



Appendix H Hydraulic Modelling Report

Flood Consequence Assessment

Proposed extension of the Margam Substation

BakerHicks Limited

SLR Project No.: 402.065363.00001

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Hydraulic Modelling Report

Margam Moors – Substation Extension

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Basis of Report

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Acronyms and Abbreviations

AEP	Annual Exceedance Probability
AOD	Above Ordnance Datum
CC	Climate Change
DEM	Digital Elevation Model
EA	Environment Agency
EAF	Electric Arc Furnace
FEH	Flood Estimation Handbook
FEH22	FEH's latest UK-wide statistical model for rainfall depth-duration-frequency estimation
FMC	Flood Map Challenge
FMfP	Flood Map for Planning
HPC	Heavily Parallelised Compute
LIDAR	Light Detection and Ranging
NPTBC	Neath and Port Talbot Borough Council
NGR	National Grid Reference
NRW	Natural Resources Wales
RCP	Reinforced Concrete Pipe (Culvert)
ReFH2	Latest version of the Revitalised Flood Hydrograph model.
SGS	Sub-Grid Sampling
WEM	Water and Environmental Management



1.0 Introduction

1.1 Background

SLR Consulting (SLR) has been appointed by BakerHicks Limited to complete hydraulic modelling to inform the design of the proposed substation extension at Margam Moors. The Client seeks to appraise flood risk to land East of the Port Talbot TATA Steel manufactory (the “Site”), centred on National Grid Reference (NGR) SS 78575 86379.

It is proposed that an extension of the Margam Distribution Substation is constructed at the Site to facilitate additional electrical supply and distribution capacity to TATA Steel’s new Electric Arc Furnace (EAF).

A Flood Consequence Assessment (FCA) was completed for the Site by SLR in January 2025. Analysis of the “*Margam_FMC_5_V1.0_2023.pdf*” completed by JBA was undertaken to obtain peak flood elevations at the Site for the design of flood mitigation.

The latest flood modelling undertaken for the Margam area was completed in 2023 by JBA Consulting. This modelling was commissioned by TATA Steel to update the Flood Map for Planning (FMfP) at Margam Moors. The modelled results were accepted by NRW and was integrated as part of the updated FMfP for Rivers and Sea. However, it was considered that the outputs of the model did not accurately represent flood risk at the Site and the M4 motorway 660m to the east.

The JBA modelling showed that the M4 flooded for the 1 in 2 Annual Exceedance Probability (50% AEP) from fluvial sources emanating from the Margam Duck Pond (previously known as Ty Du reservoir) and Nant Cwm Philip (previously called Ty Du watercourse), 1.6km east of the Site. After consultation with Neath and Port Talbot Borough Council (NPTBC) highways authority and the Welsh Government, it was verified that there are no records of flooding occurring on the M4 as represented by the model.

The JBA Flood Map Challenge (FMC) report acknowledged the persistent flooding from the Margam Duck Pond as a major uncertainty in the model. The report recommended that further amendments to the model should consider:

- The modelled storm duration of 6.5 hours for all inflow hydrographs, was identified as the recommended default ReFH2 duration for the downstream flow estimation point on at the Afon Cynffig;
- Revisions to the upstream extent of the Nant Cwm Philip upstream of the Duck Pond, and;
- Improvement of the 1D performance at the primary outflow for the Duck Pond.

1.2 Flood Map Challenge Objectives

NRW’s FMfP show that the Site and much of the surrounding areas are within an area at risk of flooding with more than the 1% AEP from rivers in a given year, including the effects of climate change¹. To best align the current understanding of flood risk in the local area, the objective of the hydraulic modelling seeks to:

- 1 Identify the most likely mechanism of fluvial flood risk to the Site occurring from the Nant Cwm Philip; and

¹ Natural Resources Wales (2024) Flood Map for Planning (Rivers) Available from: [Natural Resources Wales / Flood map for planning / development advice map](#) [Accessed: 03 February 2025].



- 2 Determine a design flood level at the Site for several AEP events with NRW's recommended allowances for climate change.

1.3 Site Location

The Site is located directly adjacent to the existing Margam Distribution Substation to the east and is centred on National Grid Reference (NGR) SS 78575 86379. The proposed extension to the substation extends to an area of 1.73ha.

The "Study Area" considered for the updated modelling comprises the area of land between the TATA Steel Facility and Margam Park 1.7km to the east of the Site.

The locality of the proposed extension is provided in Figure 1-1.

Figure 1-1: Site Location Plan



2.0 Hydrological Assessment

The hydraulic model update completed by JBA in 2023 reviewed the existing fluvial inflow hydrographs and updated them using the latest available software and the latest hydrometric data. The assessment was carried out for the catchments for the Nant Cwm Philip - headwaters to confluence with Kenfig and the Kenfig - headwaters to tidal². The hydrological assessment was accepted by NRW.

However, NRW requested that the updated modelling investigate the inflow estimates upstream of the Margam Duck Pond (Nant Cwm Philip – headwaters) to verify if it has been over representing Q_{med} in the hydraulic model. Therefore, SLR undertook a revised hydrological assessment in accordance with the methods described in the latest NRW flood estimation guidance (GN008³).

The following hydrological assessment is a summary of the methodology and analysis provided in SLR's '*Margam Flood Estimation Report*'⁴. Input data, project files, and output data have been provided with the full flow estimation report.

2.1.1 Catchment Boundary Delineation

A distributed approach has been applied to the flow estimation for the Nant Cwm Philip and Afon Cynffig. This approach was selected in order to review the flood risk at specific catchment locations in further detail, such as Margam Duck Pond, as well as to maintain consistency with the previous JBA flow estimation for comparison purposes.

The Nant Cwm Philip and Afon Cynffig catchments have been split into five sub-catchments being defined based on local features. Two sub-catchments were delineated for the Nant Cwm Philip, and three sub-catchments were delineated for the Afon Cynffig.

A lumped catchment comprising each of the five sub-catchments was also delineated for use in determining the critical storm duration at the Site. The five sub-catchments and their outlet locations are shown in Figure 2-1, and the lumped catchment for critical duration testing is shown in Figure 2-2.

As part of the investigation of the Site, it was noted that a catchment size of approximately 3 km² contributing directing to the site was not accounted for in the fluvial assessment completed by JBA. As such, a direct rainfall area including the site itself was delineated for use in the updated model, and should be considered for all design (Figure 2-3).

Due to the location of the Site in the low-lying areas between the TATA Steel site and Margam Park, it is considered imperative that the 3 km² catchment be considered in calculating flood risk and design levels. This is due to low-lying areas typically being volume sensitive.

² Natural Resources Wales (2025) DataMapWales – Water Framework Directive (WFD) River Waterbody Catchments Cycle 3. Available from: [New map | DataMapWales](#) [Accessed: 19 February 2025].

³ Natural Resources Wales (2024) Flood estimation – technical guidance GN 008. Available on request from NRW.

⁴ SLR Consulting Ltd (2025) Margam Flood Estimation Report, '20250513_Margam_Flood_Estimation_Report.docx'



Figure 2-1 : Catchment Delineation

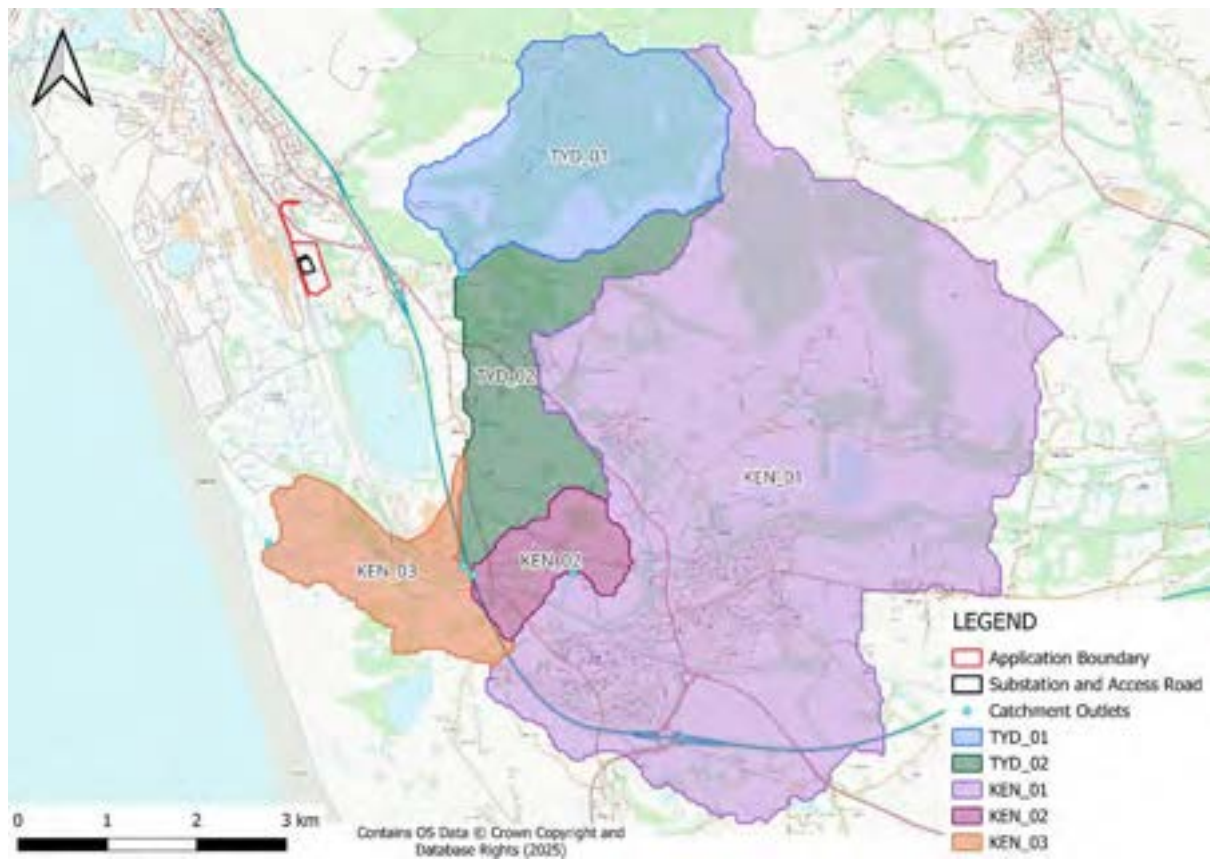


Figure 2-2 : Lumped Catchment for Critical Duration Testing

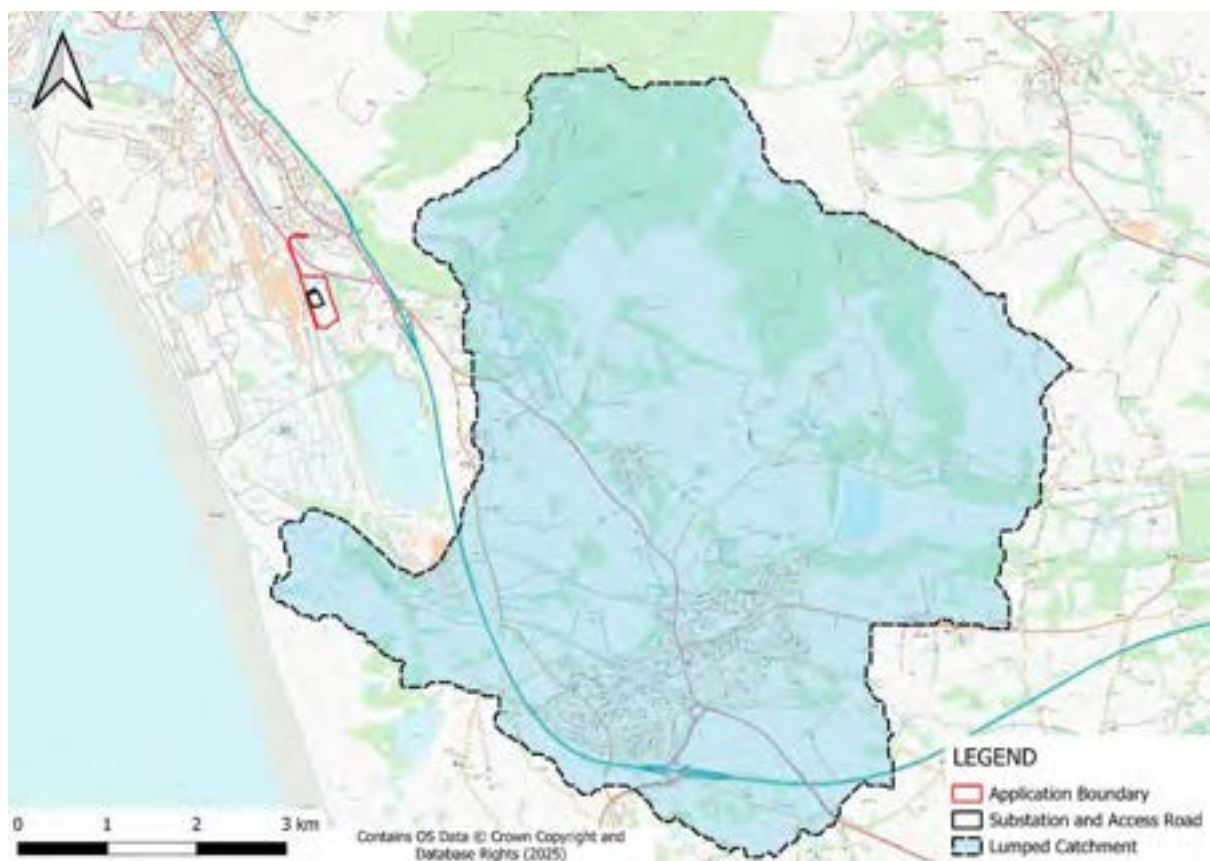
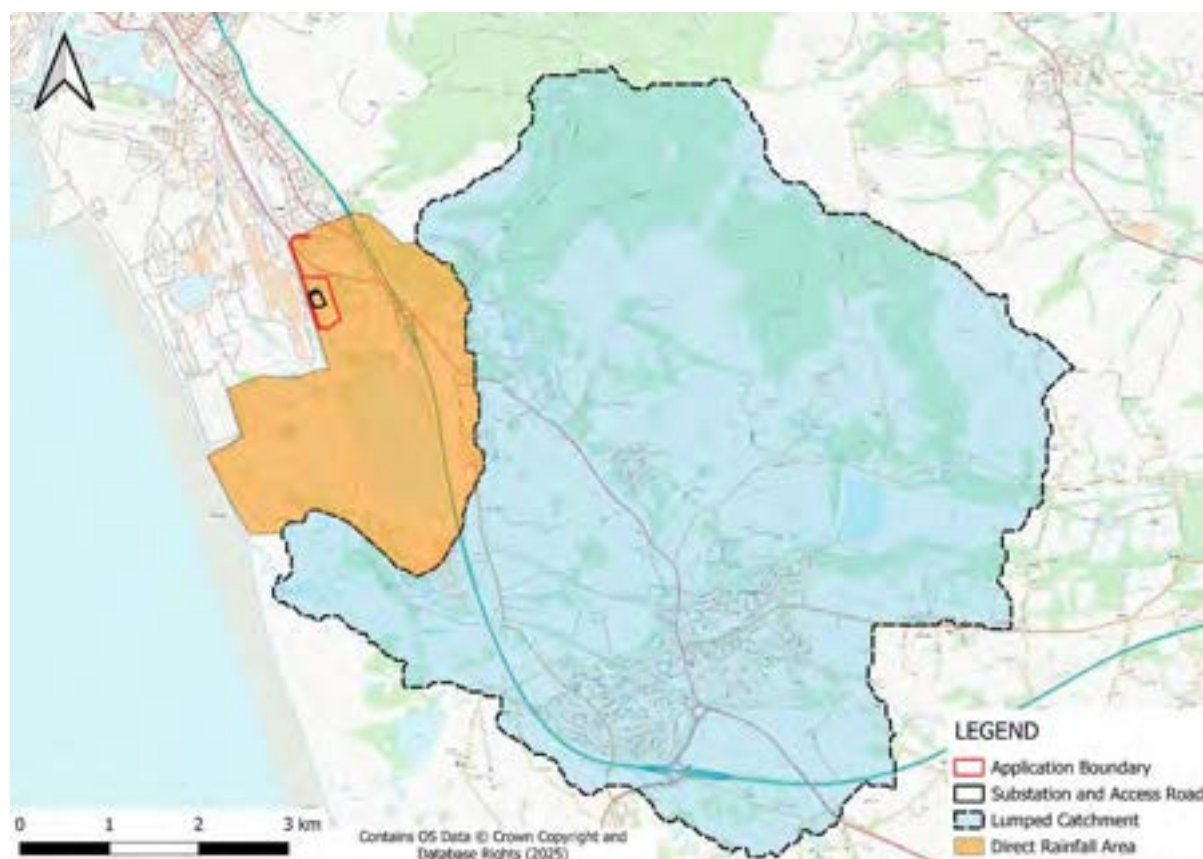


Figure 2-3 : Direct Rainfall Catchment for Sensitivity Testing



2.1.2 Catchment Descriptors

The details of the subject sites and the final catchment descriptors applied are outlined in Table 2-1 and Table 2-2 respectively. FARL, BFIHOST19, DPLBAR, DPSBAR, and URBEXT2000 values were amended where required and are marked in red where amended from the default FEH values. The reasoning and methodology for the changes are described in the Margam Flood Estimation Report.

Table 2-1 : Summary of Subject Sites

Site code	Type of estimate: lumped (L) or sub-catchment (S)	Water-course	Site name / description	Outlet Easting	Outlet Northing	AREA on FEH Web Service (km ²)	Revised AREA (if altered) (km ²)
TYD_01	S	Nant Cwm Philip	Nant Cwm Philip to Margam Duck Pond (downstream)	280300	186300	6.06	N/A
TYD_02	S	Nant Cwm Philip	Confluence with Afon Cynffig (excludes Margam)	280350	183000	10.45	4.39



Site code	Type of estimate: lumped (L) or sub-catchment (S)	Water-course	Site name / description	Outlet Easting	Outlet Northing	AREA on FEH Web Service (km ²)	Revised AREA (if altered) (km ²)
			Duck Pond upstream)				
KEN_01	S	Afon Cynffig	Upstream model extent	281550	182900	29.14	N/A
KEN_02	S	Afon Cynffig	Confluence with Nant Cwm Philip	280450	182950	30.73	1.59
KEN_03	S	Afon Cynffig	Tidal reach downstream of confluence with Nant Cwm Philip	278150	183250	55.48	2.93
Lumped catchment*	L	Nant Cwm Philip and Afon Cynffig	Full Afon Cynffig and Nant Cwm Philip combined catchments	278150	183250	55.48	44.13

* for critical duration testing

Table 2-2 : Final Catchment Descriptors

Site code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 1990	URBEXT 2000	FPEXT
TYD_01	0.949	0.52	0.485	2.45	220.4	1548	0	0.000325	0.0014
TYD_02	0.979	0.52	0.585	2.70	67.23	1433	0	0.0102	0.0498
KEN_01	0.970	0.52	0.501	5.67	95.7	1342	0.0498	0.0747	0.0489
KEN_02	1	0.52	0.522	1.3	4.85	1333	0.0473	0.00765	0.0504
KEN_03	0.952	0.52	0.854	1.77	4.75	1295	0.0502	0.0585	0.145
Lumped catch*	0.958	0.52	0.617	7.50	71.31	1295	0.0502	0.0546	0.145

* for critical duration testing

2.1.3 FEH Methodology

Stationary statistical and rainfall-runoff methods were both tested for the sub-catchments. The final choice of method for the flow estimation was the rainfall-runoff method using ReFH2 software. This methodology is considered to be suitable, and the Flood Estimation Guidelines favour the use of a rainfall-runoff approach in catchments that are tidally influenced/flood locked, such as for the lumped catchment applied in this study, as well as for the estimation of higher return period floods, such as the 0.1% AEP event.



There are no local gauges or other sources of information on either watercourse network which would aid calibration and verification of the hydrological modelling outputs.

The winter storm was selected for all sub-catchments due to the rural nature of the catchment of interest.

Critical duration testing was carried out in the hydraulic model using ReFH2 outputs for the TYD_01 sub-catchment, as well as for a lumped catchment including all five sub-catchments. The critical duration was identified to be 34 hours at the site itself, with a critical duration of 6 hours at Margam Duck Pond in catchment TYD_01. The 34-hour storm duration was therefore applied to the final peak flow estimation for all sub-catchments, with a sensitivity test carried out on the 6-hour storm duration for all sub-catchments.

Hyetographs for estimation of direct rainfall were estimated at the site of interest for the 50%, 3.3%, 1% AEP and 0.1% AEP events.

2.1.4 Climate Change

The West Wales 2080s central peak river flow allowance of 30% was applied in line with NRW guidance note GN008, as the catchment of interest and the majority of the sub-catchments in the study are above 5km² in area. Two of the sub-catchments are below 5km² in area, but are part of a wider fluvial catchment. For consistency, the peak river flow allowance was therefore applied to all sub-catchments.

Additionally, in line with NRW guidance, a test was also carried out applying the upper end peak river flow allowance of 75%.

The climate change allowances were applied as a direct multiplier to the peak flow estimates from ReFH2.

In accordance with the NRW guidance “Change to extreme rainfall intensity” for the central estimate and upper estimate have been applied as 20% and 40% respectively.

2.1.5 Peak Flow Results

The ReFH2 peak flow results are shown in Table 2-3. A comparison of the 1% AEP event and 0.1% AEP event peak flows derived from this study and the JBA study is provided in Table 2-4 for sub-catchment TYD_01.

Table 2-3 : ReFH2 Peak Flow Outputs

Site Code	AEP (%) – Peak Flow (m ³ /s)								
	3.3%	3.3% + 30% CC	3.3% + 75% CC	1%	1% + 30% CC	1% + 75% CC	0.1%	0.1% + 30% CC	0.1% + 75% CC
TYD_01	5.42	7.05	9.49	6.66	8.66	11.66	10.86	14.12	19.01
TYD_02	2.53	3.29	4.43	3.16	4.11	5.53	5.30	6.89	9.28
KEN_01	19.96	25.95	34.93	24.56	31.93	42.98	40.07	52.09	70.12
KEN_02	1.05	1.37	1.84	1.29	1.68	2.26	2.11	2.74	3.69
KEN_03	0.64	0.83	1.12	0.82	1.07	1.44	1.46	1.89	2.56

The peak flows derived for this study are lower than the ReFH2 and WINFAP peak flows estimated for the JBA study. The difference between the ReFH2 flows largely owe to the ReFH2 default duration of 6.5 hours being accepted for the JBA results, as well as to the inclusion of FEH22 rainfall data. The duration testing carried out for this study found the catchments (specifically located at the Site) to be volume-driven, and as such, scaling of the



WINFAP flows using ReFH2 outputs resulted in unrealistic flood volumes. It is considered that the ReFH2 outputs are more appropriate for flood estimation at the target site.

Table 2-4 : Comparison with JBA Peak Flow Results (TYD_01)

Source	1% AEP Event Peak Flow (m³/s)	0.1% AEP Event Peak Flow (m³/s)
SLR ReFH2	6.6	10.9
JBA ReFH2	10.3	18.1
JBA WINFAP	16.7	29.7

Peak flow results for sensitivity testing, as well as peak net rainfall results, are included in the Margam Flood Estimation Report.

2.1.6 Assumptions

The assumptions of this hydrological study include:

- There is a higher confidence in the peak flows estimated using the rainfall-runoff method than those estimated using the statistical method due to the tidally locked hydrological system and the requirement for analysis of long return period events;
- The rainfall-runoff method derived hydrograph shapes are representative of the runoff response of the catchment. There is no gauging data on the catchment itself to cross check these hydrographs;
- The proportion of baseflow in the catchments based on the FEH catchment descriptors is accurate;
- The lack of explicit representation of FARL in ReFH2 methodology will not result in overestimation of flows in the target catchments; and
- The area-weighting method of adjusting DPSBAR where applicable is appropriate for the scale of this study and does not have a major impact on flows.

Limitations and uncertainties of the study are addressed in the Margam Flood Estimation Report.

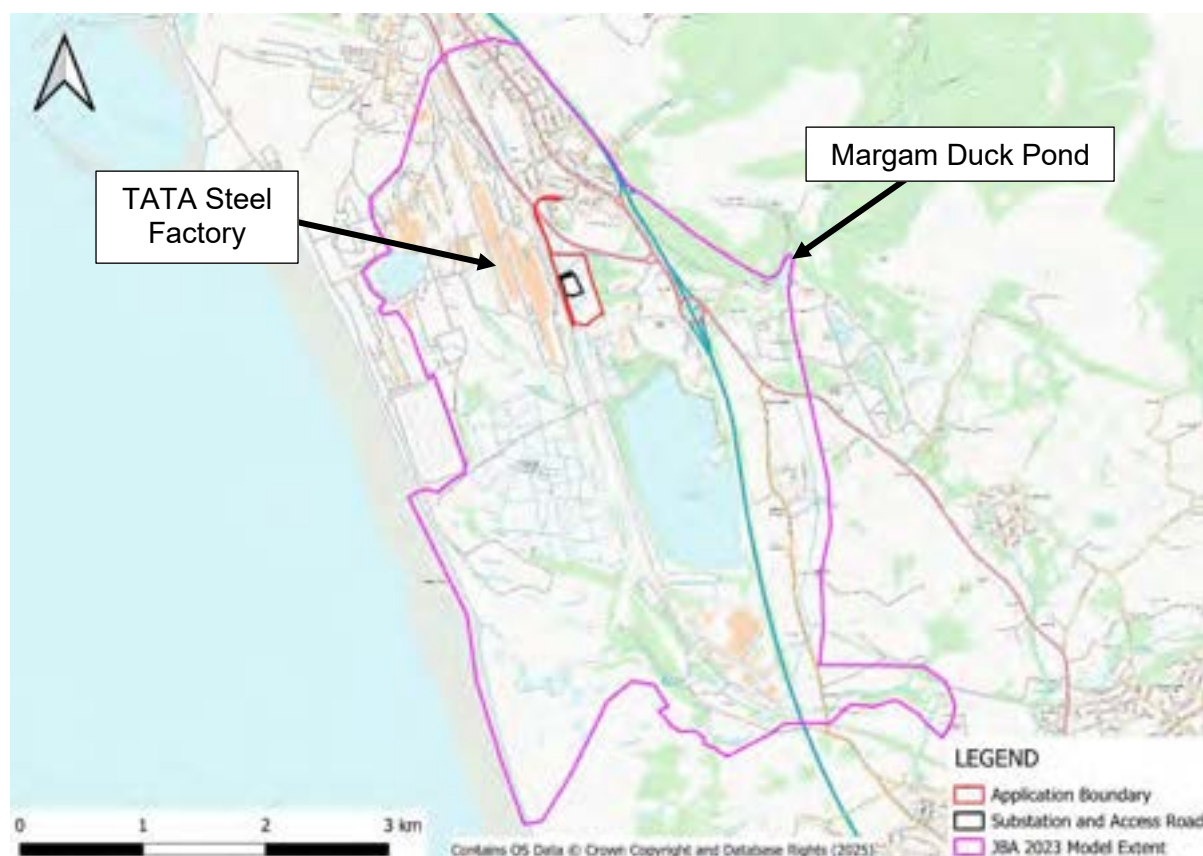


3.0 Methodology

3.1 Model History

The existing flood model (JBA, 2023) for the Margam area was originally developed in 2015 by Capita URS for NRW under the Water and Environmental Management (WEM) framework. The model assessed fluvial flood risk from the Afon Cynffig and Nant Cwm Philip, along with tidal influences from the Bristol Channel. This was a 1D-2D linked ESTRY-TUFLOW model, based on river channel survey data collected in 2013. An extract of the modelling extent is provided in Figure 3-1.

Figure 3-1: Baseline JBA Model Extent



As part of the FMC completed by JBA, updates were made to improve the model's accuracy and align with regulatory requirements of NRW. Revisions since the 2015 study include:

- **Survey Updates:**
 - A new hydrological assessment was completed using extended hydrometric data and updated methods.
 - Additional culvert surveys were undertaken in 2022, particularly for the Margam Moors area, where multiple flow routes were identified between floodplain and railway lines.
 - The representation of the Margam Duck Pond spillway and control structures was refined based on site visits and analysis of survey data, addressing long-standing concerns regarding unrealistic flood frequency projections.
- **Model Enhancements:**
 - The latest TUFLOW executable (2020-10-AF-iDP) was used.



- Base LiDAR data was updated for improved terrain representation.
- Revised tidal boundary conditions were applied using updated Coastal Flood Boundary (CFB) data.
- Hydraulic structures were enhanced with more detailed schematisation, including the introduction of 'BB' bridge units to improve loss coefficient calculations.

3.2 NRW Model Update Requirements

SLR completed an initial review of the current model Product 7 data (JBA, 2023) and submitted a request to NRW's Flood Risk Assessment Team to establish the scoping requirements necessary to update the model as part of the design requirements of the substation extension. The requirements of the revised model have been summarised below:

- NRW required that the hydraulic structure at the inlet of the Margam Duck Pond is surveyed including cross sections for up to 150m upstream and cross sections downstream of the inlet structure;
- A detailed survey is to be completed for the hydraulic structures at the outlet of the Margam Duck Pond based on the Environment Agency National Standard Technical Specification for Surveying Services;
- Details as to the operation of the lake and how it is maintained to be incorporated into the model;
- Additional Cross Section data is captured along the confluence of the two spillways and the area upstream of a receiving culvert;
- NRW identified that there are two culverts missing under A4241 (Harbour Way) that lead to the Site and may be incorporated; and
- All simulation include a revised hydrological analysis of Q_{med} .

The product 7 data was purchased and licenced for the purposes of completing an FMC from NRW. Full correspondence was documented and provided in **Appendix A**.

3.3 Model Selection

Based on the objectives of this assessment, the existing 1-dimensional / 2-dimensional linked (1D/2D Linked) hydraulic model was deemed appropriate for updating in support of the FMC.

The principal source of flood risk identified at the Site in the Margam Substation FCA was fluvial flooding from the Margam Duck Pond and Nant Cwm Philip located approximately 1.6 km to the east. To more accurately represent these key features and update the model in line with current standards, refinements have been made in accordance with the Environment Agency's River Modelling Technical Standards and Assessment Guidance⁵.

The latest version of TUFLOW (2025.0.2) was adopted for the model update, utilising the Sub-Grid Sampling (SGS) scheme to enhance the representation of small-scale terrain and flow pathways. SGS improves accuracy by incorporating finer terrain detail within coarser cell centres, allowing for improved resolution of topographic features without requiring uniformly small cell sizes across the entire domain. This is particularly beneficial in resolving complex flow paths, structures, and microtopography across floodplains and urban settings.

⁵ Environment Agency River Modelling: Technical Standards and Assessment. Available via: <https://www.gov.uk/government/publications/river-modelling-technical-standards-and-assessment>



TUFLOW Heavily Parallelised Compute (HPC) remains the selected numerical solver for simulating fluvial and pluvial driven 2D flows, dynamically linked with the 1D ESTRY modelling engine. The HPC engine incorporated in TUFLOW 2025.0.2 continues to solve the full 2D shallow water equations, including inertia and turbulence, while also benefiting from enhanced numerical stability and performance improvements introduced in this version.

Adaptive time-stepping and SGS-compatible finer grid resolutions have been applied in the model updates to assist in areas of hydraulic complexity, allowing greater fidelity in the modelling of water levels, velocities and flood extents. The model configuration aligns with current best practice and remains consistent with EA and NRW benchmarked standards. TUFLOW, developed and maintained by BMT, continues to be widely adopted across the UK and internationally for flood risk modelling and appraisal.

3.4 Model Update Construction

The construction of the 1D/2D linked hydraulic model required several datasets and parameters. These are summarised below:

- A channel and topographic survey of Nant Cwm Philip (channel cross-section data). Details of which are included in **Appendix B**;
- Floodplain topography in the form of a Digital Elevation Model (DEM). This survey was captured in the extent of the site floodplain and captured 18 July 2024;
- Bathymetry survey of Margam Duck Pond topography in the form of a Digital Elevation Model (DEM). This survey was captured in the extent of the Margam Park area and captured 31 March 2025;
- Hydraulic boundaries;
- Roughness across the Study Area (Manning's n); and
- Appropriate model cell size, and adoption of sub-grid-sampling (SGS).

3.4.1 1D Channel Cross Sections

A total of 21 channel cross section surveys were carried out in March 2025 by Storm Geomatics Ltd and were incorporated into the model (**Appendix B**). These sections informed the 1D open channel network along the length of the Nant Cwm Philip through Margam Park.

The extent of the model was updated to incorporate the Nant Cwm Philip 150m upstream of the Margam Duck Pond inlet structure. The 1D representation of the channel was updated from the current JBA model up to 600m south of the Pond (the extent of the updated survey). The remaining lengths of the Nant Cwm Philip and Afon Cynffig was retained and reconnected to the updated version where appropriate.

Each updated length of the Nant Cwm Philip was digitised with 'XZ' type 1D cross sectional (1d_xs) lines linked to updated csv's as provided by Storm Geomatics. The surveyed channel was then connected to the existing 1D network and linked to the 2D domain via the means of HX boundary connections running parallel alongside each of the channel banks.

To provide maximum compatibility with the 2D element, the underlying DEM was sampled every 2m along the channel boundary and applied to the cells lining the edge of the channel by means of a topography modifier (2d_zsh).

3.4.2 Hydraulic Structures

All current and updated hydraulic structures used in the model domain were explicitly represented in the 1D domain. Structures downstream of the surveyed extent of the Nant



Cwm Philip have been retained. In total, 12 structures were added or amended into the model.

As identified by NRW, there are two culverts to the north and northwest of the Site below Harbour Way. These structures hydraulically link areas to the north of Harbour Way (A4241) to the Site. These structures were incorporated based on local planning data for Harbour Way (Application P2010/1100 for Harbour Way) and a site walkover completed by SLR on 10 March 2025.

Furthermore, it was identified in the initial supporting FCA that a leading cause of the significant flood depths occurring at the Site was the absence of an outlet (under the TATA Steel site) for attenuated water at the Site.

A review of flood risk information and local drainage around the Site indicates that the receiving Upper Mother Ditch drains low-lying areas below the adjacent railway to the west and conveys flows to a receiving structure comprising control gates and sluices. This structure is assumed to discharge to Swansea Bay, approximately 1.7 km west of the Site. Details of ownership and operation are currently unknown. Assumptions based on site inspections completed by BakerHicks were adopted for the modelling and discussed further in **Section 3.4.2.6**.

3.4.2.1 Nant Cym Philip Bridges

The approved NRW model utilised 'BB' ESTRY bridge unit type to represent flow hydraulics through all bridges for automatic calculations of form loss coefficients based on approach and departure velocities, with accompanying weir ('W') type structures to represent overtopping of the bridge deck. This was amended to 'BBW' along the surveyed extent of the Nant Cwm Philip, represented as 1d_nwke channels, to consolidate and represent flows overtopping the structure. Elements of the structure from the deck depth to rail height and blockage were represented by populating optional attribute descriptions with Storm Geomatics Survey data.

Each bridge was populated with cross sectional data surveyed at upstream and downstream ends. Height vs width (HW) tables were applied directly to bridge layers to permit flows through the structure.

A summary of the structures along the Nant Cwm Philip and locations are provided within Table 3-1.

Table 3-1: Nant Cwm Philip Structures

Bridge ID	Name	Type	Added or Updated
PHI01_00013_B1	Access Bridge_01	BBW	Added
PHI01_00195_B1	Rail Bridge	BBW	Added
PHI01_00265_B1a	Foot Bridge_01	BBW	Added
PHI01_00332_B1	Access Bridge_02	I	Added
PHI01_00587_B1	Margam Culvert	I	Updated
PHI01_00599_B1	Arch	BArch	Updated
PHI01_00630_B1	Foot Bridge_02	BW	Added
PHI01_00653_B1	Margam Duck Pond Outfall	W	Updated
Gate 104	Emergency Overflow	SGO	Updated



3.4.2.2 Margam Duck Pond Inlet

The inlet structure of Margam Duck Pond comprises of a weir with a bridge crossing over top with a clearance of 1.97m to the soffit. Downstream of the weir is a single stepped spillway that leads into the Pond. The incoming Nant Cwm Philip is represented in the 1D domain and is linked to the upstream side of the structure as a 1d_nwke layer with an irregular (I) type structure to represent the conveyance of the flow.

A bathymetric survey was completed for the receiving Duck Pond (see **Section 3.4.4.1**) which provides accurate ground levels for the spillway and downstream of the weir. The invert level of the structure was set to 46.13m AOD and linked to the 2D domain using SX boundary conditions. This arrangement permits water to outfall into the Duck Pond according to the dimensions of the structure and flow through the spillway in the 2D domain.

It was found that the flood level upstream of the structure does not overtop the structure deck even in extreme conditions, and as such representation of the bridge deck as a weir was retained in the 2D domain.

Figure 3-2 below shows the inlet structure to the duck pond.

Figure 3-2: Margam Duck Pond Inlet Downstream Face



3.4.2.3 Margam Duck Pond Outfall

The existing model represented the outfall structure from Margam Duck Pond as a bridge structure with Height Width (HW) tables to permit flow below the soffit of the bridge. As demonstrated in Figure 3-3, the complex arrangement of the outlet also includes an orifice with a diameter of 238mm.



There is also an unused outlet located just downstream of the main spillway that was surveyed and found to have insignificant flow. It is assumed that the unused outlet was sealed off in the past and any remaining discharge is seepage flow from the reservoir. This structure has therefore not been represented.

The model represents the spillway arrangement by implementing a 1.4m width weir linked in parallel to a single orifice, connected directly to the 2D domain within the duck pond. The arrangement was then reconnected to the surveyed extent of the Nant Cwm Philip in the downstream spillway path.

Following initial test runs, it was found that the water level when exceeding the outlet did not rise above the crest of the bridge structure. It was decided that the bridge deck did not provide significant hydraulic control and was removed in favour of simplicity and stability of flow through the outfall.

Figure 3-3 Downstream Face of Margam Duck Pond Outlet at Foot Bridge_03



3.4.2.4 Emergency Overflow (Sluice 'Gate 104')

A discussion with the supervising Reservoir Panel Engineer of Margam Duck Pond took place on 12 March 2025. During the meeting, the operational details of the sluice gate were provided which indicate that the sluice gate is opened to maintain a 50mm head above the main outfall. The standard procedure is for a Margam Park attendant to manually open the sluice gate to maintain the 50mm head.

'Gate_104' was defined as an operational sluice gate (SGO) type 1d_nwke shape and modelled using a defined operational control rule (.toc). The gate was surveyed and has an invert level of 43.15m AOD, a width of 1.26m, and is operated as a vertically moving gate

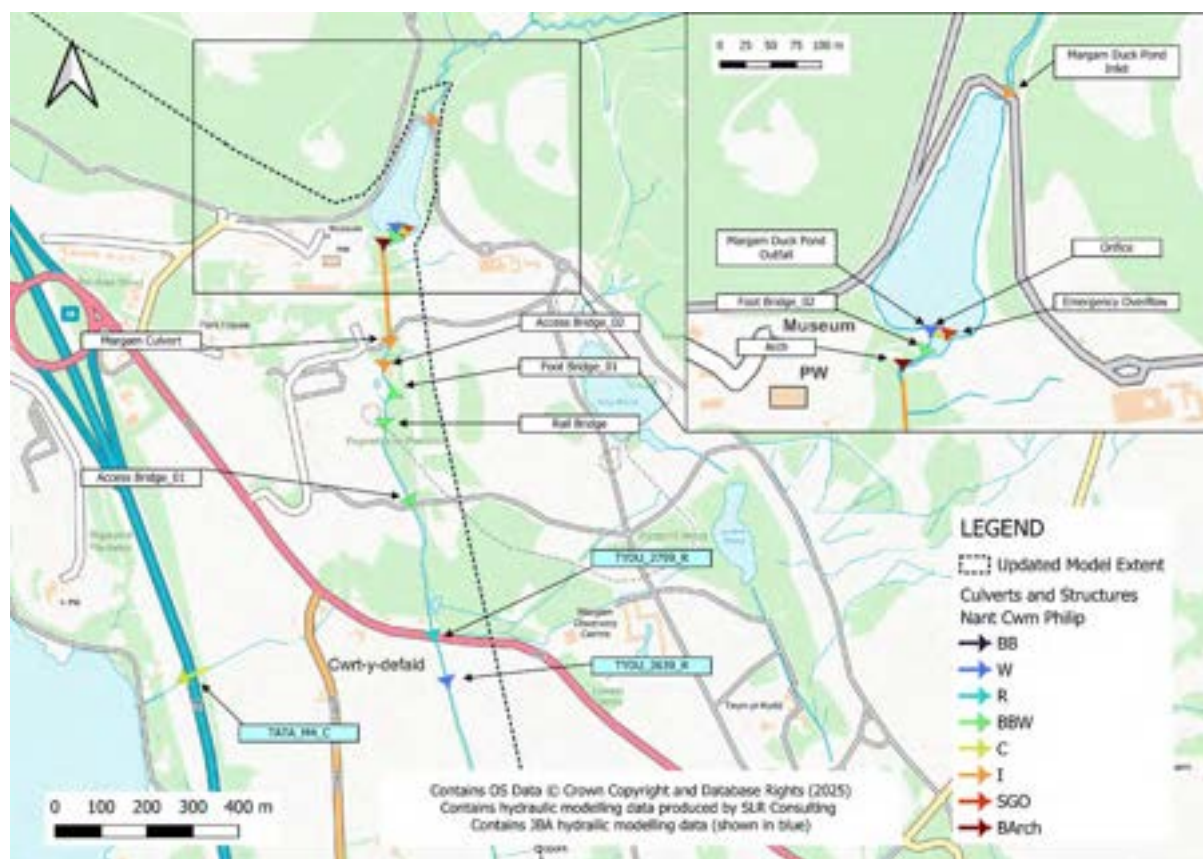


with a maximum opening height of 0.8m above the gate seat. The fully open crest elevation is set at 44.0m AOD, and the gate moves at a speed of 0.1m/s to simulate manual operation.

Control of the sluice is based on an upstream water level trigger at coordinates 280260.05, 186365.61. The operational rule specifies the gate opens only when water levels reach or exceed 43.85m AOD (50mm above the crest level of the outfall weir). This operational logic aligns with instructions from the Margam Park Reservoir Engineer and simulates an operational gate scenario for flood risk assessment purposes.

Similar to the main spillway, it was found that the water level when exceeding the outlet did not rise above the deck of the bridge structure up to and including the extreme events (0.1% AEP) and therefore was not included in the final model.

Figure 3-4: Updated and Existing Hydraulic Structures Along Extent of Nant Cwm Philip



3.4.2.5 Culverts

A summary of the culvert structures added to the model, specifically siting the TATA Steel Facility and Harbour Way culverts, is summarised in Table 3-2.

Table 3-2: Culvert Structures

Culvert ID	Description	Type	Dimensions (m)
PHI01_00933_B1	Margam Duck Pond Inlet	I	Irregular dimensions
PHI01_00332_B1	Access Bridge_02	I	Irregular dimensions
HW_001	Harbour Way Underpass	C	3.0
HW_002	Harbour Way Culvert	C	0.9



Culvert ID	Description	Type	Dimensions (m)
TATA_In_109	TATA Culvert Inlet	RU	1 x 2
TATA_Out_109	TATA Upper Mother Outlet	RU	1 x 2

It was advised by NRW that the culvert structures below Harbour Way are included to better appraise fluvial flood risk at the Site. Data derived from NPTBC planning portal (Application P2010/1100 for Harbour Way) and data collected by SLR was incorporated into the model by representing culvert structures as 1d_nwk culverts.

Harbour Way Culvert & Underpass

The approved NRW model did not include structures which could permit flow through Harbour Way. Instead, water flowing from Margam Duck Pond is attenuated behind the embankment of Harbour Way before overtopping and flooding the Site. Due to accessibility constraints of the two structures, a review of the planning application P2010/1100 was completed in lieu of surveyed information. The parameters of Harbour Way are document in Table 3-2.

TATA Steel Inlet

As seen in Figure 3-5, the culvert permits utilities below the railway and links the Site to the TATA Upper Mother Outlet. The Client provided a drawing of the dimensions of the culvert for representation in the model. To account for restriction of flows through the culvert, the equivalent void area was applied to a rectangular, unidirectional (RU type) 1d_nwk culvert.

Figure 3-5: Upstream Face of TATA Steel Inlet



3.4.2.6 TATA Upper Mother Outlet

The approved NRW model outputs show that significant flooding occurs at the Site due to fluvial flows from the Margam Duck Pond overtopping Harbour Way. Harbour Way and the railway line west of the Site are raised on significant embankments which permit flood waters to attenuate and reach significant depths.

As reported in the accompanying FCA completed by SLR (*"250516_402_065363_00001_Margam Substation FCA_BakerHicks_Rev_08.pdf"*)⁶, the existing drainage regime at the Site comprises of a series of drainage ditches that connect to the Upper Mother Ditch that leads north. Here, water is conveyed below the railway line through a culvert and to a large control structure located at NGR: SS 78302 86668. It is understood that the local catchment comprising runoff from the east portion of Harbour Way, the Upper Mother Ditch and land north of Harbour Way⁷ which ultimately leads to the outlet structure.

The TATA Upper Mother Outlet structure was implemented utilising the "RU" type culvert to represent unidirectional flows. An information request issued to TATA Steel suggested that they did not hold operational details of dimensions for the receiving inlet structure.

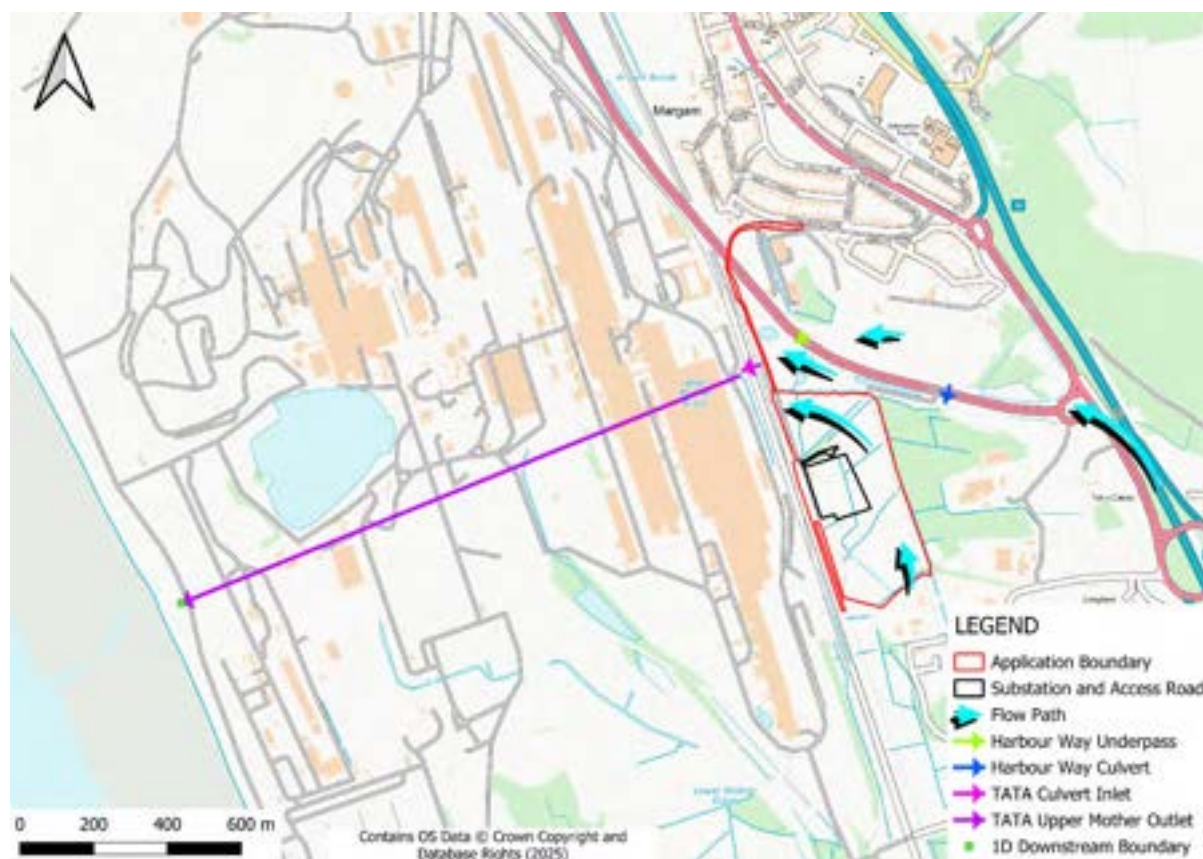
The structure has therefore been assumed to discharge directly to the Swansea Bay along a length of 1.63km through the TATA Steel Facility. The inlet was represented by 2m x 1m RU inlet and linked to the 2D domain with a simple SX boundary condition. In the absence of definitive data, the downstream connection of the structure was directly connected to the model's downstream boundary Mean High Water Springs (MHWS) tidal curve.

6 SLR Consulting (2025) Flood Consequence Assessment Proposed extension of the Margam Substation Rev.: 08.

7 Halcrow Group Limited (2007) Neath Port Talbot County Borough Council Port Talbot Peripheral Distributor Road Stage 2 Flood Consequences Assessment Supplementary Modelling Report Issue 1 (0). Available from: [P2010/1100 | Construction of the Port Talbot Peripheral Distributor Road Stage 2.amendment to application P2007/292 approved 28th August 2007. | Land between the Port Talbot Docks Area and the A48 near Junction 38 Port Talbot](#) [Accessed: 25 April 2025].



Figure 3-6: Culvert Structures at the Development Site



3.4.3 Hydraulic Boundaries

The objective of this assessment was to focus on the flood risk to the Site. The arrangement of the fluvial upstream boundary condition for the Afon Cynffig was retained with updated hydrological inputs as described in **Section 2.0**. All tidal boundary conditions were retained from the approved NRW model (JBA Consulting, 2023) and provided below for completeness.

It is expected in any event that the Margam Moors catchment would experience rainfall in both the fluvial investigated and pluvial investigated catchments. To assess the flood risk at the Site the direct rainfall contributing catchment was considered and applied to the model.

3.4.3.1 Upstream Boundaries

Hydraulic input for the upstream fluvial boundary condition for the Nant Cwm Philip upstream of the Margam Duck Pond was derived from updated flow vs time hydrographs acquired from the hydrological assessment (**Section 2.0**). This was applied within the 1D domain by means of a 1D boundary condition (1d_bc layer) positioned at the uppermost surveyed extent of the Nant Cwm Philip.

Duration testing was conducted using the 1% AEP plus 30% Climate Change to determine the critical duration on which to apply to the upstream boundary condition. As noted in **Section 2.0**, the 34-hour duration was selected, attributed heavily to the volume driven nature of the system and specifically areas of the Site. A summary of the flood peak statistics across each AEP event at the inflow location to the Nant Cym Philip is provided in Table 3-3.



Table 3-3: Nant Cym Philip Fluvial Model Inflows for the Critical Duration (34 hour)

Event Scenario (AEP)	Peak Flow (m ³ /s)
50%	3.29
3.3%	5.55
1%	6.83
1% + 30% CC*	8.88
1% + 75% CC*	11.96
0.1%	11.15
0.1% + 30% CC*	14.50
0.1% + 75% CC*	19.52

* Climate Change

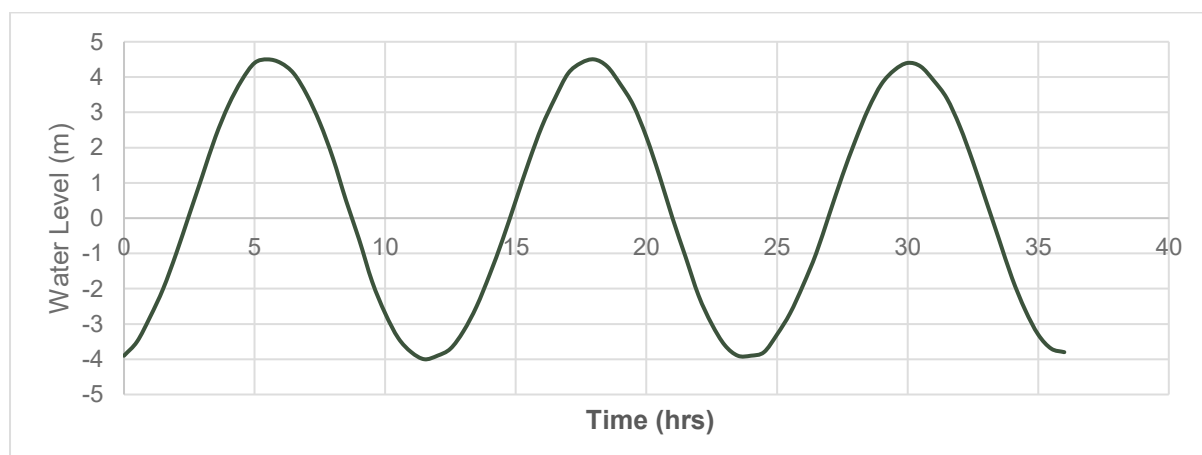
A range of uplifts has been applied to the 1% AEP and 0.1% AEP events to account for the change allowances in line with NRW guidance for West Wales. These uplifts have been directly multiplied to the respective 1% AEP or 0.1% AEP hydrographs for all fluvial boundary conditions.

3.4.3.2 Downstream Boundaries

The downstream boundary condition for the 2D domain has been retained for fluvial flows discharging to the Swansea Bay via the Afon Cynffig. The model utilises a Head/Time (HT) type downstream boundary (2d_bc) to represent oscillating tide levels over time, based on the CFB dataset (node 474). These conditions have remained unchanged.

Water discharging from the Site via the TATA Upper Mother Outlet was assumed to outflow from the 1D domain via a HT downstream boundary (1d_bc). This simulates water leaving the model through the TATA Upper Mother Outlet when the water level at the outlet is low enough to permit flow through the structure.

Figure 3-7: Downstream Boundary Mean Highwater Springs (MHWS) Curve



It should be noted that all climate change scenarios included a sea level rise of 0.84m, as per Table 3 of the Welsh Government “Climate change allowances and flood consequence assessments” guidance⁸.

⁸ Welsh Government 2021 “Climate change allowances and flood consequence assessments” guidance. Accessed at <https://www.gov.wales/climate-change-allowances-and-flood-consequence-assessments>



3.4.4 Floodplain Topography (DTM)

The available 2D topography for the model extent from the NRW⁹ is dated January 2022 and has not been updated since publication of the approved NRW model. Therefore, the existing 2m resolution DTM data has been mostly retained with exceptions made for Margam Duck Pond and the Spillway. These areas were updated based on the collected survey data, completed 31 March 2025, and the detailed site survey completed 18 July 2024.

3.4.4.1 Bathymetric Survey

To improve the representation of flood storage capacity in the Margam Duck Pond, it was determined that a bathymetric survey would appropriately represent the current capacity of the pond in the 2D Domain. A bathymetric survey measured and mapped the depth, shape, and contours of underwater surfaces using sonar or echo sounders. It provided detailed information about the submerged terrain so that capacity of the pond could be best represented.

Survey data was represented as a point cloud, a collection of data points in 3D space that accurately depicted the topography under the waterline. This point cloud was resampled to represent a 0.2m grid in QGIS, by conversion to a raster utilising processing tools.

3.4.4.2 Duck Pond Spillway Survey

It was highlighted by JBA in the previous 2023 report that the base topographic data from NRW reflected uncertainty within the modelled outputs. To refine the representation of the Margam Duck Pond spillway, embankment crests, and existing exceedance flow paths. A topographic survey was completed covering the Pond spillway and a portion of the park grounds to the southwest. It was considered necessary to refine the ground levels around the Pond and through the park grounds to determine if the existing model misrepresented the capacity of the Pond provided by flanking berms or exceedance flow pathways moving towards the Site.

Utilising a drone equipped with LiDAR sensors, a point cloud representation of the floodplain was acquired and included in the model. The point cloud output was later subjected to post-processing analysis to derive a DTM from the data at 0.2m resolution and clipped along the extents of the bathymetric survey. This data was then screened and amended to fill any sinks and incorporated into the model.

Following technical guidance (GN 039)¹⁰ presented by the Flood Risk Management Board and Flood Risk Analysis sub-group, building footprints were artificially increased in height by 0.3m.

3.4.4.3 Obstructions

The existing JBA model represents fluvial flood risk from Margam Duck Pond flowing south west from the spillway and across the park grounds. Using the Digital Surface Model (DSM) point cloud data outputs for 'not-ground' features (e.g. trees walls and buildings),

The park is characterised by several walls and buildings that would influence flood flow mechanisms. The DTM data was reviewed and overlaid with digitised 2D break lines marking wall lengths and other impermeable structures within the extent of the Duck Pond

9 Natural Resources Wales (2022) Welsh government LiDAR Tile Catalogue 2020 - 2023. Available at: [View map | DataMapWales](#). [Accessed: 25 April 2025].

10 Flood Risk Management Board and Flood Risk Analysis sub-group (2021) What hydraulic models need to include Guidance to help design tender specifications (GN 039) Available from: [Guidance note template, external](#)



Spillway. TUFLOW's asc_to_asc¹¹ utility was then used in conjunction with the break lines to capture the crest levels and ensure appropriate representation within the model.

The generated break lines were later validated and amended where the point data sampled tops of trees instead of the wall crest. As demonstrated by Figure 3-8, the validation process was necessary to align the model with the observed dimensions of intercepting walls and structures by avoiding treetops.

Figure 3-8: Margam Park Cemetery Wall to the South West of the Duck Pond.



3.4.5 Model Roughness (Manning's n)

3.4.5.1 Land Use Updates

The material roughness across the model domain has been read into the hydraulic model using a .tmf file formatted to be read by TUFLOW. The 2015 model produced by NRW utilised Ordinance Survey (OS) data produced for the whole modelling extent. The current model version from JBA updated the land use and Manning's n values based on OS MasterMap data land licenced from TATA Steel (2022) and classified by OS land use ID for Manning's n values derived from NRW's indicative roughness values¹² and texts such as Chow¹³ for open channels.

11 TUFLOW (April 2025) ASC to ASC Section 3.9: Extract Breaklines from DEM. Available from: https://wiki.tuflow.com/ASC_to_ASC [Accessed: 29 April 2025].

12 Natural Resources Wales (2023) Indicative 2D roughness values Available from: [Natural Resources Wales / Indicative 2D roughness values](#)

13 Chow, V.T. (1959) Open Channel Hydraulics. McGraw-Hill, New York.



The existing model was reviewed between Margam Duck Pond and the Site to confirm if any significant changes had occurred since the model. It was considered that the 2022 OS mapping data is current, and no significant changes had occurred. The extent of the 2022 data did not cover the grounds of Margam Park and therefore utilised the existing 2015 OS data.

It was noted that land use comprising of dense thickness of bamboo had been included in the model. It was confirmed during the site visit by SLR on the 10th of March, 2025, that these areas still exist and have thus been retained.

Representation of the complex stepped spillway outlet of the Duck Pond was selected to be within the 2D. As the 2D survey does not accurately represent discrete details of the spillway (i.e. spillway material or sharp weir like edges), the spillway outlet was represented in the model with a manning's roughness coefficient of 0.09.

3.4.5.2 1D Channel Roughness

Cross sectional data along the surveyed length of the Nant Cwm Philip provided by Storm Geomatics included truncated roughness coefficient values for the channel bed. These values were incorporated into the model using 'N' flags in the 1d_xs layer along the updated extent of the Nant Cwm Philip. Data points beyond the top bank were not included as these roughness values would be represented in the 2D domain.

3.4.6 Proposed Flood Defence Wall

The proposed development will exclude incoming fluvial floodwater by constructing a flood wall around both the existing and new substation areas. To assess the potential flood risk from displaced water, the Site was raised by 6.0m above the DTM, higher than the maximum modelled flood depths for all simulated events as determined from the current JBA model. This approach assumes complete exclusion of floodwater from the development and represents a conservative worst-case scenario.

3.4.7 Model Operation

The hydraulic model was simulated using the HPC solver for TUFLOW Build 2025.0.2 single precision (iSP). Initialisation of the TUFLOW model utilised a standard Windows Batch File linking the TUFLOW executable, control files (.tcf) and relevant event, scenario and variant logic. All model runs were performed on high-performance computing facilities using a NVIDIA A10 GPU with an approximate run time of 4 hours per model.

A summary of the events and scenarios used within the final model are presented within Table 3-4 below.



Table 3-4: Model Scenarios Definitions

Control File	MAR~s1~_~e1~_~e2~_113.tcf
Scenarios (~s1~)	SEN08 (RoG of site-specific contributing catchment area) EXG (Baseline Conditions) - Fluvial DEV (Development Scenario) SEN01 (IWL lowering Scenario - 43.0 m AOD) SEN02 (IWL lowering Scenario - 42.5 m AOD) SEN03 (Mannings Roughness increase 30%) SEN04 (Mannings Roughness decrease 30%) SEN05 (Structure blockage 25%) SEN06 (Structure blockage 50%) SEN07 (Margam Duck Pond sluice gate not opened) SEN09 (6hr Duration) - WINFAP Scaled Hydrology SEN09a (6hr Duration) - ReFH2 Hydrology
Events (~e1~)	30Y (3.3% AEP) 100Y (1% AEP) 100YCC40 (1%+40%CC AEP) 100YCC75 (1%+75%CC AEP) 1000Y (0.1% AEP) 1000YCC40 (0.1%+40%CC AEP)
Durations (~e2~)	34hr 6hr (sensitivity only)



4.0 Results and Discussion

4.1 Model Results

Finalised mapping of all hydraulic modelling results has been provided within the Appendices as follows:

Appendix C – Base Case Model Results

Appendix D – Proposed Case Model Results

Appendix E – Sensitivity Results

It is noted that all baseline and proposed results have considered results including the pluvial catchment. Sensitivity modelling has been completed on fluvial only model simulations to understand the model's sensitivity to change in hydraulic parameters.

4.1.1 Performance

The models performed well overall with marginal mass balance errors within the recommended +/-1% tolerance. Occurrences of negative depths appear along the extents of the Afon Cynffig, however, these are not considered to have a material impact to the Development Site or the Margam Duck Pond.

A summary of the checks and warnings which occur as a result of the updated model have been provided for below:

- WARNING 1991 – Negative depths occurred 76 times. These were ignored as impact to the Study Area is negligible.
- CHECK 1152 occurs 24 times - “using centre cross-section and ignoring end cross-section(s).” This occurs due to cross sections being digitised to the midpoint of a 1D structure. These are acceptable as they refer to surveyed data to specifically represent a structure.
- WARNING/CHECK 2118 - Lowered SX ZC Zpt by [X]m to 1D node bed level. This warning is commonly associated with the resolution of the input DTM not correlating with input levels for structures in the floodplain. This warning has been ignored due to the innate inaccuracy of the 2m resolution DTM, the location and impact in relation to the site, and the changes of the model being focused on the site only.
- CHECK 2370 - Ignoring coincident point found in Z Shape SGS layer. These occur at the Foot Bridge_01 layer where multiple vertices are digitised were unnecessary. This was not considered to have a material impact on the modelling results and were therefore ignored.
- CHECK 2541 – BC polyline selects no cells: The HX boundary condition was counted nine times using the midpoint method, but no cells were selected. This occurred because the resolution of the model grid was coarser than the digitised extent of the 1D open channel boundary condition. The issue was not pursued further, as the mismatch in resolution rendered the selected cells unsuitable for meaningful selection however is not expecting to impact results.

4.1.2 Duration Testing

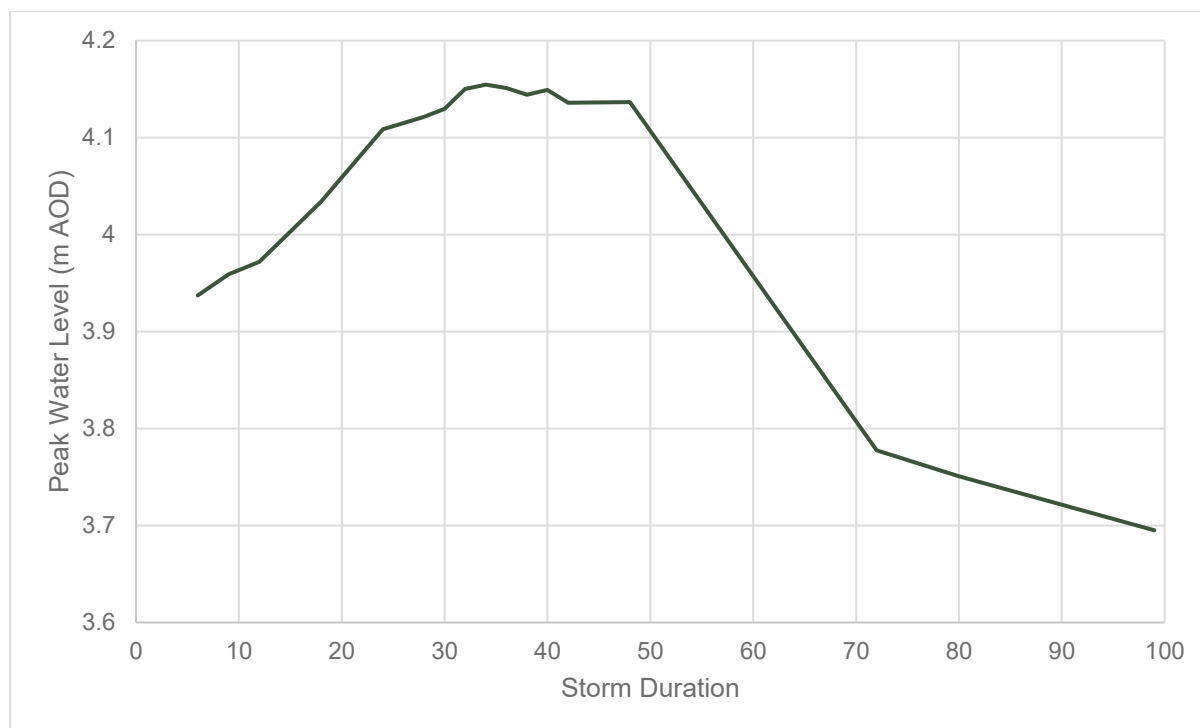
Critical duration testing was conducted as described in **Section 2.0**. A range of storm durations were simulated through the updated hydraulic model to determine maximum flood levels at the Site. The critical duration assessment was completed on the 1% AEP + 30% CC only. Seventeen (17) storm durations from the 6-hour to the 99-hour storm were simulated. The wide range of storm durations were selected based on results indicating the



Site's location being highly volume driven. As such long storm durations proved to have a large impact of water levels in the low-lying and slow draining areas of the Site.

The critical duration assessment was conducted on the fluvial ReFH2 TYD_01 catchment only, as this catchment was the main fluvial contribution. The results indicated that the 34-hour storm duration produced the highest water levels at the Site and surrounding areas. Figure 4-1 below shows the peak water level at the site verse the modelled storm durations, depicting the 34-hour storm as critical.

Figure 4-1: Peak Water Level vs 1% AEP + 30% CC Storm Duration



4.1.3 Margam Duck Pond

For the (Q_{med}) 50% AEP event, the peak flood extents are shown to be confined to the area downstream of the spillway and adjacent to the Margam Culvert Inlet. The mapping no longer shows flooding moving west towards the M4. It is therefore considered that the modelling outputs have been validated against the local flood risk history as confirmed by NPTBC highways authority and the Welsh Government for frequent return periods.

However, the peak flood extents for the Baseline Scenario (EXG) for events with a frequency up to and less than 3.3% AEP all showed that the Margam Duck Pond begins to overtop the main spillway and outfall. The addition of significant overtopping flow overwhelms the discharge capacity of the Margam Culvert downstream and thus backs up, overtopping the west bank and flooding Margam Park.

Additionally, as was identified in the current model produced by JBA, the pond also overtops the west abutment which permits flows west down towards the M4. Flood flows travel west according to the prevailing regional topography across the M4 and towards the Site.

Investigation of flows through the outfall and emergency overflow reveals no significant instabilities at the discharge locations. It is therefore understood that the Duck Pond likely provides less volumetric storage than what would be required to accommodate an extreme event flow from the Nant Cwm Philip.



In high flow events it was also found that the main culvert downstream of the Duck Pond quickly reaches capacity and begins to break the banks, sending flows west and ultimately towards the Site. It was found that the capacity of this structure is also a key limitation of the fluvial flood risks of the Site.

4.1.4 Site Specific Results

Flooding is shown to occur at the Site in all baseline scenarios with a 3.3% AEP or less, including climate change allowances. As previously described, the primary flood mechanism is the exceedance of the flow capacity at Margam Duck Pond.

Flood flows moving west was shown to be intercepted by the M4 at Junction 38 before being channelled north along the slope of the highway; water then flows west towards Harbour Way. The modelling indicated that water flows around the north and south side of Harbour Way.

Floodwater is conveyed from the north side of Harbour Way via the Harbour Way Culvert, and subsequently through the ditch network surrounding the Upper Mother Ditch. The capacity of the ditch is quickly exceeded and leads to inundation of the Site. Flows then migrate northwards along the prevailing topography, eventually draining via the culvert network beneath the western railway line and the TATA Steel facility.

The Site is low-lying within the wider catchment, when flooded, the Site is inundated for a long period. This is because the surrounding landform of the railway, Harbour Way and rising topography to the east functions as a large attenuation basin.

Results have been sampled at six (6) locations around the site and summarised in the following sections. The sampling locations are provided below in Figure 4-2. Appendix references have been summarised in Table 4-1

Figure 4-2: Sample Locations



Table 4-1: Appendix Figure Reference

Fluvial Event Scenario	Peak Water Depth	Peak Water Level	Peak Water Velocity
50% AEP	Appendix C-1	Appendix C-9	Appendix C-17
3.3 % AEP	Appendix C-2	Appendix C-10	Appendix C-18
1.0% AEP	Appendix C-3	Appendix C-11	Appendix C-19
1.0% AEP + 30% CC*	Appendix C-4	Appendix C-12	Appendix C-20
1.0% AEP + 75% CC*	Appendix C-5	Appendix C-13	Appendix C-21
0.1% AEP	Appendix C-6	Appendix C-14	Appendix C-22
0.1% AEP + 30% CC*	Appendix C-7	Appendix C-15	Appendix C-23
0.1% AEP + 75% CC*	Appendix C-8	Appendix C-16	Appendix C-24

* Climate Change

4.1.4.1 Flood Levels

Flood levels around the Site for the baseline scenario have been sampled from the mapped outputs and presented in Table 4-2.

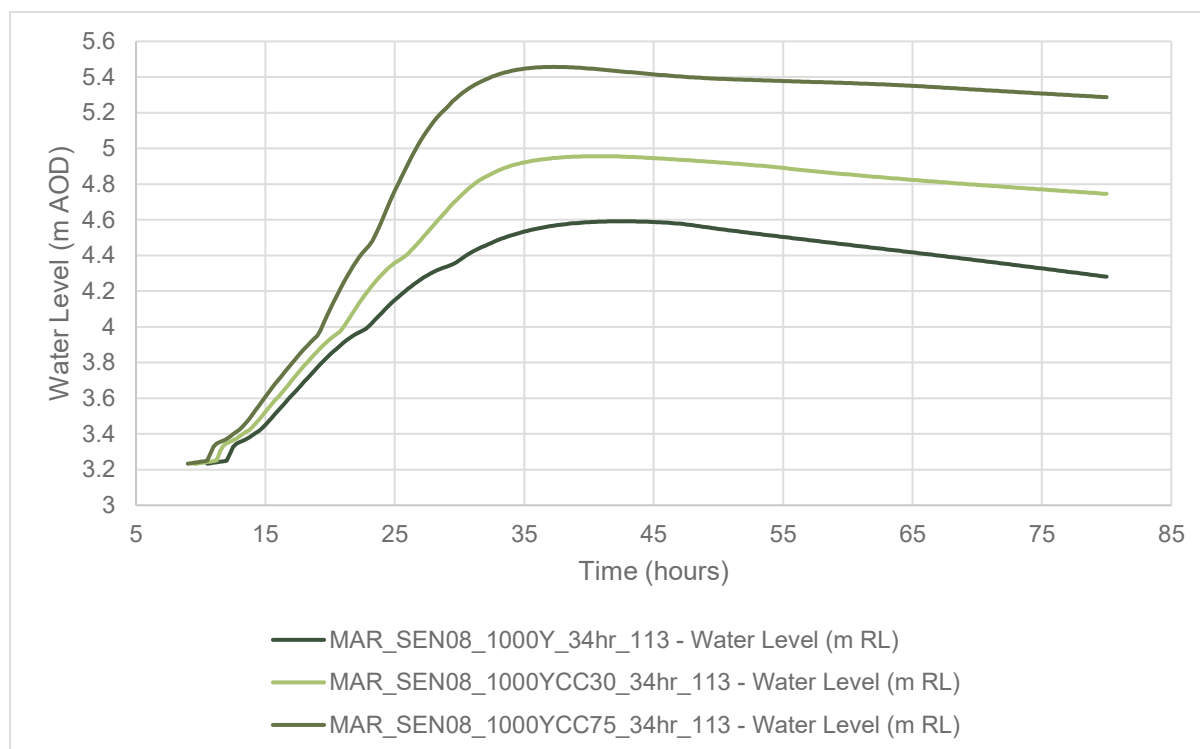
The peak flood level is shown to occur at 38 hours into the simulation for the 0.1% AEP event. The graph shown in Figure 4-3 demonstrates that the Site is flooded for an extended period and that the Site takes significant time to drain.

Table 4-2: Sampled Peak Water Levels from Baseline Scenario

Sample Location ID	Baseline Peak Water Level (m AOD)						
	3.3%	1%	1% + 30% CC	1% +75%CC	0.1%	0.1% + 30% CC	0.1% + 75% CC
1	3.82	4.13	4.35	4.68	4.59	4.96	5.46
2	3.82	4.13	4.35	4.68	4.59	4.96	5.46
3	3.82	4.13	4.35	4.68	4.59	4.96	5.46
4	3.83	4.13	4.35	4.68	4.59	4.96	5.46
5	-	-	4.35	4.68	4.59	4.96	5.46
6	-	-	-	4.68	4.59	4.96	5.46



Figure 4-3: Extreme Event Baseline Flood Elevations at the Site vs Time (Location 3)



4.1.4.2 Flood Velocities

Flows approaching the Site from Harbour Way are initially characterised by high velocities, particularly at the Harbour Way junction, where water rapidly descends embankments. Higher velocities are also observed at the inlets and outlets of the Harbour Way culvert and underpass, where flows are constricted.

The water then progresses through the lower-lying areas surrounding the Site, which include woodland and marsh habitats with high Manning's roughness values.

Peak velocities across the range of baseline scenarios were sampled around the Site. A summary of these results is provided in Table 4-3.

The results show that as the frequency of the return period decreases, flow velocities at the Site increases due to greater momentum of flood flows entering the Site. As flows reach the west side of the Site, velocities are shown to decelerate as water is distributed across the flood plain.

Table 4-3: Sampled Peak Water Velocities from Baseline Scenario

Sample Location ID	Baseline Peak Water Velocity (m/s)						
	3.3%	1%	1% + 30% CC	1% + 75% CC	0.1%	0.1% + 30% CC	0.1% + 75% CC
1	0.01	0.01	0.01	0.01	0.01	0.01	0.02
2	0.13	0.13	0.13	0.14	0.14	0.14	0.14
3	0.00	0.01	0.01	0.01	0.01	0.02	0.03
4	0.29	0.36	0.38	0.39	0.38	0.39	0.40
5	-	-	0.01	0.02	0.02	0.03	0.05
6	-	-	-	0.02	0.02	0.02	0.02



4.1.4.3 Flood Depths

The depths of flooding during baseline scenarios with a return period of 3.3% AEP, is confined to the immediate extents of the Upper Mother Ditch as the lowest portion of the area around the Site. Due to the Site's relatively flat profile, as greater flood flows from less frequent events enters the site, the water depths increase relatively uniformly.

The results have shown flood depths along the extent of the Upper Mother Ditch and the inlet of the TATA Culvert Inlet. It is also observed within the extent of the proposed development given its low-lying topography. Deeper depths are also observed north of Harbour Way. This is likely due to the limited conveyance capacity of the Harbour Way Culvert.

Sampled depths have been provided in Table 4-4.

Table 4-4: Sampled Peak Water Depths from Baseline Scenario

Sample Location ID	Baseline Peak Water Depth (m)						
	3.3%	1%	1% + 30% CC	1% + 75% CC	0.1%	0.1% + 30% CC	0.1% + 75% CC
1	0.34	0.65	0.86	1.19	1.11	1.47	1.97
2	0.61	0.92	1.13	1.46	1.38	1.74	2.24
3	0.28	0.59	0.80	1.13	1.05	1.41	1.91
4	0.14	0.45	0.66	0.99	0.91	1.27	1.77
5	-	-	0.06	0.33	0.25	0.60	1.10
6	-	-	0.00	0.35	0.28	0.63	1.13

4.2 Proposed Development Impacts

To understand the impact of storage losses and displacement of flood waters, based on the outputs of the updated model, the proposed development conditions (DEV), as described in **Section 3.4.6**, was simulated through the model. The impact assessment was considered for the 1% AEP + 30% Climate Change and 0.1% AEP + 30% Climate Change only.

Peak water level differences and Peak velocity differenced were extracted at the sampling locations and in provided in Table 4-5 and Table 4-6 respectively.

Peak water level difference maps for all modelled events have been included in Appendix D.

Table 4-5: Proposed Development Peak Water Level Difference Sampled at the Site

Sample Location ID	Difference in Peak Water Level (mm)	
	1% + 30% CC	0.1% + 30% CC
1	19	23
2	19	23
3	19	23
4	19	23
5	17	23
6	0	23



Table 4-6: Proposed Development Peak Water Velocity Difference Sampled at the Site

Sample Location ID	Difference in Peak Water Velocity (m/s)	
	1% + 30% CC	0.1% + 30% CC
1	0.00	0.00
2	-0.03	-0.03
3	0.00	-0.01
4	-0.01	-0.01
5	0.00	0.00
6	0.00	0.00

4.3 Model Sensitivity Testing

A suite of sensitivity scenarios was undertaken to test the robustness of the hydraulic model results under a range of altered input conditions and operational assumptions. These scenarios were selected to explore potential variations in flood extent, depth, and hazard to the Site and to further appraise the system behaviour. These sensitivity simulations were completed on the baseline fluvial only scenario in favour of run time and comparative nature.

The following sensitivity scenarios were assessed:

- **Initial Water Level Sensitivity (SEN01, SEN02):** Two scenarios were simulated with reduced initial water levels (IWL) of 43.0 m AOD and 42.5 m AOD respectively, to assess the influence of assumed antecedent conditions on peak flood levels and extents.
- **Channel Roughness Variation (SEN03, SEN04):** Manning's n values were adjusted by $\pm 30\%$ to evaluate the sensitivity of modelled flood behaviour to changes in assumed surface roughness across floodplain and channel domains.
- **Structure Blockage (SEN05, SEN06):** Two scenarios representing partial blockages (25% and 50%) were applied to key hydraulic structures to test how such obstructions may affect upstream water levels and local flood risk.
- **Operational Constraint Scenario (SEN07):** A conservative operational assumption was modelled in which the Emergency Overflow Sluice Gate at the Margam Duck Pond was not opened, simulating a potential failure of standard operational response.
- **Short-Duration Event Sensitivity (SEN09, SEN09a):** To explore the influence of more intense, short-duration rainfall events, a 6-hour design storm was simulated using both WINFAP-FEH scaled hydrographs (SEN09) and ReFH2-derived hydrographs (SEN09a).

Each scenario was run independently and compared against the baseline scenario. Results are presented in terms of changes in peak flood level.

4.3.1 Sensitivity Results

A mapped outputs of the different in peak water level results have been made available in Appendix E and have been summarised below.



4.3.1.1 Initial Water Level Sensitivity (SEN01, SEN02)

The modelled outputs of the initial water level sensitivity test showed virtually no change in flooding extent to the Site or downstream of the Margam Duck Pond from the baseline scenario.

4.3.1.2 Channel Roughness Variation (SEN03, SEN04)

Increasing Manning's n by 30% results in higher peak flood depths between the Duck Pond and the Site. Flows overtopping the Pond are impeded by the increased surface resistance across the floodplain, leading to backwater effects and reduced conveyance through the Pond Spillway.

This effect is illustrated in Appendix E-3, where increased flood levels are observed at the inlet to the Margam Culvert. Here, water overtopping the Pond is unable to discharge efficiently through the culvert inlet, contributing to increased flow volumes routed westwards in line with the flood mechanism described in **Section 4.1.3**.

As a result, the Site is impacted by similar increases due to the increased resistance, with flood levels increasing by approximately 100–200 mm. Expanded flood extents are also observed south of the Site and north of Harbour Way.

Conversely, when Manning's n is decreased by 30%, flood risk from the Duck Pond remains present; however, downstream areas, including those adjacent to the Nant Cwm Philip, experience a reduction in flood risk due to enhanced channel and floodplain conveyance. Floodwaters from the Pond are routed more quickly downstream, leading to increased levels in areas north of Harbour Way as flooding occurs more rapidly. Level increases of 50–200 mm were recorded, with the highest values observed at the Harbour Way underpass inlet due to broader floodplain inundation.

The impact on the Site in this scenario is minimal. This is attributed to the capacity constraints at the Harbour Way culvert, which limits flow moving into the Site. Consequently, changes in roughness within both the 1D and 2D domains have limited influence on flood behaviour at the Site itself.

4.3.1.3 Structure Blockage (SEN05, SEN06)

This sensitivity test assumes that all hydraulic structures are subjected to 25% and 50% blockage respectively. The resulting impact is generally observed as a reduction in flood levels across much of the floodplain downstream of the main dam and the Margam culvert inlet.

Blockage of the Margam Duck Pond outlet and emergency overflow leads to increased water levels within the Pond. This is evidenced by a slight rise in flood levels at the upstream end of the Pond, where backwater effects elevate upstream water levels. Consequently, increased flow is routed through the west abutment during the peak of the hydrograph, as alternative outfalls are restricted.

Downstream of the west abutment, additional areas become inundated due to redirected flow along this flood pathway. The relatively steep local topography facilitates rapid conveyance of water toward the area north of Harbour Way. As discussed in **Section 4.3.1.2**, the Site is particularly sensitive to the capacity of hydraulic structures located downstream of Harbour Way.

Flood levels north of Harbour Way are observed to increase by 20–200 mm, while flood levels at the Site decrease by approximately 20–50mm. This suggests that the Site's flood risk is sensitive to the efficiency of conveyance between the floodplain north of Harbour Way and the TATA Upper Mother Outlet.



4.3.1.4 Operational Constraint Scenario (SEN07)

This scenario tests the model's response to the inoperability of the emergency overflow sluice gate. It is understood that this sluice is normally operated by attendants at Margam Park to maintain a stable head above the primary Margam Duck Pond outfall. When the sluice is inoperable, the overall discharge capacity from the Pond is reduced, resulting in an increase in upstream water levels by approximately 50–100mm.

As water levels rise, overtopping of the main dam and west abutment becomes more significant. This leads to elevated flood levels across the model domain, with flood levels at the Site increasing by 100–200mm.

4.3.1.5 Short-Duration Event Sensitivity (SEN09, SEN09a)

The short duration sensitivity assessments assess the model's sensitivity for a the high-intensity storm event by applying a 6-hour design storm in place of the calculated critical duration of the 34-hour duration. These scenarios explore the effect of rapid catchment response on peak water levels and extents, and flow timing across the model domain.

In SEN09 (WINFAP-scaled hydrograph), the outputs indicate that both the Site and the wider catchment are particularly vulnerable to intense, short-duration storms. Rescaling to the WINFAP peak flow significantly increases flood levels across the floodplain, with flood depths at the Site rising by approximately 100–200mm. This suggests that when storm durations shorten but peak flows remain high, the capacity of the Margam Duck Pond and Nant Cwm Philip is quickly overwhelmed.

In SEN09a (ReFH2 6-hour hydrograph), the flood impacts differ. Flooding becomes more pronounced around the Pond and Margam Park, with greater flood depths occurring north of Harbour Way. However, the Site itself experiences a reduction in flood levels of approximately 50–100mm. This likely reflects the difference in hydrograph shape and timing associated with ReFH2, which produces a more physically distributed runoff response and lower peak inflows at critical routing points through the Site.

Together, these scenarios demonstrate that flood risk is sensitive not only to the magnitude of the peak flow, but also to the shape and timing of the inflow hydrograph, which varies considerably between statistical (WINFAP) and rainfall-runoff (ReFH2) methods.

4.4 Model Validation

The currently approved model, developed by JBA, produces similar flood extents to those observed in the updated model. Flooding originating from Margam Duck Pond follows expected catchment flow paths, with overtopping from the Pond and Nant Cwm Philip conveyed westward along prevailing topography. Flow is attenuated in low-lying and enclosed areas observed at the Site.

While the NPTBC Highways Authority and Welsh Government report no recorded instances of flooding on the M4, the current model outputs show significant flood extents affecting the motorway in events as small as the 50% AEP event. In contrast, the updated model no longer shows flooding at this location, marking a notable divergence between the two models and thus validating the likely flood risk frequency at the M4.

During a site visit on 10 March 2025, a 'Friends of Margam' volunteer described frequent localised flooding within the estate grounds. Anecdotal evidence highlighted flooding in the area west of the Nant Cwm Philip, downstream of the Duck Pond between the Pump House (NGR: SS 80285 86051) and the now derelict Saw Mill (NGR: SS 80213 85599). These observations are consistent with the outputs of both models. However, no direct overtopping from the Duck Pond itself was confirmed by the attendant.



Given the level of hydraulic and topographic refinement applied in the updated model, particularly around the Duck Pond, it is considered that this model more accurately represents the likely flood mechanisms and risks. Therefore, the modelled degree of risk is likely due to the current storage capacity of the Duck Pond having decreased over time due to sedimentation from upstream catchment inputs. This is supported by a walkover survey upstream of the updated model boundary, which identified extensive deposition of geological material. Southern parts of the Pond near the outfall show depth differences of up to 2m between the surveyed soft and hard bed levels.

The steep gradients of the Margam Moors to the north-east contribute to high-velocity runoff, assumed to mobilise suspended solids that are deposited downstream as flow velocities reduce in the vicinity of the Duck Pond. This process likely contributes to the reduction in effective storage and attenuation capacity within the Pond.

4.5 Limitations

Hydraulic and hydrological models are powerful tools for simulating flood behaviour and informing risk management; however, they are inherently limited by the quality and availability of input data, the assumptions required to represent complex physical processes, and the spatial and temporal resolution of the model. These models simplify real-world systems, meaning that uncertainties in topography, boundary conditions, structure operation, and rainfall-runoff relationships can all influence the accuracy of predicted flood behaviours. As such, modelling outputs should be interpreted as representations of likely conditions under defined scenarios, not absolute predictions.

4.5.1 The Development Site

A key limitation of the model is the representation of drainage capacity through the Upper Mother Ditch and the TATA Upper Mother Outlet. In the absence of detailed survey data or operational information, assumptions were required to allow outflow from the catchment to Swansea Bay. Sensitivity analysis highlights that flood risk at the Site is highly influenced by the restricted inflow capacity of structures beneath Harbour Way. Since floodwaters do not exit the Site via overland routes in the 2D domain, the Upper Mother Ditch functions as the primary hydraulic control governing flood levels in upstream areas.

It is also understood that the Site is serviced by a network of field ditches that ultimately drain to the Upper Mother Ditch. However, the full extent of culverts or connecting structures between the Site and the Upper Mother Outlet may not be fully represented in the model. This introduces uncertainty in the overall conveyance capacity through the Site toward the outlet.

Furthermore, TATA Steel's Environment Department confirmed that they do not hold detailed information on the Upper Mother Outlet; operation of the structure therefore remains unverified.

4.5.2 Harbour Way

Information obtained from the Harbour Way planning application (P2010/1100) was incomplete and required assumptions regarding the arrangement of structures. These assumptions do not account for potential environmental changes or design modifications that may have occurred since construction and would otherwise be identified through a detailed site survey.

4.5.3 TATA Upper Mother Outlet

In the absence of surveyed data, the TATA Steel outlet culvert was assigned the same dimensions as the upstream rail culvert. As ownership of the outlet remains unconfirmed, no



survey has been undertaken to verify these assumptions. This introduces uncertainty regarding the outlet's true capacity and operational behaviour.

While the true dimensions remain unknown, sensitivity of the TATA Steel outlet proved that results do not appear to be impacted by the capacity and the tide locking of the structure. In addition outlet information visible at Swansea Bay show that possible outlet structures on a similar dimension exists in the vicinity of the modelled structure.

Figure 4-4: Extract of OS Mapping Data¹⁴ of the TATA Upper Mother Outlet



4.5.4 Hydrology

Analysis of shorter storm periods rescaled with WINFAP typically provides estimates for peak flows to emulate a synthetic hydrograph for input into the model. The consequences of which may distort the flow volume or timing as flows move through Margam Duck Pond. Therefore, the outputs of these results are likely to subject to a high margin of error. This is observed when compared to the outputs of the ReFH2 hydrology which demonstrates a significant variance in modelled outputs.

Climate change uplifts prescribed by NRW are based on national-scale allowances for increases in peak river flows, rainfall and sea level rise, derived from UKCP climate projections and applied uniformly by time horizon and emission scenario. These uplifts represent plausible future conditions but do not account for local catchment-specific factors such as land use change, soil characteristics, or small-scale hydrological responses, introducing uncertainty into future flood predictions.

¹⁴ Ordnance Survey (2025) UK Map Centre OS Mastermap GIS | CAD Data 1 : 500 Scale OS Mapping. Available from: [Ordnance Survey Mastermap for CAD|GIS in Many Formats](#)



4.5.5 Topographical Information

The updated model's topography beyond the extent of the Margam Duck Pond utilises a 2m resolution grid in the 2D domain. There is a possibility that conveyance capacity through the remainder of the model domain may not be fully captured by the base DTM.

4.6 Assumptions

The main assumptions made within the Updated Model are as follows:

- Flows from the Afon Cynffig have no impact to flood risk within the Study Area;
- The downstream tidal boundary condition is consistent across all current day modelling scenarios, and all climate change modelling scenarios;
- Crest levels of obstructions within Margam Park were derived from aerial drone photogrammetry, which captures both vegetation and structural features. Where break lines were digitised to represent walls or other barriers, crest elevations were estimated using professional judgement, based on the surveyor's understanding of local topography and relative height differences observed in the data;
- Underlying 2m LiDAR was considered sufficient for use as the DTM;
- Bridge structures above the Margam Duck Pond Outlet and Emergency Overflow do not contribute to hydraulic control of water overtopping the Main Dam;
- An attendant of Margam Park operates the Emergency Overflow (sluice gate) reliably when a storm event occurs;
- The conveyance of water through structures west of the proposed development Site have not been accurately surveyed and therefore rely on assumptions only;
- Based on the assumption that the Upper Mother Outlet is subject to tidal locking, it was modelled as a unidirectional culvert discharging to Swansea Bay and linked to the MHWS boundary condition; and
- No water abstraction from the Upper Mother Ditch for onsite processes at the TATA Steel facility has been accounted for.

4.7 Recommendations

Fluvial flood risk to the Site has been shown to be highly sensitive to both inflow via structures beneath Harbour Way and outflow through the Upper Mother Ditch to Swansea Bay. The ability of the model to accurately represent flood behaviour is therefore limited by uncertainties in the arrangement, dimensions, and operation of these structures. To improve the confidence in model outputs and better inform future flood risk management, the following recommendations are made:

1. Survey of Structures beneath Harbour Way

As the culverts underneath Harbour Way play an important part of the flooding mechanise at the site, we recommend verification of these structures. It is however noted that the verification is not expected to alter the conclusions of the overall results due to the sensible assumptions based on observations including a site walk over and available environmental drawings online.

2. Survey and Investigation of the Upper Mother Outlet

The outfall structure discharging from the Upper Mother Ditch to Swansea Bay should be surveyed in detail. This includes confirming dimensions, structural condition, outfall destination, and operational arrangements (e.g., tidal flap, sluice gates or valves).



Understanding the degree to which tidal locking influences outflow is critical to assessing the Upper Mother Drain's ability to discharge during high water events.

3. Sensitivity analysis of the desilted Margam Duck Pond

To verify if the Margam Duck Pond is vulnerable to failure due to its effective storage, sensitivity testing using the 'hard' bed level bathymetry may inform future decision makers as to effective management of this particular vulnerability.



5.0 Conclusion

This report summarises the hydraulic modelling completed to inform the design of the proposed substation extension at Margam Moors. Building upon the baseline JBA model, the updated analysis incorporates refined representations of key hydraulic structures, including a detailed survey of Margam Duck Pond and its associated inflows and outflows.

The original model predicted significant flooding along the M4 due to overtopping from the Nant Cwm Philip, which is not supported by local flood history. In contrast, the updated model shows that while the Margam Duck Pond remains a critical source of flood risk, particularly during events exceeding a 3.3% AEP, the M4 does not flood for the 50% AEP event.

The current representation of the Pond in the model is considered to reflect present-day conditions given the detailed topographic and bathymetric surveys to improve its accuracy. It is considered that effective storage of the Duck Pond has likely diminished over time due to siltation from the upper catchment beyond the upstream boundary condition.

The Site remains at risk of fluvial flooding; however, the updated model indicates that this risk is highly sensitive to both inflow restrictions under Harbour Way and the outflow capacity of the Upper Mother Ditch and connecting culverts.

It is recommended that detailed survey data be collected for conveyance structures at the Site and along the Upper Mother Ditch, including the TATA Upper Mother Outlet. Although assumptions have been made on the structural dimensions, they are consistent on the pre and post development scenario and will not change the conclusions of the analysis completed.



