APPENDIX C

Peartree Hill Hydraulic Modelling Report (20-206-60-050-01)

PEARTREE HILL SOLAR

Beverley, East Yorkshire, HU17 9SS

HYDRAULIC MODELLING REPORT

Project No	20-206-60
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Issue date	11/11/24

Transport Planning | Flood Risk & Hydrology | Infrastructure & Drainage

Control Sheet

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1 EXECUTIVE SUMMARY

1.1.1 Calibro has been appointed by RWE to carry out hydraulic modelling to support a planning application for a proposed solar development at Peartree Hill, East Riding of Yorkshire. This work was informed by pre-application engagement with the Environment Agency (EA).

1.1.2 The Hull and Holderness Drain model was adapted for the purpose of assessing the actual and residual risk to the site (through multiple breach and defence removal scenarios). As part of this work, some of the model was developed from a 1D only to a 1D-2D linked model.

1.1.3 The modelling work demonstrates that the majority of the site is not at risk of fluvial flooding. The extensive tidal defences along with the embankments alongside the principal watercourses (River Hull and Monk Dike) serve to contain the majority of flood waters during the design (1 in 100 year plus climate change) event.

1.1.4 Where flooding does occur during the defended scenario, flood depths and velocities tend to be low. The development proposals have been derived taking account of these outputs by locating supporting water sensitive infrastructure outside these areas where practicable. Where this is not practicable supporting infrastructure (e.g. inverters, switch gears, batteries) would be raised at least 0.3m above the predicted flood level.

1.1.5 The modelling work also considers the Credible Maximum Scenario using the H++ allowances in accordance with Planning Practice Guidance (PPG)[1] and the Overarching National Policy Statement for Energy EN-1[2]. The two exporting substations would be located outside the predicted flooding and comfortably above the predicted flood level.

1.1.6 The modelling work also includes 18 breach simulations of earthen embankments to determine the residual risk to the site. 3 of these breaches were selected to assess the residual risk to Parcel A. No development is proposed in this parcel but the breach simulations are still presented in this document for completeness. The breach simulations provide sufficient information to determine a suitable approach to mitigating residual risk. The majority of supporting water sensitive infrastructure would be located outside areas at residual risk of flooding, but where this is not possible they would be raised above the predicted flood level.

1.1.7 Removal of large sections of the Monk Dike embankments resulted in flooding in adjacent parcels which are similar to the worst-case breach extents and therefore the mitigation measures for the breach scenarios are considered to be sufficient to safeguard against the defences being completely removed during the development's lifetime.

[1] https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances
[2] Overarching National Policy Statement for energy (EN-1) - GOV.UK (www.gov.uk)

1.1.8 Sensitivity testing concludes that the model is not particularly sensitive to the definition of the tidal boundaries, flow estimates or roughness. Furthermore, a comparison of the Credible Maximum Scenario and the design event reveals that flood levels would not increase significantly by 2100. Therefore the mitigation recommended in this document is a robust approach to safeguard against the potential of extreme climate change to 2115 despite the development's proposed operational lifetime of 40 years.

1.1.9 Subsequent simulations including structures that are not defined in the model provided by the Environment Agency determined that these structures would have an insignificant impact on design event flood levels.

1.1.10 The impact of the proposals has been tested by raising Manning's roughness to 0.1 in the areas where panels and supporting infrastructure are proposed. This value is typically used for dense brush which would provide more resistance to flow than the narrow supports for the panel arrays. The results demonstrate that there would be an insignificant change in water levels and consequently a non-material change to flood risk for third parties.

1.1.11 The modelling work and the first version of this report was submitted to the EA's National Infrastructure Team for review. The EA requested additional work including a review of missing structures and simulations considering the impact of loss of entire sections of defence. These points are addressed in a Hydraulic Modelling Addendum (contained in Appendix F) submitted to the EA on 13th August 2024. The EA responded by letter on 29th August 2024 confirming the modelling is fit for purpose.

1.1.12 Since this work was carried out the development proposals and the site boundary has changed, the most significant change being the removal of Parcel A. This is partly as a result of the findings of the modelling work which predicted deep extensive flooding in Parcel A in the event of breach of the River Hull embankments. As a consequence, the figures in this report and drawings in the Appendices do not reflect the latest site layout. The revised information is presented in the Peartree Hill Solar Farm Flood Risk Assessment (20-206-60-030-01).

2 CONTEXT

2.1 Introduction

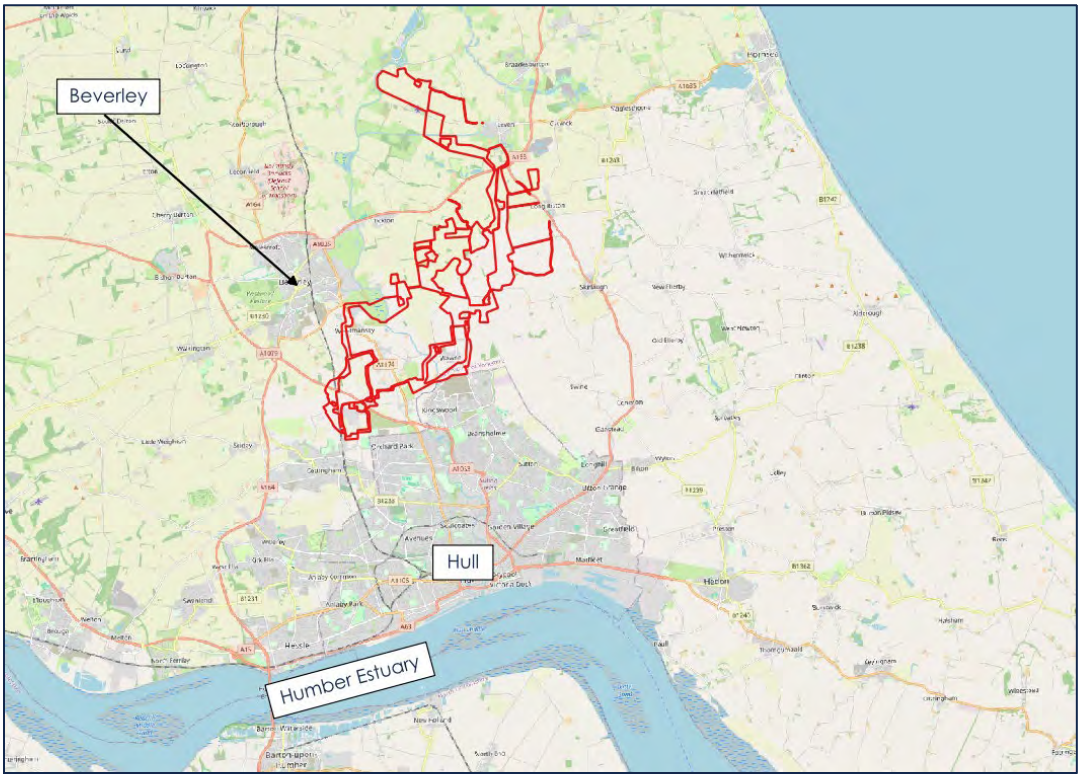
2.1.1 This report reflects the site proposals and site boundary as they were at the time that the modelling work was carried out (reproduced in Appendix A). The revised site proposals are presented Peartree Hill Solar Farm Flood Risk Assessment (20-206-60-030-01).

2.2 Site Location

2.2.1 The site is located near the town of Beverley, East Yorkshire. The approximate co-ordinates at the centre of the site are National Grid Reference (NGR) 508750, 440450. The nearest postcode to the centre of the site is HU17 9SS.

2.2.2 The site is located to the north of the city of Kingston Upon Hull (hereafter referred to as Hull) and the Humber estuary, to the east of Beverley and the River Hull and to the south of Driffield. The Draft Order Limits, hereafter referred to as the site boundary, is shown in Figure 2-1.

Figure 2-1 Site Location



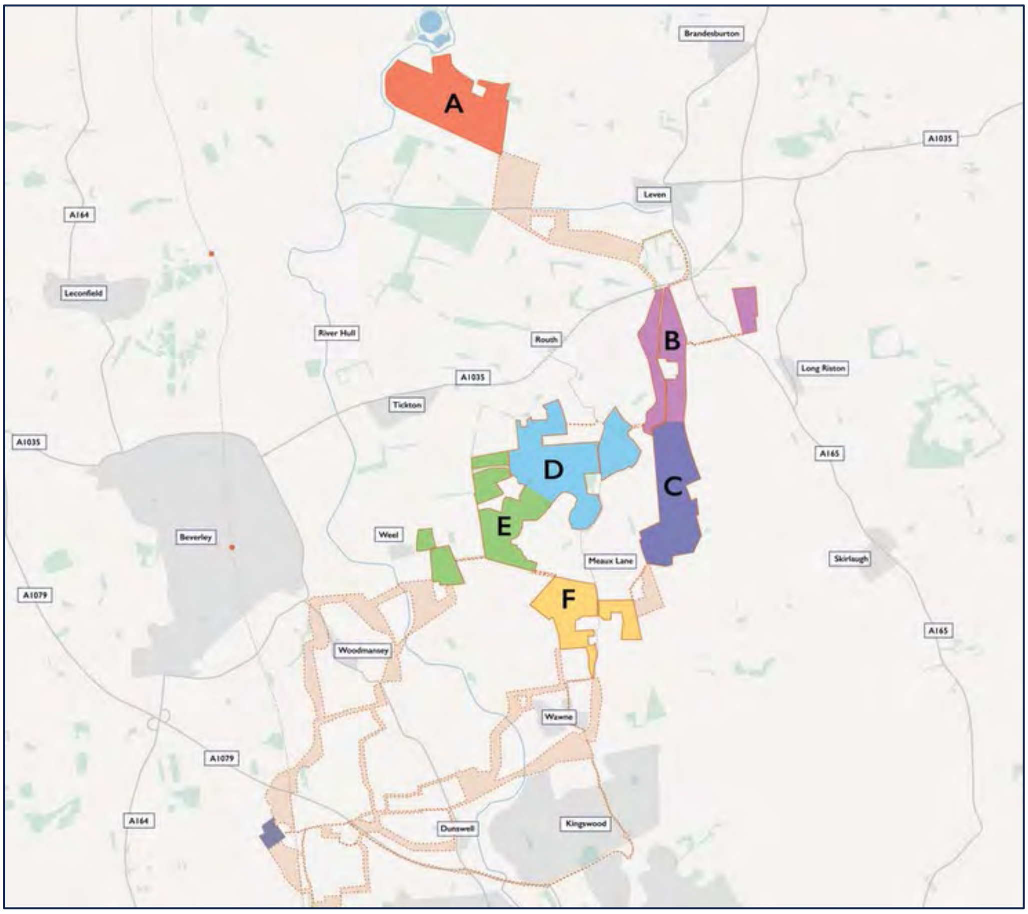
2.2.3 The site covers approximately 1,400ha. Approximately 700ha is expected to be solar generation and supporting infrastructure, with the remainder of the land holding set aside for cabling routes. The solar generation infrastructure is located in the Land

Areas labelled A-F in Figure 2-2. A copy of the Proposed Operation Phase Layout Plan is included in Appendix A. The cable routes will be buried and not water sensitive so are not discussed in this report.

2.2.4 The Proposed Development comprises the following main elements:

- Solar PV modules and associated mounting structures;
- On-site supporting equipment including inverters, transformers, and switchgear;
- A Battery Energy Storage System (BESS);
- Two on-site substations to connect the solar PV modules to distribution and transmission networks;
- Low voltage and 33 kilovolts (kV) interconnecting cabling within the Land Areas to connect the solar PV modules together and to connect the solar PV modules to the two on-site substations;
- 132 kV underground cabling connecting the Land Areas to the National Grid Creyke Beck Substation;
- Associated infrastructure including access tracks, parking, security measures, gates and fencing, lighting, drainage infrastructure and storage containers;
- Works at National Grid Creyke Beck Substation to facilitate the connection of the 132 kV underground cabling in to the Substation;
- Highways works to facilitate access for construction vehicles;
- Environmental mitigation and enhancement measures; and
- Temporary development during the construction phase of the Proposed Development including construction compounds, parking and temporary access roadways.

Figure 2-2 Land Areas

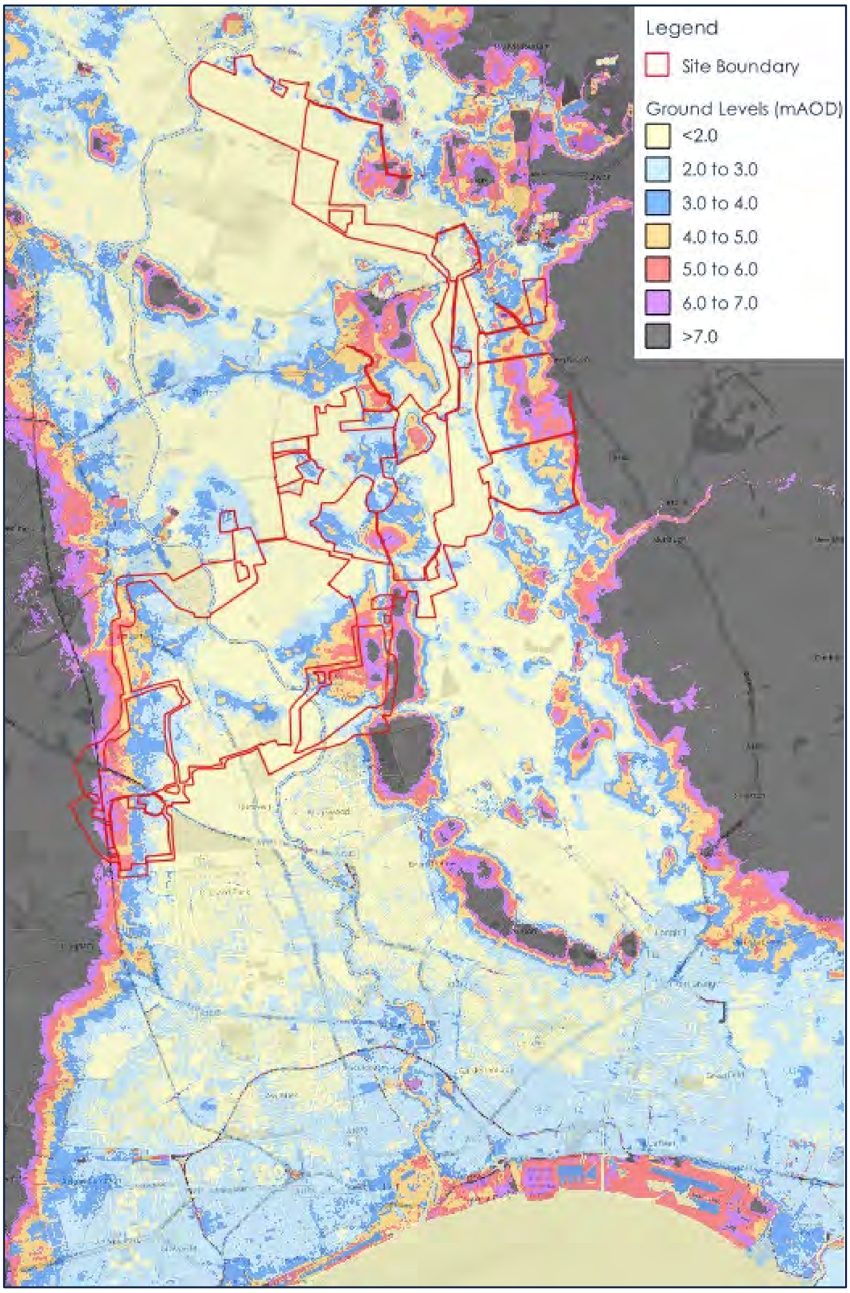


2.2.5 The focus of this study was to determine the actual and residual risk to the proposed above ground solar infrastructure in order to determine flood extents and levels to inform the development layout.

2.3 Site Topography and Hydrology

2.3.1 The proposed solar generation is predominantly on low-lying land as shown in Figure 2-3. Drawing 20-206-60-300 presents the same information in A3 format and is contained in Appendix B. Site levels generally vary between 0 and 8mAOD and the ground tends to be very flat. The cable route options extend into higher ground to the southwest.

Figure 2-3 Site Topography

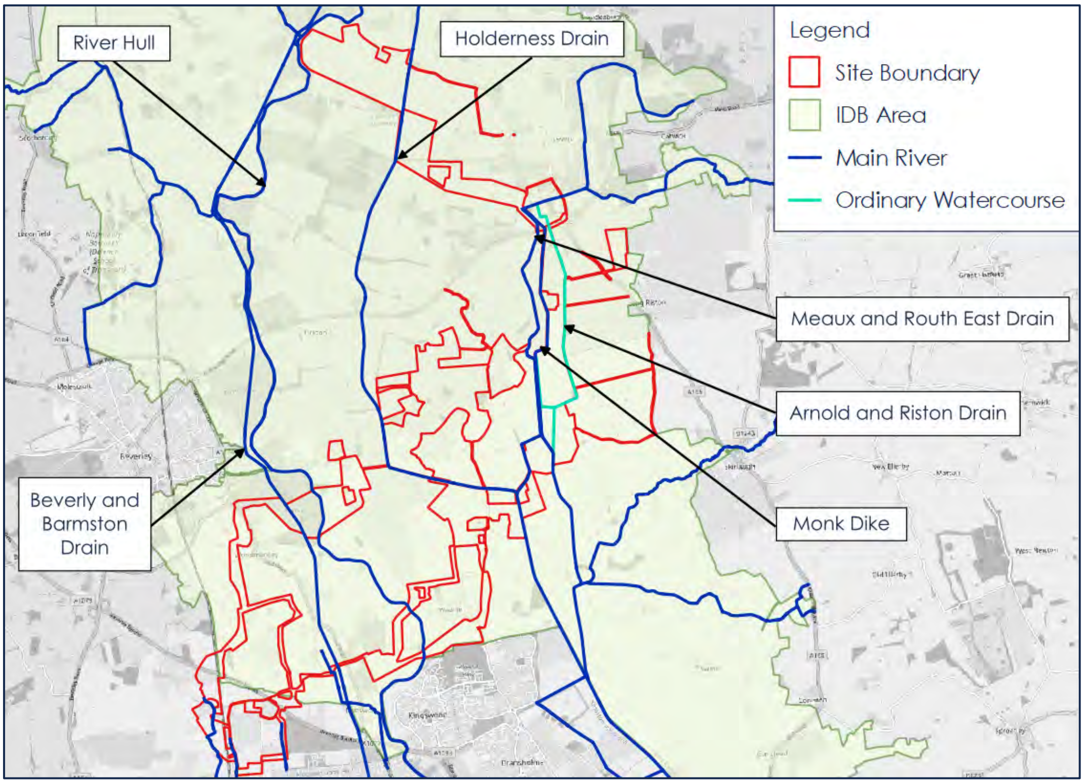


2.3.2 The Beverely and North Holderness Internal Drainage Board (IDB) administrative area covers a large area that is generally below 7mAOD. The extensive network of watercourses are managed by the IDB using control structures such as sluices and pumping stations for the purpose of drainage, flood risk management, and environmental benefit.

2.3.3 The drainage network ultimately discharges to the River Humber either via the River Hull or the Holderness Drain. Discharge from the Holderness Drain is controlled by a flapped outfall which prevents tidal ingress. Discharge from the River Hull is controlled by the Hull Tidal Surge Barrier which closes when particularly high tides are predicted.

2.3.4 There are a large number of watercourses within the study area. The principal watercourses which drain the area the Main Rivers shown in Figure 2-4. The River Hull and Monk Dike are flanked by earthen embankments and consequently they present a residual risk of flooding to the site should a breach occur.

Figure 2-4 Principal Watercourses and IDB Area



2.4 Modelling Scope

2.4.1 It was agreed during a meeting with the EA area team on 12th October 2022 and subsequently with the National Infrastructure Team on April 10th 2024 that the focus of the study should be on fluvial flood risk. The site is protected from tidal flooding by extensive defences along the River Humber Estuary. There have been several schemes recently constructed by Hull City Council and East Riding of Yorkshire Council which protect the City of Hull against a future (2040) 1 in 200 year flood and allow for a managed adaptive approach (raising the defences in the future to mitigate sea-level rise beyond 2040).

2.4.2 Should these defences be breached or overtopped, flooding of the site is unlikely as the panels and associated infrastructure are 10km or more inland and there is significant intervening low-lying land which would absorb flood waters. Furthermore, land adjacent to the River Humber is generally significantly higher than the low-lying land further inland which would reduce the flow through defences should a breach occur.

2.4.3 An assessment of tidal flood risk is contained in the Flood Risk Assessment.

3 Modelling Approach

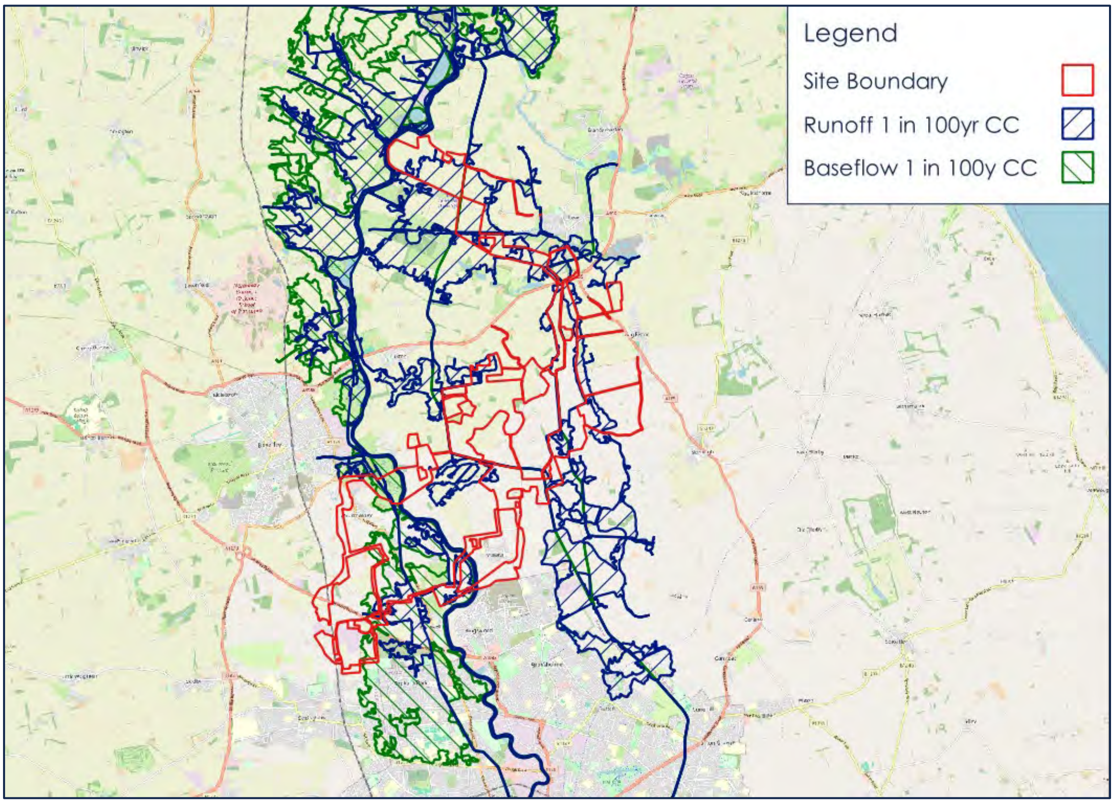
3.1 Existing Model and Run Parameters

3.1.1 As the purpose of the modelling is to establish flood levels and depths during the simulated design event and breaches, the modelling work has been based on the supplied 'defences operating' model.

3.1.2 As some of the catchments in the study area (generally to the west of the River Hull) exhibit a baseflow-dominated response. The original model simulated 'fluvial baseflow' events (derived using inflows created to produce the worst-case on baseflow-dominated catchments) and 'fluvial runoff' events (derived using inflows created to produce the worst-case on rainfall-runoff dominated catchments).

3.1.3 A review of these outputs revealed that the fluvial runoff scenario produces significantly worse flooding than the baseflow scenario for the solar generation areas[3]. The 1 in 100 year plus climate change event outputs for each of the scenarios is shown in Figure 3-1. This approach was discussed and agreed during a meeting with the EA's National Infrastructure team on April 10th 2024.

Figure 3-1 Existing 1 in 100 year plus climate change flood outlines



[3] The baseflow events are worse for land to the west of the River Hull but the cable routes are not discussed in this report being buried services.

3.1.4 The 1 in 100 year plus climate change model has been adopted for the purpose of the study. The existing model has a 15m grid and uses a 7.5s timestep for both the 1D and 2D elements. Running the existing model with a 3.75s 1D timestep, in accordance with good practice, had no discernible impact on the model outputs but did result in worse 1D mass balance and a higher number of unconverged timesteps. Consequently, the existing parameters have been retained. This was discussed and agreed during the meeting on April 10th.

3.1.5 The models were run for 200 hours (approximately 16 tidal cycles), well beyond the peak predicted flood levels which are 100 to 150 hours into the simulations.

3.2 Boundary Data

Fluvial Boundaries

3.2.1 For the design event and breach runs, the fluvial inflows were adjusted to reflect the higher central estimate of predicted climate change for the 2050s epoch (which covers the period 2040-2069) for the Hull and East Riding Management Catchment. This was completed by changing the existing scaling factors in the .IED from 20% to 17%. The H++ scenario was assessed using the 2080s Upper End estimate of 66%.

Tidal Boundaries

3.2.2 The existing 1 in 100 year plus climate change tidal curve boundaries were adjusted to represent predicted peak tidal levels. For the design event the highest astronomical tide level of 4.09m was taken from the Coastal Flood Boundary Dataset (CFB 'UK Mainland Chainage 3886') in accordance with the policy set out in the Planning Practice Guidance (PPG).

3.2.3 This level was adjusted to reflect the higher central estimate of sea-level rise to 2066 (calculated from a base date of 2018) of 356.6mm. This comprises: a rise of 93.5mm between 2018 and 2035 (5.5mm/yr); a rise of 252mm between 2035 and 2065 (8.4mm/yr), and; a rise of 11.1mm between 2065 and 2066 (11.1m/yr).

3.2.4 This resulted in a revised peak tidal flood level of 4.45mAOD. The tidal boundaries were created by adjusting the existing 1 in 100 year plus climate change boundaries (contained within Q100CC_75pt25hr.IED) which had a predicted peak level of 4.96mAOD and was presumably derived for the year 2100 or 2115.

3.2.5 The values were shifted downwards to preserve the tidal shape on the basis that the principal difference between the tides would be sea level rise which would affect all states of the tide equally.

3.2.6 For the H++ scenario the full 1.9m increase was applied, resulting in a peak tidal level of 5.99mAOD. This represents the worst-case scenario of sea level rise to 2100.

3.2.7 Although the EA agreed with this approach in the meeting April 10th, they requested that consideration be given to the outputs of the Humber Extreme Water Level (HEWL) study.

3.2.8 An alternative tidal boundary was derived with reference to the HEWL dataset to be used as a sensitivity test. The tidal level estimation points are shown in Figure 3-2. Relevant HEWL outputs are presented along with corresponding CFB values in Table 3-1.

3.2.9 A comparison of the nearest available level from the CFB with selected nodes from the HEWL dataset revealed that:

- The HEWL levels for node HU_0_069, at the mouth of the Humber Estuary, match those from the CFB Mainland Chainage _3912.
- The HEWL levels predict an increase in flood levels moving up the estuary due to a funnelling effect.
- The HEWL dataset (2071 HC) predicts levels at the confluence with the Hull to be 0.64m higher than at the mouth of the estuary, whereas the CFB data predicts an increase of 0.31m

1.2 To reflect the increase in peak tidal levels up the Humber Estuary predicted by HEWL, the CFB derived tidal boundary for the design event was increased by 0.33m (to reflect the difference between to two datasets) to 4.79mAOD to derive the alternate boundary (referred to as HEWL) used as a sensitivity test.

Figure 3-2 Selected HEWL and CFB nodes

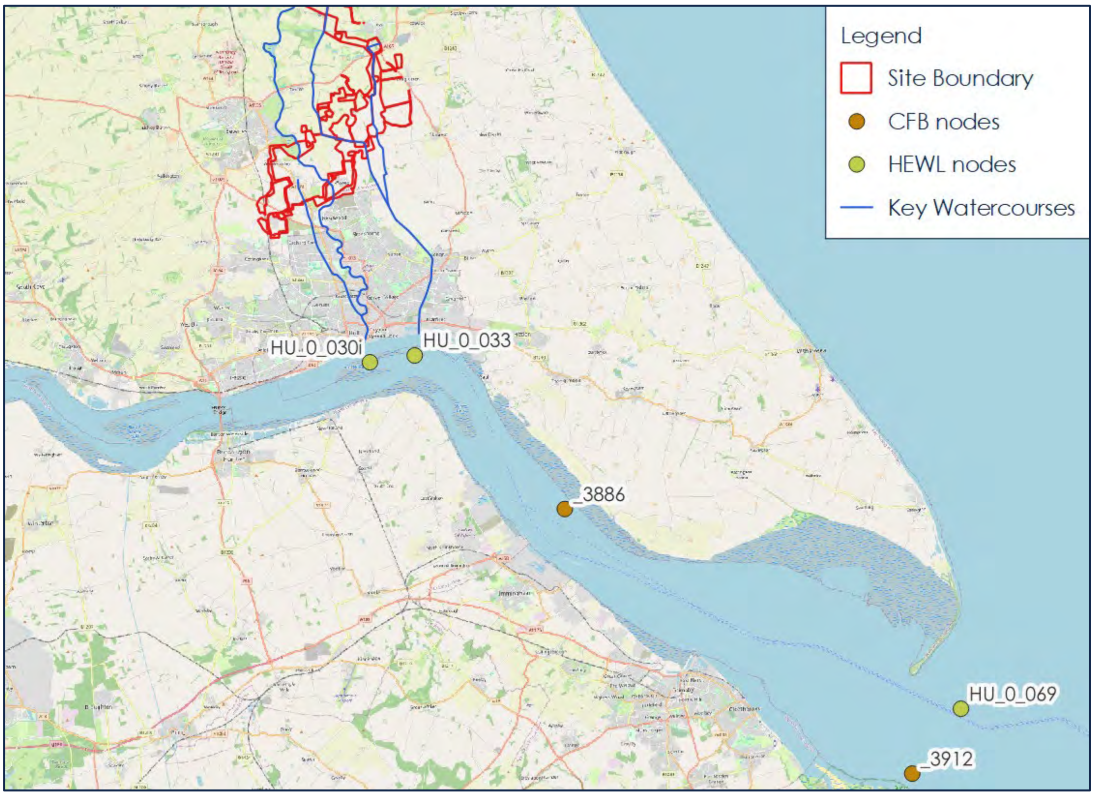


Table 3-1 Key Peak Tidal Levels

Event	2018	2046 Higher Central	2071 Higher Central
		CFB	
3912	3.96	4.15	4.37
3886	**4.27**	**4.46**	**4.68**
		HEWL	
HU_0_069	n/a	4.15	4.38
HU_0_033	n/a	4.72	4.96
HU_0_030i	**n/a**	**4.78**	**5.02**

3.3 Model Amendments

3.3.1 The following modifications were made to the model:

- The 2D element of the River Hull and Holderness drain was extended to the north near Tophill Low Nature Reserve to allow breach modelling adjacent to proposed solar generation in the northwest of the site. The 1D and 2D elements of the model are shown in Figure 3-3. Drawings showing the model extent are included in Appendix B (20-206-60-001, 20-206-60-002 & 20-206-60-003).

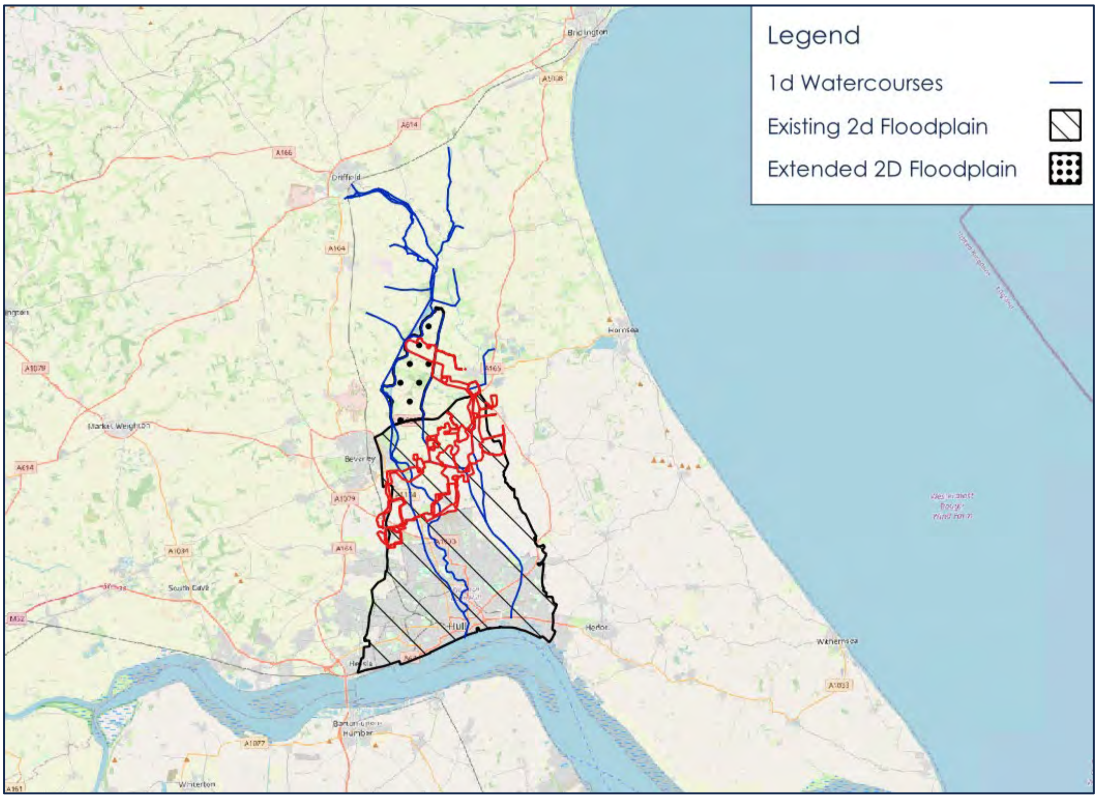
- The latest 1m filtered LiDAR data was downloaded from the gov.uk website to define the 2D model topography.

- Levels on the right bank of the Monk Dike just south of the A1035 were lowered to match LiDAR levels. Flooding has been observed in this location and it is presumed that some erosion has resulted in lowering of the crest level. Following the modification, overtopping commences earlier in the design event and results in increased flood levels to the west of the Monk Dike (approximately 100-200mm). There is also an insignificant reduction in flood levels to the east of the Monk Dike (approximately 10mm).

- The schematisation of the 1D element at the confluence of the Beverley and Barmston Drain and the River Hull was modified to stabilise the model. A spill was added where the Beverley and Barmston Drain drops into the River Hull and additional interpolates were added to stabilise the model.

3.3.2 In order to run the model with the latest versions of Flood Modeller Pro and Tuflow it was necessary to include the command ‘SX FMP Unit Type Error == OFF’ in the Tuflow control file (.trd) so that the existing model schematisation would function. Other run parameters were preserved.

Figure 3-3 Model Extents



3.4 Breach Scenarios

3.4.1 Breaches were simulated in accordance with guidance set out in the 'Breach of Defences Guidance - Modelling and Forecasting Technical Guidance Note'.

3.4.2 Breaches of the Monk Dike were carried out using the recommended parameters for earth banks on fluvial rivers: breach width 40m; time to close (rural) 56 hours. Breaches on the River Hull were carried out using the recommended parameters for Tidal Rivers: breach width 50m; time to close (rural) 56 hours. The level of the breach was defined on the basis of landward ground levels.

3.4.3 The breaches are modelled as occurring instantaneously to their full width. The timing of each breach was selected to be centred around the peak in-channel water level in order to produce the worst-case result. The in-channel water levels were taken from the design event (defended 1 in 100 year +17%) model. 30 hour breaches on the River Hull commenced 15 hours before the peak in-channel water level. 56 hour breaches on the Monk Dike commenced 28 hours before the peak in-channel water level.

3.4.4 The locations of the breaches were selected to result in maximum impact on the site with reference to the local topography (where landward ground levels were particularly low) and an indicative layout (proximity to sensitive infrastructure). The location of simulated breaches is shown in Figure 3-4, Figure 3-5 & Figure 3-6 and in Drawing 20-206-60-302 contained in Appendix B.

Figure 3-4 River Hull Breach Locations (North))

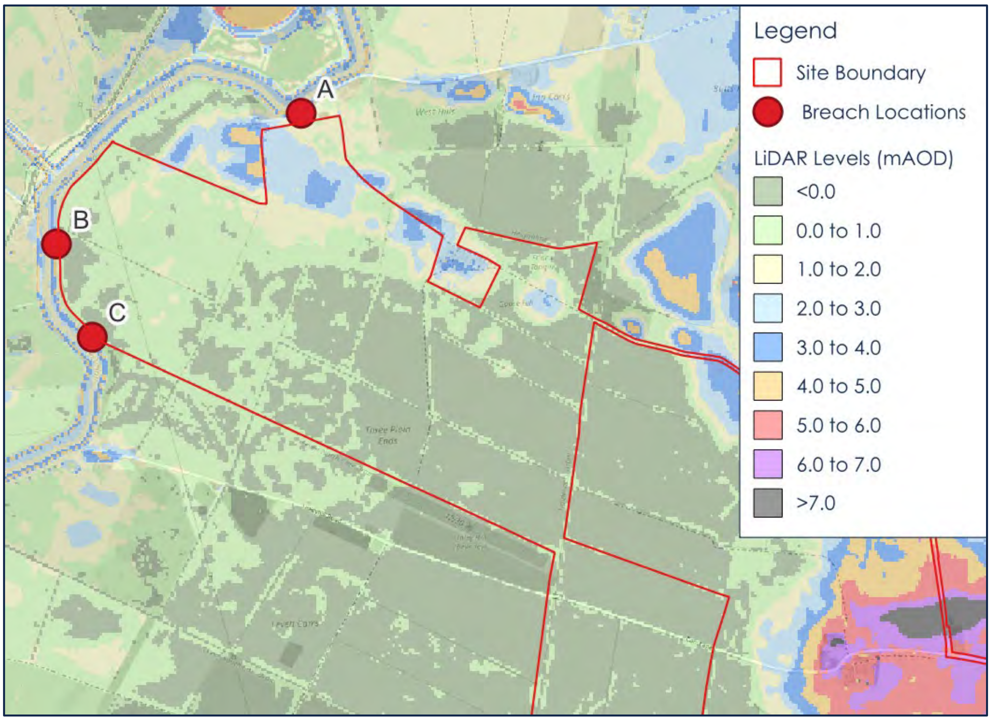


Figure 3-5 River Hull Breach Locations (South))

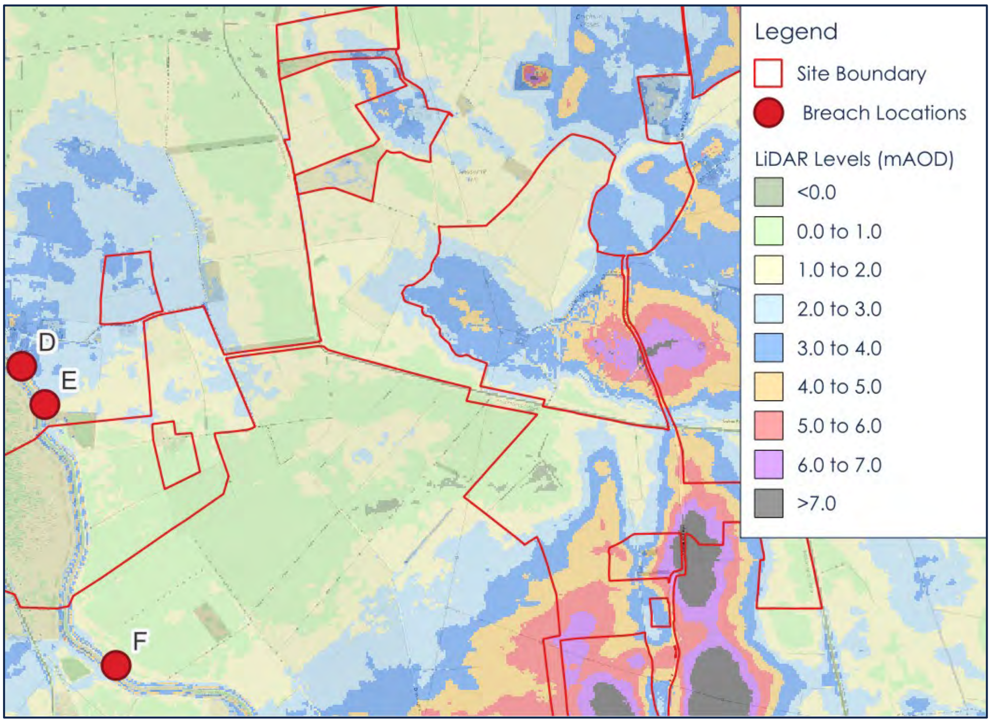


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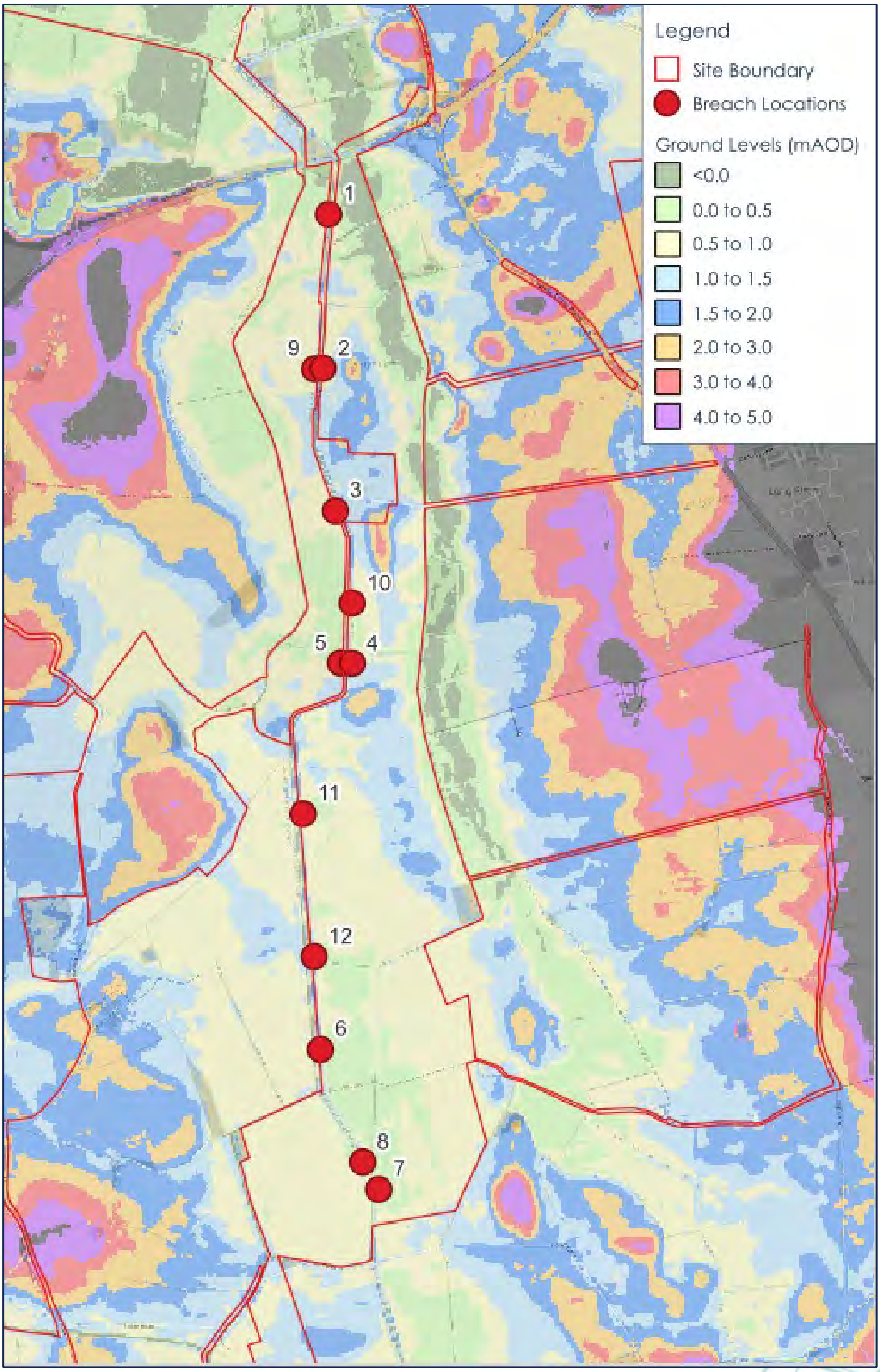
Figure 3-6 Monk Dike Breach Locations



3.4.5 The breach locations were provided to and agreed with the EA. It was queried whether the River Hull should be considered a fluvial defence. The trigger for the barrier closing is a tide of 4.2mAOD. The peak tidal level in the design event is 4.45mAOD so the barrier only closes on the two highest tides for a combined duration of 6 hours. Consequently, there is significant tidal influx into the River Hull (peaking at over 70m^3/s on each tide) and therefore it is considered to be a tidal river.

3.5 Simulations

3.5.1 The design event simulations and breach runs are summarised in Table 3-2.

Table 3-2 Design Event and Breach Simulations

Event	IEF
Design Event – Defended 1 in 100yr +17%	MD_UHL_039_100_17R_T0.ief
Monk Dike Breach 1 - 1 in 100 yr +17%	MD_UHL_MDB1_039_100_17R_T0.ief
Monk Dike Breach 2 - 1 in 100 yr +17%	MD_UHL_MDB2_039_100_17R_T0.ief
Monk Dike Breach 3 - 1 in 100 yr +17%	MD_UHL_MDB3_039_100_17R_T0.ief
Monk Dike Breach 4 - 1 in 100 yr +17%	MD_UHL_MDB4_039_100_17R_T0.ief
Monk Dike Breach 5 - 1 in 100 yr +17%	MD_UHL_MDB5_039_100_17R_T0.ief
Monk Dike Breach 6 - 1 in 100 yr +17%	MD_UHL_MDB6_039_100_17R_T0.ief
Monk Dike Breach 7 - 1 in 100 yr +17%	MD_UHL_MDB7_039_100_17R_T0.ief
Monk Dike Breach 8 - 1 in 100 yr +17%	MD_UHL_MDB8_039_100_17R_T0.ief
Monk Dike Breach 9 - 1 in 100 yr +17%	MD_UHL_MDB9_039_100_17R_T0.ief
Monk Dike Breach 10 - 1 in 100 yr +17%	MD_UHL_MDB10_039_100_17R_T0.ief
Monk Dike Breach 11 - 1 in 100 yr +17%	MD_UHL_MDB11_039_100_17R_T0.ief
Monk Dike Breach 12 - 1 in 100 yr +17%	MD_UHL_MDB12_039_100_17R_T0.ief
River Hull Breach A - 1 in 100 yr +17%	MD_UHL_HLBR1a_039_100_17R_T0.ief
River Hull Breach B - 1 in 100 yr +17%	MD_UHL_HLBR1b_039_100_17R_T0.ief
River Hull Breach C - 1 in 100 yr +17%	MD_UHL_HLBR1c_039_100_17R_T0.ief
River Hull Breach D - 1 in 100 yr +17%	MD_UHL_HLBR1d_039_100_17R_T0.ief
River Hull Breach E - 1 in 100 yr +17%	MD_UHL_HLBR1e_039_100_17R_T0.ief
River Hull Breach F - 1 in 100 yr +17%	MD_UHL_HLBR1f_039_100_17R_T0.ief

3.6 Sensitivity Tests

3.6.1 A number of runs were carried out to determine the sensitivity of the model to key assumptions. The tidal boundary was tested with reference to the HEWL outputs as discussed in Section 3.2.

3.6.2 Floodplain roughness was tested by increasing Manning's n values by 20%. An additional run was carried out where floodplain roughness in areas where panels are proposed were increased to 0.10 which is generally considered to be representative of heavy forestry or coppice. This was carried out in accordance with the EA's request in order to test the potential impact of the development on third parties.

3.6.3 The inflows were tested using an approach which reflected that undertaken in the original study. In the original study, the sensitivity of the model to baseflow was tested by increasing baseflows by 30%. The sensitivity of the model to surface runoff was tested by increasing standard percentage runoff (SPR) values for each of the inflows by 20%. The sensitivity test undertaken in this study comprises a 30% increase in baseflows along with a 20% increase in SPR. The increased flows were run not only for the design event simulation but also for Monk Dike Breaches 4 and 6 and Hull Breaches B and D.

3.6.4 A Maximum Credible Scenario for 2100 was also run in accordance with the H++ scenario guidance which in this case comprises an increase in flows of 66% and an increase in peak tidal level of 1.9m.

3.6.5 The additional simulations carried out are summarised in Table 3-3.

Table 3-3 Sensitivity Tests

Event	IEF
Maximum Credible Scenario (1 in 100+66% +1.9m sea level rise)	MD_UHL_039_100_66R_Tcms.ief
Tidal Boundary Sensitivity (HEWL)	MD_UHL_039_100_17R_T0_HEWL.ief
Manning's Roughness Sensitivity	MD_UHL_039_100_17R_T0_MNI.ief
Manning's roughness for developed areas increased to 0.1	MD_UHL_039_100_17R_T0_PRP3.ief
Design Event Flow Sensitivity	MD_UHL_039_100_17R_T0_BFSPR.ief
Monk Dike Breach 4 Flow Sensitivity	MD_UHL_MDB4_039_100_17R_T0_BFSPR.ief
Monk Dike Breach 6 Flow Sensitivity	MD_UHL_MDB6_039_100_17R_T0_BFSPR.ief
River Hull Breach B Flow Sensitivity	MD_UHL_HLBR1b_039_100_17R_T0_BFSPR.ief
River Hull Breach D Flow Sensitivity	MD_UHL_HLBR1d_039_100_17R_T0_BFSPR.ief

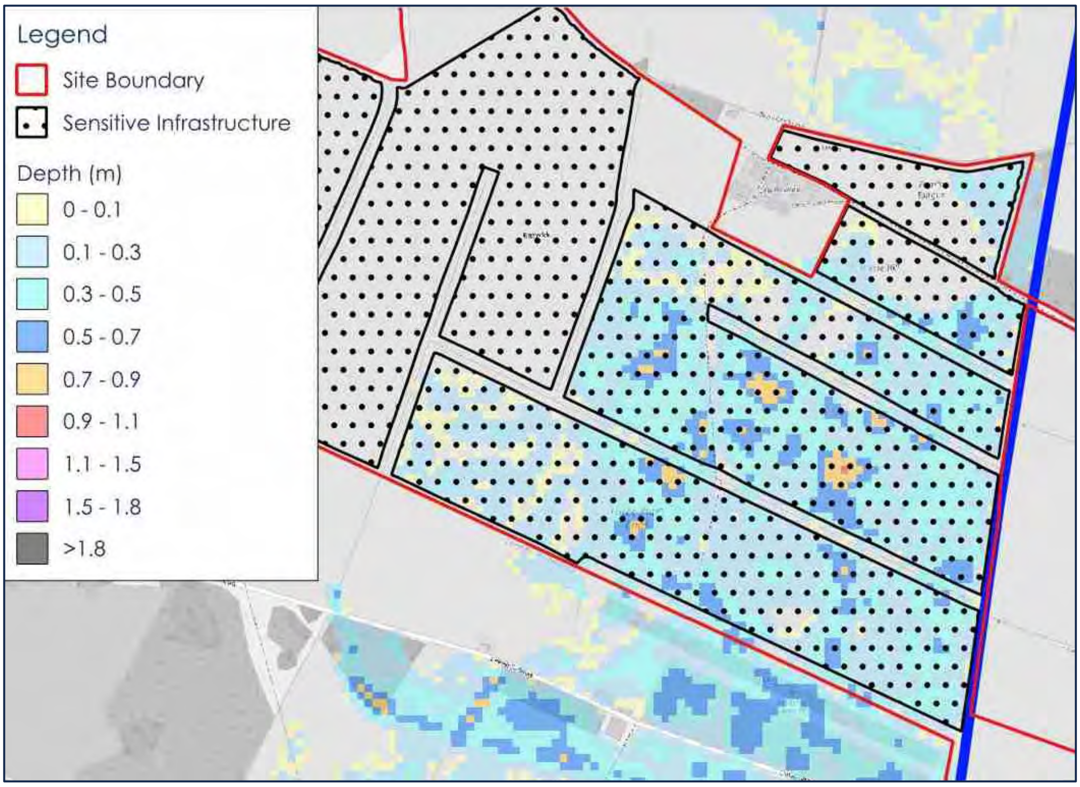
4 Model Results

4.1 Design Event

4.1.1 The vast majority of the site is not predicted to flood. Simulated flooding on the site is associated with the Hull and Holderness Drain in the west and the Monk Dike, Meaux and Routh East Drain and Arnold and Riston Drain in the east as discussed below. The design event flood depths are presented in Drawings 20-206-60-04 through to 20-206-60-06 (Appendix C).

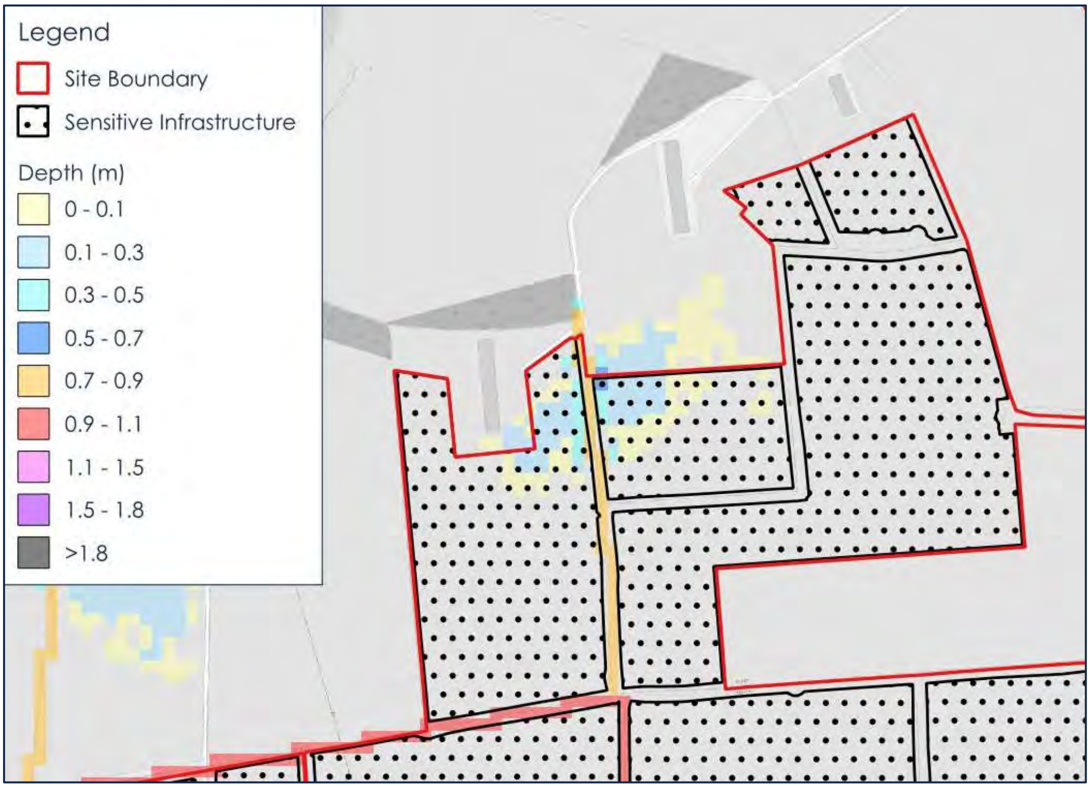
4.1.2 Drainage through the Holderness Drain is heavily restricted by high tide levels which results in flooding in the eastern part of Land Area A. Flooding is generally less than 0.5m but in some places is up to 1m deep (Figure 4-1).

Figure 4-1 Design Event Flooding Land Area A



4.1.3 Overtopping of the Holderness Drain also causes minor flooding to the northern part of Land Area D. Flooding in these locations is almost entirely below 0.3m and does not exceed 0.5m (Figure 4-2).

Figure 4-2 Design Event Flooding Land Area D



4.1.4 In the eastern part of the site, water overtops the western bank of the Monk Dike and causes flooding to a small area of land in the northwestern part of Land Area B before flowing into the Meaux and Routh Drain to the west (Figure 4-3). Flooding is also predicted in the eastern part of Land Area B caused by water from the Arnold and Riston Drain which relies on pumping to lift it into the Monk Dike. In the northeast an area of land is flooded to depths in the range 1.1-1.5m. Further south in Land Area B the flooding is constrained to the site perimeter and rarely exceeds 0.9m.

4.1.5 In the southern part of Land Area C water is predicted to overtop the Monk Dike and cause flooding. The flooding is generally shallow (<0.3m) and only a small area (~2,000m^2) is predicted to flood to depths 0.3-0.5m.

Figure 4-3 Design Event Flooding Land Area B

Figure 4-4 Design Event Flooding Land Area C

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4.1.6 During the design event, flood velocities within the proposed development area are consistently below 0.25m/s. Design event flood velocities are presented in Drawings 20-206-60-07 through to 20-206-60-09 (Appendix C).

Credible Maximum Scenario

4.1.7 The Credible Maximum Scenario which accounts for the plausible worst-case impacts of climate change have been applied in accordance with the requirements set out in National Policy Statement for Energy (EN-1). The document states that:

> *"Where energy infrastructure has safety critical elements, the applicant should apply a credible maximum climate change scenario. It is appropriate to take a risk-averse approach with elements of infrastructure which are critical to the safety of its operation."*

4.1.8 In the absence of guidance on how this should be applied for shorter time scales, the H++ climate change allowance for sea level rise of 1.9m was applied along with the upper end peak river flow allowance to 2125.

4.1.9 The predicted depths during this event are presented in Drawings 20-206-60-227 through to 20-206-60-229 (Appendix C). The flooded areas do not change significantly when compared to the design event and levels generally increase by less than 0.15m. The notable exception being some land in the south of Land Area C where levels increase by approximately 0.3m (refer to Drawings 20-206-60-247 through to 20-206-60-249 in Appendix E).

4.1.10 The substations would be located in areas unaffected by the Credible Maximum Scenario to ensure their long-term viability, despite the development lifetime being just 40 years.

4.2 Breach Simulations

4.2.1 The maximum depth and velocity outputs for each of the 18 breach scenarios are presented in Appendix D, along with combined maximum breach depth outputs.

River Hull

4.2.2 The breaches in the River Hull embankment cause widespread flooding. This is a result of both the scale of the embankments and the considerable tidal influence on the River Hull.

4.2.3 Of the northern breaches, Breach B has the most significant impact on the site, causing widespread flooding to approximately 7.5km^2 of land between the River Hull and the Holderness Drain including the majority of Land Area A. The level to which the embankment is lowered to simulate the breach is approximately 3m lower than peak in-channel flood level during the design event.

4.2.4 Peak flood depths within Land Area A are generally below 1.5m (Drawing 20-206-60-206). Peak flood levels are relatively static at approximately 500m from the breach locations.

4.2.5 Approximately 500m from the breaches, the flood levels resulting from Breaches A and C are within 50mm of Breach B demonstrating that the results are not particularly sensitive to the precise location of the breach.

4.2.6 Flood velocities at the location of breach are in excess of 4m/s but generally diminish to below 1m/s within approximately 200m. The areas of proposed development have been drawn back approximately 200m from the defence line. (Drawings 20-206-60-201, 20-206-60-204 & 20-206-60-213).

4.2.7 Of the southern breaches, Breach F causes the most significant flooding on the site with the exception of the southwestern part of Land Area E which is worst-affected by Breach D (Drawings 20-206-60-215 & 20-206-60-221). Flood depths in Land Areas D and E are generally below 0.7m. Flood depths in the western part of Land Area are up to 1.5m deep.

4.2.8 With the exception of drainage channels, flood velocities on the site are below 0.5m/s.

Monk Dike

4.2.9 Breaches on the Monk Dike have a less significant impact on the site than breaches on the River Hull due to a combination of less flow in the channel and lower embankments.

4.2.10 The maximum breach depths are principally determined by the topography behind the defence in the location of the breach. Where the ground is flat flooding disperses and results in relatively shallow depths. Deeper flooding is predicted in areas which are effectively depressions in an otherwise flat landscape.

4.2.11 As the results of the breach are influenced significantly by the location, 12 breaches have been carried out. With the exception of Breaches 4 and 10 and Breaches 6 and 7, which have almost identical results, each of the breaches result in a different area of proposed development experiencing flooding.

4.2.12 Flood depths for the breach events are generally below 1.2m. Where the ground is relatively even and there are no distinct depressions, flooding spreads out fairly quickly and depths and velocities diminish fairly rapidly generally reducing to below 0.5m and 0.5m/s within 50m of the simulated breaches.

4.2.13 Where there are localised depressions water accumulates in these areas and flood depths are predicted to be as high as 1.5m. However these locations are well-defined - e.g. adjacent to the defence for Breaches 4 and 10 but outside the generation area; adjacent to Breach 11; and adjacent to Breach 6 not particularly sensitive to the breach location.

4.2.14 All breaches of the eastern bank of the Monk Dike result in increased levels in the Arnold and Riston Drain. The combined worst-case simulation predicts an increase in flood levels of 0.2 to 0.3m when compared with the design event levels.

4.2.15 The breach that results in the most widespread flooding is Breach 7 which causes deep flooding in the southeastern part of the site. Flood depths predicted by Breach 6, approximately 600m upstream, are approximately 5mm lower than those predicted by Breach 7 and those predicted by Breach 12 approximately 1km upstream are approximately 10mm lower. It can therefore be concluded that flood depths in the worst-affected area are not sensitive to breach location.

4.2.16 With the exception of land within 50m of the breaches, velocities are generally less 0.5m/s.

4.3 Defence Reach Removal

4.3.1 Simulations with sections of the Monk Dike embankments removed are discussed in the addendum contained in Appendix F

4.4 Sensitivity Tests

4.4.1 The impact of the various sensitivity tests has been assessed by subtracting the peak water levels from those of the design event which provides not only a change in level but also delineates the change in flood outline (areas which were dry but become wet and vice versa). These outputs are presented in drawings contained in Appendix E.

4.4.2 It should be noted that outliers in flood level difference were observed in the same location for numerous runs. These outliers centre around the cell at NGR 51078076, 440026 and generally propagate up to two cells in each direction. This cell has a Zc elevation of -1.14m and is surrounded by cells with Zc elevations of -0.58 to 0.97mAOD. Consequently, it is concluded that the 'increases' predicted in these locations are an artefact of the modelling computation rather than any actual effect that would be expected to occur. This area is hereafter referred to the low cell in Land Area C.

Tidal Boundary Increase

4.4.3 Testing an increase of 0.338m in tidal levels to account for the increase in tidal levels predicted by HEWL, results in a minor increase in flood levels in locations flooded by watercourses which discharge via the Holderness Drain (Land Areas B and C). Levels associated predominantly with flooding from the Hull (Land Areas A, D, E & F) are reduced. This is because the increase in tidal levels results in more frequent closing of the Hull Tidal Surge Barrier and marginally reduces the significant influx of tidal waters into the River Hull and associated tributaries.

4.4.4 The increase in flood levels is less than 10mm within the developed areas. The only exception is three cells centred on the low cell in Land Area C which increase by

0.025m-0.047m. Four additional cells are wetted in this area. The maximum increase outside of the site is 0.081m in Swine Moor and the maximum decrease is 0.236m in Sutton in the northern part of Hull.

4.4.5 It is concluded that the model is not particularly sensitive to the definition of the tidal boundary.

4.4.6 The level difference resulting from increasing the tidal boundary is shown in Drawings 20-206-60-231 to 20-206-60-233.

Flow Increase - Design Event

4.4.7 Increasing SPR by 20% and baseflows by 30% results in an increase in fluvial inflows of approximately 20% and a minor increase in flood levels within developed areas as shown in Drawings 20-206-60-234 to 20-206-60-236.

4.4.8 Within Land Area A flood levels increase by approximately 0.08m. Within Land Area D flood levels are predicted to increase by approximately 0.18m.

4.4.9 In the land area affected by flooding from the Monk Dike, levels increase by less than 0.15m with the exception of cells associated with the low spot in Land Area C where increases of 0.245, 0.395, 0.295 and 0.158m are predicted.

4.4.10 It is concluded that flooding during the design event is not overly sensitive to the model inflows.

Flow Increase - Breach Events

4.4.11 The impact of increasing SPR by 20% and baseflows by 30% for four breach scenarios was also tested. For the majority of the model extent the results were equivalent to the baseline sensitivity test.

4.4.12 For Hull Breach B, levels in the vicinity of the breach and within Land Area A generally, increase by approximately 0.035m, approximately half the increase predicted during the baseline event (see Drawing 20-206-60-237).

4.4.13 For Hull Breach D levels in the vicinity of the breach are predicted to increase by less than 0.01m. Flood levels in Land Area D and E increase by 0.04m and 0.02m respectively (see Drawing 20-206-60-238).

4.4.14 The Hull Breaches are not sensitive to flow estimates due to the significant influx of tidal waters into the River Hull.

4.4.15 For Monk Dike Breach 1 the increase in the vicinity of the breach is up to 0.10m and levels further south in Land Area B increase by approximately 0.15m (see Drawing 20-206-60-239).

4.4.16 For Monk Dike Breach 6 the impact in the vicinity of the breach is approximately 0.06m and levels associated with the Arnold and Riston Drain to the east increase by approximately 0.16m (see Drawing 20-206-60-240).

4.4.17 The Monk Dike Breaches are not particularly sensitive to inflows.

Roughness Sensitivity Increase

4.4.18 Increasing Manning's roughness by 20% generally results in levels changing by +/- 0.05m (see Drawings 20-206-60-241 to 20-206-60-243). Some limited areas report a change in the +/- 0.1m range. Within the developed areas the changes are consistently within +/- 0.01m. The exception is the southern part of Land Area C which generally have a predicted increase of approximately 0.025m. There are four cells associated with the low spot in Land Area C which have predicted increases of 0.141m, 0.276m, 0.177m and 0.041m.

Development Roughness Increase

4.4.19 Increasing Manning's roughness in the developed areas to 0.1 results in a change in flood levels of +/- 0.005m (see Drawings 20-206-60-244 to 20-206-60-246). The only exception to this is in the southern part of Land Area C where an increase in flood levels of approximately 0.015m is predicted. This does not propagate outside the site boundary. This is not surprising given that the flooding is slow moving, slow rising and volume rather than conveyance driven.

4.4.20 It is concluded that the development proposals would not result in a material change in flood risk and would not negatively impact third parties.

Missing Structures

4.4.21 A suite of additional runs testing the impact of structures which were not included in the original model are discussed in the addendum in Appendix F.

5 DEVELOPMENT RECOMMENDATIONS

5.1 Managing Actual Risk

5.1.1 The majority of the site is not at risk of flooding during the design event. However, there are parts of the site where flooding is predicted.

5.1.2 In accordance with the sequential approach, these areas should be used for the least vulnerable uses which in this case is solar panels. The minimum height of the panels would be 0.8m.

5.1.3 The sensitivity tests demonstrate that the flood levels are not particularly sensitive to model assumptions. The increases are generally less than 0.1m and less than 0.2m in Land Area D. Furthermore, simulation of the Credible Maximum Scenario for 2100 generally only results in increases of 0.15m.

5.1.4 On that basis, a freeboard allowance of 0.3m should be sufficient to account for uncertainty and any floating debris. The catchment is almost entirely agricultural with limited tree cover, the major watercourses are embanked and the flood velocities in the floodplain are very low and for the most part originate from low-level ditches that drain pasture or arable land. Therefore raising panels 0.3m above the design event flood should be sufficient.

5.1.5 The supporting water sensitive infrastructure (inverters, DNO substations etc.) would be inside containers and as a minimum raised 0.5m above surrounding ground levels. These should be located outside the areas predicted to be flooded in the design event. If this is not possible they would set at least 0.3m above the design event flood level. Sensitive infrastructure in the predicted flood extents would be raised using plinths or pads to negate the impact on floodplain displacement. Based on the model sensitivity test results, such plinths or pads would have negligible impact on the propagation of floodwater.

5.1.6 The proposals include two exporting substations. These substations would be located outside the Credible Maximum Scenario flood extents. Water-sensitive infrastructure within the substation compounds should be raised at least 0.3m above the predicted maximum water levels during the Credible Maximum Scenario.

5.2 Managing Breach Risk

5.2.1 The breach simulations represent flooding in an incredibly unlikely scenario. It assumes that a 1 in 100 year flood (with 17% uplift for climate change) coincides with the peak of a highest astronomical tide. It is also assumed that a breach of 40m-50m occurs at the peak of the resultant flood.

5.2.2 In the case of the Hull Breach 1, this assumes an instantaneous loss of 50m of bank approximately 3.5m high and 35m deep which is clearly physically implausible.

5.2.3 Nonetheless, where possible, it is recommended that the panels are designed so that the lowest panel edges are above the breach flood level. This should mitigate against the risk of flooding should there be a breach of the River Hull defences.

5.2.4 Breaches on the Monk Dike result in less predictable flooding. However, the 12 breach simulations have identified the areas where deep flooding could occur and also demonstrated that flooding in these locations is not particularly sensitive to the precise location of the breach. Elsewhere, it is unlikely that breach depths would exceed the minimum panel height of 0.8m in proposed areas of development which are offset approximately 30m from the banks.

5.2.5 Supporting containerised infrastructure should be located outside of the breach extents where possible. However, this infrastructure does need to be distributed throughout the site. In the case of Land Areas B and C which are potentially at risk of a breach of the Monk Dike this infrastructure should be sited on the highest available land and be raised above the predicted breach levels where necessary.

6 SUMMARY AND CONCLUSIONS

6.1.1 Detailed 1D-2D hydraulic modelling has been carried out as requested by the EA to inform the layout for a proposed solar development at Peartree Hill Farm, north of Hull.

6.1.2 The modelling work is based on the Hull and Holderness model provided under licence by the EA. Minor changes were made to the model to stabilise it with the latest Flood Modeller and Tuflow executables.

6.1.3 The fluvial inflows and tidal boundary were updated to produce outputs for the design event at the end of the proposed development’s lifetime; a 1 in 100 year flood in 2066.

6.1.4 During the design event, the vast majority of the site is not predicted to flood. There is flooding associated with the Holderness Drain in the east and the Monk Dike and Arnold Riston Drain. The layout available at the time of this report excluded all water-sensitive supporting infrastructure from the areas shown to be at risk. Panels should be raised above the flood level to ensure that they remain operation during a flood.

6.1.5 18 breach simulations have been carried out. These breaches assume a catastrophic, instantaneous failure of substantial earth embankments which protect vast areas of land. They also assume that this failure occurs at the peak of a future 1 in 100 year flood coinciding with a future highest astronomical tide. This is incredibly unlikely, but where possible the development should be designed so no water sensitive infrastructure is affected, and the site remains operational.

6.1.6 The 6 breaches for the River Hull are considered to adequately cover the range of potential impacts of breach on the western land areas. It is recommended that panels and all water sensitive infrastructure should be raised above the maximum breach level. The northern River Hull breaches resulted in extensive deep flooding and were a key consideration of the removal of Parcel A from the development proposals.

6.1.7 The 12 breaches for the Monk Dike are considered to adequately represent the worst-case scenario for various land areas in terms of breach flooding. However, given the topography some areas adjacent to the flood defences is not shown to be flooded in the combined breach depth outputs. To safeguard against the potential for breaches in other locations it is recommended that the containerised water-sensitive infrastructure is located at least 100m from the Monk Dike banks and least 0.5m above existing ground levels. Panels are proposed to commence approximately 30m from the banks and would have a minimum height of 0.8m when tilted and 1.5m when flat which should be sufficient to mitigate breaches in locations that have not been modelled.

6.1.8 Sensitivity testing of the tidal boundary, fluvial inflows and Manning’s roughness demonstrate that the model is not particularly sensitive to these conditions. Generally, increases in flood level are below 0.1m and entirely below 0.2m.

Modelling of the H++ Credible Maximum Scenario flood for 2100 resulted in an increase in flood levels of up to 0.15m. Accordingly it is concluded that 0.3m freeboard should be sufficient to account for uncertainty and any limited floating debris.

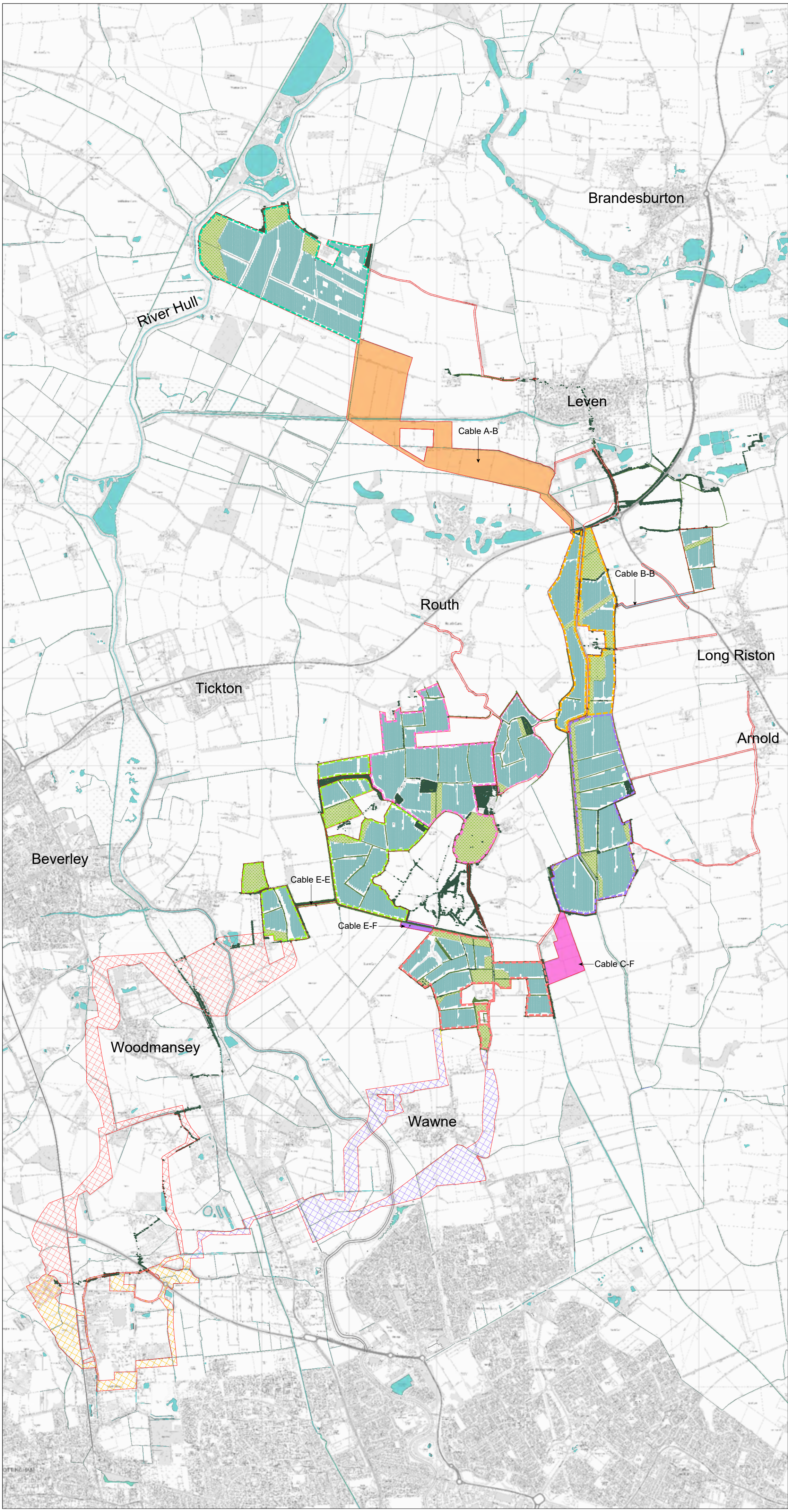
6.1.9 Given the importance of the two exporting substations, they should be located outside the flood extents for the Credible Maximum Scenario. To further safeguard again the potential for catastrophic climate change it is recommended that any water-sensitive infrastructure in the substations is at least 0.3m above the Credible Maximum Scenario water level.

6.1.10 The modelling work presented in this document was submitted to and reviewed by the EA. The EA review included requests for clarification and some additional simulations which have been addressed and are discussed in the modelling addendum submitted to the EA on August 14th 2024 (Appendix F). The EA confirmed that the hydraulic modelling work is ‘fit for purpose’ in a letter dated 29th August 2024.

APPENDICES

APPENDIX A

Proposed Operational Phase Layout Plan



Key

Draft Order Limits

Existing Features

- Woodlands within and around the Site
- Hedgerow/Trees within and around the Site
- Waterbodies and Watercourses

Proposed Development Construction Elements

- Solar PV Modules
- Indicative Areas for Mitigation, Enhancement and/or Retained Agricultural Land

Interconnecting Cabling Corridors between Land Areas:

- Cable A-B
- Cable B-B
- Cable C-F
- Cable E-E
- Cable E-F

Cable Route Corridor Options to Creyke Beck Substation:

- Cable Route Option 1
- Cable Route Option 2
- Cable Route Mixed Option

Land Areas:

- Land Area A
- Land Area B
- Land Area C
- Land Area D
- Land Area E
- Land Area F

Coordinate System: WCS

Rev	Date	Description	Drn	Chk	App

Peartree Hill Solar

RWE

TITLE: Proposed Operational Phase Layout Plan

ID: Stage 2 Peartree NTS

0 0.5 1 1.5
Kilometers

Scale:1:60,000 @ A4

N W E S

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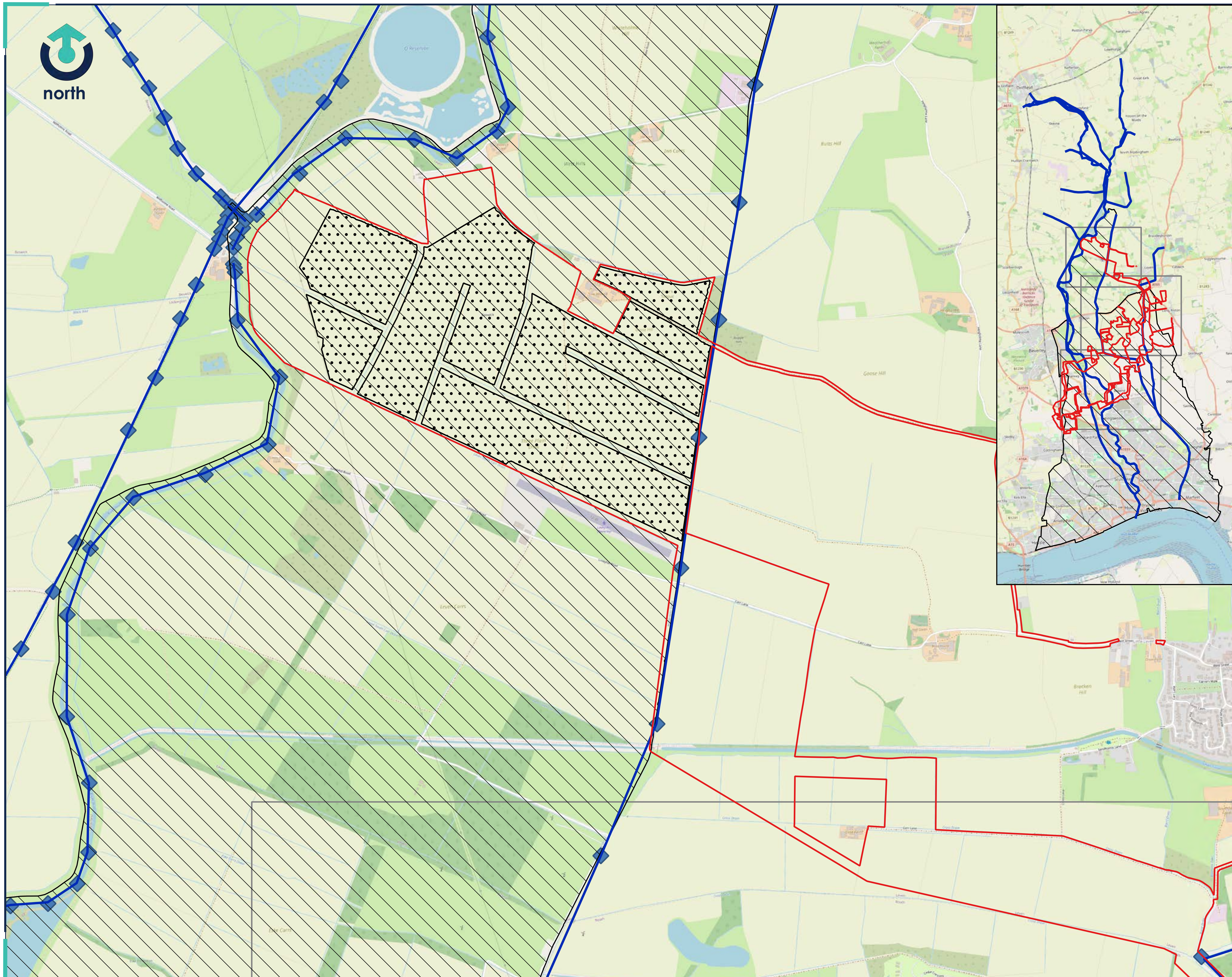
APPENDIX B

Model Overview and Topography Drawings



Legend

Site Boundary	
Sensitive Infrastructure	
1D Nodes	
1d Watercourses	
2d Model Extent	

Notes

Beyond the 2D model extent the floodplain is modelled in 1D using reservoir units. Mapping outputs have not been generated for these areas as no development other than cabling are proposed within them.

Sensitive infrastructure areas encompass the coverage of solar panels, substations, inverters, battery storage etc. but do not include access or cable routes.

-	SECOND ISSUE	AB	17.04.2024
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STATUS: FOR INFORMATION

CLIENT: RWE

SITE: Peartree Hill Solar Farm

TITLE: Hydraulic Model Extent
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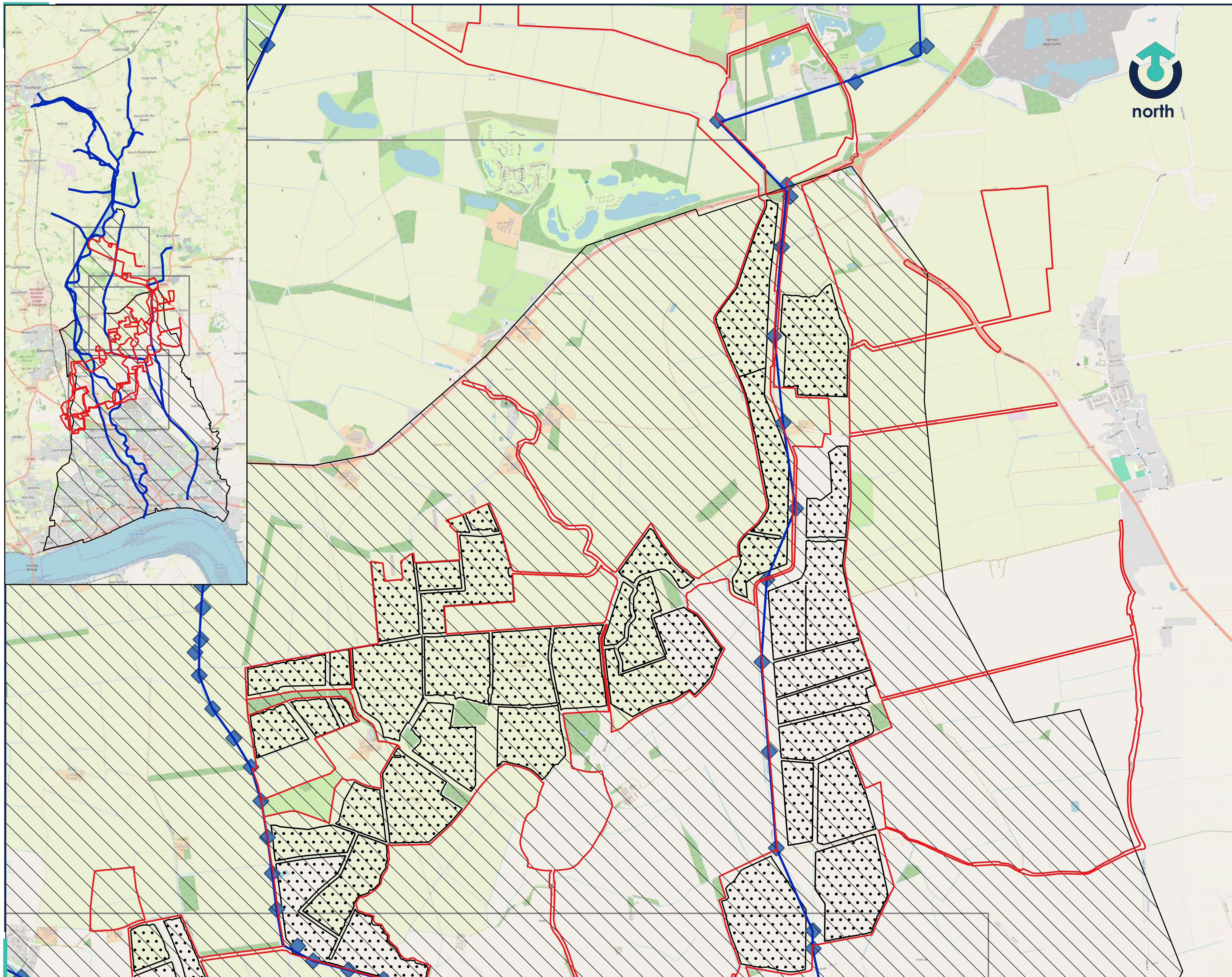

Legend

- Site Boundary
- Sensitive Infrastructure
- 1D Nodes
- 1d Watercourses
- 2d Model Extent

Notes

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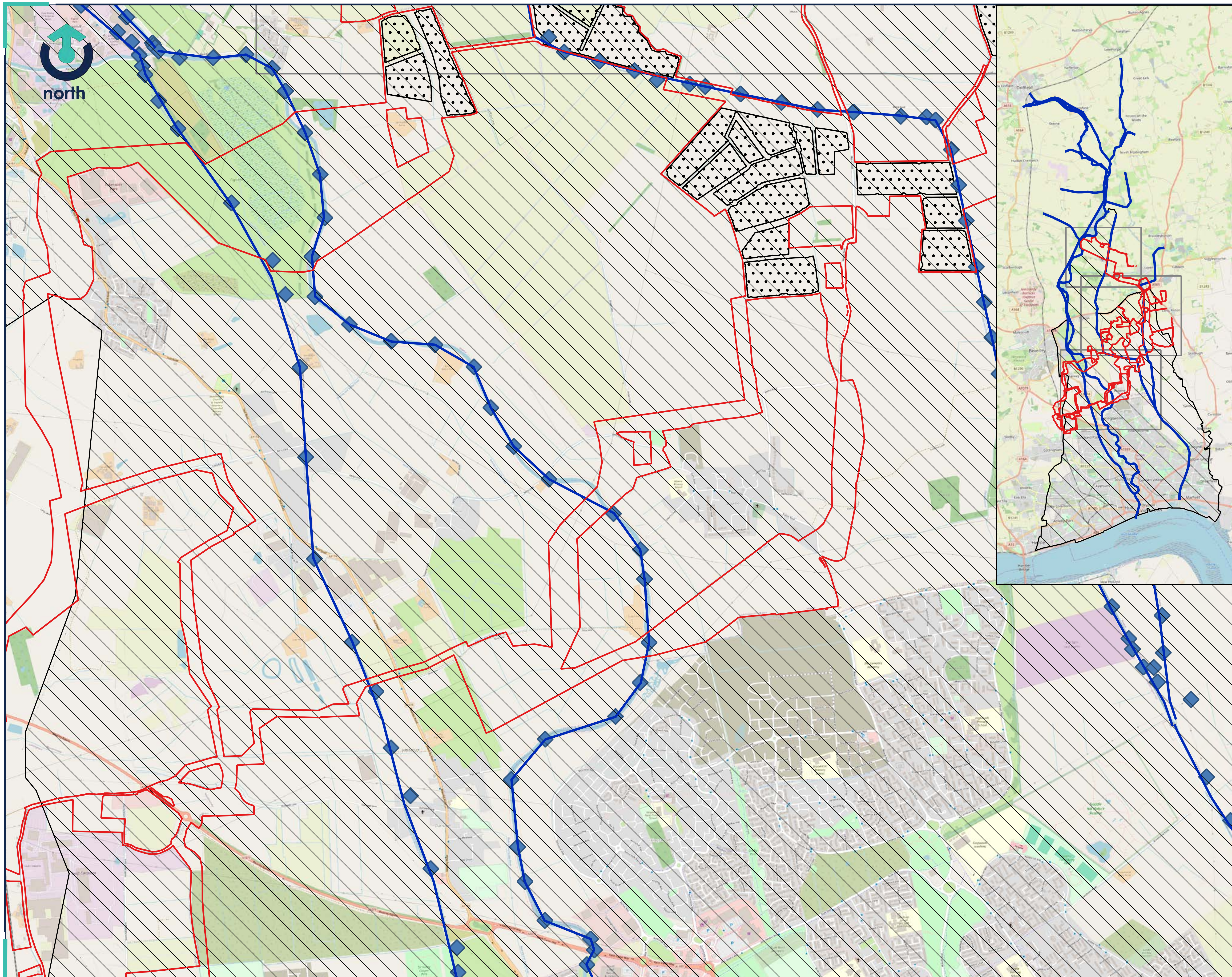

Legend

- Sensitive Infrastructure
- 1D Nodes
- 1d Watercourses
- 2d Model Extent
- Site Boundary

Notes

Beyond the 2D model extent the floodplain is modelled in 1D using reservoir units. Mapping outputs have not been generated for these areas as no development other than cabling are proposed within them.

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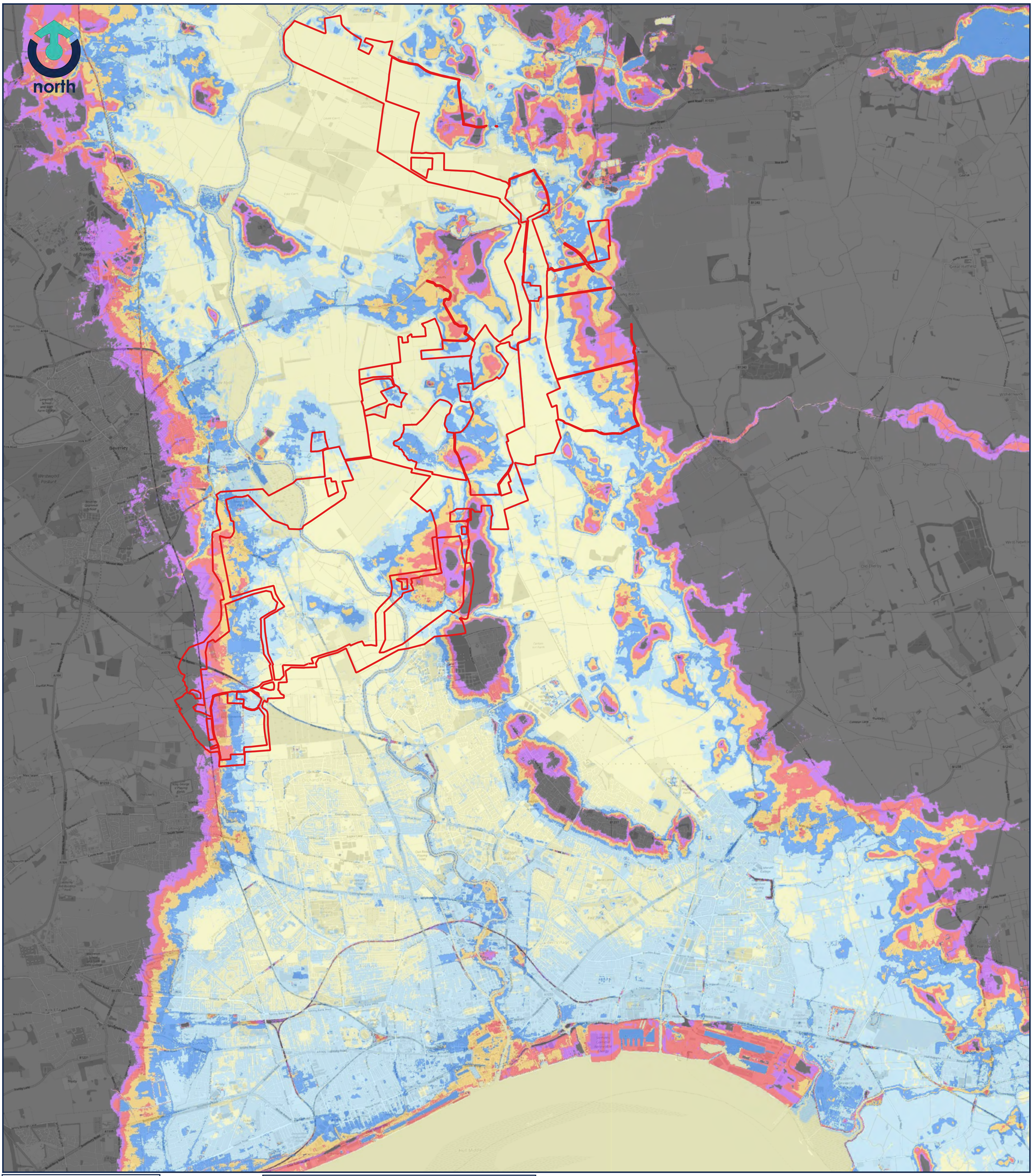

Legend

Site Boundary

Ground Levels (mAOD)

- <2.0
- 2.0 to 3.0
- 3.0 to 4.0
- 4.0 to 5.0
- 5.0 to 6.0
- 6.0 to 7.0
- >7.0

STATUS: FOR INFORMATION

CLIENT: RWE

SITE: PEARTREE HILL SOLAR

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-	FIRST ISSUE		CF	15.04.24

TITLE: TOPOGRAPHY

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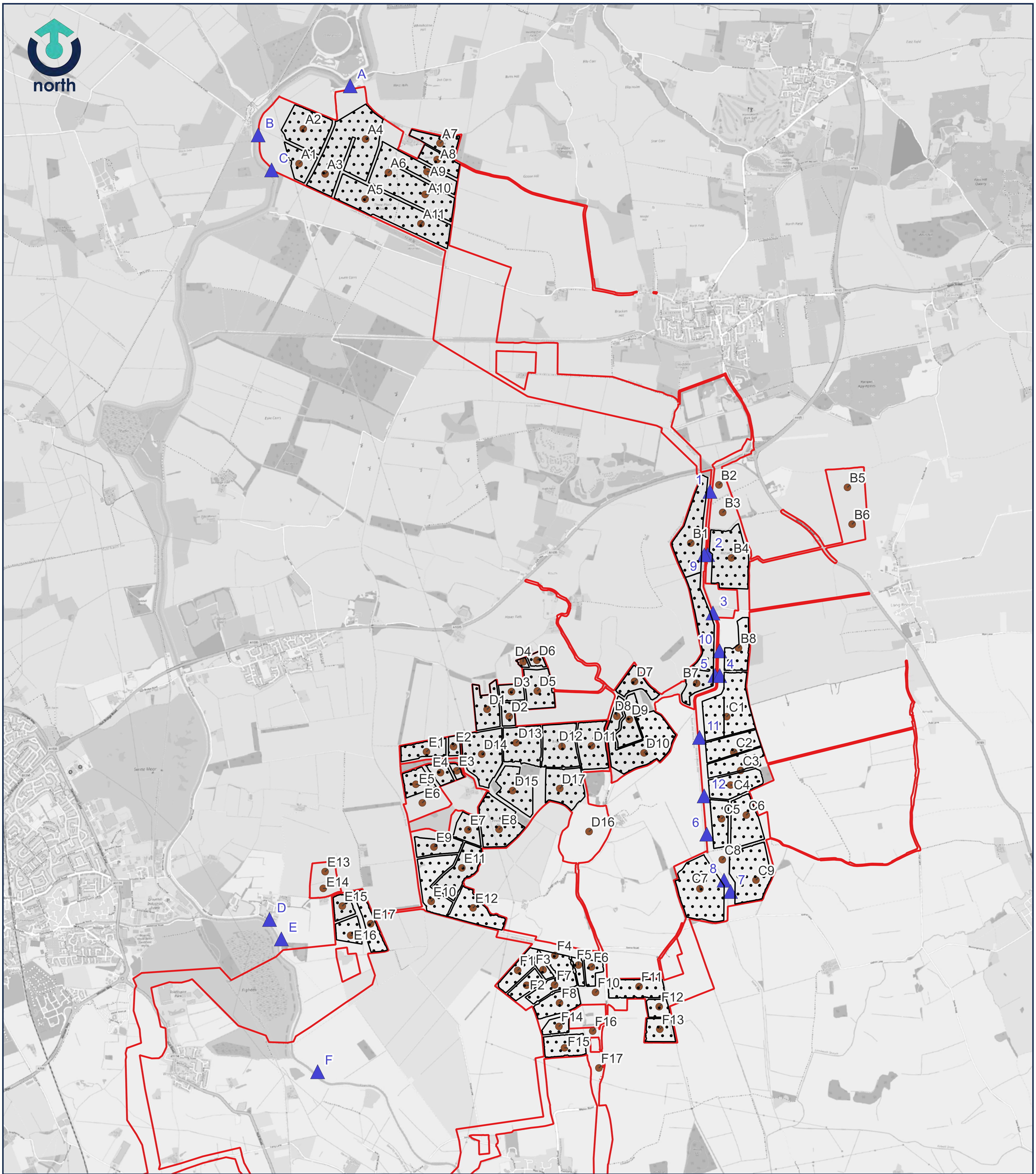

Legend

- Site Boundary
- Breach Locations
- Sensitive Infrastructure
- Parcel Names

STATUS: FOR INFORMATION

CLIENT: RWE

SITE: PEARTREE HILL SOLAR

REV:	DESCRIPTION:	AMENDMENTS:	BY:	DATE:
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TITLE: BREACH LOCATIONS AND PARCEL NAMES

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