute winter	1	Infiltration	0.0