TECHNICAL NOTE

JBA Project Code	2024s0854
Contract	RSPB Conwy Flood Consequence Assessment (FCA)
Client	Conwy County Borough Council
Day, Date and Time	29 August 2024
Author	Chulani Herath
Reviewer / Sign-off	Kevin Frodsham
Subject	RSPB Conwy Model - Technical Appendix

1 Introduction

Conwy County Borough Council (CCBC) wish to undertake some works within the RSPB Conwy reserve between Llandudno Junction and Llansanffraid (Figure 1-1). The proposed works include the installation of a combined cycle and pedestrian path around the northern and eastern boundaries of the reserve and two new footbridges over the Afon Ganol and Conwy Valley Railway Line, respectively. A pedestrian ramp is also proposed on the RSPB side of the railway footbridge. The details of the works are provided in the main Flood Consequence Assessment (FCA) document, and this Technical Note has been written to summarise the hydraulic modelling methodology that underpins the results listed in the FCA.

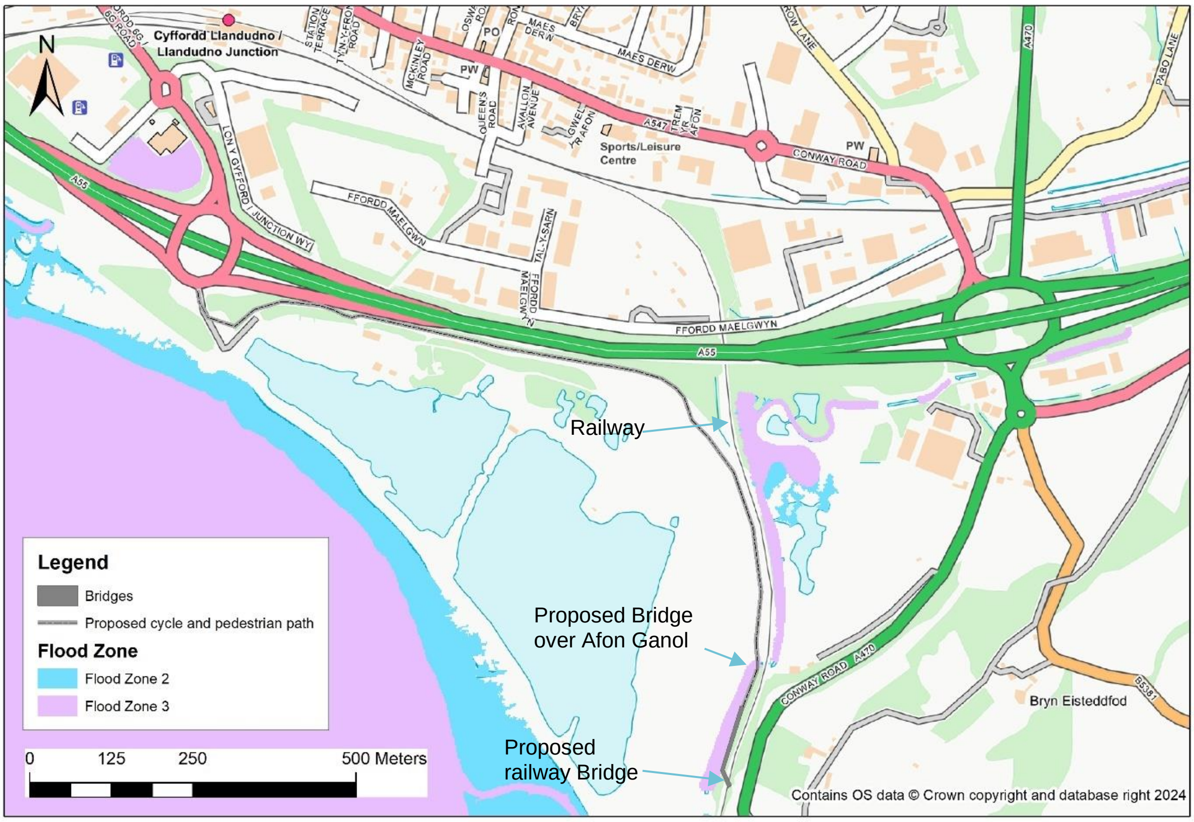


Figure 1-1 Location map

1.1 Purpose of hydraulic modelling

Following preliminary consultation between CCBC and Natural Resources Wales (NRW), it was apparent that quantifying the flood risk impact of the bridges and combined cycle and pedestrian path would be a useful step for project approval. NRW advised that the application would need to consider both fluvial and tidal risks for a range of events up to and including that of the 0.1% event with an allowance for climate change, where possible. There was an additional NRW requirement that the works would neither hinder NRW access to nor provide additional loading to the nearby tidal doors. Although a specific approach was not mandated by NRW for quantifying the flood risk, it was suggested that an existing hydraulic model of the Afon Ganol might be a suitable starting point.

The purpose of the hydraulic modelling was, therefore, to provide up-to-date flood risk information to the FCA, which would need to demonstrate that the bridge had been designed to appropriate design levels and would cause no adverse off-site impacts.

1.2 Understanding of watercourse and associated catchment

The River Ganol catchment is mostly rural with a total area of 18.0km². An important feature of the catchment hydraulics is the presence of a bifurcation (splitter) structure (at NGR 282191, 378495) which divides the catchment into two channels; east and west (Figure 1-2). The western branch flows in a general south-westerly direction parallel to A55 for most of its length but undergoes a change in direction where it meets the Conwy Valley railway embankment after which it flows in a southerly direction through the RSPB Conwy site to discharges into the Conwy Estuary via a tidal outfall north of Llansanffraid (at NGR 280218, 376652). The eastern branch of the Ganol discharges directly into Penrhyn Bay.

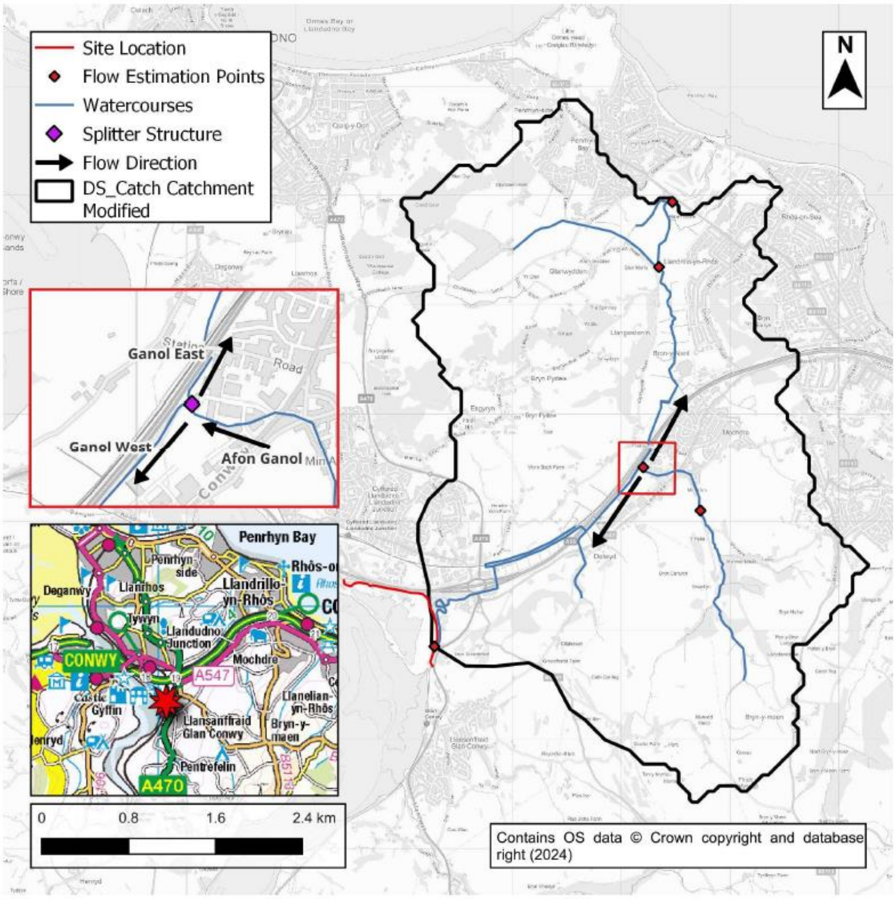


Figure 1-2 Catchment overview and splitter structure

The proposed works are located on a reach of the western Ganol between the railway line and tidal outfall. The culvert beneath the railway line upstream of the works is a flapped, twin-barrelled, box culvert with a relatively low capacity (i.e. each barrel has a dimension of 0.75 x 0.75-metre) and the tidal outfall (Figure 1-3) is a flapped, twin-barrelled, cylindrical culvert with a larger capacity (i.e. each barrel has a diameter of 1.5 metres).

Although, the RSPB Conwy FCA is only concerned with the hydraulics near the downstream end of the western branch of the Ganol, the modelling needs to capture upstream hydraulics sufficiently to simulate appropriate design flows along the western branch. In addition, the site location near the tidal outfall means that tidal conditions may affect the fluvial flood risk and there is also a potential risk of direct tidal flooding. The tidal risk may be exacerbated by the fact that a local low point in the estuary embankments corresponds to the tidal outfall.

Figure 1-3 Ganol West outfall (photos taken from NRW's Afon Ganol 2012 report)

1.3 Existing Hydraulic Models

NRW's Afon Ganol hydraulic model was sourced under licence from Natural Resources Wales (NRW). The supplied model folder actually comprises separate fluvial and tidal models that were created in 2012 for NRW by JBA Consulting as part of a River Ganol at Mochdre Flood Hazard Mapping study.

The fluvial model is a 1D-2D (Flood Modeller -TUFLOW) model. The accompanying model reports states that the 1D model largely utilised cross section data from 2000 (90 sections) and 2012 (28 sections). This model starts approximately 780 metres upstream of the splitter structure and includes both the East and West branches of the Ganol to their respective tidal outfalls. Additional files were included with the supplied model that represent some additional climate change modelling that was carried out by Edenvale Young Associates (EVY) in 2021. An accompanying note stated that the 2021 model runs were run using ISIS 6.7.0.110 and TUFLOW 2012-05-AD-iSP-w64 as the model did not run with more recent software.

The tidal model is a 2D-only (TUFLOW) model that simulates tidal overtopping of the estuary embankments with no fluvial inputs. This model has (ESTRY) culverts inserted along the course of the Afon Ganol to allow tidal water to pass along flow routes that were not present in the LIDAR based DTM. The tidal model was also supplied with two flood mapping scenarios, defended and undefended. The western tidal outfall is an Environment Agency Wales maintained asset, so the outfall structure and overlying segment of embankment had been removed from the model[1]. However, the remainder of the embankment around the Glan Conwy Reserve is not an Environment Agency Wales maintained asset, so this had been retained at crest level within the undefended model.

A second model was sourced from NRW to help provide appropriate tidal boundaries for the Afon Ganol model. This was the Conwy Estuary (Prism) model that was created for NRW by JBA Consulting in 2018 and updated by Arup in 2023. This is a 2D only (TUFLOW) model of the Conwy Estuary that simulates the impact of offshore tidal boundaries (as generated from the coastal extremes database) on tidal series at locations within the inner Conwy Estuary between the coast and Tal-y-Cafn.

[1] These changes were achieved by not reading the ESTRY representation of the outfall into the model and using a z-shape to lower LIDAR levels down to the channel levels just upstream of the embankment.

2 Fluvial Modelling for the RSPB Conwy FCA

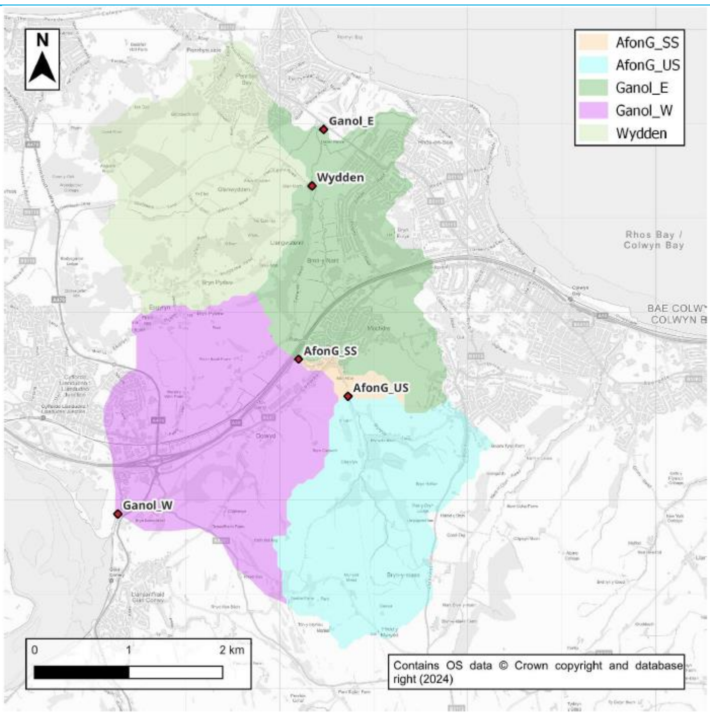
2.1 Introduction

Given that the previous modelling preceded the replacement of ReFH by ReFH2 as a method of choice required by NRW, a new hydrology calculation record was undertaken to help inform the fluvial flood risk to the site. In addition, up-to-date downstream (tidal) boundaries were generated using the Conwy Estuary (Prism) model. These were then run through the 2012 Afon Ganol model to generate flood risk results for the RSPB site. Two scenarios were run through the model, an existing risk scenario and a post development scenario (with the new bridge and walkway as the proposed design drawings). A small number of changes were made to the supplied model in order to allow the model to run with the latest modelling software and provide suitably stable results.

2.2 Hydrology Update

An updated hydrology was calculated for the study. The full calculations are provided in an accompanying FEH Calculation Record[2] so this section simply highlights the headline findings of the hydrology exercise.

Flow estimates were derived at five locations as shown in Figure 2-1.



Site code	Type of estimate:	Watercourse	Site name / description	Easting	Northing
AfonG_US	L	Afon Ganol	Upstream Study Extent	282725	378102
AfonG_SS	S	Afon Ganol	Lateral flow between AfonG_US and the Afon Ganol splitter structure	282190	378495
Wydden	L	River Wydden	Wydden tributary catchment	282343	380339
Ganol_E	S	Afon Ganol East	Lateral flow between the Afon Ganol splitter structure and Ganol_E – flows to the north east	282466	380938
Ganol_W	S	Afon Ganol West	Lateral flow between the Afon Ganol splitter structure and Ganol_W – flows to the south west.	280281	376861

L = lumped catchment; S = sub-catchment

Figure 2-1 Flow estimation points

[2] NGV-JBAU-00-00-RP-C-0001-S1-P1-RSPB_Conwy_Calculation_Record_With_Appendix.pdf

Peak flow estimates were derived from both ReFH2 and FEH statistical methods and it was recommended to use the FEH Statistical method to develop model inflows for events up to 1% AEP with the "Hybrid" approach used to develop the 0.1% AEP model inflows.

Model hydrographs were derived in ReFH2 for a summer storm of 5.5 hours and input into the supplied model in the appropriate locations as shown in Figure 2-2. The updated model inflows (point inflow and lateral inflows) for the 1% AEP event are shown in Table 2-1 and Figure 2-3.

In summary the updated model inflows were more conservative than the supplied model inflows in two ways. Firstly, the peak flows were higher (as shown in Table 6-1 of the FEH Calculation Record) by around 10% and 30% for the 2 locations, respectively, where a direct comparison of lumped catchment estimates was possible. Secondly, the recommended storm duration of 5.5 hours arising from the ReFH2 analysis was longer than the 4-hour duration that had been used in the previous modelling. Given that the site is close to the tidal outfall, a longer storm could exacerbate the fluvial flood risk due to a greater duration of tide locking.

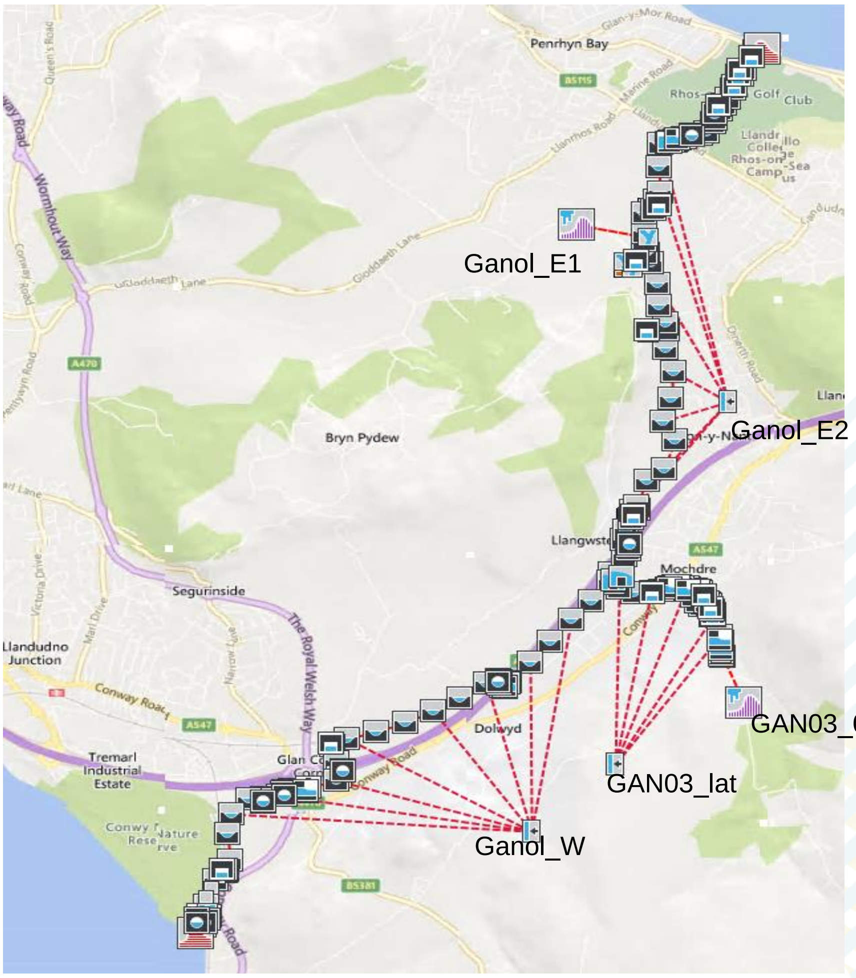


Figure 2-2 1D Model Boundary Distribution

Table 2-1: Final Calculated Peak Flows

Site code	50%	3.3%	1%	1% +30% Climate Change Allowance Central	1% +75% Climate Change Allowance Upper	0.1%
AfonG_SS	0.1	0.3	0.3	0.4	0.6	0.6
AfonG_US	1.3	2.9	3.7	4.9	6.6	6.3
Ganol_E	1.0	2.2	2.9	3.8	5.1	4.9
Ganol_W	1.3	3.0	3.8	5.0	6.7	6.5
Wydden	1.3	2.8	3.7	4.8	6.5	6.3

Flood peak in m^3/s for the AEP (%) events

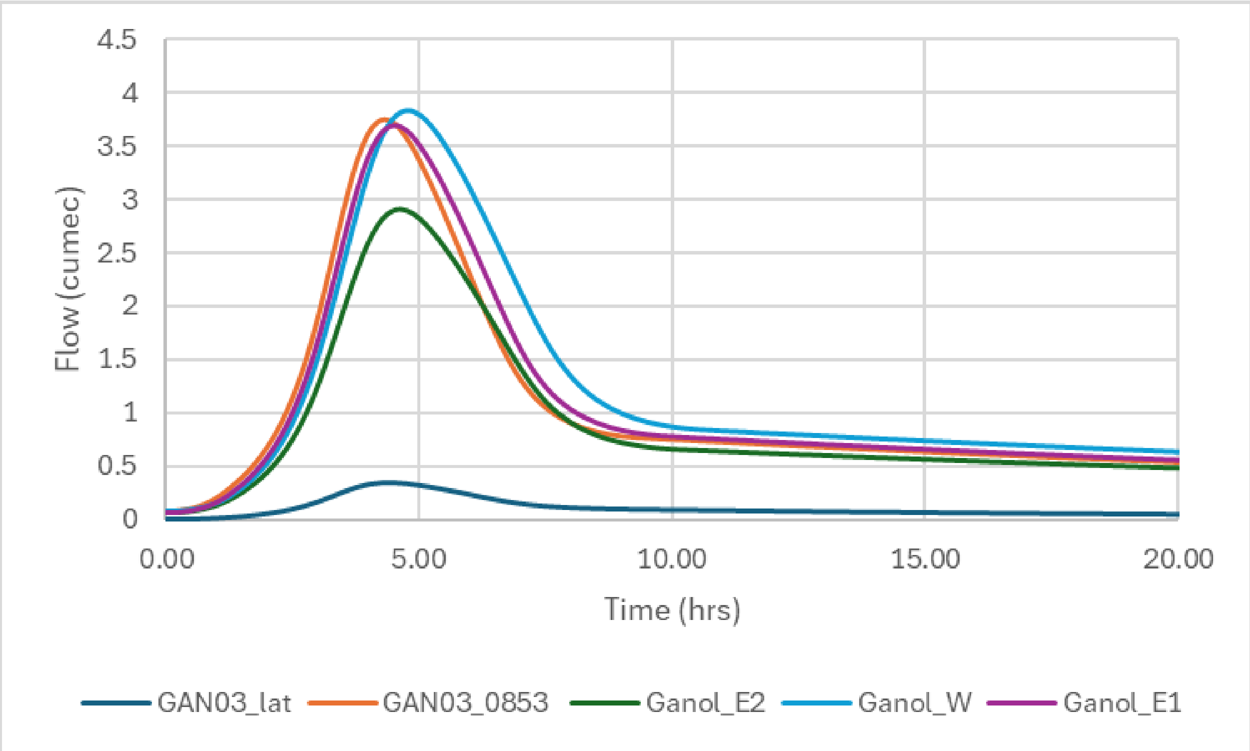


Figure 2-3 Final model (point and lateral) 1% AEP model inflows (based on 5.5-hour storm)

2.3 Downstream Boundary updates

The fluvial Ganol model has two downstream boundaries; located at the Ganol West and Ganol East tidal outfalls, respectively. The supplied model assumed that a Mean High-Water Spring (MHWS) boundary would provide a suitable joint probability condition for fluvial modelling at both locations and this approach was maintained for the RSPB FCA modelling.

Whereas the previous model had simply applied an offshore derived boundary directly to the Ganol West outfall, it was now possible to obtain an updated MHWS for this location by running the Conwy Estuary Tidal (Prism) model with a MHWS offshore boundary and 50% AEP inflows along the Afon Conwy. As the Ganol East outfall discharges directly into Penrhyn Bay, an offshore MHWS series was applied directly to the eastern outfall[3]. The same approach was used to derive MHWS series in 2125 to apply to the fluvial with climate change model runs.

One further change required to the downstream boundaries was to ensure that the MHWS tide peaked at the same time as the peak fluvial discharge along the Ganol West. A time shift was required relative to the original model due to the change in modelled storm duration.

2.4 Fluvial (1D-2D / FM-TUFLOW) Model updates

Three model scenarios were created to inform the FCA.

- A baseline (existing risk) model, which included the existing conditions of the development area. This scenario was run for a 1% AEP event with and without climate change (modelled via a 30% increase in model inflows[4]) and a 0.1% AEP event.
- A post-development model, which had the existing ground levels replaced with elevated levels along the combined cycle and pedestrian paths and installation of new foot bridges. This scenario was run for a 1% AEP event with and without climate change (modelled via a 30% increase in model inflows) and a 0.1% AEP event.
- A 50% blockage scenario for the proposed new bridge was created and run with a 1% AEP with climate change event.

Some adjustments were made to both the 1D and 2D models to ensure compatibility with the latest software versions and improve stability. These changes are listed in Table 2-2. The main changes were to update the floodplain to the latest LIDAR (which was flown in 2022 so post-dates the supplied model) and to undertake a local reconfiguration the reach of interest between the railway embankment and tidal outfall.

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[3] The applied Ganol East MHWS series was a copy of the offshore tidal series that had been generated for the Tidal Prism model adjusted by the small change in peak level apparent in the coastal extremes database for a location in Penrhyn Bay.

4 Note that it was not possible to obtain stable results for the fluvial 0.1% AEP plus climate change event, but this was not ultimately believed to be critical for this development.

In addition, some changes were made to increase the ease of use of the model. These were to geo-reference the 1D model nodes within Flood Modeller and to update the TUFLOW control files to allow for the use of scenarios and events.

Should anyone seek to re-use the Conwy RSPB FCA model, Table 2-4 provides a list of updated 1D files and Table 3-2 does likewise for 2D files components of the model.

Table 2-2 Adjustments made to original fluvial model

1D model	
Model Node	**Modification/remark**
River_Ganol_Defended_KF02_v1a.dat (Existing Risk Scenario)	
GAN03_0734u	Culvert inlet unit was removed from the model to improve model stability and this would not be affected to the model results as this study focused far downstream in the Ganol west. Chainages were slightly amended in upstream and DS sections.
GANE02_0128l, GANE02_0078, GANE02_0053, GANE02_0025, GANE02_0000	Conduit units were removed from the model to enhance 1D model stability, with minimal impact expected as a result.
GANW02_0250, GANW02_0250d	Copied US sections to make consistency between baseline and post development models
River_Ganol_Defended_KF02_PDM_v2.dat (Post-development Scenario)	
GANW02_0250	Copied US sections to add bridge unit in Post development scenario
GANW02_0250d	
River_Ganol_Defended_KF02_PDM_V2_Blockage.dat (Blockage Scenario)	
GANW02_0251	Two additional sections (copy of GANW02_0259) was added to the model to add a blockage unit in between.
GANW02_0251d	
2D model	
Read MI Z HX Line == 2d_bc_HX_Ganol_007.MIF | mi\2d_bc_HX_Ganol_004_pts.MIF	Reads bank crest level point layer to the model

Table 2-3 New or updated files used in the 1D component of the fluvial model

1D software and Key files used to run the design model	
1D Software version	Flood Modeller VER=7.0.0.9977
DAT Files (.dat)	River_Ganol_Defended_KF02_v1a.dat (Existing Model representation for 1% AEP, 1% AEP+CC and 0.1% AEP events) River_Ganol_Defended_KF02_PDM-v2.dat (Post Development Model representation for 1% AEP, 1% AEP+CC and 0.1% AEP events)
Event Files (.ief)	**Baseline Scenario** ER04_XX_Q100_MHWS.ief ER04_XX_Q100CC30_MHWS_2125.ief ER04_XX_Q1000_MHWS.ief **Post Development Scenarios** PD01_XX_Q100_MHWS.ief PD01_XX_Q100CC30_MHWS_2125.ief PD01_XX_Q1000_MHWS.ief

Table 2-4 New or updated files used in the 2D component of the fluvial model

2D software and Key files used to run the design model	
1D Software version	Classic - 2023-03-AE-iSP-w64
TUFLOW Control files (.tcf, ecf, .tef)	~s1~_~s2~_~s3~_~e1~.tcf Ganol_Fluvial_001.tef
GIS Format	MIF (Built in MapInfo)
TUFLOW geometry (.tgc) file	Ganol_Fluvial&Tidal_Defended.tgc
TUFLOW Boundary Control files	Ganol_001.tbc
TUFLOW materials (.tmf) file(s)	Ganol_roughness.tmf
1d node/ network / WLL layer	**All Scenario** 1d_WLL_Ganol_001.MIF **Baseline** 1d_nwk_Ganol_005.MIF **Post Development Scenario** 1d_nwk_Ganol_004.MIF
Active / Inactive model cells files (s)	2d_code_Ganol.MIF (Defines active domain) 2d_code_Ganol_Inactive_002.MIF (Removes active 1D Watercourses from the active 2D domain)
Grid Orientation, dimensions and cell size	Origin = 281588, 374694 Orientation == 286200, 378400 Cell size = 4m Grid Size (X,Y) == 6310,5540
Main topographic zpt sources file(s)	LiDAR_1m_DTM_2022_site-specific.asc (updated LiDAR)
Additional Topographic Changes to the basic model grid (i.e. Z-line, z-shape, z-point layers)	2d_zln_Tidal_Defences.MIF 2d_zln_reserve_embankment.MIF **Baseline Scenario** 2d_bc_HX_Ganol_007.MIF | 2d_bc_HX_Ganol_004_pts.MIF **Post Development and Blockage Scenarios** 2d_bc_HX_Ganol_006.MIF | 2d_bc_HX_Ganol_004_pts.MIF 2d_zln_proposed footpath_002.MIF
2D roughness layer(s)	**All Scenarios** 2d_mat_Ganol.MIF

3 Tidal Modelling for the RSPB Conwy FCA

3.1 Introduction

As previously noted, in addition to the fluvial 1D-2D model, NRW's Ganol (2012) model download also contained a separate 2D-only (TUFLOW) model version that had been used to model extreme tidal events[5].

The supplied model was used to inform the tidal risk to the RSPB Conwy site with the following updates.

- Appropriate tidal boundaries were created based on running up-to-date tidal series through the Conwy Estuary Tidal (Prism) model.
- The model was converted from TUFLOW Classic to TUFLOW GPU to speed up model run times and enforce model stability.
- A small number of model updates including an update of the floodplain to the latest available LIDAR DTM (believed flown in 2022).

Two model scenarios were created to inform the tidal risk for the FCA.

- An existing risk scenario based on the supplied defended model scenario, in which the tidal outfall and overlying embankment function as intended. This scenario was run for 0.5% and 0.1% AEP events both with and without climate change.
- A breach scenario based on the supplied undefended model, which has the outfall and overlying segment of embankment removed to channel levels. This effectively models an open breach at the outfall, which may represent the most likely locations for a breach given that it is the lowest point of the estuary embankments alongside the RSPB reserve. This scenario was also run for 1% and 0.1% AEP events both with and without climate change.

Note that a post-development scenario was not run because the above scenarios should be enough to provide tidal design levels at the site and it is not expected that the bridge and raised footpath would have any significant impact on the tidal risk, given the volume of water involved and the fact that there is a restrictive (railway) culvert immediately upstream of the proposed new bridge.

3.2 Updated Tidal Boundaries

Both the coastal extremes database and tidal climate change allowances have been updated since the Ganol (2012) model was created. Hence, because the tidal risk obtained from that model is now out-of-date, updated boundaries were created to simulate the impact of extreme tide events on the RSPB Conwy site.

The updated tidal series were created by JBA's coastal team based on the extreme sea levels for a location offshore of the Conwy Estuary obtained from the Coastal Flood Boundary Extreme Sea Levels (2018). Tidal series were obtained for both present day

[5] A 2D only approach was presumably necessary to avoid a 1D (Flood Modeller) representation of the Afon Ganol channel to prevent the model from going unstable when large volumes of tidal water overtopped the estuary embankments.

(2024) and future (with climate change) 0.5% and 0.1% AEP events in the year 2125 (i.e., with 100 years of sea level rise).

To obtain an appropriate tidal boundary series to apply to the RSPB Conwy reserve along the western edge of the Ganol catchment, the offshore tidal series were run through the Conwy Estuary Tidal (Prism) model to extract a boundary series adjacent to the reserve. The Ganol East boundary is unlikely to influence conditions at the RSPB site so a tidal series for Penrhyn Bay was simply obtained as the tidal series for the Conwy Estuary with the peak level shifted by the amount necessary to match the value in the coastal extremes database for a location offshore of Penrhyn Bay.

Table 3-1 lists the peak sea levels used in the modelling exercise. The offshore entries correspond to the values extracted from the coastal extreme database with the appropriate sea level uplift, whereas the Ganol West entries represent the values obtained from running the offshore values through the Conwy Estuary (Tidal Prism) model. The resulting tidal boundary series applied to the Ganol Tidal model for the Ganol West and Ganol East boundary locations are shown in Figure 3-1.

Table 3-1 Calculated and modelled peak sea levels (m AOD) for specified events

Location	0.5 % 2024	0.5 % 2125	0.1 % 2024	0.1 % 2125
Offshore	5.28	6.23	5.48	6.43
Ganol West	5.24	6.15	5.48	6.33

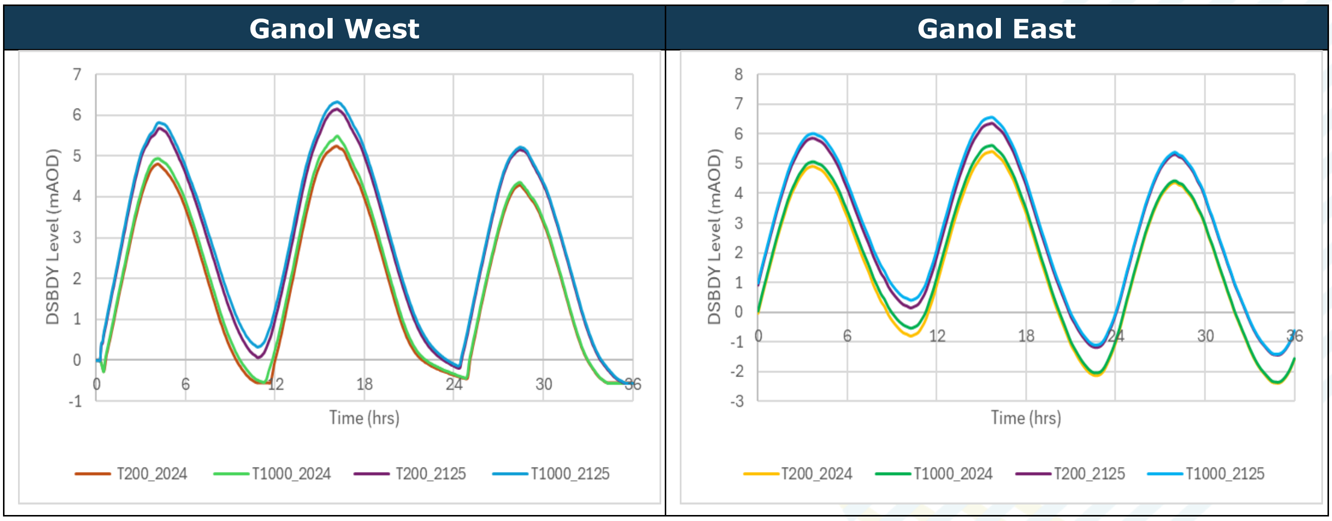

Figure 3-1 Modelled tidal boundary series for Ganol West and East

Table 3-2 lists the files used in the tidal FCA model.

Table 3-2 2D files used in the Tidal model

2D software and Key files used to run the design model	
1D Software version	GPU - 2023-03-AE-iSP-w64
TUFLOW Control files (.tcf, ecf, .tef)	~s1~_~s2~_~s3~_~e1~.tcf Ganol_Tidal_001.tef
GIS Format	MIF (Built in MapInfo)
TUFLOW geometry (.tgc) file	Ganol_Tidal_(2024)_001.tgc
TUFLOW Boundary Control files	Ganol_Tidal_001.tbc
TUFLOW materials (.tmf) file(s)	Ganol_roughness.tmf
1d node/ network / WLL layer (Estry component)	**For Defended Scenarios** 1d_nwke_Ganol_Structures_003.MIF **For Undefended Scenario** 1d_nwke_Ganol_Structures_002.MIF
Active / Inactive model cells files (s)	2d_code_Ganol.MIF (Defines active domain)
Grid Orientation, dimensions and cell size	Origin = 281588, 374694 Orientation == 286200, 378400 Cell size = 4m Grid Size (X,Y) == 6310,5540
Main topographic zpt sources file(s)	LiDAR_1m_DTM_2022_site-specific.asc (updated LiDAR)
Additional Topographic Changes to the basic model grid (i.e. Z-line, z-shape, z-point layers)	**Defended Scenario** 2d_zln_Rhos_0n_Sea_Prom_001.MIF 2d_zln_reserve_embankment_001.MIF 2d_zln_Tidal_Defences.MIF **Undefended Scenario** 2d_zsh_defence_removal_001.MIF
2D roughness layer(s)	**All Scenarios** 2d_mat_Ganol.MIF
1D Boundary layer(s)	1d_bc_HT_Tides.MIF
2D Boundary layer(s)	**All Scenarios** 2d_bc_HT_Tides.MIF 2d_bc_SX_Ganol_Structures_002.MIF
Updated TUFLOW bc dbase	Yes
TUFLOW tef file	Yes
Check files enabled	Yes (for 0.5%AEP)

4 Modelling outcomes

The main outcomes of the fluvial and tidal hydraulic modelling of relevance to the FCA are included in the main FCA document. This section is therefore limited to a discussion of some of the modelling outcomes and limitations that are not listed in the main FCA text.

4.1 Fluvial Flood Risk (FM-TUFLOW)

4.1.1 Comparison of Existing (Baseline) Risk Outlines and Existing Flood Zones

The results of the updated fluvial model are compared with the existing NRW River Flood Zones for Planning in Figure 4-1; noting that the River Flood Zones are based on the results of the Afon Ganol (2012) fluvial modelling study. This shows that the updated fluvial outlines upstream of the railway embankment are noticeably larger than were previously modelled but that the 1% and 0.1% AEP events are still modelled to remain in-channel between the railway embankment and tidal outfall. The increase in upstream risk is mainly attributable to the hydrology update (which produced elevated peak flows and a longer storm duration) in combination with a sizeable area of available floodplain. The limited capacity of the railway culvert is also modelled to lead to a headloss across the railway embankment (of around 0.25 metres at the peak of a 1% AEP with climate change event).

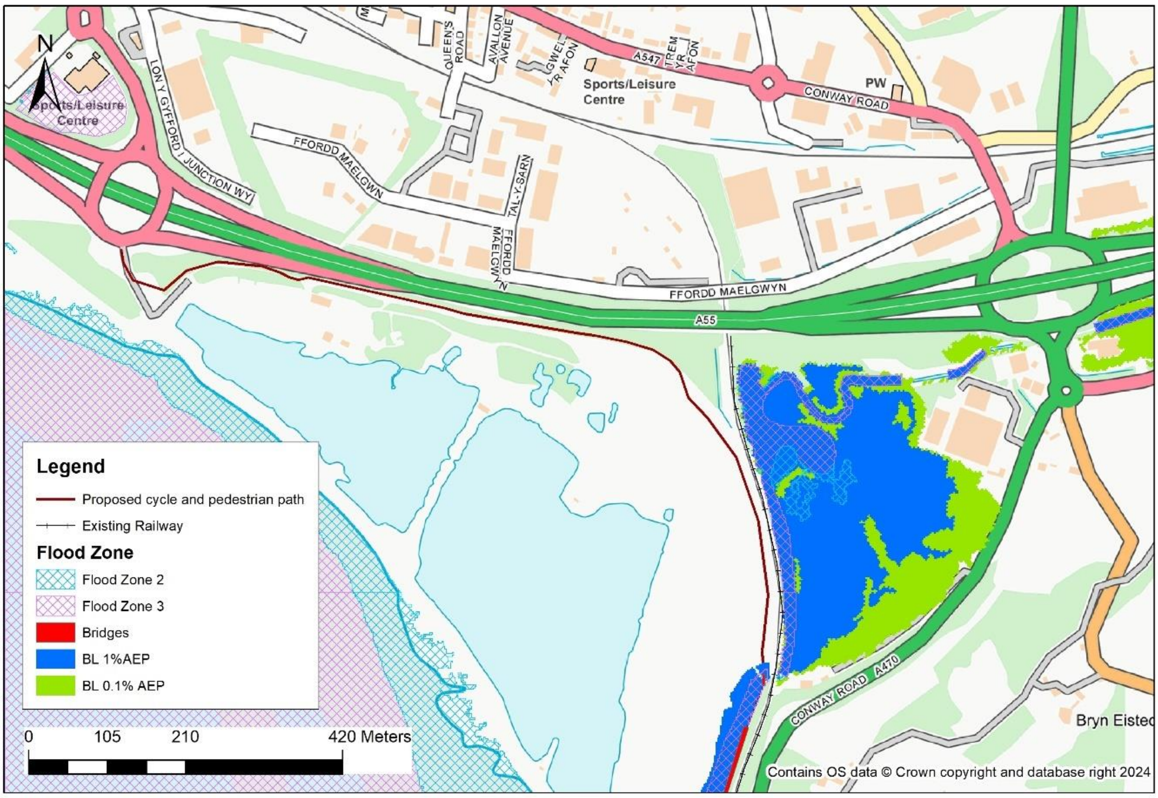

Figure 4-1 Flood outline comparison for baseline (BL) 1% AEP and 0.1% AEP events

4.1.2 Impact of Post Development Scenarios

Table 4-1 lists the modelled flood levels at a set of monitoring points for both pre and post development scenarios. The results from the post development blockage model run are also included in this table. The location of the monitoring points is shown in Figure 4-2 and the flood levels were obtained by querying the 2D results grids. The table ultimately shows that the pre and post development levels are near identical across the range of modelled events and there is no evidence in the modelled flood levels of any adverse impact due to development. This is also reflected in the flood outlines as demonstrated for the 1% AEP with climate change event in Figure 4-2.

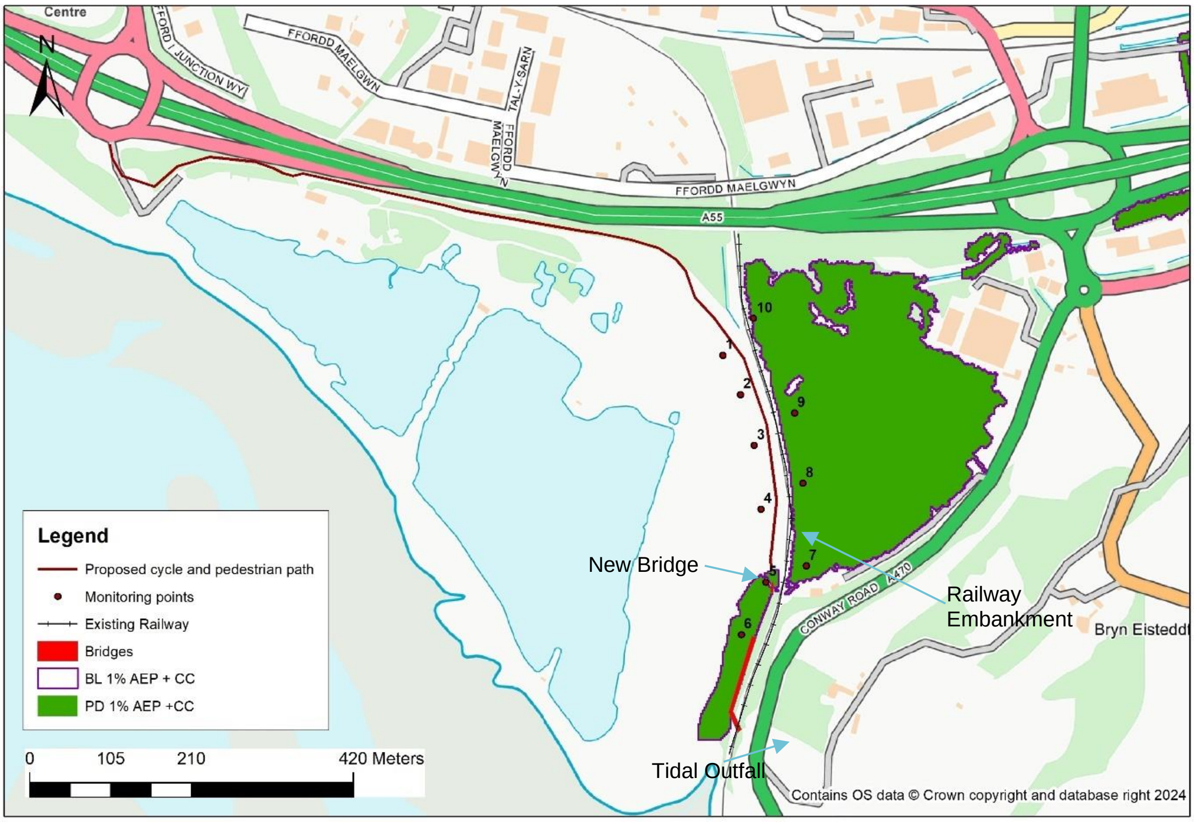

Figure 4-2: 1% AEP with climate change pre and post development flood outlines with monitoring point locations

Table 4-1 Flood levels at monitoring points

No	Baseline			Post Development			Blockage
	1% AEP	1% AEP + CC	0.1% AEP	1% AEP	1% AEP + CC	0.1% AEP	1% AEP + CC
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	3.40	3.50	3.47	3.40	3.50	3.47	3.50
6	3.40	3.50	3.47	3.40	3.50	3.47	3.50
7	3.47	3.74	3.95	3.46	3.74	3.95	3.74
8	3.47	3.74	3.95	3.46	3.74	3.95	3.74
9	3.46	3.74	3.95	3.46	3.74	3.95	3.74
10	3.47	3.74	3.95	3.46	3.74	3.95	3.74

4.2 Tidal Flood Risk (TUFLOW)

The Ganol tidal modelling including several updates that had the potential to influence the modelled flood outlines and peak levels at the RSPB Conwy site. The main change was the updated tidal boundaries but the LIDAR update and software change from TUFLOW Classic to GPU could also have caused some changes relative to the previous (2012) modelling. Both studies predicted that present day 0.5 and 0.1% AEP events would not affect the site but that the future 0.5% AEP event in 100 years would flood the site; noting that there will have been 12 years of additional sea level rise to influence the tidal boundary series between the studies.

Figure 4-3 compares the 0.5% AEP in 100 years flood extents obtained from the two studies. This shows that the tidal risk has been slightly reduced relative to the 2012 study, despite the previous study only including for sea level rise up to 2112. This is because the modelled downstream boundary was lower due to a combination of the revised extreme sea level, reduced climate change uplift (relative to FCDPAG3 that was applied in 2012) and the fact that the updated offshore boundaries were subsequently run through the Conwy Estuary (Tidal Prism) model.

It should be noted that the undefended Ganol (2012) model scenario was very much a localised defence removal scenario in the Ganol West catchment, in which the NRW tidal outfall and immediate embankment assets were removed. Therefore, it is not appropriate to compare the results of the 2024 'undefended' model re-run with the tidal Flood Zones that were obtained from a much wider scale of coastal defence removal.

Table 4-2 provides a summary of the modelled (2024) peak tidal flood levels at the monitoring points shown in Figure 4-3. This illustrates that the flood levels tend to equilibrate to different levels on either side of the railway embankment in the defended with climate change and undefended without climate change scenarios. However, in the future undefended scenarios levels tend to also equilibrate across the railway embankment because of the volume of tidal water entering the catchment.

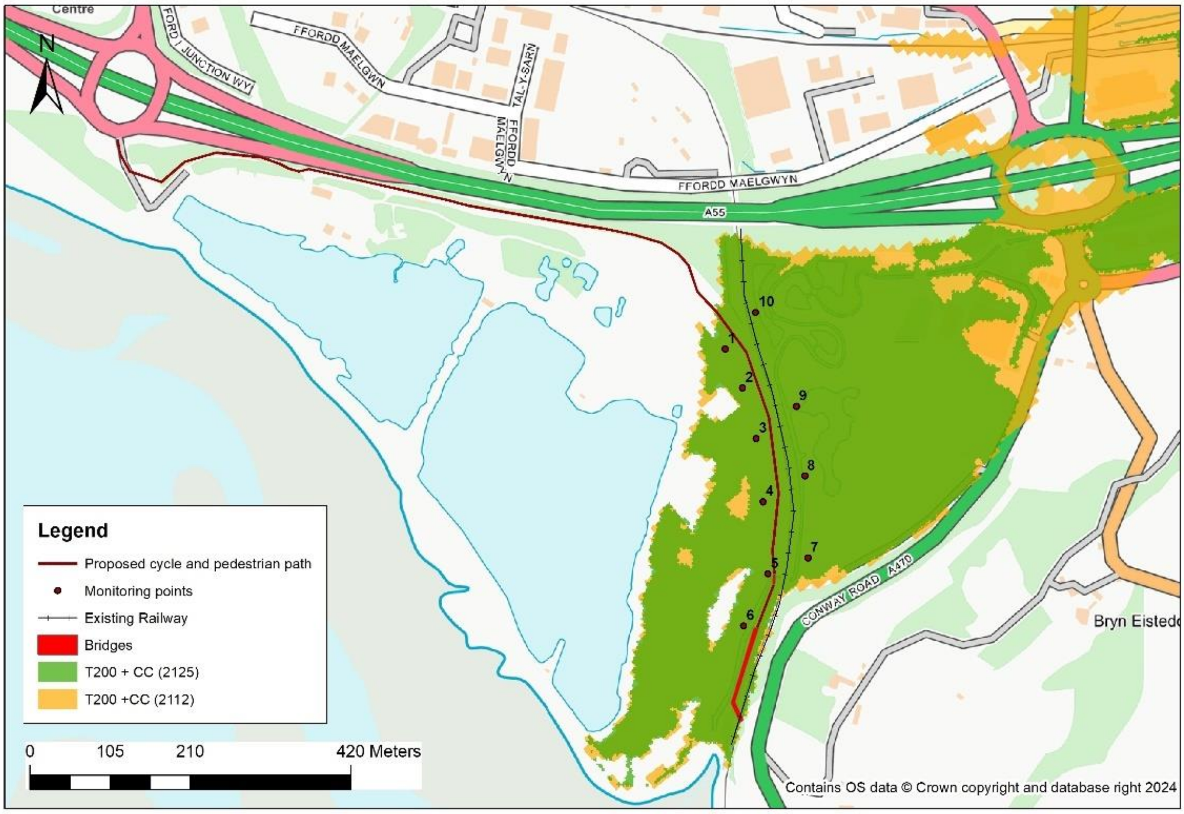

Figure 4-3 Comparison of 0.5% AEP with climate change flood outlines between 2012 and 2024 studies

Table 4-2 Tidal flood levels (m AOD) along proposed development

No	Defended				Undefended			
	0.5% AEP	0.5% AEP + CC	0.1% AEP	0.1% AEP + CC	0.5% AEP	0.5% AEP + CC	0.1% AEP	0.1% AEP + CC
1	DRY	5.33	DRY	5.38	5.19	6.10	5.31	6.27
2	DRY	5.33	DRY	5.38	5.19	6.10	5.31	6.27
3	DRY	5.35	DRY	5.41	5.20	6.10	5.33	6.27
4	DRY	5.38	DRY	5.45	5.20	6.10	5.35	6.27
5	DRY	5.48	DRY	5.61	5.24	6.12	5.46	6.29
6	DRY	5.49	DRY	5.62	5.24	6.13	5.46	6.30
7	DRY	4.35	DRY	5.31	2.50	6.10	4.14	6.27
8	DRY	4.35	DRY	5.31	3.33	6.10	4.14	6.27
9	DRY	4.35	DRY	5.31	2.89	6.10	4.14	6.27
10	DRY	4.35	DRY	5.31	3.35	6.10	4.14	6.27

5 Assumptions, limitations, and uncertainty

All hydraulic modelling studies are subjected to a set of assumptions and limitations, given the nature of trying to represent real-world scenarios with the use of equations and computer software.

The main limitations and assumptions of the Ganol (2024) modelling are:

- The predictions of the updated model are partly reliant on the accuracy of the existing Afon Ganol (2012) model, particularly in relation to the fluvial channel capacity and bank crest elevations. The original model was constructed using river survey from 2000, supplemented with check survey data from 2012.
- The design events required from an FCA are generally quite extreme so there will be a high degree if uncertainty in the model hydraulic boundaries (both fluvial flow and extreme sea level). This will be compounded by uncertainties in the impact of climate change over the lifetime of the development.
- The predictions of the fluvial model include for an assessment of the joint probabilities of fluvial and tidal conditions by assuming a fluvial event coincides with a MHWS tide. This is important considering that the flood risk at the site will be influenced by the duration of any tide-locking. In this regard the assumption of a MHWS tidal event is likely to provide a conservative assessment of the fluvial flood risk at the site. Conversely, the tidal models lack a fluvial inflow component, but the volume of fluvial input will likely be insignificant once tidal overtopping commences near the western outfall.
- The supplied fluvial model included FM ORIFICE units to assess both inlet and outlet losses at culverts. This will generally be more conservative than including FM INLET and OUTLET losses.
- Both fluvial and tidal models were run with up-to-date software versions, which could cause some subtle differences relative to the original modelling.