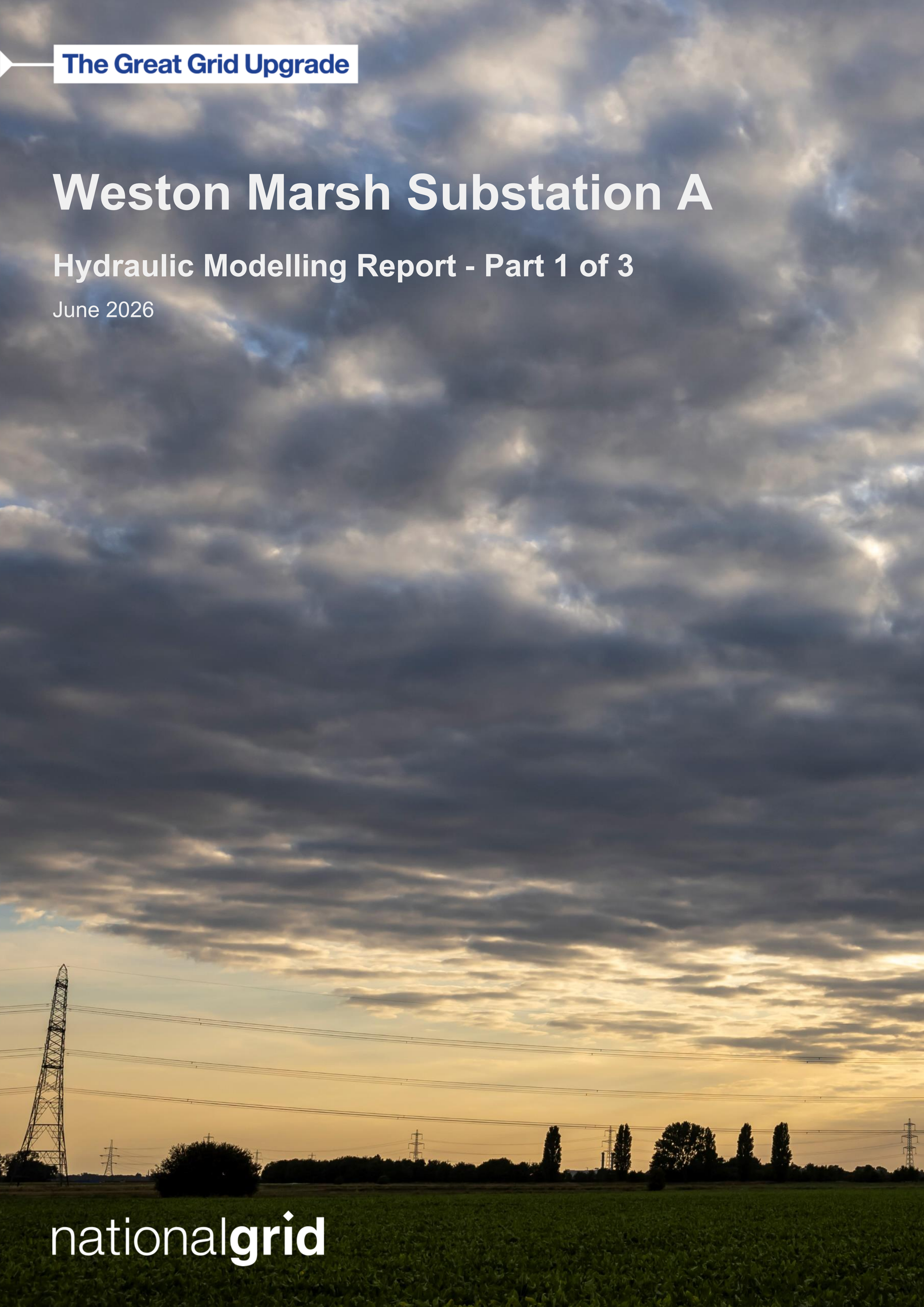
The Great Grid Upgrade



Weston Marsh Substation A

Hydraulic Modelling Report - Part 1 of 3

June 2026

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Weston Marsh Substation A
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Contents

Executive summary

This hydraulic modelling report has been prepared by WSP on behalf of National Grid Electricity Transmission plc (National Grid) to summarise the hydraulic modelling analysis undertaken to inform a Flood Risk Assessment (FRA) for the proposed Weston Marsh Substation A, located northeast of the town of Spalding, in Lincolnshire.

As explained in further detail within the FRA, Weston Marsh Substation A is a key component of a standalone Scheme to enable connection of the Outer Dowsing Offshore Wind Farm to the national electricity transmission system. The Scheme in its totality also includes works to the existing 4ZM and 2WS 400 kV overhead lines which meet at what is referred to as the 'Spalding Tee-Point'.

The modelling undertaken aims to assess the potential flood risk to the proposed Weston Marsh Substation A from tidal overtopping as well as the residual flood risk resulting from a breach failure of the flood defence that lines the River Welland, which runs adjacent to the site. In agreement with the Environment Agency (EA), fluvial flood risk is not a concern due to upstream sluices within the catchment, and thus only tidal flood risk has been modelled.

The basis of the modelling is the EA approved River Welland Breach model (Ref 2) built by SLR Consulting Limited for the Outer Dowsing Offshore Wind project (ODOW) (2025).

To inform a site-specific flood risk assessment for the area of the proposed Weston Marsh Substation A, the existing model was reviewed and updated to ensure its suitability for this assessment. The updates made to the model mainly consist of ground level alterations to represent the proposed Weston Marsh Substation A layout, in addition to minor model updates to enhance the model accuracy and stability.

Prior to commencing the modelling work, a modelling methodology statement (Ref 3), including details on the above model updates, was issued to the EA and the modelling approach was subsequently agreed with them.

To assess the impacts of climate change, the model was run using the revised climate change allowances as set out in the latest EA's guidance for climate change (Ref 4).

In agreement with the EA, the following design standards have been adopted:

- The design event is the 0.1% AEP (Annual Exceedance Probability) plus climate change event (thus 1000yr+CC event), based on the Upper End climate change allowance.
- To ensure that the proposed Weston Marsh Substation A is resilient to the effects of climate change during its design life of 75 years, a climate change scenario with a 75-year horizon (i.e. in year 2105) is assessed through the tidal overtopping and breach modelling.
- National Grid stipulates that the finished floor level of the proposed asset is to be set 300mm (that is a 0.3m freeboard) above the modelled flood level for the design event.

Key outcomes of the modelling assessment are outlined below:

- Results from tidal overtopping scenario runs indicate that the proposed Weston Marsh Substation A remains outside the modelled flood outlines, even for the most extreme event i.e. 0.1% AEP plus (Upper End) climate change event in year 2105.

- Residual flood risk associated with potential defence breach/failure will pose the greatest risk to the proposed Weston Marsh Substation A.
- A peak flood level of 4.123mAOD is predicted from the breach scenario model run for the design 0.1% AEP plus (Upper End) climate change in 2105 event.
- The finished floor level of the proposed Weston Marsh Substation A will be set to a minimum elevation of 4.423mAOD, as obtained by adding 0.3m freeboard to the predicted peak flood level above.

This report supplements the FRA for the site and provides flood depth, level, impact and hazard maps to inform a better understanding of the magnitude and extents of flooding for a range of tidal overtopping and breach scenarios.

1. Background

1.1 Context

1.1.1 WSP have undertaken hydraulic modelling on behalf of National Grid Electricity Transmission plc (National Grid) to support a Flood Risk Assessment (FRA) for the proposed Weston Marsh Substation A, located northeast of the town of Spalding, in Lincolnshire.

1.1.2 The land required permanently for the Weston Marsh Substation A operational compound and associated ancillary works is referred to in this report as 'Weston Marsh Substation A'. The proposed Weston Marsh Substation A lies in the right-bank floodplain area of the River Welland (**Image 1.1**) within an area benefitting from the presence of linear defences that line the River Welland channel, as does the wider extent of land required to construction and operate the substation (the Substation Works Site).

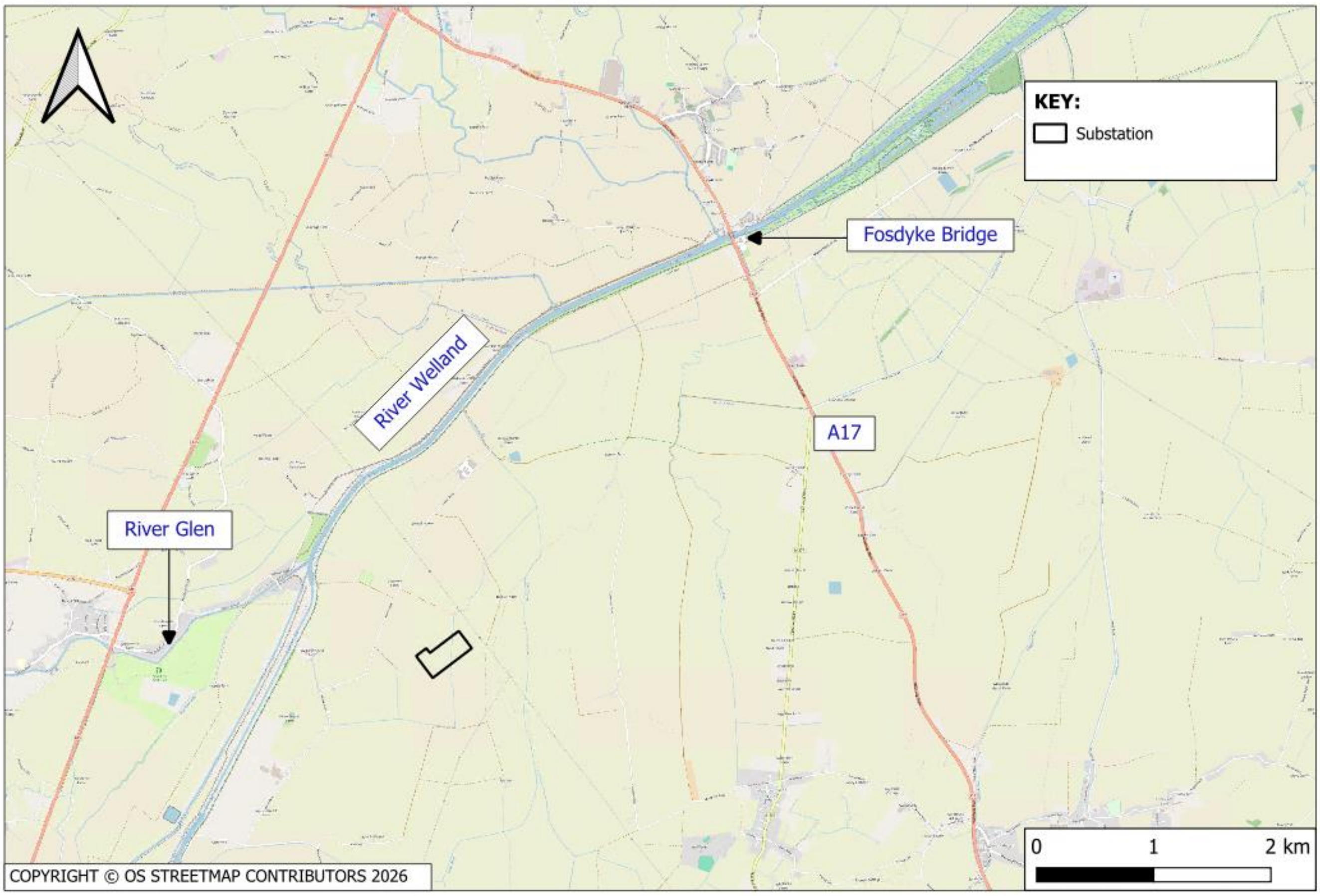

Image 1.1 Weston Marsh Substation A Location

1.1.3 Based on the Environment Agency (EA) Asset Information Management System (AIMS) data (Ref 5), the defences provide a Standard of Protection (SoP) that varies from a 2% Annual Exceedance Probability (AEP) flood event to a 1% AEP event for the majority of the primary defence line, with a few defence segments achieving a SoP up to a 0.5% AEP event.

1.1.4 Owing to the upstream Surfleet Sluice (River Glen) and Marsh Road Sluice (River Welland), which serve to control fluvial flows, flood risk posed by the River Welland in the vicinity of the proposed Weston Marsh Substation A is entirely tidal.

1.1.5 Therefore, hydraulic modelling analysis has been undertaken to assess the potential tidal flood risk to the proposed Weston Marsh Substation A from overtopping of the River Welland flood defence as well as the residual flood risk resulting from a possible defence collapse or breach failure.

1.1.6 The modelling work was carried out using the EA approved River Welland Breach model (Ref 2) as a basis. The existing hydraulic model was developed by SLR Consulting Limited as part of the ODOW project (2025).

1.1.7 Prior to commencing the modelling work, a modelling methodology statement (Ref 3), including details on the above model updates, was issued to the EA and the modelling approach was subsequently agreed with them.

1.1.8 The main objectives of the modelling assessment are as follows:

- Update the existing River Welland Breach model to make it suitable to inform a site-specific FRA for the Weston Marsh Substation A, by incorporating the model updates recommended within the modelling methodology statement (Ref 3).
- Provide peak flood level prediction for the key design event, notably 0.1% AEP plus (Upper End) climate change in 2105, considering worst case scenario conditions among breach and tidal overtopping; this is to inform design levels at the proposed Weston Marsh Substation A.
- Produce flood depth maps to inform on local flood risk from both tidal overtopping and defence breach, for a range of events including the 0.5% AEP (for tidal overtopping runs only) and 0.1% AEP (for both tidal overtopping and breach runs), and both for present day and future scenarios.
- Produce flood impact and hazard maps to inform an assessment of impact on (third-party) sensitive receptors.

1.2 Scope of Works

1.2.1 The following modelling tasks were undertaken:

- Acquire the revised peak tide predictions where the River Welland discharges into The Wash, near Fosdyke Bridge (downstream end of the model), as informed by the EA Coastal flood boundary conditions guidance (Ref 6).
- Derive a base tidal curve for the design 0.5% AEP (200yr) and 0.1% AEP (1000yr) events, using the info above in combination with tide curves generated from TotalTide software (Ref 7).
- Apply the revised sea level rise uplifts as informed by the latest EA climate change guidance (Ref 4) to obtain tide profiles with a 75-year horizon (i.e. in year 2105) to reflect the 75-year design life of the proposed Weston Marsh Substation A.

- Update the existing River Welland Breach model as recommended in the modelling method statement (Ref 3) (including improved representation of flood defences in the model, adoption of a revised Manning’s N roughness coefficient for urban areas, fixing of the model instability near the upstream boundary and raising of the substation platform to the design finish floor level to simulate post-development scenario conditions).
- Undertake sensitivity analysis to enhance the level of confidence in the model and its results, including sensitivity on 2D roughness coefficients, downstream boundary condition and grid cell size.
- Identify potential defence breach locations that lead to the highest peak water level predictions at the proposed Weston Marsh Substation A, to be tested independently through the modelling.
- Using the revised tidal boundaries, run the updated model for tidal overtopping and breach scenarios, for 0.5% AEP (200yr) and 0.1% AEP (1000yr) events, both for present day (i.e. in year 2025) and future scenarios (i.e. in year 2105).
- Assess modelled flood levels at the proposed Weston Marsh Substation A, by extracting results.
- Evaluate potential impact on sensitive receptors, by reviewing flood impact and flood hazard maps.
- Undertake additional sensitivity analysis for the H++ climate change allowances, to assess a credible maximum scenario using the informed total sea level rise of 1.9m to year 2100, for both the 0.5% AEP and 0.1% AEP climate change scenario runs, as requested from the EA; this will be used to inform design levels for flood resilience measures (such as waterproofing, raising of critical electricity assets, etc.).
- Undertake a sensitivity test on the breach scenario, based on a defence breach duration significantly longer than the 35 hours assumed in the model; this is to demonstrate that residual flooding would remain within the extents predicted for the design runs, with no new areas of flooding occurring elsewhere.
- Produce flood maps and a technical report.

1.3 Site Location

1.3.1 Weston Marsh Substation A is centred on National Grid Reference (NGR) TF 29403 28560, approximately 3.5km north of the village of Weston, 3km north west of Moulton Seas End and approximately 1km east of the eastern bank of the River Welland. Its footprint is approximately 8.4 ha. Proposed permanent access to Weston Marsh Substation A is via a new dedicated access road from Marsh Road to the north-west.

1.3.2 The proposed Weston Marsh A Substation will comprise the construction of a new 400kV substation, which will be connected to existing 4ZM and 2WS 400 kV overhead lines. The tallest equipment would reach up to 12.5m, with overhead line gantries up to 15m high.

2. Data collection and review

2.1 Review of the existing hydraulic models acquired

2.1.1 To support a flood modelling exercise, a data request was made to the EA to obtain their Product 5, 6 and 7 data packages that are relevant for the area of the proposed Weston Marsh A substation. In response to this request, the EA provided the following information:

- A copy of the existing EA's East Coast Overtopping and Breach models (2010) (Ref 8), including model files, selected model outputs and reports.
- A copy of the existing EA's River Welland Fluvial model (2016) (Ref 9), including model files, selected model outputs and reports.

2.1.2 In addition to this, National Grid provided the River Welland Breach model (Ref 2), a 2D (TuFLOW) tidal overtopping and breach model developed as part of the ODOW project (2025).

2.1.3 The hydraulic models received were reviewed by WSP to assess their suitability for use to quantify flood risk at the proposed Weston Marsh Substation A.

2.1.4 Following this review, the two EA models have been disregarded for different reasons. Specifically, the East Coast Overtopping and reach models (Ref 8) were discarded because they do not include overtopping or breach modelling of the River Welland. The River Welland Fluvial model (Ref 9) is a fluvial only model and cannot be used to assess tidal overtopping of the River Welland defences or their potential breach/collapse.

2.1.5 Conversely, the River Welland Breach model has been deemed fit for purpose because **a)** it simulates flood mechanisms associated with tidal overtopping and defence breach along the tidally influenced lower reach of the River Welland, **b)** its model domain includes the proposed Weston Marsh Substation A, and **c)** the model has been reviewed and approved by the EA in 2025.

2.1.6 As such, the National Grid River Welland Breach model (Ref 2) has been taken forward to provide flood levels, depths and hazard predictions at Weston Marsh Substation A and its surrounds, considering both flood risk from tidal overtopping and residual flood risk from potential breaching of the River Welland defences, and both for present day and future scenarios. This information is used to inform the FRA, to which this document is appended.

2.2 Input data

2.2.1 **Table 2.1** provides a summary of the data collected, along with a description of how the data has been used in the model.

Table 2.1 Summary of data collected

Data	Source	Purpose of the Data
River Welland Breach model and accompanying modelling report document (2025)	National Grid	Re-use of the model (with limited updates) to undertake tidal and breach modelling exercise
EA AIMS Spatial Flood Defences dataset (2025)	Government website	Defines the alignment and crest levels of the River Welland defences for the model input
EA filtered LiDAR data (2022 LiDAR 1m Composite DTM)	Defra Data Services platform	Forms the basis of the ground model
EA Coastal Flood Boundary Extreme Sea Levels dataset (2018)	Government website	Obtain revised peak tide predictions at Fosdyke Bridge (upstream boundary of the model)
EA sea level allowances for climate change (Anglian Region)	Government website	Derive tidal curves for both present day (2026) and future scenario (in year 2105, assuming a 75-year design life of the development)

3. Modelling Methodology

3.1.1 Following a detailed technical review of the River Welland Breach model (Ref 2), WSP prepared a modelling methodology statement report (Ref 3) to confirm the suitability of the model to inform an FRA for the Weston Marsh Substation A and to set out the proposed modelling approach.

3.1.2 Within this document, WSP highlighted various model updates that were deemed necessary to inform a site-specific FRA for the Weston Marsh Substation A.

3.1.3 The following model updates were proposed:

- Derive a revised base tidal curve to update the hydrological input of the model (i.e. upstream tidal boundary), in accordance with the EA's Coastal Flood Boundary user guide (Ref 6) and using the latest EA Coastal Flood Boundary Extreme Sea Levels dataset (Ref 10) (2018) at Tabs Head (which is the nearest coastal location to the tidal estuary of the River Welland).
- Uplift the base tidal curve obtained above, using the revised sea level rises as set out in the latest EA's climate change guidance (Ref 4), with a 75-year horizon (i.e. in year 2105) to reflect the assumed 75-year design life of the proposed Weston Marsh Substation A.
- Update the model to assess the post-development scenario conditions, by raising the substation platform (footprint) area above the modelled 0.1% AEP+CC (Upper End) peak flood level in year 2105, with the addition of a 0.3m (i.e. 300mm) freeboard, in accordance with the design standard for critical infrastructure adopted by National Grid.
- Change Manning's N roughness coefficient for urban areas from 0.1 (current value) to 0.025, in accordance with recommended range of values adopted for urban land use.
- Review LiDAR (Ref 11) and EA AIMS data (Ref 5) over the extents of the River Welland defence, to determine which dataset among these two is to be used for setting defence crest levels in the model.
- Improve the representation of the River Welland defences, by ensuring that the Z-shape feature used to enforce defence crest levels in the (TuFLOW) model consistently apply the 'NO MERGE' function to the 2D cells underlying the river defence line.
- If possible/feasible, fix the local instability that was reported to affect the model in proximity of its downstream (HQ) boundary.

3.1.4 For the purpose of this study, the model was run for a set of tidal overtopping and breach scenarios as described below:

Tidal overtopping

- Baseline model runs for the 0.5% AEP (i.e. 1 in 200 year) tidal event for both present day (i.e. in year 2026) and future scenario (in year 2105), using the Upper End climate change allowance.
- Baseline model runs for the 0.1% AEP (i.e. 1 in 1000 year) tidal event for both present day (i.e. in year 2026) and future scenario (in year 2105), using the Upper End climate change allowance.

Defence breach

- Baseline model runs for the 0.5% AEP (i.e. 1 in 200 year) tidal event for both present day (i.e. in year 2026) and future scenario (in year 2105), using the Upper End climate change allowance.
- Baseline model runs for the 0.1% AEP (i.e. 1 in 1000 year) tidal event for both present day (i.e. in year 2026) and future scenario (in year 2105), using the Upper End climate change allowance.
- Post-development model run for the design 0.1% AEP (i.e. 1 in 1000 year) plus (Upper End) climate change tidal event in year 2105, with the Weston Marsh Substation A platform being set to the agreed design finished floor level (i.e. modelled peak flood level for the 1000 year with Upper End climate change event in year 2105 with the addition of a 0.3m freeboard).

3.2 Environment Agency Consultation

3.2.1 As discussed above, WSP prepared a modelling methodology statement (Ref 3) to present the outcomes of the internal technical audit of the hydraulic models received and to describe the proposed approach for the tidal overtopping and breach modelling exercise for the proposed Weston Marsh Substation A.

3.2.2 The modelling methodology statement was submitted to the EA, and following this a meeting was held with the EA on 20th of October 2025 to agree the modelling approach plus model parameters to adequately assess flood risk to the proposed Weston Marsh Substation A.

3.2.3 In this meeting, the EA confirmed their agreement in principle with the proposed modelling methodology, including the re-use of the ODOW model. Additionally, the EA highlighted that a defence breach scenario is of main relevance for informing flood mitigations, not the overtopping scenario. This is due to the low-lying nature of the (right-bank) River Welland floodplain area that encompasses the new proposed substation.

3.2.4 In March 2026, the EA issued a consultation response on the wider Grimsby to Walpole Preliminary Environmental Information Report (PEIR) (Ref 12), with a focus on Section 5 for Weston Marsh Substation A and Weston Marsh Substation B (this is a different site for which flood risk will be assessed as part of the Grimsby to Walpole Development Consent Order application). Given the relevance of this response to the Weston Marsh Substation A, it has informed this hydraulic modelling report. The relationship between Grimsby to Walpole and the Weston Marsh Substation A proposals is explained in further detail in the FRA.

3.2.5 Within the response, the EA requested that sensitivity test runs be undertaken on both the tidal overtopping and breach model scenarios, using the H++ climate change allowance. The model is to be run for H++, for both the 0.5% AEP and 0.1% AEP tidal events, to evaluate future resilience of the proposed Weston Marsh Substation A.

3.2.6 In accordance with the EA climate change guidance (Ref 4), an increase of 1.9m is to be applied for total sea level rise to 2100 to carry out the H++ scenario runs.

3.2.7 Following the completion of the tidal and breach modelling exercise, WSP have held a meeting with the EA (on 26th March 2026), to describe the modelling done and present its results in anticipation of the TCPA modelling package submission.

3.2.8 In this meeting, the EA confirmed the appropriateness of the modelling presented to support the TCPA application (subject to their subsequent technical review audit confirming that hydraulic model is fit for purpose).

3.2.9 In addition, the EA requested that a sensitivity test be undertaken on breach scenario based on breach failure persisting for a longer time interval than the 35-hour duration assumed in the design runs. This is to ascertain that flooding areas predicted from the model would remain unchanged even if it takes significantly longer than expected to repair the defence breach once occurred. This has been carried out, with results illustrated by Figure 15.

4. Tidal boundary derivation

4.1 Methodology

4.1.1 Tidal boundaries for the model have been updated from those present in the ODOW model (Ref 2) to reflect current EA guidelines indicated within the Coastal Flood Boundary user guide (Ref 6). The tidal boundary location has been retained from the River Welland Breach model (Ref 2), and the boundary type remains a Head vs Time (HT) boundary curve.

4.1.2 The underlying tide curve used to generate the design tidal boundaries is a tidal curve extracted from the Admiralty Total Tide Software (Ref 7), while the Extreme Water Levels (EWLs) for the model were obtained from the EA Coastal Flood Boundary Extreme Sea Levels dataset (Ref 10) alongside the corresponding storm surge shape. Tidal boundaries were uplifted to account for Sea Level Rise to the year 2105, representative of the 75-year design life of the scheme starting from 2030.

4.2 Base Tide

4.2.1 The base tide for the boundaries was obtained for Station 0165, Tabs Head, located at the mouth of the River Welland, where the tide type is Semi-Diurnal. Following the Coastal Flood Boundary user guide (Ref 6), the tide was extracted for a period of 7 days, with the peak at a level between Mean High Water Spring (MHWS) and Highest Astronomical Tide (HAT). Levels were converted from Chart Datum (CD) for Tabs Head to Ordnance Datum (OD) using the -3.7m site specific conversion provided directly on Admiralty Total Tide (Ref 7).

4.2.2 Tidal levels for Tabs Head are presented in **Table 4.1**.

Table 4.1 Tidal Levels for Tabs Head from UKHO

Tide Level	mCD	mOD
Highest Astronomical Tide (HAT)	8.4	4.7
Mean High Water Springs (MHWS)	7.5	3.8
Mean High Water Neaps (MHWN)	5.6	1.9
Mean Sea Level (MSL)	3.85	0.15
Mean Low Water Neaps (MLWN)	2.4	-1.3
Mean Low Water Springs (MLWS)	0.7	-3.0
Lowest Astronomical Tide (LAT)	-0.1	-3.8

4.2.3 The tidal record was cut to a range of 5-days with the peak tidal level occurring around the centre of the selected period and forms the base astronomical tide curve for the design tides created for the modelled events. This is shown in **Image 4.1** below.

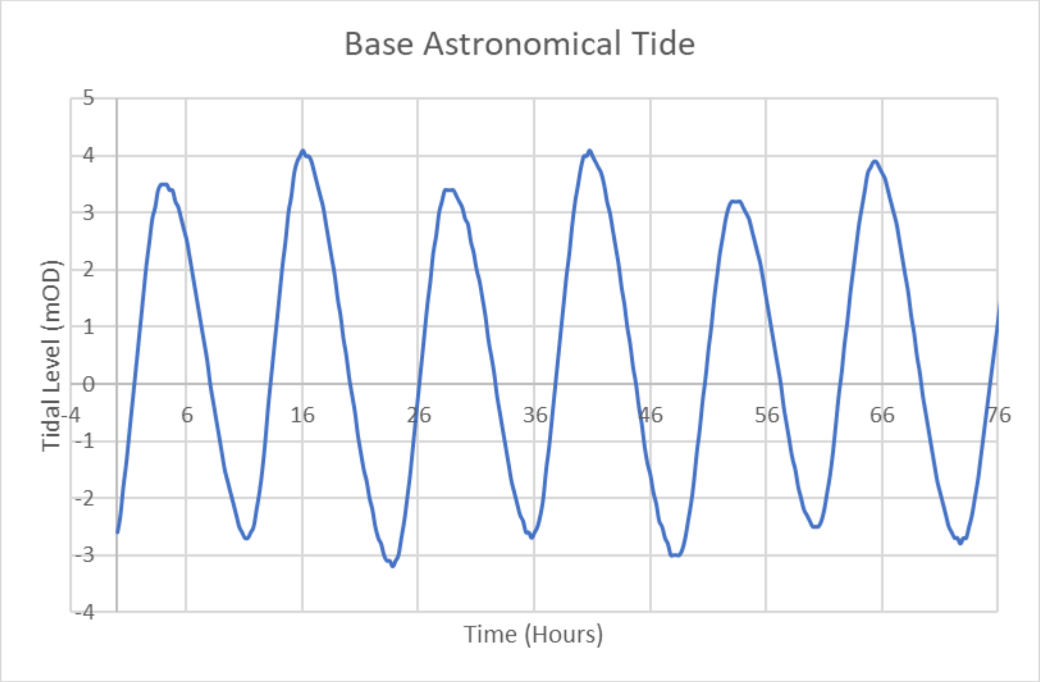

Image 4.1 Base Astronomical Tide for Tidal Boundary Creation

4.3 Extreme Water Levels

4.3.1 EWLs were extracted at the estuary of the River Welland for the EA Coastal Flood Boundary Extreme Sea Levels dataset (Ref 10) chainage point ‘*3992.6’* (Easting: 532972.15; Northing: 332864.78) for the 0.5% AEP and 0.1% AEP events.

4.3.2 As described in the Coastal Flood Boundary user guide (Ref 6), a surge shape was applied to uplift the peak of the tide and allow it to reach the corresponding EWL for each event. This procedure accounts for the effect of storm surges in the occurrence of extreme water levels. The relevant surge shape for the site as indicated within the EACFB Dataset is Surge Shape 7 – Immingham is shown in **Image 4.2**.

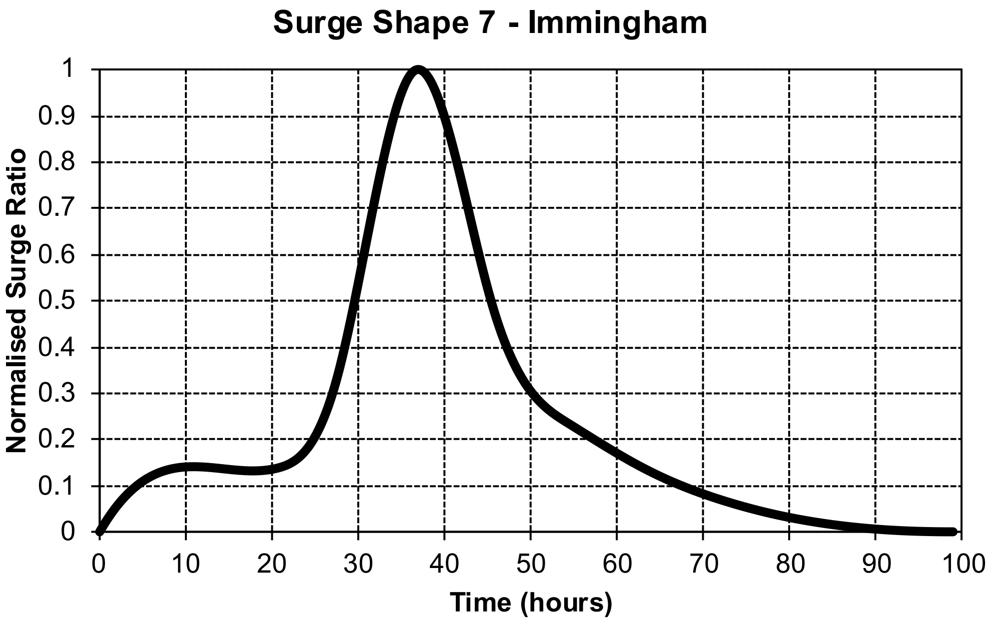

Image 4.2 Area Specific Storm Surge Shape from EACFB Dataset

4.4 Sea Level Rise

4.4.1 EA Coastal Flood Boundary Extreme Sea Levels dataset (Ref 10) available was last updated in 2018, uplifts for sea level rise were applied to the different events to match the present day 2026 epoch and the 2105 future epoch. Sea level rise uplifts were calculated for both Higher Central and Upper End climate change allowances with reference to the Anglian River Basin District sea level allowances for each epoch in mm as indicated in the latest EA's climate change guidance (Ref 4), as shown in the excerpt in **Image 4.3**.

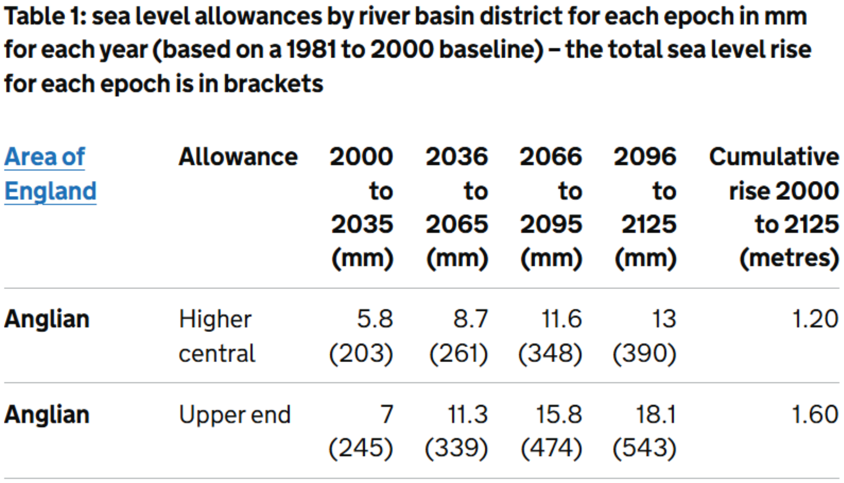

Table 1: sea level allowances by river basin district for each epoch in mm for each year (based on a 1981 to 2000 baseline) – the total sea level rise for each epoch is in brackets

Area of England	Allowance	2000 to 2035 (mm)	2036 to 2065 (mm)	2066 to 2095 (mm)	2096 to 2125 (mm)	Cumulative rise 2000 to 2125 (metres)
Anglian	Higher central	5.8 (203)	8.7 (261)	11.6 (348)	13 (390)	1.20
Anglian	Upper end	7 (245)	11.3 (339)	15.8 (474)	18.1 (543)	1.60

Image 4.3 EA climate change allowances for sea level rise

4.4.2 Sea level rise uplift was also calculated for the H++ scenario, a credible maximum scenario for sea level rise to year 2100 (there is no value for H++ beyond 2100). This scenario is specified by the EA as an increase of 1.9m for the total sea level rise to 2100.

4.5 Resulting Design Boundary

4.5.1 The final tidal boundary peak levels for each event are shown in **Table 4.2**.

Table 4.2 Tidal boundary peak water levels

Scenario	Levels (mAOD)	Climate Scenario
0.5% AEP (1 in 200) in 2026	6.03	Higher Central
	6.04	Upper End
0.5% AEP (1 in 200) in 2105	6.82	Higher Central
	7.10	Upper End
0.1% AEP (1 in 1000) in 2026	6.34	Higher Central
	6.35	Upper End
0.1% AEP (1 in 1000) in 2105	7.13	Higher Central
	7.41	Upper End
0.5% AEP H++	7.94	H++
0.1% AEP H++	8.25	H++

4.5.2 The final design tidal boundaries, with the surge shape and sea level rise uplifts already included can be seen in **Image 4.4** .

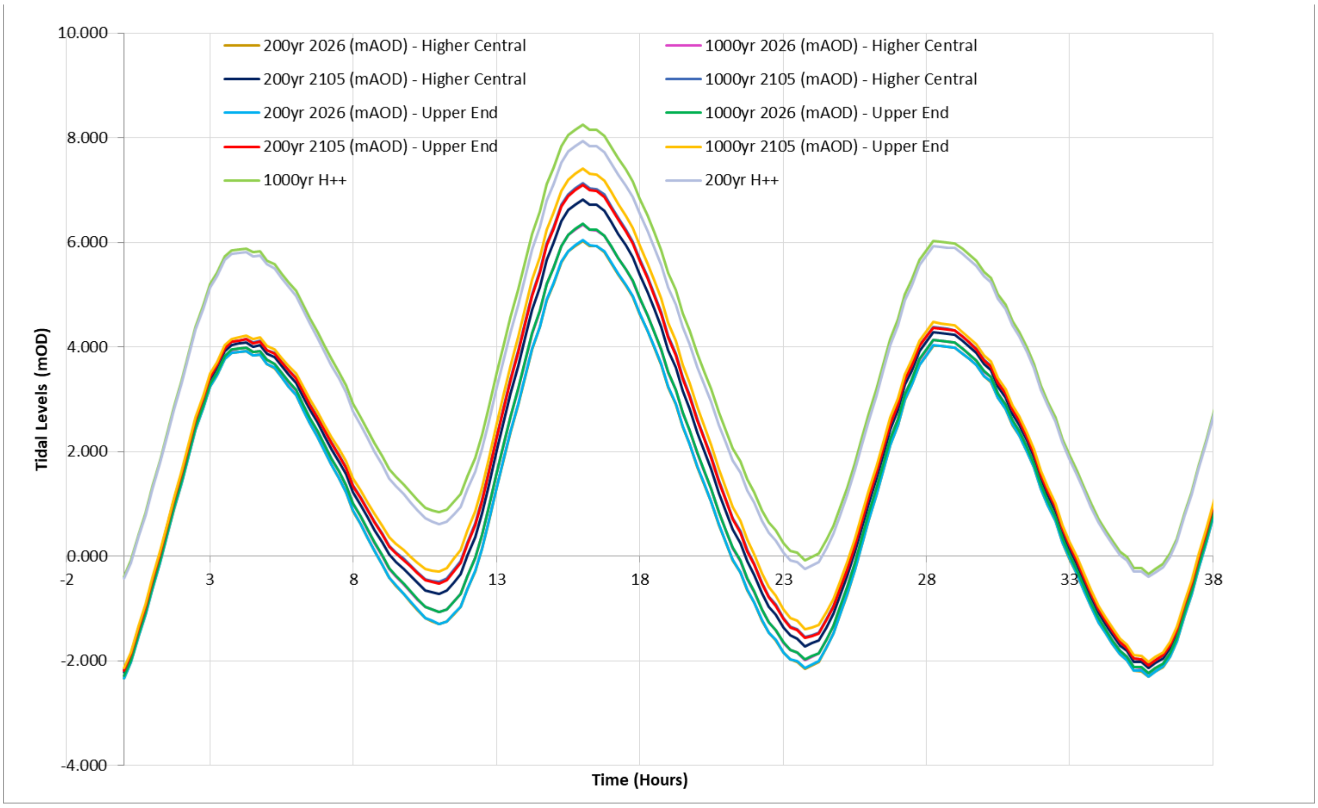

Image 4.4 Final Design Tidal Boundaries for different events

5. Model details and implementation

5.1 Introduction

5.1.1 As outlined above, the basis of the modelling is the EA approved River Welland Breach model (Ref 2) that was developed by SLR Consulting as part of the ODOW project (2025). This model is hereafter referred to as the 'ODOW model'.

5.1.2 The ODOW model is a two-dimensional (2D) model built using TuFLOW, to assess both tidal and defence breach flood risk for the Outer Dowsing Offshore Wind Onshore Substation (OnSS) at Surfleet Marsh.

5.1.3 The ODOW model schematic has been largely retained in the model that is developed for the present study. However, various model refinements have been implemented in accordance with recommendations from our modelling methodology statement report (Ref 3).

5.1.4 Basic sensitivity analysis has been carried out, to assess the impact on results when varying critical model parameters, including Manning's N roughness coefficients, grid cell size and slope of downstream boundary condition. Additional sensitivity test runs have been completed to fulfil a specific request from the EA notably for H++ climate change allowances as well as for a longer duration of the breach failure. The latter is to assess the magnitude and extent of flooding if defence breach is kept in place for a significantly longer period of time than the 35 hours' time interval assumed in the design runs.

5.1.5 The key elements of the model, alongside our model refinements and details of the sensitivity test runs, are summarised in this Section of the report.

5.2 Model Extents

5.2.1 The 2D model domain has been kept unchanged from that used in the ODOW model overtopping model runs. This consists of a single 2D model domain that covers the areas both to the north and the south of the River Welland, the latter of which also encompasses the proposed Weston Marsh Substation A. The chosen model domain, which covers an area of approximately 93km^2, is illustrated in Figure 1 (refer to drawing nbr '*WMA-TCPA-FLMOD-001'*), alongside the footprint of the Weston Marsh Substation A and the main model components (including River Welland defences, 2D roughness areas associated with land use, and boundary conditions).

5.2.2 The adoption of a smaller model domain which would cover only the area to the south of the River Welland, was considered prior to the inception of the breach modelling exercise for the purpose of reducing computational run time. However, this was not deemed necessary, as fast run simulations could be achieved through the deployment of TuFLOW HPC solver on GPU (Graphics Processing Unit) card, as the initial overtopping runs had demonstrated.

5.3 Model Topography

5.3.1 The topographical input, which has been retained from the ODOW model, consists of a Digital Terrain Model (DTM) built using EA 1m filtered LiDAR from 2022 (Ref 11). Checks undertaken during the model build stage, confirmed this LiDAR is the most up-to-date available for download from the Defra Data Service portal.

5.3.2 The 1m resolution of LiDAR data is deemed suitable to accurately represent storage capacity of the River Welland and adjacent floodplain areas. Furthermore, it allows to adequately capture all relevant floodplain features that can have a bearing on flow patterns originating from tidal overtopping or breach defence failure, including physical obstructions on the ground (such as buildings, embankments and ridges) and preferential flow pathways (such as roads and local drains/streams).

5.3.3 The DTM within the area that covers the proposed Weston Marsh Substation A is illustrated in **Image 5.1** .

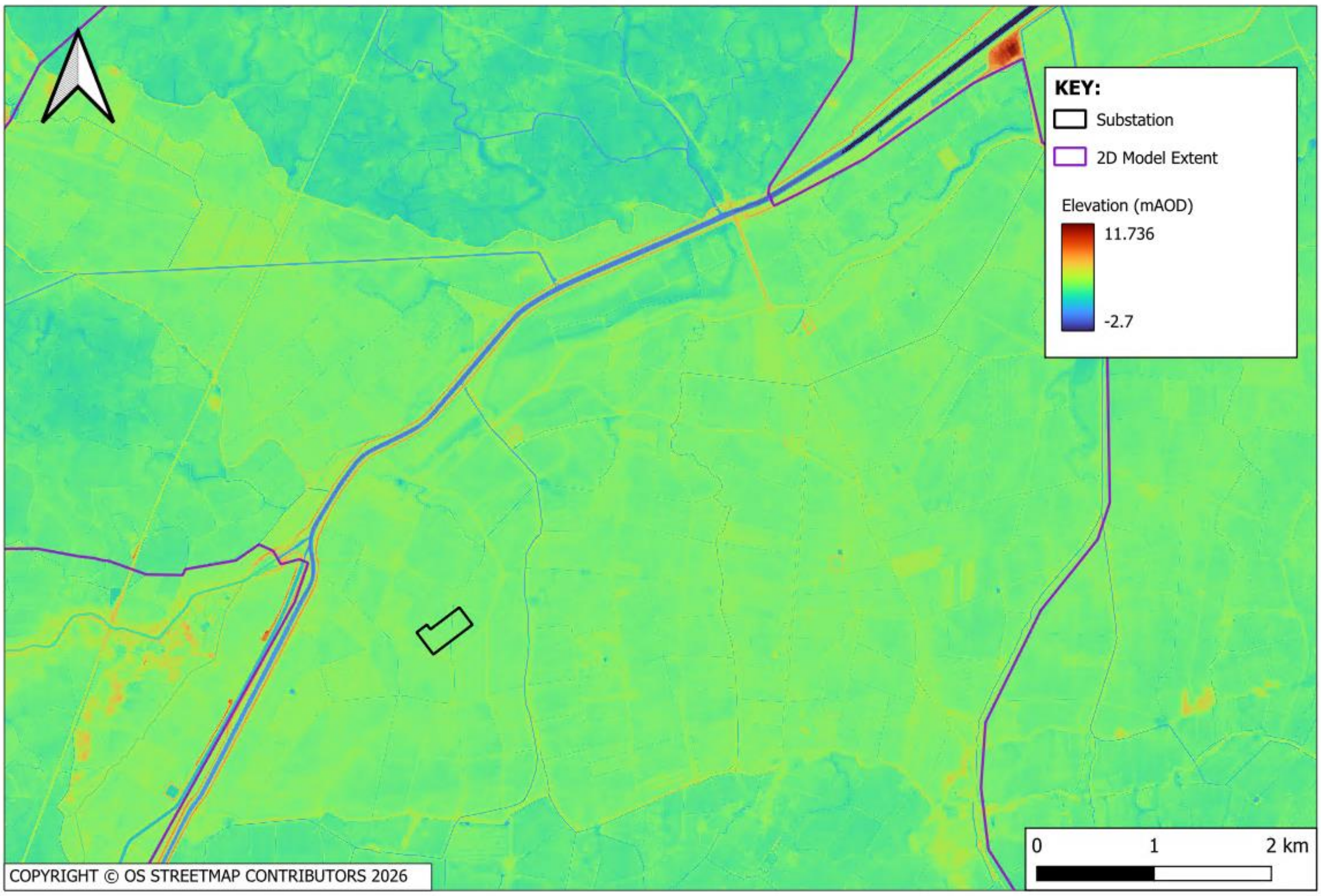

Image 5.1 View of the LiDAR-based DTM

5.3.4 As shown, the right-bank floodplain of the River Welland consists of an extensive and relatively flat land, mostly covered by agricultural areas with scattered farm buildings. Terrain levels at the proposed Weston Marsh Substation A vary from a minimum of 3.5mAOD at the eastern part of the site, to a maximum of 4mAOD towards the northern part of the site.

5.4 Grid Cell Size

5.4.1 The ODOW model is built using a fixed mesh approach in TuFLOW at a 10 metres grid resolution, thus the underlying computational mesh consists of individual square grid cells that have a side length of 10m.

5.4.2 Such grid resolution is retained in the model developed for the present study, as deemed suitable to capture all relevant flow pathways that route overland flows through the adjacent floodplain areas (once overtopped from the River Welland defences or released through a breach in the primary defence line). This is in consideration of the topography and nature of the River Welland floodplain, characterized by relatively flat terrain and predominantly occupied by agricultural/farmland, with limited presence of flow obstructions such as buildings and road embankments.

5.4.3 Additionally, in consistency with the original ODOW model, run simulations are performed whilst deploying sub-grid sampling (SGS) feature from TuFLOW HPC scheme solver. This functionality would allow to resample the ground model DTM on a finer resolution than the 10 meters resolution adopted for the 2D computational mesh.

5.4.4 Unlike TuFLOW Classics solver where (grid) cell volume varies linearly with depth (i.e. volume increases in direct proportion to the depth, given a constant base area), TuFLOW HPC via SGS feature defines a non-linear volume versus depth relationship. The latter, which is obtained from the DTM resampling, enables to better represent the cell volumetric capacity, allowing to achieve a greater granularity in the model results and when capturing topographical features on the ground.

5.4.5 SGS feature is configured in the model based on a Target Distance (TD) of 1 metre, thus the same resolution as the underlying LiDAR-based DTM, by applying a sample frequency of 11 meters (that means subdividing the grid cell into a mesh formed of 11x11 points).

5.5 Boundary Conditions

5.5.1 The upstream boundary condition derived from the original ODOW model has been retained. This consists of a Head versus Time (HT) boundary unit, which is based on the tidal profile at the River Welland estuary, just off the Fosdyke Bridge. More details on the tidal curves used in the model runs are provided in the previous Section, including peak tide level predictions for present day and future scenarios, alongside derivation of base tidal cycle and sea level rise uplifts.

5.5.2 The downstream boundary condition of the model consists of a (HQ) outflow boundary unit which is applied at the lower limit of the modelled River Welland. The HQ boundary would allow flows to leave the model along its southern boundary, thus preventing flood water from glass-walling along the edge of the 2D model domain.

5.5.3 As described in the ODOW modelling report document (Ref 13), model instabilities were found to occur in proximity of the HQ boundary unit, when breach scenario runs were performed.

5.5.4 Following recommendations from the modelling method statement (Ref 3), model troubleshooting has been undertaken with the aim to fix the model instabilities near the HQ boundary unit. These have been resolved through the adoption of a slightly adjusted direction of the HQ boundary line and an increase of the b-value from

0.00001 to 0.0001. The revised line direction allows incoming flows to intersect the boundary at a nearly perpendicular angle, thus preventing the formation of a curvature in the surface water profile of approaching flows which was the likely source of the model instabilities.

5.6 Manning's N Roughness Coefficients

5.6.1 As detailed in the modelling methodology statement document (Ref 3), 2D Manning's N roughness coefficients used in the original ODOW model were reviewed and it was concluded that the most appropriate roughness coefficients were adopted in most cases.

5.6.2 However, the 2D Manning's N roughness value of 0.1 that was assigned to urban areas, was considered too high compared to the standard range of values adopted for urban land use.

5.6.3 As such, a Manning's N roughness coefficient of 0.025 was used in the urban areas of the model, in accordance with the recommended range of values (typically 0.02-0.025) from standard practice. No alteration was made to Manning's N values assumed for other land uses. Details of 2D Manning's N roughness coefficients adopted in the model are presented in **Table 5.1**.

Table 5.1 Roughness coefficients

Manning's N value	Land Use
0.1	Deciduous woodland
0.035	Arable
0.03	Improve grassland
0.035	Neutral grassland
0.035	Fen
0.05	Heather
0.025	Saltwater
0.025	Freshwater
0.04	Supralittoral sediment
0.04	Littoral sediment
0.035	Saltmarsh
0.025	Urban
0.06	Suburban
0.1	Buildings

5.7 Representation of Buildings

5.7.1 Buildings have been represented in the model as ‘stubby buildings’, by raising the building footprint area 0.3m (i.e. 300mm) above the surrounding ground level to reflect the assumed building threshold height. This approach, which is in accordance with best practice, would enable the model to simulate the deflection on incoming (overland) flows caused by the presence of the buildings.

5.7.2 As described above, a Manning’s N roughness coefficient of 0.1 was chosen for buildings (mostly consisting of farm and associated outbuildings such as barns and sheds) across the predominantly agricultural land that occupies the low-lying floodplain area known as ‘The Fens’.

5.8 Modelling of Defences

5.8.1 There are various defences along the lower reach of the River Welland, mainly consisting of earth embankments according to the EA AIMS spatial defence dataset (Ref 5Ref 4). The dataset was used to inform the alignment and crest levels of the River Welland (linear) defences. The most up-to-date EA 1m LiDAR data (Ref 11) was also acquired to sense check defence crest levels informed by the EA AIMS Spatial Defence dataset (Ref 5). More details can be found in Section 5-3 above.

5.8.2 Defences are represented in the ODOW model as 3d breaklines using a ‘*2d Zshape*’ feature in TuFLOW. Whilst this representation has been retained, the ‘*Shape Width’* attribute value of the Z shape (line) layer has been changed from the original value of 4 to a value of 10. This was to ensure that defence crest heights are applied consistently to all Z-points of the underlying 2D cells, according to the ‘*THICK*’ option approach when a Z shape layer is read into TuFLOW.

5.9 Model Updates

5.9.1 In accordance with recommendations from our Modelling Method Statement (Ref 3), various minor updates have been made to the ODOW model to make it suitable to inform a site-specific flood risk assessment for the proposed Weston Marsh Substation A.

5.9.2 These model updates are described below:

- The ‘Shape Width’ attribute value of the 2d_Zshape line used for defences has been altered from 4 to 10 to enforce defence crest levels via ‘*THICK*’ lines in TuFLOW, as ensured by setting a value that matches the 10 meters model grid resolution.
- 2D Mannings N value for urban areas has been changed from 0.1 to 0.025, in accordance with standard range of values adopted for urban land use.
- The line direction of the downstream (HQ) outflow boundary unit has been adjusted to become (nearly) perpendicular to the main direction of incoming (overland) flows, this to remove the local (model) instabilities occurring in the ODOW model.
- Defence crest levels in the model have been reviewed and adjusted where appropriate using EA AIMS Spatial Flood Defences dataset (Ref 5) and EA LiDAR dataset (Ref 11).

- The baseline model built in the breach modelling exercise has been altered to reflect post-development scenario conditions, by raising the proposed Weston Marsh Substation A footprint area to match the design finished floor level of 4.423mAOD.

6. Tidal overtopping and breach modelling

6.1 Introduction

6.1.1 As outlined above, modelling has been undertaken using as a basis the ODOW model with minor updates to make the model suitable to inform a site-specific FRA for the proposed Weston Marsh Substation A.

6.1.2 In agreement with the EA, the modelling focuses on flood risk from tidal sources, as a main risk of flooding to the site, with the assessment of both tidal overtopping and breach defence failure along the lower River Welland.

6.1.3 This Section of the report summarises the principles of the tidal overtopping and breach modelling exercises completed.

6.2 Tidal overtopping assessment

6.2.1 To evaluate flood risk to the site resulting from tidal overtopping of the River Welland defences, the model built has been run for various tidal events, by applying to its upstream HT boundary the design curves derived from the hydrological analysis (for details see Section 4).

6.2.2 The River Welland defences are represented in the model using their current crest levels. These were primarily informed by the EA AIMS Spatial Defence dataset (Ref 5), and sense-checked using LiDAR (Ref 11), as described in Section 5.8.

6.2.3 Defence crest levels along the right-bank (i.e. bank side facing the substation) of the River Welland vary from a minimum elevation of 7.03mAOD to a maximum elevation of 7.79mAOD.

6.2.4 In comparison with peak tidal levels obtained from the hydrological analysis (refer to **Table 4.2**, the minimum defence crest level of 7.03mAOD is higher than peak tide level predictions up to and including the 0.5% AEP plus Higher Central climate change in year 2105, and is only marginally lower than the predicted peak tide level for the 0.5% AEP plus Upper End climate change in year 2105.

6.2.5 Notably, the peak tide level of 7.41mAOD predicted for design 0.1% AEP plus Upper End climate change event tallies with the average defence crest level calculated from the above range.

6.3 Breach Modelling

6.3.1 To assess residual flood risk from a defence breach failure, the model used for tidal overtopping has been modified to simulate the occurrence of a breach along the section of the River Welland defence near the proposed Weston Marsh Substation A.

6.3.2 The breach has been modelled using variable Z-shape feature (2d_vzshape) in TuFLOW. The EA breach modelling guidance (Ref 14) was used to determine the correct breach dimensions to be represented in the model, based on the defence type and location.

6.3.3 Given the defence consists of an earth embankment and it lines a tidal river, a breach width of 50m was imposed in the model. Three alternative breach locations were initially identified in consideration of distance to the proposed Weston Marsh Substation A, local topography and defence crest heights. The three breach locations, which are labelled as '*WMA1*', '*WMA2*' and '*WMA3*' in the model, are illustrated in **Image 6.1**.

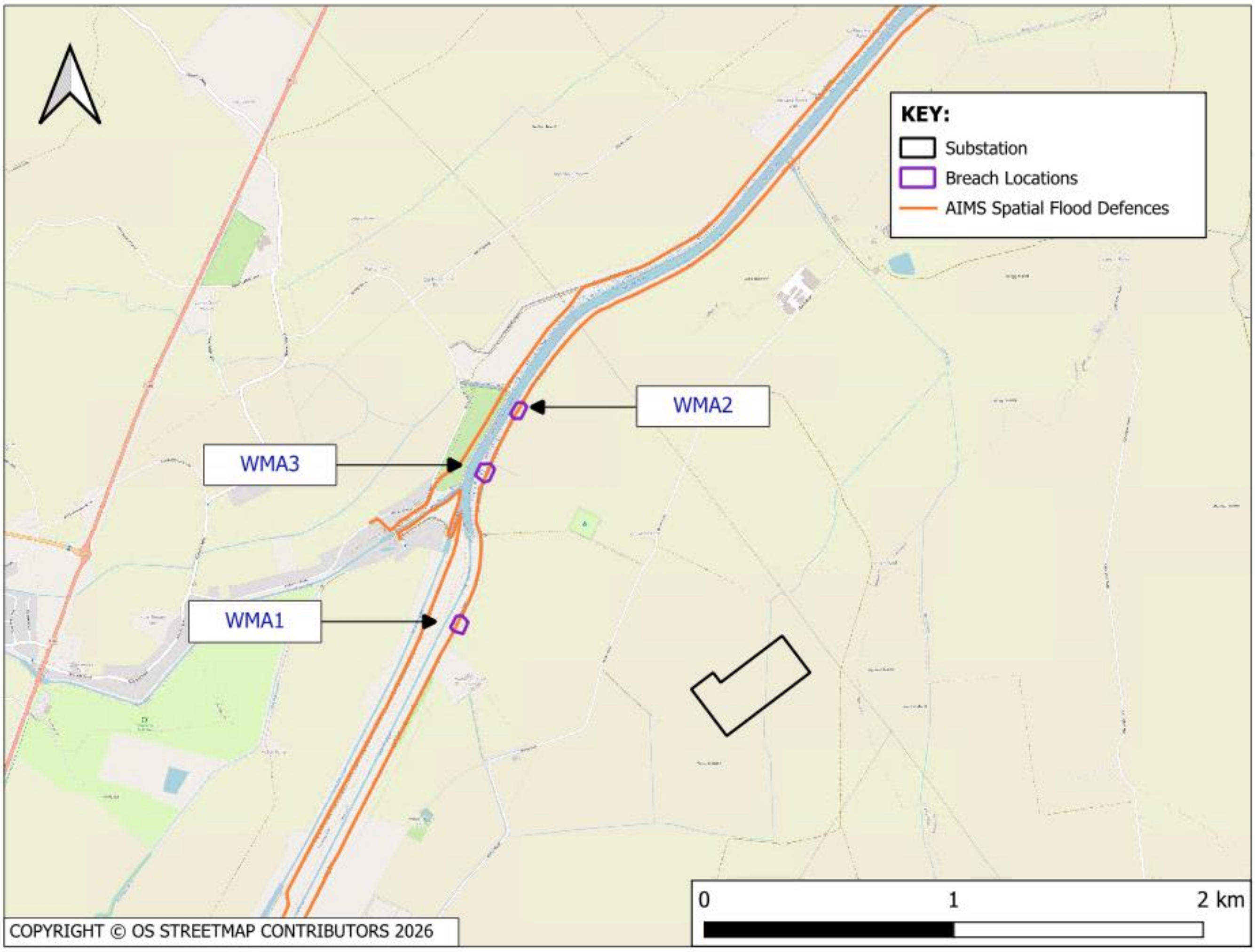

Image 6.1 Breach locations

6.3.4 Breach location 'WMA1' was selected because of being the closest to the proposed Weston Marsh Substation A, which is situated directly opposite.

6.3.5 Although occurring further downstream (along the right-bank defence of the River Welland), breach locations 'WMA2' and 'WMA3' were selected because of the underlying defence height (as measured from the defence crest to its toe on the land facing side) being greater than that occurring at breach location 'WMA1'.

6.3.6 Notably, defence heights of 2.40m, 2.69m and 2.70m, are observed at breach locations 'WMA1', 'WMA2', and 'WMA3' respectively.

6.3.7 The three breach locations have been tested independently through the modelling, based on the 0.1% AEP plus Upper End climate change tidal event in year 2105 (i.e.

with a 75-year horizon to reflect the assumed design life of the proposed Weston Marsh Substation A).

6.3.8 At each breach location, a base breach level was derived using the EA AIMS Spatial Defence dataset (Ref 5) and LiDAR dataset (Ref 11). Breach base level was calculated by deducting the defence toe level (as obtained on the landward side of the defence) from the defence crest level. A portion of the adjacent floodplain area within a radius equivalent to the breach width (i.e. 50m) was examined when determining the defence toe level to use in the calculation, as recommended in the EA Breach of Defences guidance (Ref 14).

6.3.9 Furthermore, according to the guidance, the defence breach would occur at the time when water level in the adjacent River Welland reach is approximately at ¾ of the defence height. On this basis, the breach has been set to start at 16 hours into the model run simulation, with the breach being kept open until the end of the simulation, which is at 51 hours (notably, 35 hours since the onset of the breach failure).

6.3.10 Following a review of the preliminary breach model results, breach ‘WMA3’ was chosen as the breach location to be progressed in the design (breach) model runs, as it provides the most conservative flood level prediction at the proposed Weston Marsh Substation A. Notably, a maximum flood level of 4.123mAOD is predicted from the breach ‘WMA3’ run at the proposed Weston Marsh Substation A.

6.3.11 Following preliminary breach location testing, the model used for tidal overtopping was altered to incorporate a breach in the defence, according to breach location ‘WMA3’.

6.3.12 The resulting baseline (breach) model was run for a set of design tidal events, to inform predicted flood levels and depths within the area of the proposed Weston Marsh Substation A.

6.3.13 To assess post-development scenario conditions, the baseline breach model was further modified, by raising the proposed Weston Marsh Substation A footprint area to the design finished floor level of 4.423mAOD (as calculated by adding 0.3m freeboard to the above maximum modelled flood level of 4.123mAOD).

6.4 Model Run Scenarios

6.4.1 The model runs performed are listed in **Table 6.1**.

Table 6.1 List of model run scenarios

Scenario	Description
Tidal Model	
0.5% AEP in 2026	0.5% AEP event for present day scenario conditions (including Upper End sea level rises from tidal base year of 2017 to 2026)
0.1% AEP in 2026	0.1% AEP event for present day scenario conditions (including Upper End sea level rises from tidal base year of 2017 to 2026)

0.5% AEP+CC (Higher Central) in 2105	0.5% AEP plus climate change event, using Higher Central climate change allowances up to year 2105 (i.e. with a 75-year horizon)
0.5% AEP+CC (Upper End) in 2105	0.5% AEP plus climate change event, using Upper End climate change allowances up to year 2105 (i.e. with a 75-year horizon)
0.1% AEP+CC (Higher Central) in 2105	0.1% AEP plus climate change event, using Higher Central climate change allowances up to year 2105 (i.e. with a 75-year horizon)
0.1% AEP+CC (Upper End) in 2105	0.1% AEP plus climate change event, using Upper End climate change allowances up to year 2105 (i.e. with a 75-year horizon)
Breach Scenarios	
Breach 0.5% AEP in 2026	0.5% AEP event under both baseline breach scenario and post-development breach scenario conditions. Includes Upper End sea level rise from tidal base year of 2017 to 2026
Breach 0.1% AEP in 2026	0.1% AEP event under both baseline breach scenario and post-development breach scenario conditions. Includes Upper End sea level rise from tidal base year of 2017 to 2026
Breach 0.5% AEP+CC (Upper End) 2105 Epoch	0.5% AEP plus (Upper End) climate change event under baseline breach scenario conditions. Upper End climate change allowances applied up to year 2105 (i.e. with a 75-year horizon)
Breach 0.1% AEP+CC (Upper End) 2105 Epoch	0.1% AEP plus (Upper End) climate change event under both baseline breach scenario and post-development breach scenario conditions. Upper End climate change allowances applied up to year 2105 (i.e. with a 75-year horizon)
Sensitivity Scenarios	
Materials/Manning’s ‘n’ sensitivity (0.1% AEP+CC (Upper End))	Sensitivity test for both 20% increase and 20% reduction in Manning’s ‘n’ roughness values. Tested on 0.1% AEP Upper End Climate Change allowances applied up to the year 2105
HQ downstream boundary b-value sensitivity (0.1% AEP+CC (Upper End))	Sensitivity test for both 20% increase and 20% reduction in ‘b’ value (slope) at the downstream HQ boundary across the channel. Tested on 0.1% AEP Upper End Climate Change allowances applied up to the year 2105
Grid Cell Size sensitivity (0.1% AEP+CC (Upper End))	Sensitivity test for both increase and decrease in model grid cell size. Grid cell size tested to an increased value of 14m and a decreased value of 6m. Tested on 0.1% AEP Upper End Climate Change allowances applied up to the year 2105
Longer defence breach duration sensitivity (0.1% AEP+CC (Upper End))	Sensitivity test for longer duration defence with respect to the 35-hour assumed in the design runs. Tested for 70 hours breach duration. Tested on 0.1% AEP Upper End Climate Change allowances applied up to the year 2105

0.5% AEP H++ 2105 Epoch	0.5% AEP H++ event under both baseline scenario and post-development scenario conditions
0.1% AEP H++ 2105 Epoch	0.1% AEP plus H++ climate change event under both baseline scenario and post-development conditions
Breach 0.5% AEP H++ 2105 Epoch	0.5% AEP plus H++ climate change event under both baseline scenario and post-development scenario conditions
Breach 0.1% AEP H++ 2105 Epoch	0.1% AEP plus H++ climate change event under both baseline scenario and post-development scenario conditions

6.5 Model Run Parameters

6.5.1 All model runs have been carried out using TuFLOW version 2025.2.1 and deploying the TuFLOW HPC solver.

6.5.2 Model run simulations have been performed using an end time of 51 hours, including design tidal and breach runs plus sensitivity runs (except for long duration runs; see details below). The chosen run simulation time is deemed sufficiently long to ensure that peak of flooding is reached even in the most remote locations over the 2D domain area.

6.5.3 Furthermore, running the breach scenario model over a 51-hour time interval would allow to retain the breach open for up to 35 hours since the onset of the breach failure. This would satisfy the (minimum) breach opening duration of 30 hours that is set out in the EA Breach of Defences guidance (Ref 14).

6.5.4 Lastly, the EA had requested to undertake a sensitivity test run on breach scenario, to determine if modelled flood extents would differ should the breach persist over the 35-hour duration assumed in the model. For this purpose, two distinct sensitivity test runs have been performed, to prolong the breach defence failure up to 70 hours and 120 hours respectively since the onset of the breach.

6.6 Model Stability

6.6.1 TuFLOW console run window was regularly monitored during the run progression, and simulation logs and check files were reviewed when the simulations ended. This was to allow an early detection and resolution of model instabilities and to evaluate the model run performance.

6.6.2 Unlike in TuFLOW Classic, mass balance error outputs cannot provide robust evidence on the overall model run stability when the TuFLOW HPC solver is deployed, given the inherent mass conservation nature of the TuFLOW HPC numerical scheme.

6.6.3 Instead, the critical health indicators are the three control factors Nu (Courant Number), Nc (Shallow Wave Celerity Number) and Nd (Diffusion Number), alongside the timestep (dt) and efficiency (in percentage).

6.6.4 The above health indicators have been extracted from the baseline breach run for the design 0.1% AEP plus (Upper End) climate change event in 2105, and their variation over time is illustrated in **Image 6.2** below.

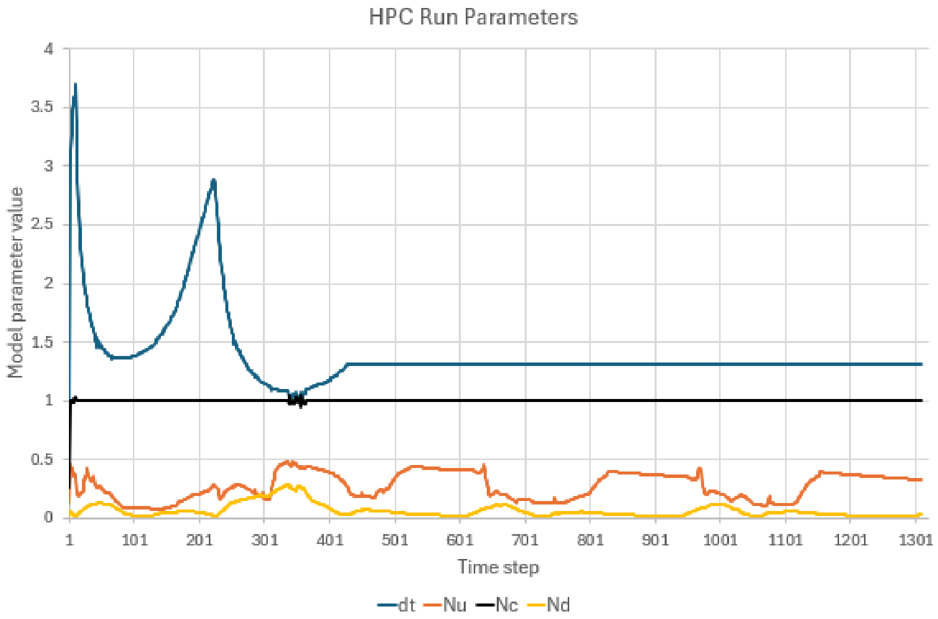

Image 6.2 HPC parameters from 0.1% AEP+CC (UE) in 2105 base breach run

6.6.5 As shown, during the entire simulation, control factors remain within their respective acceptable tolerance ranges, notably Nu<1, Nc<1 and Nd<0.3. After initialising from a relatively low value of 0.7 (due to the sudden wetting of 2D cells at the start of the simulation), the timestep (dt) rapidly stabilises to a healthy range between 1 second and 3.7 seconds. Notably, all HPC run parameters discussed above are consistent with those presented in the model stability plot within the River Welland Breach Modelling report document (Ref 3).

6.6.6 **Image 6.3** illustrates the change in dVol parameter over time. As shown, dVol changes smoothly during the entire run simulation. This is except for the occurrence of sudden peaks at the onset of the breach, at and just past 16 hours into the run simulation. Such variations are expected in consideration of the large volume of water released onto the adjacent floodplain once the breach has occurred.

6.6.7 The analysis of the run health indicators confirms that the model is stable, and a good run performance is achieved.

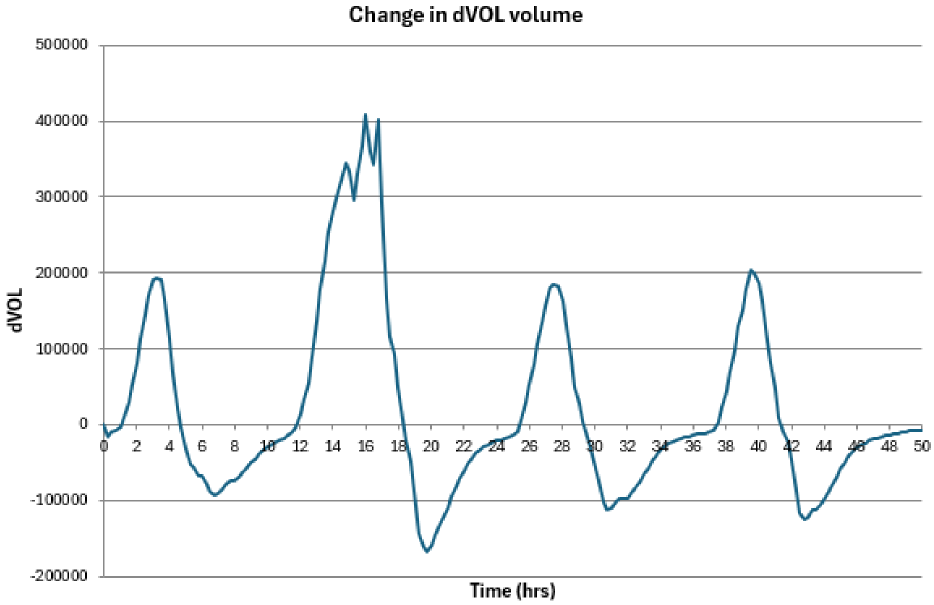

Image 6.3 dV plot from 0.1% AEP+CC (UE) in 2105 base breach run

6.7 Assumptions and Limitations

6.7.1 The hydraulic modelling undertaken is based on the EA approved ODOW model (Ref 3), hence limitations associated with the original model remain valid.

6.7.2 The primary sources of uncertainty relevant to this assessment relate to:

- Representation of extreme tidal events, including the tide level predictions, wave surge profiles, and sea level rises for climate change.
- Defence crest levels, which are based on the most recent available EA AIMS Spatial Defence dataset (Ref 5) (and sense-checked using LiDAR), but may not be capturing localised variations in levels due to deteriorated defence conditions (since input data was captured) and/or future degradation.
- Parameterisation of channel and floodplain roughness, for which sensitivity testing has demonstrated a moderate influence on flood extents.
- Breach scenario assumptions, including breach location, breach dimensions (including breach width, base level and shape) and onset timing of the breach and breach duration.

7. Model Results

7.1 General

7.1.1 A group of figures is provided at the end of this report to show results obtained from the tidal overtopping and breach modelling assessments. According to the chosen naming convention, an alphanumeric string is shared by all figures, notably '*WMA-TCPA-FLMOD',* followed by a sequence number that identifies the order in which figures are presented. For easiness, figures are hereafter described in relation to their sequence number only (thus ignoring the prefix '*WMA-TCPA-FLMOD'* in the figure name*).*

7.1.2 The following is a list of all the figures included in the Appendix:

- Figure 1 is for the model schematic.
- Figure 2 is the flood depth map relating to the tidal overtopping modelling for the most extreme event (i.e. 0.1% AEP plus Upper End climate change in 2105).
- Figures 3 to 8 are the flood depth maps relating to the breach modelling scenarios (baseline and post-development) for the 0.1% AEP and 0.5% AEP events, both present day and future scenarios.
- Figure 9 is the flood impact map based on breach scenario runs and for the design 0.1% AEP plus (Upper End) climate change in 2105 event.
- Figures 10 and 11 are the flood hazard maps relating to the breach modelling scenarios (baseline and post-development), and for the design 0.1% AEP plus (Upper End) climate change in 2105 event.
- Figure 12 is the flood extents progression from the baseline breach run and for the design 0.1% AEP plus (Upper End) climate change in 2105 event.
- Figures 13 and 14 are the flood depth maps relating to the H++ sensitivity (on baseline and post-development breach scenarios) for the 0.1% AEP and 0.5% AEP events.
- Figure 15 is the flood extents map relating to the long duration breach sensitivity on post-development breach scenario and for the design 0.1% AEP plus (Upper End) climate change in 2105 event.

7.1.3 Industry standard post-processing tools, including '*TUFLOW_to_GIS'* and '*asc_to_asc'* tool batches, were used to extract mapping outputs from the 2D TuFLOW model (raw) results.

7.1.4 Maximum flood depths, levels and hazard grids were used to produce flood depth and hazard maps, whilst flood impact maps were informed by maximum flood level difference grids, alongside Was Wet Now Dry (WWND) and Was Dry Now Wet (WDNW) outputs.

7.2 Results from Tidal Overtopping Modelling

7.2.1 To assess flood risk resulting from potential tidal overtopping of the River Welland defences, tidal overtopping modelling has been carried out, according to the methodology described in Section 6.2. Refer to **Table 6.1** for a full list of the tidal run scenarios performed.

7.2.2 The modelled flood extents derived from the tidal overtopping (model) runs do not affect the proposed Weston Marsh Substation A, even for the 0.1% AEP plus (Upper End) climate change event, as illustrated in Figure 2 in the Appendix. This demonstrates that the proposed Weston Marsh Substation A is free from any flooding associated with tidal overtopping of the River Welland defences.

7.3 Results from Breach Modelling

7.3.1 To assess the residual flood risk resulting from potential collapse or breach failure of the River Welland defence, breach scenario modelling has been carried out, according to the methodology described in Section 6.3.

7.3.2 Three alternative breach locations were initially considered, notably '*WMA1*', '*WMA2'* and '*WMA3*', based on various factors including distance to the proposed Weston Marsh Substation A, local topography and defence crest heights. Results from the initial modelling of alternative breach locations are presented below, followed by results from the design breach modelling undertaken on chosen breach location '*WMA3*'.

Initial breach locations assessment

7.3.3 Breach locations '*WMA1*', '*WMA2'* and '*WMA3*' were initially assessed through the modelling, to determine which would provide the most conservative flood level prediction at the proposed Weston Marsh Substation A, for the most extreme tidal event i.e. 1% AEP plus (Upper End) climate change in 2105. Peak flood levels obtained at the substation location, are presented in **Table 7.1**. As shown, breach location 'WMA3' provides the highest flood level among the three, therefore it has been taken forward for the breach modelling assessment.

Table 7.1 Peak flood levels for breach locations

Breach Location	Peak flood water levels (mOD)
WMA1	4.013
WMA2	4.109
WMA3	4.123

Final breach modelling

7.3.4 Breach modelling has been undertaken for the chosen breach location '*WMA3'*, to assess both pre (i.e. baseline) and post development scenario conditions. Refer to **Table 6.1** for a full list of the breach run scenarios performed.

7.3.5 Figure 5 and Figure 6 in the Appendix illustrate results from the baseline breach runs for the 0.5% AEP plus (Upper End) climate change in 2105 and 0.1% AEP plus (Upper End) climate change in 2105 respectively.

7.3.6 Results from the baseline breach runs show extensive flooding over the right-bank floodplain of the River Welland. This is expected as overland flows rapidly spread across the relatively flat adjacent land once released from the defence breach opening. A maximum flood level of 4.123mAOD is predicted at the proposed Weston Marsh Substation A, for the 0.1% AEP plus (Upper End) climate change in 2105.

7.3.7 The above modelled flood level increased by the 0.3m assumed freeboard will be used to inform the design finished floor level of the proposed Weston Marsh Substation A. As such, a minimum elevation of 4.423mAOD is required for the finished floor level. To simulate post-development scenario conditions, the entire substation platform was raised in the model to the target finished floor level of 4.423mAOD.

7.3.8 With reference to the flood extents progression figure in the Appendix (Figure 12), it would take approximately one hour since the onset of the breach failure for flood water to reach the proposed Weston Marsh Substation A platform.

7.4 Impact on Sensitive Receptors

7.4.1 Following the completion of the breach modelling exercise, model results have been subject to a further analysis to assess potential impact on sensitive receptors with the proposed Weston Marsh Substation A in place. As part of this, difference grid outputs were generated using maximum flood level grids obtained from the baseline and post-development results for the design 0.1% AEP plus (Upper End) climate change event.

7.4.2 Differences were calculated by deducting baseline results from post-development results. Consequently, positive values reflect an increase in flood levels thus a detriment, whilst negative values reflect a decrease in flood levels thus a betterment.

7.4.3 Flood impacts are presented with reference to minor (between 0.01m and 0.05m), moderate (between 0.05m and 0.1m) and major impact (greater than 0.1m), as illustrated in Figure 9. Differences within the +/-0.01m range are deemed negligible, thus no impact is assumed within those areas.

7.4.4 As shown, a minor increase in flood level (yellow region) occurs over a large area extending both the to the north and the east/south-east of the proposed Weston Marsh Substation A. A more significant impact is observed within a narrow strip of land adjacent to the right-bank of the River Welland, approximately 2km to the north of the proposed Weston Marsh Substation A. This area, which is entirely occupied by farmland (but no buildings), is affected by mainly moderate impact (orange region) with major impact (red region) being limited to its far end. A few small areas of moderate impact are observed at selected locations across the farmland.

7.4.5 Aside from the above, the only other detrimental impact is in relation to small patches of Was Dry Now Wet areas (magenta region) that occur along the edge of the modelled flood outlines. These are areas that do not flood in the baseline scenario but do flood in the post-development scenario.

7.4.6 Furthermore, a minor decrease in flood level (green region/area) is observed within the area adjacent to the eastern side of the proposed Weston Marsh Substation A i.e.

the side not exposed to the breach. This is expected given the raised substation would act as a barrier towards flows derived from the breach located directly opposite.

7.4.7 It is important to note that the entire Weston Marsh Substation A platform is covered by a Was Wet Now Dry area (light blue region), as the substation becomes flood free once raised.

7.4.8 Minor flood impact areas are shown to affect a limited number of potentially sensitive receptors, located both to the north and the south of the proposed Weston Marsh Substation A. Upon inspection of publicly available background mapping, three potentially sensitive receptors have been identified within the land surrounding the proposed substation. These receptors are displayed in **Image 7.1** using node points labelled as ‘A’, ‘B’ and ‘C’. Of these three receptors, only that associated with node point ‘B’ has been ascertained to be a residential property at the time of writing.

7.4.9 For the design breach scenario event (0.1% AEP+CC Upper End in 2105), a flood depth increase of 24mm is predicted at node point ‘B’ with the proposed Weston Marsh Substation A in place, as illustrated in **Table 7.2**. A flood depth increase of 13mm is predicted at node points ‘A’ and ‘C’. The same hazard rating is predicted at the three node point locations from the baseline and post-development breach scenario runs.

7.4.10 Although minor increases in flood depths are predicted from the model at the three potentially sensitive receptors identified, no change in flood hazard rating occurs at any of these receptors with the proposed Weston Marsh Substation A in place.

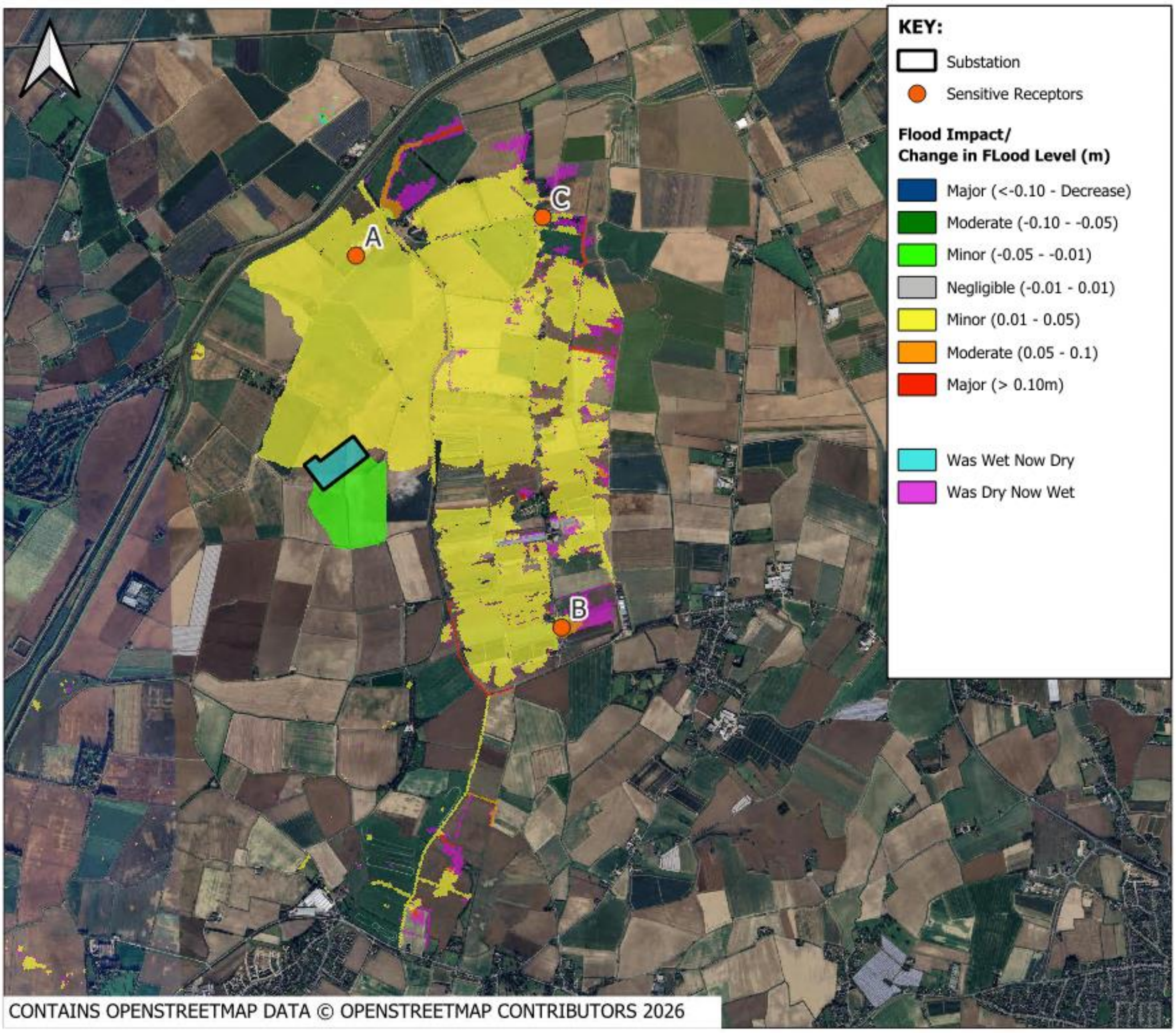

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Image 7.1 Flood Impact map at (potentially) sensitive receptors

Table 7.2 Change in flood depths and hazard rating at (potentially) sensitive receptors

Point	Flood Depth	Change in Flood Depth (m)	Hazard Rating	Has hazard rating changed from baseline (Y/N)
A	0.039	+0.013	Caution	N
B	0.054	+0.024	Caution	N
C	0.247	+0.013	Danger for some	N

8. Sensitivity analysis

8.1 General

8.1.1 Due to the lack of suitable calibration data, model calibration could not be undertaken. Instead, sensitivity analysis has been carried out to assess the sensitivity of the model to a variation of key model parameters, with the aim to gain an enhanced level of confidence in the model and its results.

8.1.2 Results from the sensitivity analysis indicate that some changes, although mostly minor, to the magnitude and/or extents of flooding occur when varying selected model parameters, more noticeably for Manning's N and grid cell size. However, these changes are deemed to have negligible effects on model results for breach scenarios, due to large flood volumes (and subsequently flood depths) resulting from a breach defence failure.

8.1.3 In addition to the above, sensitivity tests have been completed for H++ climate change allowances as well as for longer breach duration, as requested by the EA.

8.2 Basic Sensitivity Analysis

8.2.1 To gain an enhanced understanding of the uncertainties associated with the model parameterisation and the relative impact on results, sensitivity analysis has been conducted on the model built. In accordance with basic sensitivity analysis, the following sensitivity tests have been undertaken:

- A 20% increase and decrease of channel and floodplain roughness.
- A 20% increase and decrease of the slope attribute value pertaining to the downstream HQ boundary.
- A grid cell size of 6m and 14m, to adopt respectively a lower and greater cell size value than the 10m used in the model.

8.2.2 The above sensitivity test runs have been performed using the 0.1% AEP design event with Upper End climate change allowance to the year 2105.

8.2.3 Additional sensitivity tests have been carried out to fulfil a specific request from the EA, as follows:

- Re-run the tidal overtopping and breach models for climate change using H++ climate change allowances, and for both the 0.5% AEP and 0.1% AEP tidal events, to evaluate future resilience of the proposed Weston Marsh Substation A.
- Re-run the breach model whilst prolonging the defence breach for a longer time duration than the 35-hour assumed in the design runs, to establish if the extents of flooding remain unchanged.

Sensitivity to roughness coefficients

8.2.4 The sensitivity of the model results to changes in Manning's 'n' has been evaluated by adjusting the 2D roughness values by ±20%. **Image 8.1** illustrates the variation in flood extents between the baseline and the ±20% Manning's 'n' scenarios. A noticeable increase in flood extent occurs when roughness is reduced, due to greater channel conveyance and lower floodplain friction. Despite these differences, none of the scenarios indicate a flood risk to the proposed Weston Marsh Substation A location. Sensitivity testing indicates that the model is moderately sensitive to changes in roughness.

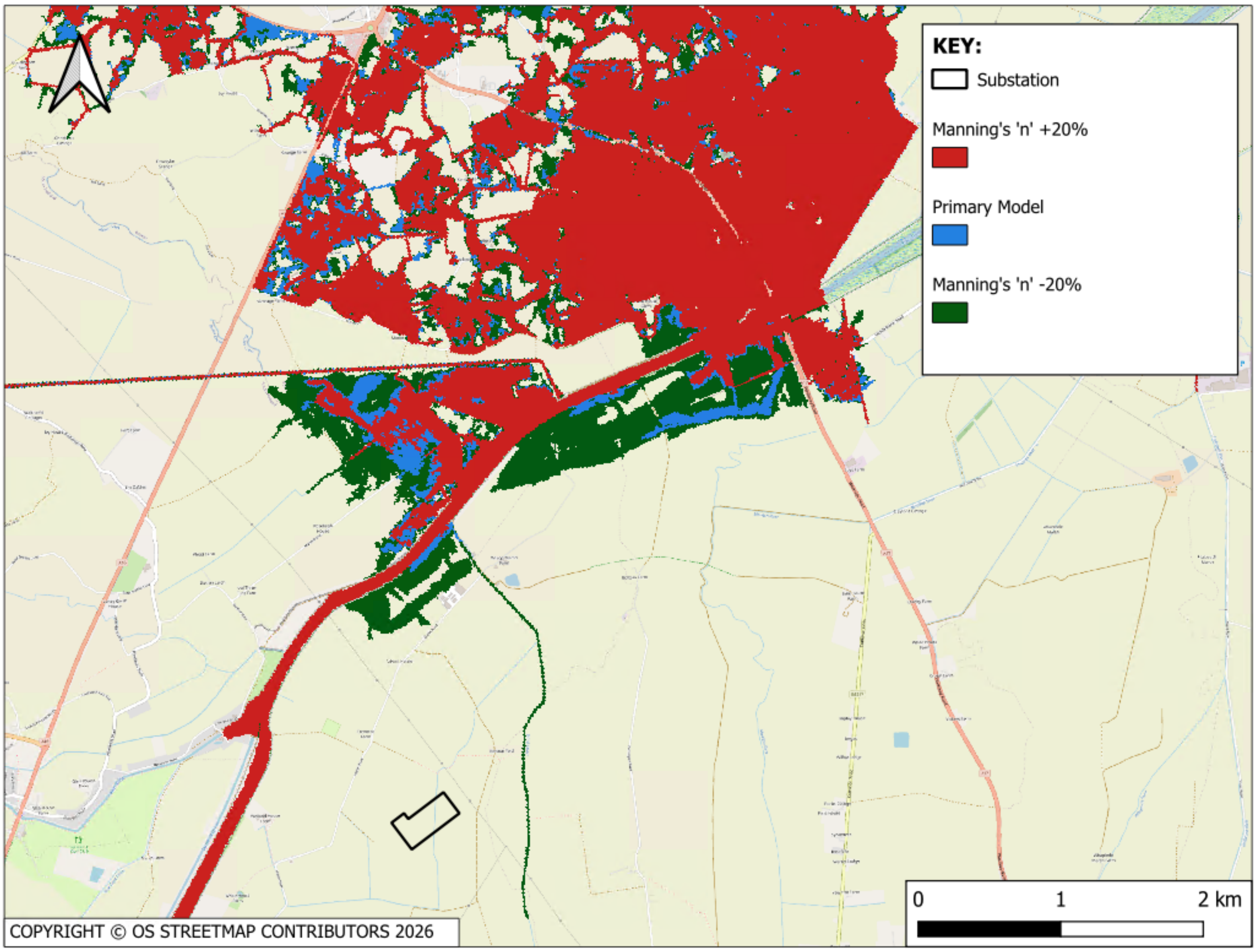

Image 8.1 Sensitivity on Manning's 'n' roughness

Sensitivity to Downstream Boundary

8.2.5 The outflow HQ boundary was modified to improve slope stability – firstly it was re-positioned to lie perpendicular to the direction of flow. Secondly, the slope ('b' value) was increased by an order of 10 to encourage flow out of the model. The flood extents shown in **Image 8.2** indicate only small change in the mapped flood extent for the sensitivity tests.

8.2.6 These changes resulted in a significant improvement in numerical stability. With these adjustments applied, all simulations ran to completion without exhibiting instability warnings. As these refinements provide a more stable and physically realistic representation of the downstream control, they are incorporated into the design run simulations.

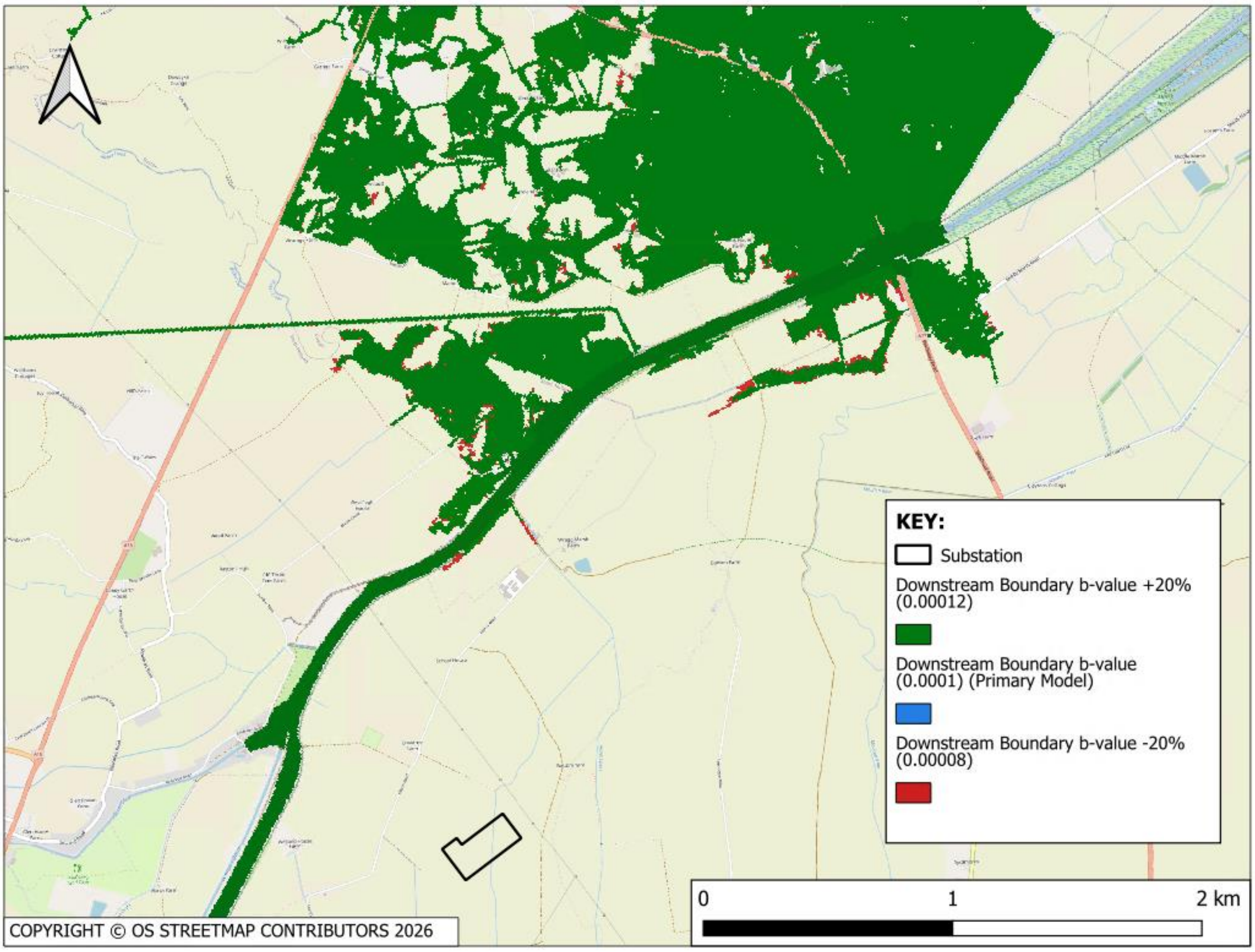

Image 8.2 Sensitivity on downstream boundary

Sensitivity to Model Grid Cell Size

8.2.7 A sensitivity test was undertaken to confirm the impact of cell resolution on model outputs. The results of these sensitivity runs (**Image 8.3**) demonstrate that there were minor differences between the maximum flood extents between the 6m and 10m grid cell size runs. This confirms that the 10m cell size accurately captures the relevant flow paths contributing to flooding. Using the larger 10m cell size thus can produce accurate results while reducing the model’s computation time. On the other hand, the 14m cell size shows a much larger flood extent, which is likely due to this coarser resolution failing to accurately capture defence crest levels, resulting in more spilling from the river.

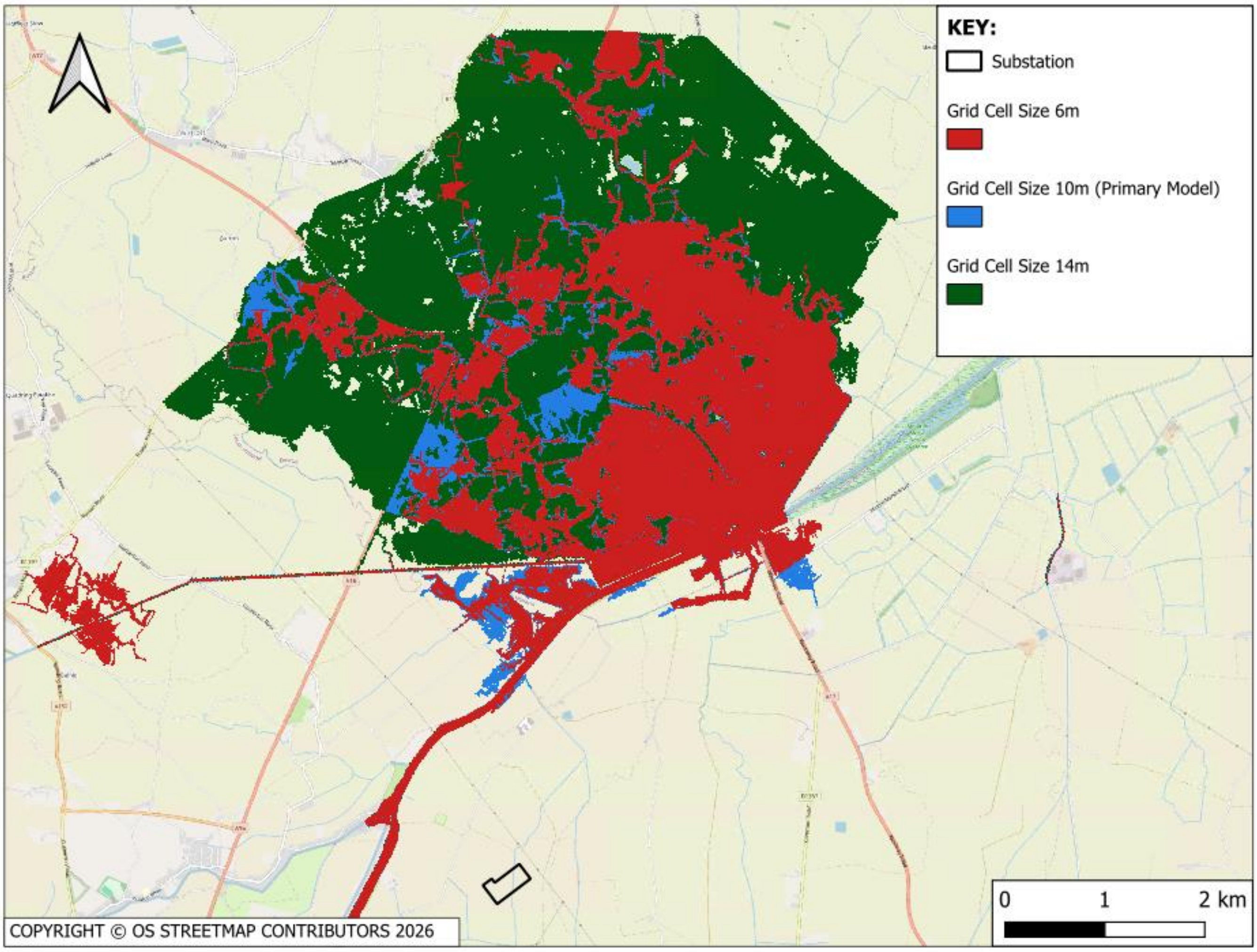

Image 8.3 Sensitivity to model grid cell size

8.3 Sensitivity to H++

8.3.1 Sensitivity test runs for H++ climate change allowance have been completed, for tidal overtopping and breach scenarios, and for both 0.5% AEP and 0.1% AEP climate change scenario events. For this purpose, base tide curves for the above events have been uplifted through the application of a single increase of 1.9m for total sea level rise to year 2100.

8.3.2 A peak flood level of 4.23mAOD is predicted from the breach run undertaken for the 0.1% AEP plus climate change event, when using H++ climate change allowance. Flood depth maps from the H++ breach runs are provided in the Appendix (refer to Figure 13 and Figure 14 in Appendix).

8.3.3 Notably, flood depth maps were produced from the H++ breach runs only as these provide the most conservative peak level predictions at the proposed Weston Marsh Substation A. However, sensitivity test results from the tidal overtopping are included in the model data package submission.

8.4 Sensitivity to long duration run

8.4.1 A sensitivity test run has been undertaken for the post-development breach scenario, to assess residual flooding if the breach persists over a longer time interval than the 35-hour duration assumed in the model. To reflect this, the breach duration is extended in the model from 35 hours to 70 hours since the onset of the breach (which occurs at approximately 16 hours into the run simulation), thus resulting in a total simulation time of 86 hours.

8.4.2 The run was performed using the design 0.1% AEP plus (Upper End) climate change in 2105 event, and once completed, flood depth results were extracted at the 86th hour (i.e. at the end time of the simulation) and post-processed to generate flood extents.

8.4.3 The resulting flood extents were compared against the maximum flood extents obtained from the design post-development breach run, as illustrated in Figure 15 in the Appendix. As shown, residual flooding derived from the sensitivity test run at the end of the simulation (i.e. 70 hours after the breach occurrence) has a good correspondence with maximum flood extents derived from the design breach run.

8.4.4 Minor differences can be observed along the edge, as slightly larger flood extents are obtained from the sensitivity test run (due to the additional flood volume released from the breach over the extended duration). Model results demonstrate that residual flooding obtained from the long breach duration run largely remains within the floodplain predicted from the design breach run.

9. Conclusions

9.1.1 WSP was commissioned by National Grid to undertake hydraulic modelling work to support a Flood Risk Assessment for the proposed Weston Marsh Substation A, located northeast of the town of Spalding, in Lincolnshire. The proposed Weston Marsh Substation A lies in the right-bank floodplain area of the River Welland, within an area benefitting from the presence of linear defences that line the River Welland channel.

9.1.2 Owing to the upstream Surfleet Sluice (River Glen) and Marsh Road Sluice (River Welland), which serve to control fluvial flows, flood risk posed by the River Welland is entirely tidal. Therefore, hydraulic modelling has been undertaken to assess potential tidal flood risk to the proposed Weston Marsh Substation A from overtopping of the River Welland defences as well as residual flood risk resulting from a defence collapse or breach failure.

9.1.3 The basis of the modelling is the EA approved River Welland Breach model (Ref 2) initially built by SLR to support the Outer Dowsing Offshore Wind project (2025). In accordance with our Modelling Method Statement report (Ref 3), various model updates were made to the existing model, including ground level alterations to suit the proposed Weston Marsh Substation A layout plus a few (minor) model updates to enhance the model accuracy and stability.

9.1.4 Basic sensitivity analysis (including Manning's N roughness coefficients, grid cell size and downstream boundary) was undertaken to enhance confidence in the model and its results. Additionally, sensitivity test runs for H++ climate change allowance and longer breach duration were completed as requested by the EA.

9.1.5 Key conclusions from the modelling exercise are as follows:

- The proposed Weston Marsh Substation A is outside any influence of flooding from tidal overtopping sources, even for the most extreme event i.e. 0.1% AEP plus (Upper End) climate change event in year 2105.
- Residual flood risk associated with potential defence breach failure will pose the greatest risk to the proposed substation.
- A peak flood level of 4.123mAOD is predicted from the breach scenario model run for the design 0.1% AEP year plus (Upper End) climate change event in year 2015.
- The finished floor level of the proposed Weston Marsh Substation A will be set to a minimum elevation of 4.42zmAOD, as obtained by adding 0.3m freeboard to the modelled flood level above.
- Flood maps have been produced to provide modelled flood levels, depths and hazard results, alongside flood impact maps to assess changes in extents and/or magnitude of flooding with the proposed Weston Marsh Substation A in place.
- Some impact, although mostly minor (notably, flood level increases within the 0.01m-0.05m range), is predicted from the model on the surrounding land.

- Minor impact is shown to affect a few properties, although no change in hazard rating is predicted at any of these.

9.1.6 The model has been subjected to a thorough (internal) technical review, which concluded that the model is healthy and stable and is fit for purpose.

References

Ref 1 Planning Act 2008 [online]. Available at: https://www.legislation.gov.uk/ukpga/2008/29/contents [Accessed July 2024].

Ref 2 SLR Consulting Limited (2025). Outer Dowsing Offshore Wind River Welland Breach model (PP1-ODOW-GRD-ME-MOD-0001_01 - Hydraulic Model Files.zip). Received by WSP in August 2025

Ref 3 WSP (2025). River Welland model audit technical report, relating to Weston Marsh TCPA for National Grid. File: 'NG_WM_Model_Methodology_FINAL_005.docx'.

Ref 4 The Environment Agency (2025). Flood risk assessments: climate change allowances [online]. Available at: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#sea-level-allowances (Accessed October 2025)

Ref 5 The Environment Agency (2025). AIMS Spatial Flood Defences (inc. standardised attributes). Retrieved from Data.gov.uk: https://www.data.gov.uk/dataset/cc76738e-fc17-49f9-a216-977c61858dda/aims-spatial-flood-defences-inc-standardised-attributes. (Accessed October 2025)

Ref 6 The Environment Agency (2025). Coastal flood boundary conditions for the UK: updated 2018 User guide [online]. Available at: https://assets.publishing.service.gov.uk/media/60365303e90e0740ac3ea1b5/Coastal_flood_boundary_conditions_for_the_UK_2018_update_-_user_guide.pdf. (Accessed October 2025)

Ref 7 UK Hydrographic Office (UKHO) (2026). ADMIRALTY TotalTide. ADMIRALTY Digital Publications [online]. Available at: https://www.admiralty.co.uk/publications/admiralty-digital-publications/admiralty-totaltide. (Accessed October 2025)

Ref 8 The Environment Agency (2010). EA Product 5/6/7 relating to the NTM East Coast Overtopping Model. Received by WSP in August 2024

Ref 9 The Environment Agency (2016). Product 5/67 relating to the River Welland and Glen Fluvial Model. Received by WSP in September 2025

Ref 10 The Environment Agency (2025). Coastal Design Sea Levels – Coastal Flood Boundary Extreme Sea Levels (2018). Retrieved from: https://www.data.gov.uk/dataset/73834283-7dc4-488a-9583-a920072d9a9d/coastal-design-sea-levels-coastal-flood-boundary-extreme-sea-levels-2018 (Accessed October 2025)

Ref 11 The Environment Agency (2025). EA LiDAR Composite DTM (1m resolution). Retrieved from Data.gov.uk: https://environment.data.gov.uk/survey. (Accessed October 2025)

Ref 12 National Grid (202). Preliminary Environmental Information Report Volume 3 Part C Route-wide Assessments Chapter 5 Water Environment and Flood Risk Appendices. Document Register ID GWNC-ARUP(AEC)-ENV-REP-002

Ref 13 SLR Consulting Limited (2025). Chapter 24 Appendix 3 Annex 1 River Welland Breach Modelling – Outer Dowsing Offshore Wind Environmental Statement report. Received by WSP in August 2025

Ref 14 The Environment Agency (2017). EA Breach of Defences Guidance [online]. Available at: https://docs.planning.org.uk/20241113/116/SKFFE4BJLZ100/8vhlhbyuib6v5qbx.pdf. (Accessed October 2025)

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