FENWICK SOLAR FARM

Fenwick Solar Farm
EN010152

Environmental Statement

Volume III Appendix 9-3: Flood Risk Assessment, Annexes

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BOOM POWER

Revision History

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00	October 2024	DCO application
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Prepared for:
Fenwick Solar Project Limited

Prepared by:
AECOM Limited

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1. Introduction

1.1 Commission

1.1.1 AECOM Limited (AECOM) has been commissioned by Fenwick Solar Project Limited (the Applicant) to undertake a flood modelling assessment to support the Development Consent Order (DCO) application for the proposed Fenwick Solar Farm, near Askern, Doncaster, South Yorkshire (hereafter referred to as the 'the Scheme').

1.1.2 This flood modelling report is an Annex to **Environmental Statement Volume III Appendix 9-3: Flood Risk Assessment (FRA) [EN010152/APP/6.3]**. This report describes the fluvial modelling completed for the River Went, Fleet Drain and Fleet Common Drain, along with breach modelling to assess residual risk to the Scheme from the tidal River Don.

1.1.3 Following review of **Volume III Appendix 9-3: FRA [EN010152/APP/6.3]** and supporting hydraulic modelling by the Environment Agency in February 2025 an addendum report providing additional hydraulic modelling evidence has been produced and attached to the report. The addendum includes a sensitivity analysis of catchment initial conditions and the assessment of the proposed removal of the Fleet Drain culvert scenario. The reader is referred to Appendix D for full details of the additional modelling undertaken.

1.1.4 The main outcome from the additional sensitivity analysis was the decision to use the original modelled Credible Maximum Scenario (Section 6.5) as the design event for assessment of the scheme and design of mitigation measures, rather than the 1% AEP + 38% CC simulation that was considered the design event for the DCO FRA (Section 5). This report has been updated, where required, in order to reflect the findings of the sensitivity analysis.

1.1.5 It should be noted that the sensitivity and proposed scenario simulations have been undertaken for the fluvial design events only, and no updates have been made to the breach modelling.

1.2 Aims and Objectives

1.2.1 The primary aim of this report is to document flood modelling work that has been undertaken to support the FRA and DCO application for the Scheme.

1.2.2 In order to fulfil this aim, the following objectives have been met:

a. Initial data collection, including new topographical survey;

b. Catchment review and hydrological analysis of all contributing catchments, culminating in the estimation of design flows for use in the hydraulic model;

c. Baseline hydraulic model construction, refinement, and simulation for a range of Annual Exceedance Probability (AEP) events, including the application of the latest climate change allowances in accordance with Environment Agency guidance;

d. Undertake model proving, including a verification exercise and sensitivity analysis, in order to enhance confidence in the model and associated outputs;

e. Breach model construction and simulation for two breach locations;

f. Produce a hydraulic modelling report (this document) as an Annex to the FRA to support the DCO application.

1.3 Location

1.3.1 The Scheme is located approximately 5 kilometres (km) northeast of the centre of Askern and 3 km south of the centre of Pollington (Plate 1-1). The centre of the Scheme is located at NGR SE 59827 16181 and the nearest postcode is DN6 0HB. The Scheme is generally rural and is comprised of greenfield land and cropland. Within the vicninity are the following features:

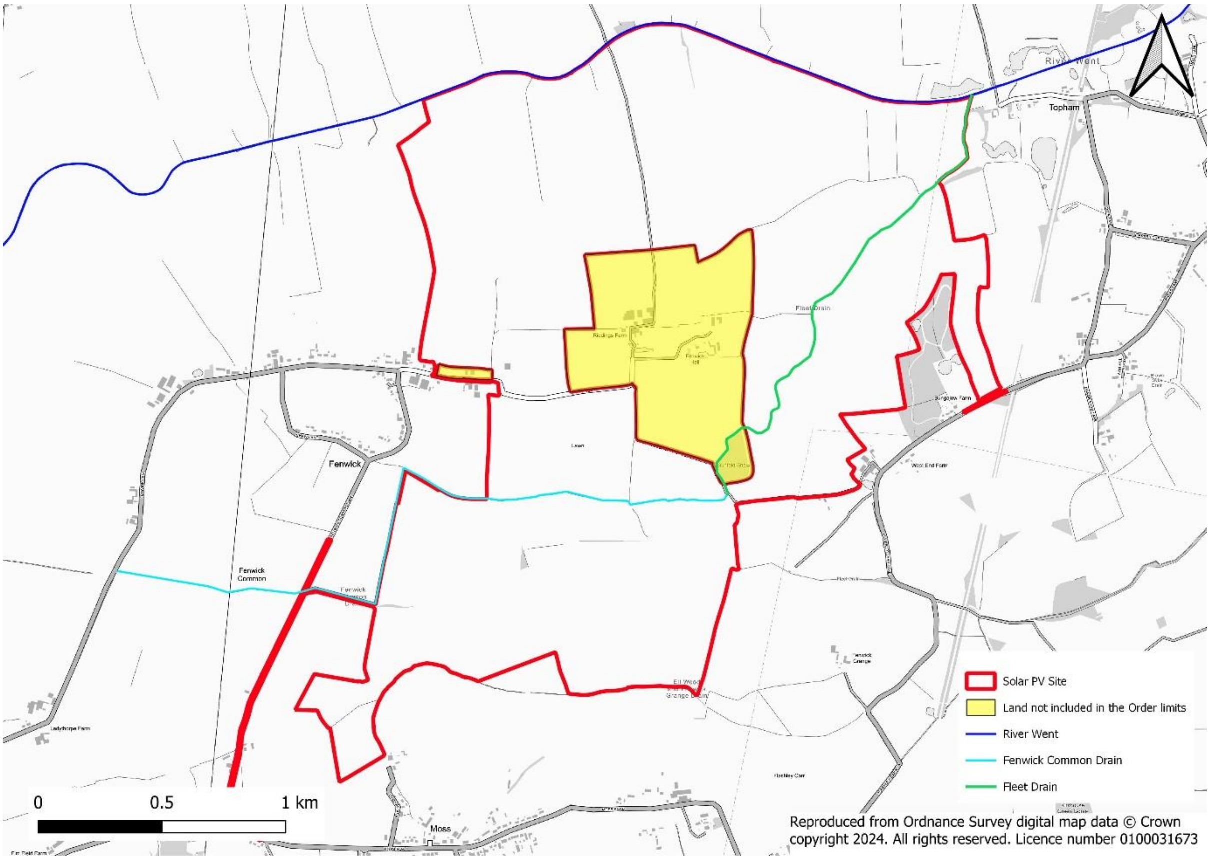
a. Immediately north of the Scheme is the River Went. North of the River Went are fields and agricultural land. Approximately 2 km north is the Aire and Calder Navigation canal. The M62 is located 3.5 km north of the Scheme.

b. The Scheme's eastern boundary is bordered by agricultural land. Further, 250 metres (m) east is a disused railway line, 2.15 km east is the New Junction Canal Viaduct which conveys the canal over the River Went and 5 km east is the River Don and Selby Road (A614).

c. Immediately south of the Scheme are fields and agricultural land. Approximately 500m to the south is the village of Moss.

d. To the west of the Scheme are fields and agricultural land. Approximately 700 m to the west is the East Coast Main railway line and 3.2 km west is the A19.

1.3.2 The Scheme boundary is shown in Plate 1-1. The Scheme is currently occupied by agricultural land divided by hedgerows and trees, and is approximately 420 hectares (ha) in area.



~~Figure~~Plate 1-1: Solar PV Site Overview

1.4 Local Water Features

1.4.1 The Scheme is bounded by the River Went to the north which is classified as a ‘statutory main river’. The River Went drains into the River Don, with the confluence located over 5 km downstream of the Scheme. The outfall structure of the River Went is sluice gates that are fully closed when water levels are high in the River Don.

1.4.2 The River Don is a statutory main river, drains a large catchment area and is tidally influenced at the Went outfall location. The River Don has flood defence embankments that, along with the outfall sluice, prevent water from the River Don entering the River Went and its floodplain~~.~~

1.4.3 There are two additional watercourses that intersect the Scheme and are relevant to flood risk for the development. These include:

a. Fenwick Common Drain, which is 3 km long, and merges with the Fleet Drain at Bunfold Shaw Lane.

b. Fleet Drain, which is 0.5 km long and merges with the River Went at the northeast corner of the Scheme site.’

1.4.4 The Scheme boundary, and the watercourses described above, are shown in Plate 1-1.

2. Data Collection

2.1 Environment Agency Liaison

2.1.1 Key consultation with the Environment Agency in relation to the Scheme, and associated FRA, is shown in Table 2-1.

2.1.2 Following submission of the baseline hydraulic model that informed the DCO FRA and subsequent review by the Environment Agency (05/02/2025), agreement between the design modelling outputs and the available observed gauge data record in the catchment was discussed. As a result, further sensitivity analysis was undertaken to understand the impact of the initial conditions within the catchment on the modelled maximum water levels. This is presented as an addendum technical note to the main report and provides an additional evidence base to support the conclusions of this report and the FRA.

Table 2-1: Environment Agency Key Consultation

Date of Consultation	Key Considerations
3 October 2023	Environment Agency- Meeting 1- Flood risk modelling- available data and methodology
17 May 2024	Environment Agency - Meeting 2- Flood risk modelling methodology and survey limitations. Modelling methodology document supplied to the Environment Agency following meeting.
5 September 2024	Environment Agency - Meeting 3- Flood risk modelling results and mitigation
28 February 2025 to 22 April 2025	Environment Agency- Meeting 3,4 & 5 - Flood risk modelling results and mitigation
8 May 2025	Model verification results and agreement email

2.2 Historic Flood Information

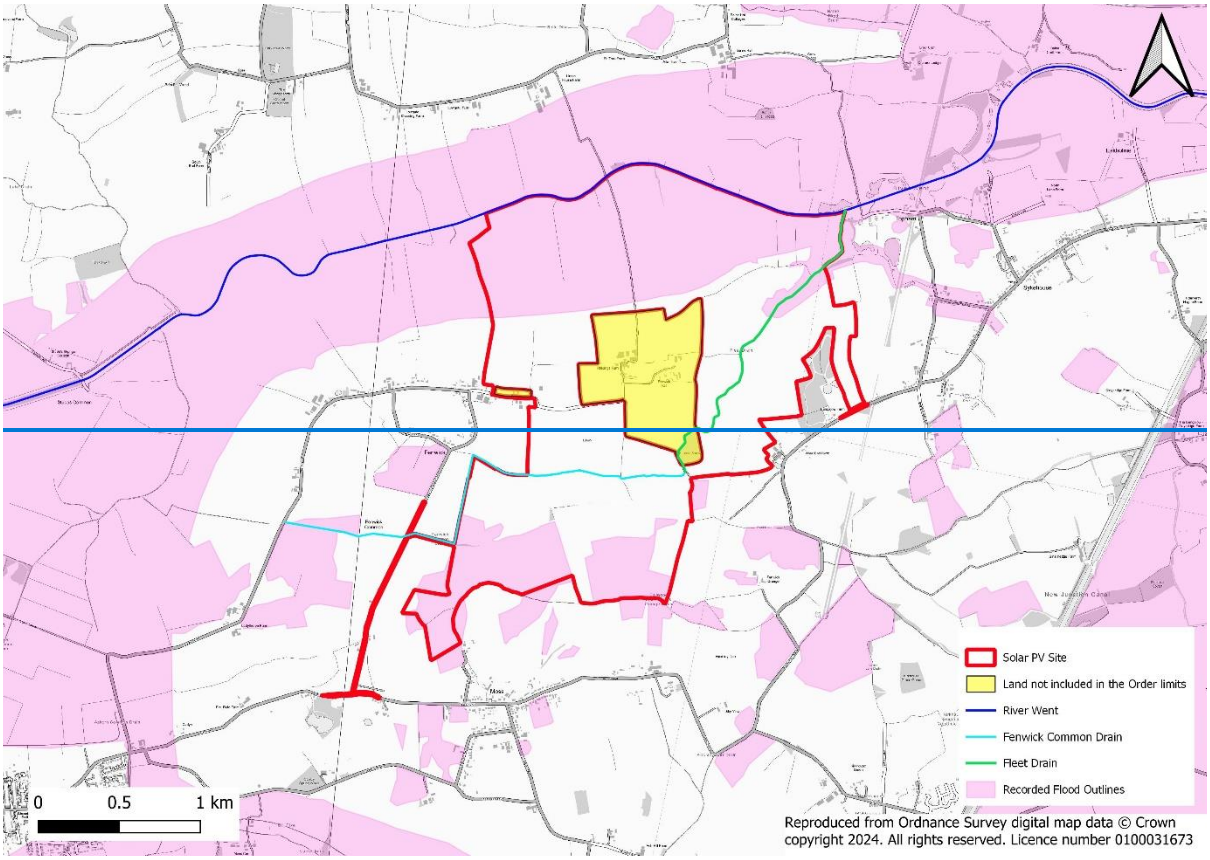
2.2.1 The Environment Agency's Recorded Flood Outlines GIS layer[1],which shows all records of historic flooding from rivers, the sea, groundwater, and surface water since 1946, has been reviewed. As detailed in Table 2-2, this layer shows that there has been marginal flooding of the Scheme in 1947, 1995, 2000, 2007 and 2020 by the River Went and surface water flooding.

2.2.2 The recorded flood outlines for three flood events in March 1947, February 1995, November 2000, June 2007, November 2019 and February 2020, overlap the boundaries of the Scheme as shown in Plate 2-1.

[1] Environment Agency Recorded Flood Outlines: https://environment.data.gov.uk/dataset/8c75e700-d465-11e4-8b5b-f0def148f590 [Accessed June 2024].

Table 2-2: List of recorded flood outlines overlapping the boundary of the Scheme

Date of event	Source of flooding	Mechanism of flooding	Description
March 1947	River Went	Operational failure/breach of defence	Northern sections of the Scheme shown to be in flood due to River Went
February 1995	River Went	Channel capacity exceeded (no raised defences)	Northern sections of the Scheme shown to be in flood due to River Went
November 2000	Fleet Drain	Channel capacity exceeded	Northeast section of the Scheme shown to be in flood due to Fleet Drain
June 2007	Surface water	Rainfall	Surface water flooding in low-lying areas at southern boundary of the Scheme
November 2019	River Went	Channel capacity exceeded (no raised defences)	Northern sections of the Scheme shown to be in flood due to River Went
February 2020	River Went and Fleet Drain	Channel capacity exceeded (no raised defences)	Northern sections of the Scheme shown to be in flood due to River Went and Fleet Drain



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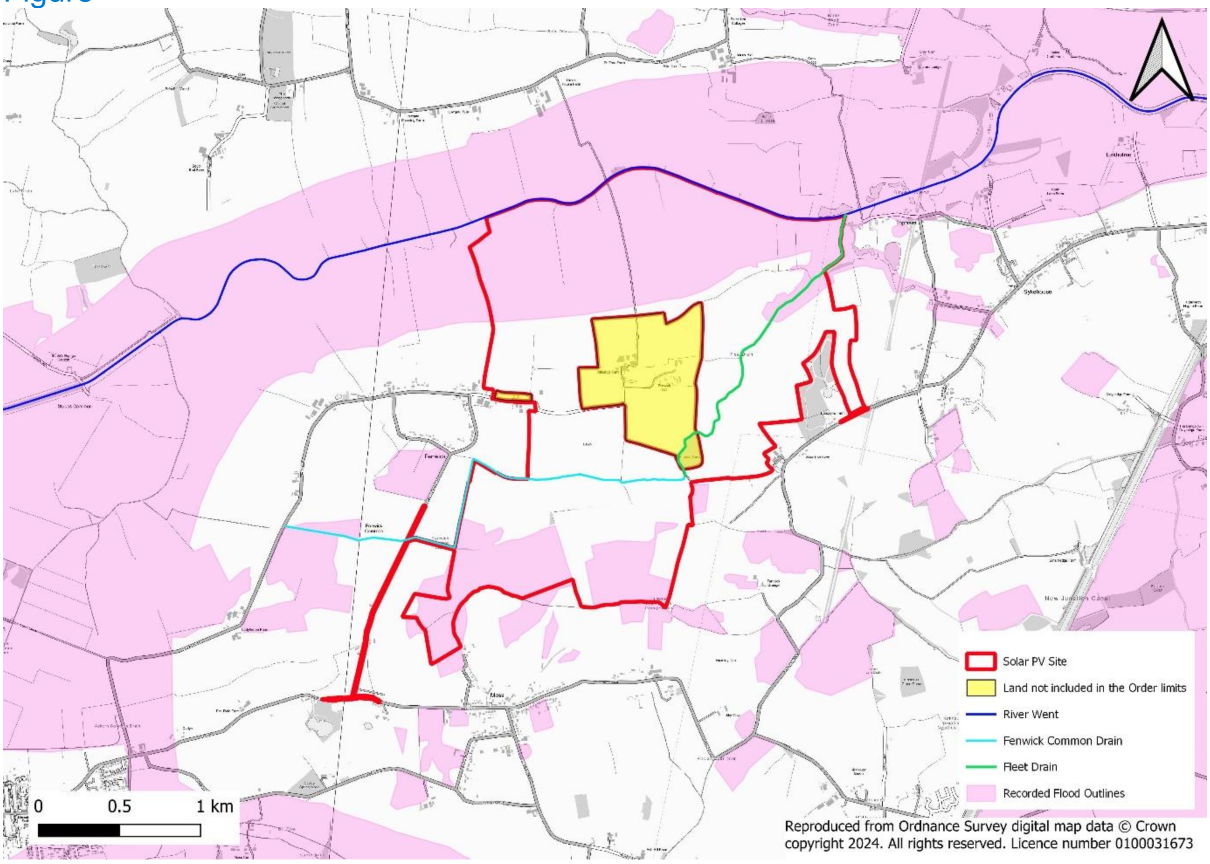


Plate 2-1: Environment Agency's Recorded Flood Outlines

2.3 Channel Survey

2.3.1 Storm Geomatics were commissioned to undertake a channel cross-sectional survey of River Went, Fenwick Common Drain and Fleet Drain in January 2023 and March 2024. The survey was carried out to meet the Environment Agency's National Survey Specification v5.0[2] and contained the following:

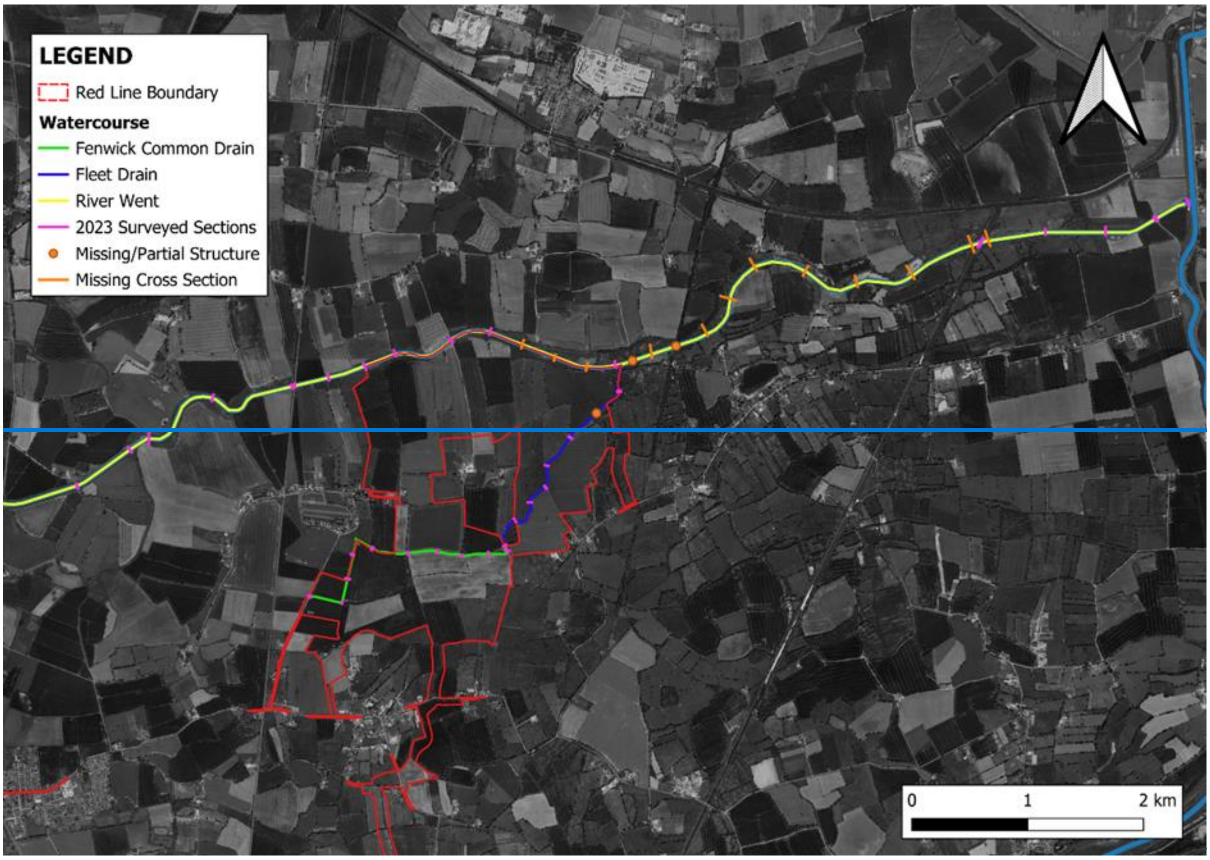
a. 29 open channel cross-sections of the River Went, 20 open channel cross-sections of the Fenwick Common Drain and ~~9~~nine cross-sections of the Fleet Drain~~.~~; and

b. ~~10~~Ten structures on the River Went, ~~9~~nine structures on the Fenwick Common Drain and ~~3~~three structures on the Fleet Drain.

2.3.2 The locations of the surveyed channel cross-sections and structures are shown in Plate 2-2. This information was then used to create the 1D model in Flood Modeller Pro.

2.3.3 The survey was unable to capture all cross-sections and structures due to land access and high river levels during survey. The missing cross-section and survey data is one of the main limitations of the fluvial model. The limitations are listed in Section ~~9.~~9. The missing cross section and structure locations are shown in Plate 2-2.

[2] Environment Agency National Standard Technical Specifications for Surveying Services (March 2021). Available at: https://coastalmonitoring.org/ccoresources/specificationsandbriefs/Survey_National_Specifications_V5.0.pdf [Accessed June 2023].



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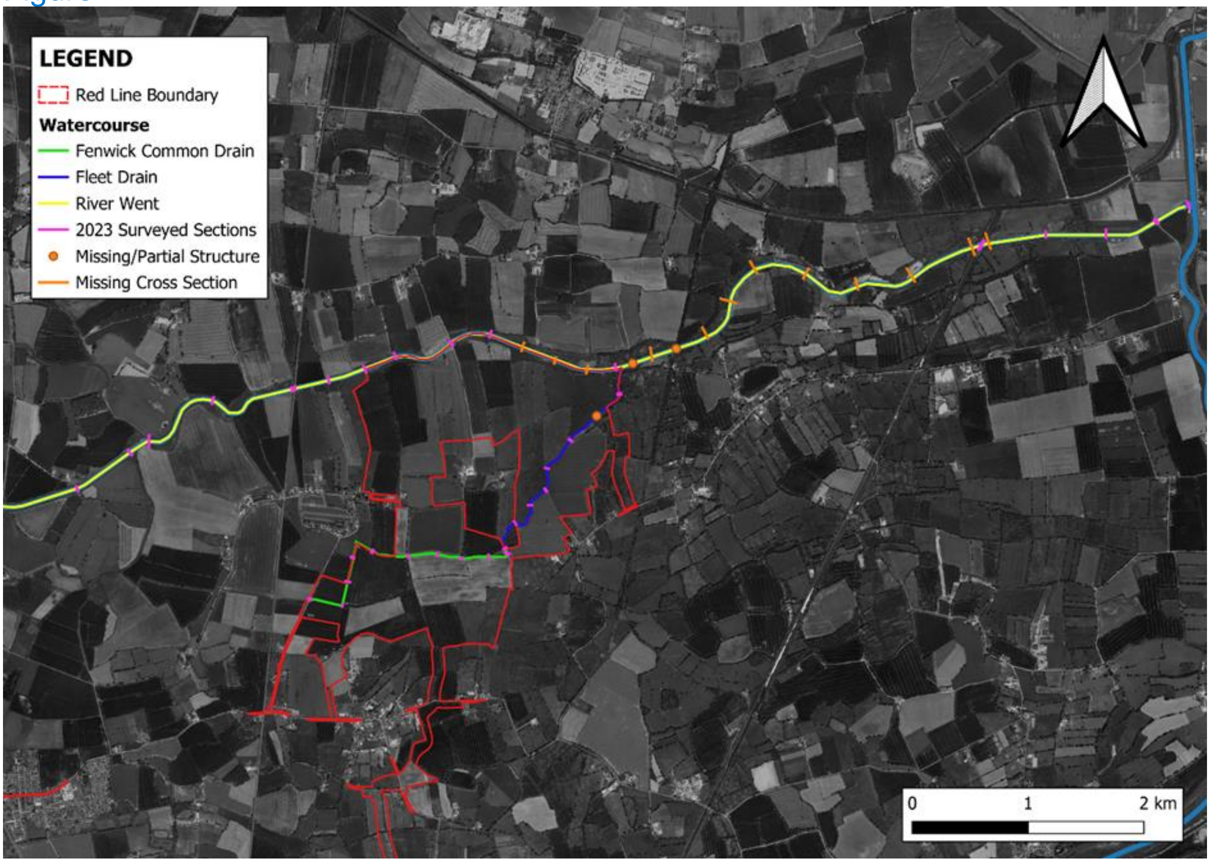
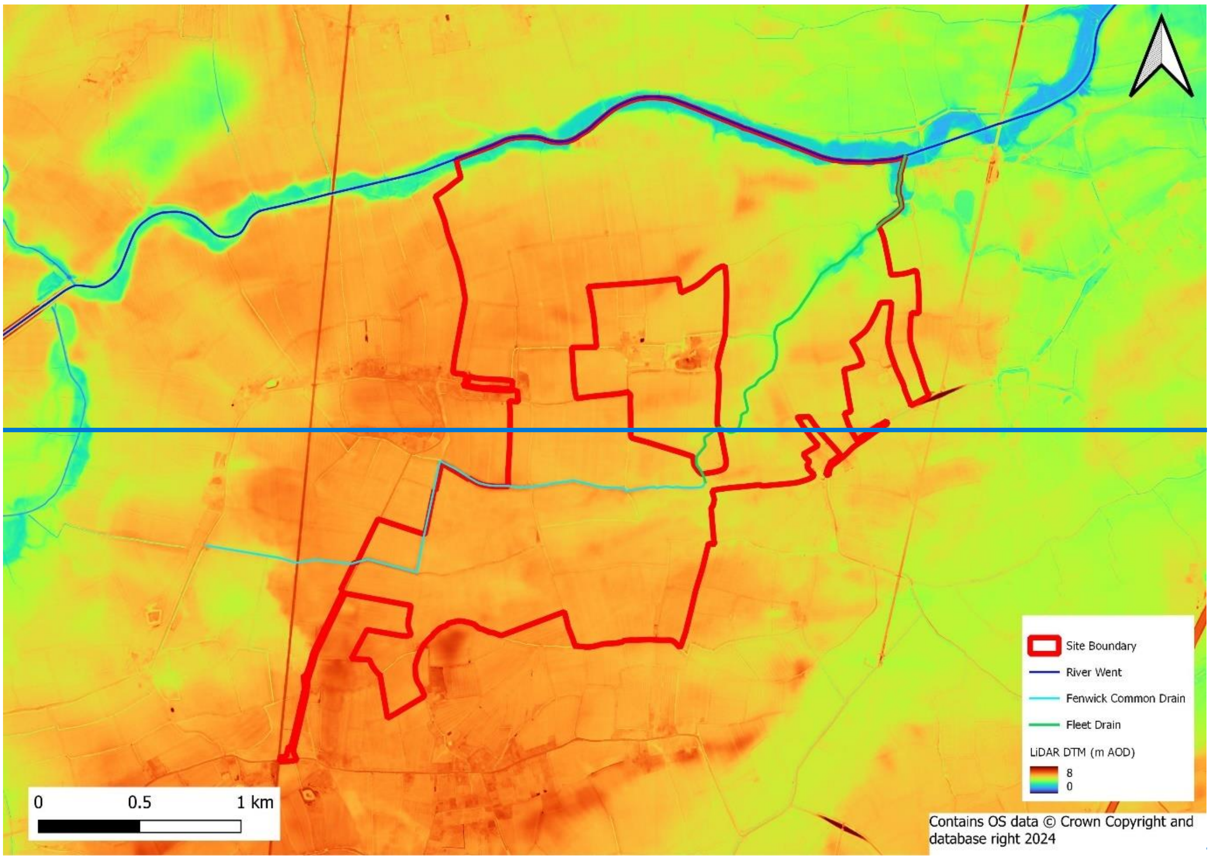


Plate 2-2: Surveyed cross-sections and structures

2.4 LiDAR Data

2.4.1 Plate 2-3 shows the LiDAR Digital Terrain Model (DTM) for the Study Area obtained from the Environment Agency's online data repository[3]. The LiDAR data that has been used is composite data from surveys undertaken between February 2003 and May 2022. The survey metadata shows that majority of the LiDAR used was flown in 2020. The LiDAR has a 1m resolution. This is considered the most up to date topographic data for the area, and was used to inform the floodplain levels in the hydraulic models. Where survey data was unavailable the LiDAR DTM was used to estimate the channel geometry, notably on Fleet Drain downstream of the flapped outfall and the River Went downstream of Topham Ferry Bridge.

[3] Environment Agency National LiDAR Programme: https://environment.data.gov.uk/dataset/2e8d0733-4f43-48b4-9e51-631c25d1b0a9 [Accessed June 2024].



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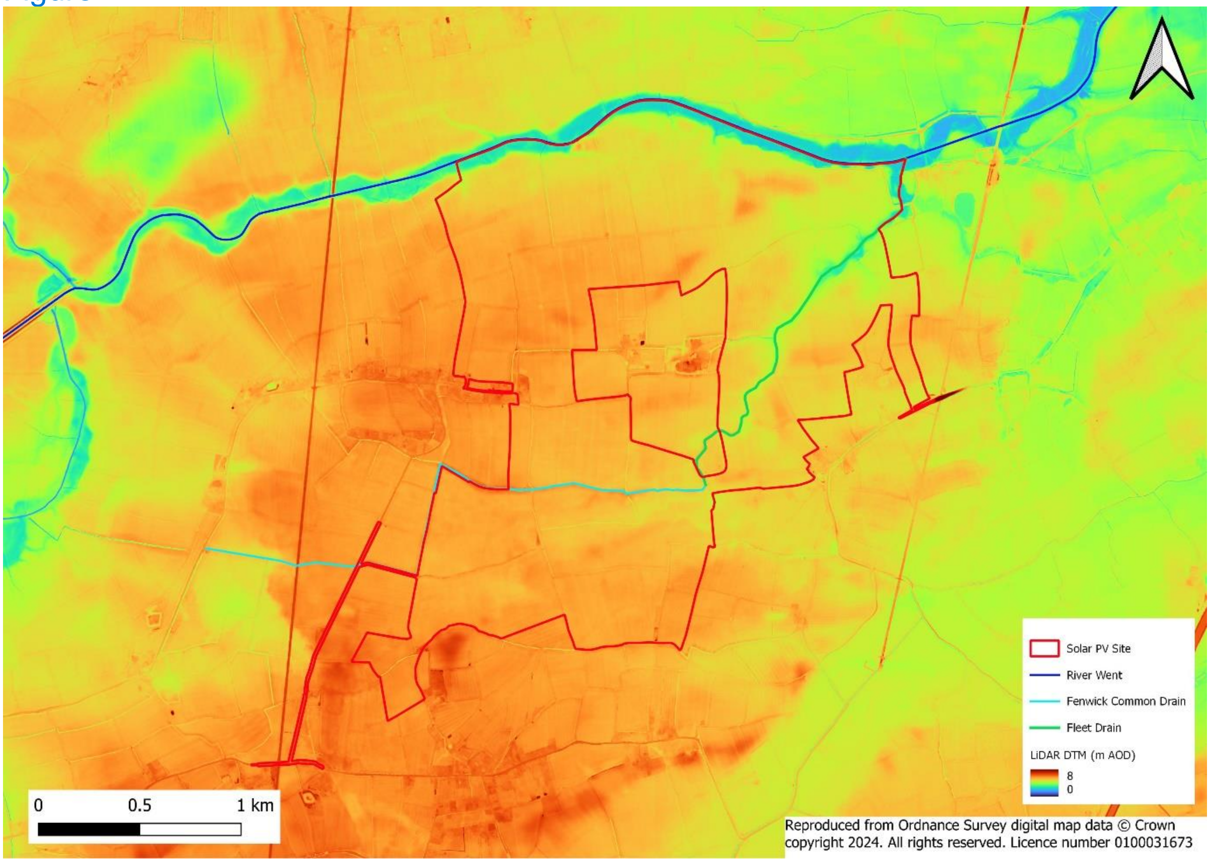


Plate 2-3: 1m LiDAR coverage

2.5 Hydrometric Data

2.5.1 Table 2-3 show shows the available hydrometric data used in this study. The Walden Stubbs flow gauge is approximately 6km upstream of the Scheme and a major confluence. The gauge has known data quality issues and therefore has only been used for a check on the hydrological flows at the upstream of the model.

2.5.2 The Topham Ferry Bridge level gauge is close to the Scheme and used to undertake an LMED assessment (Section 6.5)6.5) for model proving. It is known that the locking of the River Went from the River Don influences the gauge levels and therefore it is limited in use. This is also applicable to the level gauge situated at the Went outfall.

Table 2-3: Hydrometric Data

Watercourse	Gauge Name	Type	Start and end of record	NGR	Comments
River Went	Walden Stubbs	Rated	1979-present	SE5506416309	Flow gauge not suitable for QMED or Pooling. Upstream of major confluence. Limited use.
River Went	Topham Ferry Bridge	15min Level/Daily Maximum	2003-present	SE6196617384	Level only station, near the Scheme and used for LMED assessment
River Went	Went Outfall	15min Level/ Daily Maximum	1990-present	SE6676118738	Level only station. 5.5km downstream of the Scheme.

2.6 Flood Defences

2.6.1 According to the Environment Agency's website[4], the Scheme benefits from "'Natural High *Ground*"Ground' defences on both banks of the River Went. It also benefits from embankments on the downstream end of the Fleet Drain near the River Went confluence. These defences have been represented based on the Storm Geomatics surveyed cross-sections.

2.6.2 The Went outfall structure is a key flood defence on the River Went. This is a sluice gate where the River Went discharges into the River Don. The gates are fully closed when the water levels in the River Don are high, preventing flooding propagating up the River Went from the River Don.

2.6.3 There is a sluice gate at the downstream end of the Fleet Drain where it discharges into the River Went. The sluice gate is closed when water levels

[4] Defra Data Services Platform AIMS Spatial Flood Defences: https://environment.data.gov.uk/dataset/8e5be50f-d465-11e4-ba9a-f0def148f590 [Accessed May 2023].

are high in the River Went, preventing flooding propagating up the Fleet Drain from the River Went.

2.6.4 The River Don has flood defences on both banks of the ~~River~~river. These are typically raised embankments but also include walls and natural high ground.

3. Hydrological Analysis

3.1.1 This section provides an overview of the hydrological analysis undertaken as part of the Scheme. The full Flood Estimation Handbook (FEH) Calculation Record is provided in Appendix A.

3.2 Overview

3.2.1 QMED has been estimated using catchment descriptors and donor adjustment making use of good quality local data from similar catchments. Pooling group analysis has been used to derive the growth curve factors for flood frequency estimates, with a non-flood years adjustment.

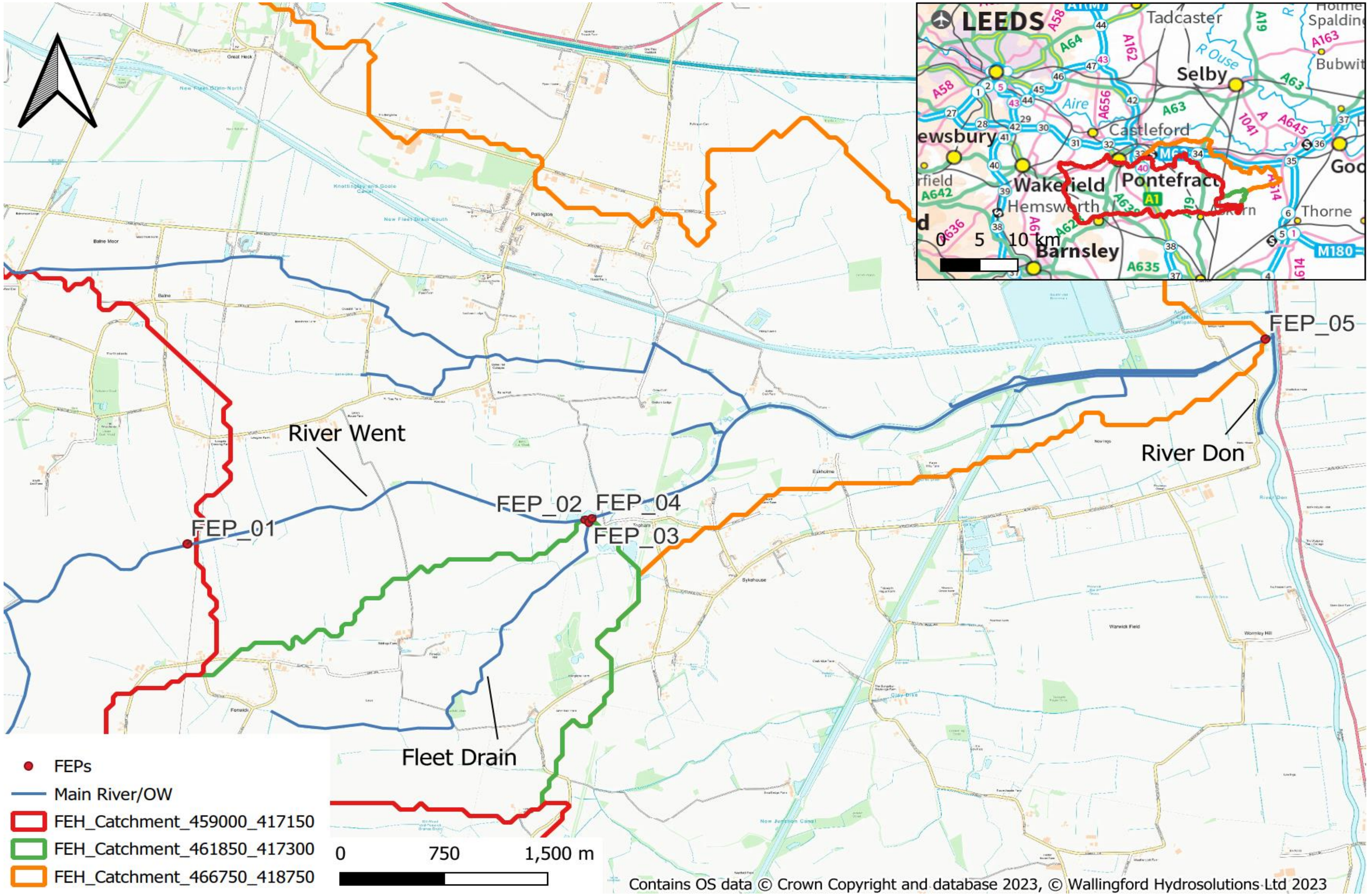
3.2.2 Comparisons with ReFH2 estimates at the subject site showed ReFH2 derived estimates were lower than the statistical. -The statistical method has therefore been chosen, and all of the hydrographs used in the model have been scaled according to the peak flows produced by it.

3.2.3 The final peak flow results for use in the hydraulic model are provided in Table 3-1. This includes the higher central 2050's and higher central 2080's allowances for climate change (Don and Rother catchment climate change allowance[5]). The upper end 2080's climate change allowance of 60% has been used as the credible maximum scenario. The catchment schematisation is shown in Plate 3-1.

Table 3-1: Flood peak ($m^3 s^{-1}$) for required return periods (in years)

Site Code	2	30	50	100	100 + 21%	100 + 38%	100 + 60%	1000
FEP_01	9.56	17.40	18.65	20.31	24.58	28.03	32.50	25.54
FEP_02	10.21	19.59	21.18	23.31	28.21	32.17	37.30	30.39
FEP_03	1.14	2.71	3.07	3.61	4.37	4.97	5.78	6.04
FEP_04	10.88	20.66	22.48	25.03	30.29	34.54	40.05	34.60
FEP_05	13.52	25.95	28.06	30.88	37.36	42.61	49.41	40.27

[5] EA (2024) Climate Change Allowances. Available online at: https://environment.data.gov.uk/hydrology/climate-change-allowances/rainfall?mgtmcatid=3029



~~Figure~~Plate 3-1: Catchment schematisation

4. Fluvial Hydraulic Modelling Methodology

4.1 Overview

4.1.1 Flood Modeller Pro (FMP) provides a one-dimensional (1D) package for modelling river channels, including in-channel structures such as bridges, culverts, and weirs. FMP computes the varying water levels and velocities within the channel, and the associated transference of channel flow to the floodplain when hydraulically linked to a two-dimensional (2D) model.

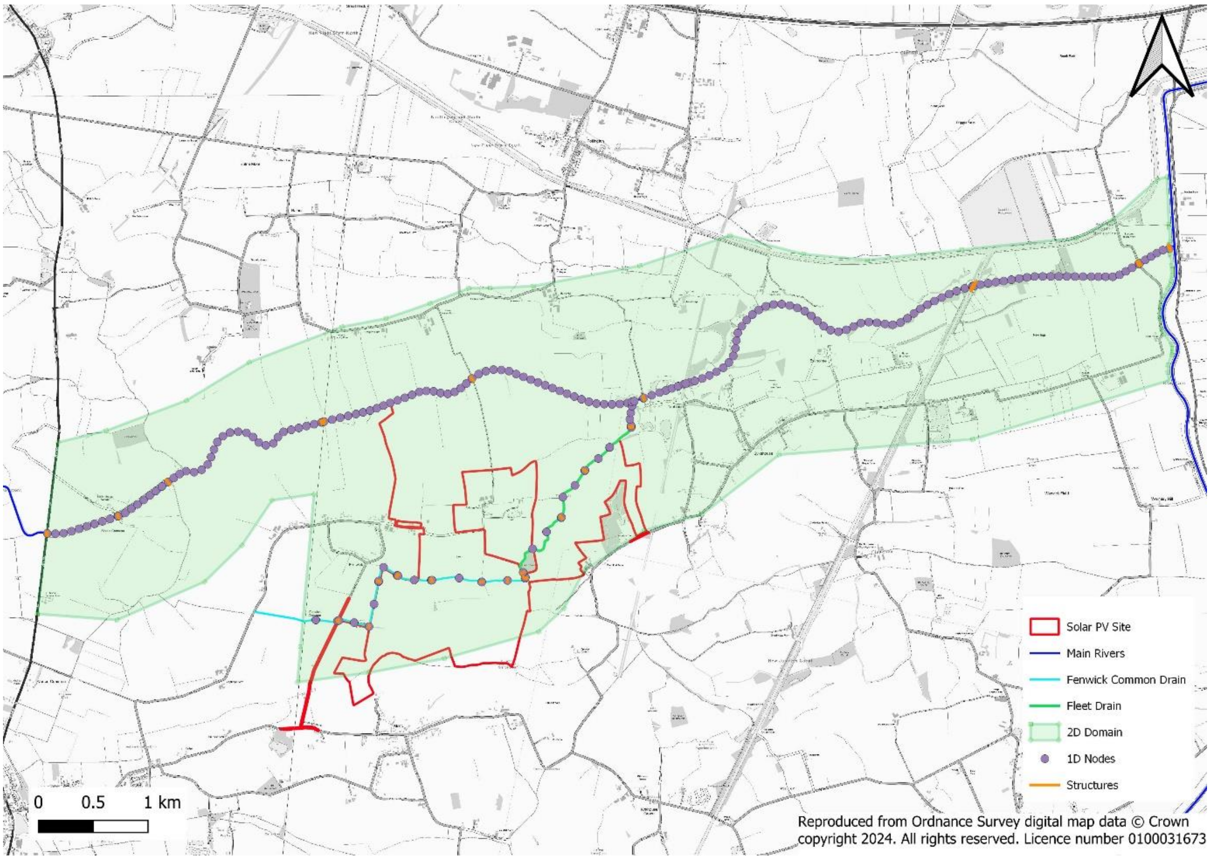
4.1.2 TUFLOW is a 2D hydraulic modelling package that simulates the hydrodynamic behaviour of floodwater across the land surface using a grid-based approach. The combination of FMP and TUFLOW permits the full hydraulic linkage between the channel and floodplain, enabling water from the 1D channel to enter the 2D floodplain, and vice versa.

4.1.3 The models were simulated using FMP version 7.0 and TUFLOW version 2023-03-~~AC.~~ AF.

4.2 Model Extent

4.2.1 A 1D-2D modelling approach was employed for the River Went, Fleet Drain and Fenwick Common Drain in order to ensure the accurate representation of flood risk and water propagation from each channel for a range of design events. Surveyed watercourses were represented as 1D channels in FMP. Inflows have been applied at the upstream end of the River Went and Fenwick Common Drain. Lateral inflows have been applied to represent tributaries inflows, as detailed in the hydrological assessment (Appendix A). A normal depth (HQ) boundary has been applied along the ~~eastern~~northern edge of the model along ~~the River Don flood defences~~raised ground. A tidal head-time (HT) boundary has been applied at the downstream end of the River Went.

4.2.2 A single 2D domain with a 4m grid was employed; this resolution was considered suitable based on the channel width, the available LiDAR data, and workable model run times. The 1D model nodes and 2D domain are presented in Plate 4-1. The model upstream extent is the A19 for the River Went and the railway line for the Fenwick Common Drain.



~~Figure~~Plate 4-1: 1D & 2D Model Schematisation

4.3 1D Model Build

4.3.1 The surveyed cross-sections of the watercourses were imported into the 1D FMP model from the .DAT data files provided as part of the survey. The hard bed profiles were used to represent the bed levels as it is presumed that loose sediment would be conveyed downstream during high flow events.

4.3.2 In order to ensure connection to the 2D model domain, deactivation markers have been established within the cross-sections which coincide with channel bank heights. The deactivation markers have been configured such that channel width remains consistent throughout the modelled reach as far as practicable.

4.3.3 Panel markers and changes in roughness were added to river cross sections to better represent the conveyance capacity of the watercourse and improve model stability. This was based upon surveyed information, photographs, and site observations.

4.3.4 Interpolate sections were added to the FMP model. Interpolates were typically used in areas between cross-sections where there was a large distance between them, and channel gradient and geometry were relatively consistent. Interpolate sections were also added within reaches where survey was missing. Examination of aerial imagery and the LiDAR DTM suggested that the channel geometry and gradient were generally consistent within these reaches. The following approach was taken when interpolating cross-sections:

a. Channel width was estimated using the LiDAR DTM;

b. Bank elevations were extracted from the LiDAR DTM;

c. Bed elevations were interpolated from the nearest surveyed upstream cross-section to the nearest downstream cross-section; and

d. The channel profile was adopted from the nearest surveyed cross-section and trimmed as necessary to the determined section height and bed elevation adjusted to the interpolated elevation.

e. Downstream of the Fleet Drain outfall (FLE_00234) the channel profile was estimated from LiDAR DTM and bed elevation lowered to match the channel gradient.

4.3.5 Table 4-1 shows the river cross sections that are included in the model that were approximated by either copying of surveyed sections or using LiDAR DTM to define the channel. These are predominately in areas where the channel capacity is exceeded in the design events. As the catchment is volume driven the uncertainty in the channel geometry would produce a difference that is small compared to the wider floodplain.

~~4.3.5~~4.3.6 For structures that were unable to be surveyed the following approach was taken:

a. Where practicable the size and dimensions were estimated from photographic evidence. Where no suitable photographic evidence was available, then a suitable surveyed structure was used as a proxy for the structure.

b. The bed elevation was interpolated from the nearest surveyed upstream cross-section to the nearest downstream cross-section.

~~4.3.6~~4.3.7 A list of the structures included in the model is provided in Table 4-1. All structures were modelled as surveyed, with the exception of four structures where survey information was not available. These structures have been assumed based on nearby structures and site photos and are summarised in Table 4-2.

Table 4-1: Representation of cross sections that have not been surveyed

Watercourse	Model Node ID	Method	Justification
River Went	05286	Estimated geometry from LiDAR DTM. Bed elevation from average channel gradient	River Went is relatively uniform and low gradient channel. Survey sections upstream and downstream demonstrate a consistent width and the LiDAR DTM defines the channel well. The areas for lowering the bed have been compared to surveyed sections and show consistent width. There is uncertainty in the channel geometry however in the design events the channel capacity is greatly exceeded and any difference in volume is negligible compared to the wider floodplain.
	05286C	Copy of 05286 with bed elevation adjustment	
	05286C1	Copy of 05286C	

Watercourse	Model Node ID	Method	Justification
	04947	Estimated geometry from LiDAR DTM. Bed elevation from average channel gradient	Conveyance is not as important because the channel is flat and the flooding is volume driven rather than peak flow driven. This is acknowledged as a limitation of the modelling but is considered not to impact the results.
	04013		
	01950		
	WEN_00000a	Copy of WEN_00000	
Fenwick Common Drain	US	Copy of FEN_02287	Upstream of site, uniform linear channel
	FEN_01559_I1	Estimated geometry from LiDAR DTM. Bed elevation from average channel gradient	Channel is uniform and straight through this reach and considered a good representation
	FEN_01262_I1		Channel is uniform and straight through this reach and considered a good representation
Fleet Drain	FL0833C	Copy of FL0833	This is the nearest representative channel section.
	FL0833C1	Copy of FL0833	This is the nearest representative channel section.
	FLE_00188 to FLE_00000	Estimated geometry from LiDAR DTM. Bed elevation from average channel gradient	Downstream of the Fleet Drain outfall the model required more resolution than interpolates. Given the change in bank levels LiDAR DTM presented a better solution than interpolates. Channel is fairly uniform and consistent with upstream sections. As with the River Went the channel is capacity is greatly exceeded in the design events. Conveyance is not as important here as Fleet Drain will be locked from the River Went.

Table 4-2: Key structures included within the the hydraulic model based on survey

Watercourse	Model Node ID	Structure	FMP Representation	Comments
River Went	WEN_10843_BU	Bridge	Arch Bridge	

Watercourse	Model Node ID	Structure	FMP Representation	Comments
River Went	WEN_10286BU	Bridge	Arch Bridge	
River Went	WEN_08557BU	Bridge	Arch Bridge	
River Went	WEN_08539BU	Arch Bridge	Arch Bridge	
River Went	WEN_07092BU	Bridge	Arch Bridge	
River Went	WEN_05441BU	Arch Bridge	Arch Bridge	
River Went	WEN_01876BU	Canal Viaduct	Arch Bridge	Soffit Level assumed from photos because of poor survey. Assumed 1m below surveyed water level. Structure does not account for piers as no information available
River Went	WEN_00326BU	Arch Bridge	Arch Bridge	
River Went	WEN_00006Cua	Sluice Gates	Flapped Orifice	
Fenwick Common Drain	FEN_02287cu	Culvert	Conduit Circular	
Fenwick Common Drain	FEN_01565cu	Culvert	Conduit Circular	
Fenwick Common Drain	FEN_01270cu	Culvert	Conduit Circular	
Fenwick Common Drain	FEN_00949cu	Culvert	Conduit Circular	
Fenwick Common Drain	FEN_00477bu	Bridge	Arch Bridge	
Fenwick Common Drain	FEN_00235bu	Bridge	Arch Bridge	
Fenwick Common Drain	FEN_00062cu	Culvert	Conduit Circular	
Fenwick Common Drain	FEN_00004bu	Arch Bridge	Arch Bridge	
Fleet Drain	FLE_01355cu	Culvert	Conduit Circular	Culvert removed in

Watercourse	Model Node ID	Structure	FMP Representation	Comments
				Proposed Scenario documented in Appendix D
Fleet Drain	FLE_00839cu	Culvert	Conduit Circular	Opening of structure could not be located due to high water levels. Have assumed 1.0m diameter based on other culverts along the drain.
Fleet Drain	FLE_00234ou	Sluice Gate	Flapped Orifice	Bore area calculated from US dimensions.

~~**Table 4-2: Key structures included within the the hydraulic model based on nearby information**~~

~~Watercourse~~	~~Model Node ID~~	~~Structure~~	~~FMP Representation~~	~~Comments~~
~~River Went~~	~~DisRail_bu~~	~~Bridge~~	~~Arch Bridge~~	~~No survey information provided. This bridge was assumed same dimension as Topham Ferry Bridge.~~
~~Fleet Drain~~	~~FLE00833_cu~~	~~Culvert~~	~~Conduit Circular~~	~~No survey information provided. Assumed to be a 1m diameter culvert based on upstream culvert (FLE_00839_cu).~~

4.4 2D Model Build

4.4.1 The hydraulic model was simulated with a 4m grid resolution for the 2D domain which was deemed sufficient to resolve the majority of floodplain features and significant topographic variations.

4.4.2 Topographical survey was used to define elevations at the end of 1D cross sections, these were used to form bank lines within the 1D-2D model. TUFLOW linearly interpolates cell elevations between these points. Where topographical survey wasn't available bank elevations were interpolated, and in some instances were derived from the underlying LiDAR DTM. Links between the 1D and 2D models were established along the banklines.

4.4.3 Where modelled in the 2D TUFLOW domain bridge decks were reinforced within the model based upon LiDAR levels, photos and topographical survey.

4.5 Manning's Roughness Coefficients

4.5.1 Based on Chow (1959) and survey information, it was elected to use a Manning's n roughness value of 0.030 for the main channel of the River Went and between 0.022 to 0.033 for the Fleet Drain and Fenwick Common Drain, which represents a clean, straight, full stage channel with some stones and weeds but no riffles or deep pools. A Manning's roughness coefficient value of 0.050 (the average value for light brush and trees in winter) was generally utilised for the channel banks throughout the 1D domain, with values of 0.070 (the average for medium to dense brush in winter) used occasionally as recommended by the survey data in areas with denser bankside vegetation.

4.5.2 Manning's n roughness values in the 2D domain were assigned based on the Ordnance Survey MasterMap (OSMM) material layers. The different material layers were assigned feature codes with corresponding values in the TUFLOW material file. A summary of the feature codes used in the Study Area, as well as the corresponding material types and roughness values can be viewed in Table 4-3:. Given the predominantly rural nature of the area, a default roughness value of 0.050 was used for the 2D domain. The OSMM layer available did not cover the entire model extent, in these areas the land use type was updated using Ordnance Survey Local Map information for roads, water and buildings. The land use type for the remaining areas was determined to be grass parkland based on aerial photography.

Table 4-3: List of material roughness values and feature codes used in 2D domain

Feature Code	Material Type	Manning's n value
10021	Buildings	0.300
10053	Residential Yards	0.040
10054	Step	0.025
10056	Grass Parkland	0.030
10089	Water Inland	0.035
10096	Slope	0.040
10111	Natural Environment	0.100
10123	Roads dirt	0.025
10167	Railway	0.050
10172	Roads/Paths Tarmac	0.020
10183	Road/Paths Pavement	0.020

Feature Code	Material Type	Manning's n value
10185	Roadside structures	0.030
10193	Pylon	0.050
10217	Unclassified	0.035

4.6 Boundary Conditions

4.6.1 The FEH Statistical Method was used to estimate the peak flows for of the AEP events on the catchment. Full details of the hydrological analysis and inflows are viewable within Section 3 and Appendix A. The inflows in the 1D model were applied as point sources at the upstream extents of the River Went and Fleet Drain. Lateral inflows were applied to represent the flows from tributaries and intervening catchment area.

4.6.2 A stage-time boundary was applied at the downstream extent of the model, where the River Went discharges into the River Don. The stage-time boundary was extracted from the 2018 Lower Don modelling study results for a range of events. The model was simulated with the 5% AEP Lower Don results as the downstream boundary. Downstream boundary testing was undertaken as part of model proving, this is detailed in Section 6.

4.6.3 Within the 2D model, a head-flow (HQ) boundary was incorporated along the boundary of the 2D domain to represent the natural propagation of water across the floodplain according to the local floodplain gradient. This boundary was located along the top of the River Don flood defence embankment, and flood waters did not reach this level within any of the simulated scenarios.

4.7 Model Runs

4.7.1 The hydraulic model was run in unsteady state with a 1 second 1D timestep and a simulation length of 60 hours. In line with current guidance, a 2 second timestep was applied to the 2D model, double the 1D timestep and half of the 2D grid size.

4.7.2 The model was simulated for a range of AEPs including 3.3%, 1%, 1% plus 38% climate change, and 0.1% were simulated for the 1D-2D model to generate baseline results.

4.7.3 The Environment Agency's climate change allowances were updated in July 2021[6]. To determine the allowance for the area of interest, the Don and Rother Management Catchment peak river flow allowances were assessed. According to this, the 'Higher Central' allowances for the 2080s epoch is +38%. This has therefore been applied to the 1% AEP event as the climate change allowance for the design event.

4.8 Model Health

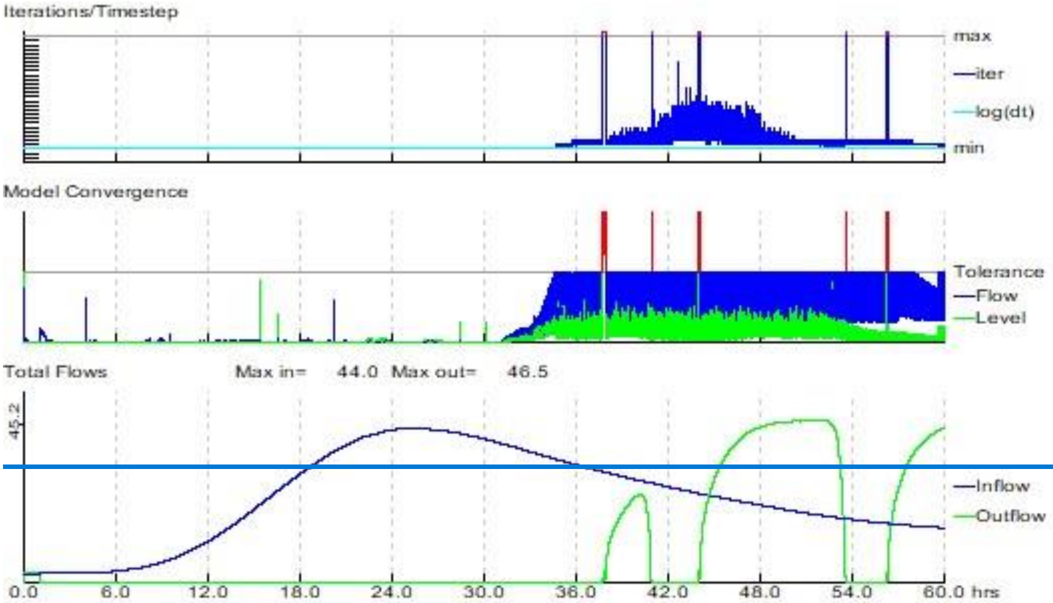
4.8.1 A bitmap of the FMP convergence plot for the 1% AEP plus 38% climate change allowance baseline simulation is presented in Plate 4-2. There are several instances where convergence exceeds the recommended tolerance

[6] Environment Agency (2021) 'Flood Risk Assessments: Climate Change Allowances'. Available at: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances (accessed July 2021)

through the course of the simulation between 36 hours and 57 hours. It should be noted that these convergence issues have not had an impact upon model results, and the model is deemed to be suitable for assessment of flood risk to the Scheme. The value of the dflood parameter was raised to 5 and, maxitr was raised to 29, whilst all other modelling parameters have been retained at default values.

4.8.2 In order to improve model stability an ‘a’ parameter value of 0.5 has been used at the 1D to 2D boundary. and the Boundary Viscosity Factor was raised to 5 for consistency with the Credible Maximum Scenario (See Section 6.4).

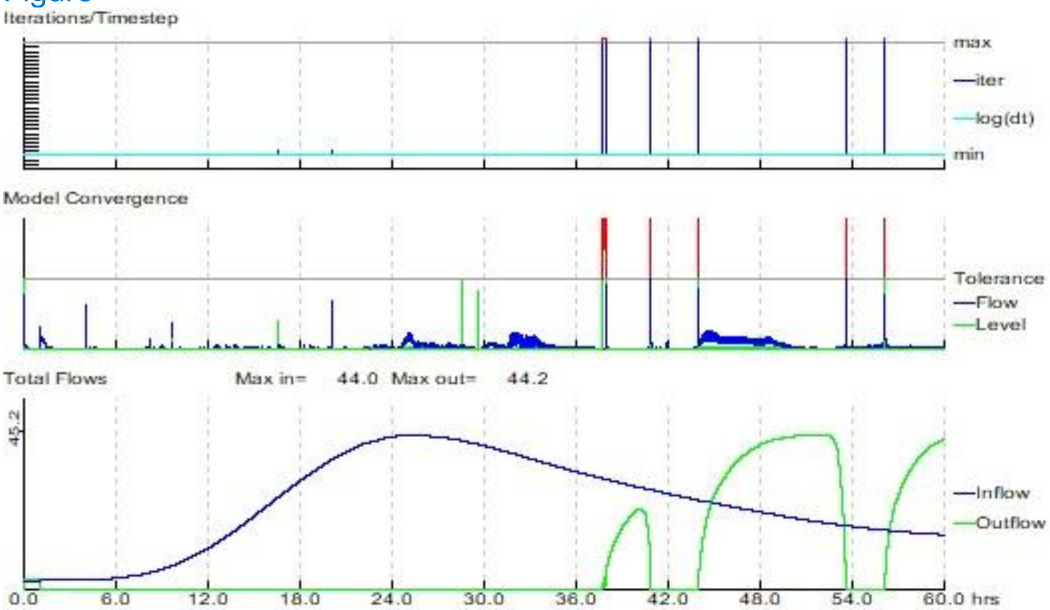
4.8.24.8.3 There are slight oscillationsfluctuations in the 1D stage and flow hydrographs. These oscillations do not occur in the 3.3% AEP event suggesting that the oscillations occur due to large flood depths across the 1D to 2D boundary. The peak water level will be used for the assessment. A test simulation was undertaken on the impact of the Boundary Viscosity Factor and it was found to have minimal impact on the stage hydrograph whilst improving fluctuations and so was retained for all simulations.



Datafile: ...\FMP\DAT\WEN_BASELINE_015_TIDAL.DAT
Results: ...\FMP\RESULTS\WEN_BASELINE_0100YR_38CC_015.zzl
Ran at 11:28:44 on 08/08/2024
Ended at 21:15:03 on 08/08/2024
Start Time: 0.000 hrs
End Time: 60.000 hrs
Timestep: 1.0 secs

Current Model Time: 60.00 hrs
Percent Complete: 100 %

~~Figure~~

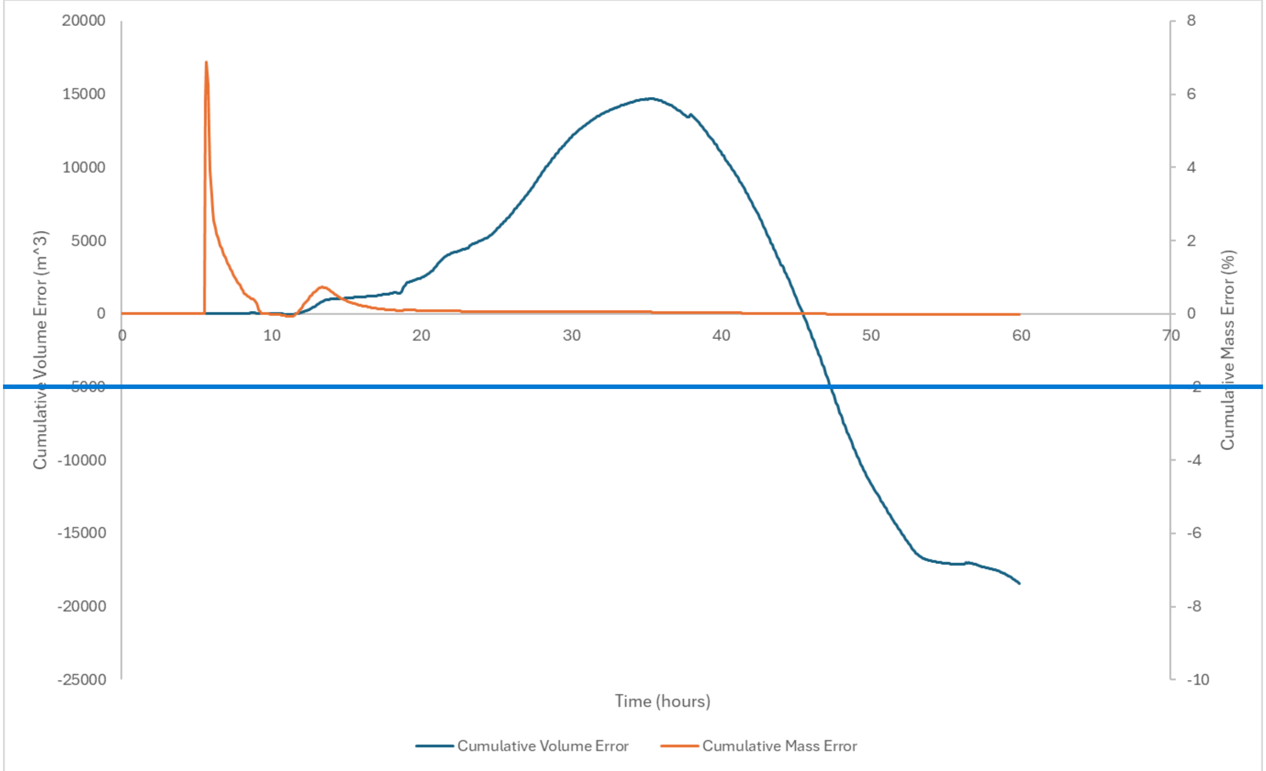


Datafile: ...\FENWICK\FMP\DAT\WEN_BASELINE_020_TIDAL.DAT
Results: ...\FMP\RESULTS\WEN_BASELINE_0100YR_38CC_021.zzl
Ran at 15:56:47 on 07/05/2025
Ended at 02:49:41 on 08/05/2025
Start Time: 0.000 hrs
End Time: 60.000 hrs
Timestep: 1.0 secs

Current Model Time: 60.00 hrs
Percent Complete: 100 %

Plate 4-2: 1% AEP plus 38% climate change convergence plot

4.8.34.8.4 As shown in Plate 4-3, the 2D mass balance error for the 1% AEP plus climate change event is generally shown to be within the acceptable tolerance of +/- 1%, this is typical for across the other AEPs simulated. It should be noted that mass balance error exceeds 1% between 5.5 and 7.5 hours into the simulation. As shown in Figure 4-3 and for all AEP events, the increase in mass balance above tolerance occurs where there is a very small volume of water in the model and is likely associated with initial wetting of the floodplain and flow of very small volumes into the 2D model. Mass balance returns to well within the recommended tolerance as greater volumes of water flow into the 2D model and remains within tolerance for the remainder of the simulation through the peak of the event. Mass balance within the 2D model is therefore considered acceptable for the purposes of this assessment. There are 3750 TUFLOW warnings and checks prior to the simulation. These have been reviewed and are all non-critical and will not be impacting the model results.



~~Figure~~

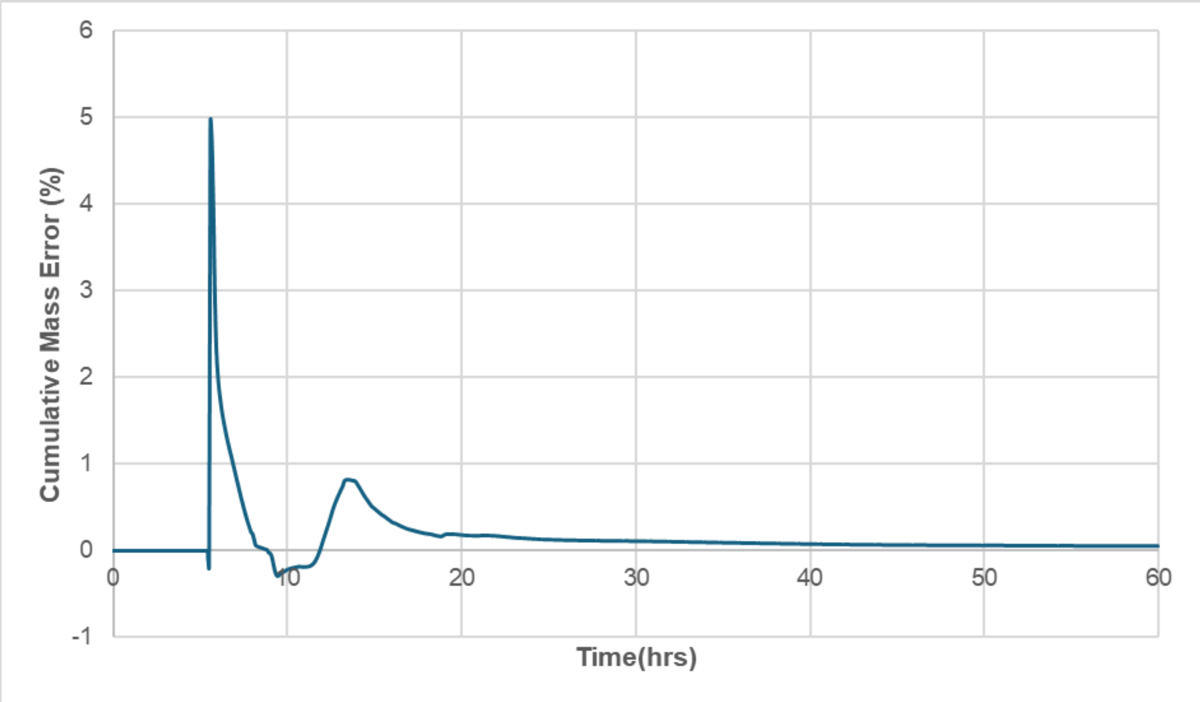


Plate 4-3: 2D Mass Balance Error for 1% AEP + 38% climate change

5. Fluvial Model Results

5.1 Overview

5.1.1 In this section the results from the baseline model are described for the ~~design event (~~1% AEP + 38% climate change~~)~~ event and the mechanism of flooding modelled within the ~~Study Area~~study area is discussed. Following review by the Environment Agency only the 3.33% AEP, 1% + 38% climate change and 0.1% AEP events were re-simulated and presented in this report, because the Credible Maximum Scenario is considered as the design event following completion of additional sensitivity analysis (Appendix D). Further commentary on the credible maximum scenario model stability, results and flood mechanisms are provided within Section 6.5.

5.1.2 The results of the proposed culvert removal scenario are included within the addendum report (Appendix D). These show negligible impact on the flood risk to and from the Scheme and therefore are not discussed further in this report.

5.2 Flooding Mechanism

5.2.1 The maximum flood extents for the 3.3~~%,~~% AEP and 1% AEP + 38% climate change and 0.1% AEP are shown in Plate 5-1. The flooding mechanism can be summarised as follows:

a. The River Went outfall is tidally locked by the River Don from 1hr until approximately 37hrs-46hrs of the simulation when all flood volume is stored within the catchment. Levels on the River Went increase as a result of this locking, this contributes to the extent of out of bank flooding close to the confluence and propagates back up the Went towards the Scheme through the course of the event.

b. After 6 hours there is out of bank flooding from the River Went, with this first taking place 600 m upstream of the New Junction Canal.

c. After 11 hours out of bank flow occurs along the Fleet Drain. This occurs at the confluence of the River Went and 500 m upstream of the confluence.

d. From 12 hours flooding begins to occur along the northern boundary of the Scheme due to out of bank flow from the River Went in this area.

e. From 16 hours flooding occurs from the Fenwick Common Drain upstream of Bunfold Shaw Lane.

f. The flood extent continues to expand through the course of the modelled event with the peak flooding at the Scheme occurs at approximately 46 hours into the simulation. Flooding to the Scheme occurs at the downstream of Fleet Drain where high water levels in the River Went restrict the outfall through the flapped sluice and water must be stored in the channel and floodplain.

5.2.2 The maximum flood depths for the 1% AEP + 38% climate change AEP event are shown in Plate 5-2. This map shows that the inundation of the Scheme due to fluvial flooding is restricted to:

a. The northern edge of the Scheme that borders the River Went.

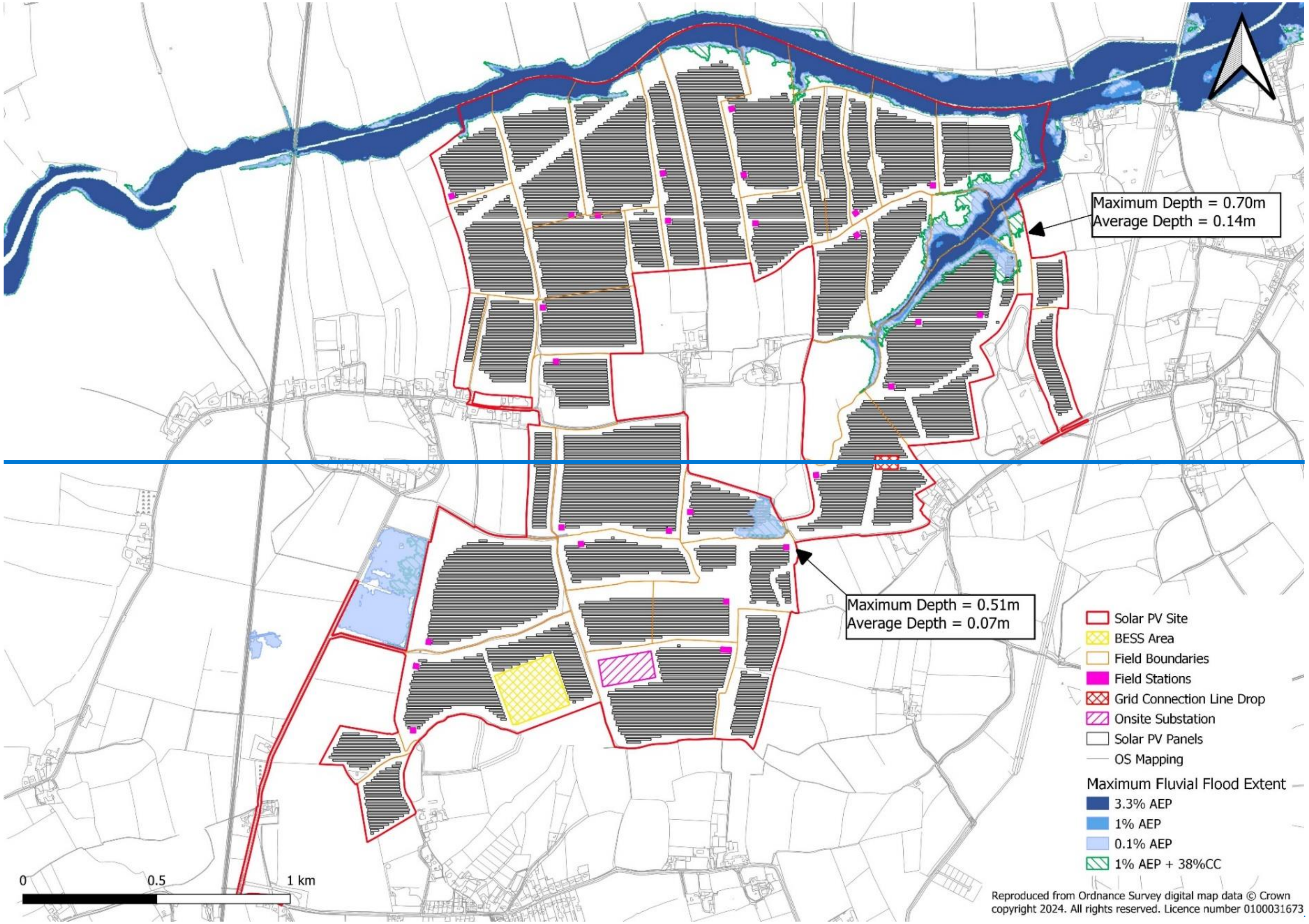
b. The northeast corner of the Scheme at the confluence of the Fleet Drain and the River Went. This area shows overtopping of channel banks for both the River Went and Fleet Drain. This flooding extends 1.4 km upstream.

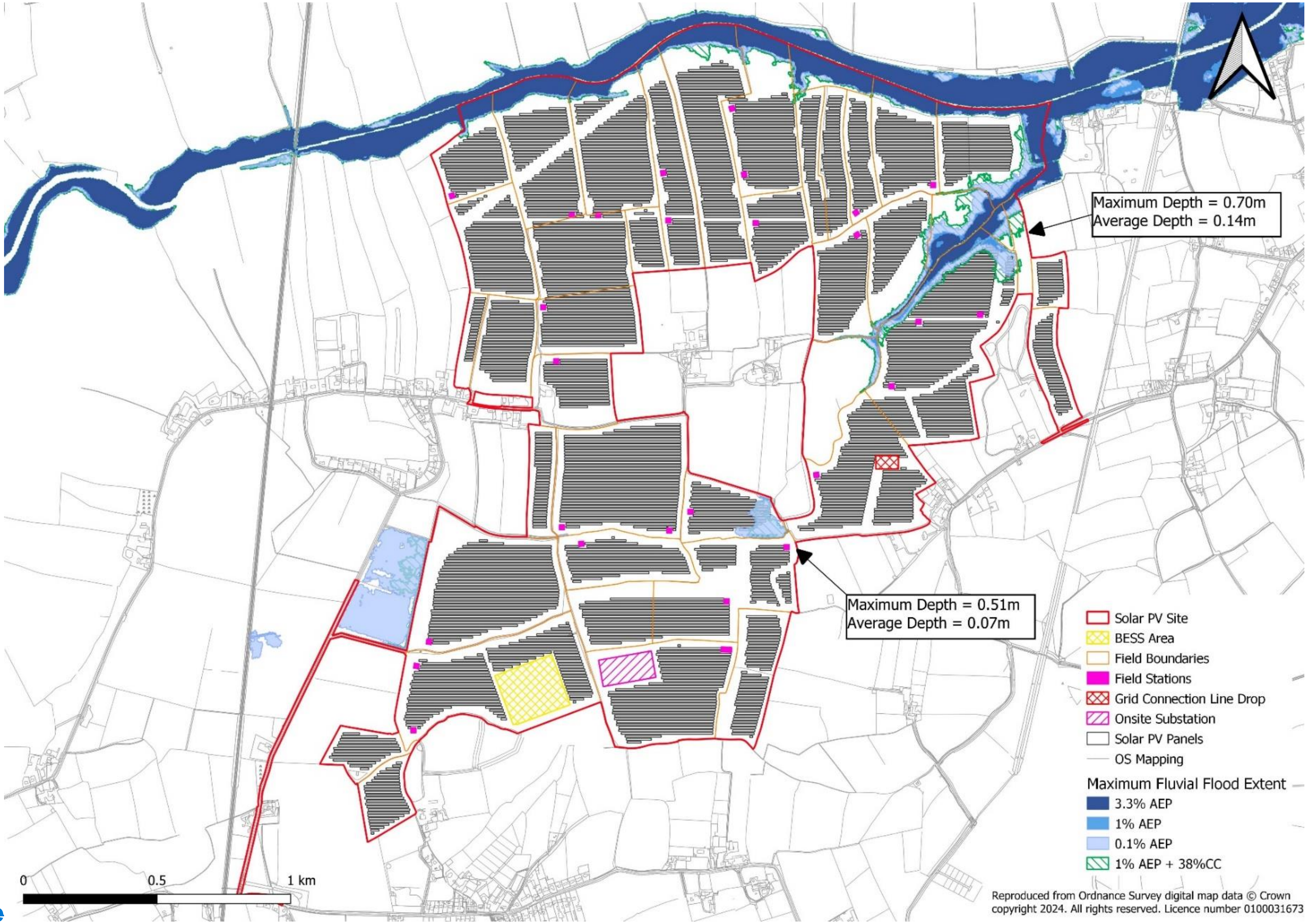
c. Upstream of Bunfold Shaw Lane the Fenwick Common Drain overtops, the extent of this flooding is localised with a typical flood depth of 0.05 to 0.10 m.

5.2.3 The flooding mechanism is largely similar for all AEP events, with out of bank flooding generally occurring earlier and the flooding area being greater in the larger AEP events. Maximum flood depth maps for 3.3% AEP, 1% AEP and 0.1% AEP are included in Appendix B.

5.2.4 The maximum fluvial flood extent is smaller than the River Went flood extent in the Environment Agency's Recorded Flood Outlines GIS layer[7] (shown in Plate 2-1).). It was found that both the 1% AEP + 38%CC and 0.1% AEP maximum water elevation has been exceeded in the observed level gauge record at Topham Ferry Bridge in the past 21 years. It was agreed with the Environment Agency (11/04/2025) that further investigation into the initial catchment conditions was required to understand this mismatch with the observed record, with further details provided in the addendum report.

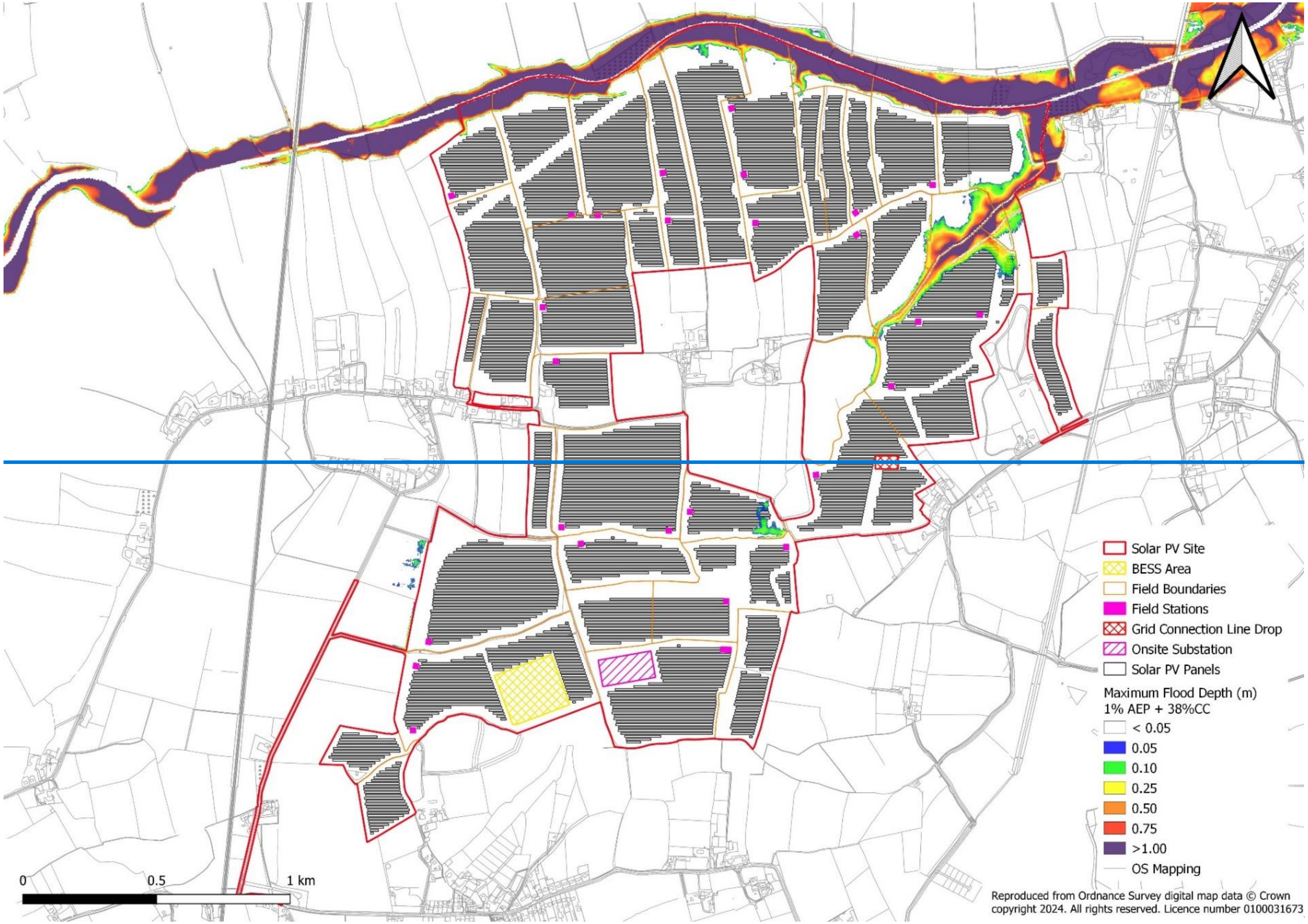
[7] Environment Agency Recorded Flood Outlines: https://environment.data.gov.uk/dataset/8c75e700-d465-11e4-8b5b-f0def148f590 [Accessed June 2024].

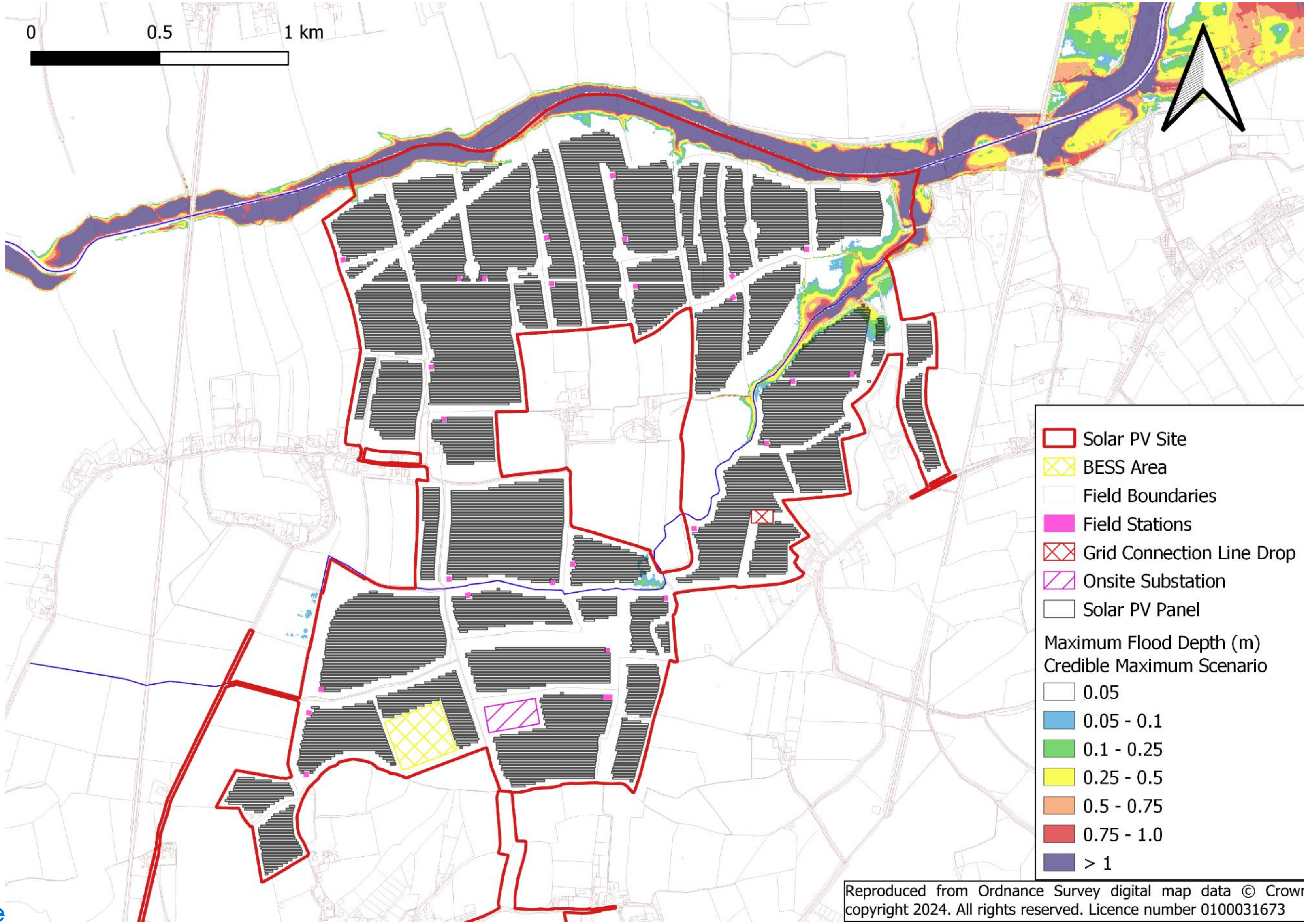

Maximum Depth = 0.70m
Average Depth = 0.14m
Maximum Depth = 0.51m
Average Depth = 0.07m
Solar PV Site
BESS Area
Field Boundaries
Field Stations
Grid Connection Line Drop
Onsite Substation
Solar PV Panels
OS Mapping
Maximum Fluvial Flood Extent
3.3% AEP
1% AEP
0.1% AEP
1% AEP + 38%CC
0
0.5
1 km
Reproduced from Ordnance Survey digital map data © Crown copyright 2024. All rights reserved. Licence number 0100031673



~~Figure~~

Plate 5-1: Maximum flood extents for the 3.3% AEP, 1% AEP + 38% climate change and 0.1% AEP events


Solar PV Site
BESS Area
Field Boundaries
Field Stations
Grid Connection Line Drop
Onsite Substation
Solar PV Panels
Maximum Flood Depth (m)
1% AEP + 38%CC
< 0.05
0.05
0.10
0.25
0.50
0.75
>1.00
OS Mapping
0
0.5
1 km
Reproduced from Ordnance Survey digital map data © Crown copyright 2024. All rights reserved. Licence number 0100031673



~~Figure~~

Plate 5-2: Maximum flood depth for the 1% AEP + 38% climate change event

6. Model Proving

6.1.1 Proving of the model was undertaken to help assess and enhance confidence in the model, proving of the model comprised sensitivity simulations, along with an LMED comparison exercise.

6.1.2 Sensitivity analysis was completed to determine the influence of parameter assumptions made during the model development upon the model outputs. The following sensitivity simulations were completed for the 1% AEP event:

a. Manning's roughness coefficients: +/-20% in 1D and 2D values (1% AEP)

b. Model inflows: +/- 20% on all 1D inflows (1% AEP)

c. Downstream boundary: River Don 50% AEP/2% AEP (1% AEP)

d. Credible Maximum 1% AEP + 60% Climate Change (Upper End) with ~~2~~0.1% AEP 2121 H upper scenario Humber Extreme Water Level on the River Don.

6.1.3 The LMED assessment comprised check on the hydrological inflows was completed using the level gauge data from the Topham Ferry Bridge. The average annual maximum water level (LMED) was calculated from the hydrometric data and compared to the modelled QMED (50% AEP) water level at the gauge.

6.1.4 Following the review of the hydraulic model by the Environment Agency (05/02/2025) the hydraulic model was improved and the Credible Maximum Scenario was re-simulated. Further sensitivity analysis was undertaken on the initial conditions within the catchment and are presented within the addendum report. No other sensitivity scenarios were re-simulated because the sensitivity to the model parameters identified in the initial model runs was considered clear and not critical to the conclusions of this report. The additional sensitivity simulations undertaken were:

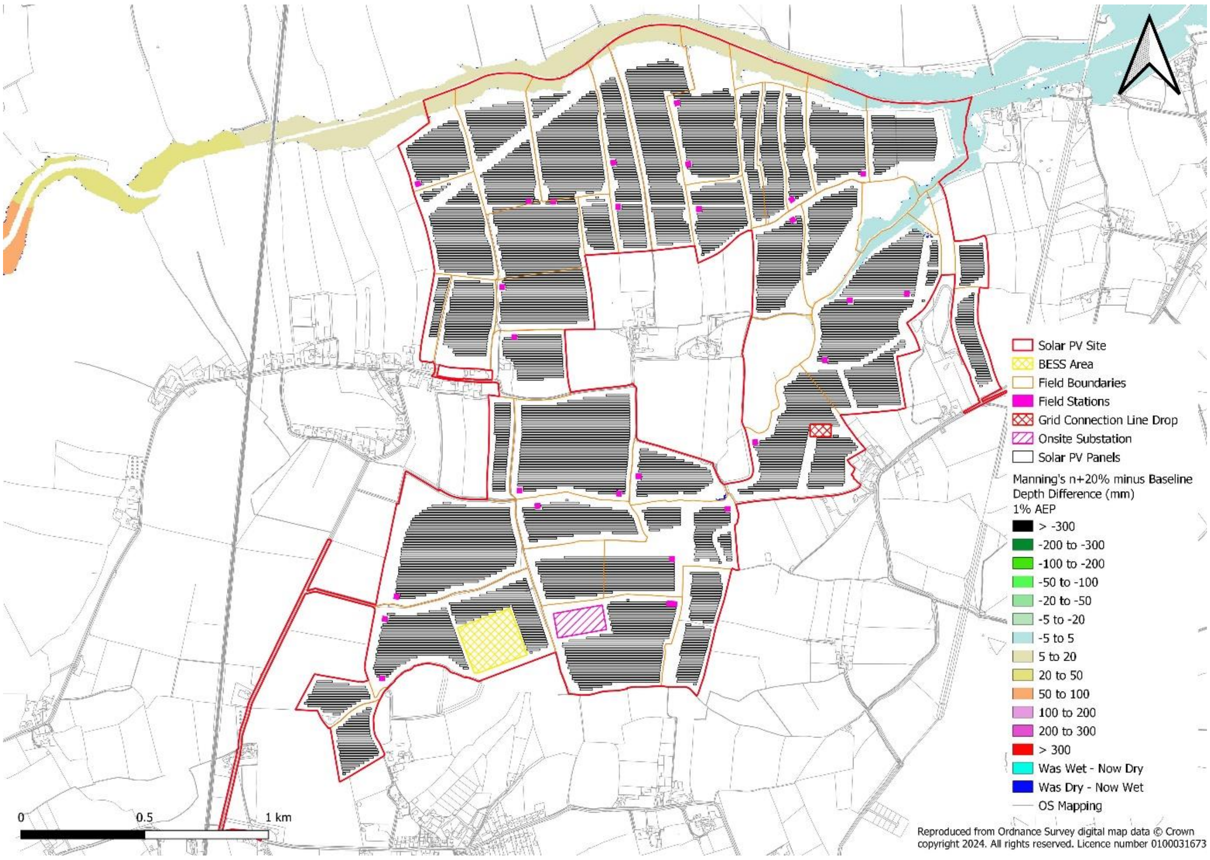
a. Initial Conditions: Design events simulated with a 50% AEP initial conditions and 0.1% AEP 2121 upper scenario Humber Extreme Water Level on the River Don. The results of this are presented in the addendum report and referenced in discussion of the Credible Maximum scenario results.

6.2 Manning's n

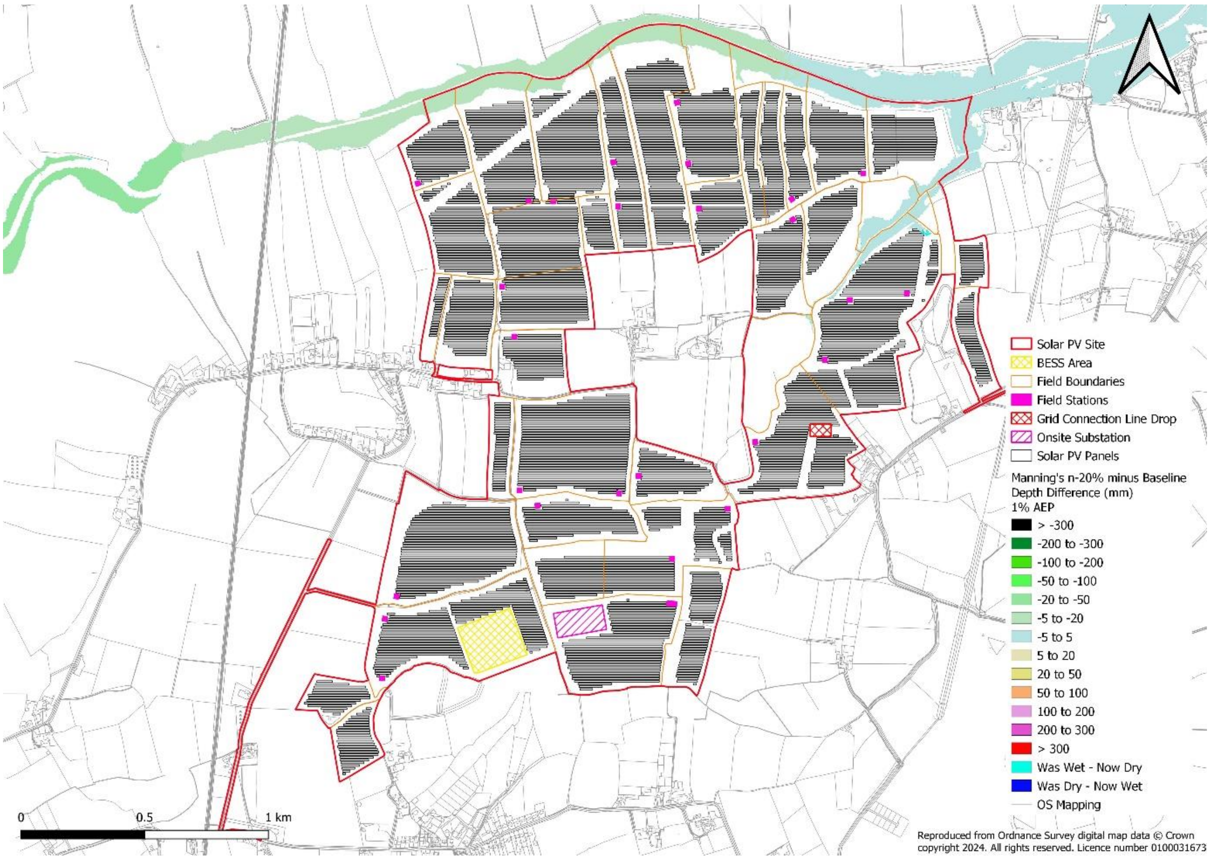
6.2.1 Manning's roughness coefficient sensitivity was conducted by applying a +20% and -20% adjustment to all 1D (open channel/culverts/pipes) and 2D (floodplain) 'n' parameters as specified in the 1D FMP DAT file and 2D materials layer respectively. This effectively creates either a rougher (+20%) or smoother (-20%) path for water to propagate through the hydraulic model.

6.2.2 Plate 6-1 and Plate 6-2 show the maximum depth difference for the n +/-20% compared to the baseline n scenario. Within both scenarios there is a relatively small change in the maximum flood depths, generally less than 20mm, with little change in the maximum flood extents.

6.2.3 The change in Manning's roughness may change the floodplain and channel conveyance however, as the system is essentially locked the same volume of water must be stored within the catchment and the maximum levels and extents do not change. It can be concluded that the model sensitivity to Manning's Roughness is within the expected range.



~~Figure~~Plate 6-1: Maximum Depth Difference, Manning's Roughness +20% vs. Baseline (1% AEP)



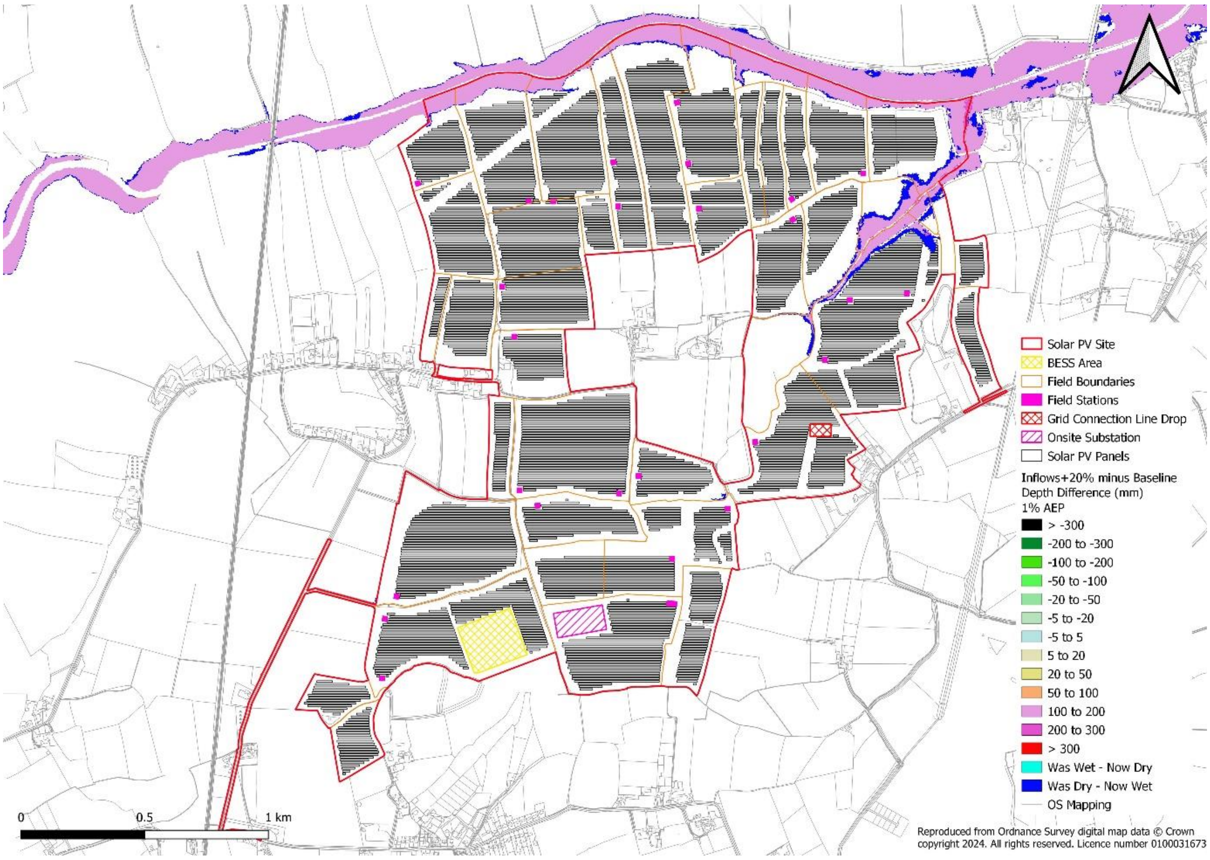
~~Figure~~Plate 6-2: Maximum Depth Difference, Manning's Roughness -20% vs. Baseline (1% AEP)

6.3 Model Inflows

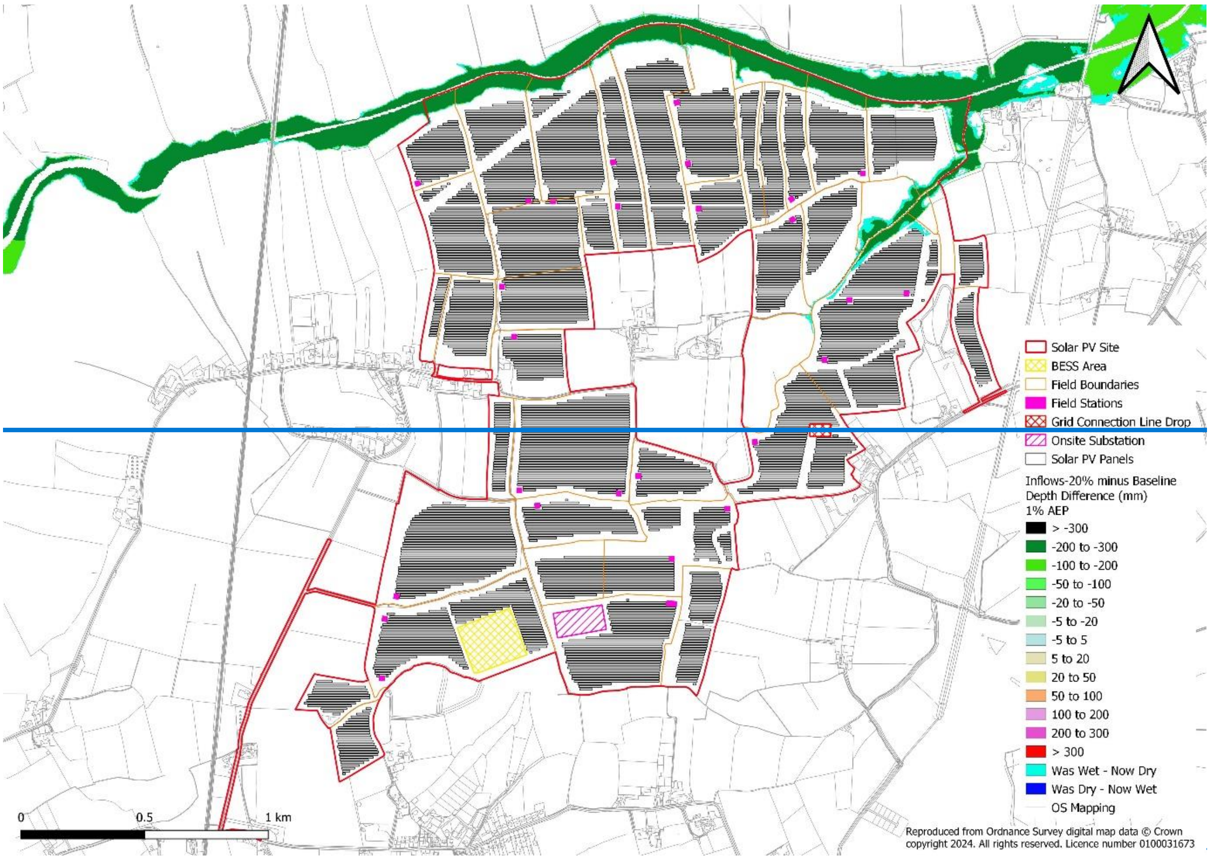
6.3.1 The model inflow sensitivity was conducted by applying a +20% and -20% adjustment to all model inflows within the IED for the 1% AEP event. No adjustments were made to the flow splits within the IED. This sensitivity is to reflect uncertainty within the hydrological flow estimates described in Section 3.

6.3.2 Plate 6-3 and Plate 6-4 show the maximum depth difference for the flow +/- 20% compared to the baseline scenario. As expected, there is a general decrease in maximum flood depths of approximately -0.21m in the -20% flow scenario along the Fleet Drain and the River Went at the Scheme (Plate 6-4). The maximum flood extents are marginally reduced on the River Went and a little more on Fleet Drain though flooding is still present within the confined floodplain.

6.3.3 The reverse is true in the +20% flow scenario where maximum flood depths at the Scheme increase by c.+0.18m. Flood extents increase by a small amount primarily within the proposed Ecology and Heritage Mitigation Areas on Fleet Drain. There is some increase on maximum flood depth within the Solar PV Site to the east, but this is small.



~~Figure~~Plate 6-3: Maximum Depth Difference, Model Inflow +20% vs. Baseline (1% AEP)



~~Figure~~

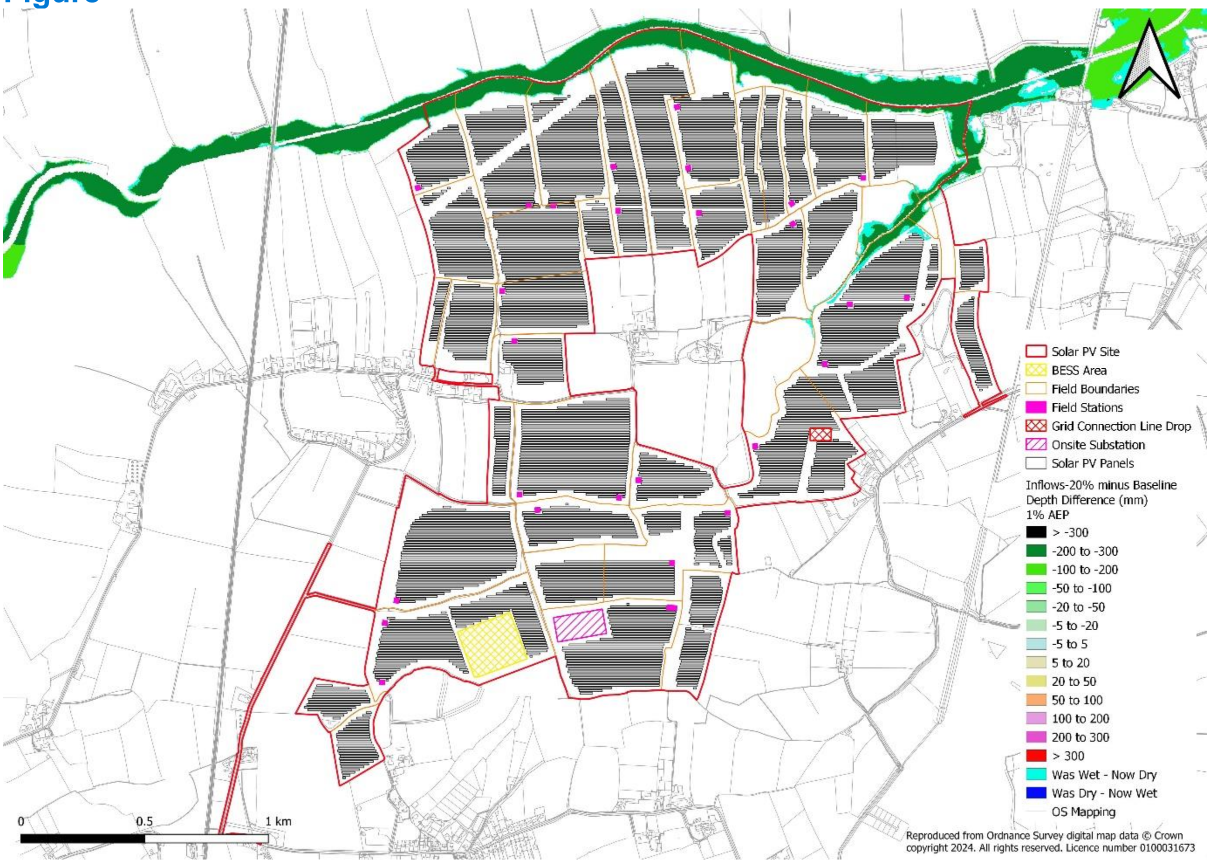


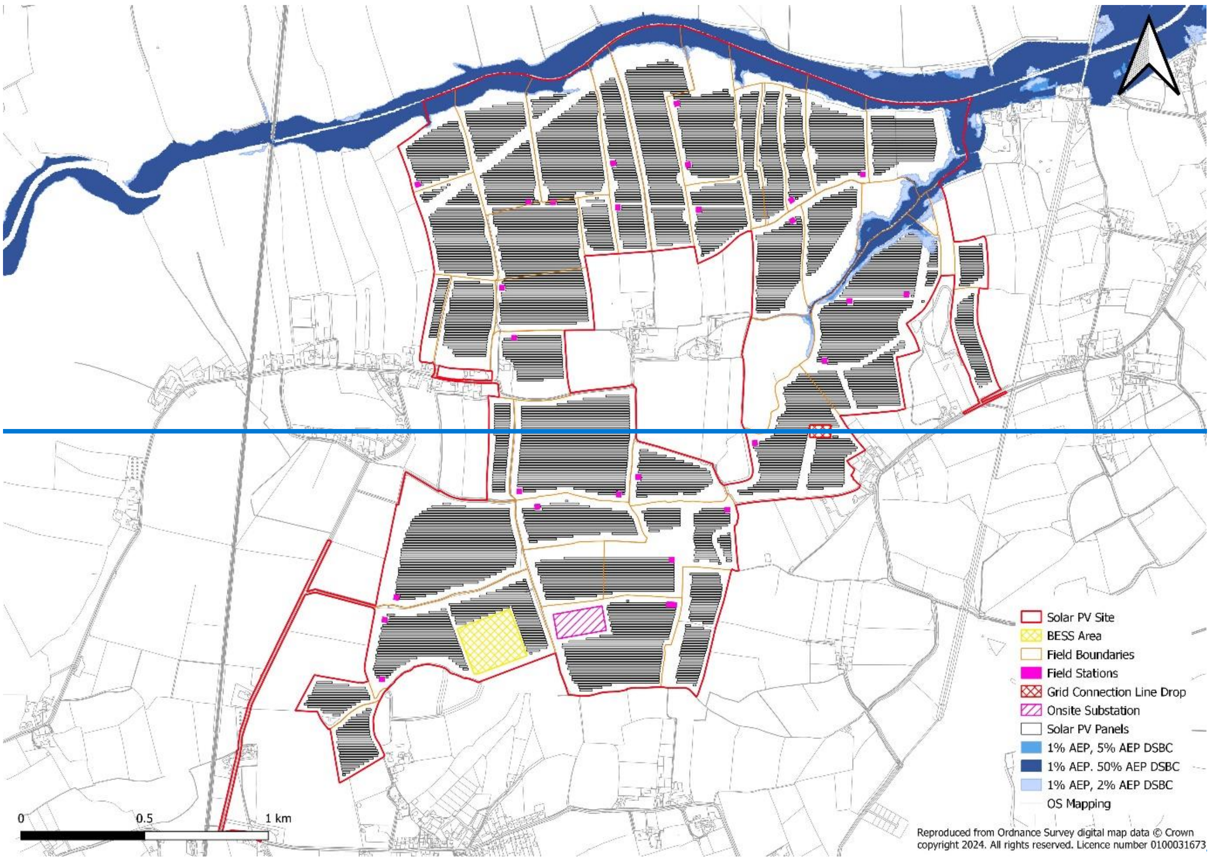
Plate 6-4: Maximum Depth Difference, Model Inflow -20% vs. Baseline (1% AEP)

6.3.4 The increase and decrease in model inflows in the model shows a commensurate response to the increase and decrease in volume of flood water stored within the catchment. The increases and decreases in maximum flood depths and extents at the Scheme are relatively small and primarily confined to Ecology and Heritage Mitigation areas and do not have a significant impact on the development.

6.4 Downstream Boundary

6.4.1 The model uses a HT boundary (stage-time) for the confluence of the River Went and River Don at the downstream end of the 1D model domain. The 5% AEP results from the 2016 Lower Don modelling study have been used as the HT boundary for the design events. As a sensitivity test for the downstream boundary the model was run with the 50% AEP and 2% AEP results from the 2016 Lower Don modelling study to capture a range of conditions on the River Don.

6.4.2 Plate 6-5 ~~shows~~shows the extent comparison for the 50% AEP and 2% AEP compared to the 5% AEP downstream boundary. When the 50% AEP River Don downstream boundary is applied there is a general decrease in the maximum flood depths throughout the model of less than 0.1m as more water is able to discharge from the River Went into the River Don. It should be noted that despite the lower maximum depths there is a limited change in flood extent. This demonstrates that there remains a significant locking of the River Went even in lower magnitude events on the River Don.



Figure

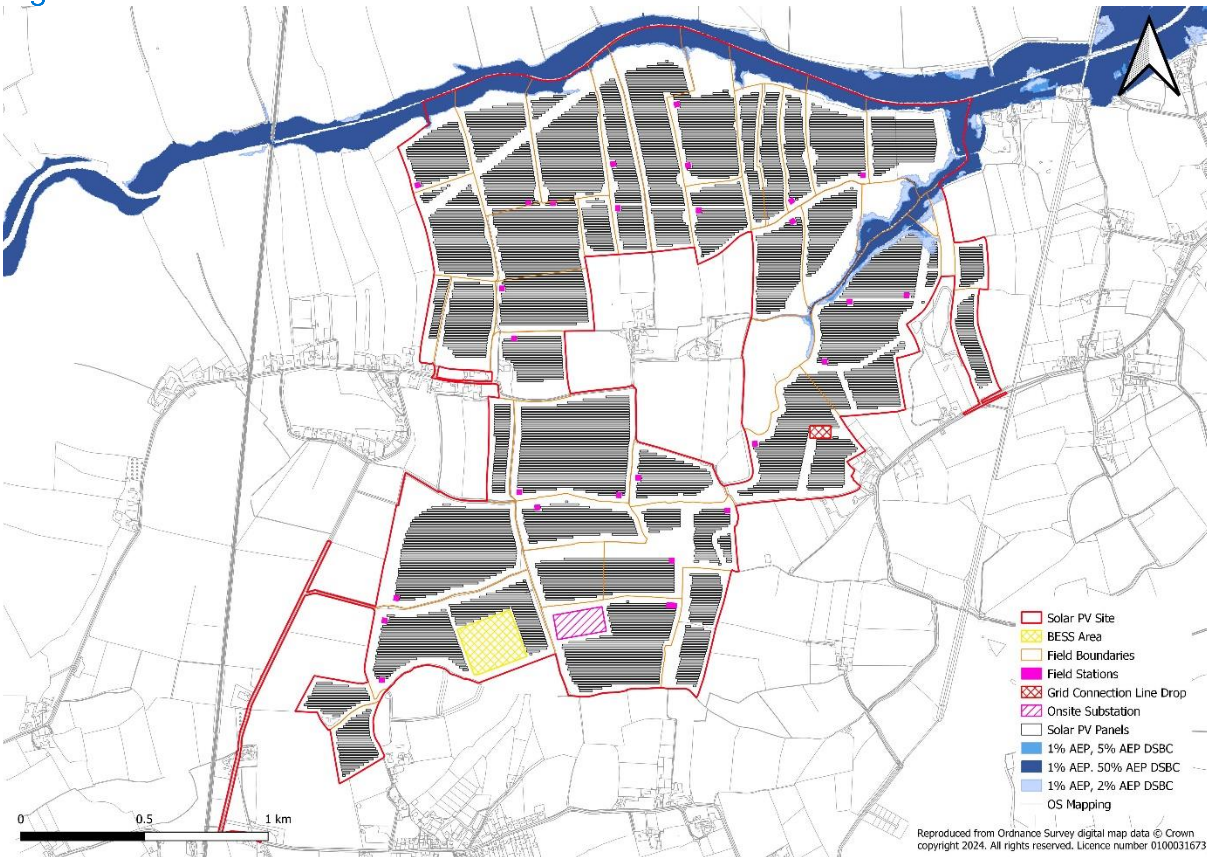


Plate 6-5: Downstream Boundary Sensitivity Test Extent Comparison

6.4.3 The 2% AEP downstream boundary results show a larger increase in maximum flood depths (0.2 – 0.3m) within the floodplain, as the River Went is locked for the entire simulation and all volume is stored within the catchment. Whilst this also results in a large increase in maximum flood extents downstream of the disused railway line, the change at the Scheme is relatively small and confined to the downstream extent of the Fleet Drain. Maximum flood depths here increase between 0.1m-0.2m, with increases in maximum flood extent occurring mainly in the Ecology and Heritage Mitigation Areas with some encroachment into the Solar PV Site to the east. There is no impact further upstream on the Fleet Drain and overall, the sensitivity test demonstrates that even when the downstream boundary is completely locked the results at the Scheme are comparable to the design scenario.

6.5 Credible Maximum Scenario

6.5.1 To assess the credible maximum scenario the hydraulic model was simulated for the 1% AEP + 60% allowance for climate change (Upper End). In addition, a HT time series extracted from the 2% AEP simulation from the River Don model was applied as the downstream boundary condition, which effectively locks the River Went for the entire simulation and all flood water is stored within the catchment. Given that the Went outfall is locked through the entirety of the simulation when applying levels in the River Don in a 2% AEP event, there was no need to apply a downstream boundary for a more extreme event for the credible maximum scenario. It should be noted that the

Boundary Viscosity Factor of 5 was also applied to the TUFLOW model to help smooth exchange of flow across the 1D-2D boundary. This was found to have limited impact on the 1D stage results but helped reduce the instability at high depths. The model was run without the Boundary Viscosity Factor. The stage results from the model were identical to the results with the Boundary Viscosity Factor to the point of the onset of model instability. Given there is already significant out of bank flooding at this point it is concluded that the Boundary Viscosity Factor has little impact on the 1D results but helps reduce instability at high depths.

6.5.2 Figure 6-6 show the maximum flood depths map for the credible maximum scenario compared to the 1% AEP + 38%CC design event. In general, the maximum flood depths within the River Went and Fleet Drain increase by c.0.3m compared to the design event. The maximum flood extents for the credible maximum scenario are increased along the right bank of the River Went through the Scheme though this is predominantly within the Ecology Mitigation Area. Both banks of the Fleet Drain at the downstream extent are increased with the two solar PVareas at the northeast of the Scheme become inundated to depths up to c. 0.35m but in general flood depths are below 0.25m. The solar PV area on the right bank of Fleet Drain becomes further inundated to depths of less than 0.35m. In the upper Fenwick Common Drain catchment there is increased flooding on the left bank but this is not within the development.

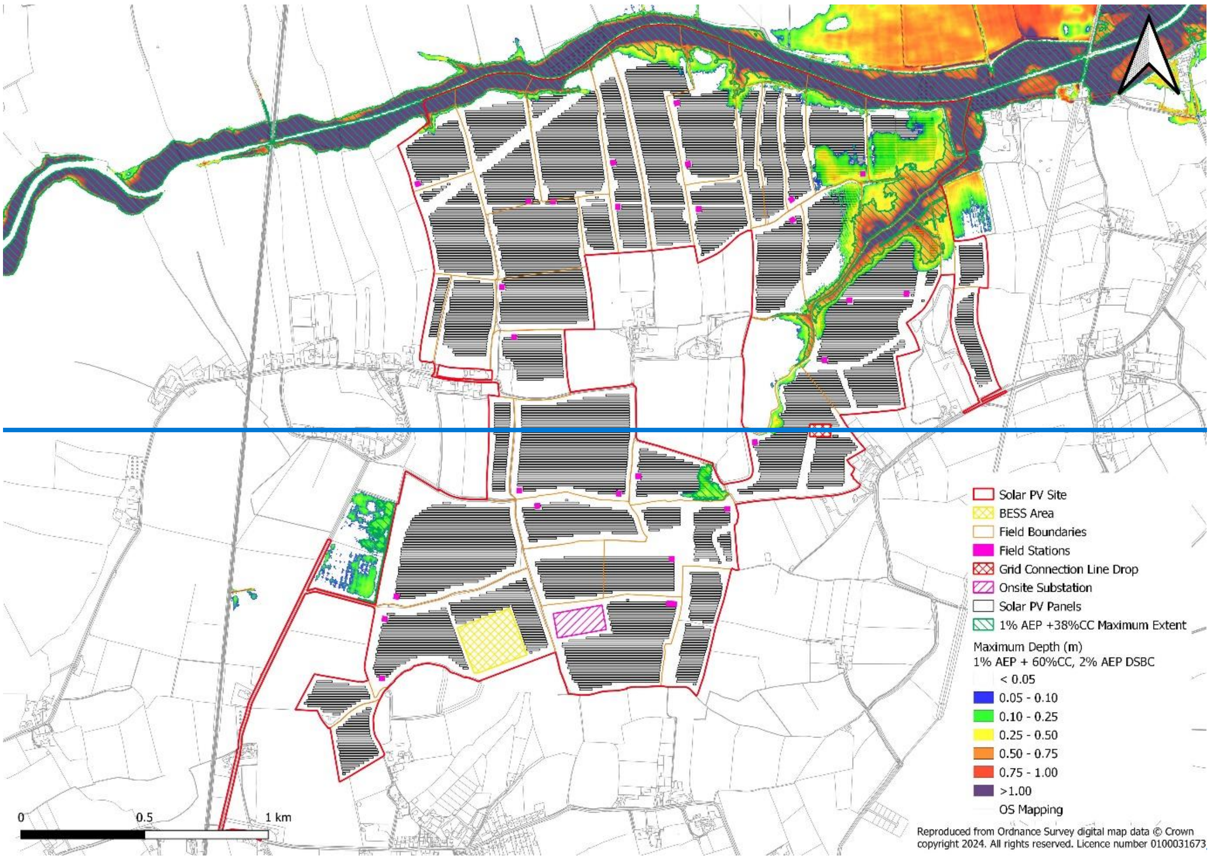


Figure 6-6: Baseline Credible Maximum, 1% AEP + 60% + 2% AEP River Don downstream boundary.

6.5.3 Simulation of the credible maximum scenario as part of the sensitivity testing undertaken demonstrates the potential flood risk to the Scheme in a fluvial

~~flood event that exceeds the magnitude of the design event, and also takes into account the impact of locking from the tidal River Don. Results show that whilst maximum flood depths generally exceed those for the design event, maximum flood extents are comparable. It should be noted that the changes in depth and extent do not pose a significant additional risk to the Scheme, with these changes occurring predominantly in the Solar PV Site and other elements such as the BESS Area and substation remaining outside the flood extent.~~

~~6.6~~6.5 LMED Estimation

~~6.6.1~~6.5.1 The hydraulic model has not been calibrated due to the absence of suitable flow gauges and the uncertainty associated with the influence of the downstream tidal boundary on the River Don. To provide more confidence in the model set up the Topham Ferry Bridge level gauge has been used to estimate LMED to compare to the modelled QMED (50% AEP) flows within the hydraulic model. This provides a sensibility check of the model compared to observed local data.

~~6.6.2~~6.5.2 An LMAX series was first created from the 21 years of level data at the Topham Ferry Bridge using data extracted from the DEFRA Hydrology Data Explorer website. Non complete water years (2002 – 2003 and 2023 – 2024) were removed from the calculations.

~~6.6.3~~6.5.3 ~~Table 6-1~~Table 6-1 shows the comparison of the 50% AEP maximum stage at the Topham Ferry Bridge level gauge against the LMED estimated from hydrometric data. The model results estimate the QMED stage to be c.-0.~~15m~~15 m below the level gauge data.

Table 6-1: LMED ~~estimation~~Estimation

	Stage (mAOD)
LMED	3.57mAOD8
50% AEP	3.42mAOD
Difference	-0.15m

~~6.6.4~~6.5.4 Given the LMED estimate is within +/-150mm this indicates that the hydraulic model may underestimate stage at the Topham Ferry Bridge but is within reasonable tolerance for matching the gauge. Possible reasons for differences between modelled and observed levels may include:

a. The reliable estimation of LMED at the Topham Ferry Gauge is limited by the influence of tide locking of the River Went by the River Don. This may lead to higher LMED values than would be expected without the tidal influence;

[8] Assuming a gauge datum of 0.86mAOD. Source: Gauge Map UK at https://www.gaugemap.co.uk/#!Detail/17636

b. The survey of the Topham Ferry Bridge Gauge was incomplete due to flooding during the survey. This means a direct comparison with the gauge level is less certain; and

~~c. The gauge datum has been assumed from Gauge Map UK as 0.86mAOD. If the gauge datum is incorrect then the comparison would be affected.~~

c. In the absence of suitable hydrometric data for calibration of the hydrology and hydraulics the comparison of the 50% AEP modelled event to LMED shows an acceptable level of agreement. Given LMED appears to be influenced by the locking of the downstream boundary, accounting for the impact of locking of the Went outfall by the tidal River Don, as per the methodology adopted for this assessment, is key to representation of flood risk within the Went catchment. Further analysis of the initial conditions is presented in the addendum report.

6.6 Credible Maximum Scenario

6.6.1 Following the additional sensitivity analysis undertaken and consultation with the Environment Agency, documented within the addendum included as Appendix D of this report, the credible maximum scenario documented within this section of the report was selected as the design event for the scheme assessment and basis of mitigation measures detailed within the FRA. This section of the report has been updated to reflect this, although the reader is referred to the addendum for further details of the additional simulations.

Model Setup

6.6.2 To assess the credible maximum scenario the hydraulic model was simulated for the 1% AEP + 60% allowance for climate change (Upper End). In addition, a static HT time series using the 0.1% AEP 2121 H upper scenario Humber Extreme Water Levels taken from the River Don at the River Went outfall was applied as the downstream boundary condition, which effectively locks the River Went for the entire simulation and all flood water is stored within the catchment.

6.6.3 It should be noted that the Boundary Viscosity Factor of 5 was also applied to the TUFLOW model to help smooth exchange of flow across the 1D-2D boundary. This was found to have limited impact on the 1D stage results but helped reduce the instability at high depths. The model was run without the Boundary Viscosity Factor. The stage results from the model were identical to the results with the Boundary Viscosity Factor to the point of the onset of model instability. Given there is already significant out of bank flooding at this point it is concluded that the Boundary Viscosity Factor has little impact on the 1D results but helps reduce instability at high depths. Following the Environment Agency review of the model the Boundary Viscosity Factor was also applied to the baseline model simulations documented in Section 5.

Model Health

6.6.4 The FMP 1D convergence plot for the credible maximum scenario is shown in Plate 6-6 and 2D Cumulative Mass Balance Error is shown in Plate 6-7. The combination of locking of the downstream boundary and increased volume in the catchment has meant that large water depths are present across the 1D-2D boundary, greater than 3m in some locations. This, combined with the flat characteristics of the catchment and low velocities, have led to poor 1D model convergence after 50hrs. This results minor fluctuations in level at the downstream of Fleet Drain and on the River Went but within the 2D domain the fluctuations in the water level are dampened. Importantly, the results shows that the poor model convergence occurs after the peak of the event and so have less impact on the conclusions of this report. Similar convergence issues are seen at high water levels in the sensitivity analysis documented in the addendum report (Appendix D) where further discussion and analysis of model stability is presented.

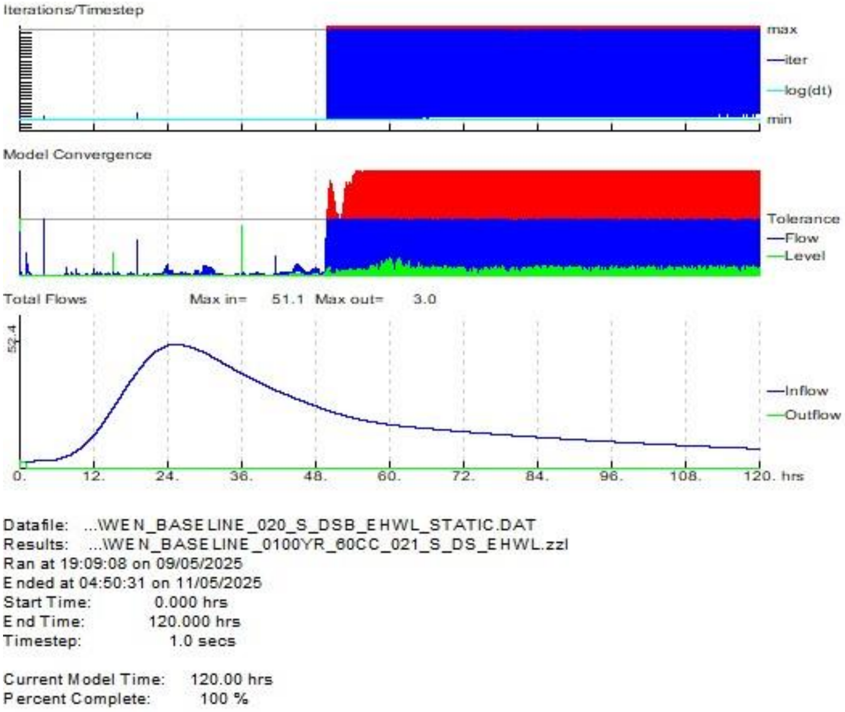


Plate 6-6: Credible maximum scenario 1d FMP convergence plot

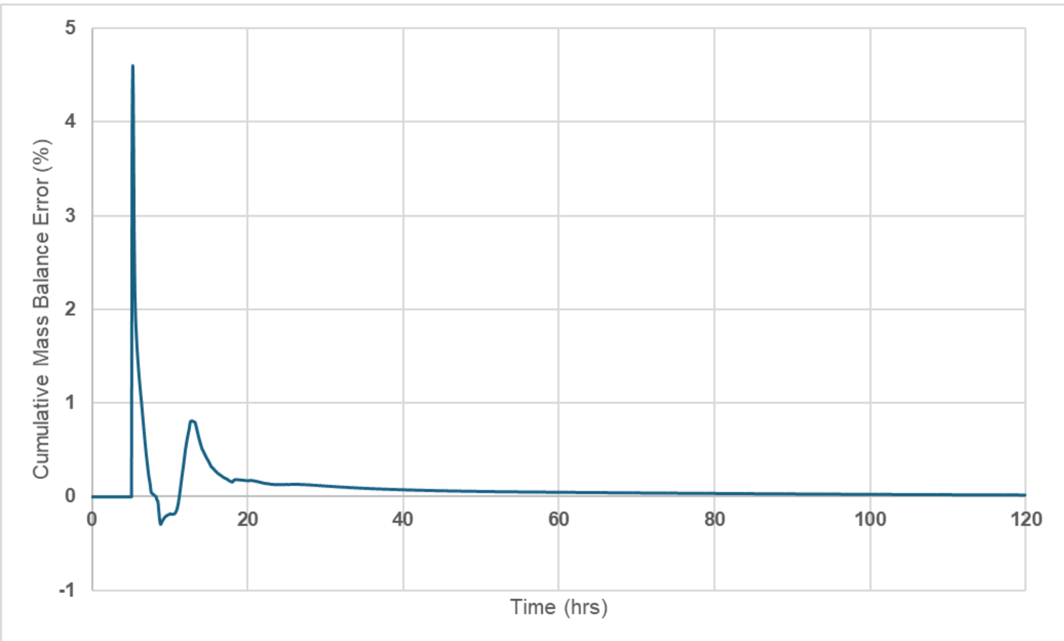


Plate 6-7: 2D Mass Balance Error for Credible Maximum Scenario

Results and Flood Mechanisms

6.6.5 Plate 6-8 shows the maximum flood depths map for the credible maximum scenario compared to the 1% AEP + 38%CC baseline event. In general, the maximum flood depths within the River Went and Fleet Drain increase by c.0.55m compared to the design event. The maximum flood extents for the credible maximum scenario are increased along the right bank of the River Went through the Scheme inundating some of the northern PV solar areas to 0.3mand deeper flooding of up to 1m is found within the Ecology Mitigation Area. Both banks of the Fleet Drain at the downstream extent are increased with the two PV solar areas at the north-east of the Scheme become inundated to depths up to c. 0.5m but in general flood depths are below 0.4m. The PV solar area on the right bank of Fleet Drain becomes further inundated with small parcels reaching depths of c.0.8m though this is predominately below 0.4m. In the upper Fenwick Common Drain catchment there is increased flooding on the left bank but this is not within the development. It is noted that some field stations on the left and right bank of Fleet Drain become inundated during the credible maximum scenario. One if these is to a depth of 0.4m whilst the others are generally below 0.1m.

6.6.6 It was identified in Section 5.2 that the baseline design simulations have been exceeded a number of times in the observed record at Topham Ferry Bridge level gauge within the 21 year record. Further investigation documented in the addendum report demonstrates that the credible maximum scenario is +0.27m above the highest observed record of 4.60mAOD at the gauge (February 2021). Results from the credible maximum scenario, demonstrate that flood levels around the Site plateau after reaching 4.70mAOD - 4.80mAOD, with this occurring due to flood water spilling over a flood defence on the left bank of the River Went and significantly expanding the area of the floodplain. As a result substantial volumes of additional flood water would be required in order to further raise the flood level around the site.

6.6.7 The credible maximum scenario was compared to the 2000 and 2007 recorded flood outlines and is shown to be similar but greater than the recorded events. This builds confidence that the flooding mechanism is consistent with the observed record.

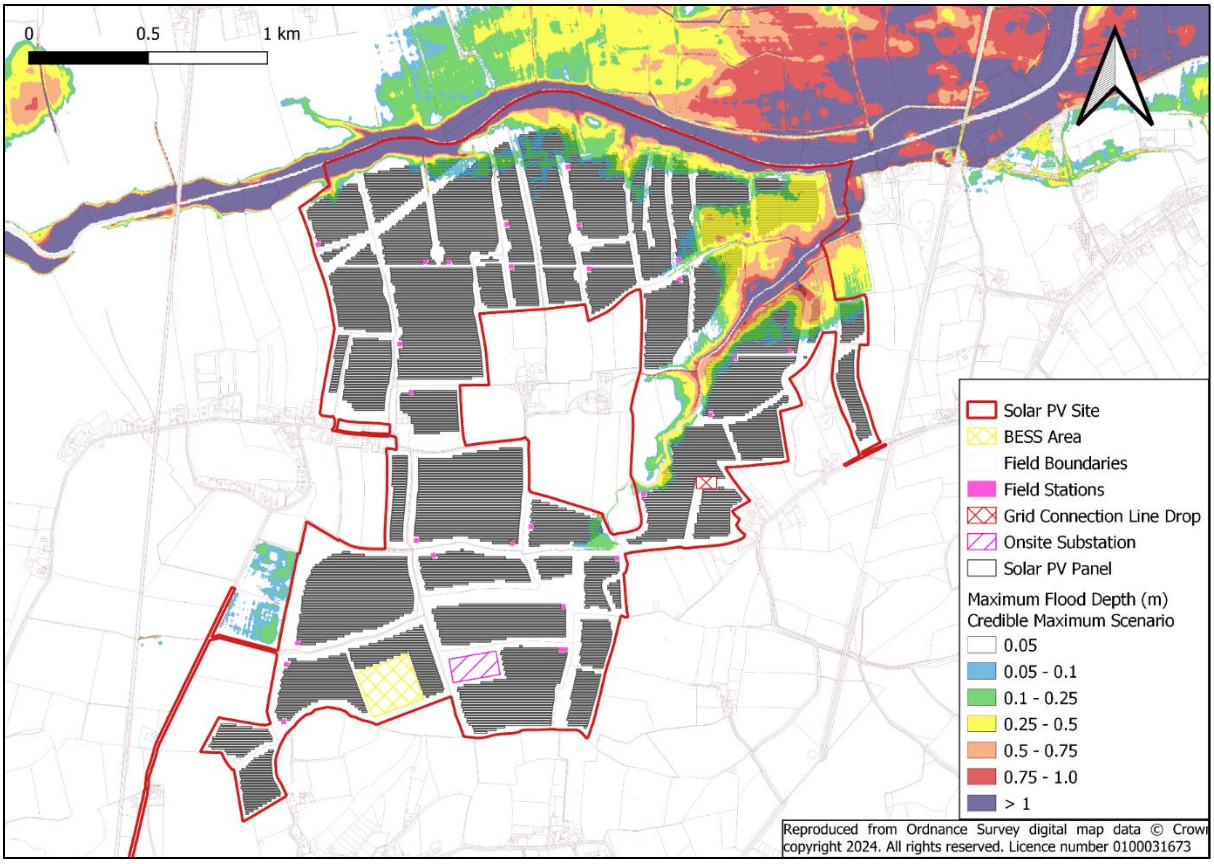


Plate 6-8: Baseline Credible Maximum, 1% AEP + 60% + 2% AEP River Don downstream boundary.

Credible Maximum Summary

6.6.56.6.8 The credible maximum scenario demonstrates the potential flood risk to the Scheme in a fluvial flood event that exceeds the magnitude of the modelled design events and also takes into account complete locking of the River Went from the tidal River Don. The changes in depth and extent within the credible maximum scenario, compared to the modelled design events, do not pose a significant additional risk to the Scheme. Changes in extent and depths occur predominantly in the Solar PV Site, and other more vulnerable elements of the Site such as the BESS and substation remain outside the flood extent. Based on the conclusions of the addendum it is recommended that the credible maximum scenario is used as the design event as a precautionary approach.

6.7 Summary

6.7.1 The results of sensitivity tests demonstrate that the modelled floodplain depths for the 1% AEP event at the Scheme show the expected level of sensitivity to changes in Manning's roughness, model inflows or changes in the downstream boundary on the River Don. Whilst there is a relatively large increase in the overall maximum flood depths when the River Went is locked from the River Don the increases in maximum level at the Scheme are generally confined to the Ecology and Heritage Mitigation Areas.

6.7.26.7.1 ~~A credible maximum scenario has been simulated with the Upper End climate change allowance (+60%) and an effectively locked downstream~~

boundary on the River Went to take into account the influence of the tidal River Don. The maximum flood extent within this scenario is comparable to the chosen design event and all additional flooding is located within solar PV areas at depths less than 0.35m, important elements such as the BESS Area and substation remain outside the floodplain.

6.7.2 Additional model proving has been undertaken by calculating the LMED at the Topham Ferry Bridge level gauge and comparing to the modelled QMED (50% AEP) levels at the bridge. It was found that the model is c -0.15m lower than the calculated LMED value. This is within the expected tolerances.

6.7.3 A credible maximum scenario has been simulated with the Upper End climate change allowance (+60%) and an effectively locked downstream boundary on the River Went to take into account the influence of the tidal River Don. . The maximum flood extent within this scenario shows all additional flooding is located within PV solar areas, important elements such as the BESS and substation remain outside the floodplain. Additional analysis in the addendum report (Appendix D) shows that the credible maximum scenario is a more preferable design event and robust against uncertainties in the catchment initial conditions and hydrology. Following additional sensitivity simulations and consultation with the Environment Agency, documented within the addendum report, the credible maximum scenario has been chosen as the design event for the assessment of flood risk to the Site, and forms the basis of associated mitigation measures.

6.7.36.7.4 Overall model proving undertaken builds confidence that the choices of downstream boundary conditions, hydrology and model representation are suitable for this assessment, whilst also demonstrating that the layout of the Scheme is resilient to flooding.

7. Breach Modelling Methodology

7.1 Overview

7.1.1 To understand the residual risk to the Scheme from the tidal River Don if a breach were to occur, breach modelling has been undertaken for two breach locations. The first breach location modelled is failure of the River Went Outfall structure, hereafter referred to as the ‘Went Outfall Breach’. This location was selected as failure of this structure is likely to have a significant impact on the Scheme . The second location is to the south of the Scheme at the River Don defences between Thorpe in Balne and Kirk Bramwith, hereafter referred to as the ‘Southern Breach’. The second location was selected as based upon existing modelling for the River Don, a breach at this location would pose a significant flood risk to the Scheme.

7.1.2 It was originally proposed to use the 1D-2D River Went model to simulate the breach models. However, due to the potential for convergence issues given the large depths and volumes of water associated with a breach,a standalone 2D only model representing the floodplain was built and run using TUFLOW HPC GPU version 2023-03-AC.

7.2 Model Extent

7.2.1 The model extent was delineated by key topographic features in the area of interest and was sufficient to capture flow pathways to the Scheme in the event of a breach. The southern boundary and eastern boundary are the River Don defences. The western boundary is the A19 and railway lines. The northern boundary is the Knottingley and Goole Canal. The 2D domain is presented in Figure 7-1.

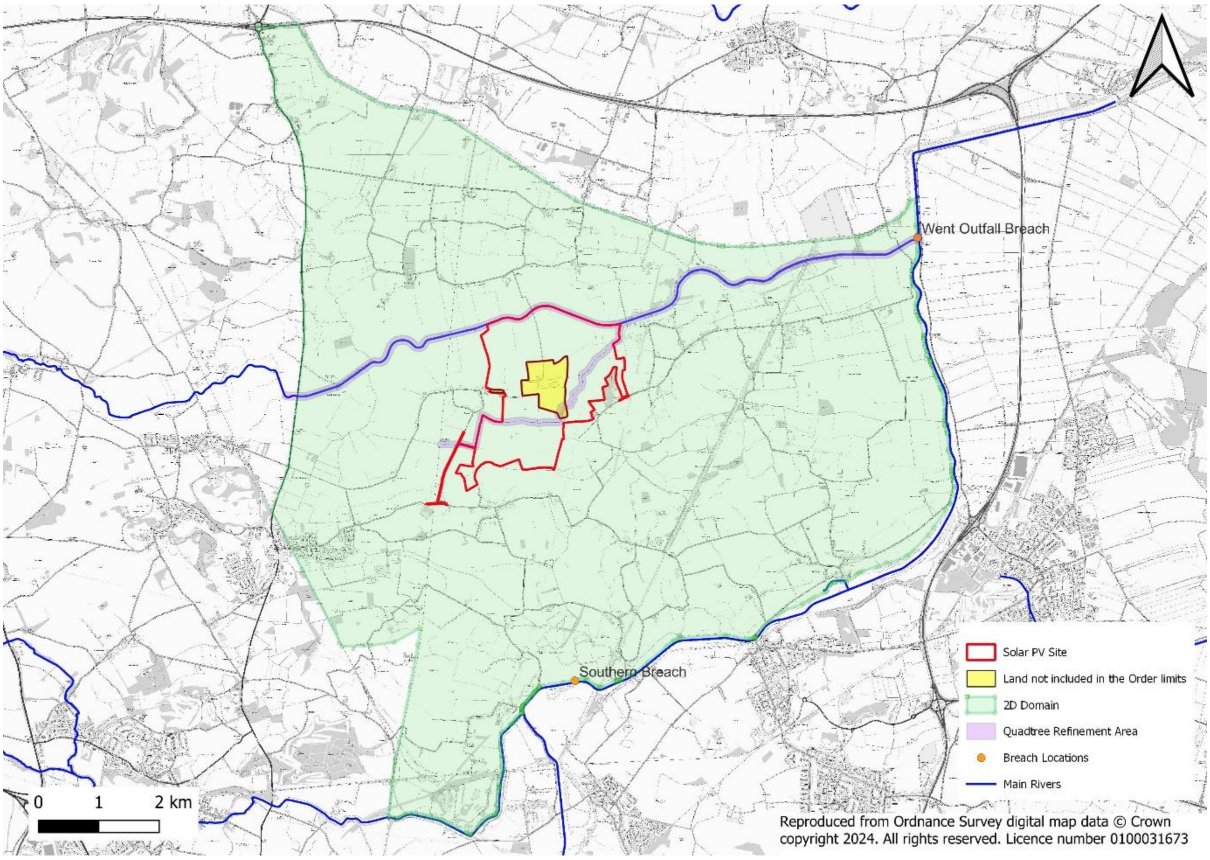


Figure 7-1: 2D Breach Model Schematisation

7.3 Grid Resolution

7.3.1 A single 2D domain with an 8 m grid was employed, and the Quadtree module was used to refine the grid size to 4 m for a 100 m wide area around the River Went, Fleet Drain and Fenwick Common Drain. This refinement was to provide more detail of the channel capacity and conveyance in the most hydraulically significant areas of the model.

7.3.2 To understand the impact the representation of the River Went channel has on the Went Outfall breach results a sensitivity test was undertaken. The model was run with sub-grid sampling to enable a more detailed representation of the channel.

7.3.3 The results show that with sub-grid sampling the flood extent at the Scheme is smaller. The flood levels are approximately 0.1 m less across the Scheme. This test shows that the existing model setup (without sub-grid sampling) is conservative. Therefore, these results will be used.

7.4 Timestep

7.4.1 The hydraulic model was run with a 2 second timestep and a simulation length of 68 hours, including an additional 12 hours after the breach has closed to ensure the peak water level is reached in the Scheme.

7.5 2D Model Build

7.5.1 The 1m resolution LiDAR DTM was considered sufficient in detail to represent the key topographic features within the 2D model domain. To ensure appropriate representation of key floodplain features the following topographical amendments were incorporated into the model:

a. The channel geometry was represented using a polygon z shapefile based on the invert levels of the cross-sections in the fluvial model. The width of the channel was defined as an average on a reach by reach basis.

b. Watercourse banklines from the fluvial model that correspond with the surveyed cross-section bank markers.

c. Crest levels of the River Don defences based on the AIMS database 'actual_ucl' attribute value. This attribute was selected as this was typically the lowest value compared to the 'actual_dcl' value and therefore this was the conservative option.

d. Topographical features zsh lines were extracted from the Lower Don model

e. The Knottingley and Goole Canal southern crest level was incorporated into the model based on LiDAR.

7.6 1D Model Elements

7.6.1 There were five structures included in the model. These structures were deemed to be key hydraulics controls along the River Went. Structures that were not included were small rural bridges that were assumed to not have a significant impact on the hydraulics in the area due to the scale of flooding from the breaches. The structures included in the model are summarised in Table 7-1.

Table 7-1: Structures included in the the breach model.

Watercourse	Model Asset ID	Structure	ESTRY Representation	Comments
River Went	WENT	Sluice Gates	2 x rectangular uni-directional culverts (4.44 x 2.78 m)	It has been represented as uni directional as it is assumed that water is only flowing from the River Don into the River Went at the outfall location.
River Went	CANAL	Canal Viaduct	1 x rectangular culvert (41.67 x 2.3 m)	This has been simplified to be represented as a rectangular culvert. The culvert dimensions are based on the area between the canal viaduct and bed level in the surveyed cross-section.
River Went	RAIL1	Railway bridge	1 x irregular culvert	This has been represented as an irregular culvert with a height-width (HW) relationship based on the FMP cross-section.

Watercourse	Model Asset ID	Structure	ESTRY Representation	Comments
River Went	RAIL2	Disused railway bridge	1 x irregular culvert	This has been represented as an irregular culvert with a height-width (HW) relationship based on the FMP cross-section.
Fleet Drain	FLE	Sluice Gates	1 x rectangular uni-directional culvert (1.14 x 1.61 m)	It has been represented as uni directional as it is assumed water is only flowing from the Fleet Drain into the River Went otherwise the gate would be closed.

7.7 Manning's Roughness Coefficients

7.7.1 As detailed in Section 6.2, the Manning's n roughness value in the 2D domain were assigned based on the OSMM materials layer. As the 2D breach model extent is larger than the fluvial model extent where OSMM data was not available Ordnance Survey Local Map information was used to extend the materials layer. Given the predominantly rural nature of the area, a default roughness value of 0.050 was used for the 2D domain. The roughness values can be viewed in Table 4-3:.

7.8 Breach Representation

7.8.1 The Southern Breach instantaneous failure was applied using a 2D variable z-shape (2d_vzsh). This lowers the breach area to the breach invert. The breach parameters were calculated based on the Environment Agency guidance[9]. For a river breach with earth bank defences the breach width is 40 m and the time to close 56 hours (for a rural location).

7.8.2 The toe level of the defence was determined by interrogating a cross-section through the LiDAR DTM on the landward side of the breach location. The lowest ground level within a radius the same width as the breach (40 m) was used. This was determined to be 4.27 m Above Ordnance Datum (m AOD). The 2d_vzsh was set to lower to 4.27 m AOD after 0.25 hours.

7.8.3 To represent the breach the Went Outfall structure was simulated as a uni-directional rectangular culvert. This assumes that a breach has occurred, and the water is only flowing from the Lower Don into the River Went and the sluice is fully open. A 1D ESTRY HT boundary was applied to the River Don side of the Went Outfall structure.

7.9 Boundary Conditions

7.9.1 The maximum water level at the Went Outfall and Southern Breach was extracted from the 2018 Lower Don model for the 1% AEP and 1% AEP + 50% climate change events. This breach was represented with a 40 m wide HT (head-time) boundary and with a 2d_vzsh to lower the ground over a 40 m x 40 m area.

[9] Environment Agency, 2021, LIT 56413 – Breach of defence guidelines

7.9.2 It should be noted that a constant water level has been applied for both breaches for the duration of the breach, corresponding to the maximum level at that location within the River Don modelling for the 1% AEP + 50% climate change event. This approach is deemed to be conservative.

7.9.3 No upstream boundary condition has been applied on the River Went. An initial water level has been applied to represent existing water in the channel. However, it is assumed that any fluvial inflows would be insignificant compared to the scale of water from the breaches.

7.9.4 Normal depth (HQ) boundaries have been applied along the western edge of the model (A19 road and railway line) and the northern edge of the model (Aire and Calder Navigation canal).

7.10 Model Runs

7.10.1 The model has been simulated for a 1% and 1% plus 50% climate change breach event.

7.11 Model Stability

7.11.1 The breach models were run using TUFLOW HPC. There are no repeated time steps and there are a few occurrences of timesteps with low dt but these occur later in the simulation and do no occur for consecutive timesteps indicating the model is stable overall.

8. Breach Model Results

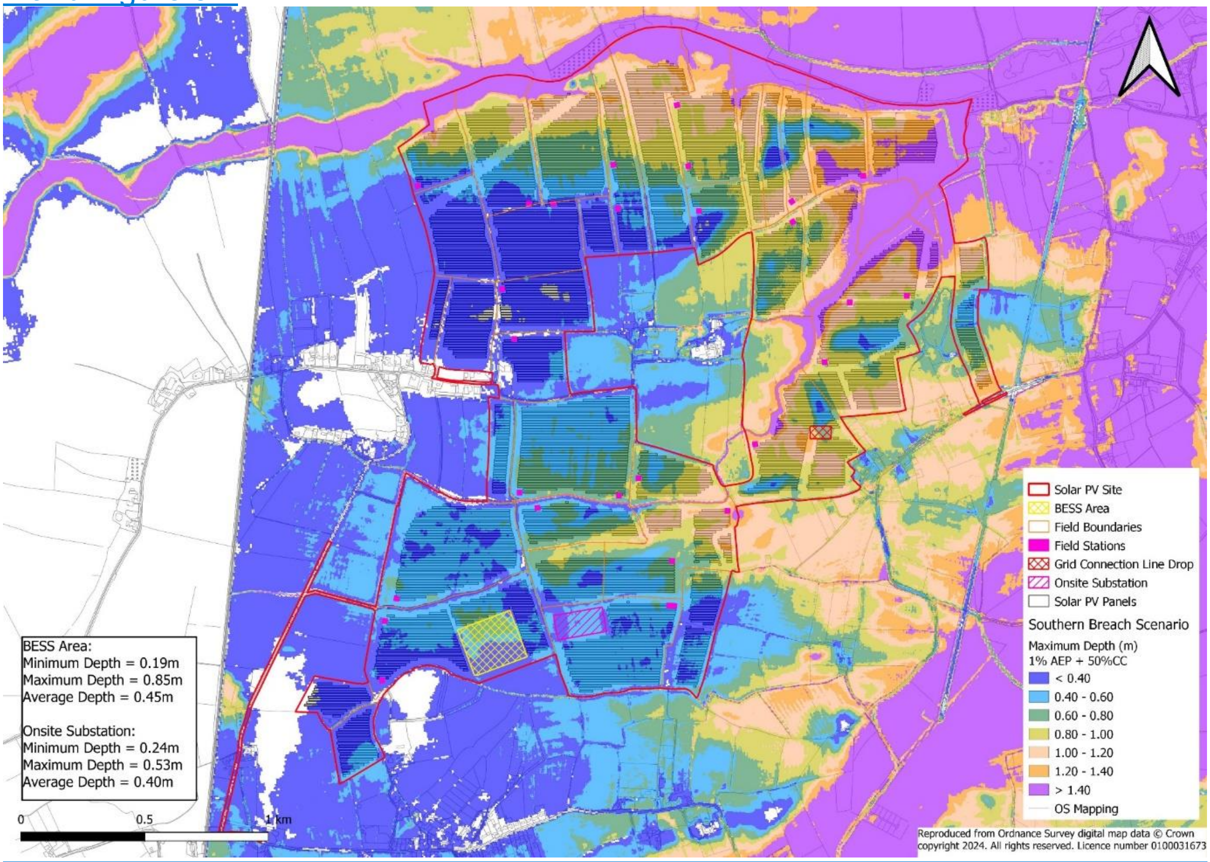
8.1 Overview

8.1.1 In this section the results from the breach model are described for the design event (1% AEP + 50% climate change) and the mechanism of flooding modelled within the ~~Study Area~~study area is discussed. The 1% AEP result maps for both breach locations are included in Appendix C.

8.2 Flooding Mechanism

8.2.1 The flooding mechanism is largely similar for both AEP events simulated at each breach location.

The 1% AEP + 50% climate change maximum flood depth for the Southern Breach and Went Outfall Breaches are shown in ~~Figure 8-1 and Figure 8-2.~~Figure 8-1 and Figure 8-2



8.2.2 Figure 8-1.

8.2.3 The flooding mechanism for the Southern Breach can be summarised as follows:

a. The breach failure occurs at 0.25 hours and then water begins to flow out of the River Don into the floodplain to the north of the breach location.

b. The water follows the low-lying areas and builds up against roads and raised areas. Flood waters from the breach propagate across the majority of the land around the Scheme, inundating a wide area to depths of over 1m.

c. The water reaches the Scheme at approximately 4.5 hours and flows along the Fleet and Fenwick Drain before spreading across majority of the Scheme. The peak level at the Scheme occurs at 57.5 hours.

d. In the 1% AEP + 50% climate change scenario almost the entire Scheme area is inundated, with approximately half of this area being inundated to depths of greater than 0.7m. The BESS ~~Area~~ and substation are flooded to an average depth of less than 0.5m, whilst ~~the Solar~~ PV ~~Sites~~ arrays across the Scheme experience varying depths of maximum flooding, with depths being greater to the north and east of the Scheme.

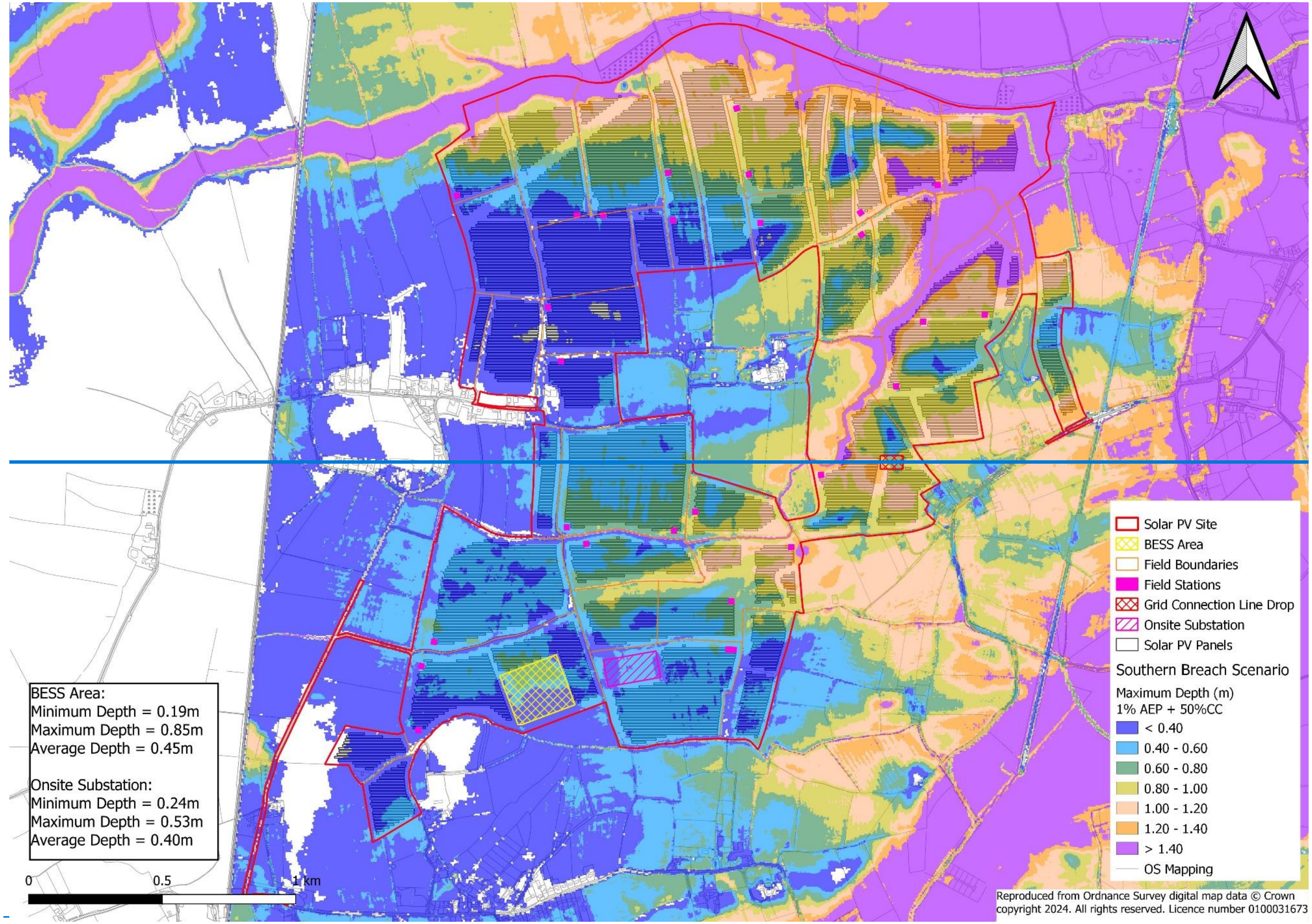
8.2.4 The flooding mechanism for the Went Outfall Breach can be summarised as follows:

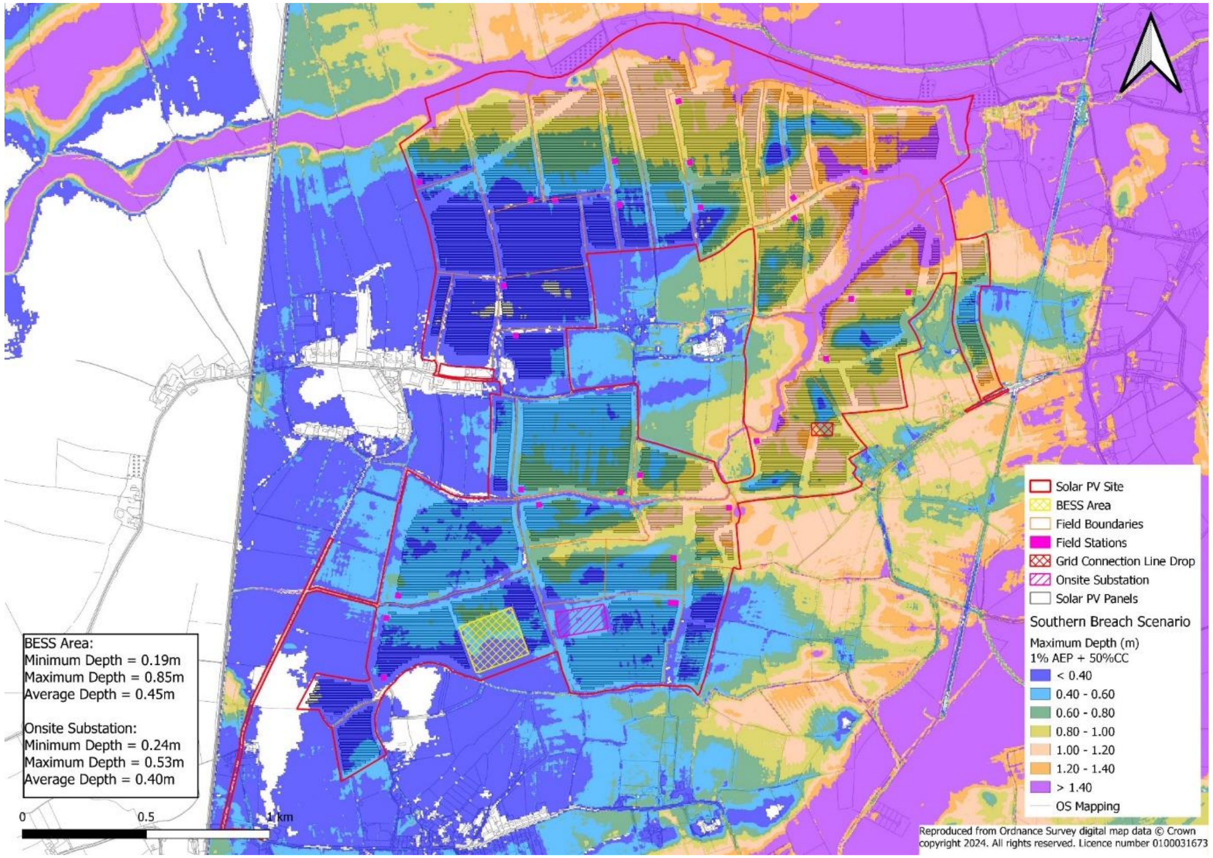
a. Flood water from the breach propagates up the River Went channel inundating a large portion of the floodplain between the Don confluence and the Scheme to depths greater than 1.5m.

b. The breach flow reaches the Fleet Drain at 5 hours and begins to flow up this channel and out of the bank at the location of the Scheme.

c. Flooding to ~~of Solar~~ PV ~~Site~~arrays from the River Went occurs along the northern boundary of the Scheme, and on either side of the Fleet Drain upstream of the Went confluence. Maximum flood depths in the ~~Solar~~ PV ~~Site~~areas are generally less than 0.7m in the 1% AEP + 50% climate change scenario. The BESS ~~Area~~ and substations remain outside of the breach extent.

d. The peak flood depths at the Scheme occurs at approximately 58 hours.


Solar PV Site
BESS Area
Field Boundaries
Field Stations
Grid Connection Line Drop
Onsite Substation
Solar PV Panels
Southern Breach Scenario
Maximum Depth (m)
1% AEP + 50%CC
< 0.40
0.40 - 0.60
0.60 - 0.80
0.80 - 1.00
1.00 - 1.20
1.20 - 1.40
> 1.40
OS Mapping
BESS Area:
Minimum Depth = 0.19m
Maximum Depth = 0.85m
Average Depth = 0.45m
Onsite Substation:
Minimum Depth = 0.24m
Maximum Depth = 0.53m
Average Depth = 0.40m
0
0.5
1 km
Reproduced from Ordnance Survey digital map data © Crown copyright 2024. All rights reserved. Licence number 0100031673


BESS Area:
Minimum Depth = 0.19m
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Average Depth = 0.45m
Onsite Substation:
Minimum Depth = 0.24m
Maximum Depth = 0.53m
Average Depth = 0.40m
0
0.5
1 km
Solar PV Site
BESS Area
Field Boundaries
Field Stations
Grid Connection Line Drop
Onsite Substation
Solar PV Panels
Southern Breach Scenario
Maximum Depth (m)
1% AEP + 50%CC
< 0.40
0.40 - 0.60
0.60 - 0.80
0.80 - 1.00
1.00 - 1.20
1.20 - 1.40
> 1.40
OS Mapping
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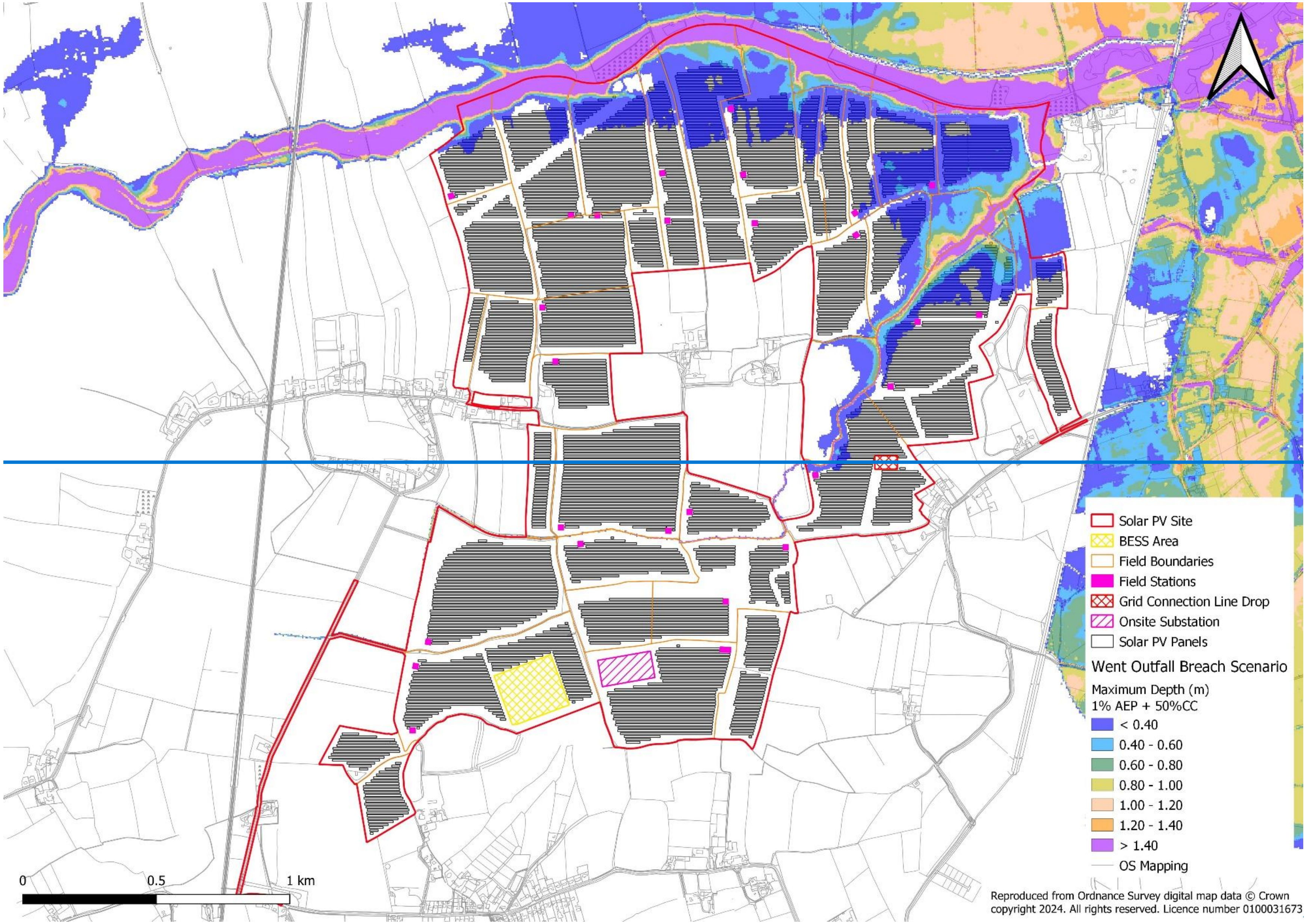
Figure 8-1: Southern Breach Flood Extent Flood Depth 1% AEP + 50%CC



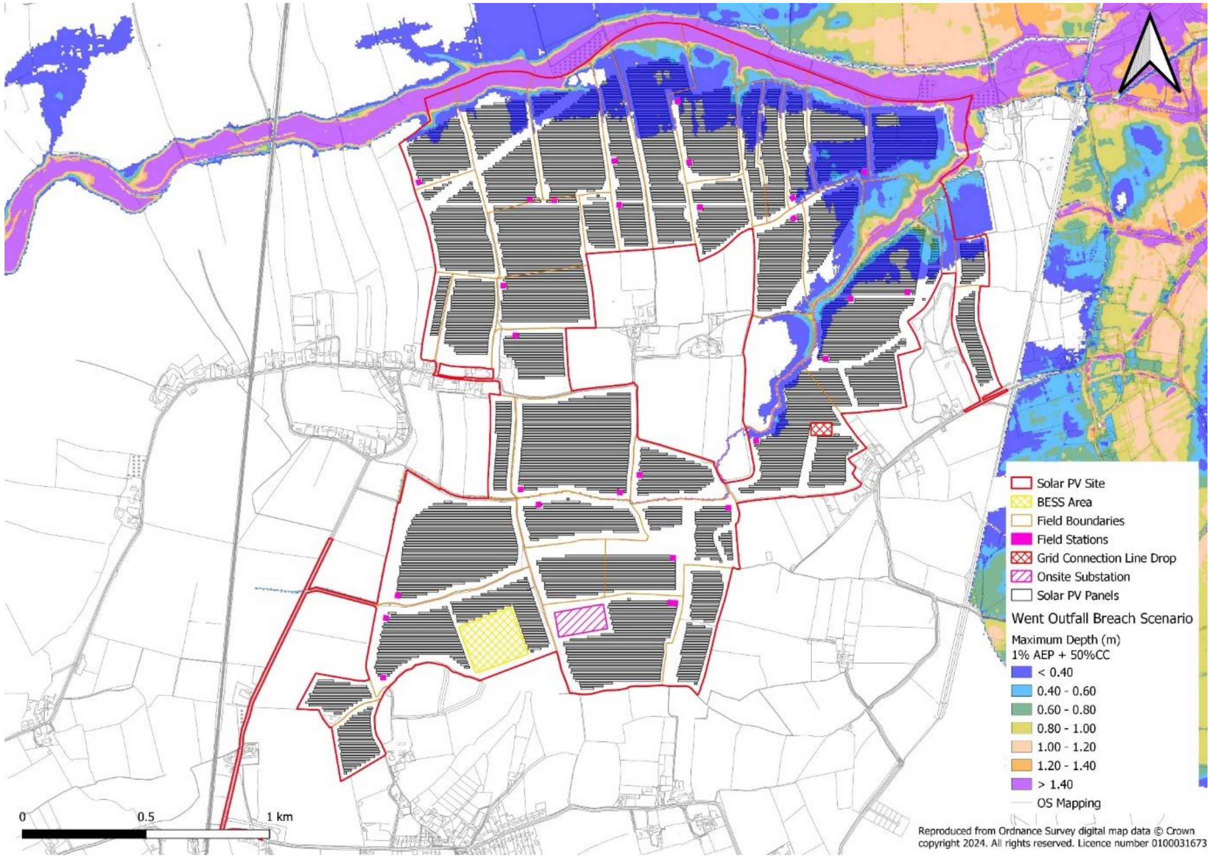


Figure 8-2: Went Outfall Breach Flood Depth 1% AEP + 50%CC

9. Assumptions and Limitations

9.1.1 When considering the results and discussion throughout this report, it is important to understand the assumptions and limitations of the models and their outputs. For the baseline fluvial model and breach model, the key assumptions and limitations include:

a. Fluvial model

i. The channel survey for the River Went, Fleet Drain and Fleet Common Drain was limited by the high river levels during the period of survey and by land access. Where survey data was not complete the best available data was used to represent the channel and structures.

ii. The representation of the soffit and bed of the New Junction Canal Bridge (WEN_01876BU) is assumed from photographs and available survey data. It was not possible to survey the bypass channels to the north and south of the crossing due to high water levels and therefore the size has been assumed from LiDAR DTM.

iii. Two structures in the fluvial model were assumed based on closest cross-section and similar structure information from the survey.

iv. Where new cross-sections were created in the 1D model at the location of structures and confluences, the channel geometry of the nearest upstream node, in tandem with the gradient of the upstream cross sections were used to create the geometry of these new cross-sections. However, this presupposes that the channel geometry and gradient remain consistent over these sections of watercourses.

v. Hydrological assessments commonly represent one of the most significant sources of uncertainty within fluvial hydraulic modelling. Whilst the catchment does have a number of gauges these are only suitable for checking of the hydrological estimates and modelled levels.

vi. There is no information available to carry out a detailed calibration of the fluvial model, model proving has therefore relied upon sensitivity testing and an LMED comparison exercise.

vii. The initial catchment conditions at the start of large flood events are complex and dependent upon the tidal river level on the River Don, fluvial flows on the River Don, period of locking of the River Went and volume of water stored in the River Went catchment during this period. Sensitivity analysis presented in the addendum (Appendix D) has presented a robust assessment of the impacts of the initial catchment conditions that is proportionate with the requirements of the FRA, but quantification of risk remains complex and beyond the scope of this study.

~~vii.~~viii. Assumed that the 2023 LiDAR DTM is representative of the current ground levels within the modelled area.

~~viii.~~ix. The topography and OSMM at the start of the Project are assumed to be the best representation of the area.

~~ix.~~x. The with scheme scenario has ~~not~~only been simulated~~, this relies upon~~ with the ~~Solar PV Site ,~~Fleet Drain culvert removed, and is reported in the ~~only elements~~ addendum report. The impact of the ~~Scheme flooded within~~inundation of PV arrays and bunding of field stations is associated with a negligible displacement of water compared to the ~~design event, do not impact upon~~volume in the floodplain ~~storage or conveyance~~, and the impact has therefore been assessed with hand calculations based upon flood depths and levels from the model.

b. Breach model

i. Watercourse channels are represented within the 2D grid at 4m resolution through lowering topographical levels. Whilst this is a simplification compared to use of a 1D model, the level of detail is considered sufficient to capture conveyance within the watercourses given the volumes of flooding.

ii. It is assumed that the simplified structure representation is suitable for this assessment. It is also assumed that the structures not included would not have significant impact on the results.

iii. The defence crest level, breach locations, breach widths, defence toe level and breach elevations are assumed to be appropriate for the purposes of this assessment.

iv. It is assumed that the calculation of the defence toe level based on the Environment Agency guidance is appropriate for the Southern Breach location.

v. Assumed that the topographic features data from the Lower Don 2018 model is suitable for use in the breach model.

vi. Assumed the roughness values used are representative of the ground conditions.

vii. Assumed that the 2018 Lower Don modelled water levels with the associated hydrology are appropriate to represent the downstream boundary in this assessment.

viii. Assumed the Southern Breach location was appropriate to represent maximum flooding at the Scheme from a breach on this stretch of the River Don.

ix. The with scheme scenario has not been simulated, given the extensive extent and depth of flooding within the breach scenario it is assumed that any mitigation, such as raising or bunding of the BESS ~~Area~~/substation will not impact upon flood extent or depths elsewhere.

x. Assumed that any flood water entering the canal in the Southern breach is insignificant due to the scale of flooding.

xi. Assumed that the ‘Actual Upstream Crest Level’ data from AIMS database is representative of defence crest levels in the area.

xii. No flows have been applied to the River Went or Fenwick Common Drain. This is assumed to be appropriate due to the significant scale of flooding from the Southern Breach. Initial water levels have been used to represent existing water in the River Went, Fenwick Common Drain and Fleet Drain.

10. Summary

10.1.1 A new fluvial 1D-2D FMP-TUFLOW hydraulic model was built covering the River Went, Fleet Drain and Fenwick Common Drain so that fluvial flood risk to the Scheme could be quantified and understood. To enable a new hydraulic model to be built, a survey of the relevant watercourses and structures was commissioned in December 2023. In addition, a new hydrological assessment was also carried out to provide upstream inflows for the 1D model.

10.1.2 The fluvial baseline model results showed that the River Went is impacted by locking by the tidal River Don, which limits outflow from the watercourse. For all AEP events simulated inundation by the Fleet Drain and Fenwick Common Drain within the boundaries of the Scheme were restricted to the ~~northeast~~north-east corner of the Scheme. In the 1% AEP + 38%CC and 0.1% AEP event there is also flooding upstream of Bunfold Shaw Lane. Importantly although some limited sections of the ~~Solar~~ PV ~~Site~~arrays become inundated within this event, the field stations, BESS ~~Area~~ and substation are all positioned outside the modelled flood extents.

~~10.1.2~~10.1.3 Peak levels within the modelled design events were shown to have been exceeded within the observed record at the Topham Ferry Bridge Gauge in the past 21 years, including the 1% AEP + 38%CC scenario. The credible maximum scenario has therefore been adopted as the design event for the Scheme, with justification for this provided in the addendum report (Appendix D) which documents additional sensitivity analysis undertaken along with consultation with the Environment Agency. Within the credible maximums scenario some areas of PV arrays and a number of field stations are located within the design flood extent, although importantly the vulnerable infrastructure such as the BESS and site compounds are positioned outside of the flood extent.

10.1.4 A 2D TUFLOW hydraulic model was built of the Scheme and surrounding area so that residual risk of flooding from a potential breach of the River Don defences from two locations could be assessed. The results showed that the Southern Breach resulted in significantly greater flood risk at the Scheme than a breach at the Went Outfall location, inundating the majority of the Scheme and surrounding area. The 1% AEP + 50%CC results for the Southern Breach showed an average depth of flooding of 0.46 m in the ~~BESS Area~~Bess area and 0.42 m in the substation area.

~~10.1.3~~10.1.5 The proposed culvert removal on Fleet Drain assessed in the addendum report shows negligible change to flood risk to and from the Scheme.

~~10.1.4~~10.1.6 Limitations of both modelling exercises have been documented within this report, and despite these limitations and uncertainties both the fluvial and breach models are considered robust tools for assessment of flood risk to the Scheme.

Appendix A Flood Estimation Handbook (FEH) Calculation Record

1 Flood estimation calculation record

Introduction

This document provides a record of the calculations and decisions made during flood estimation for the River Went, Fenwick, Doncaster. The information given here should enable the work to be reproduced in the future.

Contents

Approval

	Signature	Name and qualifications
Calculations prepared by:		[redacted] BSc (Hons) MSc
Calculations checked by:		[redacted] BSc (Joint Hons), MSc, PhD, C.WEM, CSci, CEnv
Calculations approved by:		

Revision History

Revision	Revision Date	Details	Authorised	Name	Position

Abbreviations

AEP	Annual exceedance probability
AM	Annual maximum
AREA	Catchment area (km^2)
BFI	Base flow index
BFIHOST	Base flow index derived using the HOST soil classification
CPRE	Council for the Protection of Rural England
DPLBAR	Mean drainage path length (km)
DTM	Digital Terrain Model
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
FPEXT	Floodplain extent
FSR	Flood Studies Report
HOST	Hydrology of soil types
NRFA	National River Flow Archive
OS	Ordnance Survey
POT	Peaks over threshold
QMED	Median annual flood (with return period ~2 years)
ReFH1	Revitalised Flood Hydrograph 1 method (2005)
ReFH2	Revitalised Flood Hydrograph 2 method (2013)
SAAR	Standard average annual rainfall (mm)
SPR	Standard percentage run-off
SPRHOST	Standard percentage run-off derived using the HOST soil classification
Tp (0)	Time to peak of the instantaneous unit hydrograph
URBAN	Flood Studies Report index of fractional urban extent
URBEXT1990	FEH index of fractional urban extent
URBEXT2000	Revised index of urban extent
WINFAP	Windows Frequency Analysis Package – used for FEH statistical method

2 Summary

This table provides a summary of the key information contained within the detailed assessment in the following sections. The aim of the table is to enable quick and easy identification of the type of assessment undertaken. This should assist in identifying an appropriate reviewer and the ability to compare different studies more easily.

Catchment location	River Went, Fenwick, Doncaster
Purpose of study and scope	Hydraulic model build to assess flood risk at a site of a proposed solar farm development. Moderate complexity.
Key catchment features	Mostly rural catchment, downstream boundary is the River Don.
Flooding mechanisms	Fluvial, tidal influence at the downstream boundary.
Gauged / ungauged	Number of level gauges in the catchment, only one is NRFA, data quality is poor and not reliable near and above QMED.
Final choice of method	FEH statistical
Key limitations / uncertainties in results	Lack of good quality high flow gauges in the catchment.

2.1 Note on flood frequencies

The frequency of a flood can be quoted in terms of a return period, which is defined as the average time between years with at least one larger flood, or as an annual exceedance probability (AEP), which is the inverse of the return period.

Return periods are are output by the Flood Estimation Handbook (FEH) software and can be expressed more succinctly than AEP. However, AEP can be helpful when presenting results to members of the public who may associate the concept of return period with a regular occurrence rather than an average recurrence interval. Results tables in this document contain both return period and AEP titles; both rows can be retained, or the relevant row can be retained and the other removed, depending on the requirement of the study.

The table below is provided to enable quick conversion between return periods and annual exceedance probabilities.

Annual exceedance probability (AEP) and related return period reference table

AEP (%)	50	20	10	5	3.33	2	1.33	1	0.5	0.1
AEP	0.5	0.2	0.1	0.05	0.033	0.02	0.0133	0.01	0.005	0.001
Return period (yrs)	2	5	10	20	30	50	75	100	200	1,000

3 Method statement

3.1 Overview of requirements for flood estimates and hydraulic modelling

Item	Comments
Give an overview which includes: • purpose of study including a short discussion if there is existing hydrology reports and estimates, when they were done and why we are updating the hydrology (e.g. new data or superseded methods) • approximate number and type of flood estimates required • peak flows and/or hydrographs? • range of design event AEPs (%) • climate change allowances (ref. relevant guidance)	Overview of activities: • Use the latest software and available datasets to generate updated peak flow estimates at 2no. Flow Estimations Points (FEPs). Proposed FEP locations are annotated in Figure 1; • Undertake flow estimates for the 2no. model FEPs, including 1no. at model inflow, 1no. upstream of the confluence with Fleet drain and at the discharging point of Fleet drain (Figure 1). • Undertake a comparison between FEH Statistical and ReFH2 peak flow estimates. If FEH Statistical is chosen as the preferred method, use ReFH2 to generate hydrographs scaled to the FEH Statistical peak flow estimates; • Generate design hydrographs at the 3no. model inflow locations for the 50%, 20%, 10%, 3.33%, 2%, 1%, 1% + climate change (1 scenario) and 0.5% AEP events; and, • If appropriate verify model output using local rainfall and level data. Analyse nearby gauging stations determine suitability for validation; • Summarise hydrology updates in a Flood Calculation Record.

3.2 Project Scope

Item	Comments

Give an overview which includes:
 	
• Complexity of study e.g. simple, routine, moderate, difficult, very difficult?
• What analyses are required:
  • Rating reviews
  • Review of existing study
  • Simple/detailed flood history review
  • ReFH model parameter estimation
  • Joint probability
	Routine complexity, flow estimates for 2 catchments.

3.3 Overview of catchment

Item	Comments
Brief description of catchment, or reference to section in accompanying report. Include general catchment map and specific map of hydraulic model extents and inflow locations.	Mostly rural catchment, with some small urban areas. Scattered small lakes/reservoirs in the upper catchment. Low rainfall (SAAR 550-675). Geology comprises shales, sandstones and limestones. Low-lying, predominantly arable catchment with isolated built-up areas.
Previous Hydrology studies	None

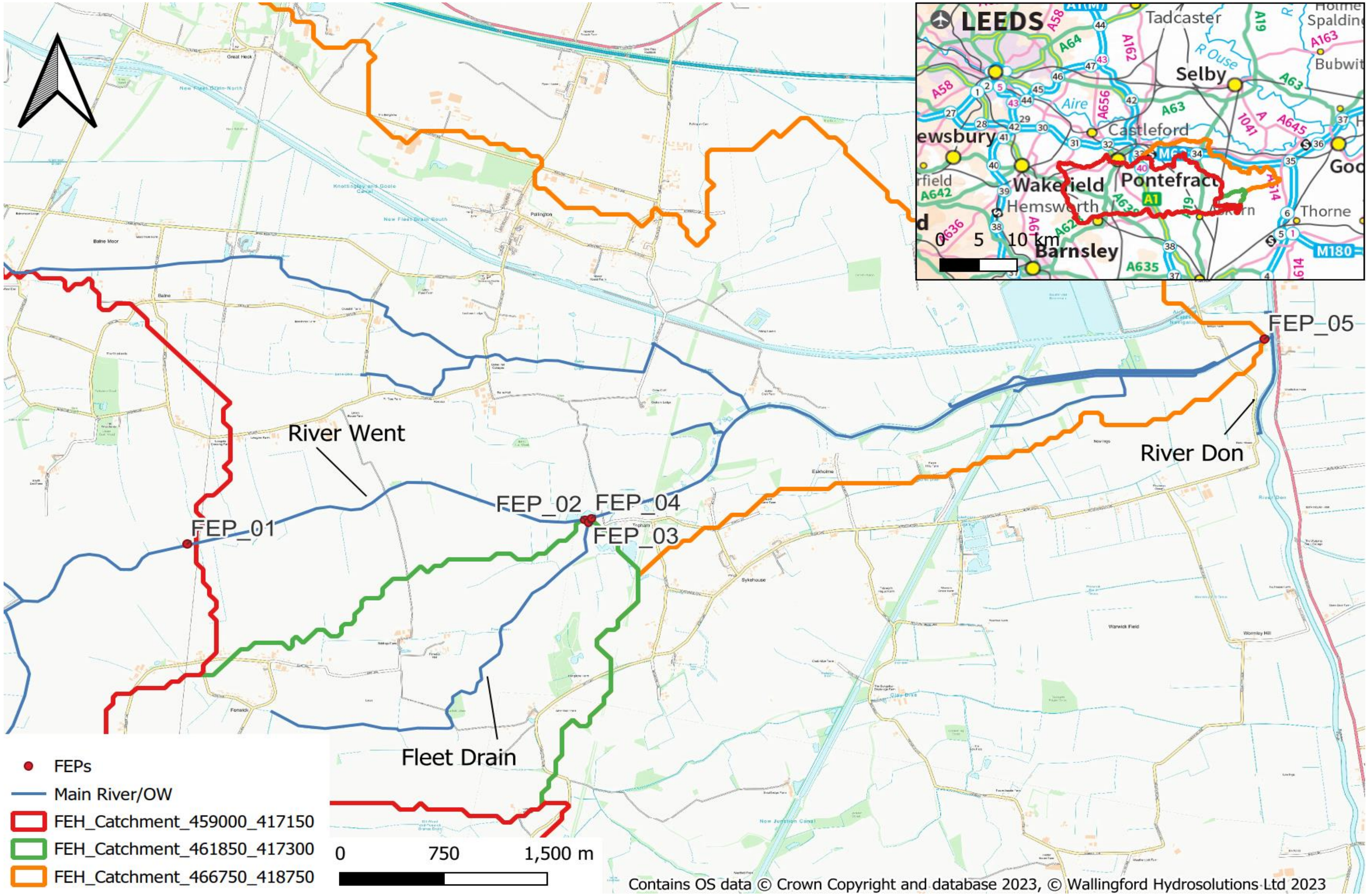


Figure 1: Catchment schematisation.

3.4 Gauging stations (flow or level)

Watercourse	Station name	Gauging authority number	NRFA number	Catchment area (km²)	Type (rated / ultrasonic / level)	Start of record and end if station closed
Went	Walden Stubbs	F0920	27064	83.7	Rated	01/1979 – present
Went	Went Bridge	L0928	-	-	Level	03/2002 – present
Went	Topham Ferry	L0923	-	-	Level	04/2003 – present
Went	Went Outfall	L0902	-	-	Level	11/1990 – present

3.5 Gauging stations (Rain)

Gauge name	ID number	Catchment area (km²)	Type (Daily/TBR)	Start of record and end if station closed
South Elmsall STW	086575	-	15 min	03/1985 – present
Wakefield	080282	-	15 min	03/1985 – present
Nutwell WTW	128322	-	15 min	03/2001 – present
Dirtness	128788	-	15 min	05/2000 - present

3.6 Data available at each flow gauging station

Station name	Start and end of NRFA flood peak record	Update for this study?	OK for QMED?	OK for pooling?	Data quality check needed?	Other comments on station and flow data quality
Walden Stubbs	1979-present	No	No	No	Yes	Flow and/or level data can potentially be used for event analysis/validation. On River Went upstream of confluence with the lake drain.
Went Bridge	2002 – present	No	No	No	Yes	Level only station, could be used for validation of events.
Topham Ferry	2003 – present	No	No	No	Yes	Level only station, could be used for validation of events.
Went Outfall	1990 – present	No	No	No	Yes	Level only station, could be used for validation of events.

3.7 Other data available and how it has been obtained

Type of data	Data relevant to this study	Data available	Source of data	Details
Check flow gaugings (if planned rating review)	Yes / ~~No~~	Yes / ~~No~~	EA	
Rating equations	Yes / ~~No~~	Yes / ~~No~~	EA	
Historic flood data	Yes / ~~No~~	Yes / ~~No~~	EA	EA historic flood maps indicate flooding at the study area. No records of flooding were found on the Chronology of British hydrological events[1] (BHS, 2024).

[1] BHS (2024) Chronology of British Hydrological Events

Type of data	Data relevant to this study	Data available	Source of data	Details
Flow or level data for events	Yes / ~~No~~	Yes / ~~No~~	EA	
Results from previous studies	Yes / ~~No~~	Yes / ~~No~~	EA	JBA (2017) Don Catchment model hydrology report
Other information e.g. groundwater, tides etc	Yes / ~~No~~	Yes / ~~No~~	EA	Model results/tides at DS boundary

3.8 Initial choice of approach

Item	Comment
Is FEH appropriate? If not, describe why and give details of the other methods to be used.	Yes
Initial choice of method(s) and reasons.	FEH statistical methods to derive QMED and higher return period peak flows, ReFH2 used as a comparison and for design event hydrographs.
How will hydrograph shapes be derived if needed? E.g. ReFH1, ReFH2 or average hydrograph shape from gauge data	ReFH2
Will the catchment be split into sub-catchments? If so, how?	Semi-distributed approach, catchment split by model inflow location and major tributary in the area of interest.
Software to be used (with version numbers) (**delete as appropriate**)	FEH Web Service[2] / WINFAP 5[3] / ReFH2.3 / Flood Modeller Pro

[2] CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, UK.
[3] WINFAP 5 © Wallingford HydroSolutions Limited 2020.

4 Locations where flood estimates are required

4.1 Summary of subject sites

The table below lists the locations of subject sites.

Site Code	Type of Estimate (L – lumped catchment; S- Sub-catchment)	Watercourse	Site	Grid Reference	Area on FEH Web Service (km^2)	Revised area if altered
FEP_01	L	Went	Model inflow, upstream of the railway embankment	459000,417150	141.1	
FEP_02	L	Went	Upstream of confluence with Fleet Drain	461800, 417350	146.2	
FEP_03	L	Fleet Drain	Fleet Drain (model inflow) upstream of confluence with River Went.	461850,417300	5.6	
FEP_04	L	Went	River Went at Went Sluice	462000, 417400	151.85	
FEP_05	L	Went	Went outlet, downstream boundary with the River Don	466750,418750	197.62	

4.2 Important catchment descriptors at each subject site (original values from FEH Web Service)

Site Code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPRHOST	URBEXT2000	FPEXT
FEP_01	0.981	0.32	0.637	14.26	26.5	606	21.91	0.0366	0.2576
FEP_02	0.982	0.32	0.627	16.90	25.7	606	22.52	0.0342	0.2672
FEP_03	1.000	0.27	0.337	2.81	4.1	590	39.57	0.0052	0.3638
FEP_04	0.983	0.31	0.617	16.58	25.0	605	23.17	0.0342	0.2713
FEP_05	0.978	0.30	0.614	20.00	20.8	603	24.36	0.0332	0.3396

4.3 Checking catchment descriptors

Item	Comment
Record how catchment boundary was checked • Describe any changes • Refer to maps if required	The catchment boundary was checked using LiDAR data in GIS software and OS mapping, no changes were required.
Record how other catchment descriptors were checked, especially soils • Describe any changes • Include a before and after table if required	Checks on catchment descriptors have been carried out using the FEH webservice, soils were checked using Magic map[4].
Source of URBEXT / URBAN	URBEXT2000
Method for updating URBEXT / URBAN • Refer to WINFAP v4 Urban Adjustment procedures / guidance • CPRE formula from FEH Volume 4 / CPRE formula from 2006 CEH report on URBEXT2000[5]	URBEXT2000 was updated (to 2023) using urban expansion factor, CPRE formula from 2006 CEH report on URBEXT2000[6].

4.4 Important catchment descriptors at each subject site (incorporating any changes made)

Site Code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPRHOST	URBEXT2000	FPEXT
FEP_01	0.981	0.32	0.637	14.26	26.5	606	21.91	**0.0382**	0.2576
FEP_02	0.982	0.32	0.627	16.90	25.7	606	22.52	**0.0356**	0.2672
FEP_03	1	0.27	0.337	2.81	4.1	590	39.57	**0.005**	0.3638
FEP_04	0.983	0.31	0.617	16.58	25	605	23.17	**0.0342**	0.2713
FEP_05	0.978	0.30	0.614	20.0	20.8	603	24.36	**0.0332**	0.3396

4 MAGIC (defra.gov.uk)
5 http://sciencesearch.defra.gov.uk/Document.aspx?Document=FD1919_5228_TRP.pdf#page=35
6 CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, UK.

5 Statistical method

5.1 Application of Statistical method

What is the purpose of applying this method?	Comment
Summarise reasons specific to study, for example lumped estimates at key locations for purpose of checking modelled peak flows.	Lumped estimates at key catchment locations for checking model outputs/scaling ReFH2 inflow hydrographs.

5.2 Overview of QMED method

What method of QMED estimation was used?	Comments
State method/s used to estimate QMED in study and why, for example gauged data, donor transfer, multiple donor transfer, flow variability, bankfull width or user defined.	QMED will be derived using CD with multi-donor adjustment, and the small catchments approach for the tributary (FEP_03).

Summary of QMED estimates at each site:

Site code	QMED rural (from CDs) (m^3s^{-1})	QMED urban (from CDs) (m^3s^{-1})	Final method	Final estimate of QMED urbanised (m^3s^{-1})
FEP_01	6.837	7.250	DA – multi-donor (4) – the catchment descriptor method is shown to be underestimating the QMED values compared to the QMED with donor adjustment method	9.557
FEP_02	7.350	7.753	DA – multi-donor (4) – the catchment descriptor method is shown to be underestimating the QMED values compared to the QMED with donor adjustment method	10.205
FEP_03	1.052	1.084	DA – small catchments approach (1)	1.137

Site code	QMED rural (from CDs) (m^3s^{-1})	QMED urban (from CDs) (m^3s^{-1})	Final method	Final estimate of QMED urbanised (m^3s^{-1})
FEP_04	7.875	8.280	DA – multi-donor (4) – the catchment descriptor method is shown to be underestimating the QMED values compared to the QMED with donor adjustment method	10.883
FEP_05	9.693	10.176	DA – multi-donor (4) – the catchment descriptor method is shown to be underestimating the QMED values compared to the QMED with donor adjustment method	13.652

Note: Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer (with urban adjustment); DA – Donor Adjusted; CD – Catchment descriptors alone (with urban adjustment);

BCW –LF – Low flow statistics. The QMED Linking Equation indicates that the QMED CD equation underestimates when compared to estimates using the QMED linking equation based on Low Flow Stats.

5.3 Search for donor sites for QMED

Comment on potential donor sites based on the above sections	Comments
• Number of potential donor sites available • Distances from subject site • Similarities in terms of AREA, BFIHOST, FARL and other catchment descriptors • Quality of flood peak data	Rural sites, URBEXT2000 threshold <0.03 URBEXT2000 FEP_03 is a rural catchment, the potential donor stations were: • 26017 (Ings Beck @ South Newbald) – closest site but distant (39.15km), similar CDs except BFIHOSt19 which is higher than the subject site – **retained**. • Remaining sites whether >48km distance so have not been considered further. Slight to moderately urbanised sites, URBEXT2000 threshold <0.125 URBEXT2000 FEP_01 is moderately urbanised, the potential donor stations and selected station were the same: • 27030 (Dearne @ Adwick) – similar catchment descriptors, long period of record (59 years), suitable for QMED only – **retained**. • 27023 (Dearne @ Barnsley Weir) – similar catchment descriptors, long period of record (63 years), suitable for QMED and Pooling – **retained**. • 28091 (Ryton @ Blyth) - similar catchment descriptors, long period of record (34 years), suitable for QMED and Pooling – **retained**.

Comment on potential donor sites based on the above sections	Comments
	27079 (Calder @ Methley) – high SAAR compared to subject site – **rejected**. 28049 (Ryton @ Worksop) - similar catchment descriptors, long period of record (52 years), suitable for QMED and Pooling – **retained**. 27031 (Colne @ Colne Bridge) - high SAAR compared to subject site – **rejected.** Slight to moderately urbanised sites, URBEXT2000 threshold <0.125 URBEXT2000 FEP_02 is moderately urbanised, the potential donor stations and selected station were the following: 27030 (Dearne @ Adwick) – similar catchment descriptors, long period of record (59 years), suitable for QMED only – **retained**. 27023 (Dearne @ Barnsley Weir) – similar catchment descriptors, long period of record (63 years), suitable for QMED and Pooling – **retained**. 28091 (Ryton @ Blyth) - similar catchment descriptors, long period of record (34 years), suitable for QMED and Pooling – **retained**. 28049 (Ryton @ Worksop) - similar catchment descriptors, long period of record (52 years), suitable for QMED and Pooling – **retained**. 27079 (Calder @ Methley) - high SAAR compared to subject site – rejected. 27031 (Colne @ Colne Bridge) - high SAAR compared to subject site – rejected. 27065 (Holme @ Huddersfield Queens Mill) - high SAAR compared to subject site – rejected. 27051 (Crimple @ Burn Bridge) - high SAAR compared to subject site – rejected. 28070 (Burbage Brook @ Burbage) - high SAAR compared to subject site – rejected. 27098 (Calder @ Dewsbury) - high SAAR compared to subject site – rejected. Slight to moderately urbanised sites, URBEXT2000 threshold <0.125 URBEXT2000 FEP_04 is moderately urbanised, the potential donor stations and selected station were the following: 27030 (Dearne @ Adwick) – similar catchment descriptors, long period of record (59 years), suitable for QMED only – **retained**. 27023 (Dearne @ Barnsley Weir) – similar catchment descriptors, long period of record (63 years), suitable for QMED and Pooling – **retained**. 28091 (Ryton @ Blyth) - similar catchment descriptors, long period of record (34 years), suitable for QMED and Pooling – **retained**. 28049 (Ryton @ Worksop) - similar catchment descriptors, long period of record (52 years), suitable for QMED and Pooling – **retained**. 27079 (Calder @ Methley) - high SAAR compared to subject site – **rejected**. 27031 (Colne @ Colne Bridge) - high SAAR compared to subject site – **rejected**. 27065 (Holme @ Huddersfield Queens Mill) - high SAAR compared to subject site – **rejected**.

Comment on potential donor sites based on the above sections	Comments
	• 27051 (Crimple @ Burn Bridge) - high SAAR compared to subject site – **rejected**. • 28070 (Burbage Brook @ Burbage) - high SAAR compared to subject site – **rejected**. • 27098 (Calder @ Dewsbury) - high SAAR compared to subject site – **rejected.** Slight to moderately urbanised sites, URBEXT2000 threshold <0.125 URBEXT2000 FEP_05 is moderately urbanised, the potential donor stations and selected station were the following: • 27030 (Dearne @ Adwick) – similar catchment descriptors, long period of record (59 years), suitable for QMED only – **retained**. • 27023 (Dearne @ Barnsley Weir) – similar catchment descriptors, long period of record (63 years), suitable for QMED and Pooling – **retained**. • 28091 (Ryton @ Blyth) - similar catchment descriptors, long period of record (34 years), suitable for QMED and Pooling – **retained**. • 28049 (Ryton @ Worksop) - similar catchment descriptors, long period of record (52 years), suitable for QMED and Pooling – **retained**. • 27079 (Calder @ Methley) - high SAAR compared to subject site – **rejected**. • 27031 (Colne @ Colne Bridge) - high SAAR compared to subject site – **rejected**. • 27065 (Holme @ Huddersfield Queens Mill) - high SAAR compared to subject site – **rejected.** • 27051 (Crimple @ Burn Bridge) - high SAAR compared to subject site **– rejected.** • 28070 (Burbage Brook @ Burbage) - high SAAR compared to subject site **– rejected.** • 27098 (Calder @ Dewsbury) - high SAAR compared to subject site **– rejected.**

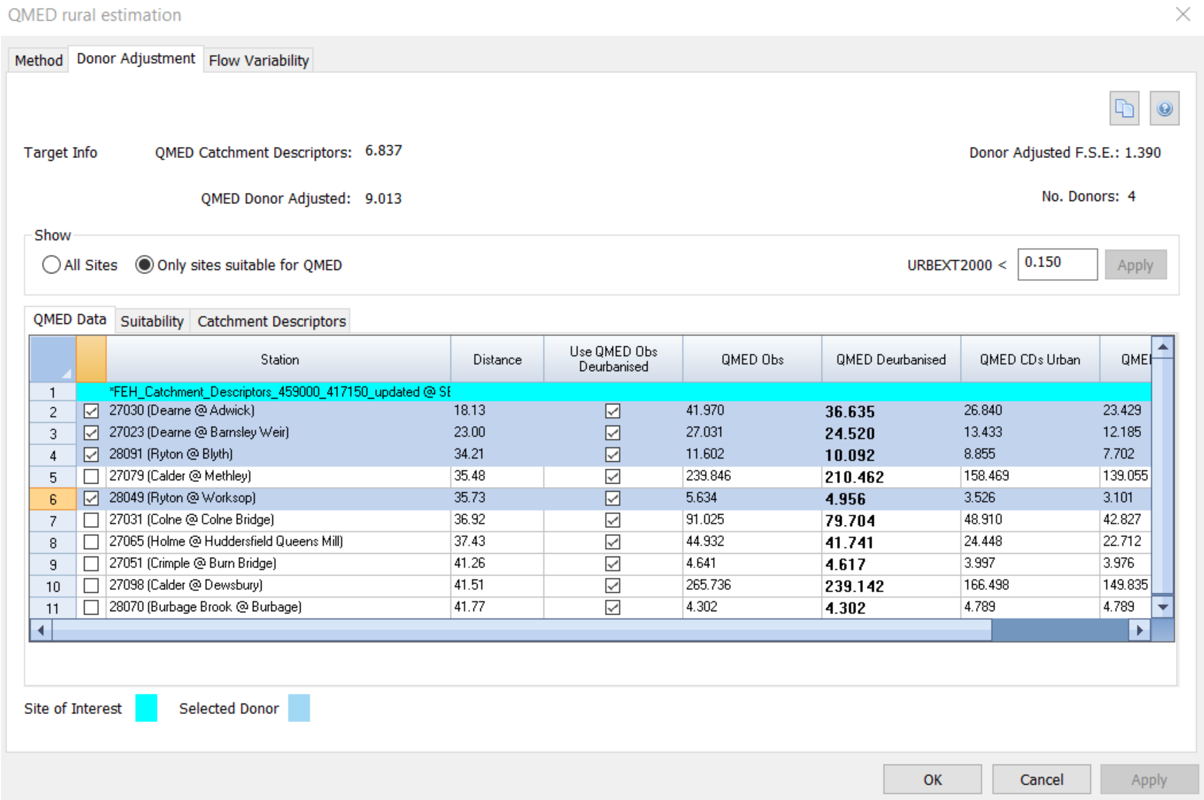
5.4 Multiple donor transfers and QMED adjustment

The multiple donor method embedded within WINFAPv5 has been utilised any adjustment for urbanisation[7] has also been applied using the functionality within WINFAPv5.

The weighting of each donor catchment to provide the adjusted QMED is not provided within WINFAPv5 but is described within Kjeldsen et al 2014.

[7] Wallingford HydroSolutions (2020), WINFAP 5 Urban adjustment procedures, Wallingford HydroSolutions Ltd 2020.

FEP_01



QMED rural estimation

Method | Donor Adjustment | Flow Variability

Target Info — QMED Catchment Descriptors: 6.837 — Donor Adjusted F.S.E.: 1.390

QMED Donor Adjusted: 9.013 — No. Donors: 4

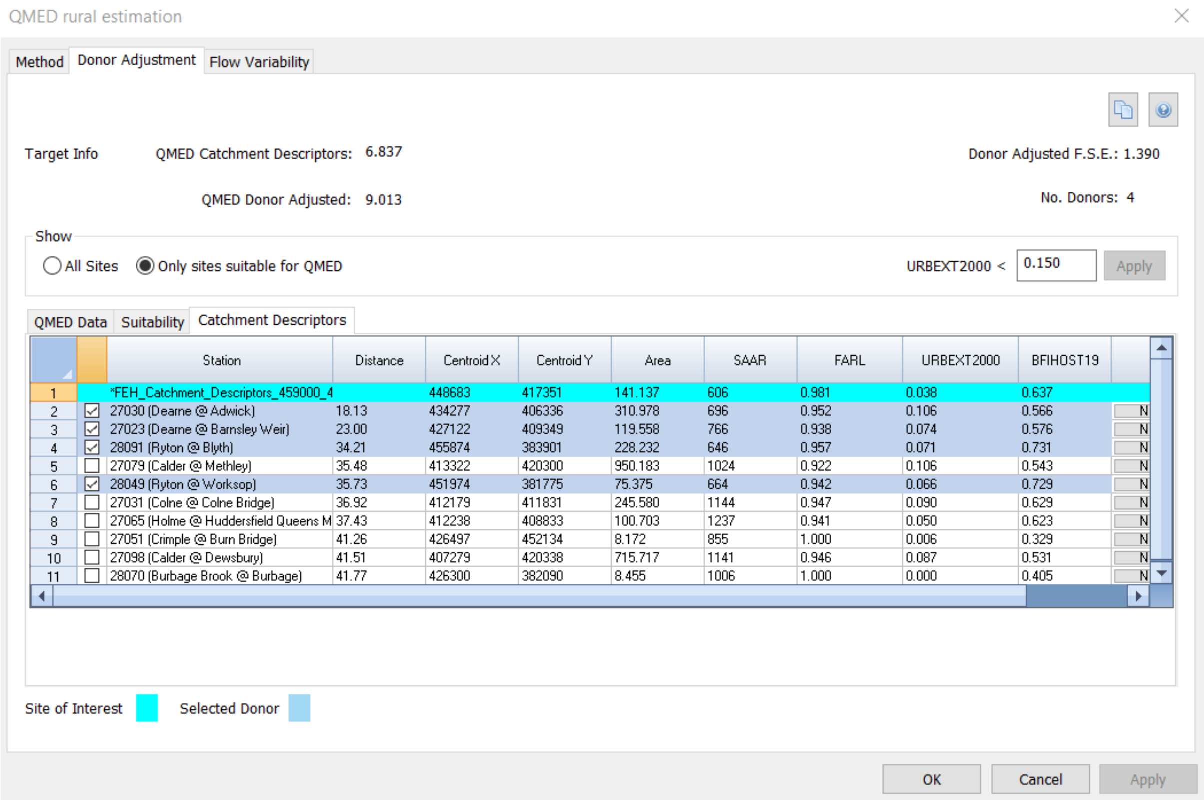
Show: ○ All Sites ◉ Only sites suitable for QMED — URBEXT2000 < 0.150 Apply

QMED Data | Suitability | Catchment Descriptors

		Station	Distance	Use QMED Obs Deurbanised	QMED Obs	QMED Deurbanised	QMED CDs Urban	QMEI
1		*FEH_Catchment_Descriptors_459000_417150_updated @ SE						
2	☑	27030 (Dearne @ Adwick)	18.13	☑	41.970	**36.635**	26.840	23.429
3	☑	27023 (Dearne @ Barnsley Weir)	23.00	☑	27.031	**24.520**	13.433	12.185
4	☑	28091 (Ryton @ Blyth)	34.21	☑	11.602	**10.092**	8.855	7.702
5	☐	27079 (Calder @ Methley)	35.48	☑	239.846	**210.462**	158.469	139.055
6	☑	28049 (Ryton @ Worksop)	35.73	☑	5.634	**4.956**	3.526	3.101
7	☐	27031 (Colne @ Colne Bridge)	36.92	☑	91.025	**79.704**	48.910	42.827
8	☐	27065 (Holme @ Huddersfield Queens Mill)	37.43	☑	44.932	**41.741**	24.448	22.712
9	☐	27051 (Crimple @ Burn Bridge)	41.26	☑	4.641	**4.617**	3.997	3.976
10	☐	27098 (Calder @ Dewsbury)	41.51	☑	265.736	**239.142**	166.498	149.835
11	☐	28070 (Burbage Brook @ Burbage)	41.77	☑	4.302	**4.302**	4.789	4.789

Site of Interest — Selected Donor

OK — Cancel — Apply



QMED rural estimation

Method | Donor Adjustment | Flow Variability

Target Info — QMED Catchment Descriptors: 6.837 — Donor Adjusted F.S.E.: 1.390

QMED Donor Adjusted: 9.013 — No. Donors: 4

Show: ○ All Sites ◉ Only sites suitable for QMED — URBEXT2000 < 0.150 Apply

QMED Data | Suitability | Catchment Descriptors

		Station	Distance	Centroid X	Centroid Y	Area	SAAR	FARL	URBEXT2000	BFIHOST19	
1		*FEH_Catchment_Descriptors_459000_4		448683	417351	141.137	606	0.981	0.038	0.637	
2	☑	27030 (Dearne @ Adwick)	18.13	434277	406336	310.978	696	0.952	0.106	0.566	N
3	☑	27023 (Dearne @ Barnsley Weir)	23.00	427122	409349	119.558	766	0.938	0.074	0.576	N
4	☑	28091 (Ryton @ Blyth)	34.21	455874	383901	228.232	646	0.957	0.071	0.731	N
5	☐	27079 (Calder @ Methley)	35.48	413322	420300	950.183	1024	0.922	0.106	0.543	N
6	☑	28049 (Ryton @ Worksop)	35.73	451974	381775	75.375	664	0.942	0.066	0.729	N
7	☐	27031 (Colne @ Colne Bridge)	36.92	412179	411831	245.580	1144	0.947	0.090	0.629	N
8	☐	27065 (Holme @ Huddersfield Queens M	37.43	412238	408833	100.703	1237	0.941	0.050	0.623	N
9	☐	27051 (Crimple @ Burn Bridge)	41.26	426497	452134	8.172	855	1.000	0.006	0.329	N
10	☐	27098 (Calder @ Dewsbury)	41.51	407279	420338	715.717	1141	0.946	0.087	0.531	N
11	☐	28070 (Burbage Brook @ Burbage)	41.77	426300	382090	8.455	1006	1.000	0.000	0.405	N

Site of Interest — Selected Donor

OK — Cancel — Apply

FEP_02

QMED rural estimation

Method | Donor Adjustment | Flow Variability

Target Info QMED Catchment Descriptors: 7.350 Donor Adjusted F.S.E.: 1.390

QMED Donor Adjusted: 9.675 No. Donors: 4

Show

All Sites / Only sites suitable for QMED URBEXT2000 < 0.1250 Apply

QMED Data | Suitability | Catchment Descriptors

		Station	Distance	Use QMED Obs Deurbanised	QMED Obs	QMED Deurbanised	QMED CDs Urban	QMEI
1		*FEH_Catchment_Descriptors_461800_417350_v4_0_0 @ SE						
2	☑	27030 (Dearne @ Adwick)	18.46	☑	41.970	36.635	26.840	23.429
3	☑	27023 (Dearne @ Barnsley Weir)	23.37	☑	27.031	24.520	13.433	12.185
4	☑	28091 (Ryton @ Blyth)	34.15	☑	11.602	10.092	8.855	7.702
5	☑	28049 (Ryton @ Worksop)	35.71	☑	5.634	4.956	3.526	3.101
6	☐	27079 (Calder @ Methley)	35.88	☑	239.846	210.462	158.469	139.055
7	☐	27031 (Colne @ Colne Bridge)	37.31	☑	91.025	79.704	48.910	42.827
8	☐	27065 (Holme @ Huddersfield Queens Mill)	37.82	☑	44.932	41.741	24.448	22.712
9	☐	27051 (Crimple @ Burn Bridge)	41.46	☑	4.641	4.617	3.997	3.976
10	☐	27098 (Calder @ Dewsbury)	41.91	☑	265.736	239.142	166.498	149.835
11	☐	28070 (Burbage Brook @ Burbage)	41.99	☑	4.302	4.302	4.789	4.789

Site of Interest Selected Donor

OK Cancel Apply

QMED rural estimation

Method | Donor Adjustment | Flow Variability

Target Info QMED Catchment Descriptors: 7.350 Donor Adjusted F.S.E.: 1.390

QMED Donor Adjusted: 9.675 No. Donors: 4

Show

All Sites / Only sites suitable for QMED URBEXT2000 < 0.1250 Apply

QMED Data | Suitability | Catchment Descriptors

		Station	Distance	Centroid X	Centroid Y	Area	SAAR	FARL	URBEXT2000	BFIHOST19	
1		*FEH_Catchment_Descriptors_461800_4		449079	417364	146.202	606	0.982	0.036	0.627	
2	☑	27030 (Dearne @ Adwick)	18.46	434277	406336	310.978	696	0.952	0.106	0.566	N
3	☑	27023 (Dearne @ Barnsley Weir)	23.37	427122	409349	119.558	766	0.938	0.074	0.576	N
4	☑	28091 (Ryton @ Blyth)	34.15	455874	383901	228.232	646	0.957	0.071	0.731	N
5	☑	28049 (Ryton @ Worksop)	35.71	451974	381775	75.375	664	0.942	0.066	0.729	N
6	☐	27079 (Calder @ Methley)	35.88	413322	420300	950.183	1024	0.922	0.106	0.543	N
7	☐	27031 (Colne @ Colne Bridge)	37.31	412179	411831	245.580	1144	0.947	0.090	0.629	N
8	☐	27065 (Holme @ Huddersfield Queens M	37.82	412238	408833	100.703	1237	0.941	0.050	0.623	N
9	☐	27051 (Crimple @ Burn Bridge)	41.46	426497	452134	8.172	855	1.000	0.006	0.329	N
10	☐	27098 (Calder @ Dewsbury)	41.91	407279	420338	715.717	1141	0.946	0.087	0.531	N
11	☐	28070 (Burbage Brook @ Burbage)	41.99	426300	382090	8.455	1006	1.000	0.000	0.405	N

Site of Interest Selected Donor

OK Cancel Apply

FEP_03

QMED rural estimation

Method | Donor Adjustment | Flow Variability

Target Info — QMED Catchment Descriptors: 1.052 — Donor Adjusted F.S.E.: 1.420

QMED Donor Adjusted: 1.103 — No. Donors: 1

Show: All Sites / (•) Only sites suitable for QMED — URBEXT2000 < 0.0300 Apply

QMED Data | Suitability | Catchment Descriptors

		Station	Distance	Use QMED Obs Deurbanised	QMED Obs	QMED Deurbanised	QMED CDs Urban	QMEI
1		FEH_Catchment_Descriptors_461850_417300_v5_0_1 @ SE						
2	☑	26017 (Ings Beck @ South Newbald)	39.15	☑	0.482	**0.457**	0.385	0.365
3	☐	28070 (Burbage Brook @ Burbage)	48.06	☑	4.302	**4.302**	4.789	4.789
4	☐	29009 (Ancholme @ Toft Newton)	49.49	☑	1.751	**1.739**	2.032	2.018
5	☐	27051 (Crimple @ Burn Bridge)	49.60	☑	4.641	**4.617**	3.997	3.976
6	☐	29004 (Ancholme @ Bishopbridge)	49.88	☑	6.049	**6.015**	4.696	4.670
7	☐	26013 (Driffield Trout Stream @ Driffield)	51.10	☑	2.778	**2.728**	1.890	1.856
8	☐	26009 (West Beck @ Snakeholme Lock)	52.61	☑	5.776	**5.646**	4.560	4.457
9	☐	28043 (Derwent @ Chatsworth)	52.65	☑	90.292	**89.723**	97.454	96.841
10	☐	26016 (Gypsey Race @ Kirby Grindalythe)	57.72	☑	0.101	**0.101**	0.521	0.521
11	☐	28011 (Derwent @ Matlock Bath)	57.91	☑	113.921	**111.742**	137.240	134.615

Site of Interest — Selected Donor

OK | Cancel | Apply

QMED rural estimation

Method | Donor Adjustment | Flow Variability

Target Info — QMED Catchment Descriptors: 1.052 — Donor Adjusted F.S.E.: 1.420

QMED Donor Adjusted: 1.103 — No. Donors: 1

Show: All Sites / (•) Only sites suitable for QMED — URBEXT2000 < 0.0300 Apply

QMED Data | Suitability | Catchment Descriptors

		Station	Distance	Centroid X	Centroid Y	Area	SAAR	FARL	URBEXT2000	BFIHOST19	
1		FEH_Catchment_Descriptors_461850_4		460416	415941	5.553	590	1.000	0.005	0.337	
2	☑	26017 (Ings Beck @ South Newbald)	39.15	493427	436988	14.203	704	1.000	0.009	0.940	N
3	☐	28070 (Burbage Brook @ Burbage)	48.06	426300	382090	8.455	1006	1.000	0.000	0.405	N
4	☐	29009 (Ancholme @ Toft Newton)	49.49	499593	385696	29.310	616	0.998	0.004	0.635	N
5	☐	27051 (Crimple @ Burn Bridge)	49.60	426497	452134	8.172	855	1.000	0.006	0.329	N
6	☐	29004 (Ancholme @ Bishopbridge)	49.88	501037	386993	59.035	615	0.996	0.004	0.566	N
7	☐	26013 (Driffield Trout Stream @ Driffield)	51.10	495225	453356	53.333	690	0.997	0.006	0.837	N
8	☐	26009 (West Beck @ Snakeholme Lock	52.61	492273	457814	195.605	721	0.991	0.005	0.898	N
9	☐	28043 (Derwent @ Chatsworth)	52.65	418886	383583	344.365	1170	0.909	0.006	0.436	N
10	☐	26016 (Gypsey Race @ Kirby Grindalythe	57.72	488328	466463	15.850	757	1.000	0.000	0.927	N
11	☐	28011 (Derwent @ Matlock Bath)	57.91	418164	376340	687.185	1114	0.947	0.015	0.542	N

Site of Interest — Selected Donor

OK | Cancel | Apply

FEP_04

QMED rural estimation

Method | Donor Adjustment | Flow Variability

Target Info   QMED Catchment Descriptors: 7.875   Donor Adjusted F.S.E.: 1.391

QMED Donor Adjusted: 10.351   No. Donors: 4

Show

○ All Sites ◉ Only sites suitable for QMED   URBEXT2000 < 0.1250 Apply

QMED Data | Suitability | Catchment Descriptors

		Station	Distance	Use QMED Obs Deurbanised	QMED Obs	QMED Deurbanised	QMED CDs Urban	QMEI
1		FEH_Catchment_Descriptors_462000_417400_v4_0_0 @ SE						
2	☑	27030 (Dearne @ Adwick)	18.77	☑	41.970	**36.635**	26.840	23.429
3	☑	27023 (Dearne @ Barnsley Weir)	23.75	☑	27.031	**24.520**	13.433	12.185
4	☑	28091 (Ryton @ Blyth)	34.01	☑	11.602	**10.092**	8.855	7.702
5	☑	28049 (Ryton @ Worksop)	35.62	☑	5.634	**4.956**	3.526	3.101
6	☐	27079 (Calder @ Methley)	36.30	☑	239.846	**210.462**	158.469	139.055
7	☐	27031 (Colne @ Colne Bridge)	37.72	☑	91.025	**79.704**	48.910	42.827
8	☐	27065 (Holme @ Huddersfield Queens Mill)	38.22	☑	44.932	**41.741**	24.448	22.712
9	☐	27051 (Crimple @ Burn Bridge)	41.73	☑	4.641	**4.617**	3.997	3.976
10	☐	28070 (Burbage Brook @ Burbage)	42.18	☑	4.302	**4.302**	4.789	4.789
11	☐	27098 (Calder @ Dewsbury)	42.33	☑	265.736	**239.142**	166.498	149.835

Site of Interest   Selected Donor

OK   Cancel   Apply

QMED rural estimation

Method | Donor Adjustment | Flow Variability

Target Info   QMED Catchment Descriptors: 7.875   Donor Adjusted F.S.E.: 1.391

QMED Donor Adjusted: 10.351   No. Donors: 4

Show

○ All Sites ◉ Only sites suitable for QMED   URBEXT2000 < 0.1250 Apply

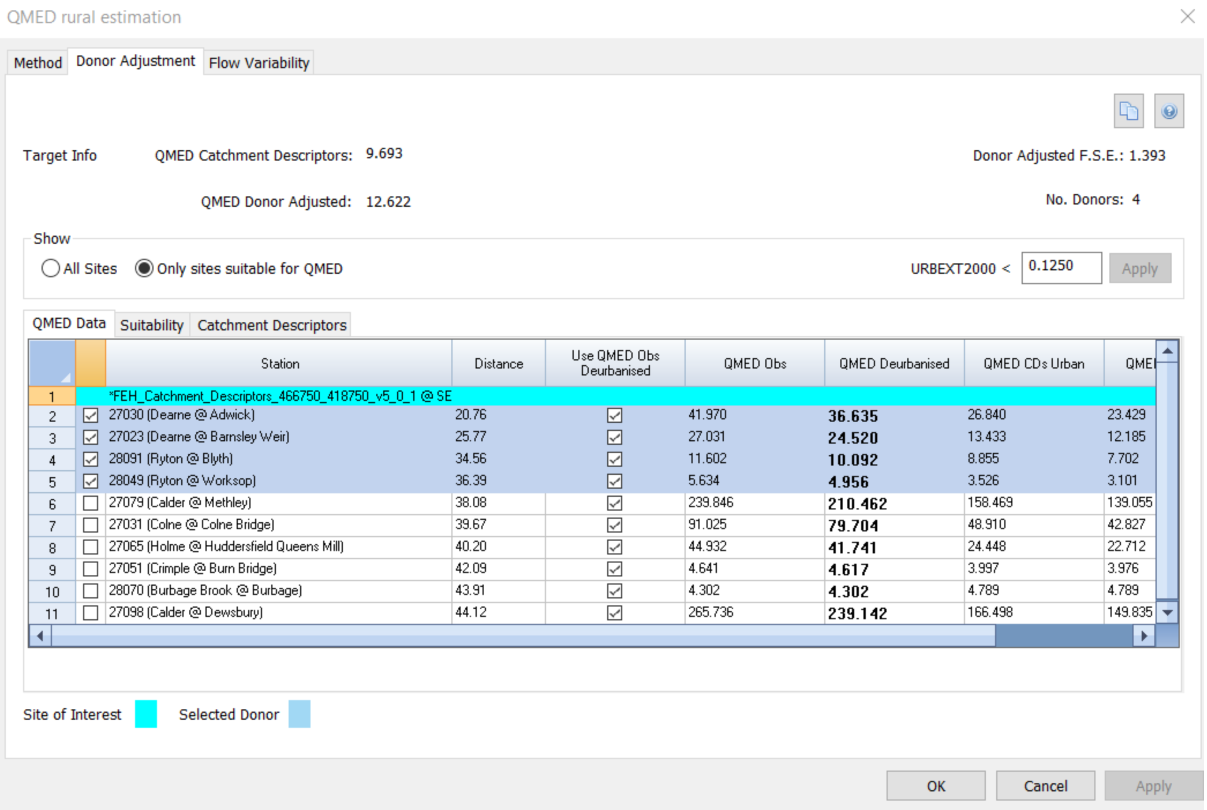
QMED Data | Suitability | Catchment Descriptors

		Station	Distance	Centroid X	Centroid Y	Area	SAAR	FARL	URBEXT2000	BFIHOST19	
1		FEH_Catchment_Descriptors_462000_4'		449502	417312	151.852	605	0.983	0.034	0.617	
2	☑	27030 (Dearne @ Adwick)	18.77	434277	406336	310.978	696	0.952	0.106	0.566	N
3	☑	27023 (Dearne @ Barnsley Weir)	23.75	427122	409349	119.558	766	0.938	0.074	0.576	N
4	☑	28091 (Ryton @ Blyth)	34.01	455874	383901	228.232	646	0.957	0.071	0.731	N
5	☑	28049 (Ryton @ Worksop)	35.62	451974	381775	75.375	664	0.942	0.066	0.729	N
6	☐	27079 (Calder @ Methley)	36.30	413322	420300	950.183	1024	0.922	0.106	0.543	N
7	☐	27031 (Colne @ Colne Bridge)	37.72	412179	411831	245.580	1144	0.947	0.090	0.629	N
8	☐	27065 (Holme @ Huddersfield Queens M	38.22	412238	408833	100.703	1237	0.941	0.050	0.623	N
9	☐	27051 (Crimple @ Burn Bridge)	41.73	426497	452134	8.172	855	1.000	0.006	0.329	N
10	☐	28070 (Burbage Brook @ Burbage)	42.18	426300	382090	8.455	1006	1.000	0.000	0.405	N
11	☐	27098 (Calder @ Dewsbury)	42.33	407279	420338	715.717	1141	0.946	0.087	0.531	N

Site of Interest   Selected Donor

OK   Cancel   Apply

FEP_05



QMED rural estimation

Method | Donor Adjustment | Flow Variability

Target Info — QMED Catchment Descriptors: 9.693 — Donor Adjusted F.S.E.: 1.393

QMED Donor Adjusted: 12.622 — No. Donors: 4

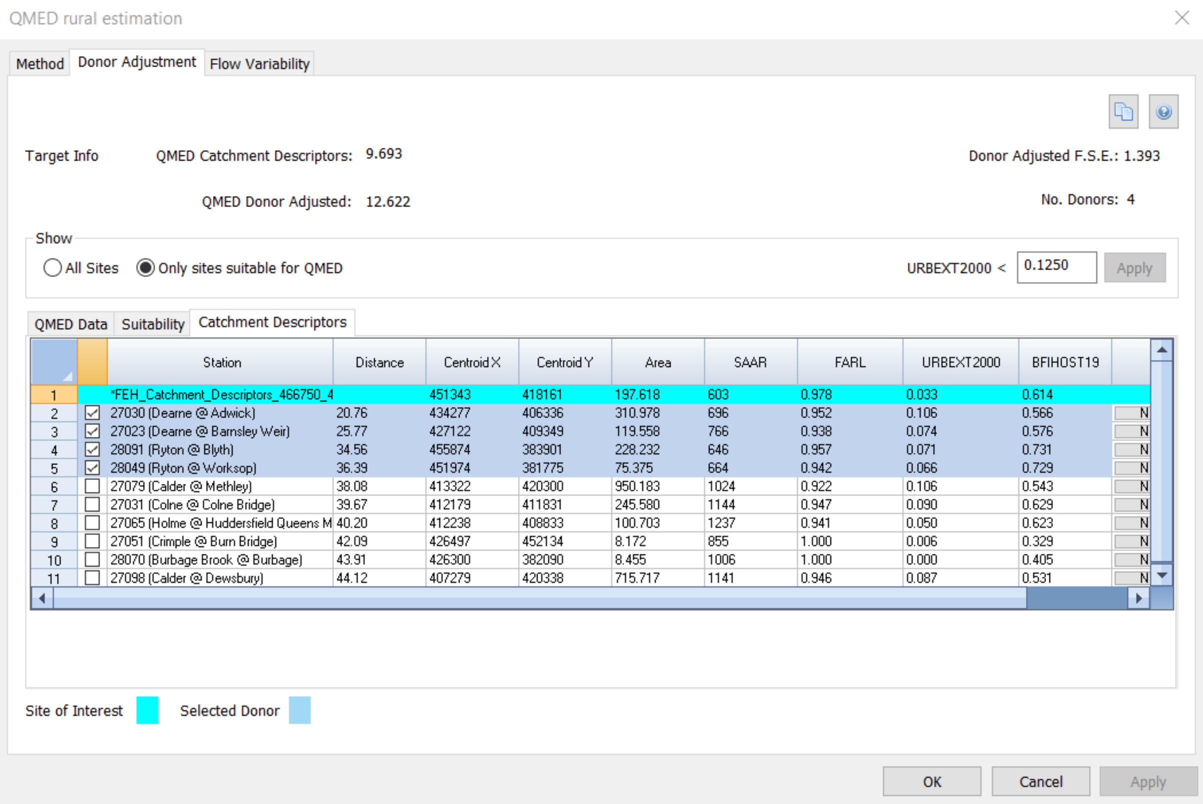
Show: All Sites / Only sites suitable for QMED — URBEXT2000 < 0.1250 Apply

QMED Data | Suitability | Catchment Descriptors

		Station	Distance	Use QMED Obs Deurbanised	QMED Obs	QMED Deurbanised	QMED CDs Urban	QMEI
1		*FEH_Catchment_Descriptors_466750_418750_v5_0_1 @ SE						
2	☑	27030 (Dearne @ Adwick)	20.76	☑	41.970	**36.635**	26.840	23.429
3	☑	27023 (Dearne @ Barnsley Weir)	25.77	☑	27.031	**24.520**	13.433	12.185
4	☑	28091 (Ryton @ Blyth)	34.56	☑	11.602	**10.092**	8.855	7.702
5	☑	28049 (Ryton @ Worksop)	36.39	☑	5.634	**4.956**	3.526	3.101
6	☐	27079 (Calder @ Methley)	38.08	☑	239.846	**210.462**	158.469	139.055
7	☐	27031 (Colne @ Colne Bridge)	39.67	☑	91.025	**79.704**	48.910	42.827
8	☐	27065 (Holme @ Huddersfield Queens Mill)	40.20	☑	44.932	**41.741**	24.448	22.712
9	☐	27051 (Crimple @ Burn Bridge)	42.09	☑	4.641	**4.617**	3.997	3.976
10	☐	28070 (Burbage Brook @ Burbage)	43.91	☑	4.302	**4.302**	4.789	4.789
11	☐	27098 (Calder @ Dewsbury)	44.12	☑	265.736	**239.142**	166.498	149.835

Site of Interest — Selected Donor

OK | Cancel | Apply



QMED rural estimation

Method | Donor Adjustment | Flow Variability

Target Info — QMED Catchment Descriptors: 9.693 — Donor Adjusted F.S.E.: 1.393

QMED Donor Adjusted: 12.622 — No. Donors: 4

Show: All Sites / Only sites suitable for QMED — URBEXT2000 < 0.1250 Apply

QMED Data | Suitability | Catchment Descriptors

		Station	Distance	Centroid X	Centroid Y	Area	SAAR	FARL	URBEXT2000	BFIHOST19	
1		*FEH_Catchment_Descriptors_466750_4		451343	418161	197.618	603	0.978	0.033	0.614	
2	☑	27030 (Dearne @ Adwick)	20.76	434277	406336	310.978	696	0.952	0.106	0.566	N
3	☑	27023 (Dearne @ Barnsley Weir)	25.77	427122	409349	119.558	766	0.938	0.074	0.576	N
4	☑	28091 (Ryton @ Blyth)	34.56	455874	383901	228.232	646	0.957	0.071	0.731	N
5	☑	28049 (Ryton @ Worksop)	36.39	451974	381775	75.375	664	0.942	0.066	0.729	N
6	☐	27079 (Calder @ Methley)	38.08	413322	420300	950.183	1024	0.922	0.106	0.543	N
7	☐	27031 (Colne @ Colne Bridge)	39.67	412179	411831	245.580	1144	0.947	0.090	0.629	N
8	☐	27065 (Holme @ Huddersfield Queens M	40.20	412238	408833	100.703	1237	0.941	0.050	0.623	N
9	☐	27051 (Crimple @ Burn Bridge)	42.09	426497	452134	8.172	855	1.000	0.006	0.329	N
10	☐	28070 (Burbage Brook @ Burbage)	43.91	426300	382090	8.455	1006	1.000	0.000	0.405	N
11	☐	27098 (Calder @ Dewsbury)	44.12	407279	420338	715.717	1141	0.946	0.087	0.531	N

Site of Interest — Selected Donor

OK | Cancel | Apply

5.5 Uncertainty in QMED

The estimation of QMED from the catchment descriptors alone is not advised. In particular, review of potential donor sites illustrates an overestimation of QMED using the catchment descriptor equation when compared with observed data. A review of local donor sites has been undertaken and a multi (FEP 01) and single (FEP 03) donor adjustment has been applied using local stations. The influence of using a single donor site or multiple donor sites also reduces the Factorial Standard Error (F.S.E) when compared to using catchment descriptors only. The reduction in F.S.E for each site is illustrated in the following table.

Factorial Standard Error (F.S.E)

Site number	Catchment descriptors	Donor adjustment
FEP 01	1.431	1.390
FEP 02	1.431	1.390
FEP 03	1.431	1.420
FEP 04	1.431	1.391
FEP 05	1.431	1.393

An urban adjustment of QMED has been applied for the final QMED estimates and are reflected in Section 3.1.

5.6 Derivation of pooling groups

Pooling groups were created within WINFAP v5 for each of the subject sites. An URBEXT2000 threshold of 0.125 (FEP 01, FEP 02, FEP 04, FEP_05) and 0.03 (FEP 03) was used to create the pooling groups in order to make maximum use of gauge data similar to the subject site. The Heterogeneity statistic (H2) for the pooling groups were assessed; this provides an indication of whether a review of the pooling group is required (not required, optional, desirable or essential).

The similarity of the subject site against stations within the pooling group is assessed by the Similarity Distance Measure (SDM) and is a function of Area, SAAR, FARL and FPEXT. A new pooling method was introduced for small catchments through Science Report SC090031[8] and uses SAAR and AREA for the SDM. Both methods are implemented in WINFAP 5 and the method is determined based on catchment area of the subject site. However, it is good practice to review the pooling group to check other parameters e.g. BFIHOST and the history of the gauge, gauge record and rating quality on the NRFA website (https://nrfa.ceh.ac.uk/data/search).

As per the Environment Agency guidelines, modifications to the pooling group tend to have a relatively minor effect on the final design flow (compared with, for example, the selection of donor sites for QMED). Science Report SC050500[9] indicates that apart from the first four or five stations within a pooling group (i.e. lowest SDM), the record length at a station will only

[8] Science Report SC090031/R0: Estimating flood peaks and hydrographs for small catchments (Phase 1) (2012). https://www.gov.uk/flood-and-coastal-erosion-risk-management-research-reports/review-of-methodology-for-estimating-flood-peaks-and-hydrographs-for-small-catchments
[9] Science Report SC050050: Improving flood frequency estimation (2008). https://www.gov.uk/flood-and-coastal-erosion-risk-management-research-reports/improving-the-flood-estimation-handbook-feh-statistical-index-flood-method-and-software

have a modest effect on its weight within the pooling group (unless the record is very short). The review of the pooling group has therefore focused on the first five stations within each pooling group, extending further where required to include stations that have moved up position following removal of others, gauges with a short record, and catchments which have extreme catchment descriptor values in comparison to the subject sites.

The tables below summarise the pooling groups used in this study, with the initial pooling groups as shown in Annex A also notes the reasons for removing catchments from the initial pooling group and which stations were added into the pooling group to ensure that sufficient years of data (>500) were included in the final group.

Name of Group	Site code from whose descriptors group was derived	Subject site treated as gauged? (enhanced single site analysis)	Changes made to default pooling group, with reasons. Include any sites that were investigated but retained in the group	Weighted average L-moments (L-CV and L-skew before urban adjustment)
Group_01	FEP_01	No	Non Flood Years adjustment has been applied - 33011 (Little Ouse @ County Bridge Euston) – Non flood years percentage greater than 15 - 33019 (Thet @ Melford Bridge) – Non flood years percentage greater than 15% - 33007 (Nar @ Marham) – Non flood years percentage greater than 15% - 34005 (Tud @ Costessey Park) – Non flood years percentage greater than 15% - 33031 (Broughton Brook @ Broughton) – Non flood years percentage greater than 15%	L-CV = 0.186 L-Skew = 0.149
Group_02	FEP_02	No	Non Flood Years adjustment has been applied - 33011 (Little Ouse @ County Bridge Euston) - Non flood years percentage greater than 15 - 33019 (Thet @ Melford Bridge) - Non flood years percentage greater than 15 - 33007 (Nar @ Marham) - Non flood years percentage greater than 15	L-CV = 0.200 L-Skew = 0.170
Group_03	FEP_03	No	• 7011 (Black Burn @ Pluscarden Abbey) – short record (10 years) • 49005 (Bolingey Stream @ Bolingey Cocks Bridge) – short record (12 years)	L-CV = 0.285 L-Skew = 0.196
Group_04	FEP_04	No	Non Flood Years adjustment has been applied • 33019 (Thet @ Melford Bridge) - Non flood years percentage greater than 15	L-CV = 0.167 L – Skew = 0.223

Name of Group	Site code from whose descriptors group was derived	Subject site treated as gauged? (enhanced single site analysis)	Changes made to default pooling group, with reasons. Include any sites that were investigated but retained in the group	Weighted average L-moments (L-CV and L-skew before urban adjustment)
			• 33011 (Little Ouse @ County Bridge Euston) - Non flood years percentage greater than 15 • 33007 (Nar @ Marham) - Non flood years percentage greater than 15	
Group_05	FEP_05	No	Non Flood Years adjustment has been applied - 33011 (Little Ouse @ County Bridge Euston) - Non flood years percentage greater than 15 - 33019 (Thet @ Melford Bridge) - Non flood years percentage greater than 15	L-CV = 0.184 L-Skew = 0.169

The table below details the H2 score and requirement for pooling group review for in the initial and final pooling groups for each site.

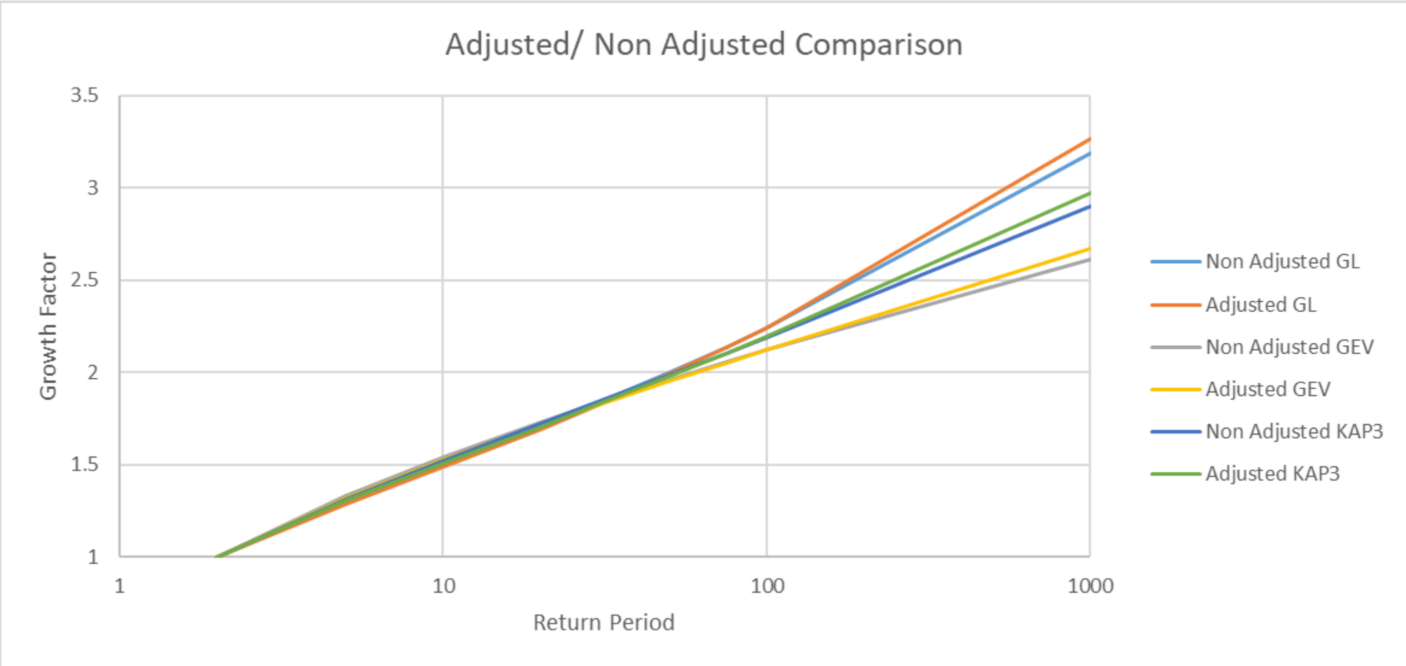
Catchment	Initial Pooling Group H2 value	Recommendation for Pooling Group Review	Final Pooling Group H2 value	Recommendation for Final Pooling Group Review
FEP_01	6.0589	Essential	6.0589	Essential. The pooling group has been reviewed.
FEP_02	8.3677	Essential	5.8664	Essential. The pooling group has been reviewed.
FEP_03	2.7097	Desirable	2.303	Desirable
FEP_04	6.0457	Essential	5.472	Essential. The pooling group has been reviewed.
FEP_05	8.2327	Essential	5.3470	Essential. The pooling group has been reviewed.

5.7 Derivation of flood growth curves at subject sites

The growth curve factors provided below have been adjusted using the Non-Flood Years adjustment. It is noted that the Growth Curve Factors are increasing only for the 0.1% AEP.

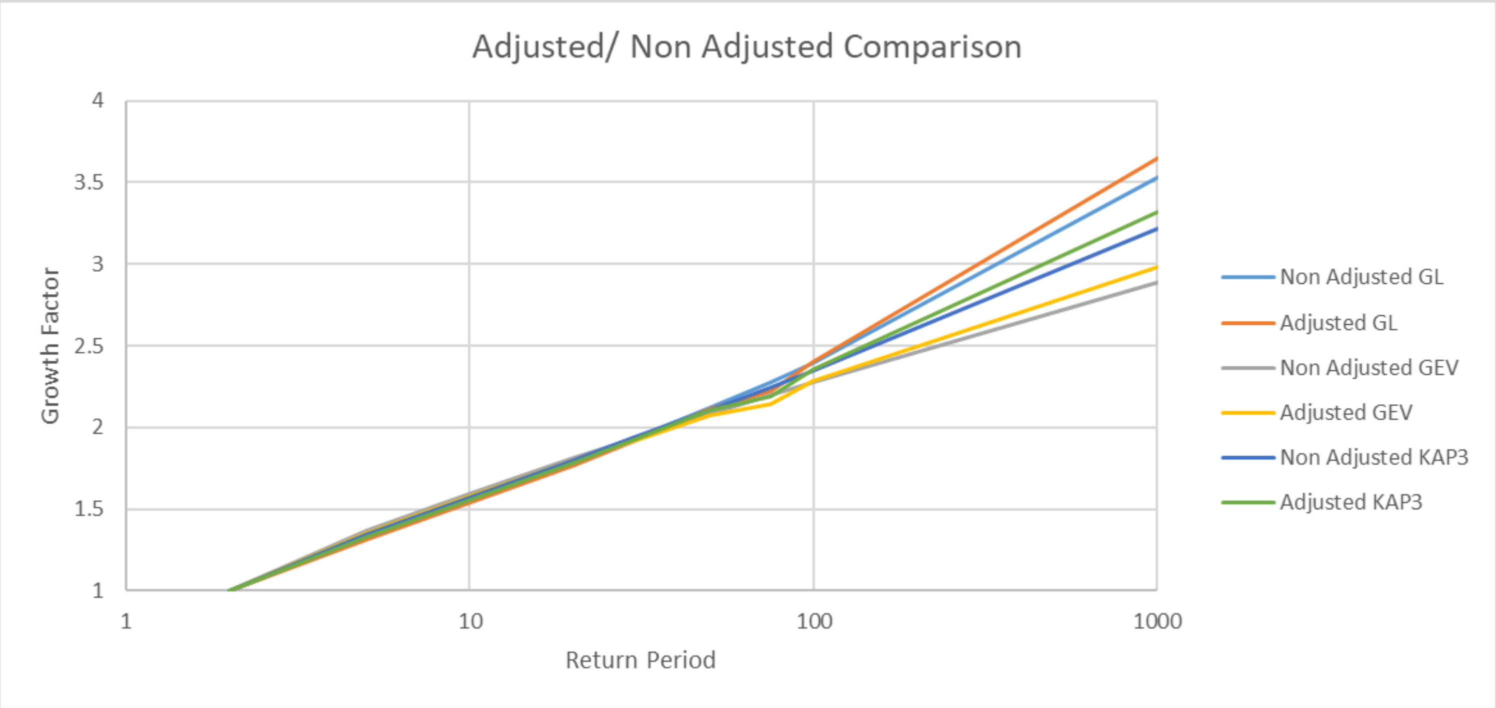
Growth Curve Factors for the following return periods for Gl, GEV and KAP3 distributions for FEP_01 Pooling Group

Distribution	2	5	10	20	30	50	75	100	1000
GL	1	1.289	1.488	1.694	1.821	1.990	2.132	2.239	3.266
GEV	1	1.322	1.526	1.715	1.821	1.951	2.054	2.125	2.673
KAP3	1	1.304	1.507	1.708	1.826	1.979	2.103	2.192	2.972



Growth Curve Factors for the following return periods for Gl, GEV and KAP3 distributions for FEP_02 Pooling Group

Distribution	2	5	10	20	30	50	75	100	1000
GL	1	1.315	1.536	1.769	1.915	2.111	2.222	2.402	3.645
GEV	1	1.350	1.579	1.796	1.920	2.076	2.144	2.284	2.978
KAP3	1	1.331	1.557	1.786	1.923	2.102	2.194	2.356	3.318

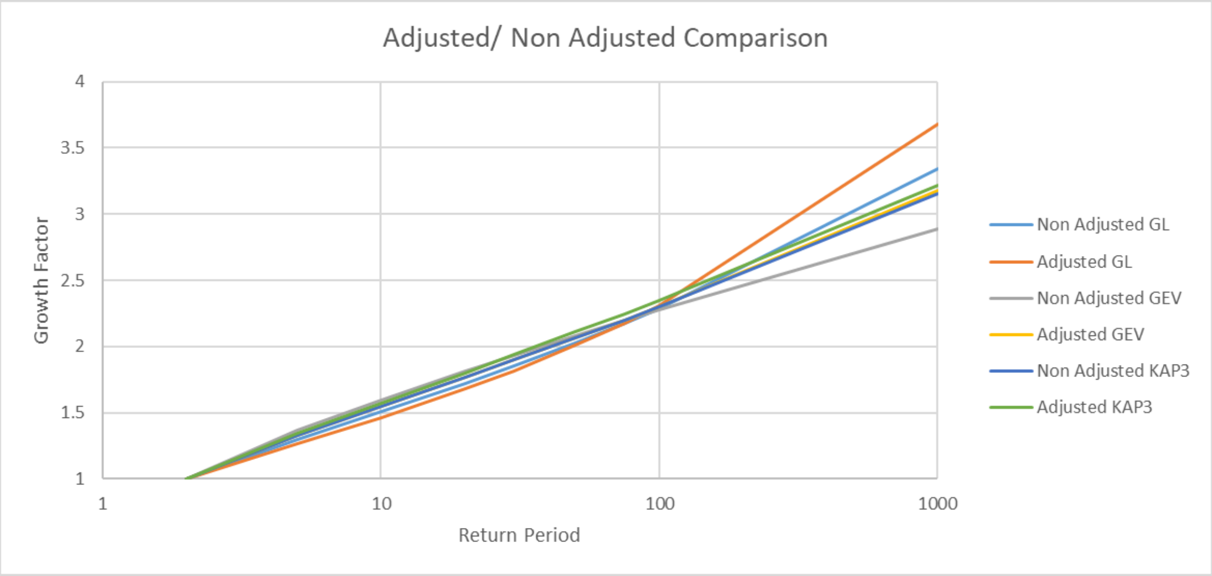


Growth Curve Factors for the following return periods for Gl, GEV and KAP3 distributions for FEP_03 Pooling Group

Distribution	2	5	10	20	30	50	75	100	1000
GL	1	1.460	1.794	2.155	2.385	2.698	2.969	3.174	5.311
GEV	1	1.507	1.858	2.207	2.414	2.678	2.891	3.045	4.350
KAP3	1	1.480	1.825	2.184	2.406	2.700	2.946	3.128	4.860

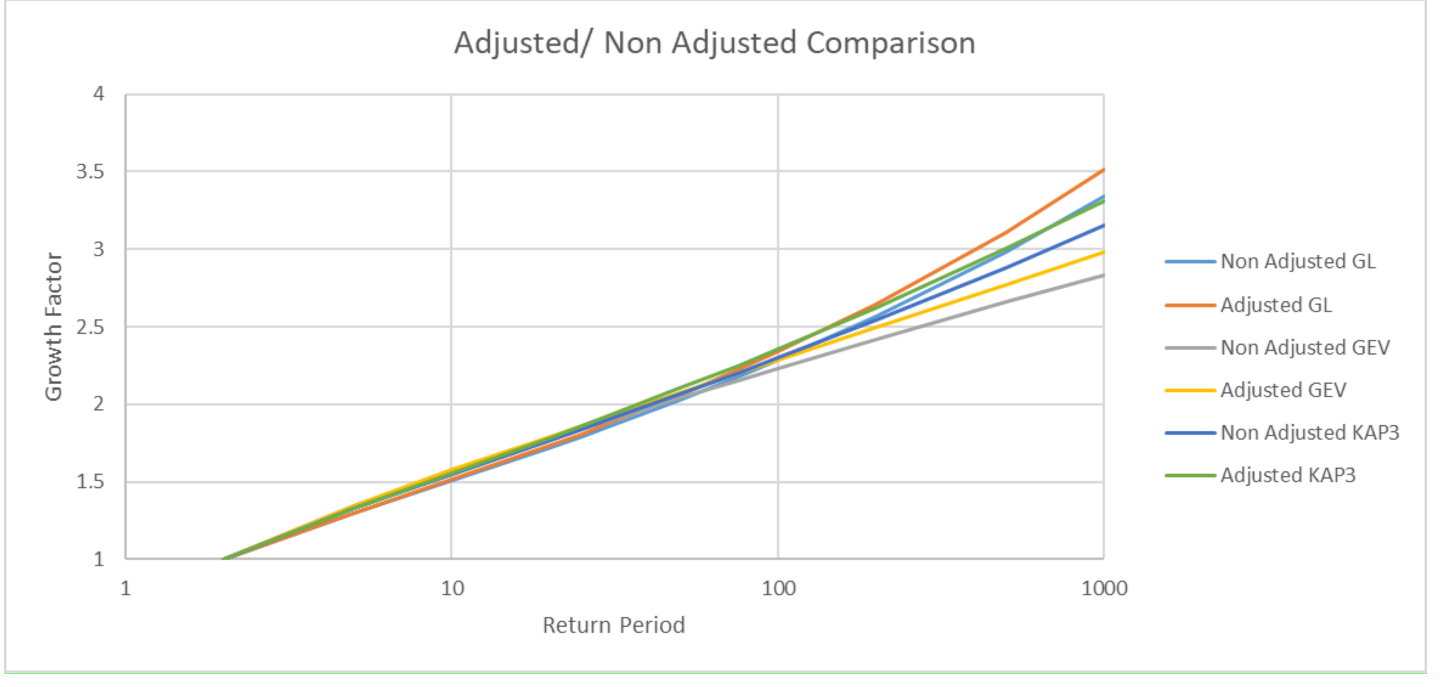
Growth Curve Factors for the following return periods for Gl, GEV and KAP3 distributions for FEP_04 Pooling Group

Distribution	2	5	10	20	30	50	75	100	1000
GL	1	1.265	1.462	1.678	1.818	2.010	2.177	2.305	3.678
GEV	1	1.327	1.549	1.768	1.899	2.066	2.202	2.300	3.179
KAP3	1	1.344	1.574	1.802	1.936	2.109	2.248	2.349	3.219



Growth Curve Factors for the following return periods for Gl, GEV and KAP3 distributions for FEP_05 Pooling Group

Distribution	2	5	10	20	30	50	75	100	1000
GL	1	1.301	1.513	1.735	1.874	2.060	2.218	2.336	3.513
GEV	1	1.348	1.577	1.795	1.920	2.075	2.199	2.284	2.978
KAP3	1	1.330	1.557	1.784	1.923	2.101	2.248	2.353	3.312



Peak flows (m^3s^{-1}) estimated for the following return periods for each statistical distribution (FEP_01)

Distribution	2	5	10	20	30	50	75	100	1000
GL	9.557	12.319	14.221	16.190	17.402	19.018	20.380	21.393	31.209
GEV	9.557	12.631	14.580	16.388	17.402	18.647	19.626	20.313	25.542
KAP3	9.557	12.461	14.401	16.322	17.449	18.914	20.094	20.953	28.400

Peak flows (m^3s^{-1}) estimated for the following return periods for each statistical distribution (FEP_02)

Distribution	2	5	10	20	30	50	75	100	1000
GL	10.205	13.418	15.679	18.056	19.542	21.538	22.676	24.510	37.200
GEV	10.205	13.782	16.113	18.330	19.592	21.182	21.879	23.313	30.389
KAP3	10.205	13.579	15.891	18.228	19.623	21.447	22.387	24.040	33.863

Peak flows (m^3s^{-1}) estimated for the following return periods for each statistical distribution (FEP_03)

Distribution	2	5	10	20	30	50	75	100	1000
GL	1.137	1.659	2.040	2.450	2.711	3.067	3.375	3.608	6.037
GEV	1.137	1.713	2.112	2.509	2.744	3.044	3.286	3.461	4.944
KAP3	1.137	1.747	2.148	2.525	2.737	2.999	3.203	3.346	4.451

Peak flows (m^3s^{-1}) estimated for the following return periods for each statistical distribution (FEP_04)

Distribution	2	5	10	20	30	50	75	100	1000
GL	10.883	13.767	15.911	18.262	19.785	21.875	23.692	25.085	40.028
GEV	10.883	14.445	16.862	19.238	20.662	22.479	23.965	25.030	34.602
KAP3	10.883	14.627	17.130	19.611	21.069	22.952	24.465	25.564	35.032

				Peak flows (m^3s^{-1}) estimated for the following return periods for each statistical distribution (FEP_05)					
Distribution	2	5	10	20	30	50	75	100	1000
GL	13.521	17.591	20.457	23.459	25.338	27.853	29.990	31.585	47.499
GEV	13.521	18.227	21.327	24.264	25.954	28.059	29.727	30.879	40.265
KAP3	13.521	17.983	21.055	24.127	25.995	28.403	30.390	31.820	44.785

5.8 Flood estimates from the statistical method

QMED estimated using donor adjustment and adjusted using UAF at site location. Growth curve factors were derived from pooling analysis at the site of interest for flood frequency estimates.

					Flood Peak (m^3s^{-1}) for the following return periods				
Site Code	2	5	10	20	30	50	75	100	1000
FEP_01	9.557	12.631	14.580	16.388	17.402	18.647	19.626	20.313	25.542
FEP_02	10.205	13.782	16.113	18.330	19.592	21.182	21.879	23.313	30.389
FEP_03	1.137	1.659	2.040	2.450	2.711	3.067	3.375	3.608	6.037
FEP_04	10.883	14.445	16.862	19.238	20.662	22.479	23.965	25.030	34.602
FEP_05	13.521	18.227	21.327	24.264	25.954	28.059	29.727	30.879	40.265

6 Revitalised flood hydrograph (ReFH2) method

6.1 Application of ReFH2 model

What is the purpose of applying this method?	Comment
Summarise reasons specific to study, for example: lumped estimates at key locations for the purpose of checking modelled peak flow estimates, distributed approach to apply inflows to a hydraulic model, deriving hydrograph shapes only, extending the flood frequency curve out to extreme events (long return periods).	Lumped estimates at the location of interest for peak flow estimates.

6.2 Parameters for ReFH2 model

If parameters are estimated from catchment descriptors, they are easily reproducible, so it is not essential to enter them in the table.

Site Code	Details of Method OPT: Optimisation BR: base flow recession fitting CD: catchment descriptors DT: Data Transfer	Tp_{rural} (hours) Time to peak	Tp_{urban} (hours) Time to peak	C_{max} (mm) Maximum storage capacity	IRF (% runoff for impermeable surfaces)	BL (hours) Base flow lag	BR Base flow recharge
FEP_01	CD	11.344	8.508	590.556	0.7	70.897	2.406
FEP_02	CD	12.624	8.630	575.41	0.7	72.87	2.371
FEP_03	CD	9.826	7.369	280.788	0.7	36.531	0.94
FEP_04	CD	13.06	8.358	564.423	0.7	72.908	2.313
FEP_05	CD	15.999	8.725	563.926	0.7	76.86	2.29

6.3 Design events for ReFH2 method: Lumped catchments

For all of the study locations the urban results have been considered and a 22hr storm duration has been used. The 22hr storm duration was considered to reflect the conditions of the study locations closest to the site of interest.

Site Code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)	Source of design rainfall statistic (FEH13 or FEH99)
FEP_01	Urban	Winter	22	FEH22
FEP_02	Urban	Winter	22	FEH22
FEP_03	Urban	Winter	22	FEH22
FEP_04	Urban	Winter	22	FEH22
FEP_05	Urban	Winter	22	FEH22

6.4 Flood estimates from the ReFH2 method

The urban results are reported in the table below, these results take account of the urban extent within the catchment based on URBEXT2000 and are considered representative of existing conditions.

	Flood Peak (m^3s^{-1}) for the following return periods								
Site Code	2	5	10	20	30	50	75	100	1000
FEP_01	8.69	11.53	13.68	16.02	17.56	19.76	21.76	23.34	41.27
FEP_02	8.73	11.54	13.67	15.97	17.49	19.63	21.59	23.14	40.86
FEP_03	1.13	1.46	1.71	1.97	2.14	2.38	2.59	2.76	4.50
FEP_04	9.21	12.14	14.36	16.78	18.36	20.61	22.66	24.29	42.60
FEP_05	10.72	13.76	16.22	18.90	20.64	23.12	25.36	27.13	47.14

7 Discussion and summary of results

7.1 Comparison of results from different methods

This table compares peak flows from the ReFH2 method with those from the FEH Statistical method (donor adjusted inclusive of urbanisation) at each site for two key return periods.

	Return period 2 years (50% AEP)			Return Period 100 years (1% AEP)		
Site Code	Statistical	ReFH2	Ratio (ReFH2/Statistical)	Statistical	ReFH2	Ratio (ReFH2/Statistical)
FEP_01	9.557	8.69	0.909	20.313	23.34	1.037
FEP_02	10.205	8.73	0.914	23.313	23.14	0.993
FEP_03	1.137	1.13	0.994	3.608	2.76	0.759
FEP_04	13.521	9.21	0.681	30.879	24.10	0.895
FEP_05	13.652	10.72	0.785	31.179	27.13	0.870

7.2 Final choice of method

Choice of method and reason Include reference to type of study, nature of catchment and type of data available	QMED has been estimated using catchment descriptors and donor adjustment making use of good quality local data from similar catchments. Pooling group analysis has been used to derive the growth curve factors for flood frequency estimates, with a non-flood years adjustment. Comparisons with ReFH2 estimates at the subject site showed ReFH2 derived estimates were lower than the statistical. The statistical method has therefore been chosen and all of the hydrographs used in the model have been scaled according to the peak flows produce by it.
How will the flows be applied to a hydraulic model?	FEP_01 flows will be applied as an inflow upstream boundary. FEP_03 flows will be applied as a tributary inflow. All hydrographs have calculated using the duration time at FEP_02 and all intervening inflows will be calculated by equal distribution of the difference of peak flows at the study locations.

7.3 Assumptions, limitations, and uncertainty

List the main assumptions made specific to the study	FEH statistical method and rainfall runoff method are appropriate.
Discuss any particular limitations For example applying methods outside the range of catchment types or return periods for which they were developed	The catchments at our site of interest are ungauged.
Give what information you can on uncertainty in the design peak flows or in the methodology For example using the methods detailed in 'Making better use of local data in flood frequency estimation' - Science Report SC130009/R	QMED at the ungauged sites has been estimated using CD with donor adjustment, which has reduced the F.S.E. The ReFH2 QMED estimate is very similar to the statistical derived estimate.
Comment on the suitability of the results for future studies For example at nearby locations or for different purposes	The flood estimates in this calculation record have been developed for the purposes of this study only and to assess the impact of the proposed works. The results may be applicable for other studies within the catchment, although users should undertake necessary checks for additional information and changes in methodologies.
Give any other comments on the study For example suggestions for additional work	NA

7.4 Checks

Are the results consistent, for example at confluences?	Yes
What do the results imply regarding the return periods / frequency of floods during the period of record?	NA – ungauged
What is the 100-year (1% AEP) growth curve factor? Is this realistic? (The guidance suggests a typical range of 2.1 – 4.0)	FEP_01 = 2.125, FEP_02 = 2.284, FEP_03 = 3.174, FEP_04 = 2.300, FEP_05 = 2.284
If 1000 year (0.1% AEP) flows have been derived, what is the range of ratios for the 1000-year (0.1% AEP) flow over the 100-year (1% AEP) flow?	See table below

ReFH2 flow estimates ($m^3 s^{-1}$)

Site Code	100-year	1000-year	Ratio (1000/100)
FEP_01	23.34	41.27	1.768
FEP_02	23.14	40.86	1.766
FEP_03	2.76	4.50	1.630
FEP_04	24.29	42.79	1.775

FEP_05	27.13	47.14	1.738

		Statistical flow estimates ($m^3 s^{-1}$)	
Site Code	**100-year**	**1000-year**	**Ratio (1000/100)**
FEP_01	20.313	25.542	1.257
FEP_02	23.313	30.389	1.304
FEP_03	3.608	6.037	1.673
FEP_04	30.879	40.265	1.304
FEP_05	31.179	40.655	1.304

How do the results compare with those of other studies? Explain the difference and conclude which results should be preferred	NA JBA hydrology report for the river Don catchment[10] (2017) does not include the study area
Are the results compatible with the longer-term flood history?	NA
Describe any other checks on the results	NA

[10] JBA (2017) Don Catchment Model Hydrology Report

7.5 Final results

The final peak flow results for use in the hydraulic model are provided in the table below. This includes the appropriate allowances for climate change (Don and Rother catchment climate change allowance[11]).

	Flood peak ($m^3 s^{-1}$) for required return periods (in years)						
Site Code	**2**	**30**	**50**	**100**	**100+21%**	**100+38%**	**1000**
FEP_01	9.557	17.402	18.647	20.313	24.579	28.032	25.542
FEP_02	10.205	19.592	21.182	23.313	28.209	32.172	30.389
FEP_03	1.137	2.711	3.067	3.608	4.366	4.97	6.037
FEP_04	10.883	20.662	22.479	25.030	30.286	34.541	34.602
FEP_05	13.521	25.954	28.059	30.879	37.364	42.613	40.265

[11] EA (2024) Climate Change Allowances. Available online at: https://environment.data.gov.uk/hydrology/climate-change-allowances/rainfall?mgtmcatid=3029

Appendix A Pooling Groups

FEP_01

Station	Distance	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised
27083 (Foss @ Huntington)	0.46	34	12.513	0.234	0.239	0.263	0.257
33029 (Stringside @ Whitebridge)	0.659	56	2.722	0.246	0.247	-0.075	-0.076
54020 (Perry @ Yeaton)	0.952	59	10.653	0.143	0.144	0.001	-0.001
54016 (Roden @ Rodington)	0.989	53	10.865	0.224	0.226	0.44	0.437
40005 (Beult @ Stilebridge)	1.282	61	37.911	0.24	0.242	0.193	0.191
40008 (Great Stour @ Wye)	1.328	62	19.658	0.163	0.167	0.081	0.074
53006 (Frome (Bristol) @ Frenchay)	1.363	61	30.804	0.207	0.222	0.134	0.115
53026 (Frome (Bristol) @ Frampton Cotterell)	1.37	44	11.85	0.161	0.168	0.156	0.145
25020 (Skerne @ Preston le Skerne)	1.559	49	14.492	0.179	0.184	0.018	0.011
15008 (Dean Water @ Cookston)	1.623	53	26.832	0.132	0.133	0.059	0.056

FEP_02

Station	Distance	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised
27083 (Foss @ Huntington)	0.388	34	12.513	0.234	0.239	0.263	0.257
33029 (Stringside @ Whitebridge)	0.76	56	2.722	0.246	0.247	-0.075	-0.076
54016 (Roden @ Rodington)	0.997	53	10.865	0.224	0.226	0.44	0.437
54020 (Perry @ Yeaton)	1.023	59	10.653	0.143	0.144	0.001	-0.001
40005 (Beult @ Stilebridge)	1.319	61	37.911	0.24	0.242	0.193	0.191
40008 (Great Stour @ Wye)	1.394	62	19.658	0.163	0.167	0.081	0.074
53006 (Frome (Bristol) @ Frenchay)	1.459	61	30.804	0.207	0.222	0.134	0.115
53026 (Frome (Bristol) @ Frampton Cotterell)	1.476	44	11.85	0.161	0.168	0.156	0.145
34005 (Tud @ Costessey Park)	1.579	60	3.13	0.292	0.297	0.239	0.234
25020 (Skerne @ Preston le Skerne)	1.664	49	14.492	0.179	0.184	0.018	0.011

FEP_03

	Station	Distance (SDM)	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised
1	27073 (Brompton Beck @ Snainton Ings	0.646	42	0.816	0.212	**0.213**	0.020	**0.018**
2	26016 (Gypsey Race @ Kirby Grindalyth	1.095	25	0.101	0.309	**0.309**	0.249	**0.249**
3	27051 (Crimple @ Burn Bridge)	1.106	50	4.641	0.218	**0.218**	0.133	**0.133**
4	25019 (Leven @ Easby)	1.258	44	5.384	0.340	**0.341**	0.367	**0.366**
5	36010 (Bumpstead Brook @ Broad Gree	1.267	55	7.590	0.352	**0.354**	0.109	**0.108**
6	26014 (Water Forlornes @ Driffield)	1.509	24	0.431	0.318	**0.319**	0.185	**0.184**
7	36004 (Chad Brook @ Long Melford)	1.744	55	4.807	0.301	**0.302**	0.176	**0.175**
8	39033 (Winterbourne Stream @ Bagnor)	1.752	60	0.401	0.340	**0.340**	0.376	**0.376**
9	27010 (Hodge Beck @ Bransdale Weir)	1.762	41	9.420	0.224	**0.224**	0.293	**0.293**
10	33054 (Babingley @ Castle Rising)	1.769	46	1.132	0.229	**0.229**	0.189	**0.188**
11	36003 (Box @ Polstead)	1.842	62	3.875	0.308	**0.311**	0.084	**0.082**

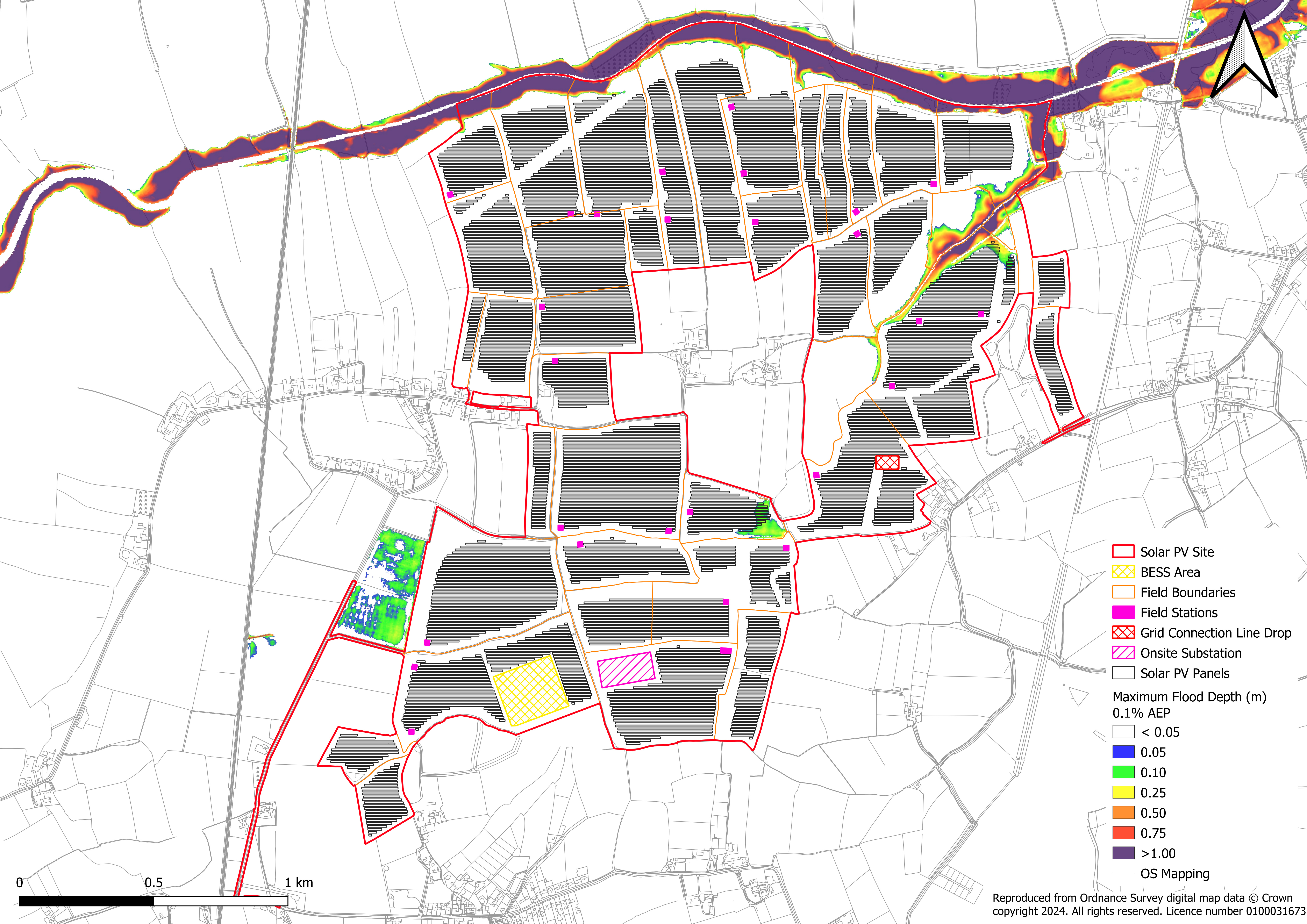
FEP_04

Station	Distance	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised
27083 (Foss @ Huntington)	0.385	34	12.513	0.234	0.239	0.263	0.257
33029 (Stringside @ Whitebridge)	0.829	56	2.722	0.246	0.247	-0.075	-0.076
54016 (Roden @ Rodington)	0.981	53	10.865	0.224	0.226	0.44	0.437
54020 (Perry @ Yeaton)	1.048	59	10.653	0.143	0.144	0.001	-0.001
40005 (Beult @ Stilebridge)	1.317	61	37.911	0.24	0.242	0.193	0.191
40008 (Great Stour @ Wye)	1.413	62	19.658	0.163	0.167	0.081	0.074
53006 (Frome (Bristol) @ Frenchay)	1.502	61	30.804	0.207	0.222	0.134	0.115
53026 (Frome (Bristol) @ Frampton Cotterell)	1.541	44	11.85	0.161	0.168	0.156	0.145
34005 (Tud @ Costessey Park)	1.648	60	3.13	0.292	0.297	0.239	0.234
25020 (Skerne @ Preston le Skerne)	1.709	49	14.492	0.179	0.184	0.018	0.011

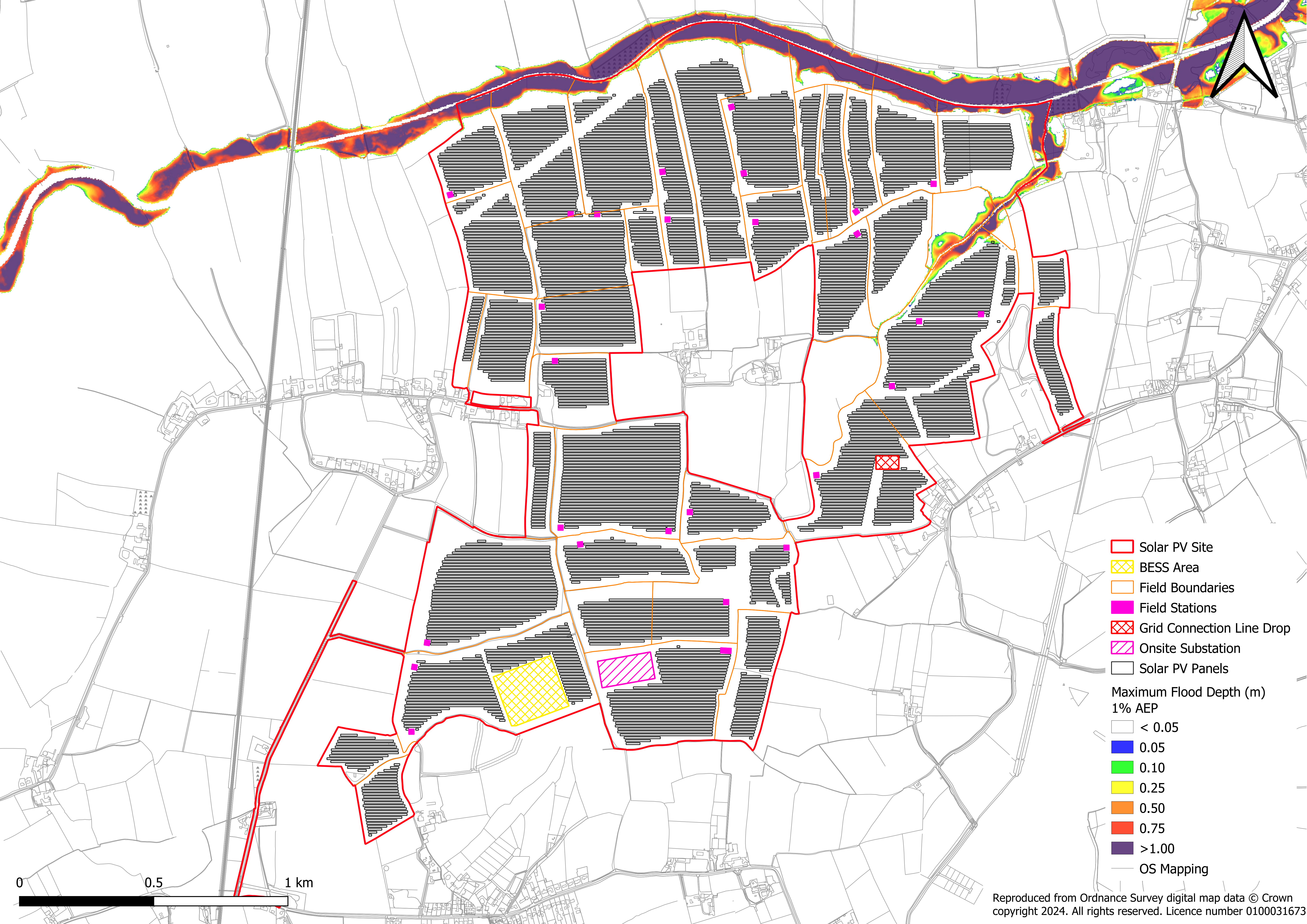
FEP_05

Station	Distance	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised
27083 (Foss @ Huntington)	0.809	34	12.513	0.234	0.239	0.263	0.257
54016 (Roden @ Rodington)	1.407	53	10.865	0.224	0.226	0.44	0.437
33029 (Stringside @ Whitebridge)	1.632	56	2.722	0.246	0.247	-0.075	-0.076
54020 (Perry @ Yeaton)	1.726	59	10.653	0.143	0.144	0.001	-0.001
40005 (Beult @ Stilebridge)	1.825	61	37.911	0.24	0.242	0.193	0.191
40008 (Great Stour @ Wye)	2.05	62	19.658	0.163	0.167	0.081	0.074
53006 (Frome (Bristol) @ Frenchay)	2.267	61	30.804	0.207	0.222	0.134	0.115
53026 (Frome (Bristol) @ Frampton Cotterell)	2.345	44	11.85	0.161	0.168	0.156	0.145
204001 (Bush @ Seneirl Bridge)	2.362	50	62.534	0.085	0.085	0.154	0.154
28026 (Anker @ Polesworth)	2.404	55	48.152	0.279	0.292	0.162	0.149

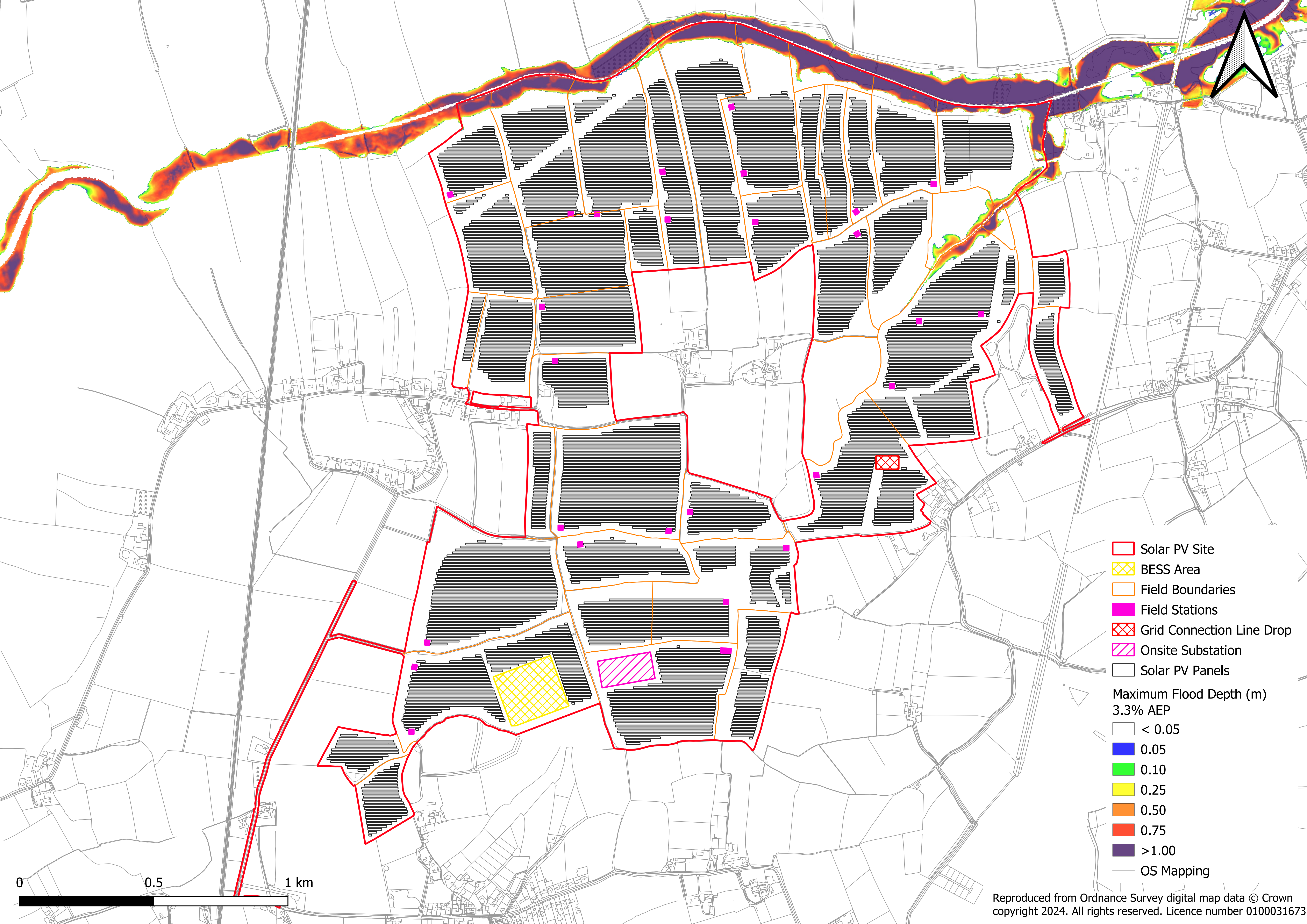
Appendix B Fluvial Maximum Flood Depth Maps



Solar PV Site
BESS Area
Field Boundaries
Field Stations
Grid Connection Line Drop
Onsite Substation
Solar PV Panels
Maximum Flood Depth (m)
0.1% AEP
< 0.05
0.05
0.10
0.25
0.50
0.75
>1.00
OS Mapping
0
0.5
1 km

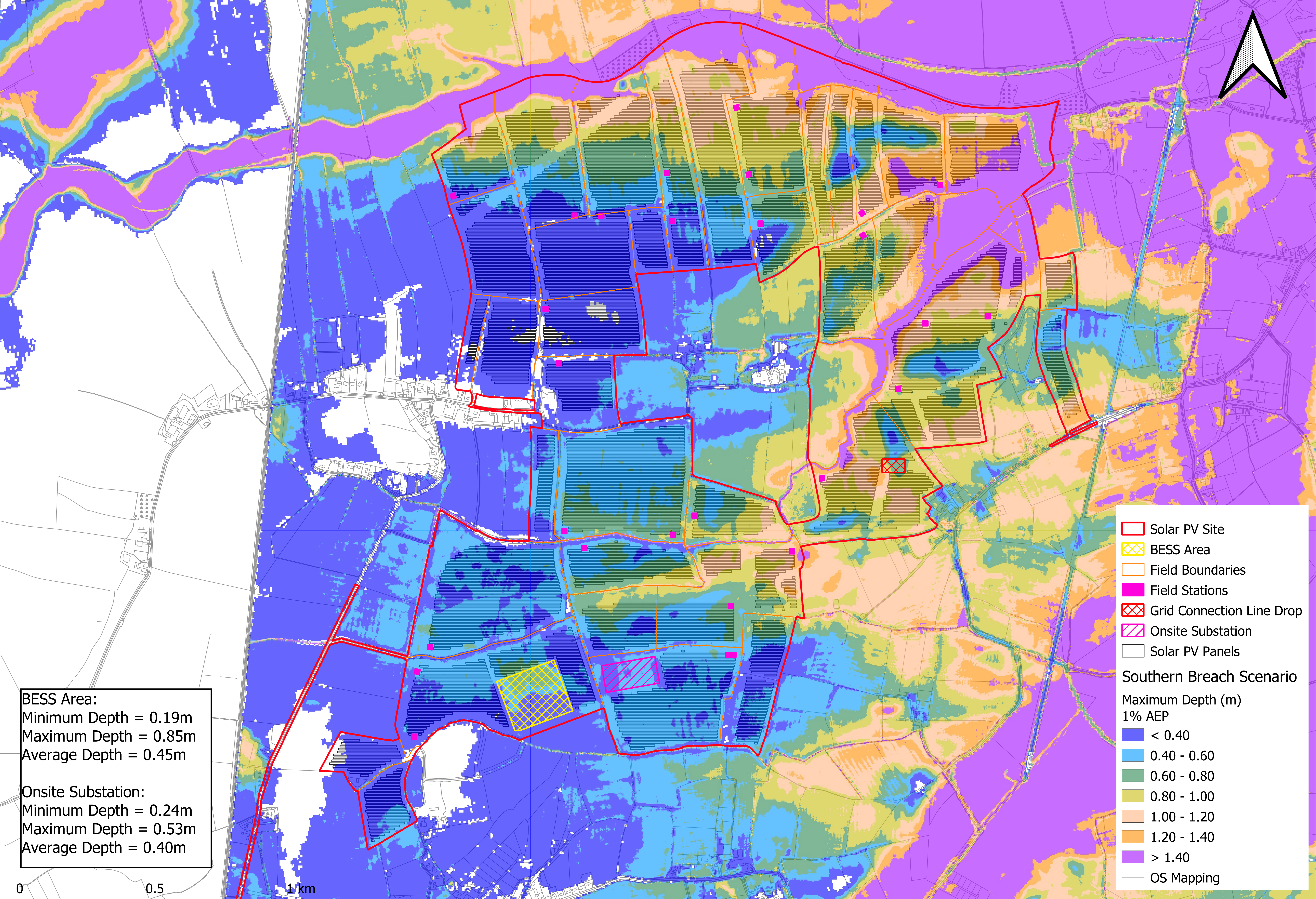


Solar PV Site
BESS Area
Field Boundaries
Field Stations
Grid Connection Line Drop
Onsite Substation
Solar PV Panels
Maximum Flood Depth (m)
1% AEP
< 0.05
0.05
0.10
0.25
0.50
0.75
>1.00
OS Mapping
0
0.5
1 km

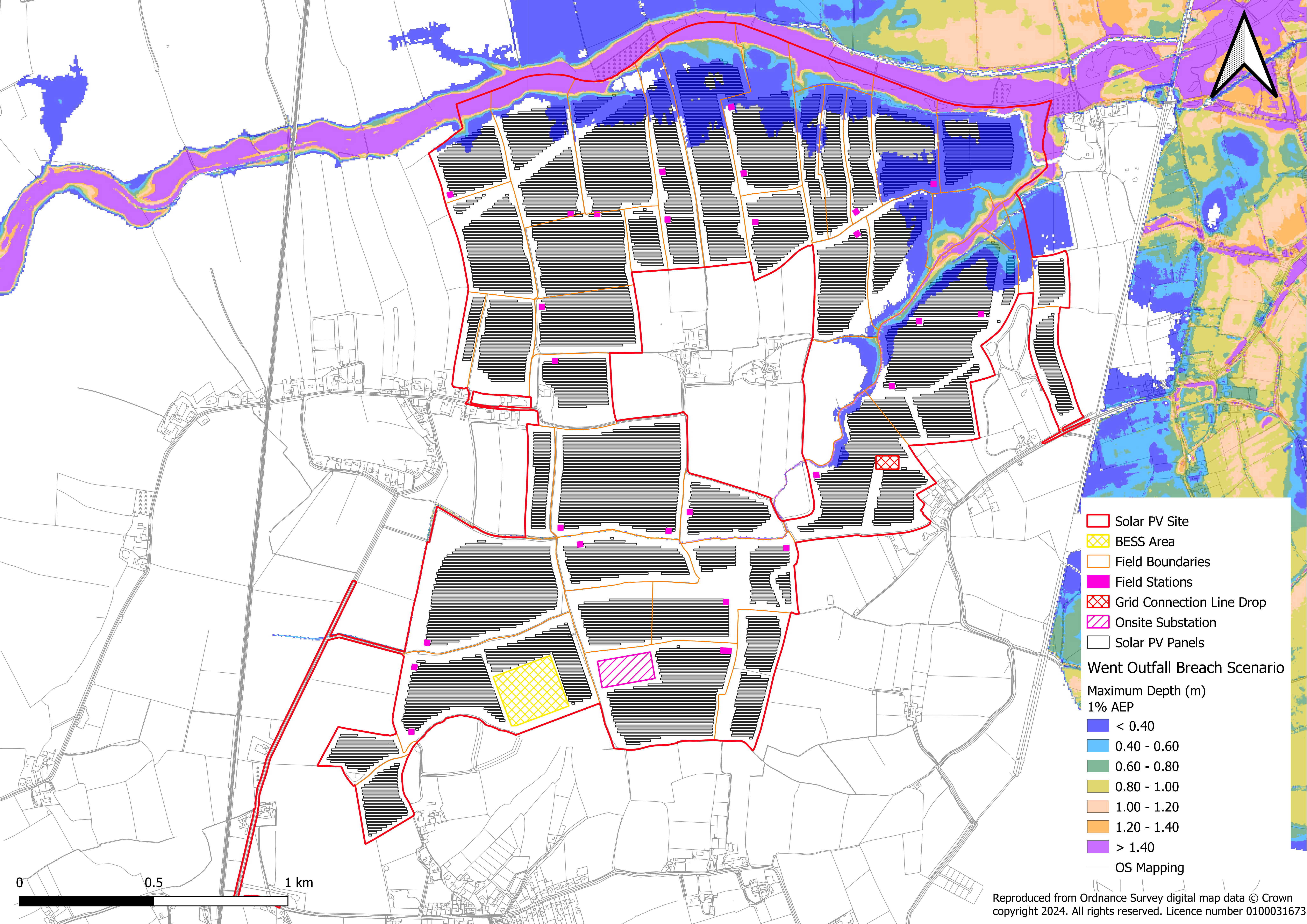


Solar PV Site
BESS Area
Field Boundaries
Field Stations
Grid Connection Line Drop
Onsite Substation
Solar PV Panels
Maximum Flood Depth (m)
3.3% AEP
< 0.05
0.05
0.10
0.25
0.50
0.75
>1.00
OS Mapping
0
0.5
1 km

Appendix C Breach 1% AEP Maximum Flood Depth Maps



Solar PV Site
BESS Area
Field Boundaries
Field Stations
Grid Connection Line Drop
Onsite Substation
Solar PV Panels
Southern Breach Scenario
Maximum Depth (m)
1% AEP
< 0.40
0.40 - 0.60
0.60 - 0.80
0.80 - 1.00
1.00 - 1.20
1.20 - 1.40
> 1.40
OS Mapping
BESS Area:
Minimum Depth = 0.19m
Maximum Depth = 0.85m
Average Depth = 0.45m
Onsite Substation:
Minimum Depth = 0.24m
Maximum Depth = 0.53m
Average Depth = 0.40m
0
0.5
1 km


Solar PV Site
BESS Area
Field Boundaries
Field Stations
Grid Connection Line Drop
Onsite Substation
Solar PV Panels
Went Outfall Breach Scenario
Maximum Depth (m)
1% AEP
< 0.40
0.40 - 0.60
0.60 - 0.80
0.80 - 1.00
1.00 - 1.20
1.20 - 1.40
> 1.40
OS Mapping
0
0.5
1 km

Appendix D Fenwick Solar Farm Hydraulic Modelling Report Addendum

Table of Contents

Plates

Tables

1. Introduction

1.1 Purpose of this Document

1.1.1 This document provides additional hydraulic modelling evidence to support the findings of the Fenwick Solar Farm Flood Risk Assessment (Volume III Appendix 9-3: Flood Risk Assessment), following the first Environment Agency hydraulic modelling review (5 February 2025) and further consultation with the Environment Agency between 22 April 2025 and 8 May 2025. Since the Environment Agency review, the following two scenarios have been assessed:

a. Initial Conditions Sensitivity – To understand how the initial catchment conditions impact flood risk within the River Went catchment the baseline model was simulated with an initial level taken from the 50% AEP modelled design event. Documented within Section 2 of this Addendum.

b. Culvert Removal Proposed Scenario – It is proposed to remove a culvert on the Fleet Drain as part of the development. The impact of this was assessed in the hydraulic model to understand the flood risk to and from the removal of the culvert. Documented within Section 3 of this Addendum.

1.1.2 This document presents the hydraulic model set up, hydraulic model results and the key conclusions of the reporting for each of the scenarios. This document forms an addendum to the Flood Risk Assessment and accompanying Modelling Report that formed part of the original Development Consent Order (DCO) submission.

1.1.3 For the purpose of this report the following terminology will be used:

a. Baseline simulations - Original design simulations included within the DCO FRA and Modelling Report. This include the 50% Annual Exceedance Probability (AEP), 3.33%, 1% AEP + 38% climate change and 0.1% AEP events with baseflow initial conditions. Covered in Section 5 of the Modelling Report;

b. Credible Maximum Scenario – 1% AEP + 60% climate change event, locked downstream boundary and with baseflow conditions presented in Section 6 in the Modelling Report;

c. Sensitivity simulations – Initial conditions sensitivity scenarios undertaken as part of this addendum report with raised initial water levels;

d. Proposed simulations – culvert removed scenario simulation; and

e. Design event – Identified in the DCO FRA as the Credible Maximum Scenario for the purposes of mitigation measures.

2. Initial Conditions Sensitivity

2.1 Overview

2.1.1 The Environment Agency noted in the model review that the hydrological analysis presented in Appendix A of the Fenwick Solar Farm Hydraulic Modelling Report may be underestimating the volumes/peak flows in the River Went catchment, because the maximum flood level reached within the design flood event had been exceeded in the observed record on multiple occasions in the past 21 years. Through the course of the hydraulic modelling assessment undertaken it has been established that the River Went catchment is volume driven because of the locking of the River Went by the River Don during flood conditions, and therefore it was identified that the initial conditions applied within the model for the baseline simulations may be a contributing factor to the underestimation of peak volumes and levels.

2.1.2 The initial catchment conditions are determined by the interaction of tidal levels and fluvial flows on the River Don locking and unlocking the River Went at the downstream boundary for a period of time. The the volume of water falling within the River Went catchment during this period must then be stored within the catchment for the period of locking. This means that the analysis of flood risk is volume driven rather than peak flow driven which in turn is dependent upon the initial catchment conditions. It was therefore agreed with the Environment Agency (05/08/2025) that sensitivity testing was undertaken on the catchment initial conditions to demonstrate that the Credible Maximum Scenario (1% AEP + 60%CC with locked downstream boundary) presented as the design event for mitigation measures is acceptable for this project. It was agreed that this approach was more proportionate than a full continuous simulation modelling approach, given the overall purpose of the hydraulic modelling assessment.

2.1.3 The following process was followed:

a. Reviewed the observed record at the Topham Ferry Bridge Level Gauge to identify suitable starting initial level in the catchment;

b. Simulate 3.33% AEP and 1% AEP + 38%CC design events with increased initial level; and

c. Compare the results of the sensitivity tests to the observed maximum levels at Topham Ferry Bridge Level Gauge and the Credible Maximum design event.

2.1.4 Further detail on the modelling approach adopted, results and interpretation are presented within Sections 2.2 to 2.7 Comparison with Observed Data at Topham Ferry Bridge

2.1.5 The Topham Ferry Bridge level gauge on the River Went is located 0.1km downstream of the Site and provides the best local observed data close to the Site. The gauge datum is recorded as 0.86mAOD and the highest recorded level is 4.60mAOD (3.735m gauge level) for the event of February 2021.The gauge record is 21 years long. The baseline model simulations were compared against the observed data at Topham Ferry Bridge level gauge. Plate 2-1 shows the modelled baseline simulations versus the maximum recorded gauge level, that occurred in February 2021. The maximum water level within the modelled design simulations was found to be lower than the observed maximum water level at the gauge. Furthermore, the modelled 1% AEP + 38%CC design event maximum level was found to have been exceeded seven times since 2001 within the gauged record.

2.1.6 The modelled Credible Maximum scenario (1% AEP + 60%CC with 0.1% AEP EHWL 2121 downstream boundary for the tidal Don), presented as the design event in the DCO FRA, is shown to be +0.27m higher than the observed maximum water level and has not been exceeded in the gauge record.

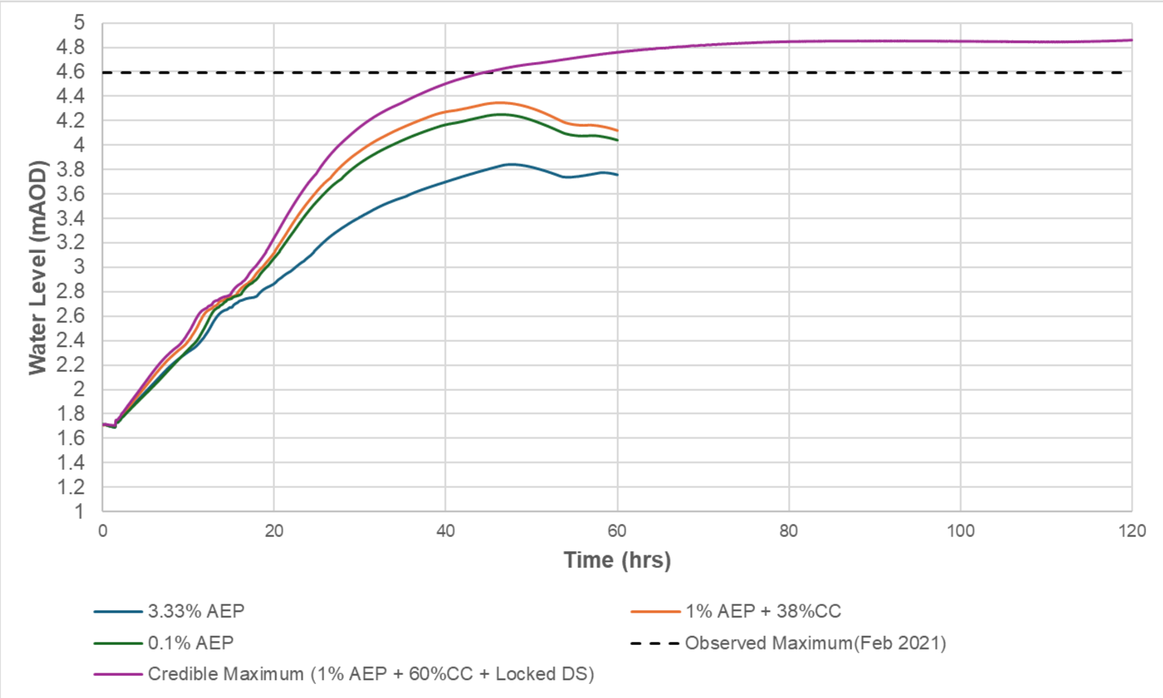


Plate 2-1: Water Level at Topham Ferry Bridge. Modelled Design Simulations vs. Topham Ferry Bridge Gauge Record

2.2 Modelling Approach

2.2.1 It was discussed and agreed with the Environment Agency within a meeting held on 22/04/2025 that the increased initial water levels in the catchment at the start of events caused by the prolonged locking of the River Went outfall, was likely the most significant reason for the differences between the modelled results and the observed record. The reasons for this are specified below:

a. Outflow from the River Went into the River Don is controlled by tidal and fluvial levels on the River Don;

b. This imposes a significant limitation on outflow from the River Went and leads substantial volumes of flood water to be stored within the River Went and its adjacent floodplain;

c. Based upon gauged record and observations of flooding in the catchment, peak flood levels within the River Went commonly occur when extreme rainfall events coincide with preexisting or antecedent raised water levels within the watercourse;

d. This is the primary indicator that the River Went catchment is volume dominated;

e. The initial conditions adopted within baseline simulation modelling for the DCO FRA did not reflect the raised levels and used a more standard baseflow driven approach;

f. This was identified as the primary reason for the differences observed between our modelled design levels and observed levels at the gauge; and

g. This sensitivity testing therefore aims to explore the model response, and resulting peak flood levels, when modelled initial conditions are raised in order to more closely reflect catchment conditions within the more extreme observed events.

2.2.2 The 50% AEP baseline event was identified as providing a reasonable approximation to the LMED elevation (3.57mAOD) at the Topham Ferry Bridge level gauge. The maximum 50% AEP event water level (3.42mAOD) was therefore used as the initial condition for the modelled sensitivity scenarios. This is considered a reasonable conservative estimate for a starting level in the catchment because only one of the largest ten recorded events begin at an elevation higher than 3.42mAOD.

2.3 Model Setup

2.3.1 The hydraulic model set up for the sensitivity simulations was the same as for the baseline simulations presented within the DCO FRA and accompanying modelling report, except for the changes outlined in this section. Table 2-1 shows the model control files used in the sensitivity scenarios.

Table 2-1: Sensitivity Model Control Files

Control File	Name
DAT	WEN_BASELINE_020_S_DSB_EHWL_Static
IED	WEN_XXXXyr_22hr_04_S_IC_LMED
IEF	WEN_BASELINE_XXXyr_021_S_IC_LMED
TCF	WEN_BASELINE_XXXyr_021_S_IC_LMED
TGC	WEN_BASELINE_020_TIDAL_S_DS_EHWL
TBC	WEN_BASELINE_019_TIDAL_S_DS_EHWL

Event Data

2.3.2 To aid model stability the event data was combined to produce a 50% AEP event followed by the specified AEP event. This was combined in the FMP IED and the model simulated for 180hrs to capture the entire hydrograph. The following simulations were run:

a. 3.33% AEP event with 50% AEP Initial Condition;

b. 1% AEP + 38%CC event with 50% AEP Initial Condition; and

c. 1% AEP + 60%CC event with 50% AEP Initial Condition

Downstream Boundary

2.3.3 A static downstream boundary water level was applied to represent levels on the tidal Don for all sensitivity simulations, in order to lock the River Went catchment for the entirety of the model simulation. The 0.1% AEP Humber Extreme Water Level for 2121_H upper scenario of 6.28mAOD was applied.

2D Domain

2.3.4 The 2D domain extent was set up the same as the Credible Maximum Scenario reported in the DCO FRA and modelling report (Section 6.4). This means that the model domain was extended to prevent glass walling and a 2d HQ boundary was applied at the north end of the catchment when compared to the baseline scenario. A check was undertaken on the volumes leaving the model via the HQ boundary and it was found that it was small and has no impact on the model outcomes.

2.4 Model Health

2.4.1 The combination of locking of the downstream boundary and increased volume in the catchment has meant that large water depths are present across the 1D-2D boundary, greater than 3m in some locations. This, combined with the flat characteristics of the catchment and low velocities, have led to poor 1D model convergence after c.90hrs across all sensitivity simulations. Plate 2-2 shows an example of the 1D model convergence plot for the 1% AEP + 38% CC sensitivity simulation. Importantly, this shows that the poor model convergence occurs after the peak of the event and is considered acceptable within the context of this assessment for following reasons:

a. The 1D mass balance error is good and less than 2% peak system volume and c0.06% of the boundary inflows. This indicates that the model convergence is not significantly impacting volumes within the 1D model;

b. The 2D mass balance error is good and within the +/-1% tolerance except for the initial wetting of the catchment (Plate 2-3). During the period of poor 1D convergence the 2D mass balance error is close to zero meaning there no concern over a misrepresentation of volumes in the 2D domain;

c. The poor model convergence causes only minor fluctuations in stage in the areas of interest and does not significantly impact the model extents;

d. Improvements have been made in the channel and structure representation, particularly on Fleet Drain, since consultation with the Environment Agency. This has improved model convergence and stability and the model now simulates to completion;

e. Further attempts to improve the model stability using stability patches and parameter adjustments after 90hrs have not been successful. Given the points above, are not expected to significantly impact the model conclusions and this should be considered a limitation of the modelling (Section 2.7).

f. Model convergence and stability have been discussed with the Environment Agency, who have indicated that they do not consider model stability to be significantly impacting upon model results and the associated conclusions.

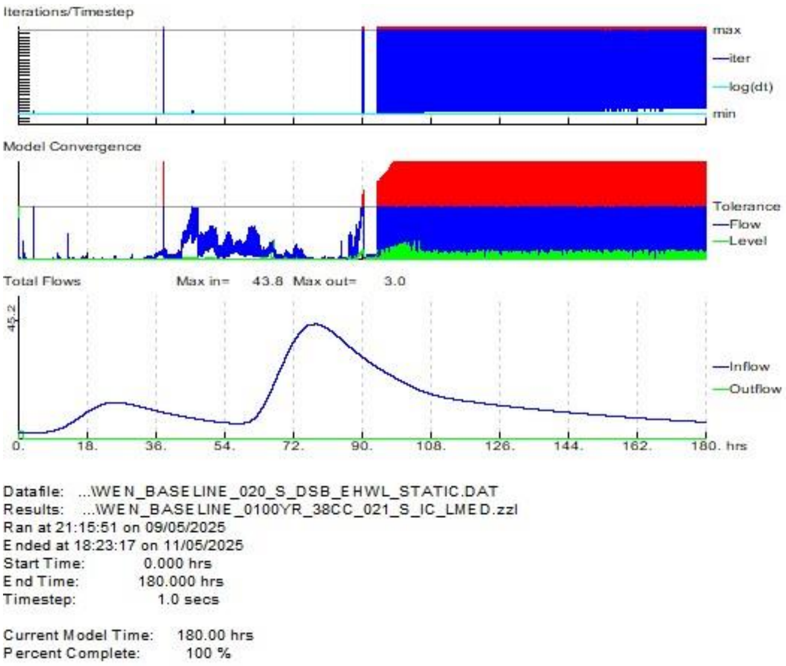


Plate 2-2: Sensitivity Scenario 1D Model Convergence, 1% AEP + 38%CC

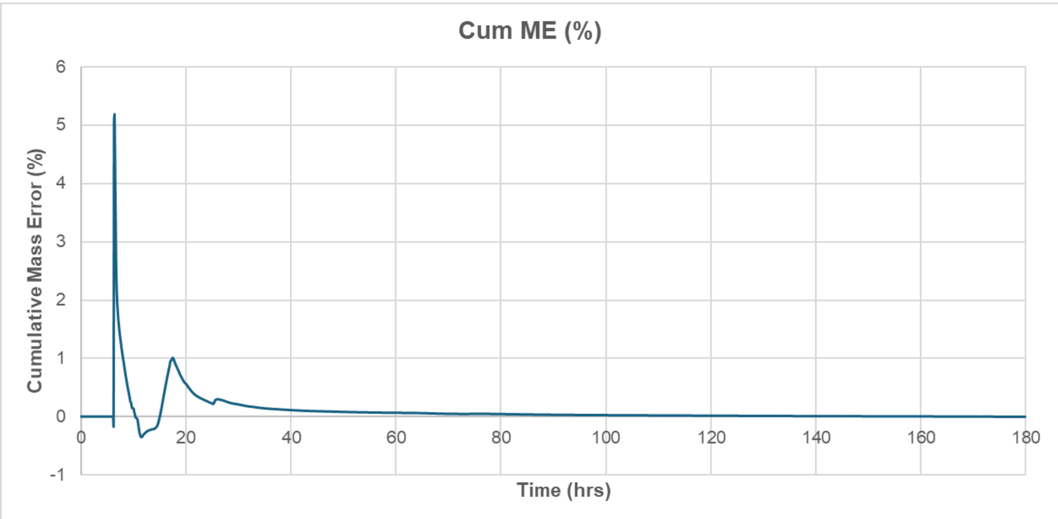


Plate 2-3: Cumulative Mass Error (%), 1% AEP + 38% CC

2.5 Model Results

2.5.1 The hydraulic model stage results at Topham Ferry Bridge for the sensitivity simulations are presented in Plate 2-4 and compared to the Credible Maximum Scenario (design event) and baseline results. The agreed freeboard of +0.4m above the Credible Maximum Scenario, which is to be used as the basis for mitigation adopted for the scheme, is also shown for context. The maximum modelled flood extents are also shown in Plate 2-6.

2.5.2 The following observations can be made:

a. In all sensitivity simulations the maximum modelled water level is higher than the observed maximum at the Topham Ferry Bridge Gauge. This shows that when the initial conditions are raised, the modelled design flood levels exceed the maximum observed level at Topham Ferry Bridge;

b. The stage hydrograph at the gauge location begins to plateau between 4.7mAOD and 4.8mAOD across all the sensitivity simulations. This coincides with the level at which the overtopping of the left bank defences of the River Went into the floodplain near the Site begins to occur (Plate 2-5). Beyond this, further water level increase is limited as increasingly larger volumes of water are required to raise the water level as it must spread out into the wider floodplain. This indicates that the local topography and floodplain features, particularly the flood defences on the left bank of the Went, act as a primary control upon flood levels at the Site;

c. The range of maximum water levels between the sensitivity 3.33% AEP and 1% AEP + 38%CC simulations is compressed compared to the baseline results. This is an indication that once the floodplain becomes inundated there are limited further increases in maximum level due to larger magnitude events;

d. The maximum flood extents within the site boundary for the sensitivity scenarios are consistent with the Credible Maximum Scenario used as the design event (Plate 2-6). This builds confidence the Credible Maximum scenario is a reasonable conservative design event to form the basis for Site flood mitigation; and

e. The freeboard level is greater than +0.3m above the maximum level of the sensitivity scenarios. This builds confidence that the Credible Maximum plus the freeboard provides a reasonable design level.

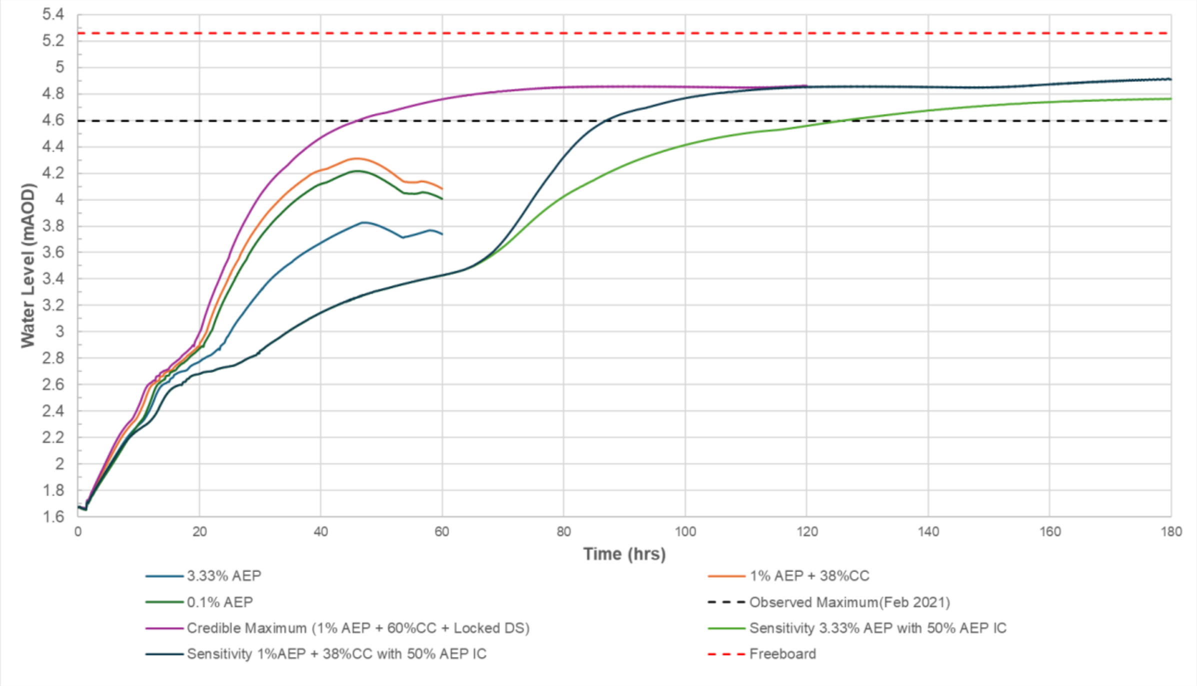


Plate 2-4: Comparison of sensitivity Stage results Topham Ferry Bridge

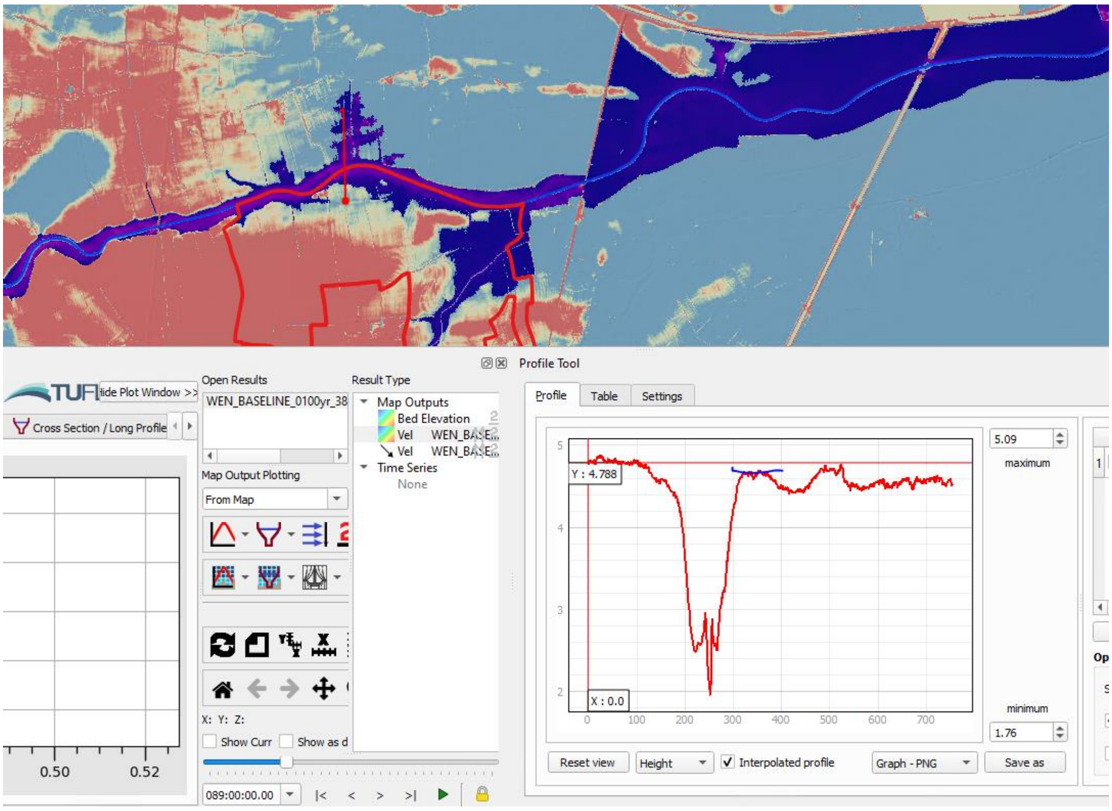


Plate 2-5: Overtopping of the left bank c. 4.7mAOD

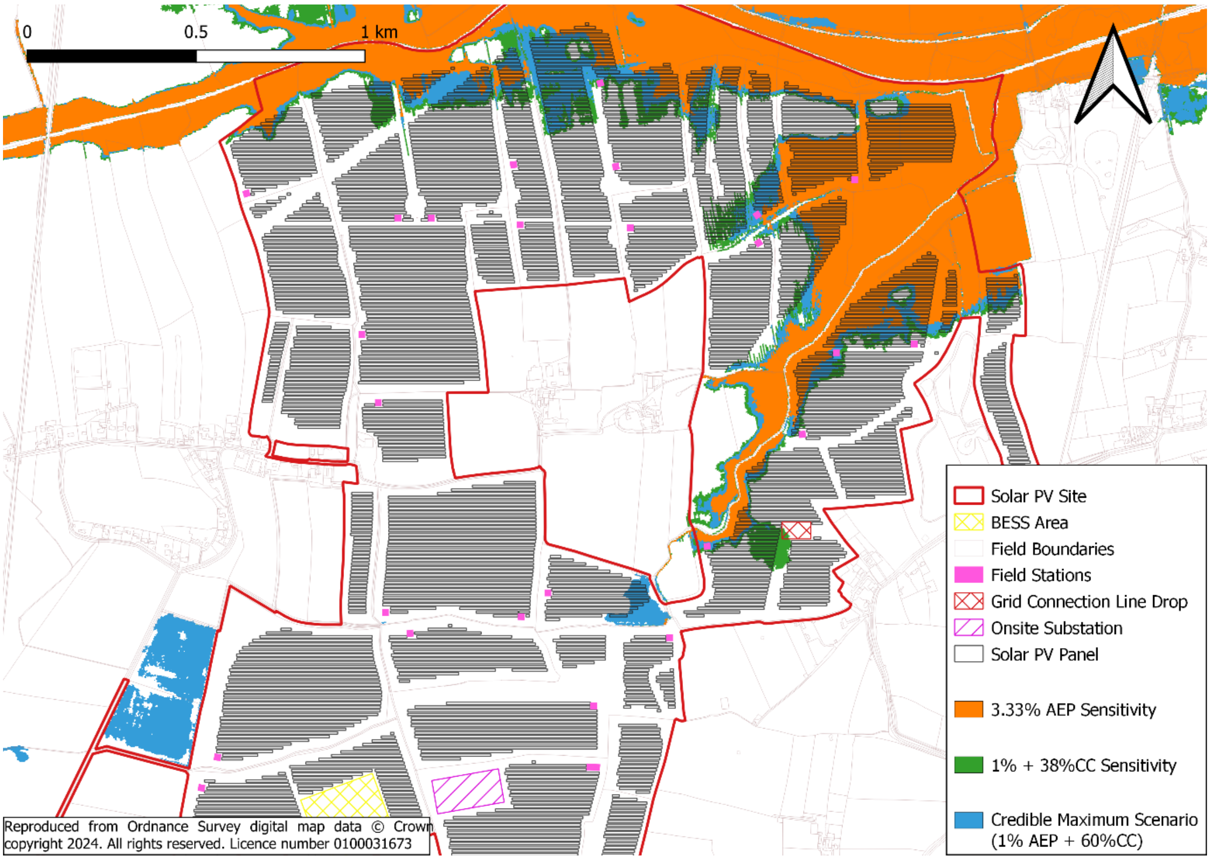


Plate 2-6: Maximum Flood Extents vs. Credible Maximum Scenario

2.6 Conclusions

2.6.1 The sensitivity testing and associated modelling results have demonstrated that once the water elevations rise above approximately 4.7mAOD the wider floodplain on the left bank of the River Went is activated near the Site. As a result, further water level increases above this level are limited and a plateau occurs, due to the large extent and storage capacity of the surrounding floodplain. Importantly, the peak flood level for the Credible Maximum Scenario presented in the original DCO FRA and hydraulic modelling report is shown to be above this level and is not sensitive to the initial catchment conditions.

2.6.2 Overall, the sensitivity analysis completed provides confidence that the Credible Maximum Scenario provides a reasonable conservative estimate of maximum water levels and flood extents at the site, and forms an appropriate basis for the design of mitigation measures.

3. Proposed Culvert Removal Scenario

3.1 Proposed Scenario Overview

3.1.1 Proposals for the Site include removal of a small culvert located on the Fleet Drain at approximate National Grid Reference 461210, 416282 (Plate 3-1). The culvert was surveyed by Storm Geomatics in 2024 as 1.4m diameter circular culvert, 4.8m in length in poor condition due to the construction.

3.1.2 The hydraulic model was simulated with the culvert removed and compared to the baseline model results to understand the flood risk impacts of removing the culvert. Given the flooding on the Fleet Drain is volume driven, the proposed scenario was simulated with the original DCO FRA baseline hydrology. The proposed scenario was simulated for the 3.33% AEP and 1% AEP + 38%CC event for comparison with the baseline.

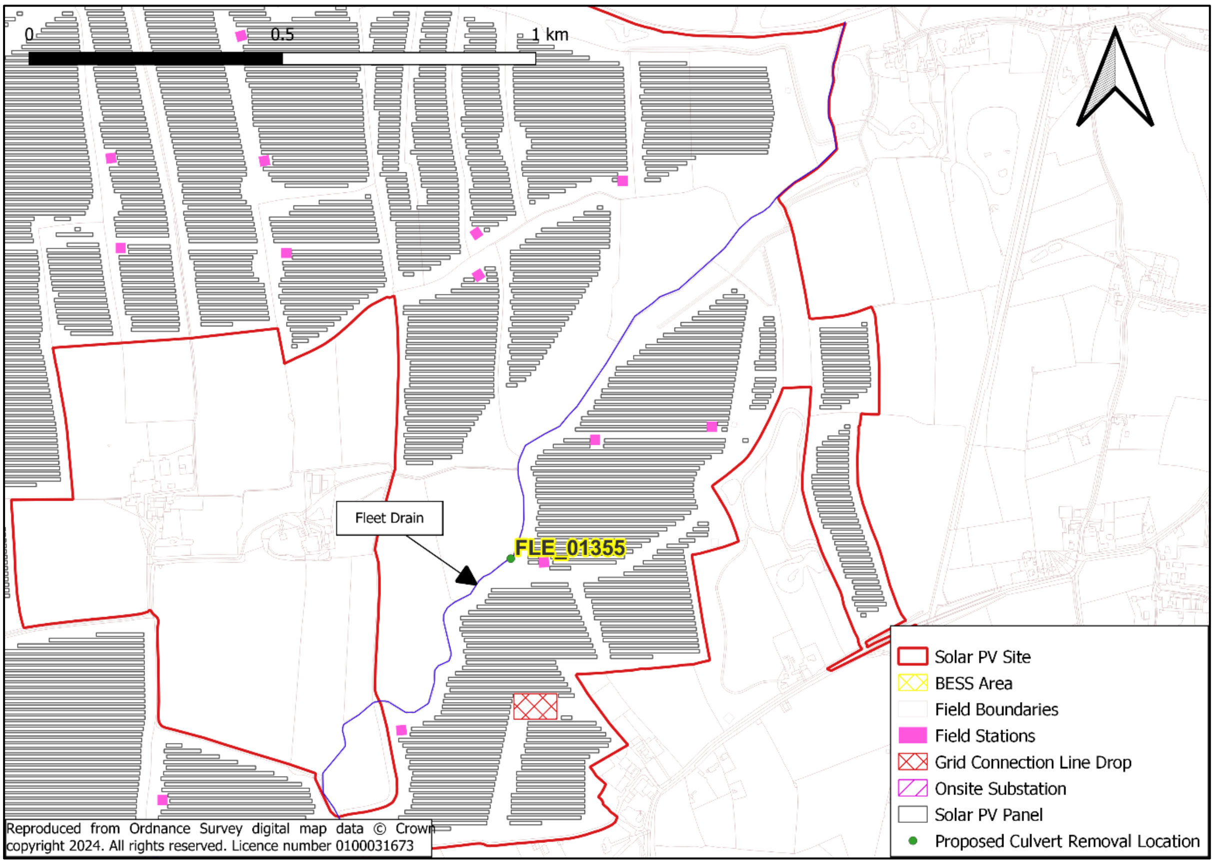


Plate 3-1: Location of proposed removed culvert

3.2 Model Setup

3.2.1 The culvert FLE_01355cu was removed from the 1D FMP model and the upstream channel chainage was updated to 4.8m, the length of the removed culvert. The 2D bank lines and 1D-2D linking were updated to reflect an open channel. The model setup adopted therefore assumed the culvert was replaced by a channel with the equivalent geometry equivalent to the existing Fleet Drain upstream and downstream. No other changes were made to the baseline model.

3.2.2 The proposed scenario model files are shown on Table 3-1.

Table 3-1: Proposed Scenario model files

Control File	Name
DAT	WEN_PROP_001_TIDAL
IED	WEN_XXXyr_22hr_04
IEF	WEN_PROPOSED_XXXyr_001
TCF	WEN_PROPOSED_XXXyr_001
TGC	WEN_PROPOSED_001_TIDAL
TBC	WEN_PROPOSED_001_TIDAL

3.3 Model Stability

3.3.1 The proposed scenario model stability is consistent with baseline model outline in the main body of the report.

3.4 Model Results

3.4.1 The maximum flood extents for the proposed scenarios are shown in Plate 3-2. The following is a summary of the results:

a. -0.01m reduction in maximum water level upstream of the removed culvert and negligible change downstream in the 3.33% AEP event. There is no change in the maximum flood extent when compared to the baseline scenario.

b. -0.05m reduction in water level upstream of the removed culvert and negligible change downstream in the 1% AEP + 38%CC event. There is a negligible change in the maximum flood extent when compared to the baseline scenario.

3.4.2 The proposed scenario flood outlines are consistent with the baseline scenario and provide a small benefit upstream of the culvert.

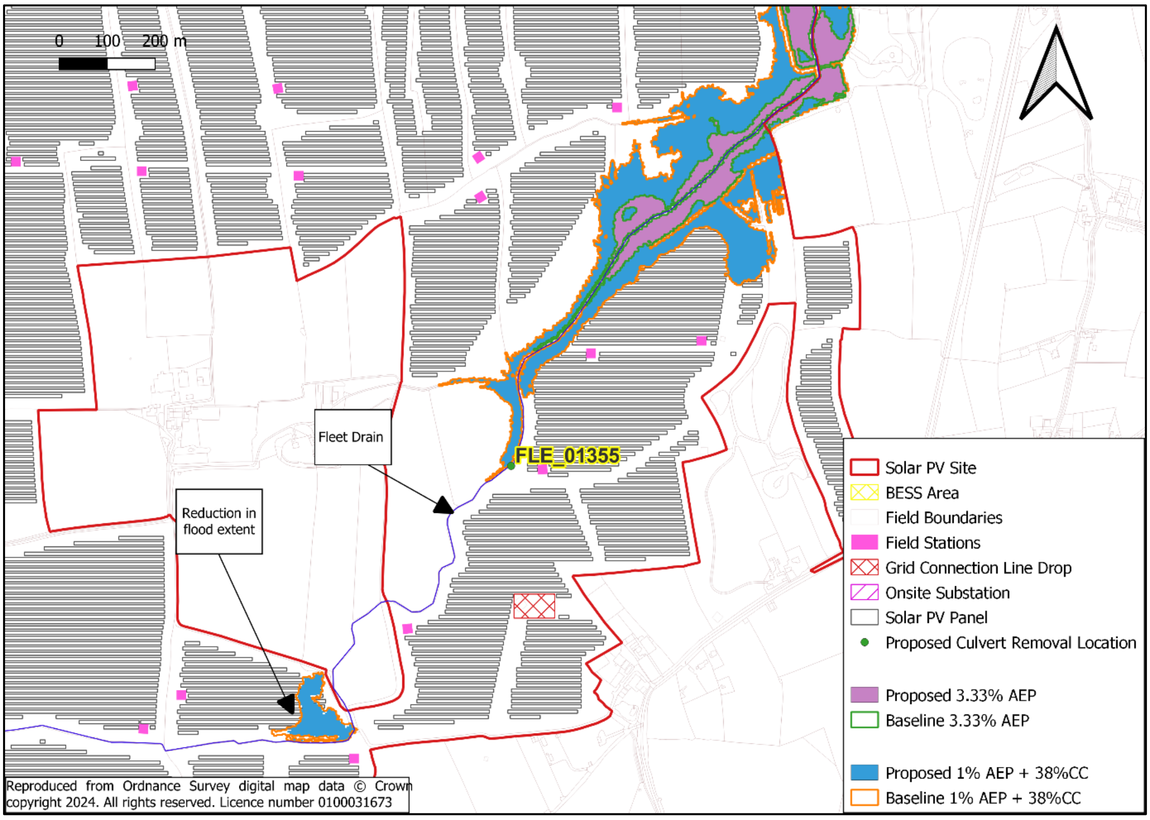


Plate 3-2: Maximum flood extents, proposed vs. baseline

3.5 Conclusions

3.5.1 Hydraulic model results show that the removal of the proposed culvert at NGR 461210, 416282 results in only small localised decreases in maximum water level in the channel upstream of the culvert location and has no detrimental impact on flood risk at the Site or to third parties.

Annex B Sequential Test Report

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Figures

Tables

Executive Summary

ES1 Fenwick Solar Project Limited (the Applicant) has commissioned this Sequential Test Report as part of the Flood Risk Assessment (FRA) in support of its application for a Development Consent Order (DCO Application) for a new solar farm with energy storage facilities at Fenwick (hereafter referred to as 'the Scheme').

ES2 The purpose of this Sequential Test Report is to explain how the Sequential Test has been met by the Applicant in selecting the land for the Scheme. This is focussed on demonstrating that there are no land areas at lower risk of flooding (which are not already part of the Solar PV Site) which would be suitable and reasonably available for inclusion in the Solar PV Site.

ES3 Demonstration of how the Scheme meets the Sequential Test within the Solar PV Site as part of its design and layout is provided in **ES Volume III Appendix 9-3: Flood Risk Assessment [EN010152/APP/6.3]**.

ES4 The Sequential Test Report therefore includes the following sections:

a. Section 2: Policy Context for the Sequential Test - sets out the legislative and planning policy requirements for the application of the Sequential Test and consideration of alternatives.

b. Section 3: Sequential Test Methodology - details the methodology used in the application of the Sequential Test for the Solar PV Site.

c. Section 4: Assessment - sets out the assessment of alternative land areas identified for the Solar PV Site.

d. Section 5: Conclusion – provides a summary of the findings of the Sequential Test.

ES5 In summary, a sequential approach has been applied in selecting the land for the Solar PV Site which has considered the risk of flooding from all sources. The Solar PV Site is located in and around the largest area of identified unconstrained land which is at lowest risk of flooding from all sources. Other areas of land in this location were considered in terms of their flood risk and other suitability factors including land availability, however, it is concluded that these are not suitable and/or reasonably available alternative land areas for the Solar PV Site. The land that is considered available and suitable at lower risk of flooding is within the Solar PV Site. The Applicant has therefore demonstrated the Sequential Test as part of site selection has been met, in accordance with NPS EN-1, the PPG and local policy.

1. Introduction

1.1 Background

1.1.1 Fenwick Solar Project Limited (the Applicant) has commissioned this Sequential Test Report as part of the Flood Risk Assessment (FRA) in support of its application for a Development Consent Order (DCO Application) for a new solar farm with energy storage facilities at Fenwick (hereafter referred to as 'the Scheme').

1.1.2 The Scheme will comprise the construction, operation and maintenance, and decommissioning of a solar photovoltaic (PV) electricity generating facility as well as a Battery Energy Storage System(s) (BESS), an export and import connection to the National Electricity Transmission System (NETS) and associated infrastructure. The Scheme will have a capacity exceeding 50 megawatts (MW).

1.1.3 It is anticipated that the earliest construction would start is in 2028. Operation is anticipated to commence in 2030 and decommissioning 40 years after final commissioning (anticipated to be 2070).

1.1.4 Due to the Scheme's proposed generating capacity being more than 50 MW, it is classified as a nationally significant infrastructure project (NSIP) and will therefore require a DCO under the Planning Act 2008 (PA 2008) (Ref. 1). The decision whether to grant a DCO will be made by the Secretary of State for Energy Security and Net Zero (hereafter referred to as the 'Secretary of State') following an Examination and Recommendation by an Examining Authority appointed by the Planning Inspectorate.

1.1.5 National Policy Statements (NPSs) are planning documents that provide the primary basis for making decisions on DCO applications for NSIPs. The Overarching National Policy Statement for Energy (EN-1) (Ref. 2) came into force on 17 January 2024 and requires that the Sequential Test is applied, and was satisfied, as part of the site selection process (Paragraph 5.8.36).

1.1.6 Paragraph 5.8.21 sets out that "*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 with medium risk areas and then, only where there are no reasonably available sites in low and medium risk areas, within high-risk areas.*"

1.1.7 The Scheme is to be located on land shown on **ES Volume II Figure 1-2: Site Boundary Plan [EN010152/APP/6.2]**. The Scheme is located on 509 hectares (ha) of land comprising the Solar PV Site, Grid Connection Corridor and the existing National Grid Thorpe Marsh Substation, shown on **ES Volume II Figure 1-3: Elements Plan [EN010152/APP/6.2]**. The Scheme is wholly within the administrative area of City of Doncaster Council and is located on land which is predominantly agricultural in nature.

Solar PV Site

1.1.8 **Figure 4-6 Fluvial Flooding within the Solar PV Site (Figure 9-3A-6 [EN010152/APP/6.2])** illustrates the extent of fluvial flooding within and surrounding the Solar PV Site. The west and southwestern parts of the Solar PV Site are within Flood Zone 1 (low risk of flooding). The north and eastern parts of the Solar PV Site are within Flood Zone 2 (medium risk of flooding) and some areas of the Solar PV site are also within Flood Zone 3 (high risk of flooding). There are also small areas of ground water flooding susceptibility (see **Figure 4-7 Groundwater Flooding within the Solar PV Site (Figure 9-3A-7 [EN010152/APP/6.2])**, surface water flood risk (see **Figure 4-8 Pluvial Flooding within the Solar PV Site (Figure 9-3A-8 [EN010152/APP/6.2])** and areas at risk of flooding from reservoirs (see **Figure 4-9 Reservoir Flooding within the Solar PV Site (Figure 9-3A-9 [EN010152/APP/6.2])** within and surrounding the Solar PV Site.

1.1.9 Given this flood risk context, policies set out in NPS EN-1 (Ref. 2), and other relevant policy documents require the Sequential Test to be demonstrated for the Solar PV Site.

Grid Connection Corridor and National Grid Thorpe Marsh Substation

1.1.10 The point of connection (POC) identified and provided to the Applicant by National Grid is at the existing Thorpe Marsh Substation. The existing National Grid Thorpe Marsh Substation and surrounding land in all directions for several km is located in Flood Zone 3 (see **ES Volume II Figure 9-4: Environment Agency Flood Map for Planning (Rivers and Seas) [EN010152/APP/6.2]**). The identification of the Grid Connection Corridor considered the flood risk context and confirmed that a corridor outside Flood Zones 2 and 3 connecting the Solar PV Site to the existing National Grid Thorpe Marsh Substation would not be possible as a result.

1.1.11 The need for a direct route that follows existing linear features, minimises the number of land owners affected, and avoids sensitive receptors, interaction with utilities and environmental designations as far as practicable, are the reasons that the Grid Connection Corridor is routed as proposed.

1.1.12 Therefore, there are no reasonable alternatives within areas of Flood Zone 1 or Flood Zone 2 that avoid Flood Zone 3, and the Sequential Test can therefore be demonstrated to be met for these elements of the Scheme. The location of the Grid Connection Corridor in Flood Zones 2 and 3 will not impact on the operation of the Grid Connection Cables.

1.2 Purpose of this report

1.2.1 The purpose of this Sequential Test Report is to explain how the Sequential Test has been met by the Applicant in selecting the land for the Scheme. As discussed above, this is focussed on demonstrating that there are no land areas at lower risk of flooding (which are not already part of the Solar PV Site) which would be suitable and reasonably available for inclusion in the Solar PV Site.

1.2.2 Demonstration of how the Scheme meets the Sequential Test within the Solar PV Site as part of its design and layout is provided in **ES Volume III Appendix 9-3: Flood Risk Assessment [EN010152/APP/6.3]**.

1.2.3 The Sequential Test Report therefore includes the following sections:

a. Section 2: Policy Context for the Sequential Test - sets out the legislative and planning policy requirements for the application of the Sequential Test and consideration of alternatives.

b. Section 3: Sequential Test Methodology - details the methodology used in the application of the Sequential Test for the Solar PV Site.

c. Section 4: Assessment - sets out the assessment of alternative land areas identified for the Solar PV Site.

d. Section 5: Conclusion – provides a summary of the findings of the Sequential Test.

2. Policy context for the Sequential Test

2.1 What is the Sequential Test and when is it needed?

2.1.1 Section 5.8 of NPS EN-1 (Ref. 2) details the aims of planning policy on development and flood risk; Paragraph 5.8.6 explains this as "*to ensure that flood risk from all sources of flooding is taken into account at all stages in the planning process to avoid inappropriate development in areas at risk of flooding, and to steer new development to areas with the lowest risk of flooding*". In determining the application, the Secretary of State should be satisfied that the Sequential Test was applied and satisfied as part of site selection and that a sequential approach was applied at the site level to minimise risk by directing the most vulnerable uses to the areas of lowest flood risk (Paragraph 5.8.36).

2.1.2 All sources of flooding is not defined by NPS EN-1 (Ref. 2) but is understood to include tidal flooding, fluvial (rivers and streams) flooding, pluvial (surface water) flooding, groundwater flooding, sewer flooding and artificial (reservoir/canal) flooding.

2.1.3 Paragraph 5.8.7 sets out that "*where new energy infrastructure is, exceptionally, necessary in flood risk areas (for example where there are no reasonably available sites in areas at lower risk), policy aims to make it safe for its lifetime without increasing flood risk elsewhere and, where possible, by reducing flood risk overall. It should also be designed and constructed to remain operational in times of flood.*"

2.1.4 Paragraph 5.8.10 of NPS EN-1 (Ref. 2) identifies types of alternative sites which would not usually be considered appropriate including those that are subject to national designations such as landscape, heritage and nature conservation designations including Areas of Outstanding Natural Beauty (now known as 'National Landscapes'), Sites of Special Scientific Interest (SSSIs) and World Heritage Sites (WHS).

2.1.5 Paragraph 5.8.21 of NPS EN-1 (Ref. 2) goes on to state that "*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 with medium risk areas and then, only where there are no reasonably available sites in low and medium risk areas, within high-risk areas.*"

2.1.6 Paragraph 5.8.29 states that "*the sequential approach should be applied to the layout and design of the project. Vulnerable aspects of the development should be located on parts of the site at lower risk and residual risk of flooding. Applicants should seek opportunities to use open space for multiple purposes such as amenity, wildlife habitat and flood storage uses. Opportunities should be taken to lower flood risk by reducing the built footprint of previously developed sites and using SuDS*."

2.1.7 NPS EN-1 (Ref. 2) footnotes the Planning Practice Guidance (PPG) (Ref. 3) flood risk section (Paragraph 023 Reference ID: 7-023-20220825 to Paragraph: 030 Reference ID: 7-030-20220825) which provides guidance explaining how the Sequential Test should be applied. The PPG (Ref. 3) states that the Sequential Test is designed to ensure that areas at little or no risk of flooding from any source are developed in preference to other areas of high risk. It provides that "*even where a flood risk assessment shows the development can be made safe throughout its lifetime…. the sequential test still needs to be satisfied*." (Paragraph: 023 Reference ID: 7-023-20220825).

2.1.8 The PPG (Ref. 3) reiterates that all forms of flood risk (pluvial – surface water, groundwater, sewer and artificial) need to be treated consistently with fluvial (river) and tidal flooding in mapping probability and assessing vulnerability, so the Sequential Test is applied across all areas of flood risk.

2.1.9 Policy 57 of City of Doncaster Local Plan (Ref. 5) reiterates the approach to flood risk, and the Sequential Test set out in NPS EN-1 (Ref. 2). It also echoes the guidance set out in the PPG (Ref. 3) and states that "*all development proposals will be considered against the National Planning Policy Framework (NPPF), including application of the sequential test and, if necessary, the exception test*."

2.2 Consideration of Alternatives

2.2.1 Paragraph 4.3.9 of NPS EN-1 (Ref. 2) does not require alternatives to be considered or to establish whether the proposed project represents the best option from a policy perspective. The consideration of alternatives should be undertaken in a proportionate manner and only consider those alternatives which can meet the objectives of the Scheme (Paragraph 4.3.22 of EN-1 (Ref. 2)). This assessment is not required to prove that the "*proposed project represents the best option*" (Paragraph 4.3.9 of EN-1 (Ref. 2)) compared to alternatives but that alternatives have been considered where relevant, which in this case is with regard to flood risk. Further details on the alternatives assessed for the Scheme are set out in **ES Volume I Chapter 3: Alternatives and Design Evolution [EN010152/APP/6.1]**.

2.2.2 Applicants are obliged to include information about the main alternatives that have been studied within the Environmental Statement (ES). This should include reasons for the Applicant's choice considering environmental, social and economic effects and, where relevant, any technical and/or commercial feasibility (Paragraph 4.3.15 of EN-1 (Ref. 2)).

2.2.3 NPS EN-1 (Ref. 2) also explains that there may be a specific policy requirement to consider alternatives such as the application of the Sequential Test for Schemes located in areas at risk of flooding as stated in Paragraph 4.3.17 of EN-1 (Ref. 2), "*where there is a policy or legal requirement to consider alternatives, the applicant should describe the alternatives considered in compliance with these requirements*."

2.2.4 NPS EN-1 (Ref. 2) Paragraphs 4.3.21 to 4.3.27 explain the weight to be given to alternatives in the Secretary of State's decision which includes, but is not limited to, the following:

a. Consideration of alternatives to comply with policy requirements should be proportionate.

b. Whether there is a realistic prospect of the alternative delivering the same capacity and at the same timescale.

c. If legislation proposes a target, permission should not be refused on one site simply because fewer adverse effects would result from developing similar infrastructure on another suitable site and it should have regard as appropriate to the possibility that all suitable sites for energy infrastructure of the type proposed may be needed for future proposals.

d. Alternatives that are not among the main alternatives should only be considered if relevant and important to the decision making.

e. Alternatives must be in accordance with relevant NPS policy.

f. Alternative proposals that mean the necessary development could not proceed due to commercial viability or physical suitability can be excluded as not relevant and important to the decision maker.

g. Alternative proposals which are vague or inchoate should be excluded.

2.2.5 Policy 57 of City of Doncaster Local Plan (Ref. 5) states that "*all windfall development proposals outside of Development Allocations in Flood Zones 2 and 3a will… normally require a borough-wide area of search unless a case can be made to narrow the search area due to certain locational needs of the development or specific catchment requirements*".

3. Sequential Test methodology

3.1 Introduction

3.1.1 As there is no standard methodology for the consideration of reasonably available alternative sites for solar energy developments, the Applicant's approach to the Sequential Test has been informed by the policy and guidance documents set out in Section 2 of this report and the Applicant's approach to selecting land for solar PV development.

3.1.2 The following approach has been undertaken to identify and consider whether there is any reasonably available land at lower risk of flooding which could be considered suitable for inclusion within the Solar PV Site. Where this is not possible, the methodology allows for the identification and consideration of reasonably available sites within areas at medium risk of flooding, and subsequently areas at high risk of flooding. This approach confirms that the Sequential Test can be demonstrated for the selection of land for the Solar PV Site.

3.2 Identifying a Point of Connection with network capacity

3.2.1 Proximity to an available grid connection with appropriate capacity is fundamental to the viability and deliverability of large-scale solar development. This is recognised at Paragraph 2.10.24 of NPS EN-3 (Ref. 7) which states: *"…the connection voltage, availability of network capacity, and the distance from the solar farm to the existing network can have a significant effect on the commercial feasibility of a development proposal."*

3.2.2 The point of connection (POC) identified and provided to the Applicant by National Grid is at the Existing National Grid Thorpe Marsh Substation. The Applicant subsequently secured a POC. Land in proximity to this POC has therefore been considered.

3.3 Identifying potentially suitable land for a Solar PV Site

3.3.1 This section explains the Applicant's consideration of planning and environmental opportunities and constraints to identify suitable land for a Solar PV Site.

Agricultural land quality

NPS EN-3 (Ref. 7) at Paragraph 2.10.29 states that: *"Where the proposed use of any agricultural land has been shown to be necessary, poorer quality land should be preferred to higher quality land avoiding the use of "Best and Most Versatile" agricultural land where possible. Best and Most Versatile agricultural land is defined as land in grades 1, 2 and 3a of the Agricultural Land Classification".*

3.3.2 In identifying areas that could be suitable for a Solar PV Site the Applicant identified locations that would avoid Best and Most Versatile (BMV) agricultural land. To identify these locations the Applicant used provisional Agricultural Land Classification (ALC) mapping published by Natural England

(Ref. 10). This allowed the identification of areas of land that comprised of non-BMV land (Grade 4, Grade 5 and non-agricultural land) within City of Doncaster Council's administrative area.

Brownfield land

Whilst Agricultural Land Classification (ALC) mapping does contain a layer for 'non-agricultural uses', it was considered appropriate to review the availability of brownfield land using local data. This is in the context of NPS EN-3 (Ref. 7) at Paragraph 3.10.14 stating that: *"While land type should not be a predominating factor in determining the suitability of the site location applicants should, where possible, utilise previously developed land, brownfield land, contaminated land and industrial land'.*

3.3.3 The Applicant therefore considered the availability of brownfield land in City of Doncaster's administrative area (Ref. 8).

Application of planning and environmental constraints (including all sources of flood risk)

3.3.4 The potentially suitable land identified through consideration of agricultural land quality and brownfield sites has been considered against planning and environmental constraints (set out in **Table 3-1 Planning and environmental constraints considered**). Regarding the available flood risk information, the Applicant has considered all sources of flooding for which there is publicly available data which includes surface water flooding, fluvial flooding, groundwater flooding and reservoir flooding.

Table 3-1 Planning and environmental constraints considered

Constraint	Policy justification for considering this as a constraint
Flood Risk	Paragraph 5.8.21 of NPS EN-1 (Ref. 2) requires 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. Fluvial flood risk has been considered at this stage. Areas at highest risk of fluvial flooding (Flood Zones 2 and 3) have been avoided. Surface water flooding, groundwater flooding and reservoir flooding have also been considered. It is noted that Annex 3 of the NPPF (Ref. 9) states that solar farms are essential infrastructure, which is compatible with land in Flood Zones 1, 2, 3a and 3b (the latter two require the Exception Test to be satisfied).
Green belt	The purpose of the green belt is to prevent urban sprawl by keeping land permanently open. As set out in NPS EN-1 (Ref. 2) there is a general presumption against inappropriate development within areas of green belt and inappropriate development should not be approved except in very special circumstances. Paragraph 5.11.38 of NPS EN-1 (Ref. 2) sets out that Local Green Spaces enjoy the same protection as Green Belt in England.

Constraint	Policy justification for considering this as a constraint
Internationally designated biodiversity sites	Section 5.4 of NPS EN-1 (Ref. 2) explains that the most important sites for biodiversity are those which are identified in international conventions and European directives. These designated sites are therefore given the highest protection in planning policy and where possible development should ensure the conservation and enhancement of them.
Nationally designated biodiversity sites	Paragraph 5.4.7 of NPS EN-1 (Ref. 2) recognises that many SSSIs are also designated as sites of international importance and are to be protected accordingly. Those that are not, or those features of SSSIs not covered by an international designation, are to be given a high degree of protection. Most National Nature Reserves are notified as SSSIs. Paragraph 5.8.10 of NPS EN-1 (Ref. 2) states that SSSIs would not normally be considered appropriate locations for development.
National landscape designations	Paragraph 5.8.10 of NPS EN-1 (Ref. 2) states that Areas of Outstanding Natural Beauty (AONBs)… would not usually be considered appropriate for solar development. Paragraph 5.10.7 of NPS EN-1 (Ref. 2) highlights that the government has confirmed that National Parks, the Broads and AONBs have the highest status of protection in relation to landscape and natural beauty.
Designated Heritage Assets	Section 5.9 of NPS EN-1 (Ref. 2) considers the historic environment and details various classifications of heritage assets. The Secretary of State is required to give great weight to the conservation of designated heritage assets, the more important the asset, the greater the weight should be (Paragraph 5.9.27) and should also give considerable importance and weight to the desirability of preserving all heritage assets. Harm can be caused to the significance of an asset not just through its loss, but also through harm to its setting.
Woodland	Ancient woodland and veteran trees are identified as valuable biodiversity resources. Areas of woodland also provide a habitat resource for biodiversity and should therefore be retained where possible. Paragraph 5.4.53 of NPS EN-1 (Ref. 2) sets out that development consent should not be granted for any development that would result in the loss or deterioration of any irreplaceable habitats, including ancient woodland, and ancient and veteran trees unless there are wholly exceptional reasons, and a suitable compensation strategy exists.

3.4 Assessing land considered at low risk of flooding from all sources and land which is in fluvial Flood Zone 2 and at risk of flooding from other sources

Land use conflicts

3.4.1 The Applicant considered the current land use and the extent of the land areas identified following the application of planning and environmental constraints to confirm whether there were any reasonably available at a low risk of flooding from all sources.

Further assessment of land areas

3.4.2 The Applicant focussed their search for a suitable solar PV site on an area of unconstrained land which has limited land use conflicts.

3.4.3 The Applicant undertook a process of further assessment of the land area at low risk of flooding from all sources against key suitability factors such as land use, proximity to residential properties and other land use consideration, interaction with PRoW, as well as accessibility and also land availability. This was also applied to land adjacent to land at the lowest risk of flooding which is in fluvial flood zone 2 and at risk of flooding from other sources.

3.4.4 In terms of availability, the Applicant undertook a process of establishing land availability by identifying landowners willing for their land to be used for the Scheme in this area. This process also considered whether the land had landholdings with minimal landownership to minimise the number of landowners affected by the Scheme; and the Applicant sought to avoid unregistered land due to uncertainty of ownership.

3.4.5 Minimising the number of landowners affected by the Scheme and identifying opportunities for necessary land rights to be acquired voluntarily have been key requirements of the Applicant's approach to the selection of the Solar PV Site.

4. Assessment

4.1 Identifying a Point of Connection with Network Capacity

4.1.1 The Applicant was aware of the legacy of coal fired power stations in the Yorkshire region and undertook a search of available capacity within this area. This was in the context that many coal fired power stations were being dismantled which would free up connection to the NETS. Following discussions with National Grid, National Grid identified and provided a POC to the Applicant at the Existing National Grid Thorpe Marsh Substation. The Applicant subsequently secured this POC. The POC is shown on **Point of Connection (Figure 9-3A-1 [EN010152/APP/6.2])**

4.1.2 The Applicant considered the compatibility of the POC and surrounding land with Solar PV and BESS technology. This mainly considered land within City of Doncaster Council's administrative area (owing to the central location of the POC in that area). Technical considerations focussed on irradiation levels from the sun and topography which are key factors in identifying suitable locations for solar development as identified in NPS EN-3, Paragraph 2.10.19 (Ref. 7). Topography is an important consideration because large scale solar development on flat land helps to reduce visual intrusion and assists the screening of Solar PV Panels due to the land not being elevated. Flat land also limits the shading between Solar PV Panels and allows for easy construction of solar developments. The Applicant found that the areas surrounding the POC had good levels of irradiation and comprised of mainly flat topography.

4.1.3 As shown in **ES Volume II Figure 10-4: Topography [EN010152/APP/6.2]**, the Solar PV Site is located within low-lying land with a relatively flat landscape thereby being suitable for large-scale solar development.

4.1.4 The availability of the POC, together with good levels of irradiation and surrounding flat topography, illustrates this area's suitability for the delivery of critical national priority infrastructure.

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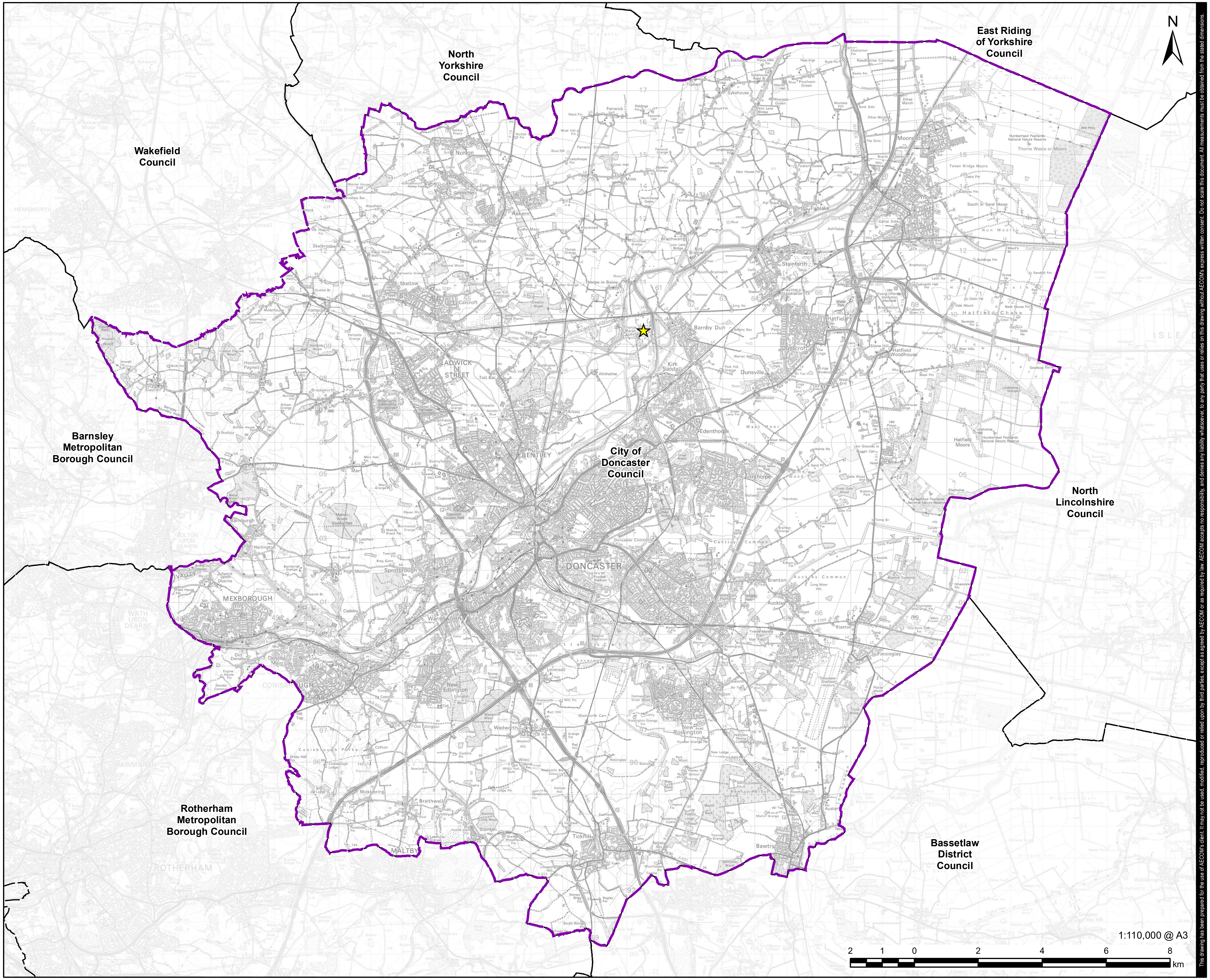

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LEGEND

- Doncaster Local Authority Boundary
- Other Local Authority Boundary
- Point of Connection (Thorpe Marsh Substation)

NOTES

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ISSUE PURPOSE

Sequential Test Report

PROJECT NUMBER

60698207

FIGURE TITLE

Point of Connection

FIGURE NUMBER

Figure 9-3A-1

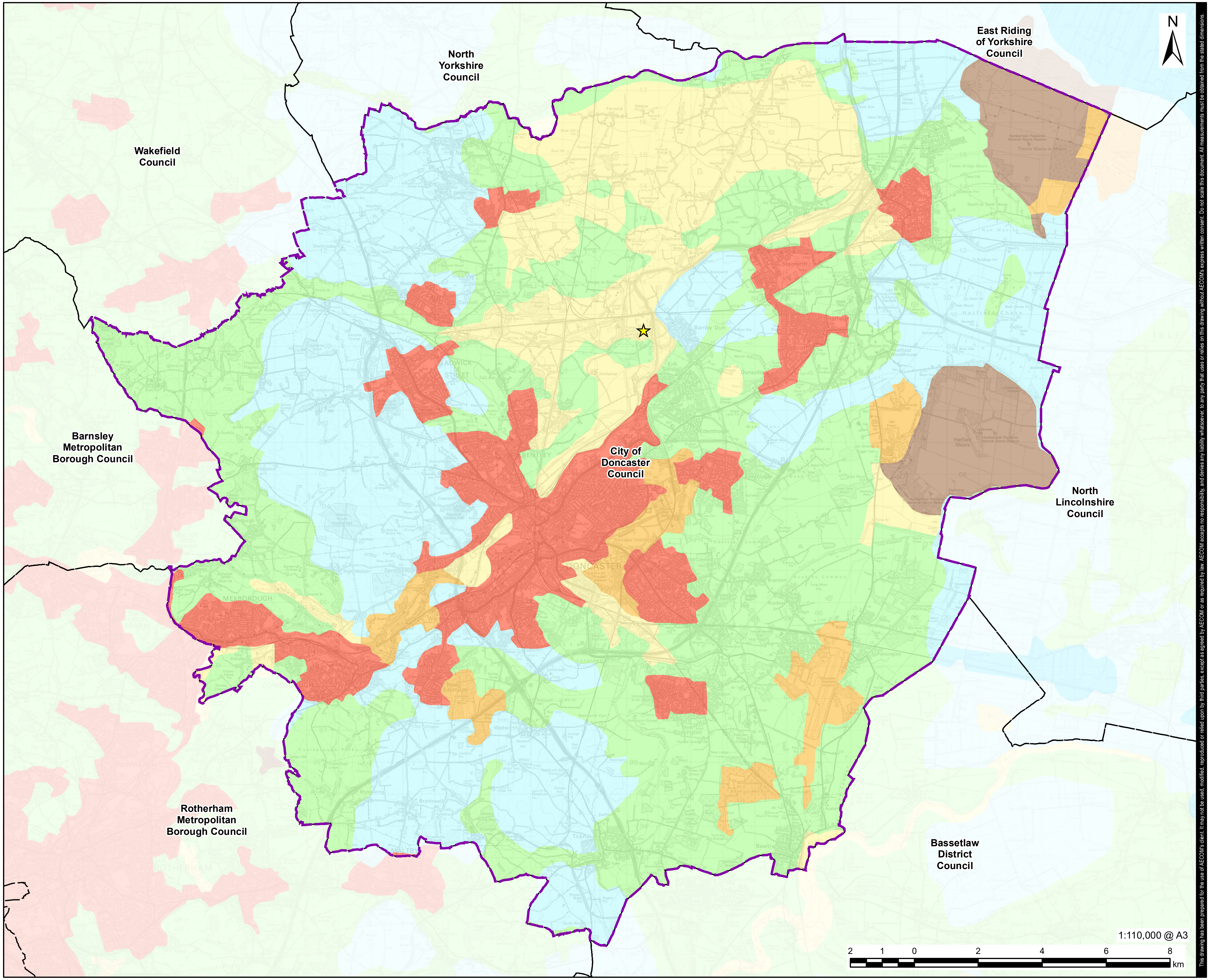
4.2 Identifying potentially suitable land for a solar PV site

Agricultural land quality

4.2.1 In accordance with Paragraph 2.10.29 of NPS EN-3 (Ref. 7) the Applicant has sought to avoid BMV agricultural land and identify potential land areas of ALC grade 4, grade 5 and non-agricultural land.

4.2.2 The ALC classification of the land within the administrative area of City of Doncaster is identified on **Agricultural Land Classification (Figure 9-3A-2 [EN010152/APP/6.2])** which shows the provisional ALC mapping published by Natural England (Ref. 10). The result of excluding BMV agricultural land in accordance with NPS EN-3 (Ref. 7) is shown on

4.2.3 **Figure 4-3 Exclusion of Best and Most Versatile agricultural land (Figure 9-3A-3 [EN010152/APP/6.2]**).



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LEGEND

- Doncaster Local Authority Boundary
- Other Local Authority Boundary
- Point of Connection (Thorpe Marsh Substation)

Agricultural Land Classification (ALC)

- Grade 1
- Grade 2
- Grade 3
- Grade 4
- Grade 5
- Non Agricultural
- Urban

NOTES

ISSUE PURPOSE

Sequential Test

PROJECT NUMBER

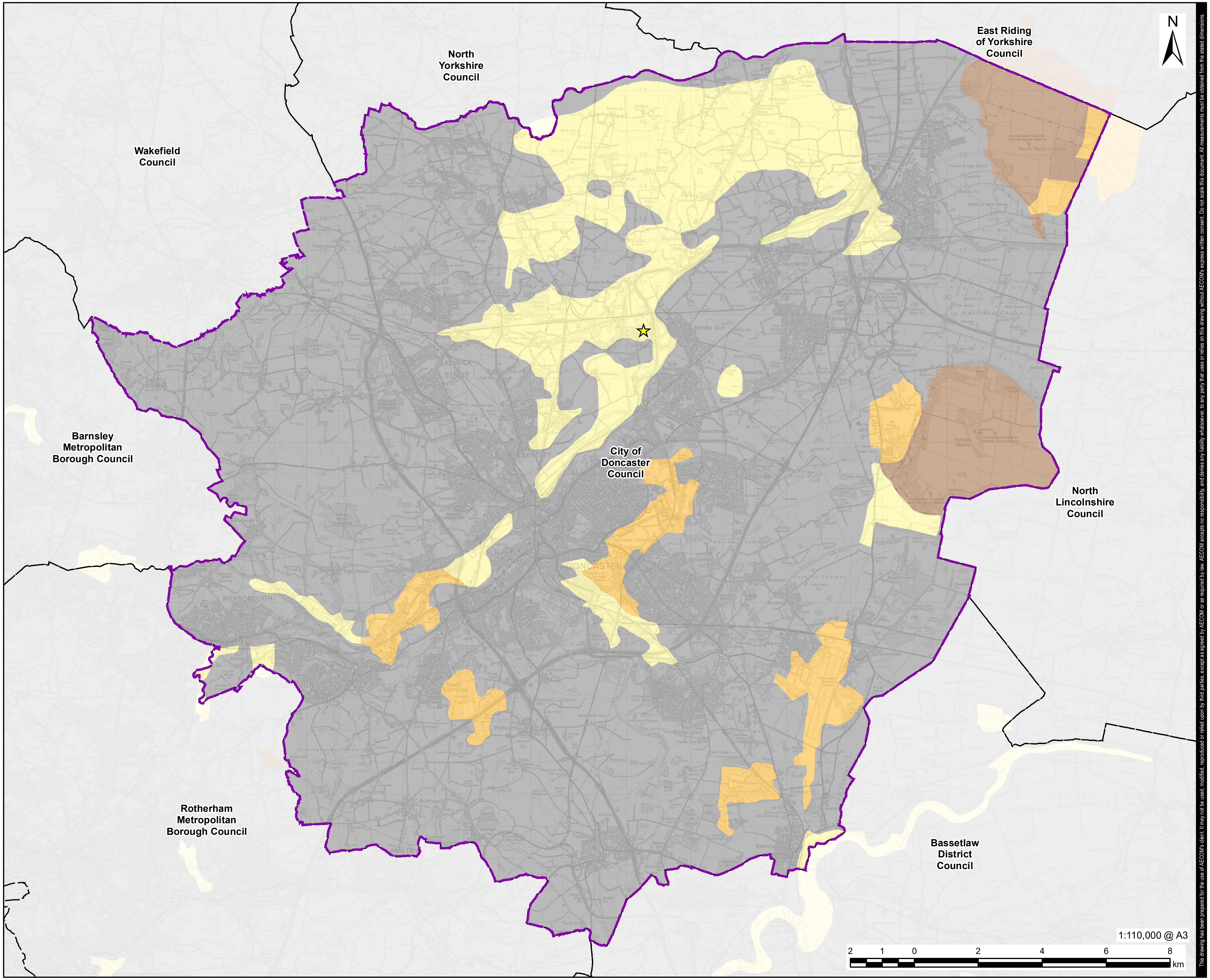
60698207

FIGURE TITLE

Agricultural Land Classification

FIGURE NUMBER

Figure 9-3A-2



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LEGEND

- Doncaster Local Authority Boundary
- Other Local Authority Boundary
- Point of Connection (Thorpe Marsh Substation)
- Constrained Land

Agricultural Land Classification (ALC)

- Grade 4
- Grade 5
- Non Agricultural

NOTES

ISSUE PURPOSE

Sequential Test

PROJECT NUMBER

60698207

FIGURE TITLE

Exclusion of Best and Most Versatile Agricultural Land

FIGURE NUMBER

Figure 9-3A--3

Brownfield land

4.2.4 The Applicant has also considered the availability of brownfield land through reference to the brownfield land register for the administrative area of City of Doncaster. The largest sites within are listed below and, where stated, are allocated in the Doncaster Local Plan (Ref. 8):

a. Former Rossington Colliery, West End Lane, New Rossington (65.8 ha). The site is allocated in the Local Plan (ref. ROS01 and ROS02), planning permissions are in place and the site is being developed for largely residential uses.

b. Former McCormick Tractors International, Wheatley Hall Road, Wheatley, Doncaster, DN2 4PG (41.1 ha). The site is allocated in the Local Plan (ref. MIX01), planning permissions are in place and the site is being developed for largely residential uses.

c. Eden Grove, Hexthorpe, Doncaster, DN4 0DA (21.3 ha). The site is allocated in the Local Plan (ref. MUA07), planning permissions are in place and the site is being developed for largely residential uses.

d. Former Yorkshire Main Colliery, Broomhouse Lane, Balby (17.6 ha). The site is allocated in the Local Plan (ref. EDL03) and planning permissions are in place for largely residential uses.

e. Askern Saw Mills, High Street, Askern (15.04 ha). The site is allocated in the Local Plan (ref. MIX04) and planning permissions are in place for mixed uses.

f. Former Brodsworth Colliery Site, Long Lands Lane, Adwick Le Street (13.04 ha). The site is allocated in the Local Plan (ref. ADW03), planning permissions are in place and the site is being developed for largely residential uses.

g. Waterdale, Doncaster (12.20 ha). The city centre site is allocated in the Local Plan (ref. MIX02), various planning permissions in place and developments underway for a variety of uses.

4.2.5 The above assessment confirms that if the Scheme was to use the above brownfield sites this would compete or be in conflict with local planning policy seeking to deliver housing and mixed-use developments. The majority of the sites also have extant planning permissions for such uses. In addition, whilst not located on the brownfield land register, land surrounding the POC at the Existing National Grid Thorpe Marsh Substation, which was part of the former Thorpe Marsh Power Station, is being developed for another energy project and is therefore not available. It was concluded that there was no suitable or available brownfield land for the Solar PV Site.

Planning and environmental constraints

4.2.6 In accordance with the methodology described in Section 3, planning and environmental constraints have been considered by the Applicant to identify potentially suitable areas for a Solar PV Site.

4.2.7 The Applicant has sought to avoid land impacted by the planning and/or environmental constraints identified in **Planning, Environmental, and Land Use Constraints (Figure 9-3A-4 [EN010152/APP/6.2])** which included areas of Flood Zone 2 and Flood Zone 3, and other sources of flooding as explained in **Table 3-1 Planning and environmental constraints considered**.

4.2.8 Through the mapping of planning and environmental constraints five parcels of land have been identified as shown in white on **Planning, Environmental, and Land Use Constraints (Figure 9-3A-4 [EN010152/APP/6.2])**:

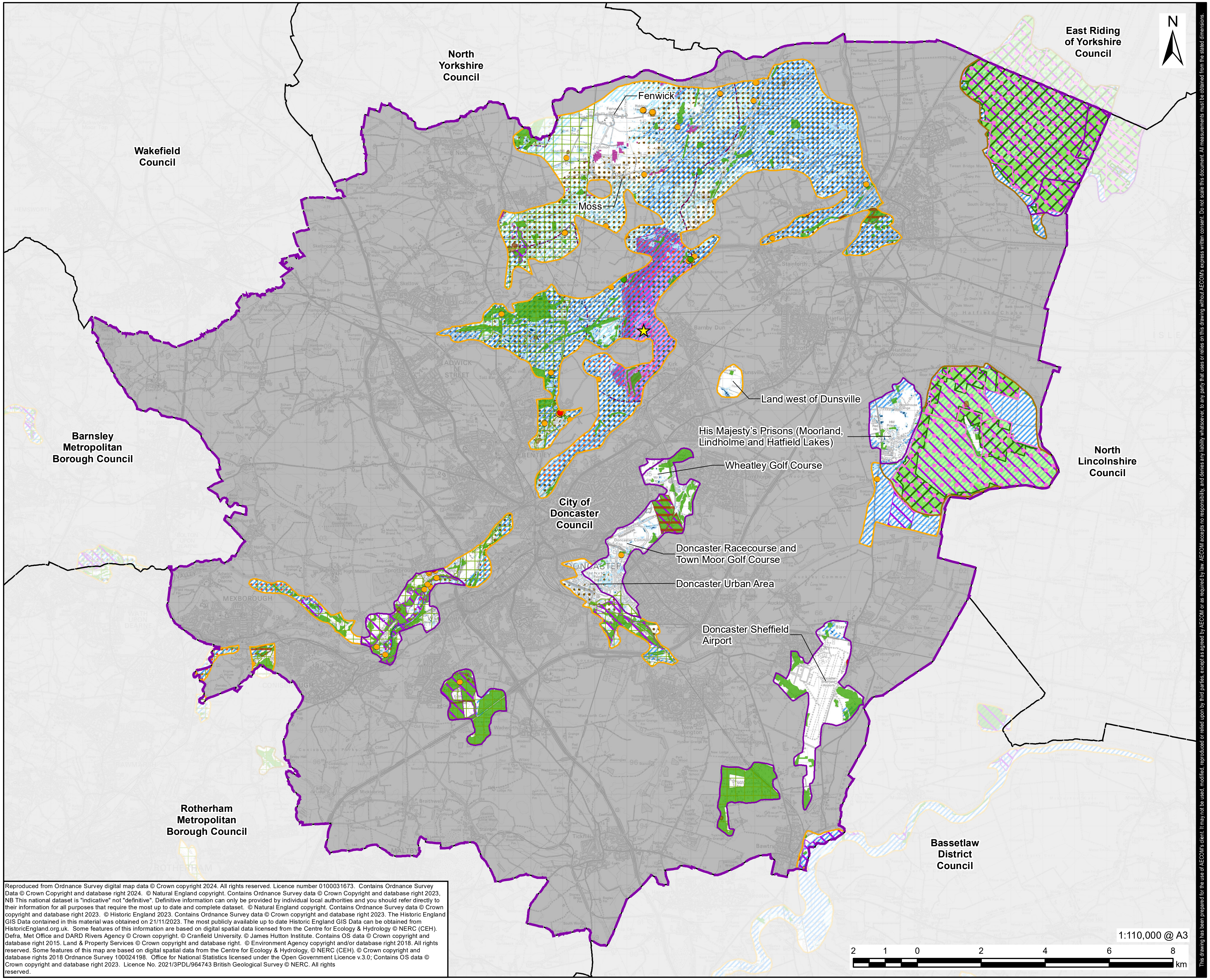
a. Land 5 km north of the POC;

b. Land immediately southeast of the City of Doncaster;

c. Land approximately 12 km southeast of the City of Doncaster;

d. Land 8 km southeast of the POC; and

e. Land 3 km southeast of the POC.



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LEGEND

- Doncaster Local Authority Boundary
- Other Local Authority Boundary
- Point of Connection (Thorpe Marsh Substation)
- Constrained Land

Agricultural Land Classification (ALC)

- Grade 4
- Grade 5
- Non Agricultural

Environmental, Planning, and Heritage Constraints

- Listed Building - Grade I
- Listed Building - Grade II*
- Listed Building - Grade II
- Conservation Area
- Scheduled Monument
- Green Belt
- Local Nature Reserve (LNR)
- National Nature Reserve (NNR)
- Ramsar
- Special Protection Area (SPA)
- Site of Special Scientific Interest (SSSI)
- Special Area of Conservation (SAC)
- National Forest Inventory

Pluvial Flood Risk

- 3.33% Annual Exceedance Probability
- 1% Annual Exceedance Probability
- 0.1% Annual Exceedance Probability

Fluvial Flood Risk

- Flood Zone 3
- Flood Zone 2

Groundwater Flood Risk

- Limited Potential for Groundwater Flooding to Occur
- Potential for Groundwater Flooding of Property Situated Below Ground Level
- Potential for Groundwater Flooding to Occur at Surface
- Extent of Groundwater Flooding Data

Reservoir Flood Risk

- Risk of Flooding from Reservoirs When River Levels are Normal (Dry Day)
- Risk of Flooding from Reservoirs When There is Also Flooding from Rivers (Wet Day)

PROJECT NUMBER

60698207

ISSUE PURPOSE

Sequential Test

FIGURE TITLE

Planning, Environmental, and Land Use Constraints

FIGURE NUMBER

Figure 9-3A-4

4.3 Assessing land considered to be at low risk of flooding from all sources and land within Flood Zone 2 and at risk of flooding from all other sources

Land use constraints

4.3.1 Pursuant to the identification of these five parcels of land, the Applicant has explored whether there was any land use constraints that would render a parcel unsuitable.

4.3.2 Land 5 km north of the POC – predominantly agricultural land with limited land use conflicts.

4.3.3 Land immediately southeast of the City of Doncaster – this area has a number of land use conflicts. The southern portion of the area is occupied by the Doncaster built up urban areas. The middle portion is occupied by Doncaster racecourse (with the central part of the racecourse occupied by Town Moor golf course). The northern portion is occupied by three schools, Doncaster Knights rugby club and Wheatley golf course.

4.3.4 Land approximately 12 km southeast of the City of Doncaster – this area is occupied by Doncaster Sheffield Airport which, owing to operational airfield limitations, is a conflicting land use.

4.3.5 Land 8 km southeast of the POC – the southern portion of this area is the built-up area of Moorland, Lindholme and Hatfield Lakes Prisons which is a conflicting land use. Further, the northern portion of this area is being developed by another solar farm developer (an EIA screening decision was issued for the solar farm under City of Doncaster planning reference 21/03685/SCRE) and therefore this land is not available.

4.3.6 Land 3 km southeast of the POC – an area of ALC Grade 4 agricultural land which extends to approximately 3.5 ha (or approximately 2.8 ha when restricted to the two main field parcels) was considered to be of insufficient scale to accommodate the Solar PV Site.

4.3.7 Therefore, the Applicant has concentrated the search for the Solar PV Site in the area of unconstrained land 5 km north of the POC, land near to Fenwick and Moss. This area is within Flood Zone 1 (low risk of fluvial flooding) and free from other sources of flooding including groundwater, reservoir and surface water sources.

Further assessment of land areas

4.3.8 As previously stated, the Applicant has focussed their search for a suitable solar PV site on the largest extent of unconstrained land (which is land at the lowest risk of flooding from all sources and avoids the stated planning and environmental constraints) which is the land 5 km to the north of the POC.

4.3.9 The Applicant considered the land within this area against key suitability factors outlined in the methodology namely: land use, proximity to residential properties and other land use considerations, interaction with PRoW, as well as accessibility and also land availability.

4.3.10 In terms of availability, the Applicant undertook a process of establishing land availability by identifying landowners willing for their land to be used for the Solar PV Site. This process also considered whether the land had landholdings with minimal landownership to minimise the number of landowners affected by the Scheme; and the Applicant sought to avoid unregistered land due to uncertainty of ownership.

4.3.11 Minimising the number of landowners affected by the Scheme and identifying opportunities for necessary land rights to be acquired voluntarily have been key requirements of the Applicant's approach to the selection of the Solar PV Site.

4.3.12 The land areas discounted for inclusion within the Solar PV Site are shown on **Figure 4-5 Selection of the Solar PV Site and Flood Risk (Figure 9-3A-5 [EN010152/APP/6.2])** and documented in **Table 4-1 Assessment of areas not selected for the Solar PV Site**.

4.3.13 The Applicant concluded that there was insufficient land that was within Flood Zone 1 and free from other sources of flooding which was otherwise suitable and available to accommodate the generating capacity of the Scheme proposed. Further, only selecting land within Flood Zone 1 which was also free from other sources of flooding would have led to the dissection of many fields which was not possible for agreements with landowners.

4.3.14 Therefore, the Applicant has considered land within Flood Zone 2 that adjoined land within Flood Zone 1 (see **Figure 4-6 Fluvial Flooding within the Solar PV Site (Figure 9-3A-6 [EN010152/APP/6.2])**). At the same time the Applicant also considered land at risk of groundwater flooding (see **Figure 4-7 Groundwater Flooding within the Solar PV Site (Figure 9-3A-7 [EN010152/APP/6.2])**), pluvial flooding (see **Figure 4-8 Pluvial Flooding within the Solar PV Site (Figure 9-3A-8 [EN010152/APP/6.2])**), and reservoir flooding (see **Figure 4-9 Reservoir Flooding within the Solar PV Site (Figure 9-3A-9 [EN010152/APP/6.2])**).

4.3.15 The presence of these sources of flood risk was considered insignificant as a differentiator of suitability for the Solar PV Site given the limited presence, and associated risk, of these types of flooding and, therefore, the risk to the Scheme was considered to be limited.

4.3.16 The land areas discounted for inclusion within the Solar PV Site are shown on **Figure 4-5 Selection of the Solar PV Site and Flood Risk (Figure 9-3A-5 [EN010152/APP/6.2])** and documented in **Table 4-1 Assessment of areas not selected for the Solar PV Site**.

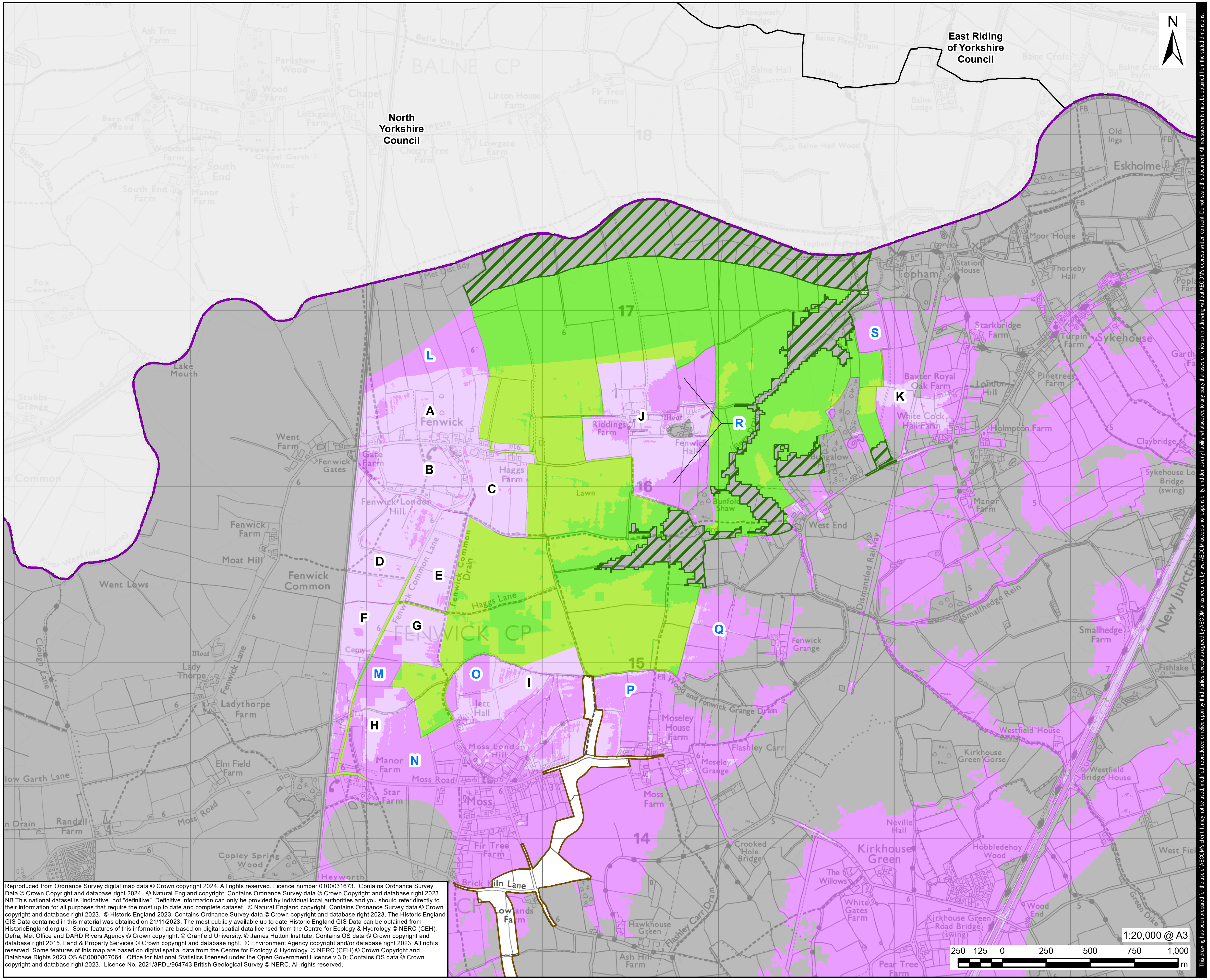
4.3.17 Through the process of negotiating land agreements for the land at lower risk of flooding, the Applicant has been required to include land within the Solar PV Site that was within Flood Zone 3 where it was also within the same landownership/field as land within the Solar PV Site. This has been to avoid land becoming inaccessible and being unable to continue in agricultural use due its severance as a result of the Scheme.

4.3.18 This has meant the northernmost extent of land has been included within the Solar PV Site. This is identified as BMV on the ALC mapping (see **Agricultural Land Classification (Figure 9-3A-2 [EN010152/APP/6.2])**) and is also in Flood Zones 2 and 3 (see **Figure 4-6 Fluvial Flooding within the Solar PV Site (Figure 9-3A-6 [EN010152/APP/6.2])**).

4.3.19 The above process led to the identification of the boundary shown on **ES Volume II Figure 3-5: EIA Scoping and Non-Statutory Consultation Boundary [EN010152/APP/6.2]** which included land adjacent in Flood

Zones 2 and 3 to the northeast, east and southeast of Fenwick due to the lack of available land within Flood Zone 1 of a sufficient scale to accommodate the Solar PV Site.

4.3.20 Following non-statutory consultation, the land within the Solar PV Site was extended to the south in response to feedback from landowners who had not previously engaged with the Scheme; see **ES Volume II Figure 3-6: Site Boundary for Statutory Consultation [EN010152/APP/6.2]**. The vast majority of the additional land included within the Solar PV Site was located within Flood Zone 1. Two areas of land within Flood Zone 2 were also included, however, both of these areas are minor parts of fields that are otherwise within Flood Zone 1, and they were included to ensure that landowners weren't left with fragmented pieces of land that are unable to continue in agricultural use due their severance as a result of the Scheme.



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LEGEND

- Doncaster Local Authority Boundary
- Other Local Authority Boundary
- Land Selected for the Solar PV Site which is at the Lowest Risk of Flooding from All Sources
- Land Selected for the Solar PV Site which is in Fluvial Flood Zone 2 and at Risk of Flooding from Other Sources
- Land Included within the Solar PV Site for Land Availability Reasons
- Land Not Selected for the Solar PV Site which is at the Lowest Risk of Flooding from All Sources
- Land Not Selected for the Solar PV Site which is in Fluvial Flood Zone 2 and at Risk of Flooding from Other Sources
- Land Selected for the Grid Connection Corridor

ISSUE PURPOSE

Sequential Test

PROJECT NUMBER

60698207

FIGURE TITLE

Selection of the Solar PV Site and Flood Risk

FIGURE NUMBER

Figure 9-3A-5

Table 4-1 Assessment of areas not selected for the Solar PV Site

Land area reference	Size (Ha) and location	Risk of flooding (from all sources)	Relationship with land at lower risk of flooding within the Solar PV Site	Interaction with Public Right(s) of Way	Proximity to residential properties/other land use conflicts	Accessibility	Availability	Conclusion
A	Approximately 56 ha of land located to the north and northwest of Fenwick.	Low risk of flooding from all sources.	Adjoins land included within the Solar PV Site that is at low risk of flooding from all sources.	A footpath (Fenwick-7) runs through the western part of this land in a north-south direction.	The southern end of this land area adjoins properties in the village of Fenwick. The Applicant was seeking to reduce impacts on the settlement of Fenwick and Moss with reference to visual impact.	Accessible via Fenwick Lane	The Applicant considered this land to be unavailable.	The Applicant considered this land area neither suitable nor reasonably available.
B	Approximately 10 ha of agricultural land located to the south of Fenwick Lane, east and north of Shaw Lane and west of Fenwick Common Lane.	Low risk of flooding from all sources.	Remote from land included within the Solar PV Site that is at low risk of flooding from all sources.	A footpath (Fenwick-8) runs through the centre of this land in a north-south direction.	There are residential properties to the north, south and west of this land area within Fenwick. The Applicant was seeking to reduce impacts on the settlement of Fenwick and Moss with reference to visual impact.	Accessible via Fenwick Lane and Shaw Lane.	The Applicant considered this land to be unavailable.	The Applicant considered this land area neither suitable nor reasonably available.
C	Approximately 8 ha of agricultural land located to the east of Fenwick Common Lane and south of Lawn Lane.	Low risk of flooding from all sources.	Adjoins land included within the Solar PV Site that is at low risk of flooding from all sources.	Footpath (Fenwick-10) runs along the southern extent of this land area in an east-west direction. Footpath (Fenwick-11) crosses the western end of the land area in a north-south direction.	There are residential properties to the north and west of this land area within Fenwick. The Applicant was seeking to reduce impacts on the settlement of Fenwick and Moss with reference to visual impact.	Accessible via Fenwick Common Lane.	Some of the land within this land area is owned by a landowner with land selected for the Solar PV Site, the landowner has confirmed to the Applicant that their land within land area C is not available for inclusion for the Solar PV Site. The Applicant considered the remainder of the land within this land area unavailable.	The Applicant considered this land area neither suitable nor reasonably available.
D	Approximately 22 ha of agricultural land located to the south of Fenwick Lane and Shaw Lane and west of Fenwick Common Lane.	Low risk of flooding from all sources.	Remote from land included within the Solar PV Site that is at low risk of flooding from all sources.	Footpath (Fenwick-4) crosses the centre of this land area in a north-south direction. Footpath (Fenwick-3) crosses the centre of this land area in a	There are residential properties fronting Shaw Lane within Fenwick. The Applicant was seeking to reduce impacts on the settlement of Fenwick and Moss with reference to visual impact.	Accessible via Fenwick Common Lane.	The Applicant considered this land to be unavailable.	The Applicant considered this land area neither suitable nor reasonably available.

Land area reference	Size (Ha) and location	Risk of flooding (from all sources)	Relationship with land at lower risk of flooding within the Solar PV Site	Interaction with Public Right(s) of Way	Proximity to residential properties/other land use conflicts	Accessibility	Availability	Conclusion
				broadly east-west direction.				
E	Approximately 11 ha of agricultural land located to the east of Fenwick Common Lane.	Low risk of flooding from all sources.	Adjoins land included within the Solar PV Site that is at low risk of flooding from all sources.	Footpath (Fenwick-10) runs along the northern boundary of the land area. Footpath (Fenwick-11) runs along the eastern boundary of the land area. Footpath (Fenwick-16) runs along the southern boundary of the land area.	Not adjacent to any residential properties. However, the Applicant considered that it is adjacent to Fenwick Common Lane which is the approach to the village of Fenwick and could therefore be visible by users of Fenwick Common Lane.	Accessible via Fenwick Common Lane.	The Applicant considered the northern end of this land area (two fields) was unavailable. Some of this land area was available at one point (southernmost field). However, the Applicant determined that to reduce the number landowners involved in the Scheme, the land was not required for the Solar PV Site.	The Applicant considered this land area unsuitable. Further, the Applicant considered part of the land area was not reasonably available and the remainder was not required for the Solar PV Site (to reduce the number of landowners affected by the Scheme).
F	Approximately 7 ha of agricultural land located to the west of Fenwick Common Lane.	Low risk of flooding from all sources.	Remote from land included within the Solar PV Site that is at low risk of flooding from all sources and also severed from the Solar PV Site by Fenwick Common Lane.	No PRoW within this land area.	Not adjacent to any residential properties, although north of Fenwick (St John) Churchyard and the Moss and Fenwick village hall.	Accessible via Fenwick Common Lane.	The Applicant considered this land to be unavailable.	The Applicant considered this land area neither suitable nor reasonably available.
G	Approximately 9.5 ha of agricultural land located to the east of Fenwick Common Lane and south of Haggs Lane.	Low risk of flooding from all sources.	Adjoins land included within the Solar PV Site that is at low risk of flooding from all sources.	Footpath (Fenwick-11) runs along the eastern boundary of the land area. Footpath (Fenwick-16) runs along the northern boundary of the land area.	Not adjacent to any residential properties. However, the Applicant considered that as it is adjacent to Fenwick Common Lane which is the approach to the village of Fenwick and could therefore be visible by users of Fenwick Common Lane.	Accessible via Fenwick Common Lane.	The Applicant considered the southern end of this land area to be unavailable. Some of this land area was available at one point (northern field). However, the Applicant determined that to reduce the number landowners involved in the Scheme, the land was not required for the Solar PV Site.	The Applicant considered this land area unsuitable. Further, the Applicant considered part of the land area was not reasonably available and the remainder was not required for the Solar PV Site (to reduce the number of landowners affected by the Scheme).

Land area reference	Size (Ha) and location	Risk of flooding (from all sources)	Relationship with land at lower risk of flooding within the Solar PV Site	Interaction with Public Right(s) of Way	Proximity to residential properties/other land use conflicts	Accessibility	Availability	Conclusion
H	Approximately 7 ha of agricultural land located to the east of Fenwick Common Lane and north of Moss Road.	Low risk of flooding from all sources.	Adjoins land included within the Solar PV Site that is at low risk of flooding from all sources.	No PRoW within this land area.	Land area is adjacent to residential property and commercial premises fronting Fenwick Common Lane and Moss Road. The Applicant was seeking to reduce impacts on the settlement of Fenwick and Moss with reference to visual impact.	No direct access to the public highway. (possibly via Fenwick Common Lane).	The Applicant considered this land to be unavailable.	The Applicant considered this land area neither suitable nor reasonably available.
I	Approximately 11 ha of a mix of developed land (clay shooting site) and agricultural land located east of London Lane.	Low risk of flooding from all sources.	Adjoins land included within the Solar PV Site that is at low risk of flooding from all sources.	At its southernmost extent footpath (Moss-5) runs along the western boundary of this land area.	Land area encompasses land that is currently occupied by an operational clay shooting establishment, this land would need to be omitted from the land area. Consideration of the impacts of the Solar PV Site would need to be considered with respect to the users of the clay shooting establishment to avoid negative visual impact on them.	No direct access to the public highway.	The Applicant considered this land to be unavailable.	The Applicant considered this land area neither suitable nor reasonably available.
J	Approximately 43 ha of predominantly agricultural land surrounding several listed buildings. Land area located north and south of Lawn Lane east of Fenwick.	Low risk of flooding from all sources.	Adjoins land included within the Solar PV Site that is at low risk of flooding from all sources.	Footpath (Fenwick-12) runs north-south along the southern end of the western boundary of this land area.	Land area accommodates several designated heritage assets. The Applicant has sought to reduce impacts on designate heritage assets by allowing a buffer. Riddings Farm and Fenwick Hall include residential dwellings. The Applicant has sought to reduce impacts on neighbouring residential occupiers with reference to landscape and visual impact.	Accessible via Lawn Lane.	The Applicant considered this land to be unavailable.	The Applicant considered this land area neither suitable nor reasonably available.
K	Approximately 2.2 ha of agricultural land west of the disused railway.	Low risk of flooding from all sources.	Adjoins land included within the Solar PV Site that is at low risk of flooding from all sources.	No PRoW within this land area.	Not adjacent to any residential properties and no other land use conflicts identified.	No direct access to the public highway.	The Applicant considered this land to be unavailable.	The Applicant considered this land unavailable.

Land area reference	Size (Ha) and location	Risk of flooding (from all sources)	Relationship with land at lower risk of flooding within the Solar PV Site	Interaction with Public Right(s) of Way	Proximity to residential properties/other land use conflicts	Accessibility	Availability	Conclusion
L	Approximately 17 ha of land located to the north of land area A.	Medium risk of fluvial flooding (FZ2) and potentially at risk of other sources of flooding (pluvial, reservoir and/or groundwater).	Adjoins land included within the Solar PV Site that is at medium risk of fluvial flooding (FZ2) and potentially at risk of other sources of flooding (pluvial, reservoir and/or groundwater).	A footpath (Fenwick-7) runs through the western part of the site in a north-south direction.	Not adjacent to any residential properties and no other land use conflicts identified. .	No direct access to the public highway.	The Applicant considered this land to be unavailable.	The Applicant considered this land area neither suitable nor reasonably available.
M	Approximately 3.5 ha of land located to the south of land area G, east of Fenwick Common Lane.	Medium risk of fluvial flooding (FZ2) and potentially at risk of other sources of flooding (pluvial, reservoir and/or groundwater).	Adjoins land included within the Solar PV Site that is at low risk of flooding from all sources.	No PRoW within this land area.	Not adjacent to any residential properties. However, the Applicant considered that it is adjacent to Fenwick Common Lane which is the approach to the village of Fenwick and would therefore be visibly prominent.	Accessible via Fenwick Common Lane.	The Applicant considered this land to be unavailable.	The Applicant considered this land area neither suitable nor reasonably available.
N	Approximately 22 ha of land located north of Moss Road and east of Fenwick Common Lane.	Medium risk of fluvial flooding (FZ2) and potentially at risk of other sources of flooding (pluvial, reservoir and/or groundwater).	Adjoins land included within the Solar PV Site that is at low risk of flooding from all sources.	A footpath (Moss-3) runs through the western part of the site in a broadly north-south direction.	Proximity to residential dwellings fronting Moss Road, proximity to village of Moss. The Applicant was seeking to reduce impacts on the settlement of Fenwick and Moss with reference to visual impact.	Accessible via Moss Road and/or Fenwick Common Lane.	The Applicant considered this land to be unavailable.	The Applicant considered this land area neither suitable nor reasonably available.
O	Approximately 3 ha of land located north of land area I.	Medium risk of fluvial flooding (FZ2) and potentially at risk of other sources of flooding (pluvial, reservoir and/or groundwater).	Adjoins land included within the Solar PV Site that is at medium risk of fluvial flooding (FZ2) and potentially at risk of other sources of flooding (pluvial, reservoir and/or groundwater).	No PRoW within this land area.	Land area encompasses land that is currently occupied by an operational clay shooting establishment, this land would need to be omitted from the land area. Consideration of the impacts of the Solar PV Site would need to be had with respect to the users of the clay shooting establishment to avoid negative visual impact on them.	No direct access to the public highway.	The Applicant considered this land to be unavailable.	The Applicant considered this land area neither suitable nor reasonably available.
P	Approximately 24 ha of land located north of Moss Lane and east of the Grid Connection Corridor.	Medium risk of fluvial flooding (FZ2) and potentially at risk of other sources of flooding (pluvial,	Adjoins land included within the Solar PV Site that is at medium risk of fluvial flooding (FZ2) and potentially at risk of other	A footpath (Moss-6) runs along the western boundary of this land area. A footpath (Moss-7) traverses the centre of	Proximity to residential dwellings fronting Moss Road, proximity to village of Moss. The Applicant was seeking to reduce impacts on the settlement of Fenwick and	Accessible via Moss Road.	The Applicant considered this land to be unavailable.	The Applicant considered this land area neither suitable nor reasonably available.

Land area reference	Size (Ha) and location	Risk of flooding (from all sources)	Relationship with land at lower risk of flooding within the Solar PV Site	Interaction with Public Right(s) of Way	Proximity to residential properties/other land use conflicts	Accessibility	Availability	Conclusion
		reservoir and/or groundwater).	sources of flooding (pluvial, reservoir and/or groundwater).	this land area in a north-south direction.	Moss with reference to visual impact.			
Q	Approximately 16 ha of land located north of Ell Wood and Fenwick Grange Drain and west of Fenwick Grange.	Medium risk of fluvial flooding (FZ2) and potentially at risk of other sources of flooding (pluvial, reservoir and/or groundwater).	Adjoins land included within the Solar PV Site that is at medium risk of fluvial flooding (FZ2) and potentially at risk of other sources of flooding (pluvial, reservoir and/or groundwater).	No PRoW within this land area.	Proximity to Fenwick Grange. Land area traversed by overhead powerlines.	No direct access to the public highway.	The Applicant considered this land to be unavailable.	The Applicant considered this land unavailable.
R	Approximately 16 ha of land, located east of land area J and north and south of Fenwick Hall.	Medium risk of fluvial flooding (FZ2) and potentially at risk of other sources of flooding (pluvial, reservoir and/or groundwater).	Adjoins land included within the Solar PV Site that is at medium risk of fluvial flooding (FZ2) and potentially at risk of other sources of flooding (pluvial, reservoir and/or groundwater).	Footpath (Fenwick-12) crosses the southern part of this land area in a broadly northwest-southeast direction.	Land area is adjacent to several designated heritage assets. The Applicant sought to reduce impacts on designated heritage assets by allowing a buffer. Riddings Farm and Fenwick Hall include residential dwellings. The Applicant has sought to reduce impacts on neighbouring residential occupiers with reference to landscape and visual impact.	No direct access to the public highway (likely to be the same as for land area J).	The Applicant considered this land to be unavailable.	The Applicant considered this land area neither suitable nor reasonably available.
S	Approximately 40 ha of land, located south of Topham.	Medium risk of fluvial flooding (FZ2) and potentially at risk of other sources of flooding (pluvial, reservoir and/or groundwater).	Adjoins land included within the Solar PV Site that is at medium risk of fluvial flooding (FZ2) and potentially at risk of other sources of flooding (pluvial, reservoir and/or groundwater).	No PRoW within this land area.	There are several residential properties within or near to this land area and it also south of the hamlet of Topham. The Applicant was seeking to reduce impacts on neighbouring residential occupiers with reference to visual impact.	No direct access to the public highway.	The Applicant considered this land to be unavailable.	The Applicant considered this land area neither suitable nor reasonably available.

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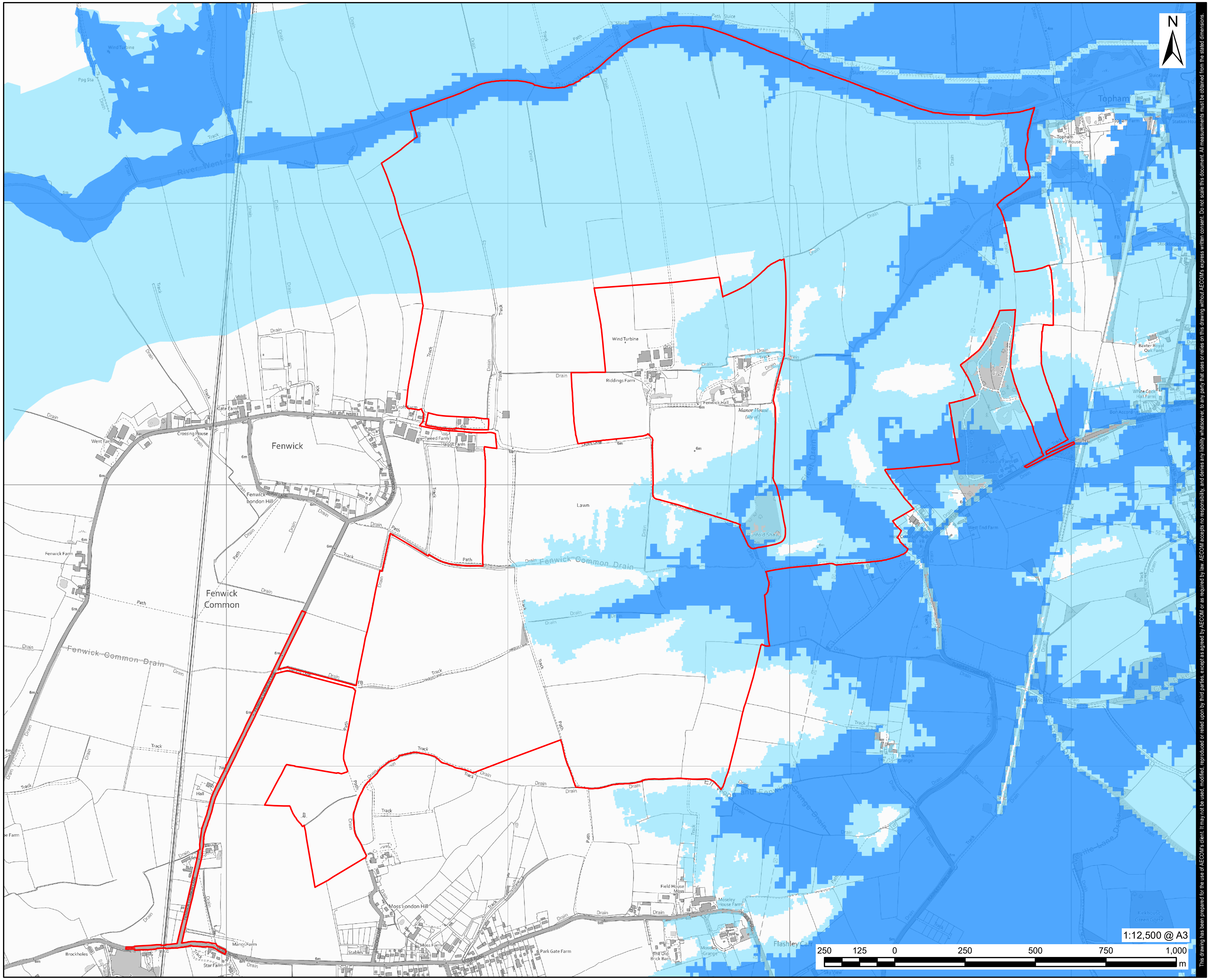
Revision: 0 Drawn: LP Checked: AK Approved: EP Date: 2024-10-25



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Fenwick Solar Farm

CLIENT

Fenwick Solar Project Limited

CONSULTANT

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LEGEND

- Solar PV Site
- Flood Zone 2
- Flood Zone 3

All non-shaded areas are Flood Zone 1.

NOTES

ISSUE PURPOSE

Sequential Test

PROJECT NUMBER

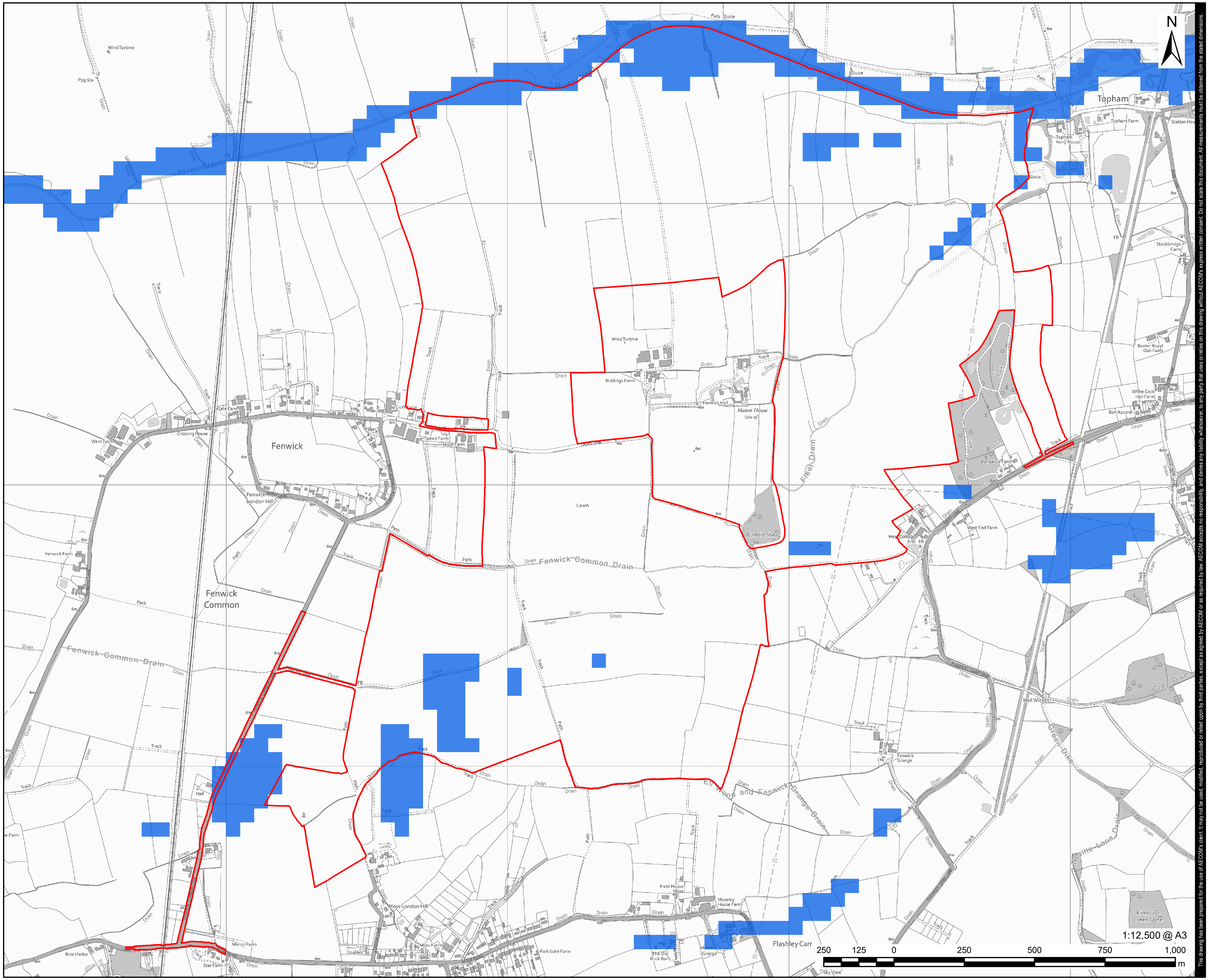
60698207

FIGURE TITLE

Fluvial Flooding within the Solar PV Site

FIGURE NUMBER

Figure 9-3A-6



Revision: 0 Drawn: LP Checked: AK Approved: EP Date: 2024-10-25

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LEGEND

- Solar PV Site
- Limited Potential for Groundwater Flooding to Occur

NOTES

ISSUE PURPOSE

Sequential Test

PROJECT NUMBER

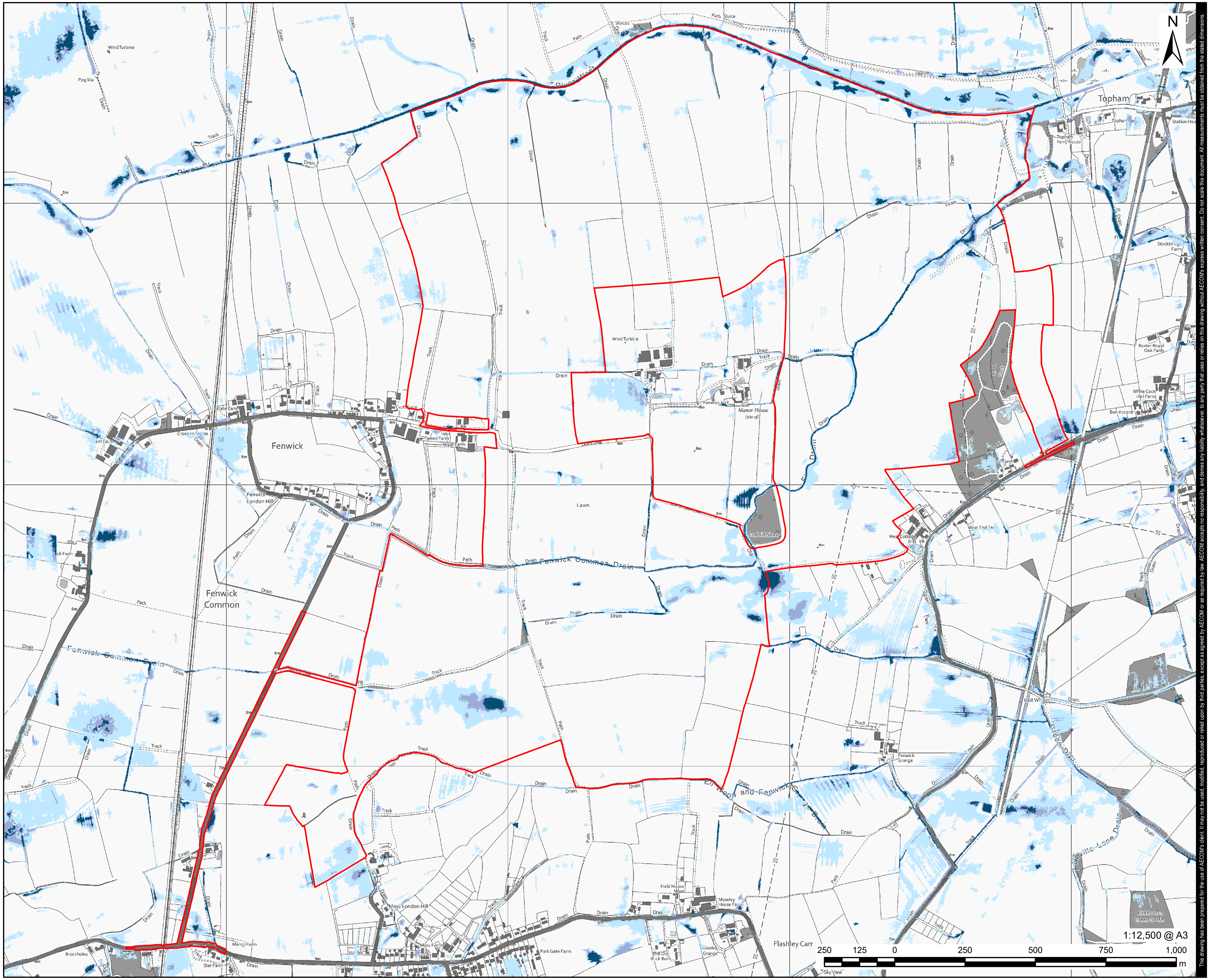
60698207

FIGURE TITLE

Groundwater Flooding within the Solar PV Site

FIGURE NUMBER

Figure 9-3A-7



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LEGEND

Solar PV Site

Risk of Flooding from Surface Water

3.33% Annual Exceedance Probability

1% Annual Exceedance Probability

0.1% Annual Exceedance Probability

NOTES

ISSUE PURPOSE

Sequential Test

PROJECT NUMBER

60698207

FIGURE TITLE

Pluvial Flooding within the Solar PV Site

FIGURE NUMBER

Figure 9-3A-8

Revision: 0 Drawn: LP Checked: AK Approved: EP Date: 2024-10-30

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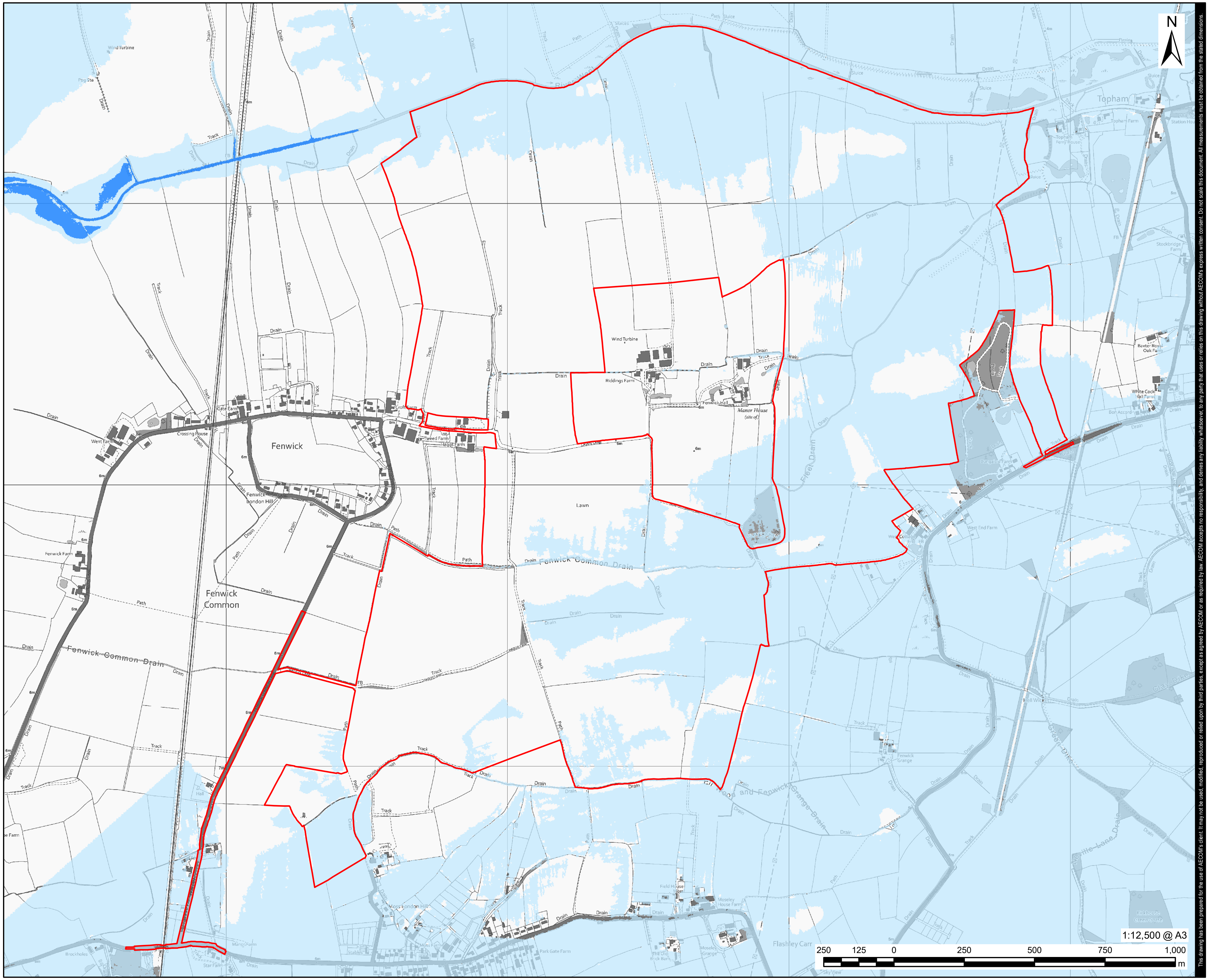

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LEGEND

Solar PV Site

Reservoir Flood Extent

Risk of Floodingfrom Reservoirs When River Levels are Dry (Dry Day)

Risk of Flooding from Reservoirs When There is Also Flooding from Rivers (Wet Day)

NOTES

ISSUE PURPOSE

Sequential Test

PROJECT NUMBER

60698207

FIGURE TITLE

Reservoir Flooding within the Solar PV Site

FIGURE NUMBER

Figure 9-3A-9

5. Conclusion

5.1.1 The purpose of this Sequential Test report has been to determine if there were any reasonably available areas of land of lower risk of flooding which would have been suitable for the Solar PV Site to confirm whether the Sequential Test has been applied as part of site selection in accordance with NPS EN-1 (Ref. 2) and NPS EN-3 (Ref. 7).

5.1.2 The Applicant identified a POC at the Existing National Grid Thorpe Marsh Substation. In accordance with NPS EN-1 (Ref. 2) and NPS EN-3 (Ref. 7), the Applicant then identified areas of non-BMV land within City of Doncaster Council administrative area (Ref. 8) and therefore in close proximity to the POC but did not identify any that were suitable and available.

5.1.3 The Applicant applied planning and environmental constraints (including all sources of flooding) to identify areas of unconstrained land, this identified five possible areas. Three were discounted due to land use conflicts and one more was discounted due to its limited size. Therefore, the Applicant identified an area of land 5km north of the POC on which to base their search for a Solar PV Site which was at low risk of flooding from all sources.

5.1.4 To select land for the Solar PV Site the Applicant undertook a process of further assessment of this land against key suitability factors including interaction with PRoW, proximity to residential properties and other land use considerations as well as accessibility and also the availability of the land. Regarding the latter, minimising the number of landowners affected by the Scheme and identifying opportunities for necessary land rights to be acquired voluntarily have been key requirements of the Applicant’s approach to the selection of the Solar PV Site.

5.1.5 The Applicant has concluded that there was insufficient land that was within Flood Zone 1 and free from other sources of flooding which was otherwise suitable and available to accommodate the generating capacity of the Scheme proposed. Further, only selecting land within Flood Zone 1 which was also free from other sources of flooding would have led to the dissection of many fields which was not possible for agreements with landowners.

5.1.6 Therefore, the Applicant considered land within Flood Zone 2 that adjoined land at lowest risk of flooding. At the same time the Applicant also considered land at risk of other sources of flooding. The presence of these sources of flood risk was considered insignificant as a differentiator of suitability for the Solar PV Site given the limited presence, and associated risk of these types of flooding, and, therefore, the risk to the Scheme was considered to be limited.

5.1.7 Through the process of negotiating land agreements for the land at lower risk of flooding, the Applicant has been required to include land within the Solar PV Site that was within Flood Zone 3 where it was also within the same landownership/field as land within the Solar PV Site. This has been to avoid land becoming inaccessible and being unable to continue in agricultural use due to the severance of this land as a result of the Scheme.

5.1.8 In summary, a sequential approach has been applied in selecting the land for the Solar PV Site which has considered the risk of flooding from all sources. The Solar PV Site is located in and around the largest area of identified unconstrained land which is at lowest risk of flooding from all sources. Other areas of land in this location were considered in terms of their flood risk and other suitability factors including land availability, however, it is concluded that these are not suitable and/or reasonably available alternative land areas for the Solar PV Site. The land that is considered available and suitable at lower risk of flooding is within the Solar PV Site. The Applicant has therefore demonstrated the Sequential Test as part of site selection has been met, in accordance with NPS EN-1, the PPG and local policy.

6. References

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