C Hydraulic Modelling report

TECHNICAL NOTE

JBA Project Code	2021s1226
Contract	Heckington Fen Solar Farm
Client	Ecotricity Generation Limited
Day, Date and Time	July 2022
Author	Ellen Corry
Reviewer / Sign-off	Stuart Harwood
Subject	Hydrology and hydraulic modelling

1 Overview

1.1 Overview

This technical note documents the hydraulic model build and hydraulic model results for analysis of flood risk from (i) a breach scenario and (ii) a pump failure scenario at a site proposed for development as a solar farm at Heckington Fen. The modelling analysis is based upon the Environment Agency's 1D ISIS hydraulic model of the South Forty Foot Drain (SFFD) (2016), which includes the Head Dike that forms the northern boundary of the study site.

A hydrology and hydraulic modelling method statement (Appendix A.1) was prepared in March 2022 and submitted to the Environment Agency for approval. The Agency's letter dated 22nd April 2022 (enclosed in Appendix A.2) confirmed that the proposed scope of work and methodology was considered acceptable for the purposes of informing scheme design and preparation of a Flood Risk Assessment.. The detailed methodology for hydraulic modelling is set out in the aforementioned method statement (Appendix A.1) and this Technical Note should therefore be read in conjunction with that document.

2 Hydrology

As set out in the method statement enclosed in Appendix A, catchment inflow estimates in the SFFD model date to 2009 and, for the low-lying, pumped catchments, are based upon the established 'trapezoidal' unit hydrograph method. Since the original analysis was completed, both the Depth-Duration-Frequency rainfall model and the rainfall-run-off methodology have been updated. Sub-catchment inflows have therefore been derived using the ReFH2.3 methodology and the FEH13 rainfall model and compared to the existing inflows in the EA's SFFD model. The analysis demonstrates that the existing flow estimates are generally similar to/higher than those based upon the ReFH2.3 method and, on this basis, it was concluded that the existing model inflows should be retained for the purposes of the Heckington Fen study. Details of the hydrology analysis are set out in the Technical Note enclosed in Appendix B.

3 Breach analysis

As set out in the method statement enclosed in Appendix A, breach analysis of the Head Dike/Skerth Drain was requested by the Environment Agency to understand residual flood risk to the site and inform scheme design (i.e. the elevation of flood-sensitive infrastructure). In this instance, the analysis is based upon (i) breach hydrographs derived from the SFFD model (using the breach parameters set out in the method statement enclosed in Appendix A) and (ii) applying the breach hydrographs to a 2D TUFLOW domain representing the floodplain to the south of the Head Dike.

3.1 South Forty Foot Drain 2016 model review and updates

The modelling method statement (Appendix A) identified a requirement to update the SFFD 2016 Flood Modeller 1D model to derive breach hydrographs at two breach locations. The updates are summarised below:

- A new Flood Modeller.dat file was produced for each breach scenario (1 and 2). In each file a single gated weir unit was used to represent the breach of the Head Dike and Skerth Drain right bank. On closer inspection of the surveyed cross-sections at each breach location, the channel bed of Head Dike and Skerth Drain was found to be lower than that of the IDB drain immediately south of and adjacent to the Head Dike. As such, the new, lower channel bed levels were used to define the breach invert as follows:

  - Breach 1 (node HD106000): Invert -0.582mAOD (updated from -0.41mAOD).
  - Breach 2 (node SD104639): Invert -1.224mAOD (updated from -0.46mAOD).

- The existing inflow data was retained from the SFFD 2016 model following a review of the model hydrology and comparison against flows derived using the latest ReFH2.3 approach (ref Section 2 above). As noted above, the analysis demonstrated that the existing flow estimates were generally similar to/higher than those based upon the ReFH2.3 method and, on this basis, it was concluded that the existing model inflows should be retained for the purposes of the Heckington Fen study. Details of the hydrology analysis are set out in the Technical Note enclosed in Appendix B.
- The SFFD model includes a number of 'spill' units representing the raised embankments adjacent to the Head Dike/Skerth Drain. These features define the threshold at which floodwater may spill from the channel and into the adjacent floodplain. A comparison of the spill elevation against the latest 2019 1m resolution LiDAR indicated that approximately 60% of the spill elevation data was within 200mm of the 2019 LiDAR elevation for the same co-ordinate location (i.e. within the generally accepted margin when comparing LiDAR survey with conventional land survey). A proportion of the points defining the spill profiles were found not to align with the embankment crest depicted by the 2019 LiDAR and were therefore excluded from the analysis (i.e., as comparison of elevation data could not be undertaken on a 'like-for-like' basis). The majority of the remaining points where the elevation differed by more than +/- 200mm were also found to be slightly offset from the embankment crest, such that a 'like-for-like' comparison of SFFD model spill elevation data vs 2019 LiDAR was not possible. Therefore, to assess the sensitivity of the breach hydrograph to potential variation in the elevation of model spill units, sensitivity testing was completed for two scenarios: (i) spill elevations +200mm and (ii) spill elevations -200mm. As such a sensitivity test was developed that altered all spill elevations of the Head Dike and Skerth Drain spill units in the SFFD 2016 model by plus and minus 200mm to establish the impact on the breach analysis.

The breach hydrographs extracted from the SFFD 2016 model are shown in Figure 3-1 and Figure 3-2 for each breach location. The peaks observed in the tail of the hydrograph reflect water levels in Head Dike and Skerth Drain beginning to be influenced by the water level in the South Forty Foot Drain, which is tidal at the confluence with Skerth drain downstream from the breach locations. Sensitivity testing as described above was undertaken only for the Breach 2 location as it was established that this location produced the greater maximum flood level across the floodplain

The breach hydrographs in Figure 3-2 show that raising the spill elevations increases the peak flow through the breach and reducing the spill elevations reduces the peak flow through the breach. However, there is little variation in the overall volume of water associated with the breach.

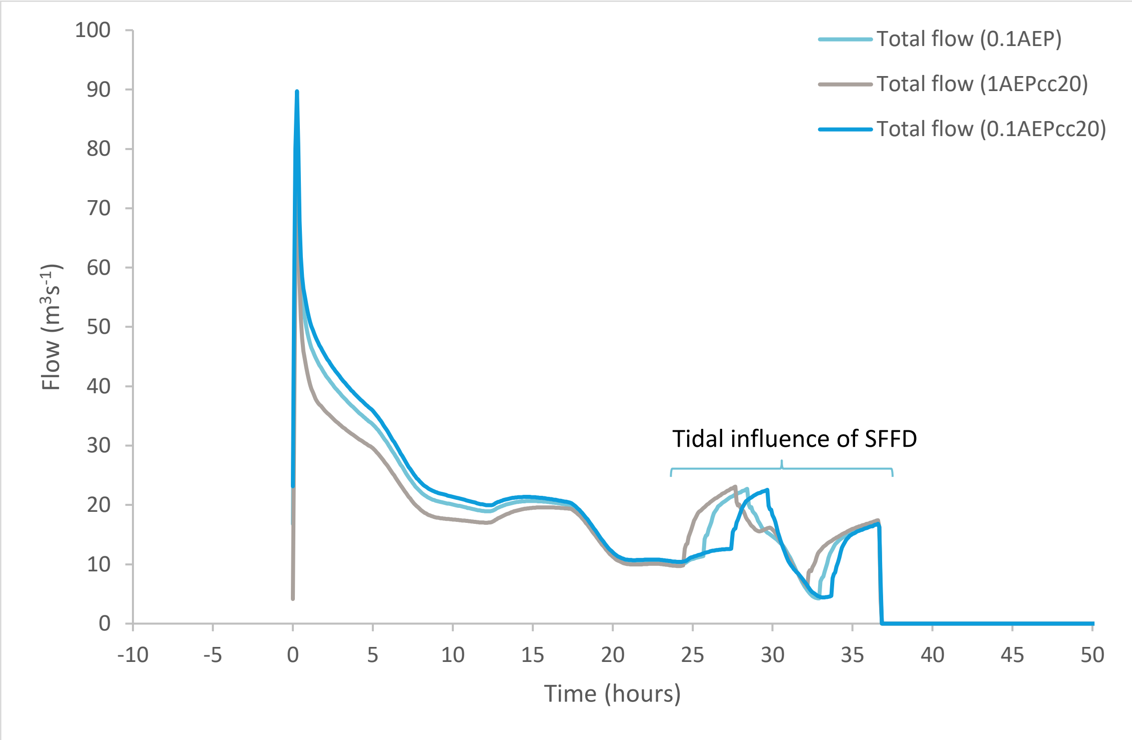

Figure 3-1: extracted hydrographs for Breach 1

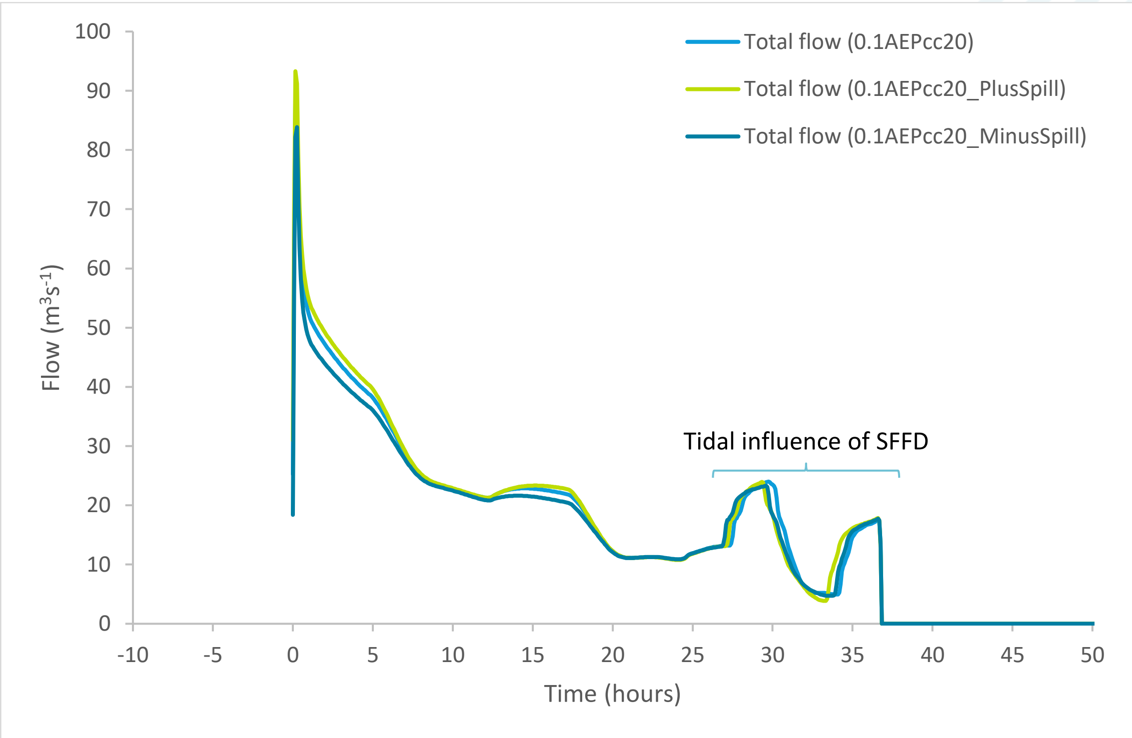

Figure 3-2: extracted hydrographs for Breach 2

3.2 TuFLOW Model

Error! Reference source not found.3 shows a schematic of the TuFLOW model while Table 3-1 details key model parameters.

Table 3-1: TuFLOW Model Parameters

Model Name	Heckington_004.tcf
Software	TuFLOW GPU
2D Domain Area (km²)	14.2
2D Domain cell resolution	4m
2D Timestep (seconds)	1
2D Boundary conditions	Flow-Time Boundary: Breach_1 Breach_2 Normal depth boundary: Downstream boundary (slope 0.001)
2D Manning's n Roughness	A materials layer is read into TUFLOW to assign manning's values to the model topography. The values have been calculated using a combination of Cowan's procedure (Cowan, 1956)[1] and the comparison of site imagery photographs with published values (e.g., Chow, 1959)[2].
1D Domain Description	1D ESTRY network-e line, representing a culvert under the B1395 Glebe Road.
1D Timestep (seconds)	0.5
1D System Length/width (m)	47/1.5 x 1.5 culvert – Glebe Road
Simulation time (hours)	100

[1] Cowan, W.L., 1956, Estimating hydraulic roughness coefficients: Agricultural Engineering, v. 37, no. 7, p. 473- 475.

[2] Chow, V.T., 1959, Open channel hydraulics: New York, McGraw-Hill, 680 p.

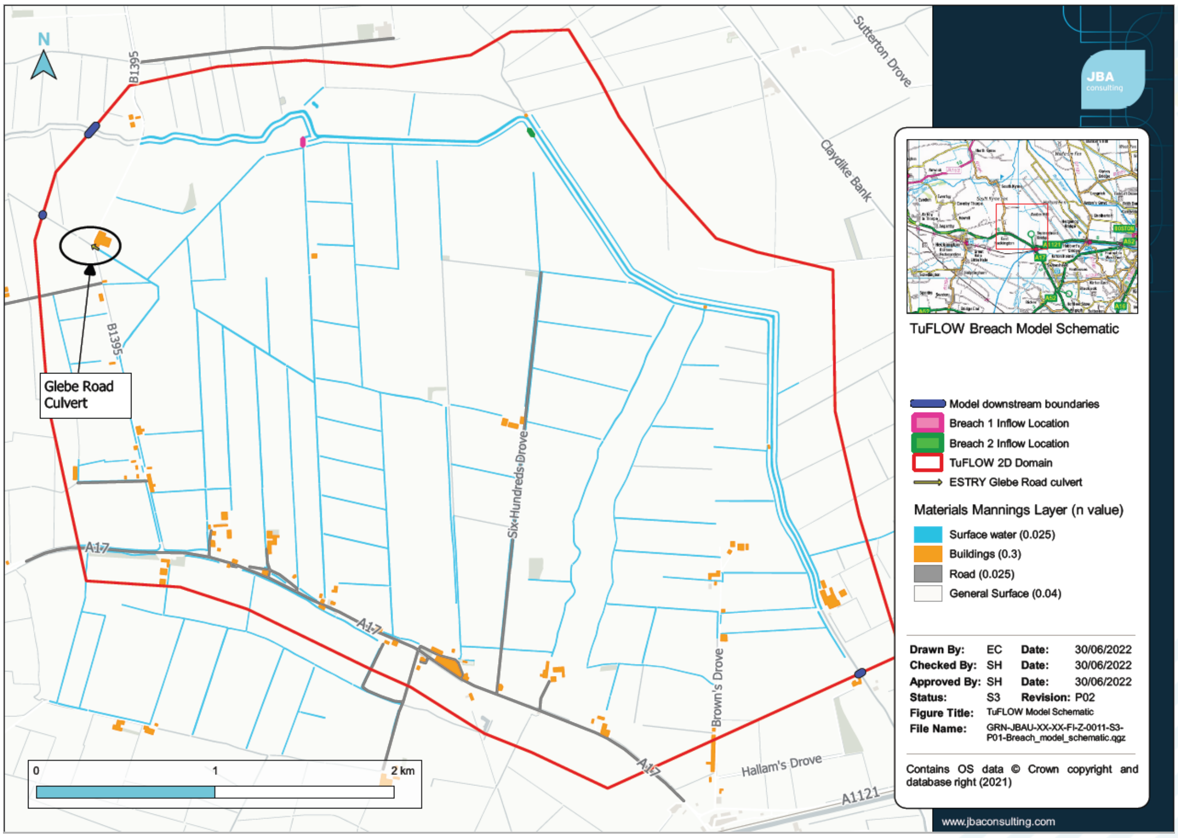

Figure 3-3:TuFLOW Model Schematic

3.2.1 Model results

Maximum flood levels for the breach scenarios are shown in Table 3-3 for each flood event at breach locations 1 and 2, and for each sensitivity test for breach 2. Flood mapping is provided in Appendix C for breach location 2 including the sensitivity tests for the 1000-year plus 20% climate change event. In all scenarios there was no active flow through the 1D culvert under Glebe Road. Peak flood levels across all modelled scenarios are within 60mm of each other. This results from water levels in Head Dike and Skerth Drain being very similar at each breach location due to the relatively 'flat' hydraulic gradient of the channel.

At breach location 1 the peak water level in Head Dike is 2.83mAOD (SFFD 2016 node HD106000) for the 1000-year plus 20% climate change event. At breach location 2 the peak water level in Skerth Drain is approximately 40mm lower than at breach location 1, at 2.79mAOD (SFFD 2016 node SD10436).

While in channel water levels within Head Dike and Skerth Drain vary only fractionally (c.40mm) prior to the onset of the breach, breach 2 has a greater hydraulic head as the depth of the breach is approximately 640mm lower than breach 1 (-1.22mAOD at breach location 2, compared to -0.582mAOD at breach location 1).

Table 3-3: Maximum flood level [mAOD]

	Maximum Water Level (mAOD)				
Scenario	100cc	1000	1000cc20%	1000cc20% Spill +200mm	1000cc20% Spill –200mm
Breach 1	1.9	1.92	1.93	-	-
Breach 2	1.92	1.94	1.95	1.96	1.94

The Maximum flood extent for the 1000-year plus 20% climate change scenario is shown in Figure 3-4. The flooded area covers most of the site to a level of 1.95mAOD. High ground associated with the B1395 road and Skerth Drain embankment limits the progression of floodwaters to the west and east respectively.

The connectivity of drains and the floodplain is represented within the TuFLOW domain to allow the dispersal of breach floodwater across the terrain to be represented by the model. However, the schematisation is 'simplified' in some respects, resulting in a conservative assessment of residual flood risk.

The maximum flood depth (m) is shown in **Error! Reference source not found.** for the 1000-year plus 20% climate change scenario for breach 2. The greatest flood depths (>1.4m) correspond with the network of drains across Heckington Fen, with flood depths of generally up to c.1.1m across the various field parcels.

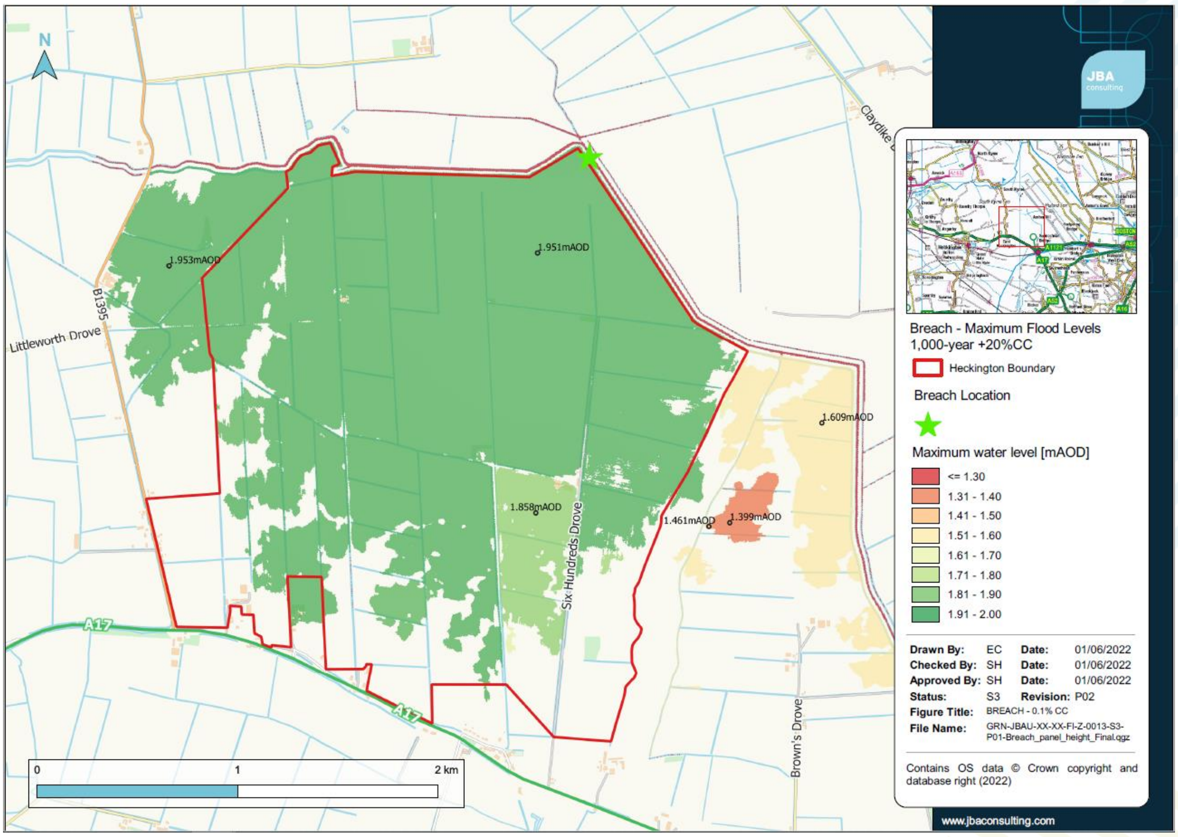

Figure 3-4: Breach 2 1000-year plus 20% climate change maximum flood level (mAOD)

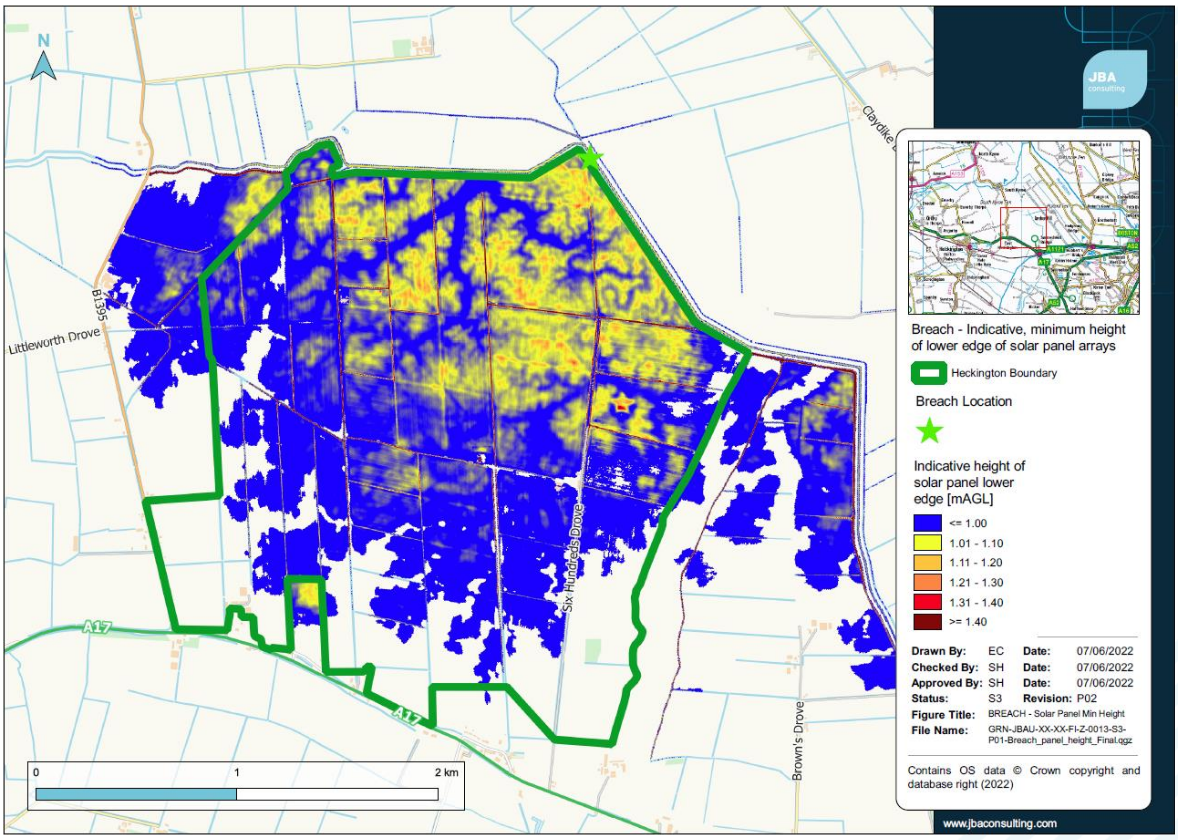

Figure 3-5: Breach 2 1000-year plus 20% climate change maximum flood depth (m)

4 Pump failure analysis

A pump failure analysis has been carried out to further investigate residual flood risk for the purposes of informing scheme design and preparation of a Flood Risk Assessment.

4.1 HEC-RAS Model

A simple 1D hydraulic model was built in HEC-RAS version 6.2.0. The Internal Drainage Board pumped catchments, Heckington Fen (west) and Trinity College (east) were each represented as 1D storage areas based on the Black Sluice Internal Drainage Board (BSIDB) Sub-Catchment boundaries (see Appendix D of the method statement included here as Appendix A.1) and the topography of the 2019 LiDAR DTM. The catchment extent of Heckington Fen is slightly reduced in comparison to the BSIDB boundary as natural boundaries to flow, such as the A17 road embankment, have been considered, in addition to the right bank of Head Dike which forms the northern boundary of the sub-catchment. This is consistent with the distribution of catchment runoff inflows in the SFFD 2016 model, where the Heckington Fen pumped sub-catchment is split into two flood modeller reservoirs, north and south of Head Dike. The sub-catchments were connected via a spill to allow exchange of flow between catchments. The elevation of the spill is derived from the 2019 1m LiDAR DTM. Figure 4-1 shows a schematic of the HEC-RAS model.

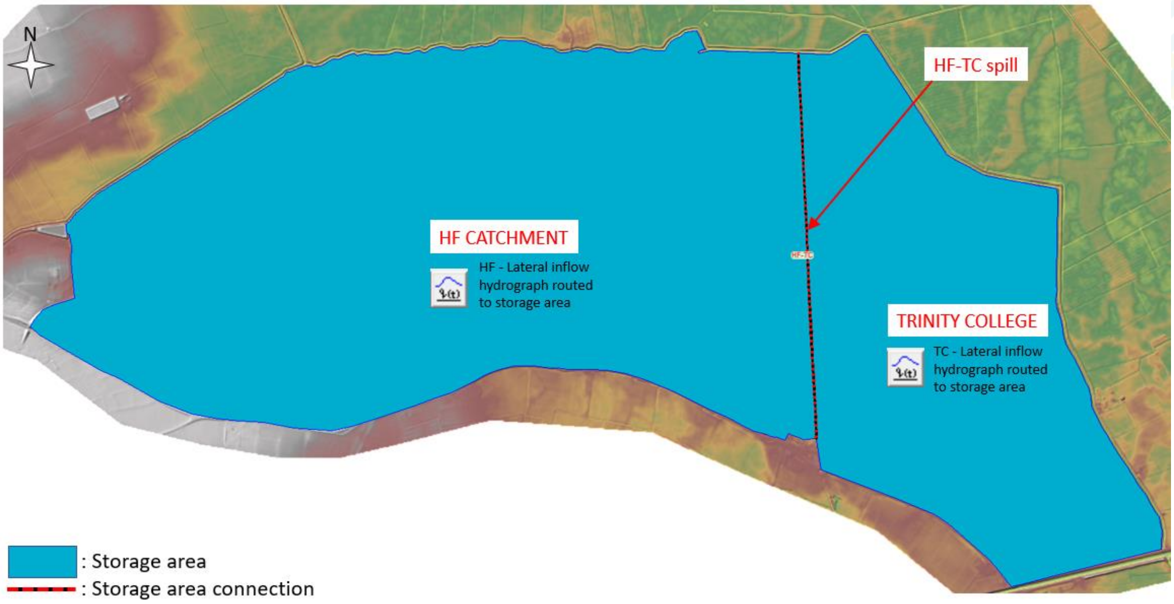

Figure 4-1: HEC-RAS Geometry Schematic – no pumps model

The FEH-derived boundary unit hydrographs applied directly to each catchment in the SFFD 2016 model were applied to each storage area using a lateral inflow hydrograph boundary condition for the 100-year, 1000-year and 1000-year plus 20% climate change scenario. A preliminary analysis included the Head Dike and Skerth Drain channels in the model, with lateral spills to the storage areas. This analysis demonstrated that there was no spill into the Heckington Fen and Trinity College sub-catchments for the 1000-year plus 20% climate change pump failure scenario. As such, only the hydrographs from the SFFD 2016 model representing the runoff from the contributing catchment were routed into each storage area.

The model represents a scenario where the pumping stations are 'off-line' (i.e. no pumping of surface water to the Head Dike/ Skerth Drain), such that surface water accumulates within the network of drains and associated floodplain to the south of Head Dike. An overview of the HEC-RAS model is provided in **Table** 4**-1**.

Table 4-1: Pump failure model overview

Software (version)	HEC-RAS (6.2.0)
Hydraulic model type	1D
Floodplain representation	1D storage areas, elevation-volume curve computed from associated 1m LiDAR DTM.
Floodplain connectivity	1D spill connecting Heckington Fen and Trinity College sub-catchments.
Model assumptions	Both pumps are offline for the entirety of the event. There is no overtopping from Head Dike and Skerth Drain in the pump failure scenario. The latest LiDAR is representative of the present floodplain topography and available floodplain storage.

4.2 Model results

The no-pumps model was run for the 100-year, 1000-year and 1000-year plus 20% climate change events. The results for each design event are provided in Table 4-2. The no-pumps model results indicated that a pump failure scenario for the 1000-year plus 20% climate change event would result in a maximum flood level of approximately 1.29mAOD across Heckington Fen. The peak water level across the two catchments, Heckington Fen and Trinity College, is uniform on account of the connectivity via the spill.

Table 4-2: Pump failure model results

Design Event	Maximum Water Level (mAOD)
100-year	1.11
1000-year	1.24
1000-year (20%CC)	1.29

5 Summary and recommendations

5.1 Summary

JBA Consulting has completed hydraulic modelling analysis to assess the residual flood risk to Heckington Fen from the breach of a high-level carrier drain (Head Dike/Skerth Drain), which bounds the site to the north. The works were completed on behalf of Ecotricity Generation Limited to inform the design and layout of a proposed solar farm and the preparation of a Flood Risk Assessment (FRA) in support of an application for Development Consent, in accordance with the Planning Act (2008).

A 2D Breach model was developed in TUFLOW which utilised a breach hydrograph derived from the Environment Agency's SFFD 2016 1D Flood Modeller model. The SFFD 2016 model was updated to represent the required breach scenarios (as previously agreed with the EA) and the required design flood events as appropriate. A sensitivity test was carried out to assess the impact of potential changes in topography along the banks of Head Dike, informed by a comparison of model spill heights against the latest LiDAR. The model indicated that the maximum water level at the site of the proposed solar farm for the 1000-year plus 20% climate change breach event was 1.95mAOD.

A second hydraulic model was used to determine the flood risk associated with failure of the IDB pumped catchment system (i.e. surface water pumps 'off-line' for the entirety of the storm event), giving a maximum water level of 1.29mAOD, also for the 1000-year plus 20% climate change event.

As such, the breach scenario was found to comprise the 'worst-case' residual risk scenario and should therefore be used to inform scheme design.

5.2 Recommendations

Following the analysis of residual flood risk to the proposed solar farm site at Heckington Fen it is recommended that:

- Solar panels and other flood-sensitive infrastructure should be positioned above the 1000-year plus 20% climate change maximum breach flood water level (1.95m AOD), This will comply with the EA's requirement that the design/layout of development comprising 'essential infrastructure' should be based upon the 1,000-year+climate change design flood event.

Appendices

A Method Statement

A.1 Modelling method statement

TECHNICAL NOTE

JBA Project Code	2021s1226
Contract	Heckington Fen Solar Farm, Lincolnshire FRA
Client	Ecotricity Generation Limited
Day, Date and Time	March 2022
Author	Ellen Corry
Reviewer / Sign-off	Stuart Harwood
Subject	Hydrology and hydraulic modelling method statement

1 Overview

Jeremy Benn Associates Limited (t/a JBA Consulting) has been appointed by Ecotricity Generation Limited to prepare a Flood Risk Assessment (FRA) in support of an application for Development Consent (in accordance with provisions set out under the Planning Act 2008) to construct a solar farm and associated energy storage infrastructure on land at Heckington Fen, Lincolnshire. The solar farm would provide capacity to generate 500MW of electricity such that it comprises a Nationally Significant Infrastructure Project within the context of the Planning Act 2008.

The principal watercourses in the area are the River Witham and South Forty Foot Drain (SFFD), located approximately 4km and 1.5km to the east and south of the site (Figure 1-1). Both are classified as Main River and therefore under the jurisdiction of the EA. The site itself is dissected by drains (Ordinary Watercourses) which form part of the Black Sluice Internal Drainage Board (BSIDB) network. Head Dike, a tributary of SFFD is another high-level carrier which forms the northern boundary of the site and, following consultation with the EA, is deemed to be the principal source of flood risk to the site of the proposed development. Holland Dike forms the eastern boundary of the site. South of Trinity College Pumping Station, the Head Dike becomes Skerth Drain (Figure 1-1).

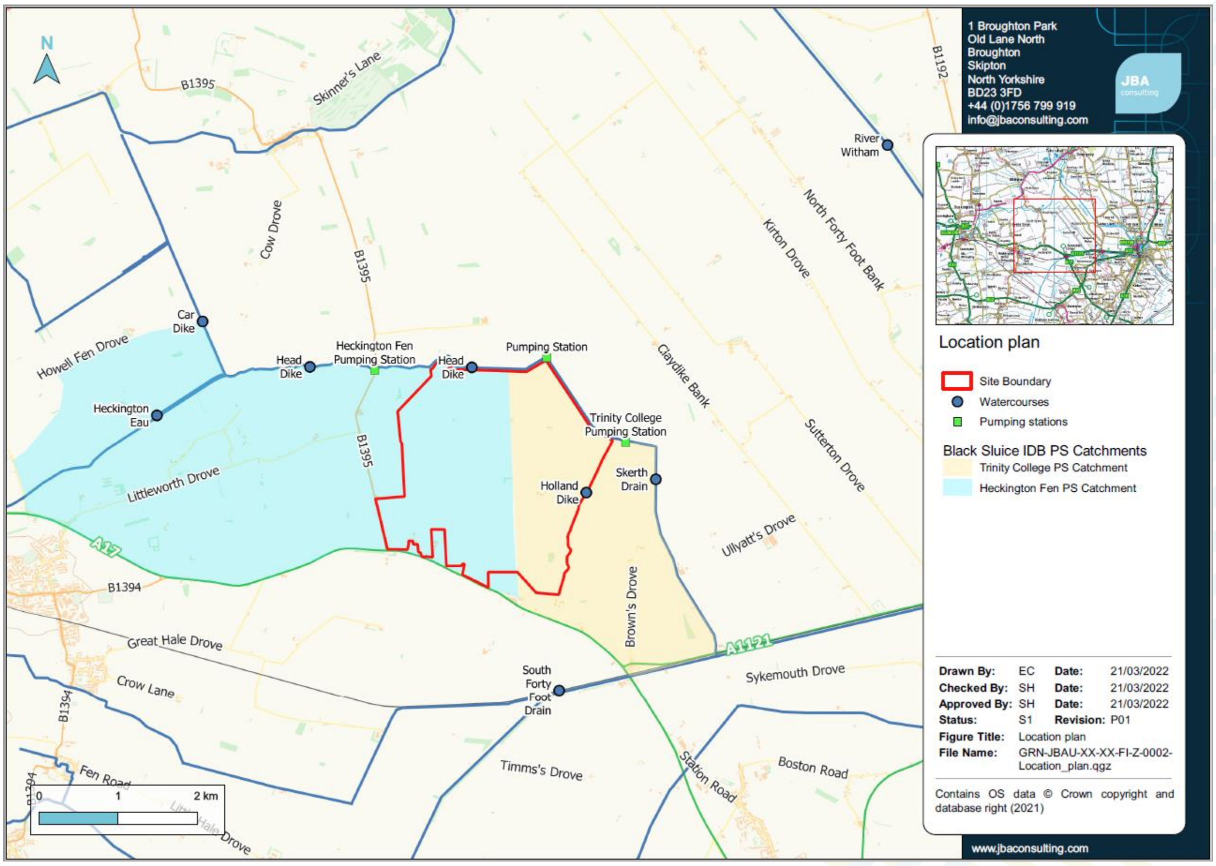

Figure 1-1: Location plan

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Water levels within the site are managed through the use of pumping, with three pumping stations located on Head Dike. The site extends over two pumping station catchments of BSIDB - Heckington Fen Pumping Station and Trinity College.

The EA was consulted regarding the data available to support/inform preparation of both a Flood Risk Assessment and a chapter of the Environmental Statement. The EA advised as follows (EA ref: AN/2021/132242/03-L01 – Appendix A):

The water levels provided are in-channel only. We aren't able to provide a flood level for the site due to the way it has been modelled as a one-dimensional (1D) hydraulic model with spill and floodplain units. As we are not able to provide a flood level, breach analysis of the Head Dike / Skerth Drain should be undertaken to understand the residual risk to site. This would be the key aspect of the site Flood Risk Assessment [FRA] which would also set out mitigation measures for the estimated flood depth

The EA subsequently (February 2022) provided a copy of the South Forty Foot Drain model (2016) to be used as the basis for breach analysis.

This technical note details the quality and suitability of the available data and sets out the methodology and scope of work required to undertake the analysis needed to define flood levels across the site.

1.1 Data

The data provided is listed in Table **1-1**.

Table 1-1: Available data

Data	Source	Description
LiDAR 1m DTM	DEFRA	1m resolution LiDAR data – National LiDAR Programme DTM – 2019 1M
Topographic Survey	Geo-4D Ltd.	Spot levels collected at 30m intervals across the site by surveyors Geo-4D Limited in October 2021 – Appendix B.
EA Model	Environment Agency	South Forty Foot Drain 2016 Model - 1D Flood Modeller
EA Model reports	Environment Agency	Three modelling reports detailing model building and sensitivity testing for the South Forty Foot Drain model: • 2015 Black Sluice Upper Catchment Revised Modelling Note • 2016 Black Sluice Catchment Works Modelling Report RevD • 2017 Black Sluice model conversion Draft report Rev6
Advice letter	Environment Agency	Advice letter 18.11.2021.pdf – Appendix A. EA Advice letter stating FRA requirements.
Catchment information	Black Sluice IDB	HeckingtonTrinityA1.pdf – Appendix D. Figure identifying pump locations and sub-catchments for each pumped system (Heckington Fen and Trinity College).

2 Data review

2.1 Environment Agency Model

2.1.1 Overview

The Environment Agency provided their approved hydraulic model for the Heckington Fen area. This comprises a 1D ISIS v6.6 model of the Lower South Forty Foot Drain (SFFD) catchment completed in January 2016. The model covers a 400km^2 area between Boston in the north and Bourne in the south and includes SFFD and the eight main tributaries to the drain including Head Dike, which comprises the northern boundary of the study site.

2.1.2 Model review summary

A detailed review of the hydraulic model is provided in Appendix C, while a summary of the model review is detailed in Table **2-1**

Table 2-1: Hydraulic model review summary

Detail	Observation
Software	ISIS v6.6
Model Scenarios	Baseline scenario – y0_nobreach, and breach scenarios y0_breach, and y10_breach. Gated weirs are used across the catchment to simulate breach between watercourse and floodplain once a certain level is reached.
Model Data	The SFFD 2016 model is based on the previous 2013 model which used cross section survey from 1999-2000 and 2006. LiDAR used to represent the floodplain dates to 2005-2006 at 1m or 2m resolution, newer data is available (National LiDAR Programme DTM 2019 1M).
Schematisation	1D cross sections for the main watercourses. Floodplains are represented mostly using 'reservoir' units and in some cases 1D cross sections. Spill units are used to represent the high-level bank units connecting the 1D cross sections to 'reservoir' floodplain units. Pumping stations are included as abstraction units which remove water from the floodplain to the watercourse.
Results	The largest simulated event with the model is the 100-year plus 20% climate change. There is no overtopping from Head Dike into Heckington Fen for this event.

2.1.3 Model Hydrology

Inflows to the model are applied at the upstream extents of channels. As the main watercourses are high-level carriers, inflows are also applied directly to the floodplain (reservoir units). The schematisation appears sensible overall, with the upper reaches representing a "typical" catchment that drains via gravity, and a lower reach representing the low-lying pumped region, including Heckington Fen.

Within the vicinity of Heckington Fen there are three FEH boundary units linked to the 1D channels of Car Dike (from Ewerby Fen), Heckington Eau and Head Dike. Holland Dike is not modelled upstream of its junction with Head Dike and does not have its own boundary unit. The Trinity College sub-catchment is represented as one reservoir unit with an FEH boundary unit, while the Heckington Fen sub-catchment is represented by two reservoir units, for the areas north and south of Heckington Eau, again each with an

FEH boundary unit. A further three reservoir units are used to represent the area north of Head Dike, these are linked by spills to Head Dike. This suggests a minimum of six inflow hydrographs are required for analysis of the Heckington Fen site.

The following design events are available for the SFFD 2016 model:

- Baseline design events: 2, 5, 10, 20, 50, 75, 100-year
- Sensitivity design events: 100-year plus climate change (20%)

The 2016 Black Sluice Catchment Works (BSCW) revised modelling report states that the inflows to the model were first calculated for the 2009 Flood Map Improvements Study, deriving a 14.5-hour storm duration for the upper catchment and identifying that the 40-hour storm duration is critical for the lower catchment (SFFD model) using the Flood Studies Report (FSR) rainfall-runoff approach. Therefore, the 40-hour storm duration inflow data will be adopted for the Heckington Fen study.

It appears the current inflows have been copied from a 2009 analysis and not updated since, using the FEH rainfall-runoff method, with the "Trapezoidal" unit hydrograph method used on the low-lying, pumped section, of the catchment at Heckington Fen. This is an older standard approach for a lowland catchment system, however current-day guidelines, (updated since the original calculations were undertaken), generally recommend application of the ReFH2.3 model in preference. The most recent 2016 report carries out some simplified checks of catchment descriptors from the 2009 analysis, with no changes applied. The current calculations are also dependent on catchment descriptor methods. It appears that the previous analysis concluded that there would be minimal benefit in the use of local level data to improve the hydrological inputs, given the lack of a high-quality flow record at the downstream end of the catchment.

Since the inflows were calculated, the Depth Duration Frequency (DDF) rainfall model for rainfall-runoff analyses has also been updated (from FEH99 to FEH13). The rainfall-runoff approach has also been updated to ReFH2.3, although the older FEH rainfall-runoff model is calibrated to use the older FEH99 rainfall inputs. The model and hydrology will need to be assessed for sensitivity to these changes.

2.2 Topographic Data

2.2.1 EA LiDAR

The latest Environment Agency 1m resolution DTM shows good representation of the banks along Head Dike at the northern boundary of the site, and of ditches and smaller scale topographic variation within the site. The National LiDAR Programme Index Catalogue indicates the available data was flown in 2005, but this is not the latest data. The National LiDAR Programme Survey Plan indicates that an area including Heckington was surveyed to 1m resolution in March 2019 and this data is available to download from the DEFRA LiDAR survey data portal.

2.2.2 Topographic Survey

Topographic survey for the site was collected in October 2021 and comprised spot levels taken at 30m intervals. The coverage and detail of the topographic survey was assessed from drawing 'P1543-DW-F137-R0 Heckington Fen 2D Topo R1' (Appendix B). The topographic survey is sufficient to capture the general elevation of Heckington Fen. However, the measurement points at 30m intervals do not capture features such as drains across the floodplain and the banks of Head Dike.

The topographic survey points were used to assess the agreement between the 2019 LiDAR and survey data. Across much of the site the LiDAR is between 50mm and 200mm lower than the survey data. There is better accuracy across the higher ground across the south of the site. The National LiDAR Programme[1] survey plan information states that this survey has an accuracy of +/-150mm. The differences observed between the LiDAR and topographic survey are mostly within the range expected.

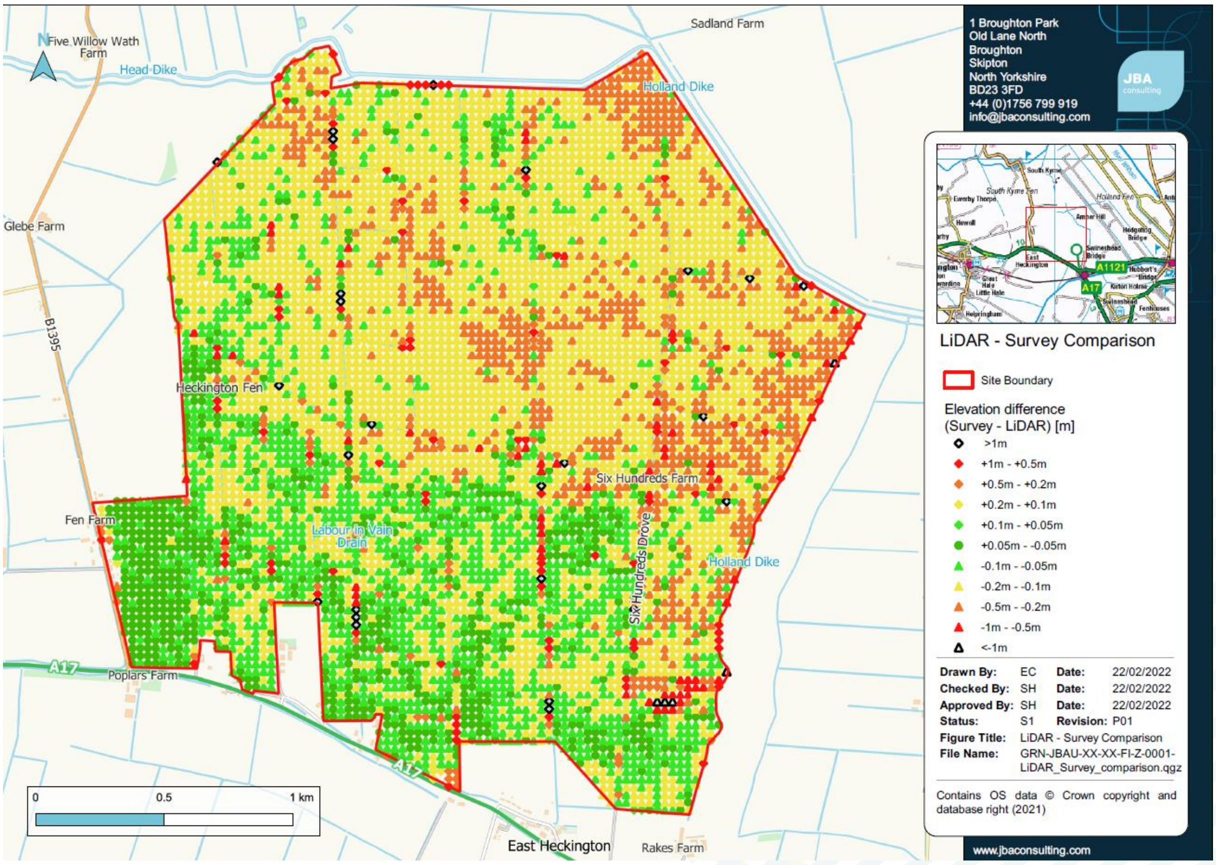


Figure 2-1: LiDAR – Survey level comparison

1 [redacted]

3 Modelling methodology

3.1 Hydraulic modelling

Following a review of the EA SFFD 2016 model and information provided by the EA the following scenarios are proposed to assess the worst-case flood risk and define the flood water levels to be used to inform scheme design (i.e., the elevation of flood-sensitive infrastructure)

- A breach of the Head Dike watercourse
- Pumped catchment model – pump failure scenario.

3.1.1 Pumped catchment model

A simple pumped catchment model will be developed for the Black Sluice Internal Drainage Board Pumped catchment system at Heckington Fen. The extent of the model will match that of the Heckington Fen and Trinity College Pumping Station sub-catchments (as defined by the BSIDB), represented within the existing SFFD 2016 model as reservoir units.

The model will follow an industry-standard approach for pumped catchments representing the sub-catchments as storage areas within a 1D HEC-RAS model:

- Storage areas will be digitised for each pumped catchment system based on the IDB catchment boundaries and the 2019 LiDAR DTM.
- A 1D spill (representing high ground such as roads as appropriate), with elevations derived from the LiDAR, will enable flow between the pumped sub-catchments.
- Head Dike will be represented as a 1D channel with spills to the floodplain storage areas.
- The inflows will be applied directly to the storage areas and channel using the SFFD 2016 hydrological boundaries as necessary (these inflow boundaries being subject to review, as outlined in Section 3.2 below).

3.1.2 Breach model

A site specific 2D-TuFLOW model will be developed to assess the residual flood risk from breach of the Head Dike high-level carrier watercourse:

1. The existing SFFD 2016 model will be updated. Updates will involve using the latest LiDAR and topographic survey to update the model geometry, particularly spills from Head Dike, and the floodplain. LiDAR data will be used only where it is considered to improve upon existing data. The required events, 100-year, 100-year plus 20% climate change, and 1000-year plus 20% climate change will then be simulated to derive a breach hydrograph using a Flood Modeller breach unit.
2. The breach hydrograph(s) will then be applied to the TuFLOW domain at the two locations indicated in Figure 3-1.

The breach parameters detailed in Table 3-1 are based on the Environment Agency 2017 Breach of Defences Guidance Note recommended for a river earth embankment. The topographic data has been reviewed to identify possible breach locations, identified based on topographic low points in Head Dike's south bank. As there is an IDB drain at the foot of the Dike's south bank, the breach invert is defined based on whichever is lower (either the Head Dike channel invert or the invert of the ditch/drain to the south).

Table 3-1: Breach parameters

Parameter	Details	
Breach location/s *See Figure 3-1	1	Presumed outfall from Head Dike (519527, 346754)
	2	Area located close to a pumping station (520787, 346816).
Breach width (m)	40	
Breach invert (mAOD)	1	-0.41mAOD
	2	-0.46mAOD
Time to close – rural (hrs)	56	

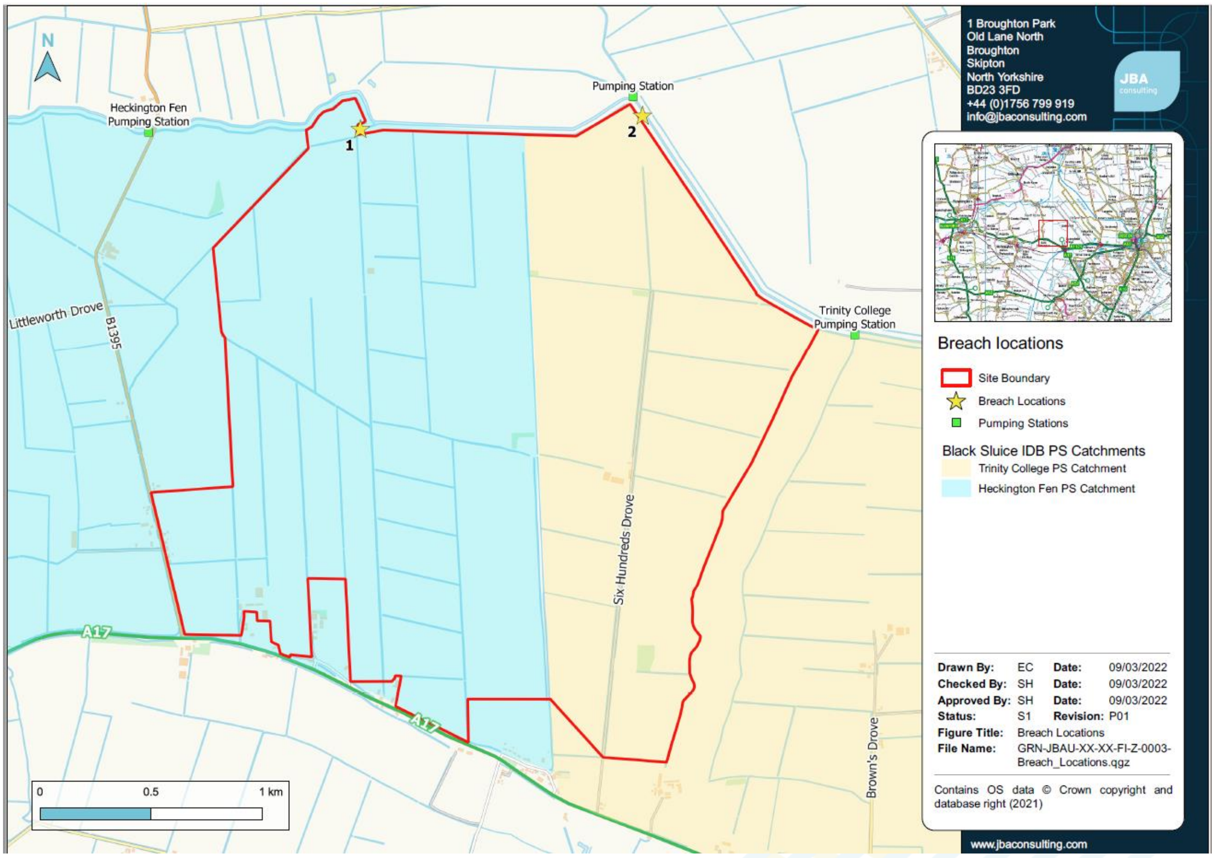


Figure 3-1: Proposed breach locations

3.2 Hydrology

The EA advised by letter dated 18 November 2021 (EA ref: AN/2021/132242/03-L01) the design event requirements for the proposed solar farm as follows:

"Essential infrastructure requires use of the higher central allowance which for the 2050's epoch, i.e., that for a development with a 40-year lifespan, is a 15% increase in peak

flows. Therefore, using the 0.1% level + 20% in a FRA would be acceptable. Given the relatively small variation in flood level in the channel we do not consider this to be an overly precautious approach."

The existing hydrology for the SFFD 2016 model does not include the 1000-year event. This has been requested from the EA.

Once all necessary data is available, the existing model inflows will be compared to flows independently calculated using ReFH2.3 with the FEH13 rainfall model. The proposed approach is as follows:

1. For the pump failure scenario modelling, inflows for the Heckington Fen and Trinity College Pumping Station sub-catchments will be calculated using ReFH2.3, compared to the existing (2016) model inflows and model sensitivity testing undertaken to assess the impact of potential changes to inflows upon modelled water levels;
2. For the breach analysis, inflow boundaries for the upper (gravity) sub-catchments will be calculated using ReFH2.3, compared to the existing (2016) model inflows and model sensitivity testing undertaken to assess the impact of potential changes to inflows upon modelled water levels along the SFFD and at the confluence with the Head Dike. It is not considered necessary to update inflows that are applied directly to the various reservoir units representing the low-lying pumped catchments as inflows from these catchments to the high-level carriers are controlled by the pumping stations.

It is recommended in this case to carry out these updated ReFH2.3 calculations using catchment-descriptor methods. Having reviewed the locations and types of gauges available within this catchment, the lack of a high-quality flow record at the downstream end, is a significant limiting factor on the robustness of any hydrological calibration that could be attempted in this case. General advice from Wallingford Hydro Solutions on this topic states that calibration to limited datasets can increase, rather than decrease, the uncertainty associated with design flood modelling. Therefore, in this case it is recommended that catchment-descriptor methods should form the basis of inflow checks when applying the ReFH2.3 method.

The following approach is proposed to review/update model inflows:

- Obtain updated catchment descriptors and FEH13 rainfall data for the inflow locations used in the previous hydraulic modelling, matching the set-up with the existing model where possible (i.e. matching the number and general locations of model inflow boundary conditions in the existing modelling, for consistency with previous work).
- Use the catchment-descriptor ReFH2.3 model to derive design event inflows for the required return periods, using a 40-hour design storm duration, as recommended from the existing modelling of this catchment.
- Compare these ReFH2.3 hydrographs against the existing inflows used in the model and complete model sensitivity runs to assess the impact of potential changes to inflows (based on the ReFH2.3 analysis) upon modelled water levels.

If the difference in ReFH flow estimates compared to the existing model inflows is minor, the existing flows will be adjusted to the updated ReFH flood peak hydrograph using a scaling factor. Simplified comparisons of modelled water levels against typical flood levels recorded at level gauges will also be considered (subject to the availability of suitable level records in the lower catchment) to help judge where adjustments may be appropriate.

If there is a significant difference between ReFH estimates and the existing inflows, 1% AEP event runs of the model using both the old and updated flows will be used to assess the effect on levels at Heckington Fen. In this case the modelled levels (using either the existing or updated ReFH2.3 flows) which best correspond with level records (if available) will be adopted, or the most conservative flows will be adopted in the absence of level records.

Once model inflows have been validated/updated following the ReFH analysis, the SFFD 2016 model will then be used to produce a breach hydrograph to apply to the proposed 2D TuFLOW domain at each breach location.

For the pump-failure scenario the reviewed and updated catchment hydrology will be applied to the model without any operational pumps.

4 Summary

Jeremy Benn Associates Limited (t/a JBA Consulting) has been appointed by Ecotricity Generation Limited to prepare a Flood Risk Assessment (FRA) in support of an application for Development Consent to construct a solar farm and associated energy storage infrastructure on land at Heckington Fen, Lincolnshire.

The EA was consulted in October 2021 and advised that breach analysis should be undertaken to inform scheme design/layout. The EA subsequently (February 2022) provided a copy of the South Forty Foot Drain hydraulic model (2016) to be used as the basis for breach analysis.

This technical note has reviewed the quality and suitability of the available data and set out the methodology and scope of work required to (i) undertake the breach analysis and (ii) simulate a pump-failure scenario and define flood levels across the site.

The outcome of this review is summarised as follows:

- The existing SFFD 2016 model will be updated where the latest LiDAR and topographic survey is considered to improve upon existing data. This will involve improving the representation of topographic features such as the floodplain and banks of Head Dike.
- Model inflows may be adjusted based upon the results of analysis using the current ReFH2.3 methodology and FEH13 rainfall data.
- The updated model will be used to generate a breach hydrograph to be applied to a simple TuFLOW domain representing the catchment at Heckington Fen.
- A further pump-failure scenario will be modelled using the 1D HEC-RAS model to assess the impacts of pump failure during a flood event and determine a worst-

case scenario (by comparison with the breach analysis results) for the purposes of scheme design.

Table **4-1** summarises the key points requiring agreement from the Environment Agency and also outstanding data to be provided by the EA (highlighted in **BOLD**).

Table 4-1: Points requiring agreement with the Environment Agency

Theme	Item requiring confirmation/data to be provided
Hydrology	• Confirmation that the proposed methodology based upon ReFH2.3 and catchment descriptors is appropriate for reviewing (and adjusting where required) current model inflows. • Confirmation that the 40-hour critical design storm duration, determined from previous modelling, is adopted for the purposes of further analysis. • **EA to provide model files (Product 7 data) for the SFFD 2016 model relating to the 0.1% scenario**
Modelling	• Confirmation that the proposed methodology and parameters for assessing a pump-failure scenario are acceptable. • Confirmation that the proposed methodology and parameters for breach analysis are acceptable (including breach scenario parameters, number of breaches and breach locations).

Appendices

A Environment Agency Advice Letter 18.11.2021

creating a better place

Environment Agency

Stuart Harwood
[redacted]@jbaconsulting.com

Our ref: AN/2021/132242/03-L01

Agreement number: ENVPAC/1/LNA/00127

Date: 18 November 2021

Dear Stuart

Solar park proposal East Heckington, Lincolnshire

Thank you for your email dated 15 November 2021 addressed to Chris Walker.

Chris has provide the comments below under the cost recovery project number ENVPAC/1/LNA/00127 and an invoice for £50 (.5 hours) plus VAT will be issued shortly to Ecotricity Group Limited under PO-008261.

Comments

"The water levels provided are in-channel only. We aren't able to provide a flood level for the site due to the way it has been modelled as a one-dimensional (1D) hydraulic model with spill and floodplain units. As we are not able to provide a flood level, breach analysis of the Head Dyke / Skirth Drain should be undertaken to understand the residual risk to site. This would be the key aspect of the site Flood Risk Assessment [FRA] which would also set out mitigation measures for the estimated flood depth.

Essential infrastructure requires use of the higher central allowance which for the 2050's epoch, ie that for a development with a 40 year lifespan, is a 15% increase in peak flows. Therefore using the 0.1% level + 20% in a FRA would be acceptable. Given the relatively small variation in flood level in the channel we do not consider this to be an overly precautious approach.

The nature of the system(s) is Head Dyke flows into Skerth Drain which then joins the South Forty Foot Drain".

Should you request that we review a document or provide further flood risk advice we will estimate how much time is required and seek your acceptance prior to continuing as outlined in our previous letter.

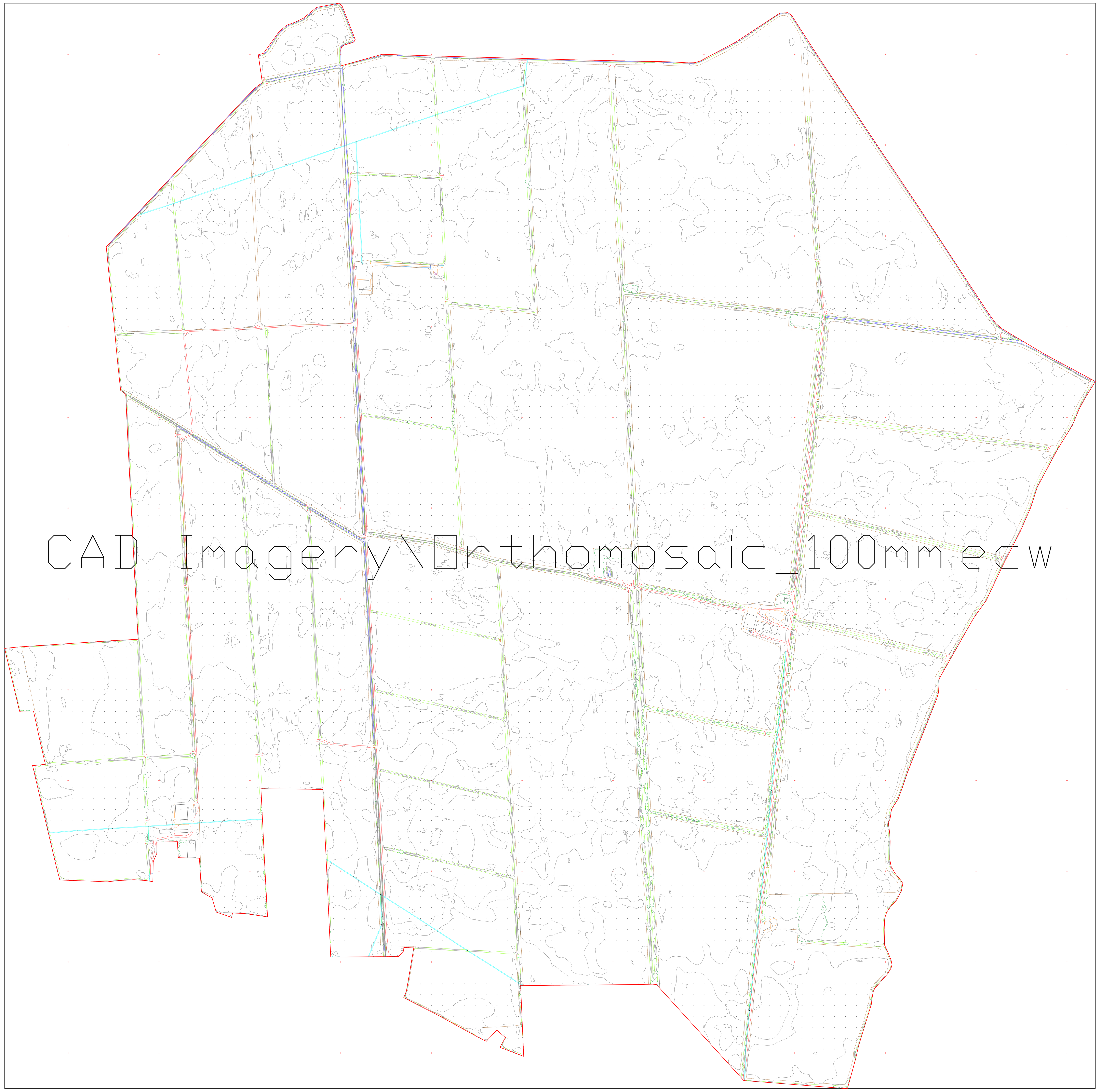
Should you require any additional information, or wish to discuss these matters further, please do not hesitate to contact me on the number below.

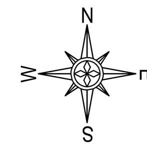
Yours sincerely

Mrs Sharon Nolan
Sustainable Places Planning Advisor

Direct dial [redacted]
E-mail lnplanning@environment-agency.gov.uk

B Topographic survey (P1543-DW-F137-R0 Heckington Fen 2D Topo R1')





Legend

- Culvert
- Ditch
- Fence
- Gate
- High Vegetation
- Manhole
- Overhead Line
- Structure
- Surface Material Change
- Survey Extent
- Topo Point
- Track
- Water Body
- Worked Field Extent

Notes

1. Data collected on 13th September 2021 by Geo-4D Ltd
2. Data collected using PPK-enabled WingtraOne UAV, GPS base station and RTK GNSS receiver
3. Ground control points surveyed using RTK GNSS in ETRS89 coordinate system and projected to OSGB36 using OSTN15 transformation within Grid Inquest software
4. Imagery data processed using photogrammetry method to derive an orthomosaic image and digital surface model (DSM)
5. Non-ground points removed from DSM to create a digital terrain model (DTM)
6. The DTM is locally interpolated where ground points were not visible from the UAV, and therefore may be of reduced accuracy in vegetated areas
7. Ditches were locally inaccessible and overgrown, and therefore presented topo heights and contours are locally of reduced accuracy
8. Topo grid heights and contours extracted from the DTM
9. All features extracted from the 16mm resolution photogrammetry-derived orthomosaic imagery
10. Elevations subject to ~50 mm XYZ absolute accuracy

Coordinate Reference System: OSGB36 (EPSG:27700)
Vertical Datum: Ordnance Datum Newlyn
Projection: Transverse Mercator
False Easting: 400,000
False Northing: -100,000
Central Meridian: 2° West
Scale Factor: 0.9996012717

Client

Pegasus Group
Querns Business Centre
Whitworth Road
Cirencester
GL7 1RT

Survey Contractor

Geo-4D

Geoconsultancy and Remote Sensing Specialists

www.geo-4d.com
info@geo-4d.com
+44 (0)345 257 0877
Geo-4D Limited, Unit 5A, RAC Estate, Faringdon, Oxfordshire SN7 7BP

Project

Heckington Fen

Drawing Name

Topographical Survey

Drawing Number

P1543-DW-F137

Drawn By: DH

Checked By: BC

00 Scale at A0

C Hydraulic model review

B	Review of South Forty Foot Drain
Date of model	January 2016
Name of reviewer	
Date of review	11/02/2022
Revision	
Applicable standards or guidance	
Nature of study watercourse(s)/constraints	South Forty Foot Drain
Study objectives	The Black Sluice Catchment Works study (supplied model) aimed to update the previous 2013 ISIS model (CH2M Hill) to better reflect the existing conditions. The study identified two catchments - upper and lower. The Heckington Fen site is located in the lower catchment. In the lower catchment the representation of pump/flapped outfall operation at the Black Sluice Pumping Station at Boston was changed in the model update. This was due an issue caused by the change in software version. In the upper catchment, there were model changes with four access bridges added around Swaton. There were also various locations where floodplain representation was changed from reservoir units to extended cross sections based on LIDAR. Manning's n roughness values were updated to better reflect the area. Following the model update, average water levels across the model were within <0.01m of the previous CH2M Hill study. The main changes in water level were found in the upper catchment where the river channel/floodplain were reconfigured to better represent flood risk in the nearby communities. According to the report, the updated model was calibrated to gauged levels at the Swaton level gauge/photos from the November 2012 event. This analysis is not supplied within the reporting. The model was deemed suitable and used for options appraisal. This model review will assess the suitability of the South Forty Foot Drain 2016 model for use in the Heckington Fen solar farm FRA.
Summary of 1st review	The provided model could be used as a basis for this study. The channel survey across the catchment is quite old as it was collected in 1999/2000, but it would not be necessary for this to be updated. Similarly, the LIDAR data is from 2005-06, but this is the latest available. The representation of the model is 1D only for both the watercourses and floodplain. The EA's advice letter states that floodplain level is not available, but it is possible to extract floodplain water levels from the 1D model. In the current model, changes in water are assumed to be uniform across each 1D storage catchment unit, which is reasonable given the flat and well connected nature with drains across the floodplain. The use of 1D floodplains is often used flat, pumped catchments such as this. There appears to be a discrepancy between the predicted peak water levels within the Heckington Fen floodplain. Following analysis of LIDAR ground levels, that peak water levels used to produce the provided flood extent maps is higher than peak water level within the 1D model stage hydrograph. Further investigation of the depth-area relationship used for floodplain unit is required. For this study, the floodplain could continue to use this 1D method or could be converted to 2D within the study area. This will need to be confirmed with the EA. Looking at satellite imagery, there is potentially an outfall (519527,346754), but no such structure is included within the model. Further investigation required. High weir coefficient values used for embankments along the high-level carrier watercourses, currently there is limited flow across the embankments, so should not impact results. The channel roughness has a high value within the South Forty Foot Drain and could be reduced. Other drains such as Head Dike next to the site has more appropriate roughness values. Sensitivity test could be performed to assess the impact. The model parameters have been adjusted from defaults and there is no justification given in the provided reporting. This could be considered as a legacy issue associated with the model, and should not need to addressed as part of this study.

Category	Detail	Prompts	ID	1st Review			
				Comment	Suitability	Suggested actions	Consultants Response (if required)
Data to be reviewed							
Data to be reviewed	Software	~ Versions	B-1	ISIS v6.6	Minor issue	The model should be run in up-to-date software	
			B-2				
	AEPs provided / reviewed		B-3	2, 5, 10, 20, 50, 75, 100-year. 100-year plus climate change (20%).			
			B-4				
	Scenarios provided / reviewed		B-5	y0_breach, y0_nobreach, y10_breach. No explanation in reporting. Gated weirs are used across the catchment to simulate breach between watercourse and floodplain once a certain level is reached.			
	Reports	~ Reference versions ~ Technical reporting ~ General reporting	B-6	Black Sluice Catchment Works model report			
Reporting							
Reporting	Reporting	~ Objectives ~ Constraints ~ Approach Justification (both model scale and structure scale) ~ Clarity ~ Assumptions ~ Interpretation of results	B-7				
			B-8				
			B-9				
			B-10				
			B-11				
General comments							
General comments	File organisation / naming convention	~ Scenarios ~ Naming ~ Flags	B-12	Good file organisation, but the provision of a model log would have been useful.			
			B-13				
			B-14				
			B-15				
	Survey / topographic data	~ Age ~ Quality ~ Suitability	B-16	The provided model is based on the previous 2013 model which used survey from 1999-2000 along with updated survey in 2006. LIDAR used for model 2005-2006 (1m/2m resolution) - no newer data is available		It is unclear what age the survey is in the vicinity of the site.	
			B-17				
	Other	~ Any significant missing data	B-18				
General modelling approach							
	Model extents	~ Domain boundaries ~ Upstream/downstream boundaries ~ Potential downstream influences on water levels ~ Glass walling	B-19	The South Forty Foot Drain links to the River Witham at Boston via the pumping station. The River Witham/Haven continues down to the mouth of the river where a tidal boundary.			
			B-20				
			B-21				
			B-22				

General modelling approach	Modelling approach	~ 1D / 2D / Linked ~ georeferenced (ixy/gxy/2d links)	B-23	1D only model. 1D cross sections for the main watercourses. Floodplains represented mostly using 'reservoir' units, but in some cases 1D cross sections.			
			B-24	Mostly georeferenced.			
	Application of hydrological estimates	~ Lumped / distributed ~ Applied to 1D or 2D domain ~ Lateral or point inflows ~ Consistency with reporting	B-25	Inflows are applied at the upstream extents of channels. As the main watercourses are high-level carriers, inflows are also applied directly to the floodplain (reservoir units).	Acceptable		
			B-26				
			B-27				
ISIS/Flood Modeller							
ISIS/Flood Modeller	Model build	~ Hard bed / soft bed ~ Accuracy of modelled channel length	B-28	Assumed hard bed			
			B-29				
	Schematisation	~ Representation of flow paths ~ Representation of storage	B-30	Main watercourses (high-level carriers) are represented using 1D cross sections.			
			B-31	The floodplain is represented using 'reservoir' units which provide a depth-area relationship. In a flat catchment such as this, it is a sensible approach. However, the catchment delineation of each unit is not shown in the model. The 2017 conversion report provides catchment locations, so it should be possible to establish. Connections are provided between adjacent reservoir units with 100m v-shaped spills in the ISIS model. This will not necessarily provide the best representation. The Heckington Fen site falls into one of the units that makes use of the v-shaped spill. If the 1d-only method is used for this study, these spills should be updated to better reflect the catchment.			
	ISIS Health Check	~ Summarise key findings ~ Take care to interpret findings and consider relevance	B-32				
			B-33				
	Boundary conditions	~ Upstream boundary ~ Downstream boundary ~ Phasing of boundary conditions	B-34				
			B-35				
			B-36				
			B-37				
	Open channel representation	~ Manning's n ~ Panel markers ~ Section spacing ~ Geometry	B-38	For the main South Forty Foot Drain channel, a Manning's n value of 0.05. This seems high for the channel conditions.	Minor issue		
			B-39	Most of the smaller connected channels represented in the model use a Manning's n of 0.03. As part of the 2016 model update, channel roughness in the upper catchment was increased to 0.045 to represent flow inefficiencies in this area.	Acceptable		
			B-40	Panel markers have been used			
			B-41	Section spacing is appropriate for this type of watercourse. Interpolates have been used in between surveyed cross sections.			
			B-42				
	Hydraulic structure representation	~ Structure coefficients ~ Bypassing options ~ Choice of model unit ~ Geometry	B-43	Choice of model units for bridges along Head Dike (next to site) are appropriate. Bypassing options have not been used, but in the results provided overtopping does not occur.			
			B-44	The spill units representing the banks connecting the watercourse to the surrounding floodplain use high weir coefficients (1.5). Such values would be typical of manmade weirs rather than embankments. There is no flow over the embankment spills in the study area, so will not be affecting results.	Minor issue	Lower weir coefficients to a more appropriate value.	
			B-45	Pumping stations are included as 'abstraction' units which remove water from the floodplain to the watercourse. The pumping rules are assumed to be correct, no details provided in reporting.	Acceptable		
			B-46	The pump station on the eastern side of the site includes a flapped outfall unit connecting the floodplain to the watercourse. This is likely to be based on pumping station inlet - as the invert/soffit are below the downstream bed level, the unit doesn't operate. This is an unnecessary inclusion in the model, as the abstraction unit functions as the pump. However, it's inclusion will not impact results.		Remove outfall unit.	
			B-47	There is potential a missing outfall at 519527,346754. There is nothing in the model, but satellite imagery shows that there could be a connecting culvert.	Clarification required	Establish whether a structure is present.	
			B-48				
			B-49				
			B-50				
	Floodplain representation	~ Suitability of approach ~ Implementation ~ Glass walling	B-51	The use of 1D 'reservoir' units is an appropriate method to represent flat catchments. This method will water levels will be uniform across the floodplain. However, as stated in the EA's advice letter, they cannot provide a flood level. This is not strictly correct as the results can be extracted from the reservoir units to give a water level. However, such data extraction is not performed in the water level analysis for the EA with only levels within 1D watercourse cross sections. From the model provided, peak water levels in the 1% AEP event are 0.62mAOD. However, comparisons between the provided flood extents and LIDAR ground elevations suggest that the peak water level is higher this value. This suggests a discrepancy in the existing results. The LIDAR could be reassessed to make sure the correct water depth-area relationship curve is used in the study area.	Clarification required	Clarify with the EA as part of the method statement whether the continued use of a 1D floodplain is acceptable. Otherwise conversion to TUFLOW could be used.	
			B-52	As stated in comment B-31, there are some issues with connectivity between the separate floodplain units in the model.			
			B-53	No glass walling has been identified.	Acceptable		
	Run parameters and output data	~ Results generated ~ Temporal resolution of results ~ Run parameters	B-54	Temporal resolution of results is appropriate	Acceptable		
			B-55	Some of the run parameters have been adjusted from the defaults. Dflood increased to 6 maxitr increased to 20 theta increased to 0.99 This could be a legacy issue with the model, but suggests potential instability.	Minor issue		
			B-56				
InfoWorks ICM							
ESTRY in-channel domain							
ESTRY floodplain structures							
TUFLOW domain (1)							
TUFLOW domain (2)							
Runs							

Runs	Model simulations	Model simulation runs ~ Existing (baseline) ~ Climate change ~ Sensitivity	B-175	Baseline scenario with no breach. There is also scenarios with breaches across the catchment. A new scenario with a breach at specified location specific to the site would be more appropriate.		Establish breach location.	
			B-176	Climate change scenario for model provided includes a 20% increase. For essential infrastructure in Flood Zone 3, the higher central allowance should be considered. In the Welland management catchment, this states an increase of up to 28% should be modelled.		Run updated climate change allowance	
Model results, interpretation, verification and stability							
Model results, interpretation, verification and stability	Model stability	~ zzd, eof, tlf ~ Model warnings and errors ~ Non-convergence ~ Mass balance ~ unrealistic oscillations (water level / flow / boundaries / dVol).	B-177	There is limited non-convergence in the standard event model results			
			B-178	For climate change, there is more non-convergence, but this does not appear to be causing unrealistic oscillations in water levels near to the sutdy site.			
			B-179				
			B-180				
			B-181				
			B-182				
			B-183				
			B-184				
	Sensitivity testing	~ Suitability of sensitivity testing undertaken ~ Results & interpretation of sensitivity testing	B-185	N/A			
	Calibration / performance		B-186				

D Black Sluice IDB pumped sub-catchments

Legend

- Black Sluice IDB District Boundary
- BSIDB-maintained Open Watercourses
- BSIDB-maintained Piped Watercourses
- BSIDB Pumping Stations
- 9 - Heckington Fen sub-catchment
- 15 - Trinity College sub-catchment
- Environment Agency Main River

CATCHMENTS & PUMPING STATIONS

ID	Name	Catchment Area (Ha)	Length of Watercourses (m)	No of Pumps + Gravity Channels	Total Pumping Capacity (l/s)
9	Heckington	1576	26371	2	2661
15	Trinity College	609	9522	2 / Gravity	1133

Black Sluice Internal Drainage Board
Station Road, Swineshead,
Boston, Lincolnshire PE20 3PW
Tel: 01205 821440
Email: mailbox@blacksluiceidb.gov.uk

Date: January 2022

Scale: 1:12,500

TECHNICAL NOTE

JBA Project Code	2021s1226
Contract	Heckington Fen Solar Farm
Client	Ecotricity Generation Limited
Day, Date and Time	July 2022
Author	Ellen Corry
Reviewer / Sign-off	Stuart Harwood
Subject	Hydrology and hydraulic modelling

A.2 EA method statement approval letter

creating a better place

Environment Agency

Stuart Harwood
[redacted]@jbaconsulting.com

Our ref: AN/2021/132242/05-L01

Agreement number: ENVPAC/1/LNA/00127

Date: 22 April 2022

Dear Stuart

Planning advice for Heckington Fen Solar

Thank you for accepting our offer to provide planning advice for flood risk management at the proposed solar farm development at Six Hundred Farm. We are providing our planning advice under project number ENVPAC/1/LNA/00127 and an invoice for £300 (3 hours) plus VAT will be issued shortly to Ecotricity Group Limited under PO-008261.

We have reviewed the technical report produced by JBA Consulting, Project Code 2021s1226 in the email sent to us on the 22 March 2022.

We are satisfied the model method statement is adequate and includes enough information for the model in relation to the works being proposed and will allow the outputs to inform the flood risk assessment accordingly. We have no further comments to make and will be happy to review the model if JBA feel this appropriate once complete. We would need to provide a further cost estimate for this.

Should you require any additional information, or wish to discuss these matters further, please do not hesitate to contact me on the number below.

Yours sincerely

Mrs Sharon Nolan
Sustainable Places Planning Advisor

Direct dial [redacted]
E-mail lnplanning@environment-agency.gov.uk

TECHNICAL NOTE

JBA Project Code	2021s1226
Contract	Heckington Fen Solar Farm
Client	Ecotricity Generation Limited
Day, Date and Time	July 2022
Author	Ellen Corry
Reviewer / Sign-off	Stuart Harwood
Subject	Hydrology and hydraulic modelling

B Hydrology Report

NOTE TO FILE

JBA Project Code	2021s1226
Contract	Heckington Fen Solar Farm, Lincolnshire FRA
Client	Ecotricity Generation Limited
Day, Date and Time	June 2022
Author	Eleisha Lord
Reviewer	James Molloy
Subject	Updated Hydrology Calculations

1 Introduction

1.1 Introduction

This report describes the updated hydrology calculations required for the Heckington Fen Solar Farm Flood Risk Assessment, appointed by Ecotricity Generation Limited. This Flood Risk Assessment is in support of an application for Development Consent to construct a solar farm and associated energy storage infrastructure on land at Heckington Fen in Lincolnshire. This project required the application of ReFH2 using the catchment descriptor methods. A comparison of the ReFH2, ReFH2 Scaled and the Existing Model (FEH rainfall-runoff method) peak flows was undertaken for the 1% and 0.1% Annual Exceedance Probability (AEP) events. This comparison helped to determine which of these methods provided the most suitable inflow set to the existing hydraulic model, later used to inform embankment breach modelling.

1.2 Overview

A review of the model representation of the site deemed the model to be sensible overall. The upper reaches represented a "typical" catchment that drains via gravity, and a lower reach represented the low-lying pumped region, including Heckington Fen. Inflows to the model were applied at the upstream extent of the channels. Inflows were also directly applied to the floodplain via reservoir units.

This study assessed only the nodes directly affecting the site. In total twenty-three nodes out of the total fifty-one nodes available in the model were deemed to affect hydraulic conditions near the Heckington Fen site. Easting and Northing co-ordinates were extracted for the inflow units of the existing hydraulic model, using these to help initially locate the most appropriate catchment on the FEH Web Service (FEH WS) representing each model inflow. The updated catchment descriptors for each node included current-day design rainfall statistics from the FEH13 model. Judgement was required in some cases to manually select the most representative catchment on the FEH WS for a given model inflow node.

1.3 Retaining consistency with previous analysis

Manual alterations were then applied to the catchment descriptors obtained from the FEH WS as follows:

- The catchment area assigned to each inflow unit in the existing model was retained, over-writing the value obtained from the FEH WS. This was applied to retain consistency between the previous and updated ReFH2 calculations as much as possible. Previous modelling work also most likely undertook detailed catchment boundary updates for each inflow unit, although unfortunately these checks were not documented in the previous reporting provided. It was desirable to retain as much of this useful information from previous studies as possible in this analysis.
- A corresponding change was also applied to the DPLBAR descriptor to match the change described above, using a ratio-of-areas approach, as this is a key descriptor used in rainfall-runoff methods.
- No changes were applied to other descriptors such as SAAR or DPSBAR from the FEH WS, under the assumption that these values would not change significantly following manual catchment area modifications.

- The URBEXT2000 descriptor was also manually checked and compared against the previously used URBEXT1990 value, the latter being used in the previous FEH Rainfall-Runoff method calculations.

The ReFH2 method was applied with a 40-hour storm duration across all nodes. Again, this was to retain consistency with the previous existing modelling where possible. The previous model reporting also indicated that a 40-hour storm was found as the "critical" storm duration for this catchment.

Finally, unique calibration scaling factors, obtained from the previous modelling of the site were applied to the ReFH2 peak flow results for the 1% and 0.1% AEP events. It is suggested that the scaling factor is a form of calculated calibration in the older revision of the model, which unfortunately was not fully documented in the available accompanying reporting. The derivation of these original scaling factors is under review/information request. Two versions of the ReFH2 calculations were undertaken, separately including and omitting these calibration factors, as a sensitivity test on the results. This check also helps to retain consistency when comparing the updated ReFH2 results against the existing FEH Rainfall-Runoff calculations from the existing model.

2 Results

The 1% and 0.1% AEP peak flow results are presented in Table 2-1 and Table 2-2. The tables compare the peak flows of the existing model with the ReFH2 (Unscaled) and the ReFH2 (Scaled) results at each node.

Node	Existing Model	ReFH2	ReFH2 Scaled
6a_FEH	6.77	6.76	4.87
6b_FEH	2.35	2.18	1.57
HG953	0.63	1.53	0.38
HN1960	1.46	1.83	1.06
8a_FEH	15.06	10.04	9.44
8b_FEH	21.94	11.60	10.90
BL_FEH	10.94	9.31	8.65
BO_FEH	11.41	8.53	7.50
CD_FEH	7.50	4.13	2.44
EF_IDB	0.93	1.41	1.04
EF_FEH	0.82	0.78	0.77
EF_south_1	2.78	4.79	7.85
HD_FEH	2.47	2.02	1.58
HK_FEH	6.21	6.27	3.01
HKF_IDB	1.91	2.54	1.80
HKF_IDB!	0.49	2.83	1.72
HLF_IDB	3.75	2.92	2.76
HS_FEH	2.01	1.83	1.90

JBA Project Code	2021s1226
Contract	Heckington Fen Solar Farm, Lincolnshire FRA
Client	Ecotricity Generation Limited
Day, Date and Time	June 2022
Author	Eleisha Lord
Reviewer	James Molloy
Subject	Updated Hydrology Calculations

Node	Existing Model	ReFH2	ReFH2 Scaled
NL_FEH	3.93	2.88	2.71
PL_FEH	8.03	7.89	7.02
RR_FEH	8.38	7.78	6.38
SK_IDB	1.62	1.18	1.29
TC_IDB	1.15	0.80	1.01

Table 2-1 comparison of peak flow (m³/s) for the 1% AEP event

Node	Existing Model	ReFH2	ReFH2 Scaled
6a_FEH	11.90	10.53	7.58
6b_FEH	4.17	3.41	2.45
HG953	1.12	2.38	0.59
HN1960	2.56	2.86	1.66
8a_FEH	26.38	15.67	14.73
8b_FEH	21.24	19.03	17.89
BL_FEH	19.24	14.51	13.50
BO_FEH	20.17	13.71	12.07
CD_FEH	13.14	7.03	4.15
EF_IDB	1.79	2.30	1.27
EF_FEH	1.45	1.22	1.21
EF_south_1	5.33	7.40	12.14
HD_FEH	4.42	3.13	2.44
HK_FEH	10.97	9.71	4.66
HKF_IDB	3.48	4.11	2.92
HKF_IDB!	0.89	4.53	0.73
HLF_IDB	7.09	4.77	3.39
HS_FEH	3.58	2.84	2.95
NL_FEH	6.95	4.44	4.17
PL_FEH	14.23	12.34	10.98
RR_FEH	14.80	12.23	10.03
SK_IDB	3.02	1.94	2.11
TC_IDB	2.19	1.31	1.66

Figure 2-2 peak flow (m³/s) comparison results for 0.1% AEP event

3 Conclusion

The 1% and 0.1% AEP peak flow results, presented in Table 2-1 and Table 2-2, show considerable variation between the existing model and the ReFH2 results, both scaled and unscaled. The following main conclusions are drawn after reviewing these results:

- The scaling factors carried over from the previous modelling are typically (but not for all model nodes) less than 1.0. Therefore, carrying over these scaling factors will on average tend to reduce the model inflows.
- The existing model peak flows are typically (but not in all cases) similar or larger than the results from the unscaled ReFH2 method.
- The "'EF_south_1" node is a notable exception to the above patterns, showing a much larger flow from the ReFH2 method.

For the purposes of an FRA study when determining flood risk for planned development, it is often advisable to apply more conservative methods when calculating hydrological inflows. It is therefore concluded here that the existing model inflows, calculated using the FEH Rainfall-Runoff method, should be retained in this analysis, in preference to the ReFH2 approach.

4 Annex - Supporting calculations for ReFH2 inputs

4.1 Summary of subject sites

Site code	Type of estimate L: lumped catchment S: Sub-catchment	Watercourse	Easting	Northing	AREA on FEH WS (km2)	Revised AREA if altered
6a_FEH	L		512708	337559	10.99	12.37
6b_FEH	L		512708	337559	4.42	4.899
HG953	L		512520	336262	0.73	4.087
HN1960	L		512336	335549	2.14	4.087
8a_FEH	L		512003	341749	32.44	31.06
8b_FEH	L		512003	341749	43.07	48.03
BL_FEH	L		511591	333027	10.15	16.37
BO_FEH	L		509238	333825	20.65	25.26
CD_FEH	L		510481	321731	19.18	23.19
EF_IDB	L		520800	346900	4.99	12.43
EF_FEH	L		513045	349007	1.33	1.2
EF_south_1	L		515350	347950	6.33	12.43
HD_FEH	L		514368	347286	1.69	4.371
HK_FEH	L		513325	344819	15.22	18.3
HKF_IDB	L		519550	346750	5.6	15.61
HKF_IDB!	L		516600	346700	3.11	15.61
HLF_IDB	L		524900	343700	12.07	34.51
HS_FEH	L		513346	339139	2.34	2.847
NL_FEH	L		515271	342439	5.36	5.83
PL_FEH	L		511278	330480	10.15	11.84
RR_FEH	L		511182	328161	12.13	14.63
SK_IDB	L		519500	346950	3.33	9.907
TC_IDB	L		521750	345700	3.15	5.999

4.2 Catchment Descriptors at each site

Site code	FARL	PROPWET	BFIHOST 19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 2000	FPEXT
6a_FEH	1.000	0.22	0.358	4.255	12.6	586	0.013	0.3072
6b_FEH	0.968	0.22	0.447	4.422	14.8	588	0.013	0.2393
HG953	1.000	0.22	0.453	5.823	9.3	578	0.029	0.4089

Site code	FARL	PROPWET	BFIHOST 19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 2000	FPEXT
HN1960	1.000	0.22	0.469	3.801	17.5	583	0.029	0.2161
8a_FEH	0.998	0.22	0.504	7.928	13.3	600	0.020	0.3255
8b_FEH	0.988	0.22	0.574	9.713	21.7	604	0.016	0.1792
BL_FEH	1.000	0.22	0.324	7.371	27.1	594	0.0	0.0814
BO_FEH	1.000	0.22	0.535	6.398	30.0	605	0.014	0.0632
CD_FEH	0.990	0.22	0.659	6.517	18.5	574	0.088	0.2555
EF_IDB	1.000	0.22	0.673	6.975	1.1	565	0.001	0.9439
EF_FEH	1.000	0.22	0.375	1.471	8.3	579	0.0208	0.5135
EF_south_1	1.000	0.22	0.421	5.380	5.8	577	0.0134	0.5452
HD_FEH	1.000	0.22	0.387	4.268	6.9	576	0.0220	0.5716
HK_FEH	0.964	0.22	0.484	5.423	6.5	587	0.0420	0.5786
HKF_IDB	1.000	0.22	0.616	7.052	3.0	566	0.0004	0.7356
HKF_IDB!	1.000	0.22	0.559	9.185	2.9	573	0.0000	0.4590
HLF_IDB	0.996	0.22	0.663	17.012	1.5	563	0.0000	0.9268
HS_FEH	1.000	0.22	0.352	2.081	9.2	581	0.0000	0.4021
NL_FEH	1.000	0.22	0.368	2.730	3.2	578	0.0650	0.6774
PL_FEH	1.000	0.22	0.311	4.911	30.3	592	0.0170	0.0649
RR_FEH	1.000	0.22	0.389	4.885	27.4	587	0.0250	0.0773
SK_IDB	1.000	0.22	0.673	6.307	1.2	567	0.0000	0.7579
TC_IDB	1.000	0.22	0.682	5.923	2.5	562	0.0040	0.7323

4.3 Parameters of ReFH2 model

Site code	Method	Cmax (mm)	Tprural (hours)	BL (hours)	Area of catchment modelled as urban (km2)
6a_FEH	CD	309.6	11.0	45.5	0.25
6b_FEH	CD	390.1	10.7	52.5	0.10
HG953	CD	396.3	14.5	56.2	0.19
HN1960	CD	413.1	9.3	52.3	0.19
8a_FEH	CD	452.4	15.5	64.2	0.97
8b_FEH	CD	542.6	14.9	72.6	1.20
BL_FEH	CD	283.4	11.8	48.3	0.00
BO_FEH	CD	490.3	10.6	63.5	0.55
CD_FEH	CD	676.7	12.4	72.3	3.20
EF_IDB	CD	701.7	31.7	74.4	0.02

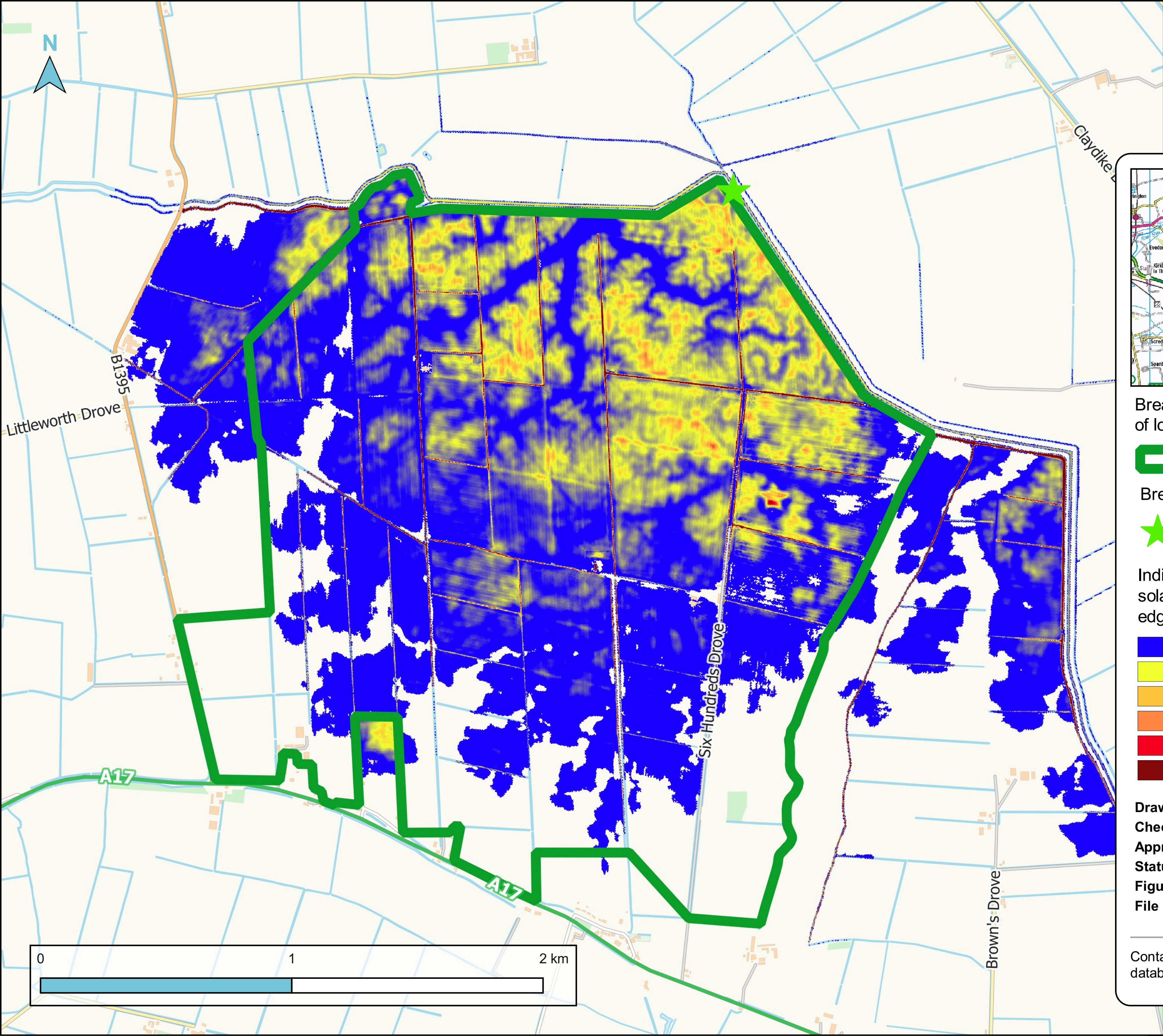
Site code	Method	Cmax (mm)	Tprural (hours)	BL (hours)	Area of catchment modelled as urban (km2)
EF_FEH	CD	322.8	6.8	37.1	0.04
EF_south_1	CD	364.7	16.1	52.9	0.26
HD_FEH	CD	333.8	13.4	47.8	0.15
HK_FEH	CD	429.5	15.6	57.6	1.20
HKF_IDB	CD	605.2	23.2	70.6	0.01
HKF_IDB!	CD	521.9	27.3	70.6	0.00
HLF_IDB	CD	683.7	47.8	89.5	0.00
HS_FEH	CD	304.8	8.1	38.6	0.00
NL_FEH	CD	317.8	13.2	42.0	0.59
PL_FEH	CD	274.0	9.0	43.1	0.31
RR_FEH	CD	335.6	9.3	49.3	0.57
SK_IDB	CD	701.7	29.1	72.7	0.00
TC_IDB	CD	718.3	22.2	72.3	0.04
Link to details of any lag or flood event analysis			Not applicable		
Version of the ReFH2 model applied			ReFH2.3 using the water balance option. This treats BR (baseflow recharge) as a state variable rather than a parameter, setting it automatically in order to conserve volume. The values of BR vary with return period and so are not reported here.		
Parameters for urban runoff model			The impervious fraction of urban areas, IF, was kept at its default of 0.4. The impervious runoff factor, IRF, (which can also be interpreted as the fraction of the impervious surface that is positively drained) was kept at its default of 0.7. The depression storage was kept at its default of 0.5mm. Tp for runoff from areas modelled as positively drained was calculated as 0.75 times Tprural.		
Methods: OPT: Optimisation from fitting to observed flow data, BR: Baseflow recession fitting, CD: Catchment descriptors, DT: Data transfer (give details)					

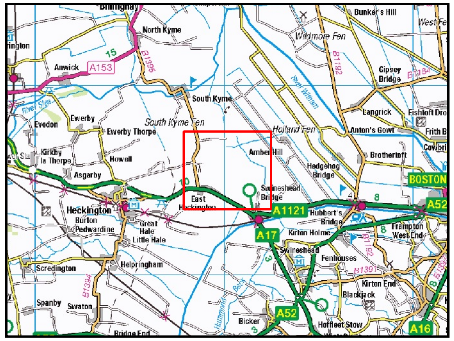
4.4 ReFH2 design events used

Site code	Season of design event	Storm duration (hours)
All	Winter	40.5hrs
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?		No. This value was determined from a previous modelling study and carried across for this comparative analysis, enabling a comparison versus previous FEH Rainfall-Runoff method results.

C Breach Flood Mapping

C.1 Breach 2: Head Dike – Maximum Depth (m), 1000-year +20% climate change





JBA consulting

Breach - Indicative, minimum height of lower edge of solar panel arrays

Heckington Boundary

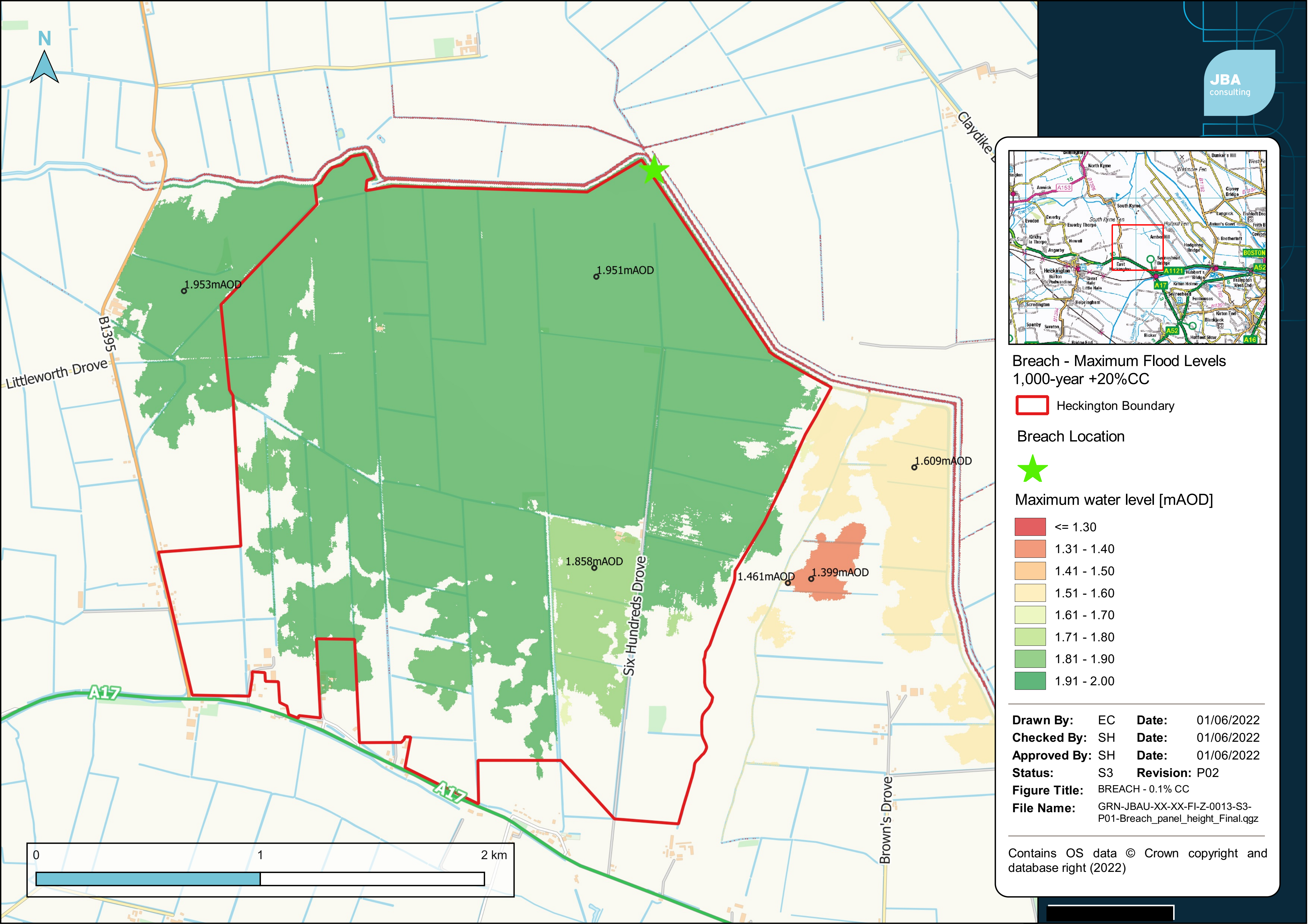
Breach Location

Indicative height of solar panel lower edge [mAGL]

- <= 1.00
- 1.01 - 1.10
- 1.11 - 1.20
- 1.21 - 1.30
- 1.31 - 1.40
- >= 1.40

Drawn By:	EC	**Date:**	07/06/2022
Checked By:	SH	**Date:**	07/06/2022
Approved By:	SH	**Date:**	07/06/2022
Status:	S3	**Revision:**	P02
Figure Title:	BREACH - Solar Panel Min Height		
File Name:	GRN-JBAU-XX-XX-FI-Z-0013-S3-P01-Breach_panel_height_Final.qgz		

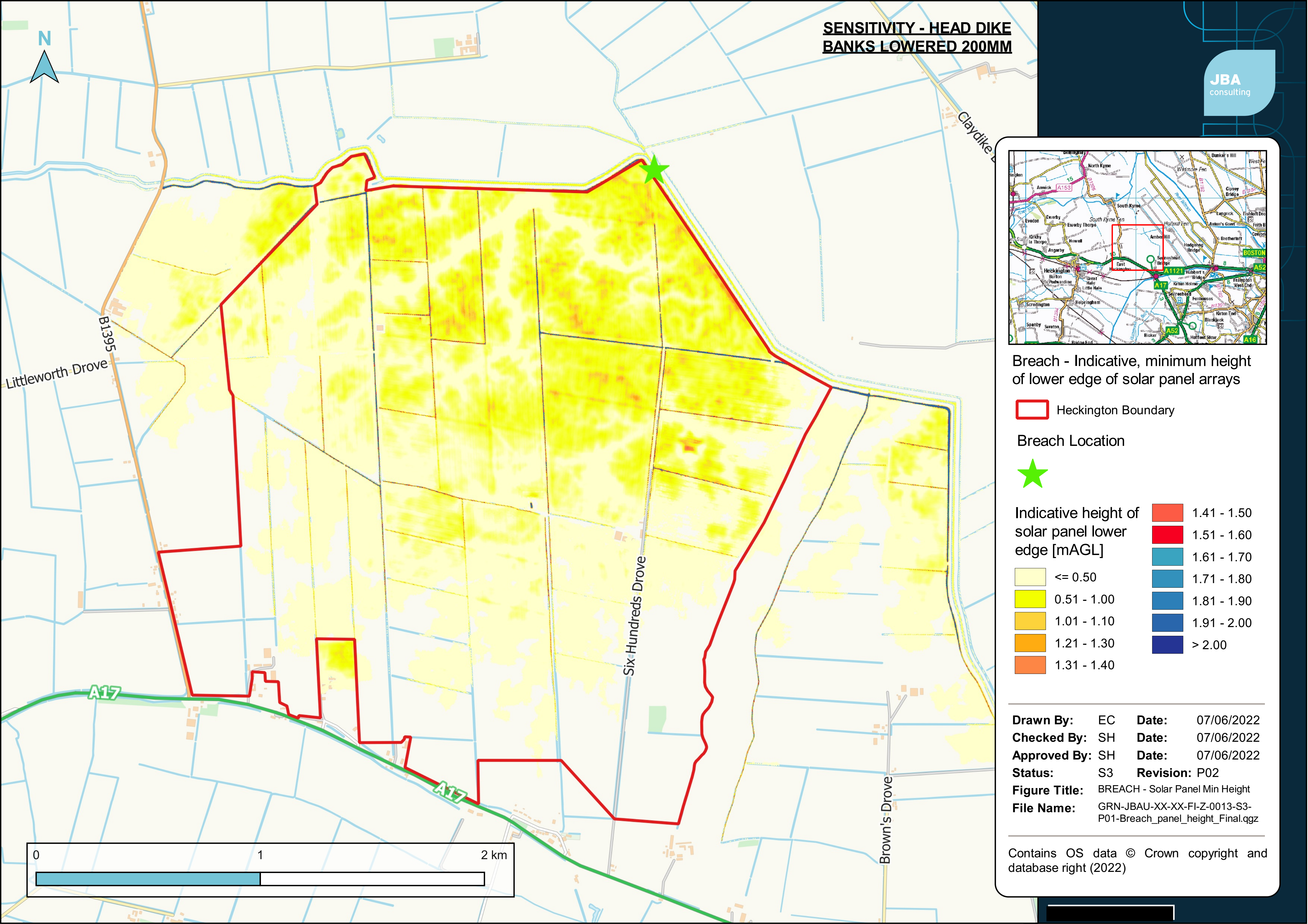
C.2 Breach 2: Head Dike – Maximum Level (mAOD), 1000-year +20% climate change


N
Claydike
B1395
Littleworth Drove
A17
Six Hundreds Drove
Brown's Drove
1.953mAOD
1.951mAOD
1.858mAOD
1.609mAOD
1.461mAOD
1.399mAOD
0
1
2 km
JBA consulting
Breach - Maximum Flood Levels
1,000-year +20%CC
Heckington Boundary
Breach Location
Maximum water level [mAOD]
<= 1.30
1.31 - 1.40
1.41 - 1.50
1.51 - 1.60
1.61 - 1.70
1.71 - 1.80
1.81 - 1.90
1.91 - 2.00
Drawn By: EC Date: 01/06/2022
Checked By: SH Date: 01/06/2022
Approved By: SH Date: 01/06/2022
Status: S3 Revision: P02
Figure Title: BREACH - 0.1% CC
File Name: GRN-JBAU-XX-XX-FI-Z-0013-S3-P01-Breach_panel_height_Final.qgz
Contains OS data © Crown copyright and database right (2022)

TECHNICAL NOTE

JBA Project Code	2021s1226
Contract	Heckington Fen Solar Farm
Client	Ecotricity Generation Limited
Day, Date and Time	July 2022
Author	Ellen Corry
Reviewer / Sign-off	Stuart Harwood
Subject	Hydrology and hydraulic modelling

C.3 Breach 2: Head Dike bank sensitivity test (lower 200mm) – Maximum Depth (m), 1000-year +20% climate change


SENSITIVITY - HEAD DIKE BANKS LOWERED 200MM
N
JBA consulting
Claydike
B1395
Littleworth Drove
Six Hundreds Drove
Brown's Drove
A17
A17
0
1
2 km
Breach - Indicative, minimum height of lower edge of solar panel arrays
Heckington Boundary
Breach Location
Indicative height of solar panel lower edge [mAGL]
<= 0.50
0.51 - 1.00
1.01 - 1.10
1.21 - 1.30
1.31 - 1.40
1.41 - 1.50
1.51 - 1.60
1.61 - 1.70
1.71 - 1.80
1.81 - 1.90
1.91 - 2.00
> 2.00
Drawn By: EC Date: 07/06/2022
Checked By: SH Date: 07/06/2022
Approved By: SH Date: 07/06/2022
Status: S3 Revision: P02
Figure Title: BREACH - Solar Panel Min Height
File Name: GRN-JBAU-XX-XX-FI-Z-0013-S3-P01-Breach_panel_height_Final.qgz
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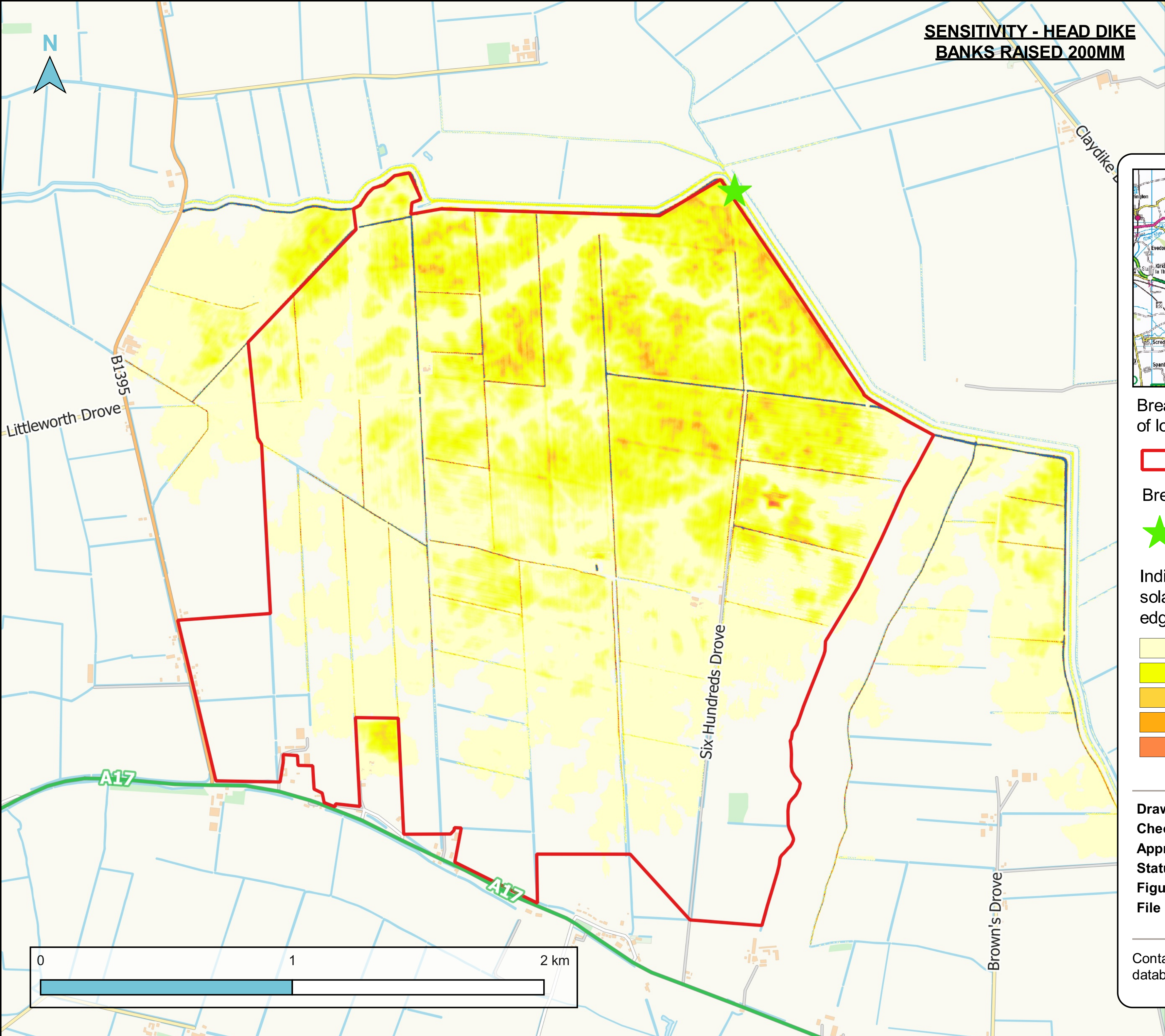
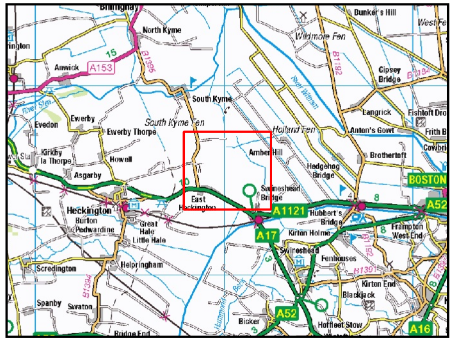
C.4 Breach 2: Head Dike bank sensitivity test (raised 200mm) – Maximum Depth (m), 1000-year +20% climate change

SENSITIVITY - HEAD DIKE BANKS RAISED 200MM





JBA consulting

Breach - Indicative, minimum height of lower edge of solar panel arrays

Heckington Boundary

Breach Location

Indicative height of solar panel lower edge [mAGL]

- <= 0.50
- 0.51 - 1.00
- 1.01 - 1.10
- 1.21 - 1.30
- 1.31 - 1.40
- 1.41 - 1.50
- 1.51 - 1.60
- 1.61 - 1.70
- 1.71 - 1.80
- 1.81 - 1.90
- 1.91 - 2.00
- > 2.00

Drawn By:	EC	**Date:**	07/06/2022
Checked By:	SH	**Date:**	07/06/2022
Approved By:	SH	**Date:**	07/06/2022
Status:	S3	**Revision:**	P02
Figure Title:	BREACH - Solar Panel Min Height		
File Name:	GRN-JBAU-XX-XX-FI-Z-0013-S3-P01-Breach_panel_height_Final.qgz		

D Pegasus Group report – Sequential Test and Exception Test

Sequential and Exception Test.

Heckington Fen Solar Park.

On behalf of Ecotricity (Heck Fen Solar) Limited .

Date: February 2023 | Pegasus Ref: P20-2370

PINS Ref: EN010123

Author: Mark Herbert

Document Management.

Version	Date	Author	Checked/ Approved by:	Reason for revision
Version 1	February 2023	Pegasus	MH	

Contents.

Appendices contents.

1. Introduction

1.1. The majority of the Energy Park lies within Flood Zone 3. Limited areas along the southern fringe of the Energy Park are located within Flood Zones 1 and 2. The majority of the Offsite Cable Route Corridor is within Flood Zone 3. The existing National Grid Bicker Fen Substation is also within Flood Zone 3.

1.2. Under Annex 3 of the National Planning Policy Framework (NPPF)[1], the Proposed Development of a solar farm is classified as 'essential infrastructure'. The National Policy Statement for Energy (NPS) - EN1 states that 'where new energy infrastructure is, exceptionally, necessary in such areas [of highest risk], policy aims to make it safe without increasing flood risk elsewhere and, where possible, by reducing flood risk overall.' (para.5.7.3)[2]

1.3. NPS EN-1 also states that the Infrastructure Planning Commission (now, for the purposes of this application, the Secretary of State) should not consent development in Flood Zone 2 in England unless it is satisfied that the Sequential Test requirements have been met and that it should not consent development in Flood Zone 3 unless it is satisfied that the Sequential and Exception Tests requirements have been met. (para. 5.7.12)

1.4. This Proposed Development is therefore subject to both tests, as described below.

1.5. The broad methodology for the Sequential Test (along with the related 'Back Check & Review' assessment within the Environmental Statement, see Chapter 3 – document reference 6.1.3), as described below, has been discussed with host authorities; North Kesteven District Council and Lincolnshire County Council.

[1] National Planning Policy Framework, July 2021, available at: https://www.gov.uk/government/publications/national-planning-policy-framework--2
[2] Overarching National Policy Statement for Energy (EN-1), July 2011, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/47854/1938-overarching-nps-for-energy-en1.pdf

2. Policy and Guidance

2.1. In terms of Government policy, the NPS EN-1 (2011), and the draft NPS-EN1 (published September 2021)[3], relate specifically to nationally significant energy infrastructure projects (NSIP), and in respect of flood risk signpost the reader to the NPPF and Planning Policy Guidance (paragraph 5.8.8 of the draft NPS). The updated NPPF (2021) paragraphs relating to development and flood risk provide a more up to date perspective on the sequential approach than the 2011 EN-1. The draft NPS EN-1, published in September 2021 does not change the required approach.

NPPF

2.2. The NPPF is clear that the aim of the Sequential Test is to steer new development to areas with the lowest risk of flooding from any source (para. 162), whilst for a site to pass the Exception Test it should be demonstrated that (para. 164):

a) the development would provide wider sustainability benefits to the community that outweigh the flood risk; and

b) the development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

2.3. Both elements of the Exception Test should be satisfied for development to be allocated or permitted. (NPPF para. 165). Applications should be supported by a site-specific flood-risk assessment. Development should only be allowed in areas at risk of flooding where, in the light of this assessment (and the Sequential and Exception Tests, as applicable) it can be demonstrated that (para. 167):

a) within the site, the most vulnerable development is located in areas of lowest flood risk, unless there are overriding reasons to prefer a different location;

[3] Draft Overarching National Policy Statement for Energy (EN-1), September 2021, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1015233/en-1-draft-for-consultation.pdf

b) the development is appropriately flood resistant and resilient such that, in the event of a flood, it could be quickly brought back into use without significant refurbishment;

c) it incorporates sustainable drainage systems, unless there is clear evidence that this would be inappropriate.

d) any residual risk can be safely managed; and

e) safe access and escape routes are included where appropriate, as part of an agreed emergency plan. (NPPF para. 167).

NPS – EN1

2.4. For the Sequential Test, EN-1 confirms that if there is no "reasonably available site[4] " in Flood Zones 1 or 2, then nationally significant energy infrastructure projects can be located in Flood Zone 3 subject to the Exception Test (para. 5.7.13). The NPS sets out the following in respect of Exception Tests:

- Para.5.7.14 - 'If, following application of the sequential test, it is not possible, consistent with wider sustainability objectives, for the project to be located in zones of lower probability of flooding than Flood Zone 3, the Exception Test can be applied. The test provides a method of managing flood risk while still allowing necessary development to occur.'

- Para.5.7.15 - 'The Exception Test is only appropriate for use where the sequential test alone cannot deliver an acceptable site, taking into account the need for energy infrastructure to remain operational during floods. It may also be appropriate to use it where, as a result of the alternative site(s) at lower risk of flooding being subject to national designations such as landscape, heritage and nature conservation designations, for example Areas of Outstanding Natural Beauty (AONBs), Sites of Special Scientific Interest (SSSIs) and World Heritage Sites (WHS) it would not be appropriate to require the development to be located on the alternative site(s).

[4] Paragraph 5.7.13 confirms that consideration of alternative sites should take account of the policy on alternatives set out in Section 4.4. of EN-1.

- Para. 5.7.16 - All three elements of the test will have to be passed for development to be consented. For the Exception Test to be passed:
  - It must be demonstrated that the project provides wider sustainability benefits to the community that outweigh flood risk;
  - The project should be on developable, previously developed land or, if it is not on previously developed land, that there are no reasonable alternative sites on developable previously developed land subject to any exceptions set out in the technology-specific NPSs; and
  - An FRA must demonstrate that the project will be safe, without increasing flood risk elsewhere subject to the exception below and, where possible, will reduce flood risk overall.'
- Para. 5.7.17 – 'Exceptionally, where an increase in flood risk elsewhere cannot be avoided or wholly mitigated, the IPC [now Secretary of State] may grant consent if it is satisfied that the increase in present and future flood risk can be mitigated to an acceptable level and taking account of the benefits of, including the need for, nationally significant energy infrastructure…In any such case the IPC [now Secretary of State] should make clear how, in reaching its decision, it has weighed up the increased flood risk against the benefits of the project, taking account of the nature and degree of the risk, the future impacts on climate change, and advice provided by the EA and other relevant bodies.'

2.5. Paragraph 5.7.23 of NPS EN-1 also requires a sequential approach to be applied to the layout and design of the project, with more vulnerable uses to be located on parts of the site at lower probability and residual risk of flooding.

NPPF Planning Policy Guidance

The Sequential Approach to the location of development

Para. 024 Reference ID: 7-024-20220825

2.6. 'The Sequential Test ensures that a sequential, risk-based approach is followed to steer new development to areas with the lowest risk of flooding, taking all sources of flood risk and climate change into account. Where it is not possible to locate development in low-risk areas, the Sequential Test should go on to compare reasonably available sites:

- Within medium risk areas; and
- Then, only where there are no reasonably available sites in low and medium risk areas, within high-risk areas.'

2.7. 'Initially, the presence of existing flood risk management infrastructure should be ignored, as the long-term funding, maintenance and renewal of this infrastructure is uncertain. Climate change will also impact upon the level of protection infrastructure will offer throughout the lifetime of development. The Sequential Test should then consider the spatial variation of risk within medium and then high flood risk areas to identify the lowest risk sites in these areas, ignoring the presence of flood risk management infrastructure.'

2.8. 'It may then be appropriate to consider the role of flood risk management infrastructure in the variation of risk within high and medium flood risk areas. In doing so, information such as flood depth, velocity, hazard and speed-of-onset in the event of flood risk management infrastructure exceedance and/or failure, should be considered as appropriate. Information on the probability of flood defence failure is unsuitable for planning purposes given the substantial uncertainties involved in such long-term predictions.'

Para. 023 Reference ID: 7-023-20220825

2.9. 'Other forms of flooding need to be treated consistently with river and tidal flooding in mapping probability and assessing vulnerability, so that the sequential approach can be applied across all areas of flood risk.'

Para. 028 Reference ID: 7-028-20220825

2.10. 'Reasonably available sites' are those in a suitable location for the type of development with a reasonable prospect that the site is available to be developed at the point in time envisaged for the development.'

The Exception Test

2.11. Para. 031 Reference ID: 7-031-20220825 reflects paragraph 164 of the NPPF (see above) with regards to a demonstration of wider sustainability benefits and a reduction in overall flood risk.

Para. 035 Reference ID: 7-035-20220825

2.12. 'The Exception Test should only be applied when following application of the Sequential Test, it has been demonstrated that it is not possible for development to be located in areas with a lower risk of flooding (taking into account wider sustainable development objectives). The applicant will need to provide…evidence to demonstrate how both elements of the Exception Test will be satisfied.'

Para. 036 Reference ID: 7-036-20220825

2.13. This paragraph provided guidance on how it can be demonstrated that wider sustainability benefits to the community would outweigh flood risk:

2.14. 'Local planning authorities need to set their own criteria for this assessment, having regard to the objectives of their Plan's Sustainability Appraisal framework, and provide advice which will enable applicants to provide relevant and proportionate evidence.'

2.15. 'Examples of wider sustainability benefits to the community could include:

- The re-use of suitable brownfield land as part of a local regeneration scheme,;
- An overall reduction in flood risk to the wider community through the provision of, or financial contribution to, flood risk management infrastructure;
- The provision of multifunctional Sustainable Drainage Systems that integrate with green infrastructure, significantly exceeding National Planning Policy Framework policy 'requirements for Sustainable Drainage Systems.'

2.16. Identified sustainability benefits need to be balanced against any associated flood risks, informed by the site-specific flood risk assessment. The impacts of flood risk on social, economic and environmental factors should be considered. Where wider sustainability benefits are absent or where they are outweighed by flood risk, the Exception Test has not been satisfied and the site allocation in the plan should not be made or planning permission should be refused.'

Para. 037 Reference ID: 7-037-20220825

2.17. This paragraph provided guidance on how it can be demonstrated that the proposed development will reduce flood risk overall:

2.18. ‘Developers should refer to the Strategic Flood Risk Assessments and site-specific Flood Risk Assessments to identify opportunities to reduce flood risk overall and to demonstrate that the measures go beyond just managing the flood risk resulting from the development. Reductions could be achieved, for example by:

- Incorporating green infrastructure within the layout and form of development to make additional space for the flow and storage of flood water;
- Providing Sustainable Drainage Systems, that manage flood risk beyond the proposed site and above the usual standard, such as by removing surface water from existing combined sewers;
- Providing or making contributions to flood risk management infrastructure that will provide additional benefits to existing communities and/or by safeguarding the land that would be needed to deliver it.’

3. The Sequential Test

Introduction

3.1. The methodology for the Sequential Test (along with an assessment of alternative sites) has been discussed with North Kesteven District Council and Lincolnshire County Council– and commencing with the identification of reasonably available sites.

3.2. Sites selected were required to meet the following criteria:

- A location within a Search Area based on a 15km radius from the Bicker Fen Substation – The Applicant has secured a Grid Connection for a development, of the scale proposed at the Energy Park site, at Bicker Fen substation. National Grid have advised that this connection would be available in 2027. An alternative site would need to utilise this Grid Connection agreement instead of the Energy Park site to be able to secure theoretical delivery within the same timescale. National Grid have confirmed that connection into the existing National Grid Substation at Spalding would not be achievable till 2030 or later. Therefore, development connecting into Spalding would not be achievable within a reasonably similar timescale as a development connecting into Bicker Fen. Hence, connection into Spalding National Grid Substation was not considered further within this assessment.

- A geographical extent similar in scale to Heckington Fen (circa 550 hectares);

- A potential suitability for large-scale ground mounted solar development (excluding sites that are allocated or safeguarded within the Development Plan); and

- A potential status as being 'reasonably available' for such development.

3.3. The approach to the Sequential Test also follows the approach recommended by the Environment Agency (April 2012).[5]

[5] 'Demonstrating the flood risk Sequential Test for Planning Applications' Version 3.1 (April 2012) Environment Agency.

Methodology

Defining the Evidence Base: Identifying the geographical area (Search Area) over which the test is to be applied

3.4. The length of the route for the cable connection to the National Grid network is a key viability consideration in terms of site identification. At Heckington Fen, the cable from the Energy Park to the 400kV substation at Bicker Fen is approximately 7.5km in length (5.5km as the crow flies). It was agreed with LCC and NKDC that the assessment distance from Bicker Fen substation should be 15km. The northern boundary of the Energy Park site is approximately 9km for the National Grid Bicker Fen Substation. Government policy states 'alternative proposals which mean the necessary development could not proceed, for example because the alternative proposals are not economically viable…, can be excluded on the grounds that they are not important and relevant to the Secretary of State's decision' (NPS EN-1 para. 4.4.3, and draft NPS EN-1 paragraph 4.2.13).

3.5. The initial proposal was therefore for a Search Area within a 9km radius of all 400kV substations within Lincolnshire. There are two of these; one at Bicker Fen and the other at Spalding. Whilst the Applicant considered that 9km should be the primary search area, the Applicant agreed to extent this to a 15km search area at the request of the host local authorities.

3.6. NPS EN-1 states that any alternative site must also have a 'realistic prospect of delivering the same infrastructure capacity….in the same timescale as the proposed development.' Whilst National Grid has confirmed with a connection date for Heckington Fen of 2027 with regards to the Bicker Fen Substation, the company has also indicated that there is no capacity for a development of a similar scale at Spalding substation until after 2030. On this basis, the sequential test is restricted to a 15km radius search area around the Bicker Fen Substation.

3.7. As the Energy Park site, for Heckington Fen, is mostly within Flood Zone 3, the search for alternatives within this defined area around the Bicker Fen Substation should be on land within each of Flood Zones 1, 2 and 3.

3.8. The Environmental Statement sets out in detail the identification and assessment of 13 'Back Check and Review sites' within Chapter 3 – Site Description, Site Selection, and Iterative Design Process (document reference 6.1.3).

3.9. The ‘back check and review’ process seeks to assess the alternatives on the basis that the Heckington Fen site was selected initially due to Ecotricity’s earlier proposal for a wind farm on the site and that there is a willing landowner which owns the whole development site. The assessment therefore ‘back checks’ that this site is acceptable in planning terms for development as a solar farm. The process generally is not seeking to identify the best site for development, only that the development is acceptable. The application of the data to the sequential test has used a number of criteria from this assessment process to assist carrying out the more specific flood risk assessment. In addition to flood risk, these criteria were are as follows:

- Agricultural Land Classification;
- Landscape and Visual;
- Residential Amenity;
- Cultural Heritage;
- Biodiversity; and
- Landowners

3.10. This criteria-based approach aligns with the Environment Agency’s guidance on the sequential test which states that sites should be compared in relation to flood risk; Local Plan status; capacity; and constraints to delivery including availability, policy restrictions, physical problems or limitations, potential impacts of the development, and future environmental conditions that would be experienced by the inhabitants of the development.

3.11. Pegasus has used a GIS platform to map site constraints, including flood zones, to provide the basis for site comparison. The layers include the DEFRA/EA flood datasets, together with wider considerations and constraints (planning, environmental and technical).

3.12. These 13 locations are identified on ES Figure 3.4: Site Search Exercise (document reference 6.2.3). All of these identified sites have multiple landowners.

Sieving and Ranking: comparing flood risk between sites

3.13. Each of the 13 sites also have an extensive proportion (ranging from 48% – 100%) of their defined land area within Flood Zone 3, as shown in **Table 1** below. More commentary on these figures is provided within Table App 3.1 Summary of 'Back Check and Review' Sites within ES Annex 3.1 (document reference 6.3.3.1)

Table 1: Potentially available sites ranked in order of flood risk.

Flood Risk Ranking	Site (Broad Location)	ES Ref	Proportion of Site within:		
			Flood Zone 3	**Flood Zone 2**	**Flood Zone 1**
1	*South of South Drove*	7	48%	28%	24%
2	*North of Long Drove*	12	51%	25%	24%
3	*West of South Kyme*	5	61%	5%	34%
4	*West of Sidebar Lane*	6	61%	6%	33%
5	*North of Fen Road*	11	62%	23%	15%
6	*South of Dunsby Drove*	13	69%	13%	18%
7	*South of Vacherie Lane*	4	71%	3%	26%
8	*South of Sempringham*	10	75%	13%	12%
9	*Swaton Fen*	9	75%	20%	5%
10	*North of Langrick*	1	93%	7%	0%
11	*North of North Drove*	8	94%	2%	4%
12	**Heckington Fen**		97%	2%	1%
13	*South of Kyme Eau*	3	97%	2%	1%
14	*East of Kirton Drove*	2	100%	0%	0%

3.14. With 97% of Heckington Fen within Flood Zone 3, it ranks low in the list of sites based on flood risk criteria, with 11 of the 13 alternative sites ranked higher.

3.15. The next step is to apply the policy tests against these 11 higher-ranked sites on the basis of the policy guidance set out on Alternatives within NPS EN-1 (paragraph 4.4); these include:

- Alternatives should be considered in a proportionate manner;

- Only alternatives that can meet the objectives of the proposed development need to be considered;

- There must be a realistic prospect of the alternative delivering the same infrastructure capacity in the same timescales.'

3.16. This can be achieved by adapting the assessment used within the Environmental Statement to compare alternative sites under the 'Back Check and Review', as described above.

3.17. To meet the EN-1 policy in respect of a realistic prospect of delivery in the same timescales as the Energy Park at Heckington Fen, consideration has been given to whether the 11 sites can be considered as 'reasonably available' (as defined at paragraph 162 of the NPPF). For this purpose, the 'Landowners' criterion within the 'Back Check and Review' has been taken here to assess the complexity of multiple site owners, the complex nature of certain strategic landowners (including the Crown Estates, the Duchy of Lancaster, and the Church of England), or equally challenging, where landowners cannot be easily identified.

3.18. This 'reasonably available' criteria is therefore critical and has been given additional weight in a comparison of the 11 sites. In **Table 2** (within **Annex 1**) the Criteria-Based Ranking of each of the 11 sites adapts the traffic-light assessment used in the 'Back Check and Review' comparison, but with an added numerical value in order to allow an objective and transparent ranking.

3.19. This output of this methodology is shown below in **Figure 1,** which presents an <u>extract</u> from Table 2 for *illustrative purposes only*, as it is important to understand the basis on which the information has been collated and presented.

3.20. Red, amber and green - applied on exactly the same basis as that used within ES Annex 3.1 (document reference 6.3.3.1) – are valued at 3, 2 and 1 respectively for all criteria with the exception of 'reasonably available'. A red rating for 'Reasonably Available' is scored at a value of 5 to reflect that it is a critical determinant, on the basis that whatever the locational and physical merits of an 'alternative site', it cannot be considered a true alternative if it simply cannot be delivered within the same timeframe as the Energy Park at Heckington Fen due to commercial, viability or other grounds (that very often relate to the ownership of the land). Similarly, an amber rating for 'Reasonably Available' is scored at 4 for ranking purposes.

3.21. On this basis, when each of the criteria scores are added together for each site, the higher the total means a worse ranking. The Energy Park at Heckington Fen has a low baseline score of 7, not least because the ownership position (with a single landowner and a legal agreement already in place) allows it to be considered as 'immediately available'.

Figure 1: Extract from Table 2: Criteria-Based Ranking of Back Check and Review Sites

Site		Criteria	Scoring	Drawbacks
Flood Risk Ranking	ES Ref.			Full commentary within ES Back Check and Review Assessment (ES Chapter 3 and Annex 3.1)
1	7	BMV	3	100% Grade 2 land
		LVIA	3	Views from 5 no. PROWs and possibly A52
		Residential Amenity	1	
		Cultural Heritage	2	2 no. Scheduled Monuments on north boundary
		Biodiversity	1	
		Reasonably Available	5	5 no. landowners; only Crown Estates identified
		Total	**15**	
2	12	BMV	3	100% Grade 2 land
		LVIA	3	Views from multiple PROWs and B1177
		Residential Amenity	1	
		Cultural Heritage	2	Scheduled Monument on southern boundary
		Biodiversity	1	
		Reasonably Available	5	11 no. owners; 2 no. known, incl. Crown Estates
		Total	**15**	
3				
4				
5				
6				
7		**EXTRACT ONLY – SEE FULL TABLE IN ANNEX 1**		
8				
9				
10				
11				
12	Heck Fen	BMV	2	**Note: Traffic-light grading based on the technical evidence base assessments in effects and impacts as part of the Environmental Statement.**
		LVIA	1	
		Residential Amenity	1	
		Cultural Heritage	1	
		Biodiversity	1	
		Reasonably Available	1	
		Total	**7**	

3.22. It is clear from the 'Back Check and Review' assessment that there are no potential alternative sites on land graded 4 or 5 under the Agricultural Land Classification, and no alternative brownfield sites of a suitable size that are available.

3.23. But it is this **scored assessment in Table 2** which takes into account policy criteria that effectively eliminates the other 11 sites that were first identified within the 'Back Check and

Review' assessment and then **ranked in Table 1** (as higher than Heckington Fen on flood risk grounds).This is in part due to the fact that they cannot be considered commercially viable and deliverable in the same timescales as the Energy Park at Heckington Fen. On the numerical-value scoring, each of the 11 alternative sites score less well (with scores ranging between 12 and 17) than Heckington Fen (with its score of 7).

3.24. It is accepted that any ranking and scoring methodology based on the high-level strategic assessment of the ES's 'Back Check and Review Assessment' must come with reasonable caveats, given that:

- It is not always possible within the required timeframe to secure a complete and comprehensive understanding of the land ownership position; without which full technical surveys and detailed design and mitigation assessments cannot be undertaken in the that timeframe (or at all);
- And, as a consequence, this necessitates a high reliance on professional judgement, for example, with regard to views, screening and the impact of site design constraints and potential mitigation measures, which in turn impact on site capacity and viability (and therefore on what may constitute 'reasonably available').

3.25. We would contend that this Sequential and Exceptions Test study and its conclusions represent a sound and transparent approach to the assessment of potentially 'reasonably available' sites within the identified area of search.

3.26. Finally, it is worth noting that the positive scoring for Heckington Fen is a reflection of the site selection process, where the following advantages of the Energy Park site were identified:

- A neatly contained and regular-shaped area of land under a single landowner;
- Potential for agreement with the landowner (signed Option Agreements are in place);
- Orientation of land and its open nature, suitable for efficient energy generation;
- No ecological designations or statutory protected areas within or in close proximity;
- No landscape designations on site or in close proximity;

- Limited visibility into the site, due to the wider low-lying nature of the landscape, existing bunding on some perimeters of the site and limited public rights of way (PROWs) in the immediate area;
- The Site had already gained planning approval for a 66MW onshore wind farm;
- A new access point off the A17 which was further away from residential properties had been granted consent with the onshore wind farm application;
- An economically achievable grid connection for a development of this generation capacity;
- Less areas of BMV land within Grade 1 and 2 when compared to the potential 'alternative sites'; and
- Limited residential properties in close proximity.

3.27. It should be noted too that NPS EN1 (para. 5.7.23) requires that the sequential approach should also be applied to the layout and design of the project. More vulnerable uses should be located on parts of the site at lower probability and residual risk of flooding Within the design iteration process of the Energy Park site various locations of the Onsite Substation were considered. The Energy Park site has a section of Flood Zone 2 in the southwestern section. However, noise assessment determined that mitigation would be required for local residents to house the electrical equipment within this flood zone 2 area. It has therefore been moved northwards, into a flood zone 3 area and designed to ensure that the equipment can operate in a 1 in 1,000 year + 20% event. The solar PV arrays will be elevated above the 1 in 1,000 year + 20% for climate change breach flood level so that the Energy Park will be safe and remain operational during any flooding. On this basis, the proposed development meets the requirements of the Sequential Test as set out in NPS EN-1, NPPF and PPG.

Conclusions

3.28. The Applicant sought to agree a methodology for sequential testing relating to the EIA for this application with North Kesteven District Council and Lincolnshire County Council in September and October 2022. As a result of discussions through the regular meetings with officers at North Kesteven District Council and Lincolnshire County Council, and related correspondence, the approach to a criteria-based assessment was developed, not least with the Applicant agreeing to extend the radius of the search area from Bicker Fen Substation from 9km to 15km. This positive dialogue is referenced within the submitted Consultation Report (document reference 5.1).

3.29. On the basis that It can be demonstrated that there are no reasonably available alternative sites appropriate for the Proposed Development located in areas with a lower risk of flooding (taking into account wider sustainable development objectives), it is necessary to provide evidence to demonstrate how both elements of the Exception Test will be satisfied. This is set out below.

4. The Exception Test – Findings and Conclusions

4.1. The Energy Park at Heckington Fen would provide wider sustainability benefits to the community that outweigh the flood risk. These benefits have been identified through a number of technical assessments supporting the DCO submission and the Environmental Statement, and the key findings and conclusions can be summarised as follows:

- The primary function of the development is to export energy from renewable sources to the national grid via Bicker Fen Substation, contributing to the decarbonisation of energy supply and assisting in meeting the international obligations of the UK and the Climate Change objectives of the host authorities;
- Based on the candidate design, the Energy Park would generate clean renewable energy for the equivalent of over 100,000 homes a year and prevent around 75,000 tonnes of harmful emissions entering the atmosphere every year. The proposal would provide a clean, renewable and sustainable form of electricity
- The co-location of energy storage within the development - with an intended design capacity of over 50MWp (megawatts peak) will assist in the smoothing out of the generation of electricity to meet demand, increase the security of supply and reduce the risk of black-outs and brown-outs;
- The development will bring tangible economic benefits, through an estimated £400 million of direct capital investment. The host community in Lincolnshire and neighbouring counties will benefit from employment and business opportunities for component suppliers and installers and those involved in grid connection, transport and logistics.

- The temporary effects include an estimated £175 million of gross value added over the 30-month construction programme. The development will provide an estimated 400 peak on-site construction jobs, with an average of 150 on-site construction jobs over this period. This will lead to an increase in demand (from up to 200 workers for serviced and non-serviced accommodation in North Kesteven.
- The operational phase will provide 5 direct additional jobs in the North Kesteven economy; £627,000 of gross added value per annum (or £13.9 million over the 40-year lifespan of the project, on present values); and business rates of £1.3 million per annum (or £29.3 million over the project lifespan, on present values). No farming jobs will be lost with the development of the Heckington Fen Energy Park. Employment will also be required for the sheep enterprise proposed onsite (1.5 full time equivalent).
- The decommissioning phase will generate 200 peak on-site construction-sector jobs over the 6-18-month programme of works, with an increase in demand (from up to 100 workers) for services and non-serviced accommodation in North Kesteven. This will provide £52.5 million of gross value added over the 18-month period.

• The design includes the creation of 66.73ha of species rich grassland and 2.15ha of traditional orchard managed specifically for nature conservation. These high-quality grasslands will be managed to maximise their value for ground nesting farmland birds, bees, butterflies and other invertebrates. These grasslands will also provide extensive foraging habitat for European Hare and Badger. A number of bat roost boxes of different designs will be placed at appropriate locations around the Energy Park. The design will also offer approximately 8.5km of new hedgerow planting around the perimeter of the Energy Park site. This new hedgerow will also offer a rich habitat for numerous species within the local environment.

• The development will deliver other environmental gains in the form of biodiversity enhancement and an improved soil resource. Beneath the solar panels some 435ha of intensive arable farmland will be converted to sheep pasture. The conversion of the land from intensive arable to grass pasture will reduce the runoff of agri-chemicals and topsoil into in the Wash SPA/SAC/SSSI via the drainage network. There will be an overall significant residual, locally beneficial effect on biodiversity of area. The Biodiversity Net Gain calculation estimated a net gain of over 100%.

- The creation and management of these pastural habitats will be secured through a Landscape and Ecological Management Plan a draft one has been submitted as part of the DCO application (document ref: 7.8). This will ensure the conservation management of grassland to increase its species richness and ensure land is available for use by ground nesting birds.
- The development will deliver enhanced opportunities for access for walkers, through the provision of an extensive permissive footpath route across the Energy Park site to complement the existing PROW Heck/15/1. The proposed on site permissive footpath will require either the reintroduction of a footbridge on the eastern boundary of the Energy Park or the creation of a new section of permissive footpath along Crab Lane, which is outside of the Order Limits.

4.2. Finally, it is important to note that Part 2 of the Exception Test is addressed by the submitted Flood Risk Assessment, which considers flood risk (from all sources) and sets out mitigation measures so that the development will be safe for its lifetime, without increasing flood risk elsewhere.

Annex 1

Heckington Fen Sequential and Exception Tests Report

ANNEX 1

Table 2: Criteria-Based Ranking of 'Back Check and Review' Sites

Key:

- Sites are listed in order of ranking of Flood Risk – see **Table 1** within report
- Criteria as used within Back Check and Review Assessment, as set out in Environmental Statement Chapter 3 (with 'Reasonably Available' relating to 'Landowners' criterion)
- Red/Amber/Green – As 'traffic-light' rating within ES Back Check and Review Assessment:
  - *Red: potential for a significant adverse impact*
  - *Amber: potential for some adverse impact*
  - *Green: unlikely to have an impact*
- Scoring based on 'traffic-light' rating for each criterion:
  - *Red: scored 3*
  - *Amber: scored 2*
  - *Green: scored 1*

  With exception of 'Reasonably Available', scored higher:
  - *Red: scored 5*
  - *Amber: scored 3*
  - *Green: scored 1*

Site		Criteria	Scoring	Drawbacks	Key Disadvantage
Flood Risk Ranking	ES Ref.			Full commentary within ES 'Back Check and Review' Assessment (ES Chapter 3 and Appendix 3.1)	Extract from ES Chapter 3
1	7	BMV	3	100% Grade 2 land	*'Any legal agreement would be protracted.'* (para. 3.127)
		LVIA	3	Views from 5 no. PROWs and possibly A52	
		Residential Amenity	1		
		Cultural Heritage	2	2 no. Scheduled Monuments on northern boundary	
		Biodiversity	1		
		Reasonably Available	5	5 no. landowners; only Crown Estates identified	
		Total	**15**		
2	12	BMV	3	100% Grade 2 land	*Loss of 'far more high-grade land' compared with Heckington Fen.* (para.3.149)
		LVIA	3	Views from PROWs and B1177	
		Residential Amenity	1		
		Cultural Heritage	2	Scheduled Monument on southern boundary	
		Biodiversity	1		
		Reasonably Available	5	11 no. landowners; 2 no. known, including Crown Estates	
		Total	**15**		
3	5	BMV	1		*'Far more environmental constraints' than Heckington Fen.'* (para. 3.116)
		LVIA	3	Views from PROWs	
		Residential Amenity	1		
		Cultural Heritage	3	Scheduled Monument abuts north-east boundary	
		Biodiversity	2	Ancient woodland adjacent to southern boundary	
		Reasonably Available	4	9 no. owners; 5 no. not known.	
		Total	**14**		

Site: Flood Risk Ranking	Site: ES Ref.	Criteria	Scoring	Drawbacks Full commentary within ES 'Back Check and Review' Assessment (ES Chapter 3 and Appendix 3.1)	Key Disadvantage Extract from ES Chapter 3
4	6	BMV	3	65% Grade 2 land	*'A series of landowners not wanting a grid cable laid.'* (para. 3.122)
		LVIA	3	Views from PROWs	
		Residential Amenity	1		
		Cultural Heritage	2		
		Biodiversity	1		
		Reasonably Available	5	Only 6/25 landowners known; concerns over cable route	
		Total	**15**		
5	11	BMV	3	100% Grade 2 land	*'…there would be significant alteration in the views…'* (para. 3.143
		LVIA	3	Proximity to settlements; views from PROW and B1397	
		Residential Amenity	1		
		Cultural Heritage	1		
		Biodiversity	1		
		Reasonably Available	4	Only 4/10 landowners known.	
		Total	**13**		
6	13	BMV	3	100% Grade 2 land	*'Far more visible' than Heckington Fen.'* (para. 3.152
		LVIA	2	Clear visibility from south and north	
		Residential Amenity	1		
		Cultural Heritage	2	Large Scheduled Monument to north of site	
		Biodiversity	1		
		Reasonably Available	4	Only one of around ten owners known	
		Total	**13**		
7	4	BMV	3	93% Grade 2 land	
		LVIA	2	B1359 forms part of southern and western boundaries	

Site		Criteria	Scoring	Drawbacks	Key Disadvantage
Flood Risk Ranking	ES Ref.			Full commentary within ES 'Back Check and Review' Assessment (ES Chapter 3 and Appendix 3.1)	Extract from ES Chapter 3
		Residential Amenity	2		*'Higher number of residents closer' than to Heckington Fen.* (para. 3.109)
		Cultural Heritage	3	Scheduled Monument and listed buildings in proximity	
		Biodiversity	2	South and North Kyme lie close to boundaries	
		Reasonably Available	5	13 out of 14 no. potential landowners not known	
		Total	**17**		
8	10	BMV	3	100% Grade 2 land	*'Any legal agreement could take a considerable length of time'* (para.3.136)
		LVIA	3	Views from PROWs and Nelsam Road	
		Residential Amenity	2	Pointon and Sempringham close to boundaries	
		Cultural Heritage	2	3 no. Scheduled Monuments close to boundaries	
		Biodiversity	1		
		Reasonably Available	5	4 no. owners; majority owned by CoE and Crown Estates	
		Total	**16**		
9	9	BMV	3	100% Grade 2 land	*'Design mitigation could…reduce the potential capacity by half'* (para. 3.134)
		LVIA	3	Views from PROWs and Billingborough Drove	
		Residential Amenity	1		
		Cultural Heritage	2	Schedule Monument on northern boundary	
		Biodiversity	2	SSSI on northern boundary	
		Reasonably Available	5	2 no. landowners; majority owned by Crown Estates	
		Total	**16**		
10	1	BMV	3	100% Grade 2	*'Far more open and expansive' than Heckington Fen site.* (para. 3.94)
		LVIA	2	Clear visibility from B1182 and B1184	
		Residential Amenity	2	Clear visibility from residential properties close to site	
		Cultural Heritage	2	3 no Grade II Listed buildings on southern boundary	
		Biodiversity	1		

Site		Criteria	Scoring	Drawbacks	Key Disadvantage
Flood Risk Ranking	**ES Ref.**			Full commentary within ES 'Back Check and Review' Assessment (ES Chapter 3 and Appendix 3.1)	Extract from ES Chapter 3
		Reasonably Available	5	6 no. owners including Church Commission and LCC	
		Total	**15**		
11	8	BMV	3	100% Grade 2 land	*'Any legal agreement could take a considerable length of time'* (para.3.131)
		LVIA	3	Views from PROWs and highways	
		Residential Amenity	1		
		Cultural Heritage	3	Listed buildings on northern boundary and in proximity	
		Biodiversity	1		
		Reasonably Available	5	7/10 no. owners unknown; majority by Crown Estates	
		Total	**16**		
12	Heckington Fen	BMV	2	**Note: Traffic-light grading based on the technical evidence base assessments in effects and impacts as part of the Environmental Statement.**	
		LVIA	1		
		Residential Amenity	1		
		Cultural Heritage	1		
		Biodiversity	1		
		Reasonably Available	1		
		Total	**7**		

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E Surface Water Drainage Strategy Report

TECHNICAL NOTE

JBA Project Code	2021s1226
Contract	Heckington Fen Solar Park
Client	Ecotricity Generation Limited
Day, Date and Time	February 2023
Author	K Koopaei
Approved by	Mark Watson
Subject	Outline Drainage Strategy

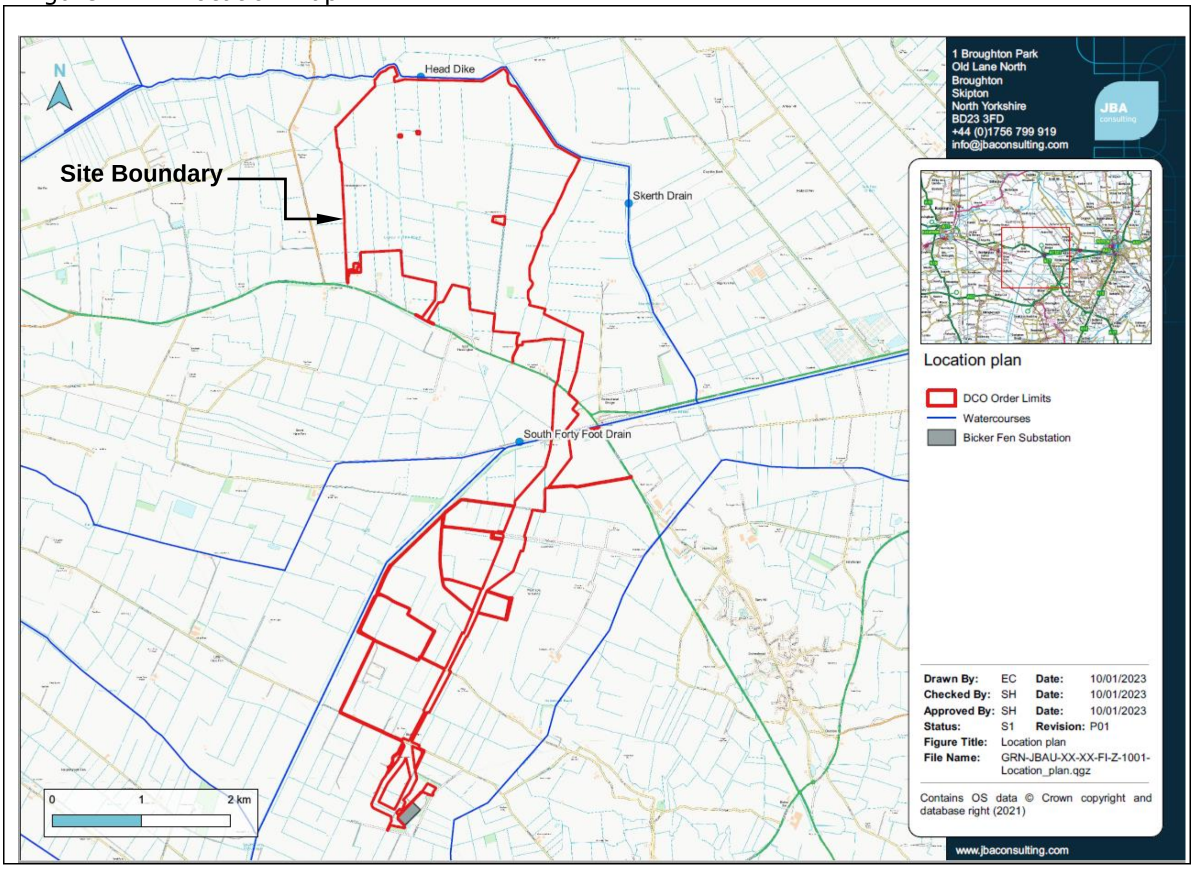
1 Outline Surface Water Drainage Strategy

1.1 Site Details

The proposed development is approximately 5.83Km^2 in size and is currently greenfield agricultural land. The site is bounded by agricultural land to the north and east, B1395 to the west and A17 Road to the to the south.

The DCO application is for the construction, operation (including maintenance), and decommissioning of "the Energy Park", cable route to, and above and below ground works at, the National Grid Bicker Fen Substation (hereafter referred to as "the Proposed Development" (inclusive of Energy Park). The design lifespan of the development is approximately 40 years. Figure 1-1 below shows the site location and site boundary. The proposed site layout is included in Appendix A which shows the full area of the energy park to the north of the A17, the off-site cable route and the site of Bicker Fen substation to the south.

Figure 1-1 – Location Map



1.2 Site topography

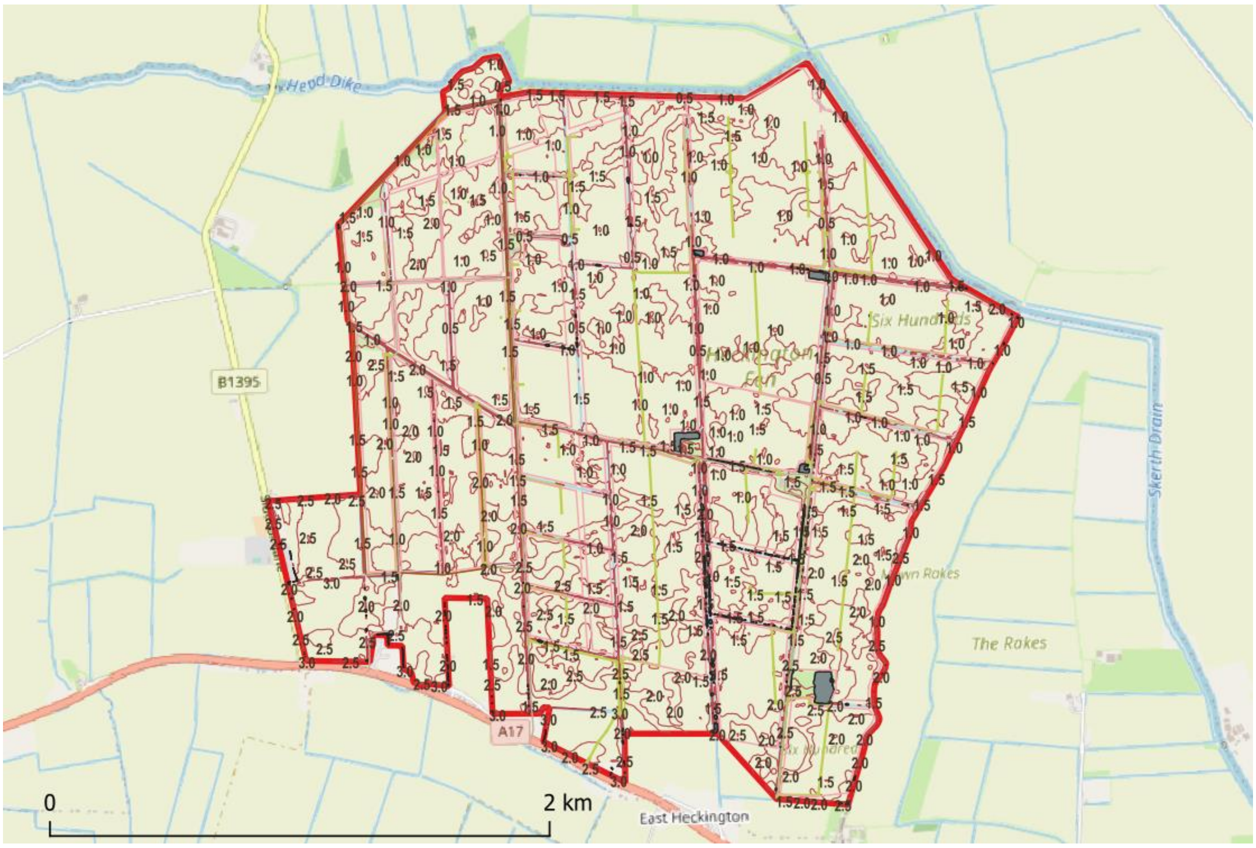
A topographical survey was carried out for the site by Geo-4D Surveys Ltd in October 2021. The survey shows the topography sloping from south to north in a general north easterly direction, from approximately 2.5m AOD along the southern boundary to approximately 1.0mAOD along the north-east boundary of the site. Figure 1-2 shows site topography. The lowest point within the site of the proposed energy park is 0.77m Above Ordnance Datum (AOD) along the northern boundary, while the highest point is 3.30mAOD along the southern boundary.

[redacted]

TECHNICAL NOTE

JBA Project Code	2021s1226
Contract	Heckington Fen Solar Park
Client	Ecotricity Generation Limited
Day, Date and Time	February 2023
Author	K Koopaei
Approved by	Mark Watson
Subject	Outline Drainage Strategy

Figure 1-2 – Site Topography



1.3 Site geology

The British Geological Survey (BGS) mapping indicates that the energy park site is underlain by Tidal Flat (superficial) deposits comprising predominantly low permeability clay, with a thickness of approximately 4m. The BGS mapping also shows that the bedrock comprises a thick layer of low permeability, unproductive mudstones and siltstones of the Ancholme Group. It comprises the West Walton Formation and the Ampthill Formation of the Jurassic Period. The northern area of the off-site cable route is underlain by bedrock comprising the West Walton Formation and the southern area of the off-site cable route and the National Grid Bicker Fen Substation are underlain by bedrock comprising the Oxford Clay Formation.

The EA aquifer designation maps at https://magic.defra.gov.uk categorise both the superficial deposits and bedrock deposits as 'unproductive' (i.e. areas comprised of rocks that have negligible significance for water supply or baseflow to rivers, lakes and wetlands).

1.4 Existing drainage conditions

The proposed development site is currently greenfield agricultural land. The site of the proposed Energy Park is bound along the northern boundary by the Head Dike/Skerth Drain (which is classified as a Main River). The Energy Park is bisected by a number of ditches/drains, some of which are operated and maintained by the Black Sluice Internal Drainage Board (BSIDB). Water levels within the network of ditches/drains are managed through pumping to the Head Dike/Skerth Drain.

The site of the proposed Energy Park is currently in agricultural use and therefore comprises natural permeable surfaces, such that surface water run-off generally infiltrates into the ground or is routed to the various ditches/drains that bisect the site and then pumped to the Head Dike/Skerth Drain

2 Proposed Surface Water Drainage Strategy

2.1 Design guidance

A drainage strategy outlining the means of surface water disposal from the proposed Energy Park has been prepared in line with the following guidance documents:

- 'Planning guidance for the development of large-scale ground mounted solar PV systems' published by BRE National Solar Centre (in association with Cornwall Council) in October 2013.
- 'Joint Lincolnshire Flood Risk and Water Management Strategy 2019-2050'.
- CIRIA 753 "The SuDS Manual", November 2015.

2.2 Water quantity

The post-development peak rate of surface water runoff can be readily managed and controlled using flow control and attenuation techniques within the site.

The reduction of runoff volume can however be more difficult to achieve as it relies upon infiltration, evapo-transpiration or re-use to reduce or eliminate additional volume of runoff. Where these volume reduction/infiltration techniques are not viable then the alternative is to provide an appropriate attenuation in underground (e.g. oversized pipes, tanks) and/or over ground (e.g. detention basins, retention ponds, swales) storage facilities by restricting the runoff rates to the greenfield equivalent.

To mitigate against increasing downstream flooding due to the additional volume of runoff alternative approaches should be considered as follows:

- segregation of the Long-Term Storage Volume (LTS), the difference between the pre- and post-development runoff volumes, from the main peak flow attenuation. The LTS is then discharged at very low rates (less than 2l/s/ha) and the remaining peak flow attenuation can be discharged at equivalent greenfield runoff rates with suitable deductions made for the discharge from the LTS. In practice this arrangement is quite complex and depends on catchment size, site layout, topography and number of outfalls and adoption of SuDS.

- restricting discharges for all return period storms up to the 100-year plus climate change storm event to the pre-development QBAR/ Q1 year flow rate. Effectively, surface water is managed collectively and discharged at low rates to extend the runoff hydrograph from the site.

2.3 Water quality

To mitigate against adverse impacts on the water quality in the receiving water environment CIRIA 753, the SuDS Manual, recommends the following steps to determine the required water quality management for discharges to surface waters and groundwaters:

- Plan land use to prevent runoff and associated pollutants for most rainfall events up to 5mm in depth,
- Identify the pollution hazard level associated with the given type of development,
- Select risk assessment approach based on receiving water environment and the pollution hazard level,
- Carry out the risk assessment for each outfall taking into account the pollution hazard level, the status of the receiving water environment and effectiveness of the proposed SuDS techniques.

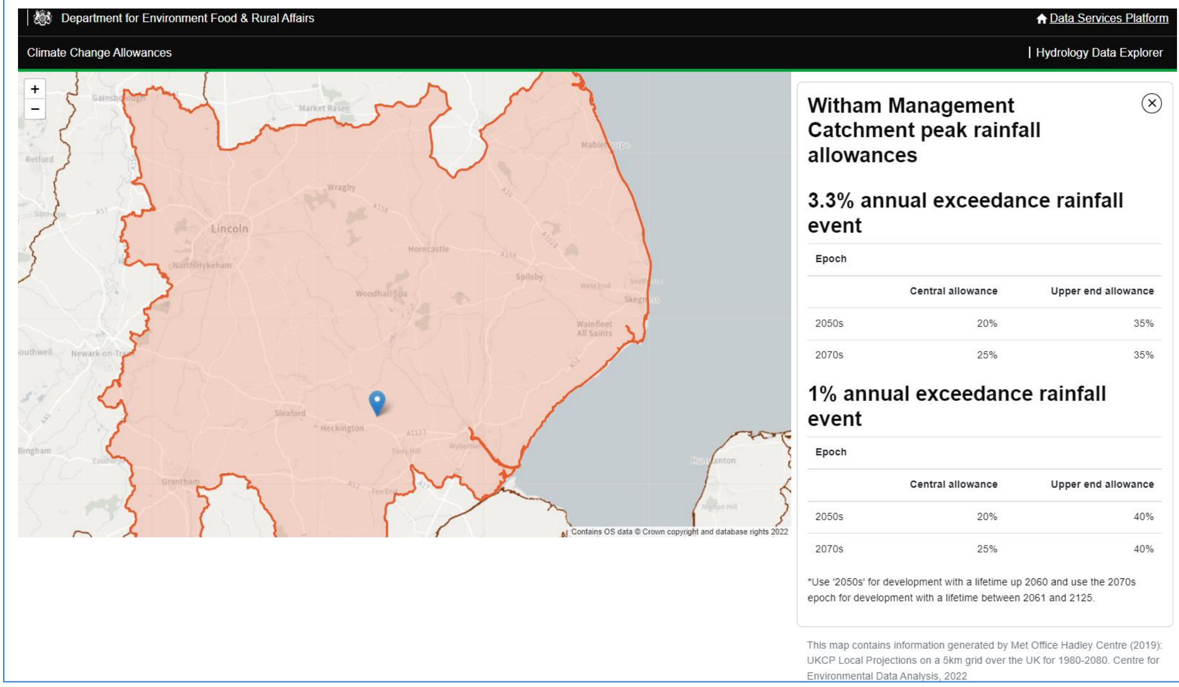
The land use classification associated with solar farms is not specifically noted in the SuDS Manual. However, considering the nature of the development and the infrequent use of access tracks the pollution hazard level of the site is considered to be very low.

2.4 Climate change impact

In line with the climate change allowances recommended by the EA in their February 2016 guidance[1], updated May 2022, the peak rainfall intensities should take into account increases for future climate change impacts on the drainage designs. It recommends that for development with a lifetime up to 2060 using a baseline of 1981-2000, to use the central allowance for the 2050s epoch (2022 to 2060). The recommended climate change allowances are shown in Table 2-1.

Table 2-1: Witham Catchment Peak rainfall intensity climate change allowance[2] (1% annual exceedance rainfall event)

Applies across all of England	Central	Upper end
2050s - Total potential change anticipated for the '2050s' (up to 2060)	20%	40%
2070s - Total potential change anticipated for the '2070s' (2061 to 2125)	25%	40%



Considering the design lifespan of the development of 40-years, the '2050s' scenario has been adopted for the purpose of this strategy. Consequently, the Central allowance of 20% has been used in the design.

2.5 Proposed Drainage Regime

2.5.1 Elements that require drainage

Following discussions with relevant stakeholders, the BSIDB and the LLFA, it was determined which elements of the proposals will require surface water drainage infrastructure and which elements are to be treated as having no impact on the existing drainage regime, these are listed as:

[1] Flood risk assessments: climate change allowances - GOV.UK (www.gov.uk)

[2]https://environment.data.gov.uk/hydrology/climate-change-allowances/rainfall

- Runoff from proposed and existing access tracks - to be treated as semi-permeable as these will be constructed from porous material but are subject to compaction and thus may generate partial runoff;
- Runoff from the solar panels - to be treated as negligible impact, runoff will be direct to natural ground and swales;
- Runoff from the sub-station and associated Energy storage area - to be treated as impermeable and require flow control and attenuation (tanks/lagoons).
- Runoff from the inverter and transformer stations (numerous containerised units throughout the solar park) - to be treated as impermeable and may increase runoff into the adjacent fields;
- Runoff from the construction compounds - to be treated as impermeable and require an additional swale/cut-off drain; and
- Outline design of the contaminated water/firewater containment system within the substation - to include sizing of the tanks/lagoons and flow controls (automatic valves/penstock-type controls) so that the SuDS tanks/lagoons that receive surface water flows can be completely isolated and all polluted water removed off site once isolated.

2.5.2 Discharge hierarchy

The following discharge hierarchy has been considered (in order of preference) during the preliminary design process:

2.5.3 Discharge to ground

Ground Investigation was carried out by Grange GeoConsulting Ltd in 2022. A total of five Cable Percussive boreholes (CP1 to CP5 inclusive), forty-six window sample boreholes (WS1 to WS46 inclusive), and thirty-three dynamic cone penetrometer tests using a handheld TRL probe (CBR1 to CBR33 inclusive) were undertaken across the site.

The Topsoil/Made Ground was recorded at the surface in each of the five boreholes excavated during the investigation. This unit was typically described as firm to stiff friable brown/dark brown slightly silty to silty, locally slightly sandy, slightly gravelly to gravelly, slightly cobbly to cobbly Clay. The thickness of the Topsoil deposits varied between 0.5m (BH1) and 1.0m (BH2). Material designated Topsoil/Made Ground was encountered in forty-five of the fifty one excavations undertaken (inclusive of Cable Percussive boreholes). Underlying these layers, the bedrock comprises a thick layer of low permeability, unproductive mudstones and siltstones of the Ancholme Group.

On that basis, the use of soakaways for surface water disposal to ground is unlikely to be viable. This option has therefore been discounted from further consideration at this stage.

2.5.4 Discharge to watercourse

As the Energy Park site lies within the catchment of the Head Dike/Skerth Drain, it is proposed to maintain the existing drainage regime and discharge the post-development surface water runoff into the main Head Dike/Skerth Drain via the ditches/drains on site and along the northern and eastern boundary of the site.

2.6 Runoff Rate and Volume Control

2.6.1 Solar panels

As the solar panels will be mounted above ground, at an angle to the ground surface, the rain falling on the panels will immediately pour to the natural ground beneath the panels. There will therefore be no increase in the runoff rates and volumes due to the panels (i.e. as the permeable, greenfield areas are retained).

It is recognised however that the rainfall distribution may not be as even as during an undeveloped scenario and the runoff may be concentrated in particular areas, principally beneath the lower edge of the panels. Conversely, the area of land in the 'rain shadow' of the panels will receive less rainfall and therefore the difference / change is deemed to be negligible.

[redacted]

2.6.2 Hardstanding areas

The Energy Park sub-station and energy storage compound will comprise both permeable and impermeable surfaces. The access tracks will be constructed using free-draining stone with a high voids ratio to mimic the current soils as best as practicable. Although not surfaced (i.e. with tarmac or similar) it is assumed that the track corridors will be compacted, thus having a slightly increased runoff rate when compared against the current condition of the soils on the site.

Considering that the above elements will result in increased runoff rates and volumes post-development, it is proposed to restrict all storm events up to and including the 100-year plus 20% climate change storm event to the pre-development QBAR greenfield runoff rate for the considered areas. Swales/ ditches positioned along the field boundaries will provide runoff conveyance and attenuation and a degree of treatment prior to discharge to the existing ditches/drains on site.

The proposed drainage layout is shown on the drawing provided in Appendix B .

2.7 Runoff rate

The QBAR Greenfield runoff rate was estimated using the IH124 method embedded in MicroDrainage hydraulic modelling software based on the parameters listed below. MicroDrainage is an industry-standard software package for the design and simulation of drainage systems. Table 2-2 provides Greenfield runoff rates for 1yr, QBAR, 30yr, 100yr and 100yr + Climate Change (20%).

Table 2-2: Greenfield Runoff from the Existing Site

Area ID	**IH 124 Peak flow (l/s) / [l/s/ha] for various return periods**				
	1-year	**QBAR**	**30-year◊**	**100-year**	**100-year + CCΔ**
Heckington Fen	574.5 l/s [0.99] l/s/ha	642.9 l/s [1.10] l/s/ha	1544.6 l/s [2.65] l/s/ha	2288.8 l/s [3.93] l/s/ha	2746.6 l/s [4.71] l/s/ha

Δ 20% increase in peak flows due to Climate Change
◊ Drainage systems are normally designed to convey 30-year storm event without flooding

- Total area – 583ha (Energy Park)
- SAAR – 574mm (from FEH Website)
- Soil – 0.30 (SPRHOST from FEH Website)
- Urban – 0 (essentially rural catchment)
- Hydrometric region – 5

The QBAR was calculated as 1.10l/s/ha (see Table 2-2 and calculation sheet in Appendix D). It is proposed to use a minimum practical flow rate of 3.5l/s to minimise the risk of blockage of the outlet control from the proposed swales. This has been used in calculations on an assumption that an orifice/penstock control will be used as a flow control (with maximum opening size of 75mm). If other flow control devices are used this flow rate may need to be increased to ensure the size of opening is adequate and the risk of blockages is not increased.

For the substation drainage scheme, a 57mm penstock opening will be used to control flows between each lagoon/ tank, whilst also having the functionality to isolate the substation flows from the rest of the site in case of an emergency or pollution incident. The final lagoon/ tank will use a penstock opening of maximum size of 107mm before flows are discharged to the existing ditches adjacent to the substation.

2.8 Attenuation sizing

2.8.1 Substation Attenuation Sizing

The 'quick storage estimate' module within MicroDrainage software has been used to estimate the required 100-year plus 20% climate change attenuation volume for the proposed substation. The storage volume has been estimated based upon the following design parameters:

- 100yr + 20%Climate Change - Design rainfall from FEH Website
- Cv calculated as 0.75 and 0.84 using Wallingford Procedure (summer and winter accordingly) – based on 100% PIMP (Percentage of Impermeable area) for sub-station and energy compound and 75% PIMP for unsurfaced access tracks
- Contributing area – 11.86ha (Based on clients proposed plan of the substation)
- Maximum allowable discharge rate – 3.5l/s

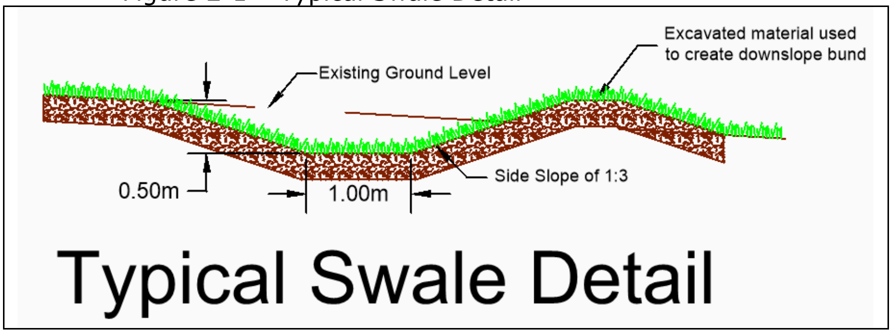
2.8.2 Field / Swale Attenuation Sizing

For each field parcel containing energy generation equipment and associated infrastructure (i.e. access tracks), the proposed impermeable area has been assessed. Using an estimated volume of storage per typical impermeable hectare (i.e. 701m^3-1022m^3), the likely surface water storage requirement for each field has been estimated which, in turn, defines the length of swale feature required to accommodate the run-off. This has been applied on a field-by-field basis with the volume of storage required correlating to the length of swale required to cater for run-off from the proposed impermeable features. The MicroDrainage calculation detail is included in Appendix C.

It is envisaged that for each individual field shown in Figure 2-2, swales will be provided to intercept, store and convey surface water run-off to the adjacent ditch network. An example swale profile is shown in Figure 2-1 below. The likely storage volumes required are summarised in Table 2-3 below.

The exact volume and size of the attenuation storage will be confirmed at the detailed stage of the design when the site layout is finalised and will depend on the type of storage facilities and outlet control device employed.

Figure 2-1 – Typical Swale Detail



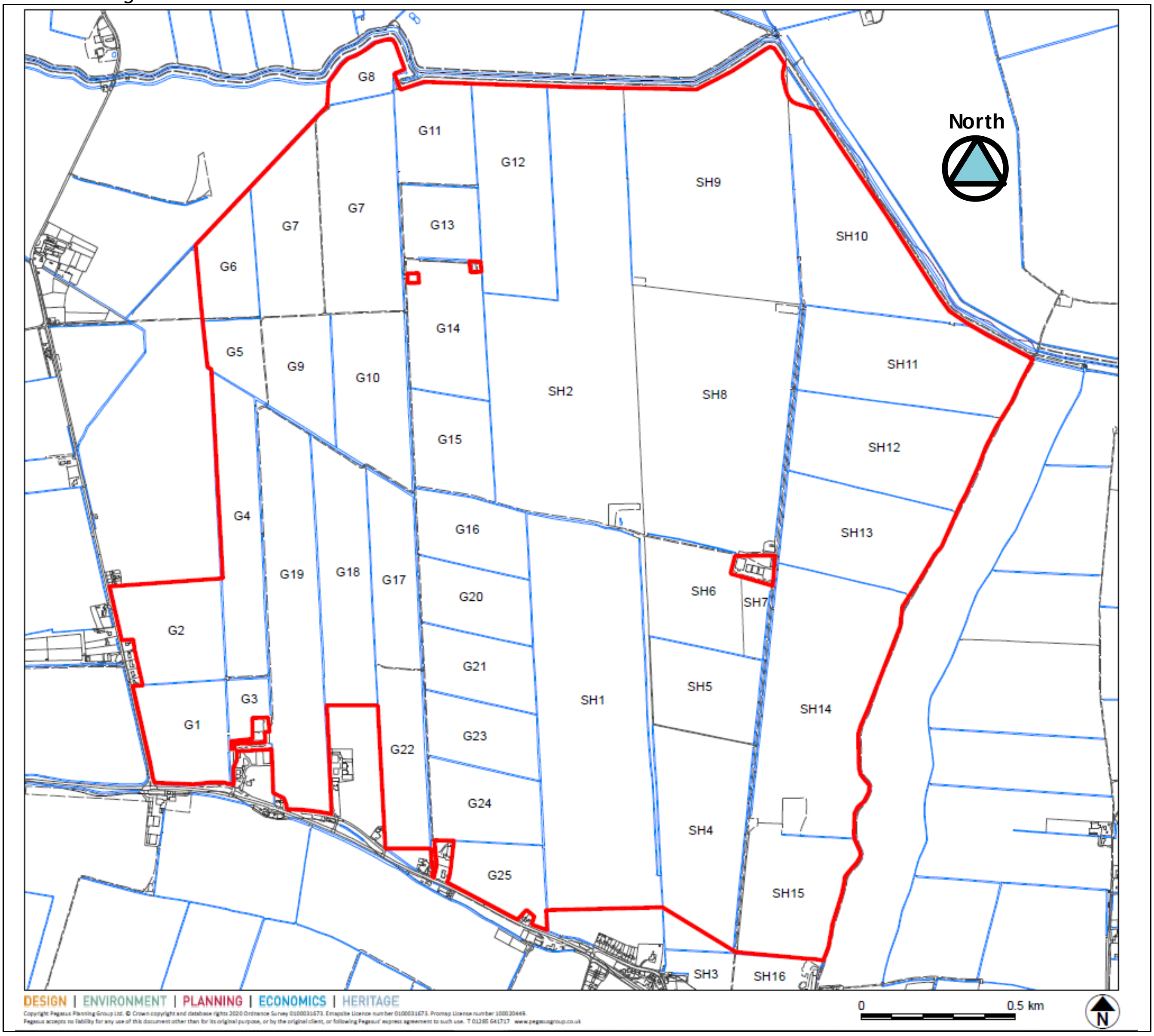
The attenuation volume for a typical impermeable hectare of development has been estimated based on the following design parameters:

- 100yr + 20%Climate Change - Design rainfall from FEH Website
- Cv calculated as 0.75 and 0.84 using Wallingford Procedure (summer and winter accordingly) – based on 100% PIMP for sub-station and energy compound and 75% PIMP for unsurfaced access tracks
- Contributing area – 1ha (Based on One hectare of Impermeable / hardstanding Area)
- Maximum allowable discharge rate – 3.5l/s

2.8.3 Attenuation Location Constraints

Archaeology investigations and ecology/habitat surveys have identified constraints within a number of the field parcels comprising the Energy Park. The constraints are generally relatively localised, with the exception of field parcel SH12, where constraints relating to archaeology affect the entire field parcel and restrict the use of excavations for swale features. The configuration of the surface water drainage infrastructure has been configured accordingly and will require further review as the design process progresses.

Figure 2-2 –Individual Fields



[redacted]

Table 2-3: Individual field's Swale \ SuDS Storage Requirement

Field ID	Total Area (Ha)	Impermeable Area (Ha)	Minimum SuDS Storage (m3)	Maximum SuDS Storage (m3)	Average Storage (m3)	Comments
G1	-	-	-	-	-	BNG
G2	-	-	-	-	-	BNG
G3	-	-	-	-	-	BNG
G4	9.62	0.40	280	409	345	
G5	3.16	0.11	77	112	95	
G6	4.59	0.16	112	164	138	
G7	17.56	0.46	322	470	396	
G8	-	-	-	-	-	BNG
G9	6.74	0.22	158	230	194	
G10	9.50	0.59	412	600	506	Including Comp1
G11	4.19	0.18	129	188	159	
G12	13.29	0.24	166	242	204	
G13	3.57	0.14	101	149	125	
G14	7.56	0.18	123	179	151	
G15	6.04	0.23	162	236	199	
G16	4.17	0.19	134	195	164	
G17	6.77	0.26	182	266	224	
G18	10.58	0.29	203	296	250	
G19	12.33	0.37	258	376	317	Including Comp2
G20	4.26	0.19	134	195	164	
G21	4.30	0.19	134	195	164	Amber Exclusion Zone
G22	-	0.00	-	-	-	BNG
G23	4.26	0.19	134	195	164	
G24	-	0.00	-	-	-	BNG
G25	-	0.00	-	-	-	BNG
SH1	27.91	0.84	585	854	720	Including Comp4
SH2	44.50	1.11	781	1139	960	Including Comp3
SH4	12.34	0.17	122	178	150	
SH5	8.02	0.09	62	90	76	
SH6+SH7	9.35	0.09	63	92	78	
SH7	-	0.00	-	-	-	BNG
SH8	23.44	0.28	198	289	244	
SH9	34.35	1.06	741	1080	911	Including Comp5
SH10	15.81	0.32	221	323	272	
SH11	16.22	0.43	305	444	374	
SH12	15.69	0.47	326	475	401	No top soil removal or levelling allowed - soft interception methods only
SH13	12.88	0.39	272	397	334	
SH14	24.36	0.67	470	685	577	
SH15	10.66	0.44	311	454	383	
SH16	-	0.00	-	-	-	BNG
Substation*	11.89	5.95	4167	6076	5122	See Figure 2-3

* 50% Impermeable Area

[redacted]

2.8.4 Archaeological zone SH12

The archaeological constraints within Field SH12 (where a former duck decoy has been identified) need to be accommodated by the drainage strategy. Field topography is to be maintained and no topsoil stripping or levelling is allowed. This restriction means that provision of swales/attenuation cannot be provided for Field SH12, therefore a different approach will be required to intercept runoff without any excavation.

It is proposed that additional soft landscaping and planting of additional vegetation to the downslope perimeters of Field SH12 to provide a buffer zone to natural runoff, improve natural interception and slow down the runoff from Field SH12 before entering the boundary ditches, to retain the natural drainage arrangement.

Figure 2-3 – Archaeological zone in SH12

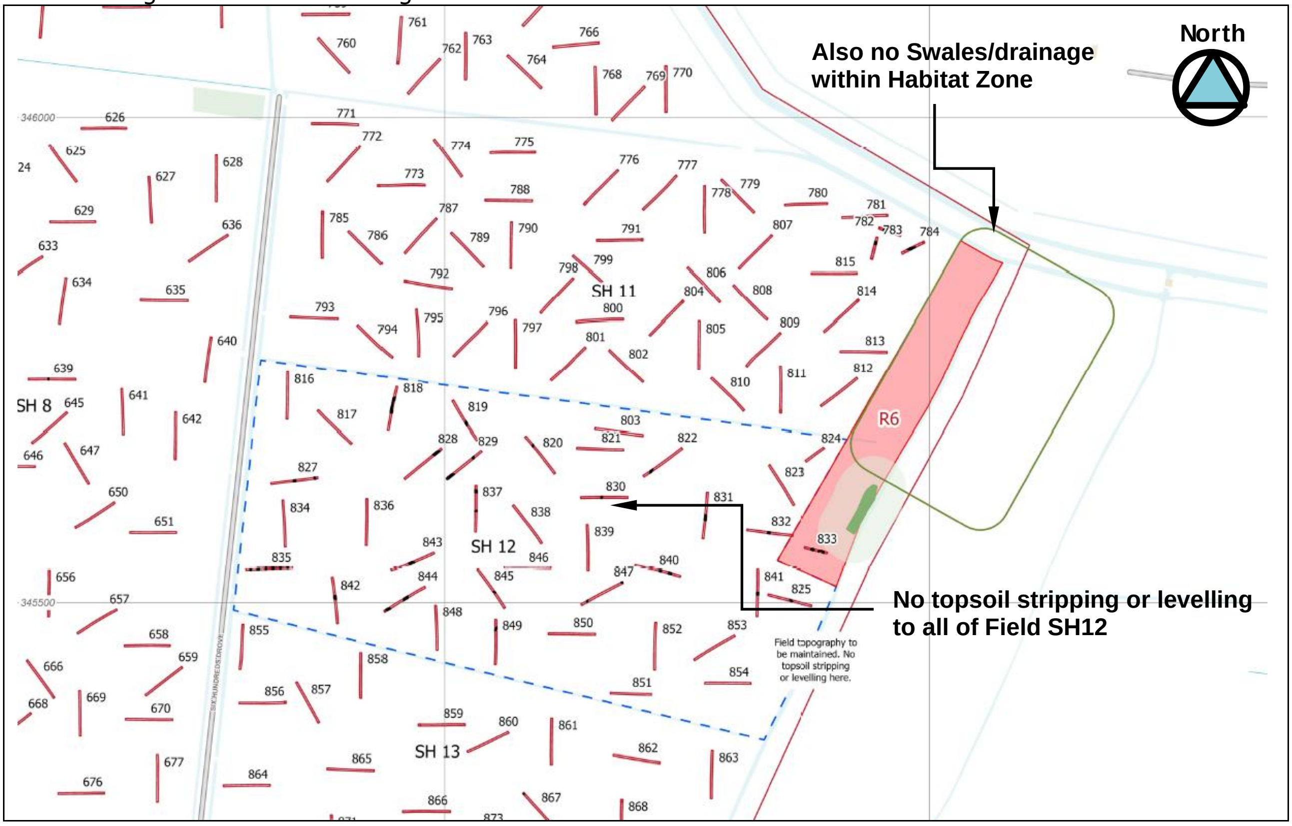
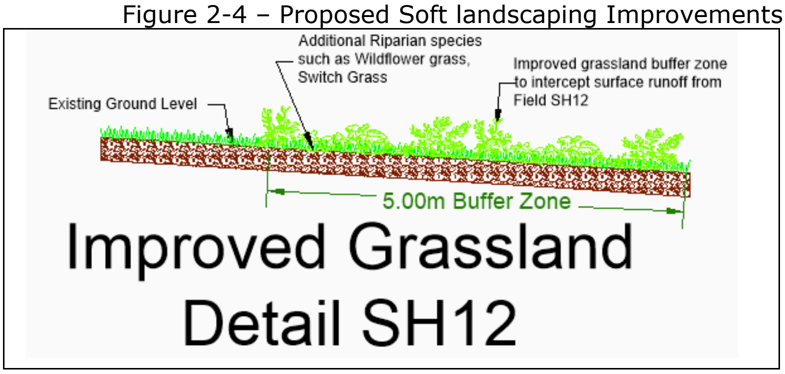


Figure 2-4 – Proposed Soft landscaping Improvements



[redacted]

2.8.5 Substation and Energy Storage Site

Field SH8 is used for the sub-station and energy storage. The compound will comprise a mix of permeable and impermeable surfaces. This requires surface water run-off from the impermeable areas to be collected by a piped system and routed to the SuDS features. In the event of battery failure/leak or fire, resulting in the pollution of surface water run-off, outflow from the SuDS attenuation lagoons/tanks would be stopped by closing off the outlet penstocks, and the polluted run-off pumped out of the lagoons/tanks, such that contaminated water is contained and may then be transferred off site.

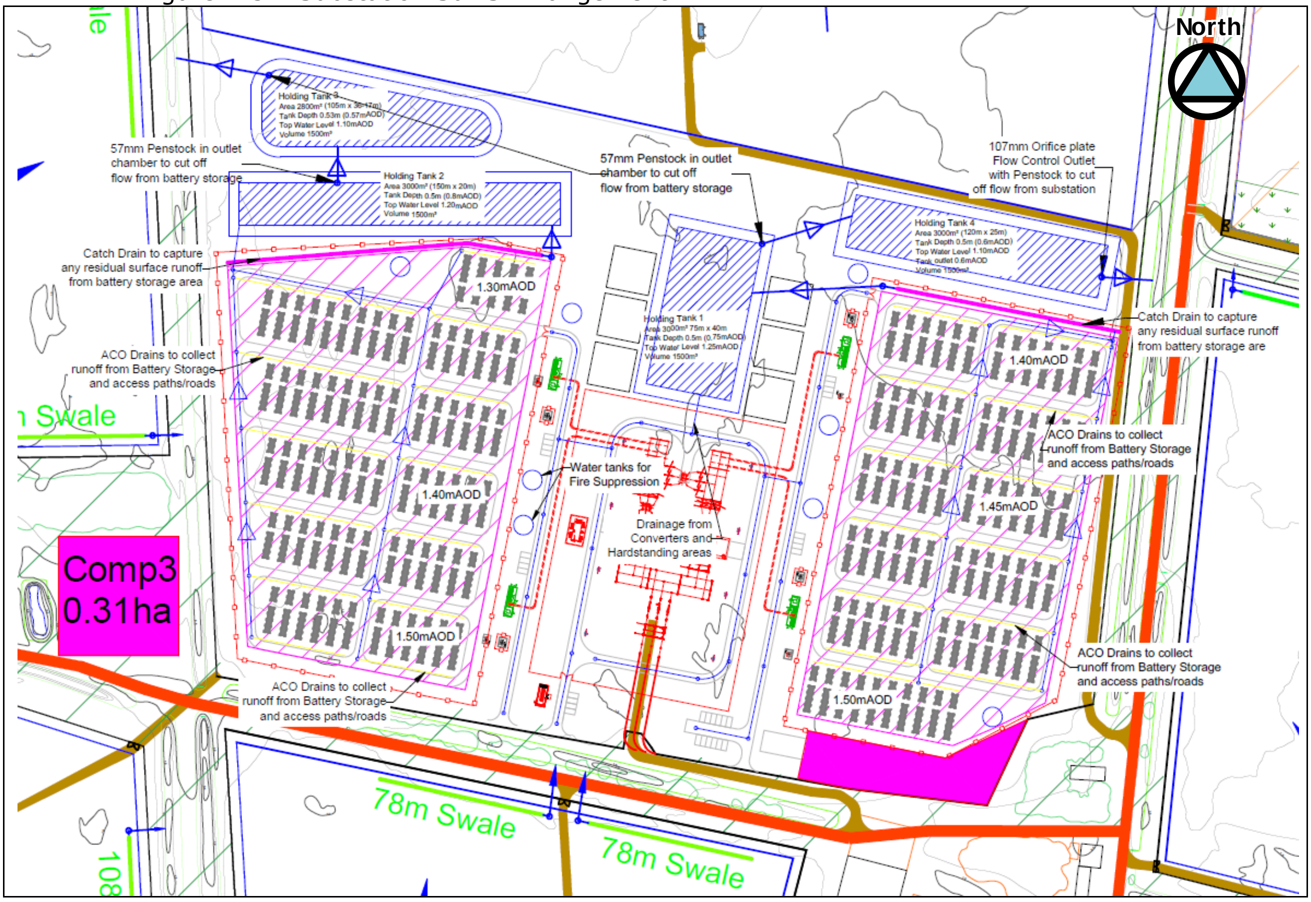
Within the substation compound, the energy storage areas will have perimeter ACO drains to capture runoff from these areas and direct flows to the main perimeter catch drain, which leads into the series of lagoons/tanks. The energy stores will have a natural fall from south-to-north, at approximately 1.5-1.25mAOD and the invert of the receiving ditch at the point of outfall is 0.5mAOD, therefore a shallow fall of approximately 1:500 for the tanks and connecting pipe networks will be required throughout.

As the substation compound is generally flat with a very shallow fall, a cascading pond system cannot be achieved, therefore the 4 lagoons/tanks will fill and operate together as an overall attenuation system, but have the capability to be isolated before entering the receiving ditch system for pollution control if necessary.

An indicative drainage schematic is shown in Figure 2-5 below. The storage volume for SuDS features to attenuate the surface water runoff from impermeable areas is estimated to be between 4200m^3 and 6100m^3 to cater for the 1 in 100 year plus climate change storm event (see Appendix C). There are a total of four SuDS features as shown on the plan with each providing an attenuation volume of 1500m^3 with additional storage available within the catch drain/ACO system of the energy storage areas and a freeboard of 300mm. Appendix C and D provides the hydraulic calculations for the storage features and how these will attenuate the surface water runoff from the substation.

[redacted]

Figure 2-5 – Substation SuDS Arrangement



It should be noted that the outline drainage design has been based on currently available information and design parameters and assumptions described in this report. If any of the design parameters, including the proposed site layout change, the design will require to be re-visited to confirm its suitability. The surface water drainage strategy plan for the site is included in Appendix B.

2.9 Runoff treatment

The proposed swales within the fields containing the solar panels will provide a degree of runoff treatment prior to discharge to the existing network of ditches/drains. No further treatment is deemed necessary considering the character of the development.

2.10 Design for exceedance

The solar panels and other flood-sensitive infrastructure (transformers, energy storage modules, control rooms, etc) will be elevated above the 1,000 year +20% breach flood level of 1.95mAOD (as per Environment Agency requirements) In the event of a blockage or exceedance of the drainage system capacity overland flow will naturally follow the site topography towards the existing Head Dike/Skerth Drain (which is an embanked, pumped IDB maintained watercourse). Considering the rural character of the area no properties will be directly affected by the overland flow routes.

The potential overland flow routes are shown on the site surface water drainage drawings included in Appendix B.

2.11 Long Term Management

The long-term management arrangements will be confirmed at the detailed design stage. It is envisaged however that the proposed drainage system will remain in private ownership and the future

[redacted]

maintenance responsibility of the proposed drainage system will lie with the site owner/ operator.

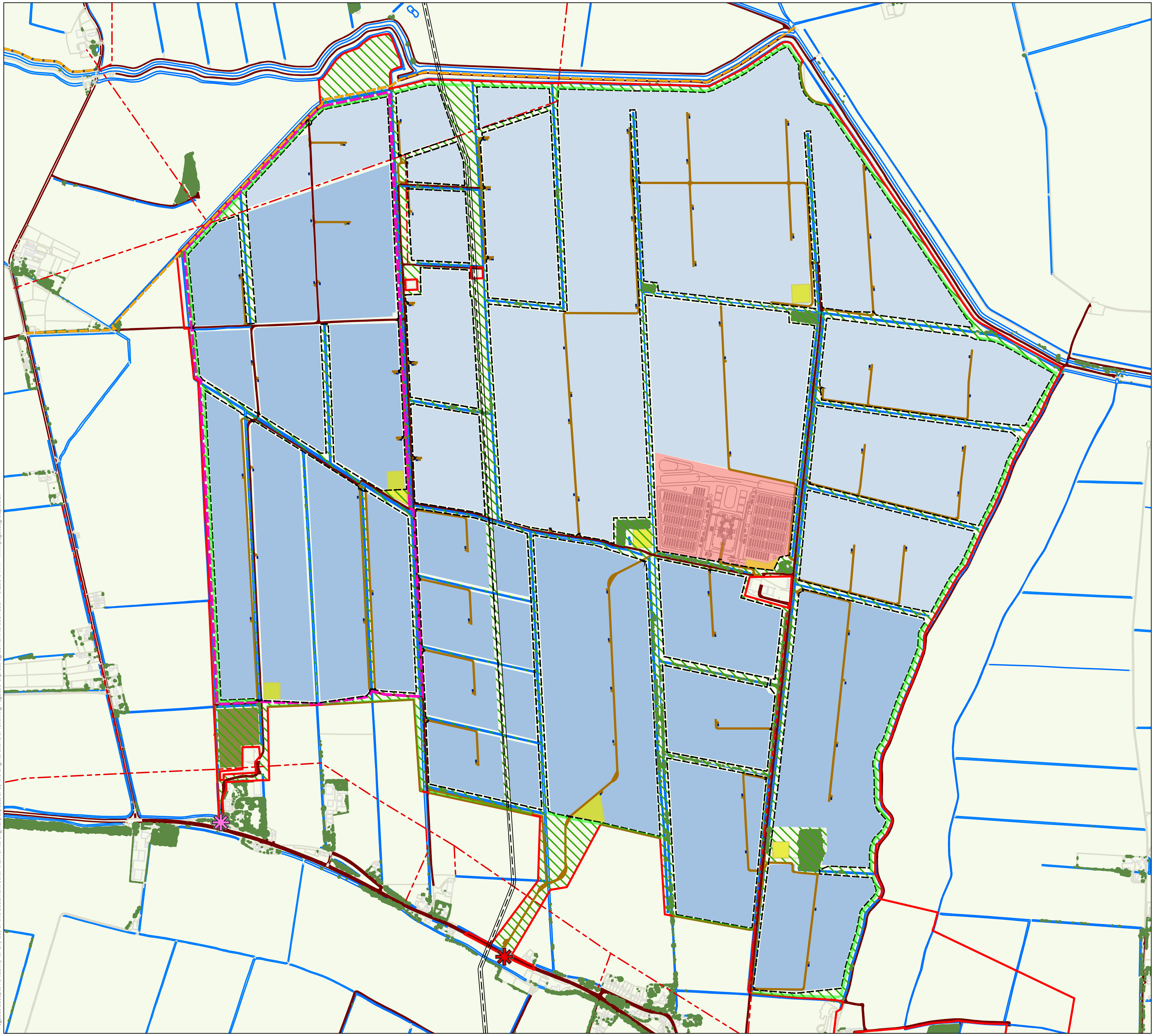
A maintenance plan for the drainage system will be prepared prior to the Energy Park becoming operational to ensure the drainage system remains effective for the lifetime of the development. The maintenance plan will be prepared in consultation with the Black Sluice Internal Drainage Board.

2.12 Consents

Any works within 9m of a watercourse (whether Board maintained or riparian) require consent from the BSIDB (as per Section 23 of the Land Drainage Act.

[redacted]

Appendix A: Proposed site layout



KEY

- Order Limits
- Security Fence
- Proposed Site Entrance
- Temporary Access
- Existing Road / Track
- Access Tracks
- Solar Park Zone Max Height 3.5m
- Solar Park Zone Max Height 3m
- Public Right of Way
- Proposed Permissive Footpath
- Habitat Enhancement Area
- Existing Vegetation
- Community Orchard
- Water Feature / Ditch
- Culvert
- Gas Pipeline
- 11kV Overhead Lines
- Inverters and Transformation Station
- Site Main Substation / Energy Storage Compound
- Construction and Operational Compounds
- Proposed Hedge

NOTES:
Buffers to development:
- 9m to BSIDB maintained open watercourses
- 8m to all other watercourses
- 12.2m to gas pipeline (total 24.4m easement strip)
- 5m to 11kV overhead line

Hedgerows would be up to 3m in width when mature and would be maintained up to 4m in height.

The Solar Development Area will include some localised electrical infrastructure such as inverters, transformers, energy storage and smaller substations.

DCO Document Reference: 6.2.2
APFP Regulation: 5(2)(a)

FIGURE 2.1 INDICATIVE SITE LAYOUT

DATE	SCALE	SHEET	REVISION
03/02/2023	1:12,000@A3	-	J

DRAWING NUMBER
P20-2370_03

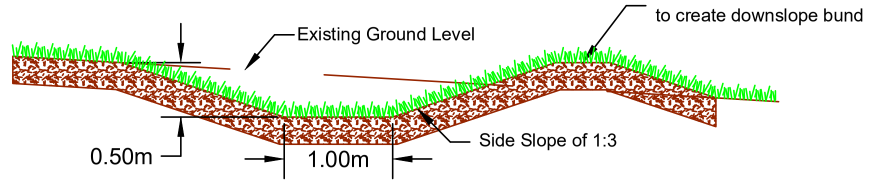
0 0.5 km

ecotricity

PEGASUS GROUP

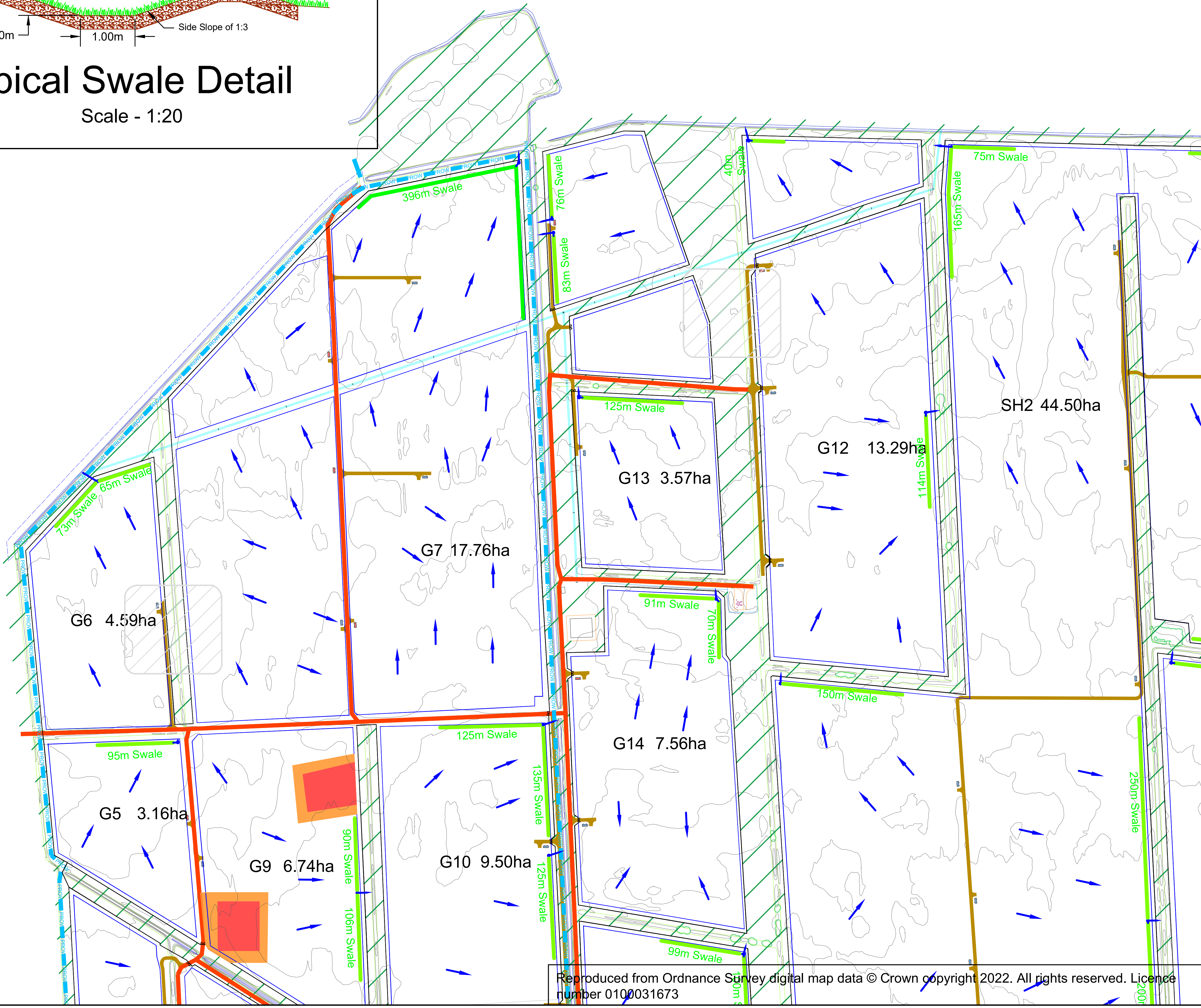
Appendix B: Proposed Site Drainage Plan

[redacted]



Typical Swale Detail

Scale - 1:20



General Notes

1. All dimensions shown are in metres unless otherwise stated and levels in metres to Ordnance Datum.
2. Do not scale from this drawing. All dimensions must be checked/verified on site.
3. This drawing is to be read in conjunction with Outline Surface Water Drainage Strategy Note to File
4. Any discrepancies noted on site are to be reported to the Engineer immediately.
5. All works in watercourses will be carried out with care to minimise the risk of pollution adhering to Pollution Prevention Guidelines.
6. All works affecting flood defences, main watercourses and/or ordinary watercourses will be subject to Consent for Permanent and Temporary Works under the Land Drainage Act 1991.
7. The locations of any known services shown on drawing are approximate and for guidance only. The Contractor will confirm the location of any services prior to the commencement of any works.
8. The electronic model of this drawing is not to be used for setting out.

LEGEND

- DCO EXTENT
- Perimeter Fence
- Ditch
- Water
- OHL
- Gate
- High Vegetation
- Access Tracks
- Existing Road
- Inverter and Transformer Station
- Construction & Operational Compounds
- Habitat Enhancement / BNG
- Public Right Of Way
- Natural Overland Drainage Routes
- Proposed Swales
- Archaeological Amber Zones
- Archaeological Red Zones
- Habitat Zone
- Grass Buffer Zone
- No Topsoil Stripping Zone

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for

Ecotricity - Heckington Fen

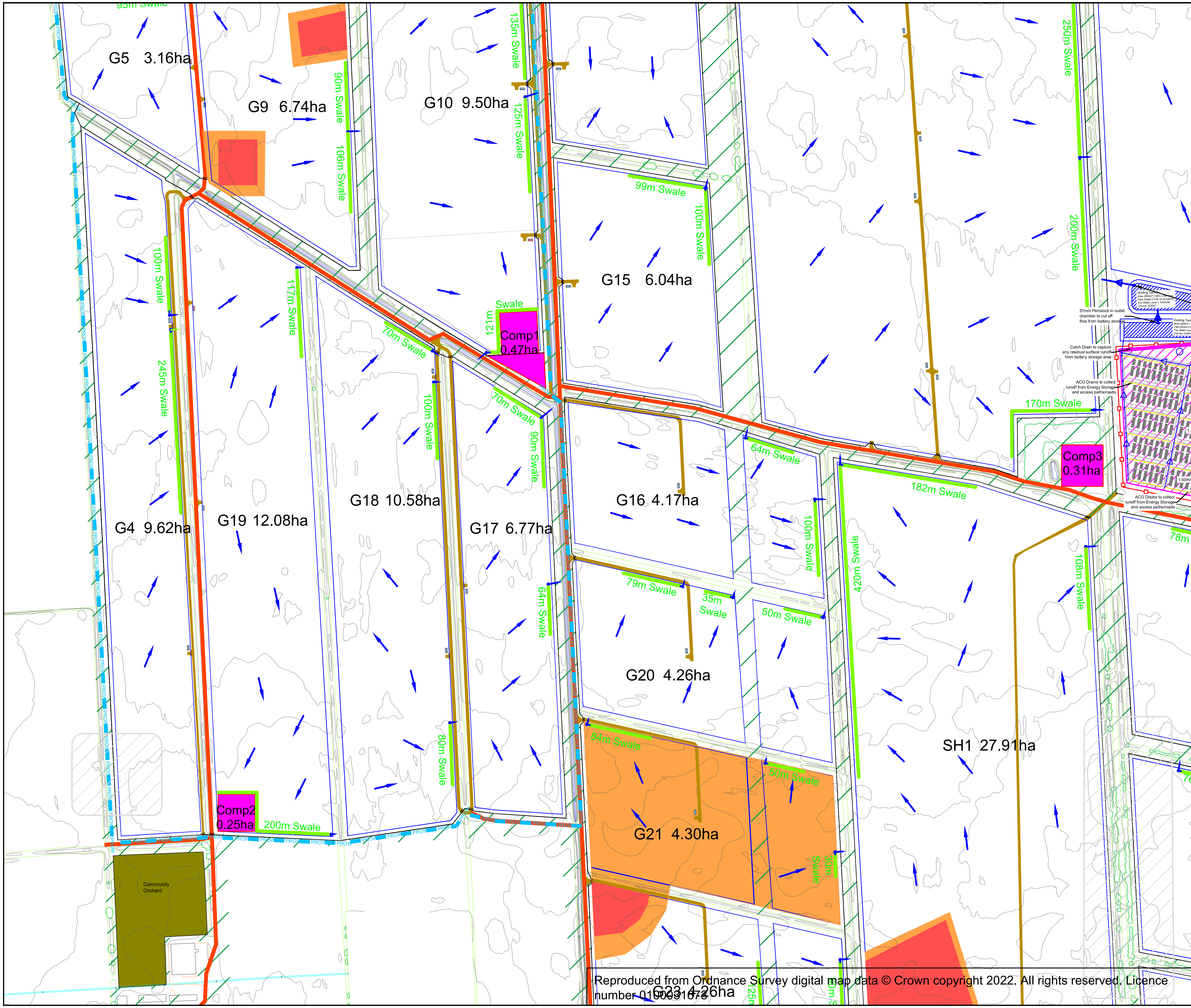
INDICATIVE SURFACE WATER DRAINAGE LAYOUT

Sheet 1 of 6

Scale:		
1:5,000 @ A3	Drawn: MW	18/01/23
	Designed: MW	18/01/23
	Checked: EP	20/01/23
	Approved: SH	20/01/23

Digital File Name: GRN-JBAU-00-00-DR-C-0001-A4-C01-Drainage_Layout

Drawing Number:	Rev.:	Sheet No.:	Status:
0001	-	1 of 1	PRELIMINARY



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- Gate
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INDICATIVE SURFACE WATER DRAINAGE LAYOUT
Sheet 2 of 6

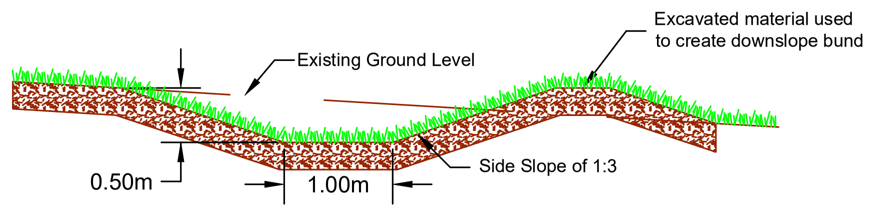
Scale: 1:5,000 @ A3		
Drawn:	MW	18/01/23
Designed:	MW	18/01/23
Checked:	EP	20/01/23
Approved:	SH	20/01/23

Digital File Name: GRN-JBAU-00-00-DR-C-0002-A4-C01-Drainage_Layout

Drawing Number:	Rev.:	Sheet No.:	Status:
0002	-	1 of 1	PRELIMINARY

Typical Swale Detail

Scale - 1:20



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Ecotricity - Heckington Fen

INDICATIVE SURFACE WATER DRAINAGE LAYOUT

Sheet 3 of 6

Scale:	Drawn: MW	18/01/23
1:5,000 @ A3	Designed: MW	18/01/23
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	Approved: SH	20/01/23

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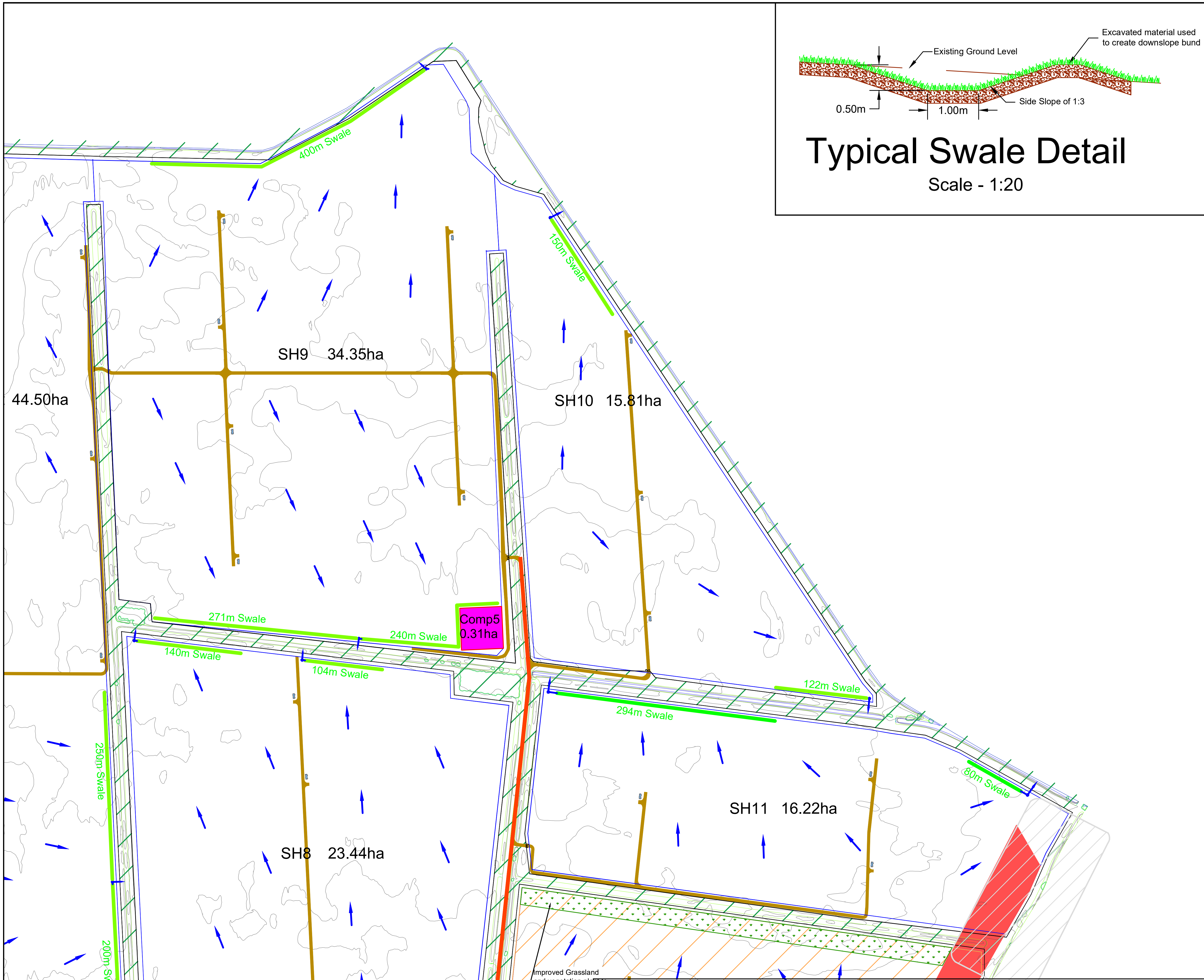
Drawing Number:	Rev.:	Sheet No.:	Status:
0003	-	1 of 1	PRELIMINARY



Typical Swale Detail

Scale - 1:20

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Sheet 4 of 6

Scale: 1:5,000 @ A3			
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	Approved:	SH	20/01/23

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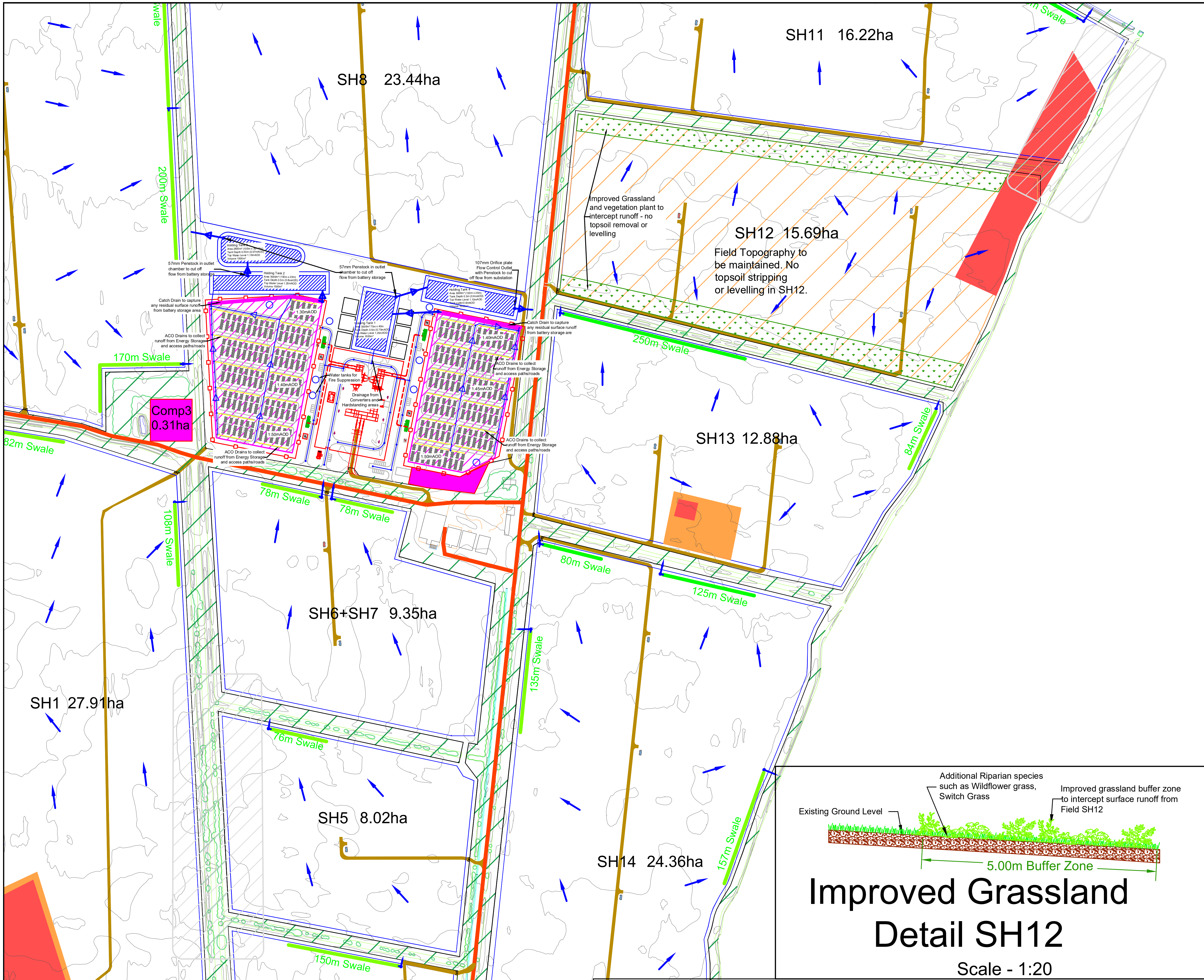
0004	-	1 of 1	PRELIMINARY



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INDICATIVE SURFACE WATER DRAINAGE LAYOUT

Sheet 5 of 6

Scale:			
1:5,000 @ A3	Drawn:	MW	18/01/23
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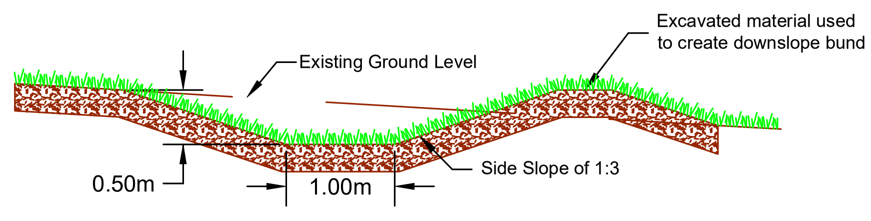
Drawing Number:	Rev.:	Sheet No.:	Status:
0005	-	1 of 1	PRELIMINARY



Typical Swale Detail

Scale - 1:20

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INDICATIVE SURFACE WATER DRAINAGE LAYOUT
Sheet 6 of 6

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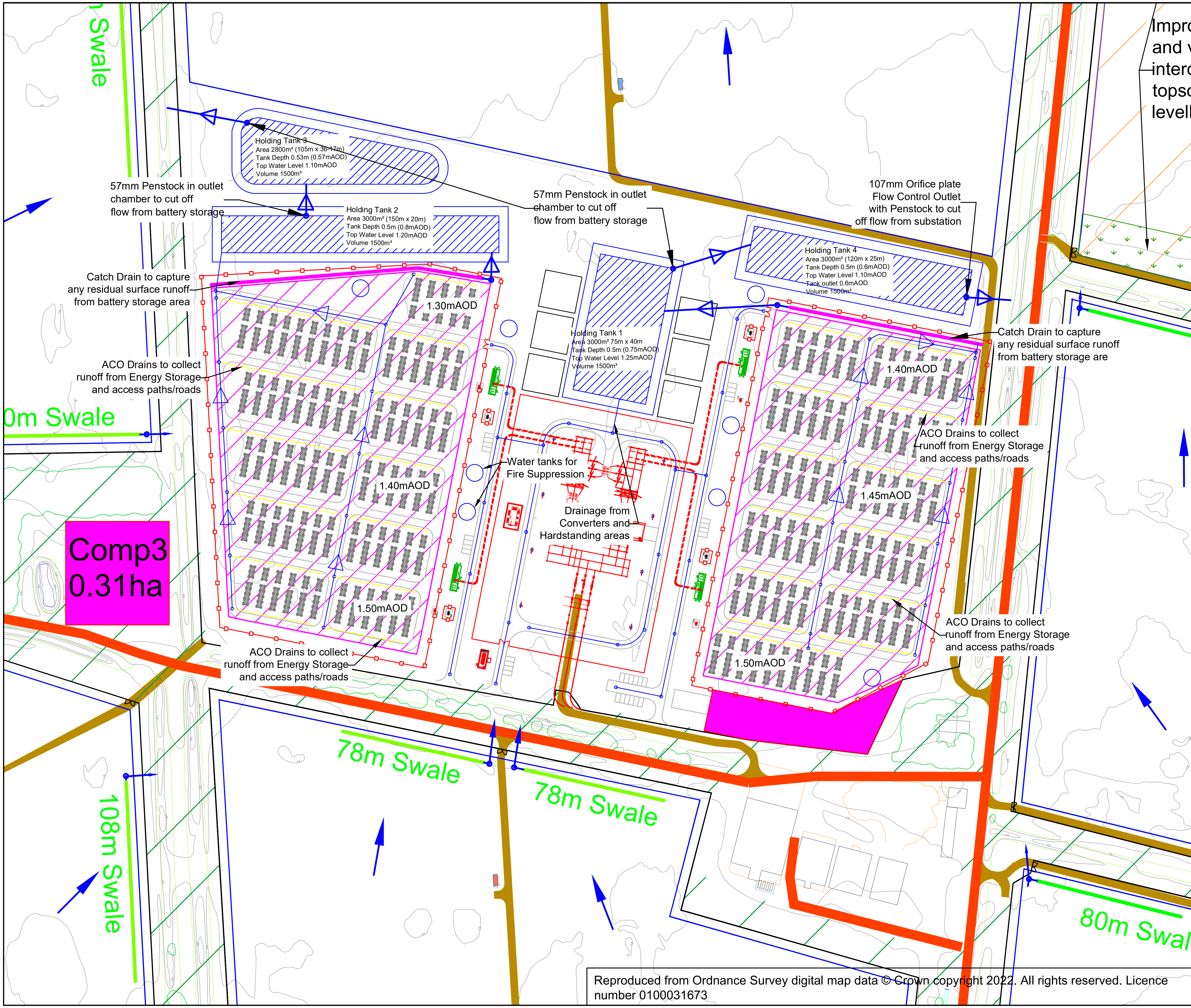
0006	-	1 of 1	PRELIMINARY



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INDICATIVE SURFACE WATER DRAINAGE LAYOUT
Substation Drainage

Scale:	Drawn: MW	18/01/23
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INDICATIVE SURFACE WATER DRAINAGE LAYOUT
Whole Site Surface Water Drainage

Scale:			
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Drawing Number:	Rev.:	Sheet No.:	Status:
0008	-	1 of 1	PRELIMINARY

Appendix C: Hydraulic Calculations

[redacted]

Summary of Results for 100 year Return Period (+20%)

Half Drain Time : 408 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	100.039	1.039	0.0	11.7	0.0	11.7	341.7	O K
30 min Summer	100.074	1.074	0.0	12.0	0.0	12.0	384.3	O K
60 min Summer	100.105	1.105	0.0	12.1	0.0	12.1	426.4	O K
120 min Summer	100.128	1.128	0.0	12.3	0.0	12.3	461.5	O K
180 min Summer	100.136	1.136	0.0	12.3	0.0	12.3	473.5	O K
240 min Summer	100.138	1.138	0.0	12.3	0.0	12.3	475.4	O K
360 min Summer	100.133	1.133	0.0	12.3	0.0	12.3	467.9	O K
480 min Summer	100.127	1.127	0.0	12.3	0.0	12.3	459.3	O K
600 min Summer	100.121	1.121	0.0	12.2	0.0	12.2	449.8	O K
720 min Summer	100.114	1.114	0.0	12.2	0.0	12.2	439.5	O K
960 min Summer	100.108	1.108	0.0	12.1	0.0	12.1	431.3	O K
1440 min Summer	100.090	1.090	0.0	12.0	0.0	12.0	406.6	O K
2160 min Summer	100.059	1.059	0.0	11.9	0.0	11.9	365.4	O K
2880 min Summer	100.026	1.026	0.0	11.7	0.0	11.7	327.5	O K
4320 min Summer	99.819	0.819	0.0	10.4	0.0	10.4	245.8	O K
5760 min Summer	99.643	0.643	0.0	9.1	0.0	9.1	192.9	O K
7200 min Summer	99.521	0.521	0.0	8.2	0.0	8.2	156.2	O K
8640 min Summer	99.432	0.432	0.0	7.4	0.0	7.4	129.6	O K
10080 min Summer	99.364	0.364	0.0	6.7	0.0	6.7	109.2	O K
15 min Winter	100.073	1.073	0.0	11.9	0.0	11.9	383.6	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
15 min Summer	188.130	0.0	348.3	0.0	26
30 min Summer	107.217	0.0	397.2	0.0	40
60 min Summer	61.103	0.0	456.7	0.0	68
120 min Summer	34.823	0.0	520.7	0.0	126
180 min Summer	25.062	0.0	562.2	0.0	184
240 min Summer	19.846	0.0	593.6	0.0	242
360 min Summer	14.283	0.0	640.8	0.0	310
480 min Summer	11.310	0.0	676.6	0.0	370
600 min Summer	9.438	0.0	705.6	0.0	432
720 min Summer	8.140	0.0	730.3	0.0	500
960 min Summer	6.609	0.0	790.5	0.0	638
1440 min Summer	4.927	0.0	883.5	0.0	912
2160 min Summer	3.674	0.0	990.9	0.0	1304
2880 min Summer	2.983	0.0	1072.6	0.0	1696
4320 min Summer	2.077	0.0	1119.6	0.0	2424
5760 min Summer	1.607	0.0	1156.5	0.0	3168
7200 min Summer	1.317	0.0	1184.5	0.0	3888
8640 min Summer	1.119	0.0	1207.7	0.0	4584
10080 min Summer	0.975	0.0	1227.1	0.0	5256
15 min Winter	188.130	0.0	390.3	0.0	26

Summary of Results for 100 year Return Period (+20%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
30 min Winter	100.109	1.109	0.0	12.2	0.0	12.2	432.1	O K
60 min Winter	100.141	1.141	0.0	12.3	0.0	12.3	480.8	O K
120 min Winter	100.167	1.167	0.0	12.5	0.0	12.5	523.0	O K
180 min Winter	100.177	1.177	0.0	12.5	0.0	12.5	539.5	O K
240 min Winter	100.180	1.180	0.0	12.5	0.0	12.5	544.6	O K
360 min Winter	100.176	1.176	0.0	12.5	0.0	12.5	538.3	O K
480 min Winter	100.168	1.168	0.0	12.5	0.0	12.5	524.1	O K
600 min Winter	100.160	1.160	0.0	12.4	0.0	12.4	511.4	O K
720 min Winter	100.151	1.151	0.0	12.4	0.0	12.4	497.0	O K
960 min Winter	100.142	1.142	0.0	12.3	0.0	12.3	481.7	O K
1440 min Winter	100.114	1.114	0.0	12.2	0.0	12.2	439.9	O K
2160 min Winter	100.065	1.065	0.0	11.9	0.0	11.9	374.0	O K
2880 min Winter	100.017	1.017	0.0	11.6	0.0	11.6	317.3	O K
4320 min Winter	99.726	0.726	0.0	9.7	0.0	9.7	217.7	O K
5760 min Winter	99.528	0.528	0.0	8.2	0.0	8.2	158.3	O K
7200 min Winter	99.401	0.401	0.0	7.1	0.0	7.1	120.4	O K
8640 min Winter	99.317	0.317	0.0	6.2	0.0	6.2	95.0	O K
10080 min Winter	99.258	0.258	0.0	5.5	0.0	5.5	77.4	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
30 min Winter	107.217	0.0	445.0	0.0	40
60 min Winter	61.103	0.0	511.6	0.0	68
120 min Winter	34.823	0.0	583.3	0.0	124
180 min Winter	25.062	0.0	629.7	0.0	180
240 min Winter	19.846	0.0	664.9	0.0	236
360 min Winter	14.283	0.0	717.8	0.0	344
480 min Winter	11.310	0.0	757.8	0.0	392
600 min Winter	9.438	0.0	790.4	0.0	466
720 min Winter	8.140	0.0	818.0	0.0	542
960 min Winter	6.609	0.0	885.4	0.0	694
1440 min Winter	4.927	0.0	989.5	0.0	988
2160 min Winter	3.674	0.0	1109.9	0.0	1396
2880 min Winter	2.983	0.0	1201.5	0.0	1788
4320 min Winter	2.077	0.0	1254.3	0.0	2512
5760 min Winter	1.607	0.0	1295.4	0.0	3232
7200 min Winter	1.317	0.0	1326.8	0.0	3960
8640 min Winter	1.119	0.0	1352.8	0.0	4664
10080 min Winter	0.975	0.0	1374.7	0.0	5352

Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
FEH Rainfall Version	1999
Site Location	GB 522100 345750 TF 22100 45750
C (1km)	-0.022
D1 (1km)	0.290
D2 (1km)	0.377
D3 (1km)	0.209
E (1km)	0.312
F (1km)	2.495
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+20

Time Area Diagram

Total Area (ha) 1.000

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	0.333	4	8	0.333	8	12	0.333

Model Details

Storage is Online Cover Level (m) 100.300

Dry Swale Structure

Infiltration Coefficient Base (m/hr)	0.00000	Trench Length (m)	1000.0
Infiltration Coefficient Side (m/hr)	0.00000	Trench Infiltration Side (m/hr)	0.00000
Safety Factor	2.0	Trench Porosity	0.30
Porosity	1.00	Side Slope (1:X)	2.0
Invert Level (m)	99.000	Slope (1:X)	0.0
Trench Height (m)	1.000	Cap Volume Depth (m)	0.000
Trench Width (m)	1.0	Cap Infiltration Depth (m)	0.000

Orifice Outflow Control

Diameter (m) 0.075 Discharge Coefficient 0.600 Invert Level (m) 99.000

Weir Overflow Control

Discharge Coef 0.544 Width (m) 2.500 Invert Level (m) 100.300

Cascade Summary of Results for 2021s1226_100yr+20%_Basin1_Outflow=7L!s.SRCX

Upstream Structures	Outflow To	Overflow To
(None)	2021s1226_100yr+20%_Cascading_Outflow=20L!s.SRCX	2021s1226_100yr+20%_Cascading_Outflow=20L!s.SR

Half Drain Time : 2000 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	100.350	0.350	0.0	3.8	0.0	3.8	525.6	O K
30 min Summer	100.398	0.398	0.0	4.1	0.0	4.1	597.3	O K
60 min Summer	100.451	0.451	0.0	4.4	0.0	4.4	676.7	O K
120 min Summer	100.508	0.508	0.0	4.7	0.0	4.7	762.5	O K
180 min Summer	100.543	0.543	0.0	4.9	0.0	4.9	813.8	O K
240 min Summer	100.566	0.566	0.0	5.0	0.0	5.0	849.7	O K
360 min Summer	100.598	0.598	0.0	5.1	0.0	5.1	897.6	O K
480 min Summer	100.618	0.618	0.0	5.2	0.0	5.2	927.6	O K
600 min Summer	100.631	0.631	0.0	5.3	0.0	5.3	947.2	O K
720 min Summer	100.640	0.640	0.0	5.3	0.0	5.3	960.1	O K
960 min Summer	100.666	0.666	0.0	5.4	0.0	5.4	998.9	O K
1440 min Summer	100.690	0.690	0.0	5.5	0.0	5.5	1035.6	O K
2160 min Summer	100.709	0.709	0.0	5.6	0.0	5.6	1063.4	O K
2880 min Summer	100.717	0.717	0.0	5.6	0.0	5.6	1076.1	O K
4320 min Summer	100.664	0.664	0.0	5.4	0.0	5.4	995.3	O K
5760 min Summer	100.615	0.615	0.0	5.2	0.0	5.2	922.9	O K
7200 min Summer	100.572	0.572	0.0	5.0	0.0	5.0	857.9	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
15 min Summer	188.130	0.0	274.7	0.0	27
30 min Summer	107.217	0.0	297.8	0.0	42
60 min Summer	61.103	0.0	536.0	0.0	72
120 min Summer	34.823	0.0	587.4	0.0	130
180 min Summer	25.062	0.0	617.1	0.0	190
240 min Summer	19.846	0.0	637.5	0.0	250
360 min Summer	14.283	0.0	663.9	0.0	368
480 min Summer	11.310	0.0	680.0	0.0	486
600 min Summer	9.438	0.0	690.0	0.0	606
720 min Summer	8.140	0.0	696.0	0.0	724
960 min Summer	6.609	0.0	711.4	0.0	962
1440 min Summer	4.927	0.0	714.5	0.0	1342
2160 min Summer	3.674	0.0	1287.8	0.0	1688
2880 min Summer	2.983	0.0	1319.4	0.0	2076
4320 min Summer	2.077	0.0	1235.8	0.0	2896
5760 min Summer	1.607	0.0	1704.9	0.0	3696
7200 min Summer	1.317	0.0	1737.8	0.0	4536

Cascade Summary of Results for 2021s1226 100yr+20% Basin1 Outflow=7L!s.SRCX

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
8640 min Summer	100.533	0.533	0.0	4.8	0.0	4.8	799.8	O K
10080 min Summer	100.499	0.499	0.0	4.7	0.0	4.7	747.9	O K
15 min Winter	100.393	0.393	0.0	4.1	0.0	4.1	588.9	O K
30 min Winter	100.446	0.446	0.0	4.4	0.0	4.4	669.4	O K
60 min Winter	100.506	0.506	0.0	4.7	0.0	4.7	758.7	O K
120 min Winter	100.570	0.570	0.0	5.0	0.0	5.0	855.3	O K
180 min Winter	100.609	0.609	0.0	5.2	0.0	5.2	913.7	O K
240 min Winter	100.636	0.636	0.0	5.3	0.0	5.3	954.6	O K
360 min Winter	100.673	0.673	0.0	5.4	0.0	5.4	1009.8	O K
480 min Winter	100.697	0.697	0.0	5.5	0.0	5.5	1045.1	O K
600 min Winter	100.713	0.713	0.0	5.6	0.0	5.6	1068.8	O K
720 min Winter	100.723	0.723	0.0	5.7	0.0	5.7	1085.0	O K
960 min Winter	100.755	0.755	0.0	5.8	0.0	5.8	1132.7	O K
1440 min Winter	100.788	0.788	0.0	5.9	0.0	5.9	1182.1	O K
2160 min Winter	100.803	0.803	0.0	6.0	0.0	6.0	1203.9	O K
2880 min Winter	100.810	0.810	0.0	6.0	0.0	6.0	1214.3	O K
4320 min Winter	100.738	0.738	0.0	5.7	0.0	5.7	1107.1	O K
5760 min Winter	100.672	0.672	0.0	5.4	0.0	5.4	1008.5	O K
7200 min Winter	100.613	0.613	0.0	5.2	0.0	5.2	920.2	O K
8640 min Winter	100.561	0.561	0.0	4.9	0.0	4.9	841.8	O K
10080 min Winter	100.515	0.515	0.0	4.7	0.0	4.7	772.1	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
8640 min Summer	1.119	0.0	1754.6	0.0	5288
10080 min Summer	0.975	0.0	1745.5	0.0	6064
15 min Winter	188.130	0.0	295.6	0.0	27
30 min Winter	107.217	0.0	320.0	0.0	41
60 min Winter	61.103	0.0	583.3	0.0	70
120 min Winter	34.823	0.0	637.3	0.0	128
180 min Winter	25.062	0.0	668.5	0.0	186
240 min Winter	19.846	0.0	689.8	0.0	244
360 min Winter	14.283	0.0	717.3	0.0	362
480 min Winter	11.310	0.0	734.0	0.0	478
600 min Winter	9.438	0.0	744.3	0.0	594
720 min Winter	8.140	0.0	750.4	0.0	708
960 min Winter	6.609	0.0	766.2	0.0	936
1440 min Winter	4.927	0.0	768.6	0.0	1374
2160 min Winter	3.674	0.0	1406.0	0.0	1756
2880 min Winter	2.983	0.0	1435.8	0.0	2200
4320 min Winter	2.077	0.0	1341.3	0.0	3116
5760 min Winter	1.607	0.0	1908.8	0.0	3984
7200 min Winter	1.317	0.0	1943.6	0.0	4840
8640 min Winter	1.119	0.0	1957.5	0.0	5704
10080 min Winter	0.975	0.0	1933.6	0.0	6552

Cascade Rainfall Details for 2021s1226_100yr+20%_Basin1_Outflow=7L!s.SRCX

Rainfall Model	FEH
Return Period (years)	100
FEH Rainfall Version	1999
Site Location	GB 522100 345750 TF 22100 45750
C (1km)	-0.022
D1 (1km)	0.290
D2 (1km)	0.377
D3 (1km)	0.209
E (1km)	0.312
F (1km)	2.495
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+20

Time Area Diagram

Total Area (ha) 1.500

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	0.500	4	8	0.500	8	12	0.500

Cascade Model Details for 2021s1226 100yr+20% Basin1 Outflow=7L!s.SRCX

Storage is Online Cover Level (m) 101.000

Infiltration Basin Structure

Invert Level (m) 100.000 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 1.00
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	1500.0	0.700	1500.0	1.400	1500.0	2.100	1500.0
0.100	1500.0	0.800	1500.0	1.500	1500.0	2.200	1500.0
0.200	1500.0	0.900	1500.0	1.600	1500.0	2.300	1500.0
0.300	1500.0	1.000	1500.0	1.700	1500.0	2.400	1500.0
0.400	1500.0	1.100	1500.0	1.800	1500.0	2.500	1500.0
0.500	1500.0	1.200	1500.0	1.900	1500.0		
0.600	1500.0	1.300	1500.0	2.000	1500.0		

Orifice Outflow Control

Diameter (m) 0.057 Discharge Coefficient 0.600 Invert Level (m) 100.000

Weir Overflow Control

Discharge Coef 0.544 Width (m) 2.000 Invert Level (m) 101.000

Cascade Summary of Results for 2021s1226_100yr+20%_Basin2_Outflow=7L!s.SRCX

Upstream Structures	Outflow To	Overflow To
(None)	2021s1226_100yr+20%_Cascading_Outflow=20L!s.SRCX	2021s1226_100yr+20%_Cascading_Outflow=20L!s.SR

Half Drain Time : 2000 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	100.350	0.350	0.0	3.8	0.0	3.8	525.6	O K
30 min Summer	100.398	0.398	0.0	4.1	0.0	4.1	597.3	O K
60 min Summer	100.451	0.451	0.0	4.4	0.0	4.4	676.7	O K
120 min Summer	100.508	0.508	0.0	4.7	0.0	4.7	762.5	O K
180 min Summer	100.543	0.543	0.0	4.9	0.0	4.9	813.8	O K
240 min Summer	100.566	0.566	0.0	5.0	0.0	5.0	849.7	O K
360 min Summer	100.598	0.598	0.0	5.1	0.0	5.1	897.6	O K
480 min Summer	100.618	0.618	0.0	5.2	0.0	5.2	927.6	O K
600 min Summer	100.631	0.631	0.0	5.3	0.0	5.3	947.2	O K
720 min Summer	100.640	0.640	0.0	5.3	0.0	5.3	960.1	O K
960 min Summer	100.666	0.666	0.0	5.4	0.0	5.4	998.9	O K
1440 min Summer	100.690	0.690	0.0	5.5	0.0	5.5	1035.6	O K
2160 min Summer	100.709	0.709	0.0	5.6	0.0	5.6	1063.4	O K
2880 min Summer	100.717	0.717	0.0	5.6	0.0	5.6	1076.1	O K
4320 min Summer	100.664	0.664	0.0	5.4	0.0	5.4	995.3	O K
5760 min Summer	100.615	0.615	0.0	5.2	0.0	5.2	922.9	O K
7200 min Summer	100.572	0.572	0.0	5.0	0.0	5.0	857.9	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
15 min Summer	188.130	0.0	274.7	0.0	27
30 min Summer	107.217	0.0	297.8	0.0	42
60 min Summer	61.103	0.0	536.0	0.0	72
120 min Summer	34.823	0.0	587.4	0.0	130
180 min Summer	25.062	0.0	617.1	0.0	190
240 min Summer	19.846	0.0	637.5	0.0	250
360 min Summer	14.283	0.0	663.9	0.0	368
480 min Summer	11.310	0.0	680.0	0.0	486
600 min Summer	9.438	0.0	690.0	0.0	606
720 min Summer	8.140	0.0	696.0	0.0	724
960 min Summer	6.609	0.0	711.4	0.0	962
1440 min Summer	4.927	0.0	714.5	0.0	1342
2160 min Summer	3.674	0.0	1287.8	0.0	1688
2880 min Summer	2.983	0.0	1319.4	0.0	2076
4320 min Summer	2.077	0.0	1235.8	0.0	2896
5760 min Summer	1.607	0.0	1704.9	0.0	3696
7200 min Summer	1.317	0.0	1737.8	0.0	4536

Cascade Summary of Results for 2021s1226_100yr+20%_Basin2_Outflow=7L!s.SRCX

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
8640 min Summer	100.533	0.533	0.0	4.8	0.0	4.8	799.8	O K
10080 min Summer	100.499	0.499	0.0	4.7	0.0	4.7	747.9	O K
15 min Winter	100.393	0.393	0.0	4.1	0.0	4.1	588.9	O K
30 min Winter	100.446	0.446	0.0	4.4	0.0	4.4	669.4	O K
60 min Winter	100.506	0.506	0.0	4.7	0.0	4.7	758.7	O K
120 min Winter	100.570	0.570	0.0	5.0	0.0	5.0	855.3	O K
180 min Winter	100.609	0.609	0.0	5.2	0.0	5.2	913.7	O K
240 min Winter	100.636	0.636	0.0	5.3	0.0	5.3	954.6	O K
360 min Winter	100.673	0.673	0.0	5.4	0.0	5.4	1009.8	O K
480 min Winter	100.697	0.697	0.0	5.5	0.0	5.5	1045.1	O K
600 min Winter	100.713	0.713	0.0	5.6	0.0	5.6	1068.8	O K
720 min Winter	100.723	0.723	0.0	5.7	0.0	5.7	1085.0	O K
960 min Winter	100.755	0.755	0.0	5.8	0.0	5.8	1132.7	O K
1440 min Winter	100.788	0.788	0.0	5.9	0.0	5.9	1182.1	O K
2160 min Winter	100.803	0.803	0.0	6.0	0.0	6.0	1203.9	O K
2880 min Winter	100.810	0.810	0.0	6.0	0.0	6.0	1214.3	O K
4320 min Winter	100.738	0.738	0.0	5.7	0.0	5.7	1107.1	O K
5760 min Winter	100.672	0.672	0.0	5.4	0.0	5.4	1008.5	O K
7200 min Winter	100.613	0.613	0.0	5.2	0.0	5.2	920.2	O K
8640 min Winter	100.561	0.561	0.0	4.9	0.0	4.9	841.8	O K
10080 min Winter	100.515	0.515	0.0	4.7	0.0	4.7	772.1	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
8640 min Summer	1.119	0.0	1754.6	0.0	5288
10080 min Summer	0.975	0.0	1745.5	0.0	6064
15 min Winter	188.130	0.0	295.6	0.0	27
30 min Winter	107.217	0.0	320.0	0.0	41
60 min Winter	61.103	0.0	583.3	0.0	70
120 min Winter	34.823	0.0	637.3	0.0	128
180 min Winter	25.062	0.0	668.5	0.0	186
240 min Winter	19.846	0.0	689.8	0.0	244
360 min Winter	14.283	0.0	717.3	0.0	362
480 min Winter	11.310	0.0	734.0	0.0	478
600 min Winter	9.438	0.0	744.3	0.0	594
720 min Winter	8.140	0.0	750.4	0.0	708
960 min Winter	6.609	0.0	766.2	0.0	936
1440 min Winter	4.927	0.0	768.6	0.0	1374
2160 min Winter	3.674	0.0	1406.0	0.0	1756
2880 min Winter	2.983	0.0	1435.8	0.0	2200
4320 min Winter	2.077	0.0	1341.3	0.0	3116
5760 min Winter	1.607	0.0	1908.8	0.0	3984
7200 min Winter	1.317	0.0	1943.6	0.0	4840
8640 min Winter	1.119	0.0	1957.5	0.0	5704
10080 min Winter	0.975	0.0	1933.6	0.0	6552

Cascade Rainfall Details for 2021s1226 100yr+20% Basin2 Outflow=7L!s.SRCX

Rainfall Model	FEH
Return Period (years)	100
FEH Rainfall Version	1999
Site Location	GB 522100 345750 TF 22100 45750
C (1km)	-0.022
D1 (1km)	0.290
D2 (1km)	0.377
D3 (1km)	0.209
E (1km)	0.312
F (1km)	2.495
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+20

Time Area Diagram

Total Area (ha) 1.500

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.500	4	8	0.500	8	12	0.500

Cascade Model Details for 2021s1226 100yr+20% Basin2 Outflow=7L!s.SRCX

Storage is Online Cover Level (m) 101.000

Infiltration Basin Structure

Invert Level (m) 100.000 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 1.00
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	1500.0	0.700	1500.0	1.400	1500.0	2.100	1500.0
0.100	1500.0	0.800	1500.0	1.500	1500.0	2.200	1500.0
0.200	1500.0	0.900	1500.0	1.600	1500.0	2.300	1500.0
0.300	1500.0	1.000	1500.0	1.700	1500.0	2.400	1500.0
0.400	1500.0	1.100	1500.0	1.800	1500.0	2.500	1500.0
0.500	1500.0	1.200	1500.0	1.900	1500.0		
0.600	1500.0	1.300	1500.0	2.000	1500.0		

Orifice Outflow Control

Diameter (m) 0.057 Discharge Coefficient 0.600 Invert Level (m) 100.000

Weir Overflow Control

Discharge Coef 0.544 Width (m) 2.000 Invert Level (m) 101.000

Cascade Summary of Results for 2021s1226 100yr+20% Basin3 Outflow=7L!s.SRCX

Upstream Structures	Outflow To	Overflow To
(None)	2021s1226_100yr+20%_Cascading_Outflow=20L!s.SRCX	2021s1226_100yr+20%_Cascading_Outflow=20L!s.SR

Half Drain Time : 2000 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	100.350	0.350	0.0	3.8	0.0	3.8	525.6	O K
30 min Summer	100.398	0.398	0.0	4.1	0.0	4.1	597.3	O K
60 min Summer	100.451	0.451	0.0	4.4	0.0	4.4	676.7	O K
120 min Summer	100.508	0.508	0.0	4.7	0.0	4.7	762.5	O K
180 min Summer	100.543	0.543	0.0	4.9	0.0	4.9	813.8	O K
240 min Summer	100.566	0.566	0.0	5.0	0.0	5.0	849.7	O K
360 min Summer	100.598	0.598	0.0	5.1	0.0	5.1	897.6	O K
480 min Summer	100.618	0.618	0.0	5.2	0.0	5.2	927.6	O K
600 min Summer	100.631	0.631	0.0	5.3	0.0	5.3	947.2	O K
720 min Summer	100.640	0.640	0.0	5.3	0.0	5.3	960.1	O K
960 min Summer	100.666	0.666	0.0	5.4	0.0	5.4	998.9	O K
1440 min Summer	100.690	0.690	0.0	5.5	0.0	5.5	1035.6	O K
2160 min Summer	100.709	0.709	0.0	5.6	0.0	5.6	1063.4	O K
2880 min Summer	100.717	0.717	0.0	5.6	0.0	5.6	1076.1	O K
4320 min Summer	100.664	0.664	0.0	5.4	0.0	5.4	995.3	O K
5760 min Summer	100.615	0.615	0.0	5.2	0.0	5.2	922.9	O K
7200 min Summer	100.572	0.572	0.0	5.0	0.0	5.0	857.9	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
15 min Summer	188.130	0.0	274.7	0.0	27
30 min Summer	107.217	0.0	297.8	0.0	42
60 min Summer	61.103	0.0	536.0	0.0	72
120 min Summer	34.823	0.0	587.4	0.0	130
180 min Summer	25.062	0.0	617.1	0.0	190
240 min Summer	19.846	0.0	637.5	0.0	250
360 min Summer	14.283	0.0	663.9	0.0	368
480 min Summer	11.310	0.0	680.0	0.0	486
600 min Summer	9.438	0.0	690.0	0.0	606
720 min Summer	8.140	0.0	696.0	0.0	724
960 min Summer	6.609	0.0	711.4	0.0	962
1440 min Summer	4.927	0.0	714.5	0.0	1342
2160 min Summer	3.674	0.0	1287.8	0.0	1688
2880 min Summer	2.983	0.0	1319.4	0.0	2076
4320 min Summer	2.077	0.0	1235.8	0.0	2896
5760 min Summer	1.607	0.0	1704.9	0.0	3696
7200 min Summer	1.317	0.0	1737.8	0.0	4536

Cascade Summary of Results for 2021s1226 100yr+20% Basin3 Outflow=7L!s.SRCX

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
8640 min Summer	100.533	0.533	0.0	4.8	0.0	4.8	799.8	O K
10080 min Summer	100.499	0.499	0.0	4.7	0.0	4.7	747.9	O K
15 min Winter	100.393	0.393	0.0	4.1	0.0	4.1	588.9	O K
30 min Winter	100.446	0.446	0.0	4.4	0.0	4.4	669.4	O K
60 min Winter	100.506	0.506	0.0	4.7	0.0	4.7	758.7	O K
120 min Winter	100.570	0.570	0.0	5.0	0.0	5.0	855.3	O K
180 min Winter	100.609	0.609	0.0	5.2	0.0	5.2	913.7	O K
240 min Winter	100.636	0.636	0.0	5.3	0.0	5.3	954.6	O K
360 min Winter	100.673	0.673	0.0	5.4	0.0	5.4	1009.8	O K
480 min Winter	100.697	0.697	0.0	5.5	0.0	5.5	1045.1	O K
600 min Winter	100.713	0.713	0.0	5.6	0.0	5.6	1068.8	O K
720 min Winter	100.723	0.723	0.0	5.7	0.0	5.7	1085.0	O K
960 min Winter	100.755	0.755	0.0	5.8	0.0	5.8	1132.7	O K
1440 min Winter	100.788	0.788	0.0	5.9	0.0	5.9	1182.1	O K
2160 min Winter	100.803	0.803	0.0	6.0	0.0	6.0	1203.9	O K
2880 min Winter	100.810	0.810	0.0	6.0	0.0	6.0	1214.3	O K
4320 min Winter	100.738	0.738	0.0	5.7	0.0	5.7	1107.1	O K
5760 min Winter	100.672	0.672	0.0	5.4	0.0	5.4	1008.5	O K
7200 min Winter	100.613	0.613	0.0	5.2	0.0	5.2	920.2	O K
8640 min Winter	100.561	0.561	0.0	4.9	0.0	4.9	841.8	O K
10080 min Winter	100.515	0.515	0.0	4.7	0.0	4.7	772.1	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
8640 min Summer	1.119	0.0	1754.6	0.0	5288
10080 min Summer	0.975	0.0	1745.5	0.0	6064
15 min Winter	188.130	0.0	295.6	0.0	27
30 min Winter	107.217	0.0	320.0	0.0	41
60 min Winter	61.103	0.0	583.3	0.0	70
120 min Winter	34.823	0.0	637.3	0.0	128
180 min Winter	25.062	0.0	668.5	0.0	186
240 min Winter	19.846	0.0	689.8	0.0	244
360 min Winter	14.283	0.0	717.3	0.0	362
480 min Winter	11.310	0.0	734.0	0.0	478
600 min Winter	9.438	0.0	744.3	0.0	594
720 min Winter	8.140	0.0	750.4	0.0	708
960 min Winter	6.609	0.0	766.2	0.0	936
1440 min Winter	4.927	0.0	768.6	0.0	1374
2160 min Winter	3.674	0.0	1406.0	0.0	1756
2880 min Winter	2.983	0.0	1435.8	0.0	2200
4320 min Winter	2.077	0.0	1341.3	0.0	3116
5760 min Winter	1.607	0.0	1908.8	0.0	3984
7200 min Winter	1.317	0.0	1943.6	0.0	4840
8640 min Winter	1.119	0.0	1957.5	0.0	5704
10080 min Winter	0.975	0.0	1933.6	0.0	6552

Cascade Rainfall Details for 2021s1226 100yr+20% Basin3 Outflow=7L!s.SRCX

Rainfall Model	FEH
Return Period (years)	100
FEH Rainfall Version	1999
Site Location	GB 522100 345750 TF 22100 45750
C (1km)	-0.022
D1 (1km)	0.290
D2 (1km)	0.377
D3 (1km)	0.209
E (1km)	0.312
F (1km)	2.495
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+20

Time Area Diagram

Total Area (ha) 1.500

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	0.500	4	8	0.500	8	12	0.500

Cascade Model Details for 2021s1226 100yr+20% Basin3 Outflow=7L!s.SRCX

Storage is Online Cover Level (m) 101.000

Infiltration Basin Structure

Invert Level (m) 100.000 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 1.00
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	**Area (m²)**	**Depth (m)**	**Area (m²)**	**Depth (m)**	**Area (m²)**	**Depth (m)**	**Area (m²)**
0.000	1500.0	0.700	1500.0	1.400	1500.0	2.100	1500.0
0.100	1500.0	0.800	1500.0	1.500	1500.0	2.200	1500.0
0.200	1500.0	0.900	1500.0	1.600	1500.0	2.300	1500.0
0.300	1500.0	1.000	1500.0	1.700	1500.0	2.400	1500.0
0.400	1500.0	1.100	1500.0	1.800	1500.0	2.500	1500.0
0.500	1500.0	1.200	1500.0	1.900	1500.0		
0.600	1500.0	1.300	1500.0	2.000	1500.0		

Orifice Outflow Control

Diameter (m) 0.057 Discharge Coefficient 0.600 Invert Level (m) 100.000

Weir Overflow Control

Discharge Coef 0.544 Width (m) 2.000 Invert Level (m) 101.000

Cascade Summary of Results for 2021s1226 100yr+20% Cascading Outflow=20L!s.SRCX

Upstream Structures	Outflow To	Overflow To
2021s1226_100yr+20%_Basin1_Outflow=7L!s.SRCX	(None)	(None)
2021s1226_100yr+20%_Basin2_Outflow=7L!s.SRCX		
2021s1226_100yr+20%_Basin3_Outflow=7L!s.SRCX		

Half Drain Time : 613 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	100.341	0.341	0.0	12.8	0.0	12.8	510.9	O K
30 min Summer	100.388	0.388	0.0	13.8	0.0	13.8	581.9	O K
60 min Summer	100.442	0.442	0.0	14.9	0.0	14.9	662.3	O K
120 min Summer	100.502	0.502	0.0	16.0	0.0	16.0	752.8	O K
180 min Summer	100.540	0.540	0.0	16.7	0.0	16.7	810.0	O K
240 min Summer	100.568	0.568	0.0	17.1	0.0	17.1	852.2	O K
360 min Summer	100.608	0.608	0.0	17.8	0.0	17.8	912.7	O K
480 min Summer	100.637	0.637	0.0	18.3	0.0	18.3	955.2	O K
600 min Summer	100.658	0.658	0.0	18.6	0.0	18.6	986.9	O K
720 min Summer	100.674	0.674	0.0	18.8	0.0	18.8	1011.2	O K
960 min Summer	100.714	0.714	0.0	19.4	0.0	19.4	1071.7	O K
1440 min Summer	100.763	0.763	0.0	20.1	0.0	20.1	1144.3	O K
2160 min Summer	100.792	0.792	0.0	20.5	0.0	20.5	1188.2	O K
2880 min Summer	100.806	0.806	0.0	20.7	0.0	20.7	1209.1	O K
4320 min Summer	100.758	0.758	0.0	20.1	0.0	20.1	1137.0	O K
5760 min Summer	100.714	0.714	0.0	19.4	0.0	19.4	1070.8	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
15 min Summer	188.130	0.0	993.0	0.0	27
30 min Summer	107.217	0.0	1075.5	0.0	42
60 min Summer	61.103	0.0	2031.3	0.0	72
120 min Summer	34.823	0.0	2217.9	0.0	132
180 min Summer	25.062	0.0	2324.3	0.0	190
240 min Summer	19.846	0.0	2395.9	0.0	250
360 min Summer	14.283	0.0	2487.0	0.0	370
480 min Summer	11.310	0.0	2540.1	0.0	488
600 min Summer	9.438	0.0	2571.1	0.0	608
720 min Summer	8.140	0.0	2587.6	0.0	728
960 min Summer	6.609	0.0	2632.3	0.0	966
1440 min Summer	4.927	0.0	2622.4	0.0	1442
2160 min Summer	3.674	0.0	4974.3	0.0	2020
2880 min Summer	2.983	0.0	5061.2	0.0	2348
4320 min Summer	2.077	0.0	4686.8	0.0	3072
5760 min Summer	1.607	0.0	6734.5	0.0	3864

Cascade Summary of Results for 2021s1226 100yr+20% Cascading Outflow=20L!s.SRCX

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
7200 min Summer	100.673	0.673	0.0	18.8	0.0	18.8	1008.9	O K
8640 min Summer	100.635	0.635	0.0	18.2	0.0	18.2	952.0	O K
10080 min Summer	100.600	0.600	0.0	17.7	0.0	17.7	899.6	O K
15 min Winter	100.381	0.381	0.0	13.7	0.0	13.7	572.1	O K
30 min Winter	100.434	0.434	0.0	14.7	0.0	14.7	651.6	O K
60 min Winter	100.494	0.494	0.0	15.9	0.0	15.9	741.6	O K
120 min Winter	100.562	0.562	0.0	17.0	0.0	17.0	842.8	O K
180 min Winter	100.605	0.605	0.0	17.7	0.0	17.7	906.8	O K
240 min Winter	100.636	0.636	0.0	18.2	0.0	18.2	953.9	O K
360 min Winter	100.681	0.681	0.0	18.9	0.0	18.9	1021.8	O K
480 min Winter	100.713	0.713	0.0	19.4	0.0	19.4	1069.7	O K
600 min Winter	100.737	0.737	0.0	19.8	0.0	19.8	1105.7	O K
720 min Winter	100.756	0.756	0.0	20.0	0.0	20.0	1133.6	O K
960 min Winter	100.802	0.802	0.0	20.7	0.0	20.7	1203.2	O K
1440 min Winter	100.860	0.860	0.0	21.5	0.0	21.5	1290.2	O K
2160 min Winter	100.900	0.900	0.0	22.0	0.0	22.0	1350.2	O K
2880 min Winter	100.911	0.911	0.0	22.1	0.0	22.1	1366.8	O K
4320 min Winter	100.850	0.850	0.0	21.3	0.0	21.3	1274.9	O K
5760 min Winter	100.790	0.790	0.0	20.5	0.0	20.5	1185.7	O K
7200 min Winter	100.733	0.733	0.0	19.7	0.0	19.7	1099.9	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
7200 min Summer	1.317	0.0	6856.5	0.0	4680
8640 min Summer	1.119	0.0	6906.7	0.0	5456
10080 min Summer	0.975	0.0	6842.7	0.0	6256
15 min Winter	188.130	0.0	1068.2	0.0	27
30 min Winter	107.217	0.0	1154.9	0.0	42
60 min Winter	61.103	0.0	2204.8	0.0	72
120 min Winter	34.823	0.0	2399.9	0.0	130
180 min Winter	25.062	0.0	2510.9	0.0	188
240 min Winter	19.846	0.0	2585.6	0.0	248
360 min Winter	14.283	0.0	2680.3	0.0	364
480 min Winter	11.310	0.0	2735.0	0.0	482
600 min Winter	9.438	0.0	2766.7	0.0	600
720 min Winter	8.140	0.0	2783.1	0.0	716
960 min Winter	6.609	0.0	2828.7	0.0	950
1440 min Winter	4.927	0.0	2815.9	0.0	1406
2160 min Winter	3.674	0.0	5414.2	0.0	2060
2880 min Winter	2.983	0.0	5490.7	0.0	2628
4320 min Winter	2.077	0.0	5074.0	0.0	3280
5760 min Winter	1.607	0.0	7539.5	0.0	4152
7200 min Winter	1.317	0.0	7665.9	0.0	5040

Cascade Summary of Results for 2021s1226 100yr+20% Cascading Outflow=20L!s.SRCX

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
8640 min Winter	100.680	0.680	0.0	18.9	0.0	18.9	1020.0	O K
10080 min Winter	100.631	0.631	0.0	18.2	0.0	18.2	946.7	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
8640 min Winter	1.119	0.0	7699.4	0.0	5880
10080 min Winter	0.975	0.0	7573.2	0.0	6664

Cascade Rainfall Details for 2021s1226 100yr+20% Cascading Outflow=20L!s.SRCX

Rainfall Model	FEH
Return Period (years)	100
FEH Rainfall Version	1999
Site Location	GB 522100 345750 TF 22100 45750
C (1km)	-0.022
D1 (1km)	0.290
D2 (1km)	0.377
D3 (1km)	0.209
E (1km)	0.312
F (1km)	2.495
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+20

Time Area Diagram

Total Area (ha) 1.450

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	0.500	4	8	0.500	8	12	0.450

Cascade Model Details for 2021s1226 100yr+20% Cascading Outflow=20L!s.SRCX

Storage is Online Cover Level (m) 101.000

Infiltration Basin Structure

Invert Level (m) 100.000 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 1.00
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	1500.0	0.700	1500.0	1.400	1500.0	2.100	1500.0
0.100	1500.0	0.800	1500.0	1.500	1500.0	2.200	1500.0
0.200	1500.0	0.900	1500.0	1.600	1500.0	2.300	1500.0
0.300	1500.0	1.000	1500.0	1.700	1500.0	2.400	1500.0
0.400	1500.0	1.100	1500.0	1.800	1500.0	2.500	1500.0
0.500	1500.0	1.200	1500.0	1.900	1500.0		
0.600	1500.0	1.300	1500.0	2.000	1500.0		

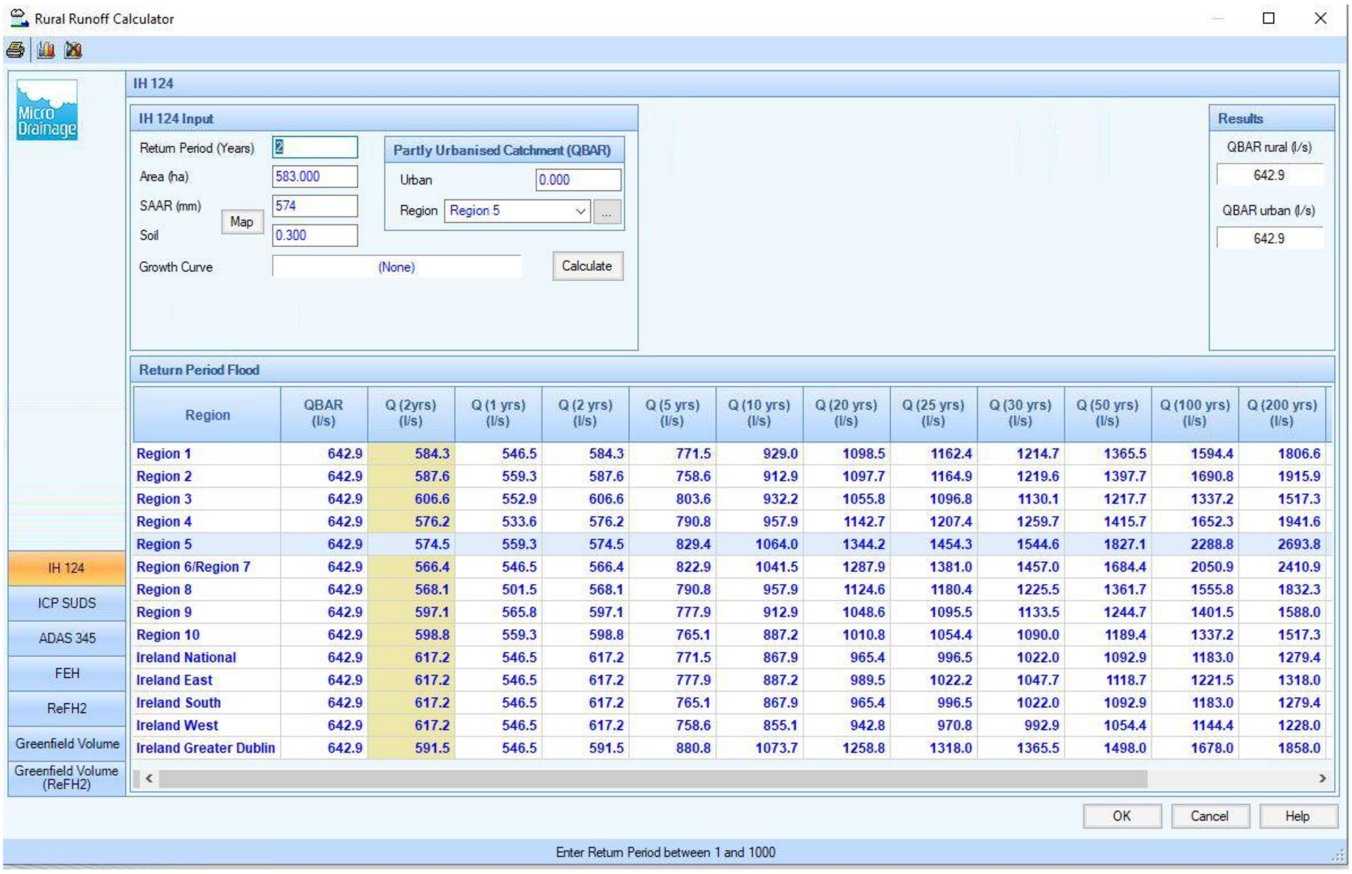
Orifice Outflow Control

Diameter (m) 0.107 Discharge Coefficient 0.600 Invert Level (m) 100.000

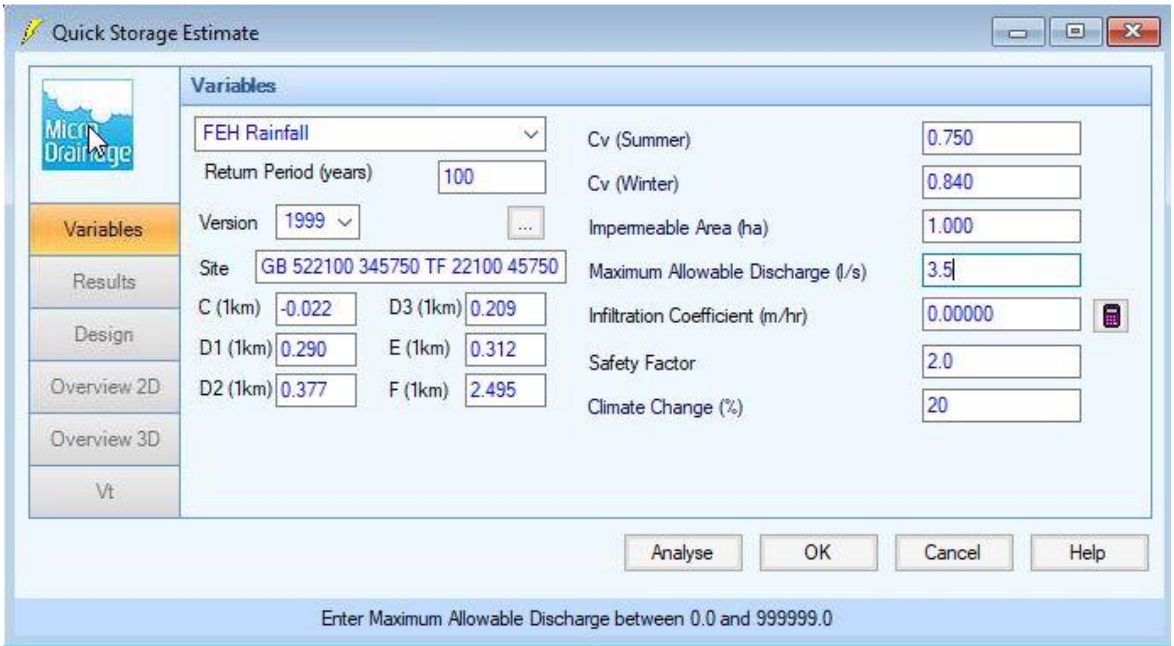
Weir Overflow Control

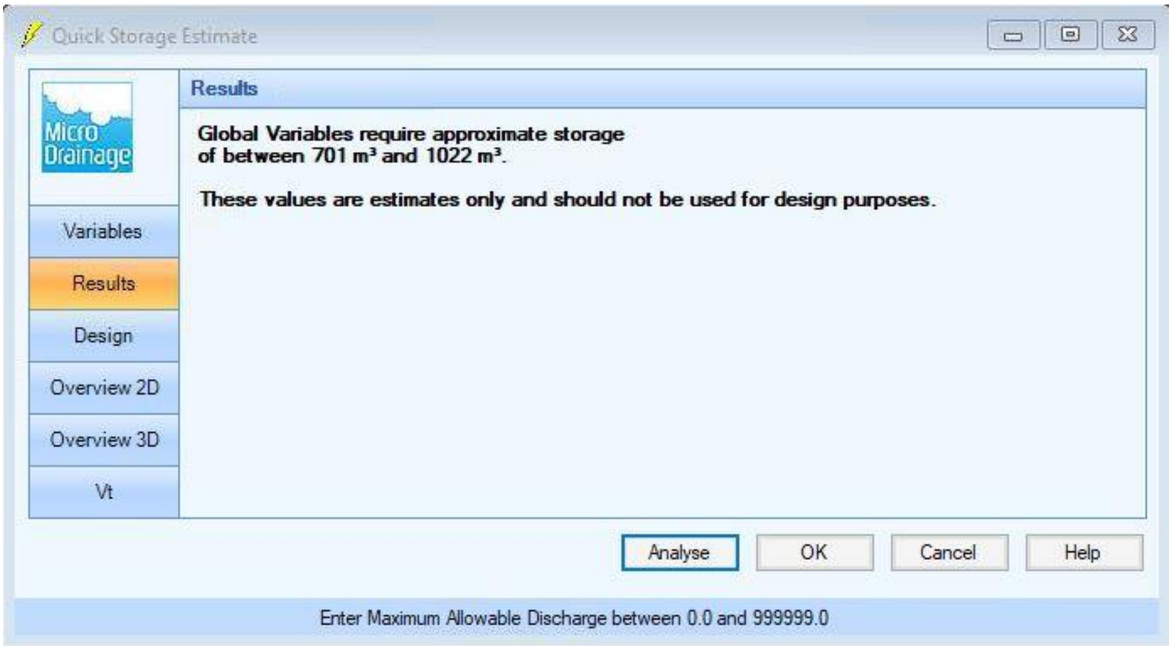
Discharge Coef 0.544 Width (m) 2.000 Invert Level (m) 101.000

Appendix D: Greenfield Runoff & Storage Calculation Record



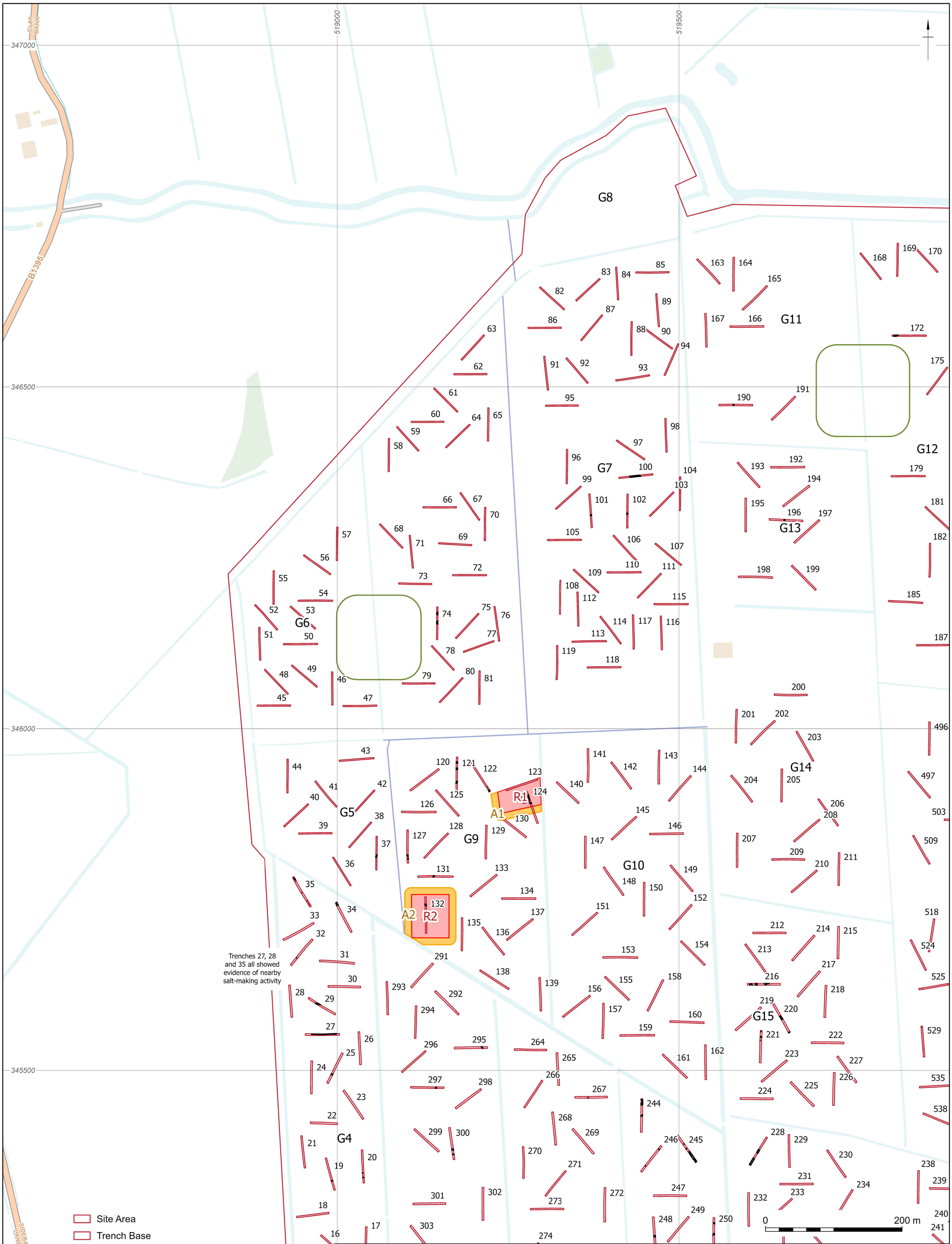
Region	QBAR (l/s)	Q (2yrs) (l/s)	Q (1 yrs) (l/s)	Q (2 yrs) (l/s)	Q (5 yrs) (l/s)	Q (10 yrs) (l/s)	Q (20 yrs) (l/s)	Q (25 yrs) (l/s)	Q (30 yrs) (l/s)	Q (50 yrs) (l/s)	Q (100 yrs) (l/s)	Q (200 yrs) (l/s)
Region 1	642.9	584.3	546.5	584.3	771.5	929.0	1098.5	1162.4	1214.7	1365.5	1594.4	1806.6
Region 2	642.9	587.6	559.3	587.6	758.6	912.9	1097.7	1164.9	1219.6	1397.7	1690.8	1915.9
Region 3	642.9	606.6	552.9	606.6	803.6	932.2	1055.8	1096.8	1130.1	1217.7	1337.2	1517.3
Region 4	642.9	576.2	533.6	576.2	790.8	957.9	1142.7	1207.4	1259.7	1415.7	1652.3	1941.6
Region 5	642.9	574.5	559.3	574.5	829.4	1064.0	1344.2	1454.3	1544.6	1827.1	2288.8	2693.8
Region 6/Region 7	642.9	566.4	546.5	566.4	822.9	1041.5	1287.9	1381.0	1457.0	1684.4	2050.9	2410.9
Region 8	642.9	568.1	501.5	568.1	790.8	957.9	1124.6	1180.4	1225.5	1361.7	1555.8	1832.3
Region 9	642.9	597.1	565.8	597.1	777.9	912.9	1048.6	1095.5	1133.5	1244.7	1401.5	1588.0
Region 10	642.9	598.8	559.3	598.8	765.1	887.2	1010.8	1054.4	1090.0	1189.4	1337.2	1517.3
Ireland National	642.9	617.2	546.5	617.2	771.5	867.9	965.4	996.5	1022.0	1092.9	1183.0	1279.4
Ireland East	642.9	617.2	546.5	617.2	777.9	887.2	989.5	1022.2	1047.7	1118.7	1221.5	1318.0
Ireland South	642.9	617.2	546.5	617.2	765.1	867.9	965.4	996.5	1022.0	1092.9	1183.0	1279.4
Ireland West	642.9	617.2	546.5	617.2	758.6	855.1	942.8	970.8	992.9	1054.4	1144.4	1228.0
Ireland Greater Dublin	642.9	591.5	546.5	591.5	880.8	1073.7	1258.8	1318.0	1365.5	1498.0	1678.0	1858.0





Quick Storage Estimate
Micro Drainage
Variables
Results
Design
Overview 2D
Overview 3D
Vt
Results
Global Variables require approximate storage of between 701 m³ and 1022 m³.
These values are estimates only and should not be used for design purposes.
Analyse
OK
Cancel
Help
Enter Maximum Allowable Discharge between 0.0 and 999999.0

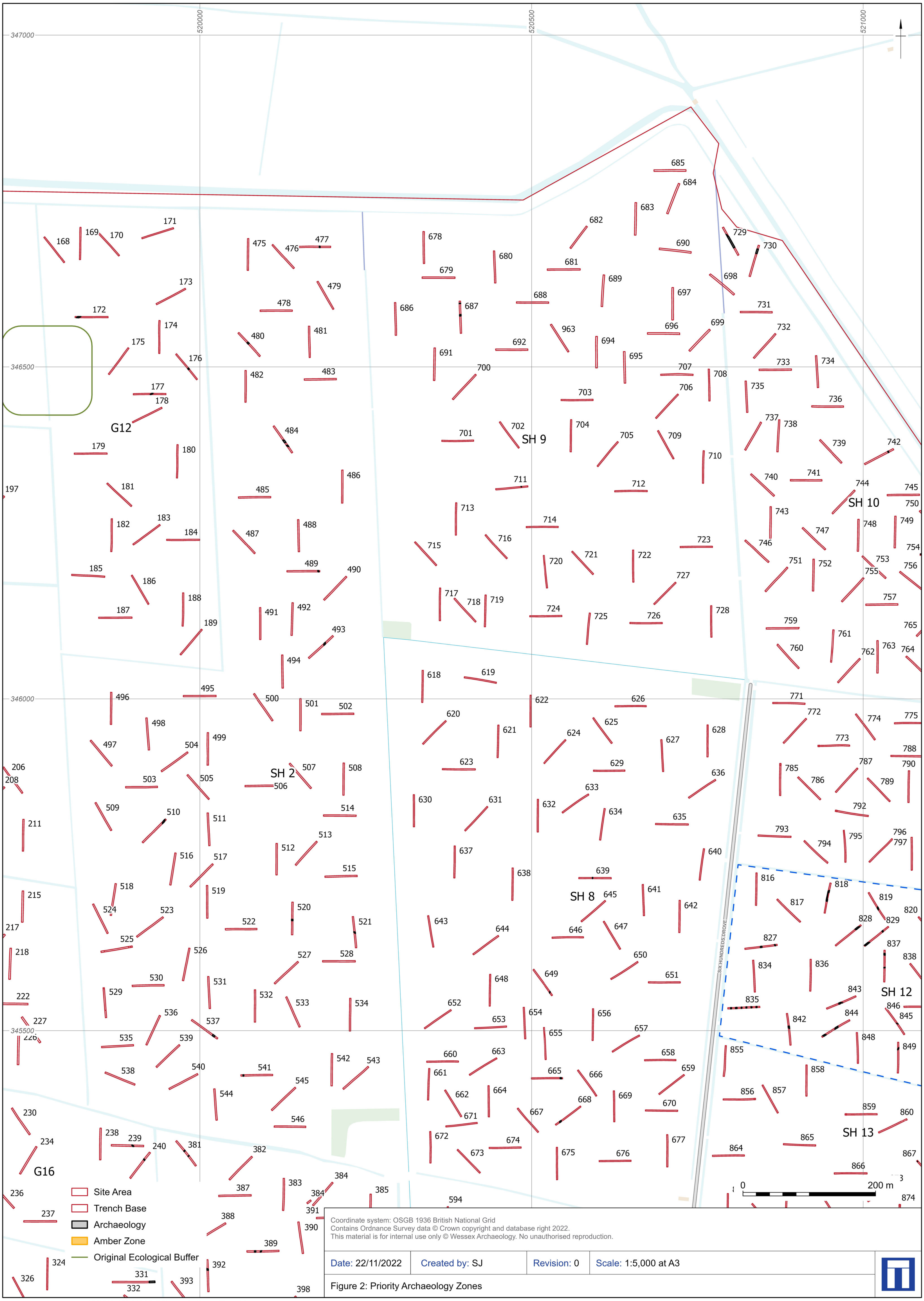
Appendix E: Priority Archaeology Zones



Date: 22/11/2022	Created by: SJ	Revision: 0	Scale: 1:5,000 at A3

Figure 1: Priority Archaeology Zones

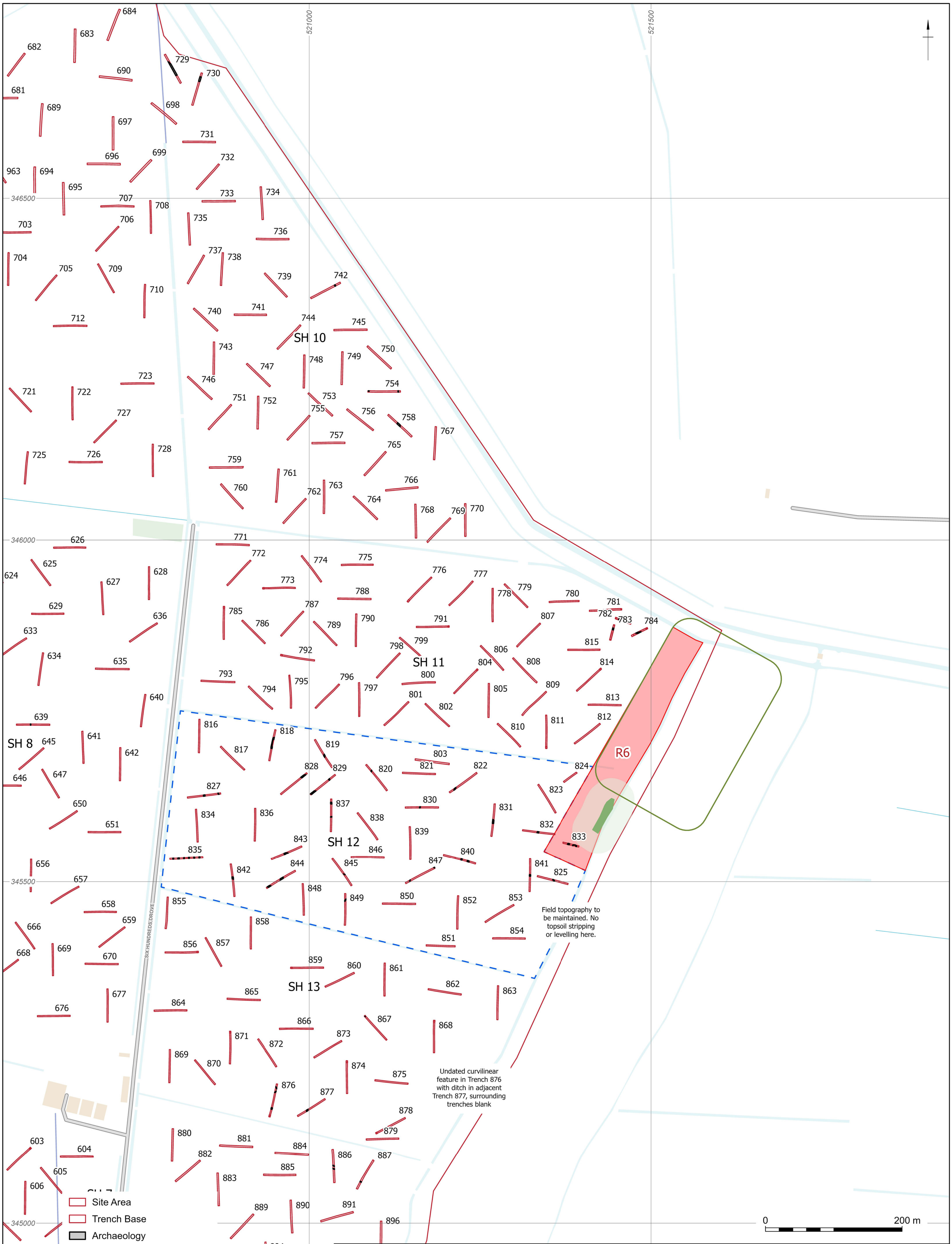
S:\PROJECTS\267010\Geomatics\Survey\267010_working.aprx



Date: 22/11/2022	Created by: SJ	Revision: 0	Scale: 1:5,000 at A3

Figure 2: Priority Archaeology Zones

S:\PROJECTS\267010\Geomatics\Survey\267010_working.aprx

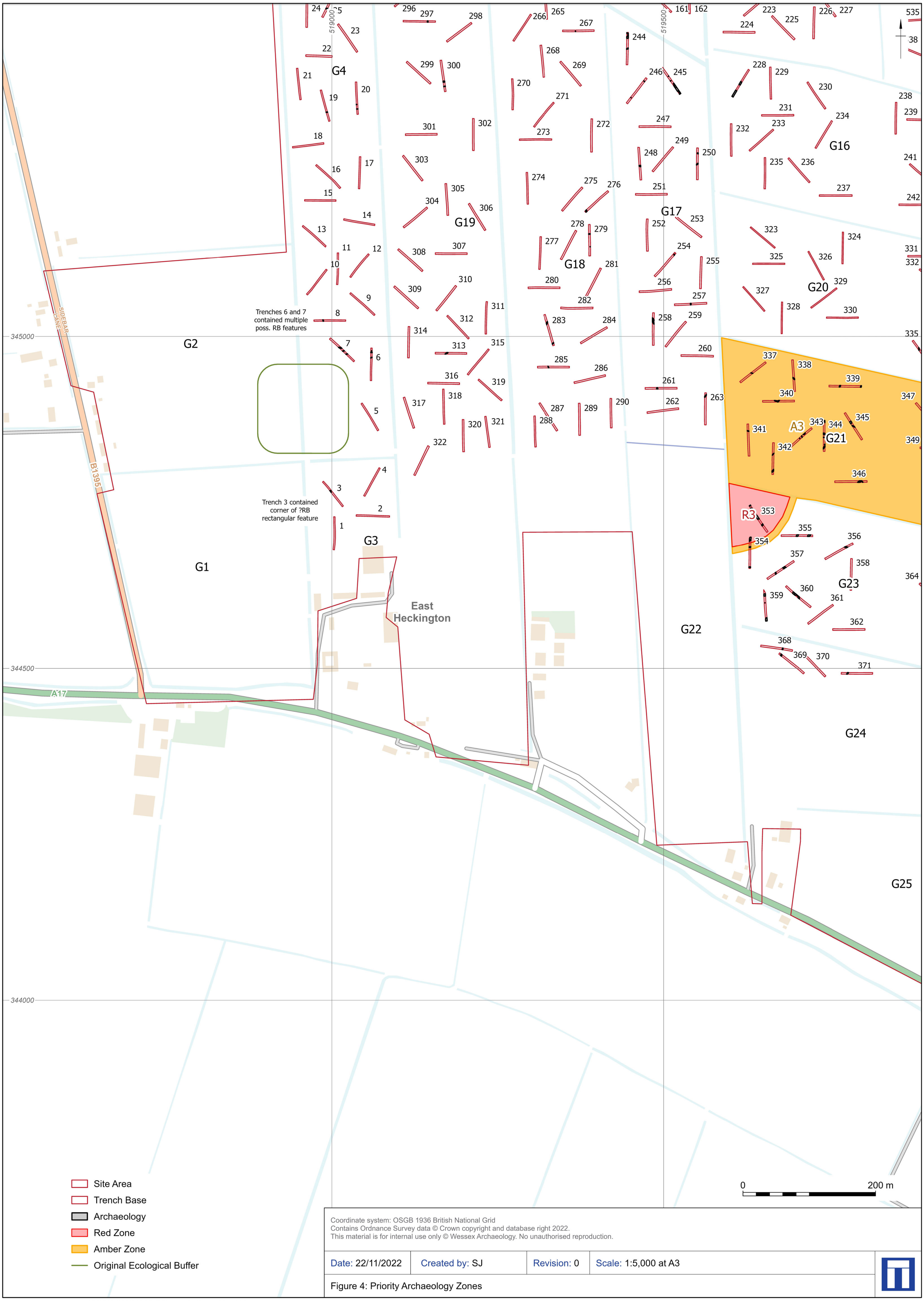


Coordinate system: OSGB 1936 British National Grid

Date: 22/11/2022 | Created by: SJ | Revision: 0 | Scale: 1:5,000 at A3

Figure 3: Priority Archaeology Zones

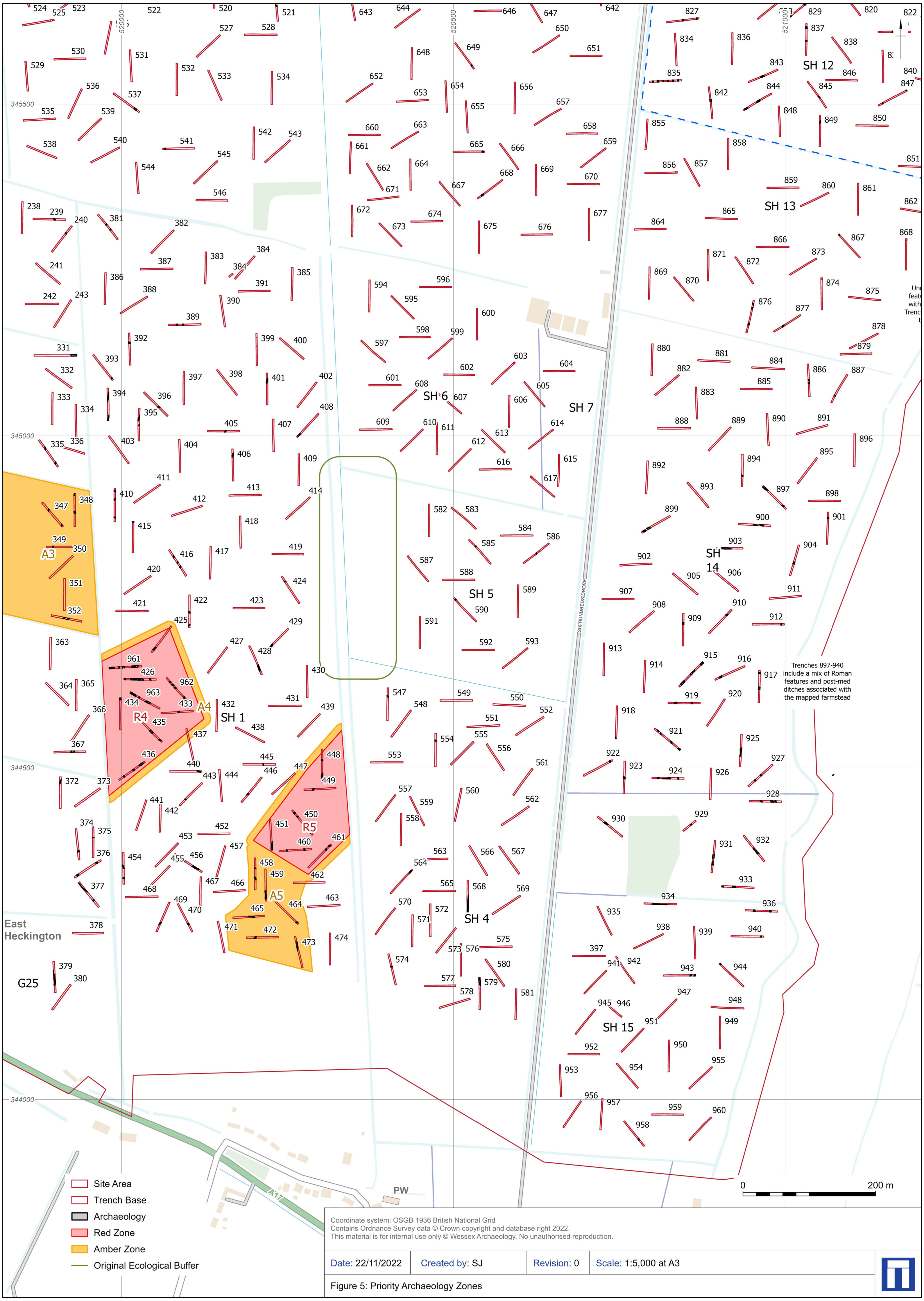
S:\PROJECTS\267010\Geomatics\Survey\267010_working.aprx



Date: 22/11/2022 | Created by: SJ | Revision: 0 | Scale: 1:5,000 at A3

Figure 4: Priority Archaeology Zones

S:\PROJECTS\267010\Geomatics\Survey\267010_working.aprx



Coordinate system: OSGB 1936 British National Grid
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Figure 5: Priority Archaeology Zones

S:\PROJECTS\267010\Geomatics\Survey\267010_working.aprx

Offices at

Coleshill
Doncaster
Dublin
Edinburgh
Exeter
Glasgow
Haywards Heath
Isle of Man
Limerick
Newcastle upon Tyne
Newport
Peterborough
Saltaire
Skipton
Tadcaster
Thirsk
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Warrington

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