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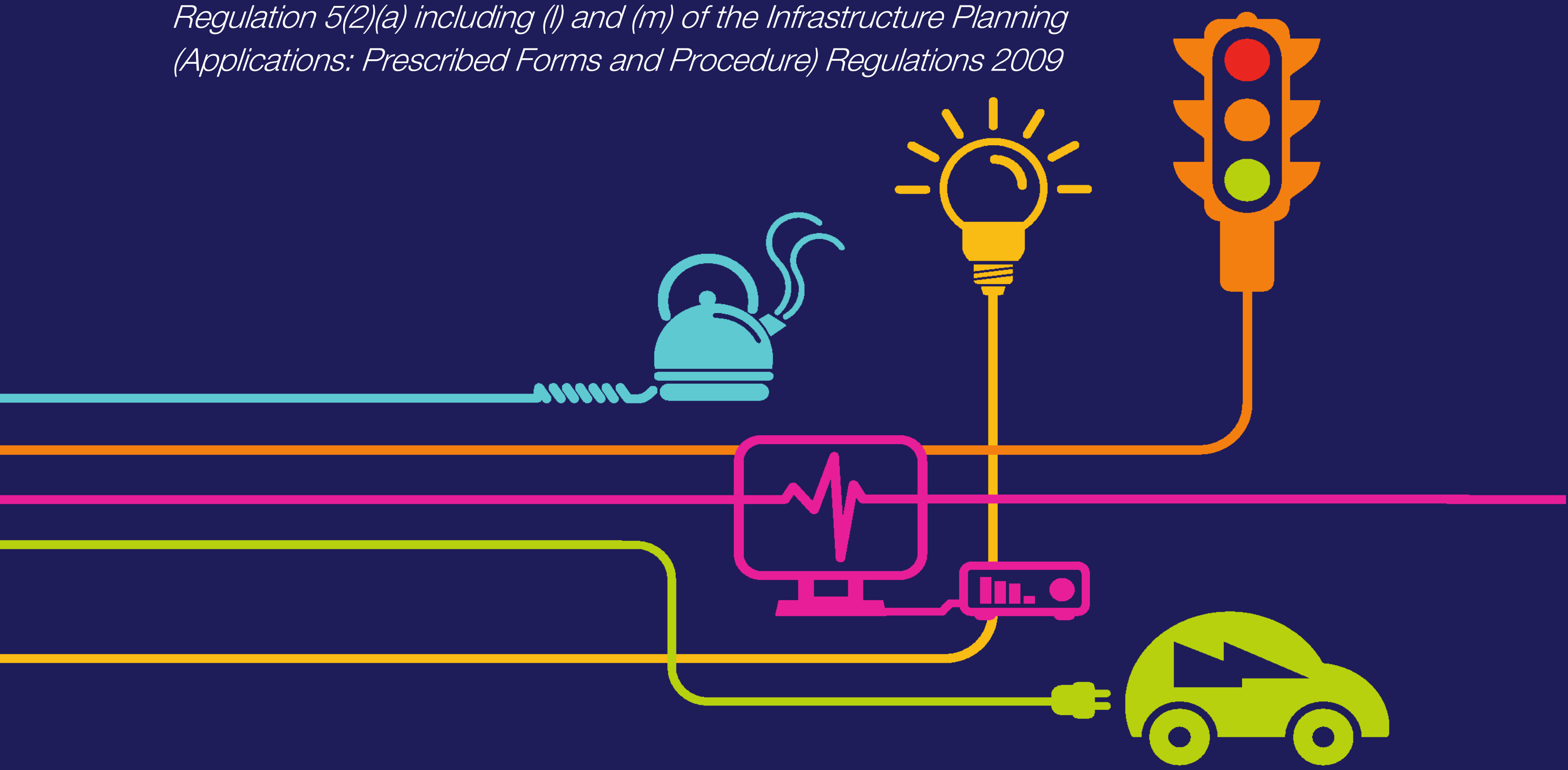
5.12.2.3

Tunnel Head Houses and Cable Sealing End Compounds Flood Consequences Assessment

Chapter 12 – Appendix 3

National Grid (North Wales Connection Project)

Regulation 5(2)(a) including (l) and (m) of the Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009



Application Reference EN020015

September 2018

North Wales Connection Project

Volume 5

Document 5.12.2.3 Appendix 12.3

Tunnel Head Houses and Cable Sealing End Compounds Flood Consequences Assessment

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Final September 2018

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Document Control			
Document Properties			
Organisation	Wood		
Author	Ben Thomas		
Approved by	Steve Anderton		
Title	Appendix 12.3 Tunnel Head House and Cable Sealing End Compound FCA		
Document Reference	Document 5.12.2.3		
Version History			
Date	**Version**	**Status**	**Description/Changes**
September 2018	Rev A	Final	Final for submission

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Contents

1 Introduction 1

1.1 Context 1
1.2 FCA scope 1
1.3 CSEC and THH Overview 2
1.4 Applicable referrals to volume 1 3
1.5 Volume 3 Structure 4

2 Study Area 5

2.1 Introduction 5
2.2 Climate 5
2.3 Topography 5
2.4 Geology, Hydrogeology and Soils 6
2.5 Land Use 6
2.6 Hydrology 7

3 Flood Hazard Identification 9

3.1 Flood Hazard Overview 9
3.2 Afon Braint FLood Modelling 16
3.3 Future changes to baseline 16
3.4 Summary of baseline flood hazard 17

4 Receptor Flood Risk 18

4.1 Introduction 18
4.2 Receptors Affected by Surface Water Flood Risk (Internal – Braint / Tŷ Fodol) 19

5 Flood Risk Assessment 20

5.1 Introduction 20
5.2 Summary of Flood Risk 20

6 Flood Risk Management 22

6.1 Introduction 22
6.2 Drainage 22
6.3 Residual Risk 24

7 Summary and Conclusions 25

7.1 Summary 25

DRAWINGS AND FIGURES	TITLE
Figure 5.12.2.4	Braint topography
Figure 5.12.2.5	Tŷ Fodol topography
Figure 5.12.2.6	Braint fluvial flood mapping
Figure 5.12.2.7	Braint surface water flood mapping
Figure 5.12.2.8	Afon Braint 0.1%AEP flood map
Figure 5.12.2.10 (Sheets 5 and 6)	Order Limits flood mapping
Figure 5.12.2.12 (Sheets 5 and 6)	Groundwater flooding susceptibility mapping

1 Introduction

1.1 CONTEXT

1.1.1 This Flood Consequences Assessment (FCA) accompanies an application by National Grid Electricity Transmission (plc) (National Grid) to seek powers to construct, operate and maintain a new 400,000 volt (400 kV) connection between Wylfa Substation and Pentir Substation, together with various associated development and other works ("The Proposed Development"). This document is the third of four FCA volumes that together comprise an appendix to Chapter 12 of the Environmental Statement: 'Water Quality, Resources and Flood Risk' (**Document 5.12**). The four FCA volumes are:

Volume 1 Overarching FCA (**Document 5.12.2.1**)

Volume 2 Pentir Substation Extension FCA (**Document 5.12.2.2**)

Volume 3 Tunnel Head Houses and Cable Sealing End Compounds FCA (**Document 5.12.2.3**)

Volume 4 Overhead Lines FCA (**Document 5.12.2.4**)

1.1.2 A list of references covering all volumes is included at the end of FCA Volume 1 (**Document 5.12.2.1**).

1.2 FCA SCOPE

1.2.1 FCA Volume 3 comprises an FCA of the two tunnel head houses and cable sealing end compounds (THH/CSEC) at Braint (Anglesey – National Grid Reference 251629 371023) and Tŷ Fodol (Gwynedd - 254631 368374) during the construction and operational phases. The Braint and Tŷ Fodol construction compounds include for above ground construction elements of the tunnelling works. The locations of the Braint and Tŷ Fodol construction compounds are shown along with the Order Limits in the Works Plans (**DCO Volume 4**).

1.2.2 The geographical scope of FCA Volume 3 includes the operational THH/CSEC sites (see **Document 4.13**, Drawings **DCO_DE/PS/09 SHEET 2 OF 8** and **DCO_DE/PS/09 SHEET 6 OF 8**), the construction compounds associated with the tunnelling and the THH/CSEC sites (see **Document 4.13**, **Drawings DCO_DE/PS/12 SHEET 2 OF 3** and **DCO_DE/PS/12 SHEET 3 OF 3**) and permanent access to both THH/CSEC sites.

1.2.3 This FCA Volume 3 has been prepared in accordance with the overall scope and methodology set out in FCA Volume 1 (**Document 5.12.2.1**).

1.3 THH/CSEC OVERVIEW

1.3.1 Braint THH/CSEC is located in section F at the southern end of the Anglesey section of the OHL where the OHL transitions from overhead line to cables and a CSEC is required to provide a point of connection. Tŷ Fodol THH/CSEC is located in Gwynedd (also in section F) where the cabled section emerges from the southern end of the tunnel and is connected to a short section of OHL prior to connecting with Pentir Substation. Further details about the CSEC, the tunnel head house and the tunnel itself are provided in ES Chapter 3 Description of Proposed Development (**Document 5.3**) and ES Chapter 4 Construction, Operation, Maintenance and Decommissioning of the Proposed Development (**Document 5.4**).

1.3.2 During the construction phase both the Braint and Tŷ Fodol construction compounds would comprise large areas to allow tunnelling activities to take place. At Braint, the total construction phase site area, including the permanent access track, would be 7.9 ha; at Tŷ Fodol, the corresponding area would be 5.01 ha (see **Document 4.13**, **Drawings DCO_DE/PS/12 SHEET 2 OF 3** and **DCO_DE/PS/12 SHEET 3 OF 3**). By contrast, the operational compound at both sites would enclose an area of approximately 1.5ha (see **Document 4.13, DCO_DE/PS/09 SHEET 2 OF 8** and **DCO_DE/PS/09 SHEET 6 OF 8**).

1.3.3 Both construction compounds would comprise a mix of permeable and impermeable surfacing and a temporary drainage system would manage water onsite and ensure that discharges to receiving watercourses are compliant with appropriate consents. Both the Braint and Tŷ Fodol construction compounds would drain to receiving watercourses via a single site discharge point, the location of which would be the same for both construction and operational / maintenance phases.

1.3.4 Areas have been set aside at each construction compound for water treatment (settlement) and attenuation ponds. A network of open ditches throughout the site would route site runoff via a hydrocarbon separator to the treatment and attenuation ponds, before final discharge to nearby watercourses.

1.3.5 Dewatering of the shafts and tunnel would be required during both the construction and operational phases. During construction, dewatering arisings would firstly be pumped through a packaged water treatment works in order to remove drilling fluids and bentonite, and then into a holding pond in order to test for salinity levels. Subject to salinity being within consented limits, water from the dewatering holding pond would be routed to the site drainage system for further treatment and eventual discharge to nearby watercourses (see **Document 4.13**, **Drawings DCO_DE/PS/12 SHEET 2 OF 3** and **DCO_DE/PS/12 SHEET 3 OF 3**). During operation, residual groundwater seepage collecting in the tunnel would be pumped either to a saline treatment area if required, or direct to the attenuation pond prior to discharge to nearby watercourses if there are no issues with salinity (see **Document 4.13, Drawings DCO_DE/PS/09 SHEET 2 of 8** and **DCO_DE/PS/09 SHEET 6 of 8**).

1.3.6 Once completed, the above ground elements of the THH/CSECs would have formal drainage systems, with runoff from impermeable surfaces draining to an attenuation pond prior to discharge to nearby watercourses at the outfall locations that were retained from the construction phase. Saline treatment areas would be provided for shaft and tunnel dewatering, if required (See **Document 4.13, DCO_DE/PS/09 SHEET 2 OF 8** and **DCO_DE/PS/09 SHEET 6 OF 8)**.

1.3.7 Outline drainage strategies for the construction and operational phases of the Braint and Tŷ Fodol sites are provided as **Annex 5.12.2.3B**. Furthermore, a detailed drainage design for each site that is consistent with these outline strategies will be produced as part of the Drainage Management Plan (DMP) for the Proposed Development that is secured through Requirement 7 of the draft DCO (**Document 2.1**).

1.4 APPLICABLE REFERRALS TO VOLUME 1

1.4.1 Reference to FCA Volume 1 (**Document 5.12.2.1**) should be made when reading this FCA Volume 3. Specifically, it should be consulted for additional information regarding the following:

FCA Policy and guidance (FCA Volume 1, section 2.1 - 2.3)

FCA definitions (FCA Volume 1, section 2.4)

Climate change requirements (FCA Volume 1, section 2.5)

Data sources (FCA Volume 1, section 2.6)

FCA consultation and scope (FCA Volume 1, section 3)

FCA methodology (FCA Volume 1, section 4)

FCA mitigation (FCA Volume 1, section 5)

1.5 VOLUME 3 STRUCTURE

1.5.1 The structure of FCA Volume 3 is as follows:

Section 1 **Introduction:** sets out the context of this volume within the wider FCA, defines its scope and structure;

Section 2 **Study Area:** describes the physical characteristics of the geographical area at the THH /CSEC locations;

Section 3 **Flood Hazard Identification:** describes the baseline flood hazards that may affect the Proposed Development, including potential changes in the baseline over the lifetime of the Proposed Development;

Section 4 **Receptor Flood Risk:** defines the main receptor groups that could be affected by the hazards identified in the previous section;

Section 5 **Flood Risk Assessment:** assesses flood risk to the main receptor groups and identifies mitigation measures;

Section 6 **Flood Risk Management:** describes the flood risk management measures to be adopted within the design, construction and operation of the Proposed Development; and

Section 7 **Summary and Conclusions:** summarises the main points arising from the FCA carried out in this volume.

2 Study Area

2.1 INTRODUCTION

2.1.1 This section describes the physical characteristics of the area around the two THH/CSEC sites and associated construction compounds. The two tunnel shafts are approximately 4 km apart, one at each end of the tunnel under the Menai Strait.

2.2 CLIMATE

2.2.1 The climate at Braint and Tŷ Fodol is discussed in FCA Volume 4 (**Document 5.12.2.4**), section 2.2, and also in ES Chapter 12 Water Quality, Resources and Flood Risk (**Document 5.12**).

2.3 TOPOGRAPHY

2.3.1 The topography in the areas of the two compounds and THH/CSEC sites is shown in Figures 12.4 and 12.5 (**Documents 5.12.1.4 and 5.12.1.5**).

Braint THH/CSEC and construction compound

2.3.2 The land surrounding the Braint THH/CSEC and construction compound rises in a north-easterly direction to 41.2 m Above Ordnance Datum (AOD). To the south and east the land slopes away from the THH/CSEC site and to the north-west it slopes away to the Afon Braint at 31.6 mAOD.

2.3.3 The Braint THH/CSEC and construction compound is partially situated in a shallow saddle between local topographic highs and river catchments (the Afon Braint to the west and those catchments draining directly to the Menai Strait to the east). The ground levels at the site range from 37.5 mAOD along the south-western perimeter to 33.7 mAOD along the south-eastern perimeter.

2.3.4 The Braint THH/CSEC and construction compound would be set at a uniform level of 35.38 mAOD. As a result, the northern and eastern areas of the site would be raised above the existing ground level in fill, whereas the rest of the site would be cut lower than the existing ground level.

Tŷ Fodol THH/CSEC and construction compound

2.3.5 To the south and west of the Tŷ Fodol THH/CSEC and construction compound the land drops steeply to the Nant-y-garth valley. The land to the north and east slope down towards the THH/CSEC.

2.3.6 The Tŷ Fodol THH/CSEC site is situated within a flat field that slopes from south-east (90.5 mAOD) to north-west (75.7 mAOD). The platform level of the operational Tŷ Fodol THH/CSEC would be between 80 and 81 mAOD.

2.4 GEOLOGY, HYDROGEOLOGY AND SOILS

2.4.1 The geology in the area of the Braint and Tŷ Fodol THH/CSECs and construction compounds is discussed in FCA Volume 4, section 2.4 (**Document 5.12.2.4**).

2.4.2 The Braint THH/CSEC and construction compound is situated on a 'Secondary B' aquifer. This designation is for aquifers consisting of predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering.

2.4.3 The Tŷ Fodol THH/CSEC and construction compound is situated on a 'Secondary A' aquifer. This designation is for aquifers consisting of permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.

2.4.4 The soil at the Braint THH/CSEC and construction compound is described as 'slowly permeable, seasonally wet acidic loamy and clayey' (Ref 12.1.4), whilst the soil at Tŷ Fodol is classified as 'freely draining loam'.

2.5 LAND USE

2.5.1 The land use surrounding both THH/CSECs and construction compounds is agricultural, mostly pasture. At Braint there are a number of small areas of woodland, farmsteads and residential properties within 500 m of the THH/CSEC and construction compound. At Tŷ Fodol, Fodol Farm can be found 200 m to the east and upslope of the THH/CSEC and construction compound. The southern perimeter is flanked by a steep wooded valley, Coed-y-garth, associated with the Nant-y-garth watercourse. A landfill site occupies the opposite (southern) valley side of the Coed-y-garth.

2.6 HYDROLOGY

Braint CSEC / THH and Construction Compound

2.6.1 The main hydrological features at Braint can be seen in Figures 12.6 and 12.7 (**Documents 5.12.1.6 and 5.12.1.7**) which show watercourses and fluvial and surface water flood risk zones. Groundwater flooding susceptibility is shown in Sheet 5 of Figure 5.12.1.12.

2.6.2 The Greenfield runoff rate (QBAR) at Braint is 3.02 l/s/ha, as calculated using the UK SuDS online assessment tool (Ref 12.1.27).

2.6.3 There are two main rivers within the vicinity of the Braint THH/CSEC and construction compound. They are the east and south branches of the Afon Braint. The source of the Afon Braint is 8.5 km to the north of the THH/CSEC and construction compound from where it flows south and under the A55, A5 and Bangor-Holyhead main railway line west of Llanfairpwll, and then east for approximately 400 m. At this point the channel bifurcates, being split into east and south branches by means of a concrete flow control structure. A greater proportion of the flow is routed to the east during normal flow events but more is routed to the south as stream levels rise. The structure is drowned out at bankfull levels.

2.6.4 The eastern branch of the Afon Braint discharges into the Menai Strait 2 km downstream of the bifurcation and the south branch discharges into the Newborough Warren RSPB Reserve and eventually to Caernarfon Bay in the south of Anglesey some 10 km southwest of the bifurcation.

2.6.5 The catchment area of the Afon Braint to the bifurcation is 21 km^2 increasing to 29.5 km^2 with the inclusion of the east branch to the Menai Strait. The south branch of the Afon Braint at Caernarfon Bay, provides an additional catchment area of 48.5 km^2. There is a small unnamed ditch which originates 140 m to the south of the THH/CSEC and construction compound, which converges with the east branch of the Afon Braint.

Tŷ Fodol THH/CSEC and Construction Compound

2.6.6 The main hydrological features at Tŷ Fodol can be seen in Figure 12.10 (**Document 5.12.1.10**) (Sheet 5) which show watercourses and fluvial and surface water flood risk zones. Groundwater flooding susceptibility is shown in Figure 12.12 (**Document 5.12.1.12**) (Sheet 5).

2.6.7 The Greenfield runoff rate (QBAR) at Tŷ Fodol is 3.2 l/s/ha, as calculated using the UK SuDS online assessment tool (Ref 12.1.27).

2.6.8 The Tŷ Fodol THH/CSEC and construction compound is situated on high ground (>80 mAOD). The nearest watercourse, a tributary of the Nant-y-garth, lies within a deeply incised valley 60 m south of the edge of the construction compound and 150 m south of the THH/CSEC. The level at the bottom of the valley is approximately 30 m below the level of THH/CSEC site. The top of the valley slope coincides with the southern perimeter of the site. The catchment area of the Nant-y-garth tributary is 4.3 km^2.

3 Flood Hazard Identification

3.1 FLOOD HAZARD OVERVIEW

3.1.1 This section describes the baseline flood hazards that may affect the Proposed Development. Section 3.2 outlines the Afon Braint flood modelling, section 3.3 examines potential changes in the baseline over the lifetime of the Proposed Development and section 3.4 presents a summary of flood hazard.

3.1.2 The approach to identifying flood hazards is provided in FCA Volume 1, section 4.3 (**Document 5.12.2.1**), where the hazards, methods, data and sources of information used are described.

3.1.3 A summary of external flood hazards that may affect the Proposed Development is presented in Table 3.1. Internal flood hazards are presented in Table 3.2. It should be noted that:

- Where the hazard is deemed to be 'Negligible', this is highlighted and the hazard is considered no further in the assessment.
- Where the hazard is deemed to be 'Low' and there is supporting information to demonstrate that no further assessment is required, then that hazard is not considered further in the assessment – as in the case for surface water flooding (External).
- Where the hazard is deemed to be 'Low' and for which there is no supporting information to demonstrate that no further assessment is required, that hazard is then considered further in this assessment – as in the case for groundwater flooding.
- Where the hazard is deemed to be greater than 'Low' then it is considered further in the assessment.

Table 3.1 Summary of external flood hazard

Source	Hazard	Description	Subject to further assessment
Fluvial	**Negligible**	***Braint*** There is no fluvial flood risk to the construction phase at the Braint construction compound as it lies outside of the mapped area of fluvial flood risk (see **Document 5.12.1.6**). For the operational phase, the Braint THH/CSEC is within 120 m of DAM Flood Zone C2 along the southern branch of the Afon Braint (see **Document 5.12.1.6**). While the fluvial design standard for operational infrastructure is the 0.1% AEP event +30% on flows (change factor for the 2080s), for the specific case of the Braint THH/CSEC an assessment has been made of the 0.1% AEP river flow event plus 75% (upper end allowance for up to the 2080s), as requested by NRW (and see FCA Volume 1, section 3.4 - **Document 5.12.1.1**). This modelling was undertaken (see section 3.2) and it demonstrated that there was no risk to the site during the 0.1% AEP +75% event. ***Tŷ Fodol*** There is no fluvial flood risk during the construction or operational phases at Tŷ Fodol as the construction and operational sites lie outside of the mapped area of fluvial flood risk (see **Document 5.12.1.6**). The Tŷ Fodol THH/CSEC is situated on high ground with a platform level of 82.16 mAOD. The closest watercourse, Nant-y-garth, is within a well incised valley which is approximately 25 m below the level of the Tŷ Fodol CSEC (see **Document 5.12.1.5**).	**NO**

Surface Water	**Low** (Braint Only) (Construction Only) **Negligible** (Braint operational and Tŷ Fodol construction and operational)	***Braint*** The north and east areas of the Braint construction compound coincide with a mapped area of surface water flood risk (see **Document 5.12.1.7**). Surface water in this area is locally sourced and thus has a small contributing catchment. The NRW surface water flood mapping provides hazard rating layers (see **Document 5.12.1.7**) and the maximum Flood Hazard Rating (HR) for the 3.33% and 1%AEP events is 'Very Low'. For the 0.1%AEP event the HR is 'Danger for some – includes children, the elderly and the infirm' [1]. Due to the quantitative nature of this analysis, external surface water flooding is assumed to be of low risk and is not subject to further assessment. External surface water flood risk to the operational site at Braint is deemed to be negligible since the maximum mapped depth is 0.15 – 0.30 across all scenarios and existing ground levels are between 33.4 and 33.8 mAOD, compared to an operational site level of 35.38 mAOD (see Figure 5.12.1.7). Moreover, once the THH/CSEC platform level is established, surface water flowpaths will be diverted around the site. ***Tŷ Fodol*** Neither the Tŷ Fodol construction compound, nor the THH/CSEC site, is located near mapped areas of surface water flood risk (see Sheet 6 of **Document 5.12.1.11**). The nearest surface water flood extent is within the Nant-y-garth valley bottom, 25 m below the THH/CSEC site.	**NO**
Sewer	**Negligible**	There are no reported DCWW, Isle of Anglesey County Council (IACC) or Gwynedd Council sewer flooding incidents in the area of Braint and Tŷ Fodol construction compounds and THH/CSEC sites. Indeed, such is the rural nature of these locations, there is unlikely to be any significant sewer infrastructure.	**NO**

Groundwater	**Low**	***Braint*** **Document 5.12.1.12** shows the BGS susceptibility to groundwater flooding mapping. Sheet 5 of the figure shows the Braint THH/CSEC and construction compound to be within groundwater flood Zone B: 'potential for groundwater flooding of property situated below ground level'. The lower lying adjacent land is associated with groundwater flood Zone C: 'Potential for groundwater flooding to occur at surface', implying that groundwater could flow onto and impact the construction site (see **Document 5.12.1.12**). However, given that the Braint construction compound is effectively located on a divide between two catchments, it is inconceivable that groundwater levels in this area would be so high as to intersect the surface. Therefore, the risk of groundwater flooding is assumed to Low. The highest point in the groundwater catchment upslope of the site is 39.5 mAOD (see Figure 5.12.1.4) compared to a site level of 35.38 mAOD. The contributing area (assumed to correspond with the surface water catchment) would be less than 2 ha (see Figure 5.12.1.4). Therefore, the risk of groundwater flooding to the construction compound and the THH/CSEC at Braint arising from the lowering of ground remains negligible. ***Tŷ Fodol*** The Tŷ Fodol construction compound and THH/CSEC is within groundwater flood Zone A with limited potential for groundwater flooding to occur. Any potential locally is associated with adjacent valley bottoms and would not affect the construction compound or THH/CSEC.	**NO**
Flooding from artificial sources	**Negligible**	There are no reservoirs, canals or other artificial waterbodies such as ponds in close proximity to either the Braint or Tŷ Fodol site.	**NO**

Table 3.2 Summary of internal flood hazard

Floodplain Displacement	**Negligible** (Braint Only) (Operational Only)	***Braint*** The operational THH/CSEC site at Braint could only cause the displacement of flood storage volume during the most extreme 0.1%AEP +75% climate change event). However, for assessment purposes only the 1%AEP event, including the change factor allowance for climate change event needs to be considered (+30% through to the 2080s – see FCA Volume 1, section 2.5 - (**Document 5.12.2.1**)). As is shown in section 3.2 which outlines fluvial modelling that was done for the 0.1% AEP +75% on flows, no flooding of the site is shown to occur and thus there is no risk of floodplain displacement. ***Tŷ Fodol*** There is no risk of floodplain storage displacement at Tŷ Fodol.	**NO**
Fluvial Flow Obstruction	**Negligible**	No elements of the construction or operational phases at Braint or Tŷ Fodol would result in activities in or near to watercourses other than the site discharge point (see ‘surface water flooding – internal) and thus there would be no risk of flooding arising from the obstruction of fluvial flows.	**NO**

Table 3.2 Summary of internal flood hazard			
Surface Water Flow Obstruction	**Low**	***Braint*** The northern and eastern areas of the operational THH/CSEC site at Braint coincide with a mapped area of NRW surface water flood risk. During the construction period at Braint, the cut and fill earthworks phase (see section 1.3 and ES Chapter 3) (**Documents 5.12.2.3 and 5.3** respectively) would be undertaken in order to form the finished site platform level of 35.38 mAOD. Therefore, prior to and once the platform level is established, surface water flows would be effectively diverted to the southeast. However, due to the small upslope contributing area it is highly unlikely that the obstruction would result in any significant increase in surface water flood depth, thus posing no additional risk to construction workers in that area. Moreover, the diverted surface waters would be intercepted by the formal drainage system (see **Document 4.13, DCO_DE/PS/12 SHEET 2 OF 3**). Section 1.3 shows that the tunnel would be dewatered to the surface water management system however the rates are so low (see Table 1.1) they would not impact this system. During the operational case at Braint, while there would be no formal drainage around the perimeter of the site other than at platform level (areas around the platform will be landscaped), no operatives would be expected to frequent the area of diverted surface water flows. Moreover, the areas of diverted surface water flows would be within a secure site with no public access and thus would not pose a risk to the public. ***Tŷ Fodol*** There is no risk of surface water flow obstruction at Tŷ Fodol.	**NO**

Table 3.2 Summary of internal flood hazard

Surface water flooding (internal)	**Medium**	Internal surface water flooding may arise at both the Braint and Tŷ Fodol sites as a result of inappropriate and/or insufficient water management measures being implemented for both the construction and operational sites, including management of dewatering arisings. This could lead to uncontrolled runoff of surface water from the site, potentially resulting in localised flooding and also exacerbating the risk of flooding from the Afon Braint.	**YES**

Table Notes:

[1] Flood hazard ratings are given in accordance with the methods provided in Defra FD2320/2321 (Ref 12.1.30 and 12.1.31). See FCA Volume 1, section 4.3 (**Document 5.12.2.1**).

3.2 AFON BRAINT FLOOD MODELLING

3.2.1 As identified in Table 3.1, a flood modelling assessment was undertaken to demonstrate that the operational Braint THH/CSEC would remain safe during the 0.1%AEP +75% climate change event to satisfy the requirements of NPS-EN1 for essential infrastructure (see FCA Volume 1, section 2.1) (**Document 5.12.2.1**).

3.2.2 The technical details of the Afon Braint modelling assessment are provided as **Annex 5.12.2.3A**. A brief summary of the results is provided here.

3.2.3 A coupled 1D/2D hydrodynamic model was developed using Tuflow/Estry for the wider Afon Braint area south of the A55. The 2D model domain is shown in **Document 5.12.1.8**.

3.2.4 **Document 5.12.1.8** shows the output of the Afon Braint model for the 0.1%AEP event with inflow hydrology factored up by 75% in accordance with the Upper End climate change allowance requirements (see FCA Volume 1, section 2.5) (**Document 5.12.2.1**). It can be seen that the mapped flood extent does not reach the footprint of the Braint THH/CSEC. The maximum flood level at the nearest point to the site is 32.73 mAOD compared to the THH/CSEC platform level of 35.38 mAOD (see **Annex 5.12.2.3A**). Therefore, it is concluded that the operational Braint THH/CSEC would remain safe during the design 0.1%AEP +75% climate change scenario and that no mitigation measures need to be incorporated into the Proposed Development.

3.3 FUTURE CHANGES TO BASELINE

Climate change

3.3.1 FCA Volume 1, section 2.5 (**Document 5.12.2.1**) gives an overview of climate change, including the relevant allowances for river flow, rainfall and sea level, together with a justification for why consideration of an H++ scenario is not applicable to the study area.

3.3.2 Climate change is of particular relevance to the Braint THH/CSEC site as it was shown in Table 3.1 that, whilst the site would not be located within a mapped area of fluvial flood risk, it is possible that the site may be at risk of fluvial flooding under the 0.1%AEP event including the Upper End climate change allowance (+75% on inflows under that scenario) and hence adaptation measures may need to be considered in future.

Other development

3.3.3 Changing land use, in the form of changing agricultural land management practices, urban development, or the development of other infrastructure upstream of the Braint and Tŷ Fodol THH/CSECs could cause changes to the surface water environment in terms of patterns and rates of rainfall infiltration, flow pathways, morphological alteration of water bodies or the diversion of smaller watercourses and drainage ditches.

3.3.4 It is not possible to incorporate changing land use or unanticipated development into this FCA as this cannot be foreseen. However, it is possible to ensure that there is no increase in internal flood risk associated with runoff relative to the present-day baseline, and to incorporate allowance for climate change. This would reduce the potential for cumulative impacts on flood risk, which could arise from the Proposed Development and any other future development.

3.4 SUMMARY OF BASELINE FLOOD HAZARD

3.4.1 Further to the flood modelling exercise outlined in section 3.2 (and see **Annex 5.12.2.3A**), it has been shown that there is no fluvial flood risk to the Braint THH/CSEC site during the 0.1%AEP event (+75% climate change allowance on inflows).

3.4.2 There would be a low risk of surface water flooding in the northern and eastern areas of the construction site at Braint and a risk of impacts arising from obstructing the surface water flow path in the same area during the operational phase due to the raising of the land. However, the risk from surface water flooding is considered to be ‘low’ due to the low range of depths and flood hazard rating.

3.4.3 There would be a low risk of groundwater water flooding in the northern and eastern areas of the construction compound at Braint but negligible risk to the operational site. The risk from groundwater flooding is considered to be ‘low’ due to the low range of depths likely given the topography around the site.

3.4.4 There would be a medium risk of internal surface water flooding for both the Braint and Tŷ Fodol construction and operational sites, if there were no robust on-site water management systems and site discharge restrictions in place.

4 Receptor Flood Risk

4.1 INTRODUCTION

4.1.1 The methodology for identifying receptors and defining receptor groups is provided in FCA Volume 1, section 4.4 (**Document 5.12.2.1**). Receptors are combined into four receptor groups (RG1, RG2, RG3 and RG4) as described in Volume 1, section 4.4 and repeated below in Table 4.1.

4.1.2 In the following sections, the potential risk to receptor groups have been discussed in the context of there being no control and management measures in place (these are discussed in section 5).

Table 4.1: Receptor groups applicable to the construction, operation and maintenance of the THH/CSEC

Group	Type	Description	Flood risk vulnerability	Duration
RG1	Construction phase activities and temporary infrastructure	Personnel, plant and temporary infrastructure associated with the construction of the infrastructure at each THH/CSEC site.	Essential Infrastructure[1] & Less Vulnerable[2]	Temporary
RG2	Operational phase infrastructure	The THH/CSEC, office space, permanent water treatment and car parking that would remain for the lifetime of the infrastructure.	Essential Infrastructure[1]	Permanent
RG3	Operational phase maintenance activities and temporary infrastructure	Personnel, plant and temporary infrastructure associated with operation, inspection and periodic maintenance activities of the THH/CSEC sites.	Essential Infrastructure[1] & Less Vulnerable[2]	Temporary

Table 4.1: Receptor groups applicable to the construction, operation and maintenance of the THH/CSEC				
Group	Type	Description	Flood risk vulnerability	Duration
RG4	Third party receptors	Third-party people, property and infrastructure within or outside of the Order Limits, including agricultural land.	Variable – see detailed assessment of specific third party receptors in the respective FCA volumes.	Temporary / Permanent

4.2 RECEPTORS AFFECTED BY SURFACE WATER FLOOD RISK (INTERNAL – BRAINT / TŶ FODOL)

4.2.1 RG1, RG2, RG3 and RG4 receptors would be at risk at both Braint and Tŷ Fodol if internal surface water runoff (including dewatering) was not adequately managed in accordance with best practice.

4.2.2 RG1 and RG4 receptors would be particularly at risk given that the effects of inadequate water management would primarily be a risk related to the construction compounds rather than the operational sites. Uncontrolled surface water runoff flow rates and depths would generally be low; however, where the topography allows, water could pond to appreciable depths at low points, with consequent increase in hazard.

4.2.3 The risk is less prevalent for RG2 and RG3 receptors as the site and formalised permanent drainage system will be established (see section 6.2).

4.2.4 This hazard would be mitigated by the robust design and implementation of a Drainage Management Plan (DMP) for both sites (see section 6.2 and WE51-59 and WE510-511 in Table 5.1 of FCA Volume 1, **Document 5.12.2.1**). The outline drainage strategy for each of the construction and operational phases for both the Braint and Tŷ Fodol sites provides a guideline for the information to be included in the DMP and is provided in **Annex 5.12.2.3B** and summarised in section 6.2.

5 Flood Risk Assessment

5.1 INTRODUCTION

5.1.1 Having identified the applicable flood hazards in section 3 and presented hazards in the context of applicable receptors in section 4, this section combines the hazard and receptor information to summarise assessment of flood risk to the main receptor groups and specify appropriate mitigation measures.

5.1.2 As described in FCA Volume 1, section 5.3 (**Document 5.12.2.1**) this assessment assumes the incorporation within the design of predetermined control and management measures during construction and operation.

5.2 SUMMARY OF FLOOD RISK

5.2.1 A summary of flood risk is provided in Table 5.1 where it can be seen that the applicable flood hazards are identified in the context of those potentially affected receptor groups. Appropriate mitigation is then prescribed in accordance with those control and management measures set out in FCA Volume 1, section 5.3 (**Document 5.12.2.1**).

5.2.2 The only applicable potential flood hazard identified is surface water (internal) for which it is possible to prescribe combinations of control and management measures that, when implemented in accordance with the procedures set out in FCA Volume 1, section 5 (**Document 5.12.2.1**) and the Construction Environmental Management Plan (CEMP) (**Document 7.4**), would ensure the risk of flooding and/or enhanced flooding as a result of the Proposed Development would be minimised to an acceptable level.

Table 5.1: Flood risk assessment summary

Flood Hazard	Location	Phase Affected	Summary Of Risk	Receptor Group(s) Affected	Mitigation Required	Exception Test Required	Further Assessment Required	Comment
Surface Water (Internal)	Braint and Tŷ Fodol	Construction and operational	Surface water and fluvial flooding arising from an inadequate DMP and drainage strategies, including management of dewatering arisings	RG1 RG2 RG3 RG4	WE51-59 WE510-511 WE41-43 FM11 FM14			Multiple control and management measures are required including specification of appropriate drainage strategies (**WE51-59, WE510-511**), dewatering plans (**WE41-43**), provision of robust FMPs (**FM11**), and appropriate watercourse crossing design (**FM14**).

6 Flood Risk Management

6.1 INTRODUCTION

6.1.1 This section presents details of the flood risk management measures, which in this case pertain only to drainage management (section 6.2), and concludes with a brief discussion of residual risk (section 6.3).

6.2 DRAINAGE

6.2.1 Outline drainage strategies, for each of the construction and operational phases for both the Braint and Tŷ Fodol sites are provided in **Annex 5.12.2.3B,** the flood risk aspects of which are summarised briefly below. Detailed drainage designs for the construction and operational phases would be developed as part of the DMP, which is secured via Requirement 7 of the draft DCO (**Document 2.1**), and which would be subject to approval by the appropriate authority prior to commencement of works. The DMP would include hydraulic modelling calculations of construction and operations phase drainage systems to accurately define attenuation storage and flow control requirements, and would adhere to the drainage principles set out in the CEMP (**Document 7.4**, measures **WE51-59** and **WE510-511**).

Construction Phase (Braint and Tŷ Fodol)

6.2.2 The indicative drainage layout for the temporary construction compounds are shown in drawings **DCO_DE/PS/12 Sheet 2 of 3** and **DCO_DE/PS/12 Sheet 3 of 3** for Braint and Tŷ Fodol respectively. Surface water runoff from the sites, construction wastewater, and groundwater ingress pumped from the tunnel and shafts (if it is not saline) passes through an oil interceptor before discharging to ponds for treatment (settlement) and attenuation, before eventually discharging to an existing watercourse via the site outfall. If the groundwater entering the tunnel and shafts is saline, provision is to be made on site to treat this or remove saline water from the site by tanker. Provision has also been made for additional proprietary treatment if required.

6.2.3 The indicative drainage layout for temporary haul roads are shown on drawings **DCO_DE/PS/12_02** and **DCO_DE/PS/12_03** for Braint and

Tŷ Fodol respectively. Surface water runoff from the temporary haul roads would pass through drainage ditches, and treatment (settlement) and attenuation features, before being discharged to nearby watercourses. Gravel banks are proposed between the road and open channel to filter the surface water runoff.

6.2.4 In the construction phase, sufficient attenuation storage would be provided in the ponds to store the runoff arising from the 1% AEP storm event with a 5% climate change allowance and to discharge at the greenfield QBAR rate. For the construction compound ponds, this flood storage volume would be in addition to storage for treatment by settlement of construction wastewater and groundwater ingress.

6.2.5 During shaft and tunnel construction, cessation of discharge of dewatering arisings would be required during periods with flood alerts/warnings in place.

Operational Phase (Braint and Tŷ Fodol)

6.2.6 **DCO_DE/PS/09 Sheet 2 of 8** and **DCO_DE/PS/09 Sheet 6 of 8** show the operational phase drainage plans for Braint and Tŷ Fodol. New impermeable surfaces within the operational compounds would be drained via a combination of filter drains, open channels and closed pipes towards an attenuation pond prior to discharge to nearby watercourses. Flow control via attenuation is proposed as the primary means of limiting runoff from the developed sites, since high groundwater tables at both sites would probably limit the potential for the use of infiltration. However, the use of infiltration approaches would be considered in more detail during the development of the DMP. Dewatered groundwater and runoff from areas surrounding oil-filled transformers would pass through oil separators before being discharged to the wider site drainage system.

6.2.7 Runoff from new permanent access roads would be intercepted by open drainage ditches parallel to the road. These would drain to attenuation ponds, prior to discharge to nearby watercourses. At Ty Fodol, it is proposed that the relatively short access road would drain to the same attenuation pond as the operational compound. At Braint, a longer access road is proposed, which would have its own separate attenuation pond and discharge point.

6.2.8 For the operational phase, the flood storage capacity of the attenuation ponds for both compounds and access roads would be sized to store the runoff arising from the 1% AEP storm event with a 20% climate change allowance and to discharge at the greenfield QBAR rate, subject to a minimum discharge rate of 5 l/s to reduce the risk of outlet blockage. Additional capacity would be provided in the compound attenuation ponds for treatment of any groundwater dewatering, if salinity is sufficiently low to permit discharge to watercourses.

6.3 RESIDUAL RISK

6.3.1 Residual risk is that risk which remains after the flood risk management measures set out above have been taken into account. For example, site operatives undertaking works in areas of defended floodplain (or accessing/egressing other areas of the site via floodplain) would be at residual risk in the event of a flooding event in excess of the design standard of the flood defences. A further example of residual risk would be the failure to identify and effectively disseminate flood warning information, as specified in the FMP.

6.3.2 The FMP (FM11) would address residual risk. Implementation of the FMP would ensure that any residual risk is proportionate to the scale, nature and location of the Proposed Development. NRW's and the LLFAs' approval of the FMP would be required prior to the commencement of construction and operational activities. Preparation of the FMP is secured by Requirement 7 of the draft DCO (**Document 2.1**).

7 Summary and Conclusions

7.1 SUMMARY

7.1.1 FCA Volume 3 has presented a detailed assessment of flood risk for the Braint and Tŷ Fodol sites for the construction and operational phases. This volume was prepared in conjunction with FCA Volume 1 (**Document 5.12.2.1**) which provides the overarching planning, guidance, scoping and methodologies applicable to this Volume.

7.1.2 External surface water flood risk was shown to be of low risk for construction and of negligible risk for the operational case. Sewer flooding and flooding from artificial sources was also shown to be of negligible risk during both the construction and operational phases.

7.1.3 External flood fluvial risk was initially considered to pose a potential hazard to the Braint THH/CSEC site during the operational phase during the 0.1% AEP +75% climate change event. For this reason hydrodynamic modelling was carried out to assess this risk. The results of the modelling showed that there would be no risk to the site from the design flood event.

7.1.4 Groundwater flooding and surface water flow obstruction hazards were shown to be of low risk and only during the construction phase at Braint.

7.1.5 In the case of drainage at the Braint and Tŷ Fodol construction and operational sites, an outline drainage strategy has been developed which allows for the attenuation of runoff to QBAR greenfield rates for all events up to the 1% AEP event, including an appropriate allowance for climate change (**Annex 5.12.2.3B**). Detail design of the construction and operational phase drainage systems would be carried out as part of the DMP, which is secured via Requirement 7 of the draft DCO (**Document 2.1**), and which would be subject to approval by the appropriate authority prior to commencement of works.

7.1.6 Section 5 has shown that in all instances where flood risk receptors may be impacted by an associated flood hazard, it has been appropriate to specify mitigation in accordance with the predetermined control and management measures outlined in FCA Volume 1 (**Document 5.12.2.1**), section 5.3 and that the incorporation of these measures in the design and construction stages would be sufficient to mitigate any potential increase flood risk due to the Proposed Development.

7.1.7 FCA Volume 3 has demonstrated that both sites are located in DAM Flood Zone A, and the fluvial flood modelling carried out for the Braint site does not change this conclusion. As a result neither the Sequential Test nor the Exception Test is applicable.

7.1.8 In summary, this FCA has demonstrated that the Braint and Tŷ Fodol sites would be adequately protected from flooding during the construction and operational phases, and would not increase flood risk elsewhere.

Annex A

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North Wales Connection Project

Volume 5

5.12.2.1 Appendix 12.1 Annex 3A: Afon Braint Modelling Report

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Final September 2018

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Document Control			
Document Properties			
Organisation	Wood		
Author	Ben Thomas		
Approved by	Bill Finlinson		
Title	Environmental Statement Appendix 12.2.3A		
Document Reference	Document 5.12.2.3A		
Version History			
Date	**Version**	**Status**	**Description/Changes**
September 2018	Rev A	Final	Final for submission

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Contents

1 Introduction 1
1.1 Context 1
1.2 Study Objectives 1
2 Available Data 2
2.1 Existing Modelling 2
2.2 Elevation Data 2
2.3 Channel Survey 2
2.4 MasterMap Data 2
2.5 Hydrological Data 2
3 Hydrological Analysis 3
3.1 Introduction 3
3.2 Catchment description 3
3.3 Methodology 4
3.4 Subcatchment Delineation 4
3.5 Catchment Descriptors 6
3.6 Peak Flow Estimates 8
4 Hydraulic Simulation 12
4.1 Software Choice 12
4.2 Terrain 12
4.3 Surface Parameters 13
4.4 Surface Water Drainage 15
4.5 Open Channel Features 15
4.6 Open Channel Parameters 17
4.7 Boundary Conditions 17
4.8 Initial Conditions 18
4.9 Simulation Parameters 18
4.10 Sensitivities 18
5 Model Results 21
5.1 Mapped Results 21
5.2 Analysis 24
6 Sensitivity Results 25
6.1 Introduction 25
6.2 Mapped Results 25
6.3 Analysis 42
7 Model Strengths/Limitations 43

7.1 Stability 43
7.2 Confidence in results 43

8 Conclusions 44

Images

Image 1 - Afon Braint general location plan with watercourses highlighted and the proposed development site indicated in red. 3
Image 2 - Layout of hydrological model node locationsschematisation 5
Image 3 - Available LiDAR elevation data, with the model extent indicated as the green outline and the site extent as the red outline 13
Image 4 - Coverage of different landuse classes to be assigned different roughness parameter values 14
Image 5 - 1D model cross section locations 16
Image 6 - Peak modelled water levels 22
Image 7 - Peak modelled flood depths 23
Image 8 - Peak modelled water levels with the structure at the bifurcation blocked (scenario B1) 26
Image 9 - Peak modelled flood depths with the structure at the bifurcation blocked (scenario B1) 27
Image 10 - Peak modelled water levels with all structures downstream of the bifurcation blocked (scenario B2) 28
Image 11 - Peak modelled flood depths with all structures downstream of the bifurcation blocked (scenario B2) 29
Image 12 - Peak modelled water levels with the 1D roughness decreased (scenario C1) 30
Image 13 - Peak modelled flood depths with the 1D roughness decreased (scenario C1) 31
Image 14 - Peak modelled water levels with the 1D roughness increased (scenario C2) 32
Image 15 - Peak modelled flood depths with the 1D roughness increased (scenario C2) 33
Image 16 - Peak modelled water levels with the 2D roughness decreased (scenario D1) 34
Image 17 - Peak modelled flood depths with the 2D roughness decreased (scenario D1) 35
Image 18 - Peak modelled water levels with the 2D roughness increased (scenario D2) 36
Image 19 - Peak modelled flood depths with the 2D roughness increased (scenario D2) 37
Image 20 - Peak modelled water levels with the downstream boundary levels increased (scenario E) 38
Image 21 - Peak modelled flood depths with the downstream boundary levels increased (scenario E) 39
Image 22 - Peak modelled water levels with the 2D cell size reduced (scenario F) 40
Image 23 - Peak modelled flood depths with the 2D cell size reduced (scenario F) 41

1 Introduction

1.1 CONTEXT

1.1.1 Flood modelling is used to inform risk associated with proposed developments. By using standardised techniques, comparative analysis of risk at different sites can be undertaken. Such analyses can also be used in the planning system to ensure that proposed developments confirm to certain requirements with regards to flood risk.

1.1.2 This hydraulic modelling work has been undertaken to inform a Flood Consequences Assessment (FCA) for the North Wales Connection Project (NWCP). Specifically, the site is a proposed cable sealing end compound (CSEC) and Tunnel Head House (THH) located in the lower Afon Braint catchment, on Anglesey, south-west of Llanfairpwll. The location of this site is shown in Image 1.

1.2 STUDY OBJECTIVES

1.2.1 This study considers an event with an annual exceedance probability of 0.1%, with an increase in modelled flows of 75%, as agreed with Natural Resources Wales (NRW) (see FCA Annex 12.1B (**Document 5.12.2.1B**)) to allow for higher end predictions of future climate change. This is the most extreme of the standard design floods, and as such if the site remains flood free in this context it may be considered to have minimal risk of flooding from rivers.

2 Available Data

2.1 EXISTING MODELLING

2.1.1 No pre-existing modelling of this area is believed to exist and as such, a new model has been built completely from component data with no elements from previous models incorporated.

2.2 ELEVATION DATA

2.2.1 LiDAR data was obtained from the Welsh Government Lle geoportal at http://lle.gov.wales/Catelogue/Item/LidarCompositeDataset/?lang=en. For the study area, this was available at 2 m and 1 m resolutions, and the 1 m data was selected for use.

2.3 CHANNEL SURVEY

2.3.1 Hydrographic survey was undertaken for the purposes of this study by Storm Geomatics. The scope of the survey met and exceeded the Environment Agency National Standards Contract and Specification for Surveying Services (v3.2 and amendments). This included sections of open channel and also structural survey at all bridges and other features within the watercourse.

2.4 MASTERMAP DATA

2.4.1 Land-use data in vector format was derived from the national coverage provided by Ordnance Survey MasterMap. This was supplied with sufficient coverage for the full model extent.

2.5 HYDROLOGICAL DATA

2.5.1 The FEH WINFAP (v4) and ReFH2.2 software in combination with the FEH web service were used to provide data for the hydrological analysis.

3 Hydrological Analysis

3.1 INTRODUCTION

3.1.1 A hydrological assessment was undertaken for the Afon Braint and its tributary watercourses upstream of Braint THH/CSEC, as shown in Image 1.

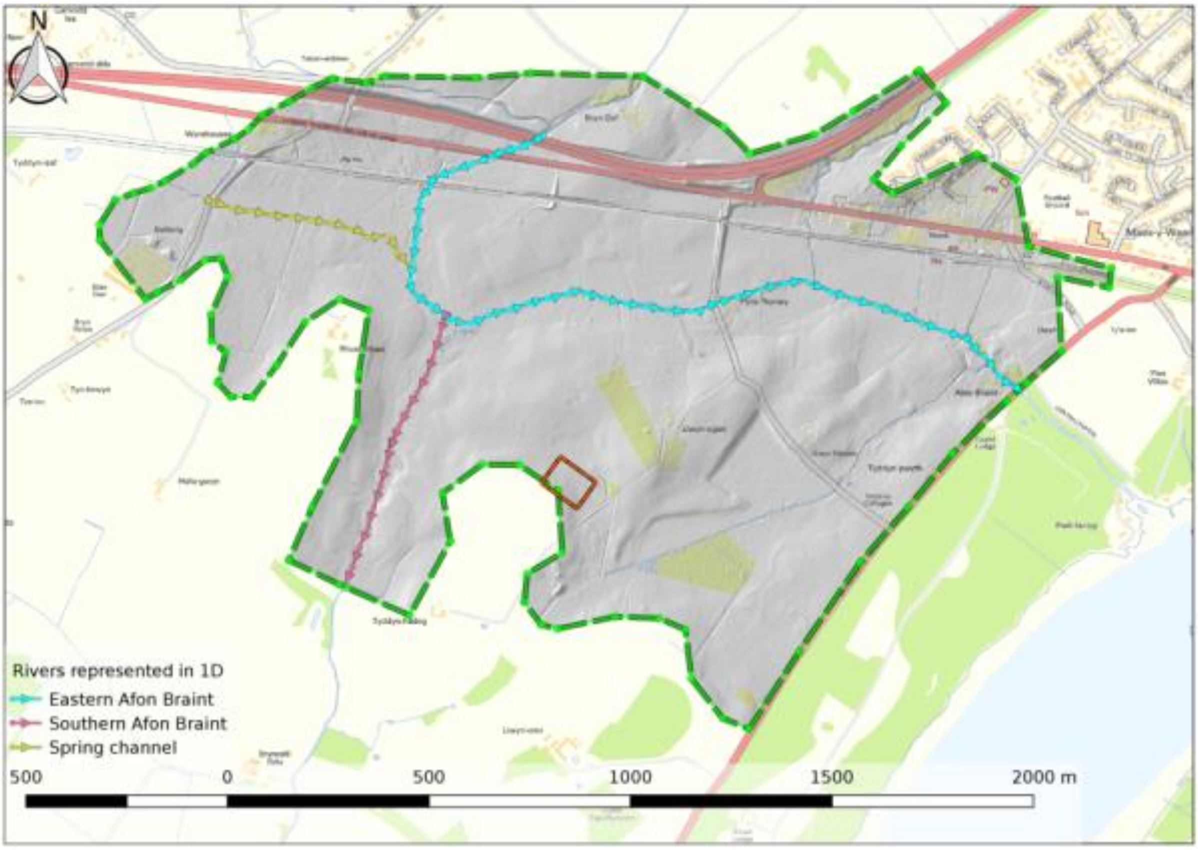

Image 1 - Afon Braint general location plan with watercourses highlighted and the proposed Braint THH/CSEC indicated in red.

3.1.2 Flood estimates are required for the 1 in 1000 (0.1% Annual Exceedance Probability, AEP) plus 75% climate change allowance flood event. The hydrological assessment is detailed in the FEH calculation record provided in Section 9 of this document.

3.2 CATCHMENT DESCRIPTION

3.2.1 The site is located in the lower Afon Braint catchment, south-west of Llanfairpwll. The Afon Braint rises to the south of Pentraeth Forest, east of Pentraeth and south-west of Llanddona, and travels west/south-west passing north-west of Llanfairpwll. Just west of Llanfairpwll the Afon Braint passes under the A55, A5 and the Bangor to Holyhead railway line. Downstream of the railway the watercourse bifurcates. The natural watercourse continues to the east, flowing under the A4080 and into the Menai Strait, with a field drain flowing towards the north-east joining the Afon Braint just west of the A4080. The diverted watercourse flows south-west past Dwyran before flowing into Caernarfon Bay east of Pen-lon. The whole natural catchment area of the Afon Braint (excluding south of the bifurcation) is 29.5 km^2. The catchment is essentially rural and ungauged.

3.2.2 According to NRW's flood risk map (Figure 12.6 (**Document 5.12.1.6**)), the site is not subject to risk of flooding from rivers and sea.

3.3 METHODOLOGY

3.3.1 Industry standard FEH methods are applicable to the area of study (statistical and ReFH2.2 rainfall runoff methods). The Afon Braint catchment at the railway crossing has been selected as an appropriate location for the hydrological analysis due to the local constraint in the watercourse caused by the railway crossing. At this location the catchment area is 19.26 km^2 and current guidelines recommend the use of standard FEH methods (Statistical and ReFH version 2.2) on catchments classified as small (less than 25 km^2).

3.4 SUBCATCHMENT DELINEATION

3.4.1 For the purpose of estimating design hydrographs for use in the hydraulic modelling, lumped inflows have been derived for the following sub-catchments:

- Afon Braint catchment upstream of the A55 (node ID AB@A55);
- Afon Braint intervening catchment between the A55 and the A5 (node ID AB@A5);
- Afon Braint intervening catchment between the A5 and the railway line (node ID AB@railway);
- Spring channel tributary of the Afon Braint at NGR 250750, 371700 (node ID West_trib);
- North tributary of the Afon Braint flowing west of Llanfair and joining the Afon Braint at NGR 252250, 371550 (node AB_trib_ds_Llanfair).

- Field drain flowing in a north-east direction east of Llwyn-Ogan and joining the Afon Braint just west of the A4080 (node ID Drain@A4080).

In addition, distributed inflows have been included in the model for the:

- Intervening area in the Afon Braint catchment at the watercourse diversion between the railway line, the west tributary and Bryncelli Ddu (node ID ABi);
- Intervening area to the east, between the diversion and the A4080 (node ID AB@A4080i).

3.4.2 A layout of the hydrological model schematization is shown in Image 2.

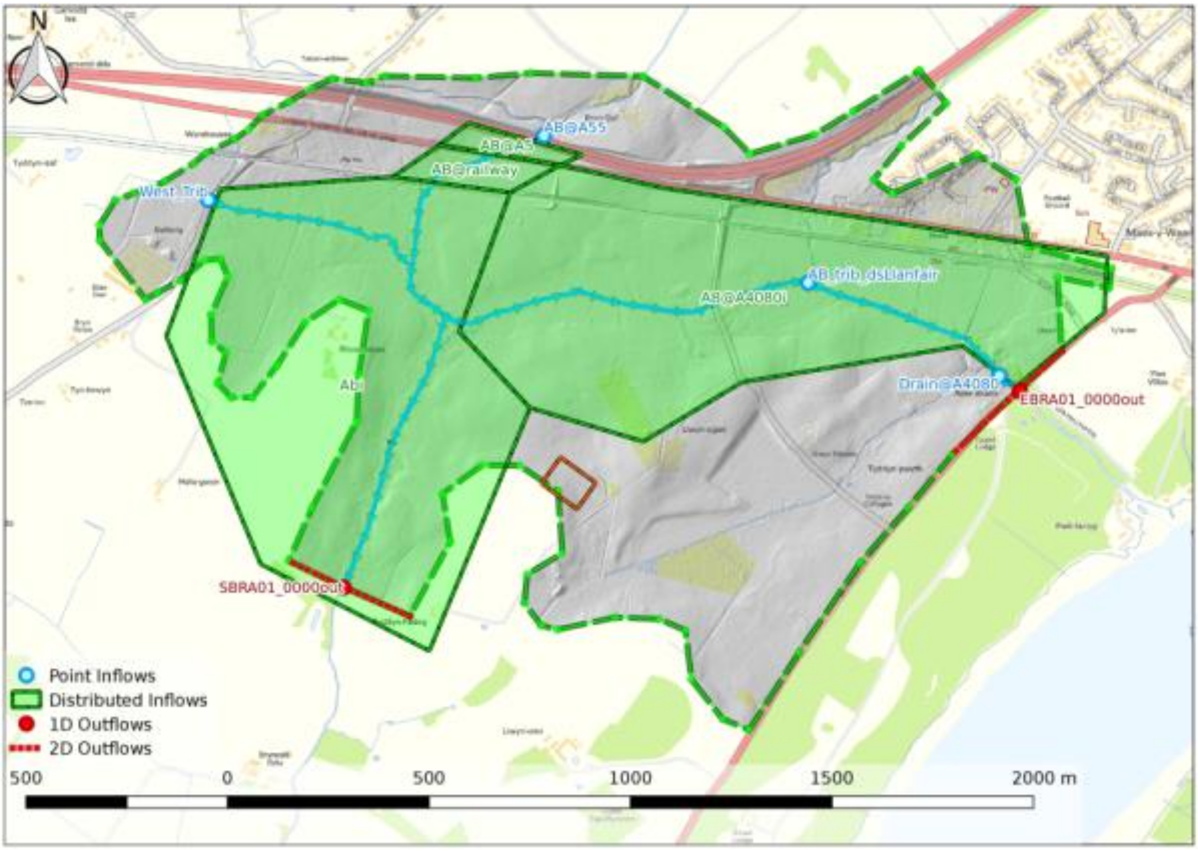

Image 2 - Layout of hydrological model node locations schematisation

3.4.3 It should be noted that the catchment area at AB@A55 has been modified to include the catchment area of a small tributary (A=0.685 km^2) joining the Afon Braint u/s of the A55 as shown on the background OS map (as identified by NRW in correspondence). The catchment areas at AB@A5 and AB@railway have been revised for the purpose of inflow estimation in order to account only for the intervening areas from the upstream estimation points. The intervening catchment area at AB@A4080i has been reduced to account for the catchment area of the field drain flowing north-east through Llywyn Adwen, east of Llwyn-Ogan and joining the Afon Braint just west of the A4080 (Drain@A4080). The field drain catchment area has been estimated from OS Mapping and LiDAR and has been considered separately in the inflow estimation process, as the catchment area is too small to be identified in FEH.

3.5 CATCHMENT DESCRIPTORS

3.5.1 A summary of catchment descriptors for the locations where inflows have been derived is provided in Table 1.

Table 1 - Summary of catchment descriptors for inflow estimate nodes

Site code	Easting	Northing	AREA on FEH Web-Service (km^2)	Revised Area (km^2)	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPRHOST	URBEXT 2000	FPEXT
AB@A55	251600	371900	18.743	19.428	0.994	0.45	0.461	5.08	52.1	1054	40.2	0.0012	0.1379
AB@A5	251450	371850	18.856	0.115	0.994	0.45	0.461	6.31	52.1	1054	40.2	0.0012	0.1379
AB@railway	251250	371750	19.26	0.403	0.994	0.45	0.461	6.46	52.3	1054	40.19	0.0012	0.1369
West_trib	250750	371700	0.833		1	0.45	0.4	0.74	43.2	1067	40.47	0	0.0961
AB_i	250850	370050		1.267	0.994	0.45	0.429	1.14	28.7	1060	40.26	0	0.1217
AB_trib_ds_Llanfair	252250	371550	6.37		1	0.45	0.51	3.65	35	1084	39.98	0.0078	0.0938
Drain@ A4080	252637	371293		0.46	0.996	0.45	0.511	0.653	16.5	1115	40.13	0.014	0.2673
AB@A4060i	252700	371300	0.9625	0.503	0.996	0.45	0.511	0.686	16.5	1115	40.13	0.355	0.2673

3.6 PEAK FLOW ESTIMATES

FEH Statistical Method

3.6.1 QMED (50% AEP) has been estimated from catchment descriptors at AB@railway, West_trib and AB_trib_ds_Llanfair, and donor transfer correction was then applied to produce an adjusted QMED. It should be noted that QMED has been estimated at AB@railway for the unrevised FEH catchment area in Table 1 (i.e. the total upstream catchment area of 19.26 km^2).

3.6.2 For the subcatchments upstream of AB@railway (nodes AB@A55, AB@A5 and the remainder of AB@railway with its revised catchment area of 0.403 km^2), QMED has been obtained by scaling the adjusted QMED at AB@railway (FEH catchment) by the ratio of catchment areas. This has also been done for the intervening area at ABi.

3.6.3 QMED has also been estimated from catchment descriptors and adjusted by donor transfer for the Afon Braint catchment at the A4080 crossing (full details are provided in the Annex), which covers a catchment area of 29.378 km^2. QMED for the intervening area at AB@A4080i and for the field drain Drain@A4080 has been obtained by scaling the adjusted QMED at this location by the ratio of catchment areas.

3.6.4 The growth factor to estimate the 0.1% AEP flood peak was derived from standard statistical pooled analysis undertaken at AB@railway (FEH catchment) and applied to all inflow estimation nodes in order to ensure consistency across the catchment. Table 2 details peak estimates from statistical analysis for selected AEPs at all inflow estimation nodes.

Table 2 - Peak estimates from statistical analysis at all inflow estimation nodes for selected AEPs (m^3/s).

Site	50% AEP (QMED)	1% AEP	0.1% AEP	0.1% AEP +75%cc
AB@A55	9.056	25.122	41.169	72.046
AB@A5	0.054	0.149	0.244	0.426
AB@railway	0.188	0.52	0.853	1.493
West_Trib	0.75	2.081	3.41	5.967
AB_i	0.591	1.639	2.686	4.7

Table 2 - Peak estimates from statistical analysis at all inflow estimation nodes for selected AEPs (m^3/s).				
Site	50% AEP (QMED)	1% AEP	0.1% AEP	0.1% AEP +75%cc
AB_trib_ds_Llanfair	3.272	9.077	14.875	26.03
AB@A4080i	0.222	0.615	1.008	1.764
Drain@A4080	0.203	0.563	0.923	1.615

ReFH rainfall-runoff analysis

3.6.5 A lumped rainfall-runoff model has been built using the ReFH model (version 2.2) for the Afon Braint catchment at the location of the railway. For this purpose the parameters of the ReFH model have been estimated from catchment descriptors, and the DDF (depth-duration-frequency) 2013 model has been used to derive the rainfall input to the rainfall-runoff model.

3.6.6 Peak estimates for the Afon Braint catchment at the location of the railway obtained from ReFH modelling are lower than those obtained from statistical analysis, with ReFH QMED being equal to 74% of the statistical QMED and the ReFH 1% AEP peak estimate being equal to 79% of the statistical estimate for the corresponding AEP.

3.6.7 Table 3 summarises the peak estimates for selected AEPs obtained by applying the growth factors from ReFH analysis undertaken at the location of the railway to QMED estimated from statistical analysis at all inflow estimation nodes.

Table 3 - Peak estimates from rainfall-runoff at all inflow estimation nodes for selected AEPs (m^3/s).				
Site	50% AEP (QMED)	1% AEP	0.1% AEP	0.1% AEP +75%cc
AB@A55	9.056	26.888	42.844	74.978
AB@A5	0.054	0.159	0.254	0.444
AB@railway	0.188	0.557	0.888	1.553
West_Trib	0.75	2.227	3.548	6.209

Table 3 - Peak estimates from rainfall-runoff at all inflow estimation nodes for selected AEPs (m^3/s).

Site	50% AEP (QMED)	1% AEP	0.1% AEP	0.1% AEP +75%cc
AB_i	0.591	1.754	2.795	4.892
AB_trib_ds_ Llanfair	3.272	9.715	15.48	27.09
AB@A4080i	0.222	0.658	1.049	1.836
Drain@A4080	0.203	0.603	0.96	1.681

ReFH ratio method

3.6.8 Table 4 summarises peak estimates obtained by applying the ReFH ratio method to all estimation nodes, i.e. the statistical estimates are used for AEPs up to and including the 1% AEP event (that is, those presented in Table 2), while peak estimates for the 0.1% AEP event are obtained as the ratio of the 1% AEP to 0.1% AEP peak estimates from ReFH multiplied by the 1% AEP statistical peak.

Table 4 - Peak flows estimated by applying the ReFH ratio method at all inflow estimation nodes for selected AEPs (m^3/s).

Site	50% AEP (QMED)	1% AEP	0.1% AEP	0.1% AEP +75%cc
AB@A55	9.056	25.122	40.03	70.053
AB@A5	0.054	0.149	0.237	0.415
AB@railway	0.188	0.52	0.829	1.451
West_Trib	0.75	2.081	3.315	5.802
AB_i	0.591	1.639	2.612	4.57
AB_trib_ds_ Llanfair	3.272	9.077	14.463	25.31
AB@A4080i	0.222	0.615	0.98	1.715
Drain@A4080	0.203	0.563	0.897	1.57

Design hydrographs

3.6.9 Design hydrographs for use in the modelling have been obtained by constructing ReFH (version 2.2) lumped models for all inflow estimation nodes, with hydrographs scaled to match the preferred peaks. A design storm consistent with the Afon Braint catchment at the railway location has been imposed on all sub-catchments.

4 Hydraulic Simulation

4.1 SOFTWARE CHOICE

4.1.1 Braint THH/CSEC was modelled using the widely-adopted TUFLOW Classic software. TUFLOW Classic has been in wide use in the UK for over 10 years and is a stable and extensively tested two-dimensional (2D) modelling package. It incorporates a one-dimensional (1D) model, ESTRY, for the simulation of open channels, culverts and structures.

4.1.2 The 1D and 2D solvers may be coupled and run simultaneously, exchanging data throughout the simulation, permitting utilisation of the strengths of both 1D (best for channels and structures) and 2D (best for floodplains and complex flood paths).

4.1.3 One of the key advantages of the software is its use of standardised and open input and output formats (ASC, SHP, CSV, TXT). This means that model data can be both prepared and inspected/reviewed without a copy of the software and the data can be readily extracted and processed using other, unrelated programs.

4.1.4 The latest version of the software was applied, specifically build 2016-03-AD-iDP-w64.

4.2 TERRAIN

4.2.1 Represented using the 2D portion of the model, the wider floodplain is split into square elements referred to as ‘cells’. The cell size should be small enough to represent flow routes with sufficient detail, however, larger cell sizes are favourable as increases to the number of cells also increases the computational effort in undertaking simulations (halving the cell size results in simulations taking approximately 8 times longer to run). In this instance a 5 m resolution was selected as there are no fine detailed features that need representing in 2D and this permits runs to complete in a few hours.

4.2.2 The majority of elevations across the terrain were obtained by inspection of the LiDAR data. Image 3 below shows the Extent of LiDAR coverage around the modelled area.

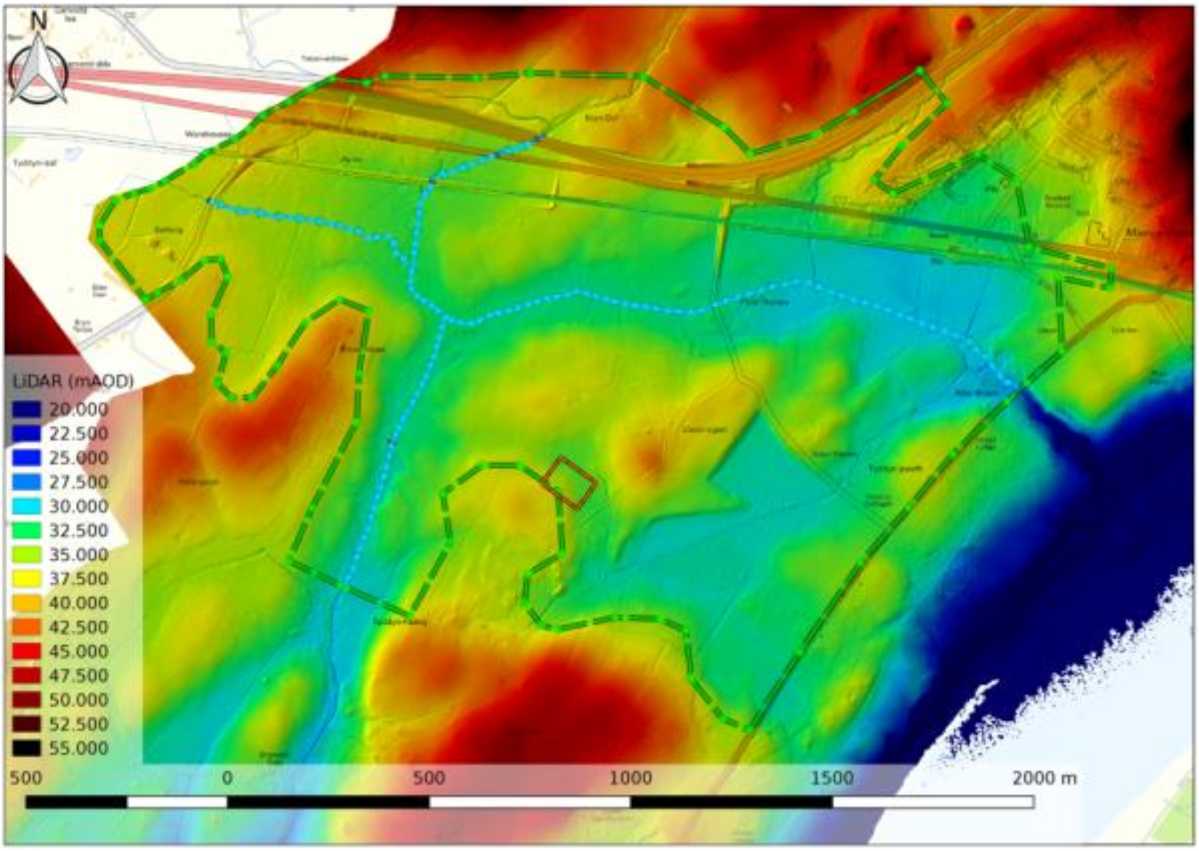

Image 3 - Available LiDAR elevation data, with the model extent indicated as the green outline and the site extent as the red outline

4.2.3 Refinements were required at some bridge decks as the LiDAR processing that removes buildings from the DTM also tends to filter out bridge decks. These were reinstated within the model using TUFLOW's 'zshape' capability. Elevations for the bridge decks were obtained from the surrounding LiDAR data.

4.2.4 The LiDAR was sufficiently recent and of sufficiently good quality that no further refinements were considered necessary, as relevant flow routes and obstructions to flow were all represented adequately.

4.3 SURFACE PARAMETERS

4.3.1 In addition to elevations, the wider terrain also needs to be assigned roughness and permeability characteristics.

Surface Roughness

4.3.2 Roughness has been spatially assigned using MasterMap data, with different classes (also known as feature codes) being assigned different Manning's n roughness parameters (the industry standard parameterisation of roughness). The values selected are typical values for floodplains in the UK.

4.3.3 Image 4 below shows the coverage of the different classes, while Table 5 below shows the roughness parameters applied to the different classes.

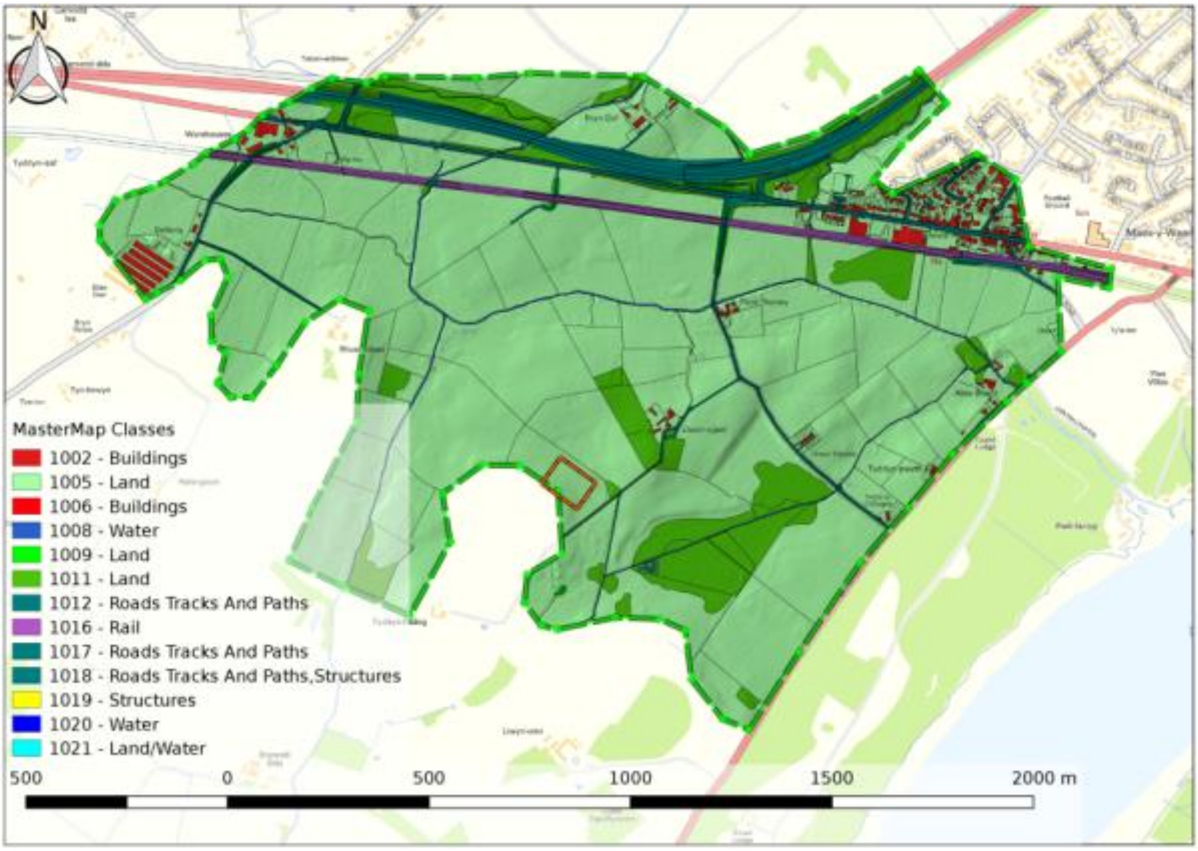

Image 44 - Coverage of different landuse classes to be assigned different roughness parameter values

Table 5 - Roughness parameters applied to MasterMap classes		
MasterMap class	Description	Manning's 'n' roughness parameter
1002	Buildings	1.000
1005	Land	0.050
1006	Buildings	0.500
1008	Water	0.030
1009	Land	0.050

Table 5 - Roughness parameters applied to MasterMap classes

MasterMap class	Description	Manning's 'n' roughness parameter
1011	Land	0.075
1012	Roads, tracks and paths	0.022
1016	Rail	0.080
1017	Roads, tracks and paths	0.022
1018	Roads, tracks and paths; structures	0.025
1019	Structures	0.055
1020	Water	0.030
1021	Land/Water	0.030

Surface Permeability

4.3.4 In reality, some flood water would be lost within the model's extents due to infiltration into the ground. In this modelling the conservative approach of neglecting these losses has been adopted (while infiltration upstream of the site is accounted for by the hydrological modelling). As such, all surfaces are considered to be impermeable and no portion of the flood water is lost to infiltration.

4.4 SURFACE WATER DRAINAGE

4.4.1 Similarly to ground infiltration, some water would typically be lost to surface water drainage features (be that in urban areas or road drainage on the main roads). In this modelling, such effects have been omitted to provide a conservative answer with respect to flood risk.

4.5 OPEN CHANNEL FEATURES

4.5.1 There are multiple watercourses within the area being modelled as 1D elements in ESTRY; these are identified in Image 1 above, which also indicates the primary flow direction.

4.5.2 Geometry for these channels and their structures was taken from the survey data obtained as part of the Proposed Development. See section 2.3 for more details on the data obtained. To make the supplied data suitable for use in a 1D model it has been truncated to bank top (so the floodplain is not present in the 1D elements as well as the 2D domain). The locations at which supplied survey section data has been applied are shown in Image 5 below.

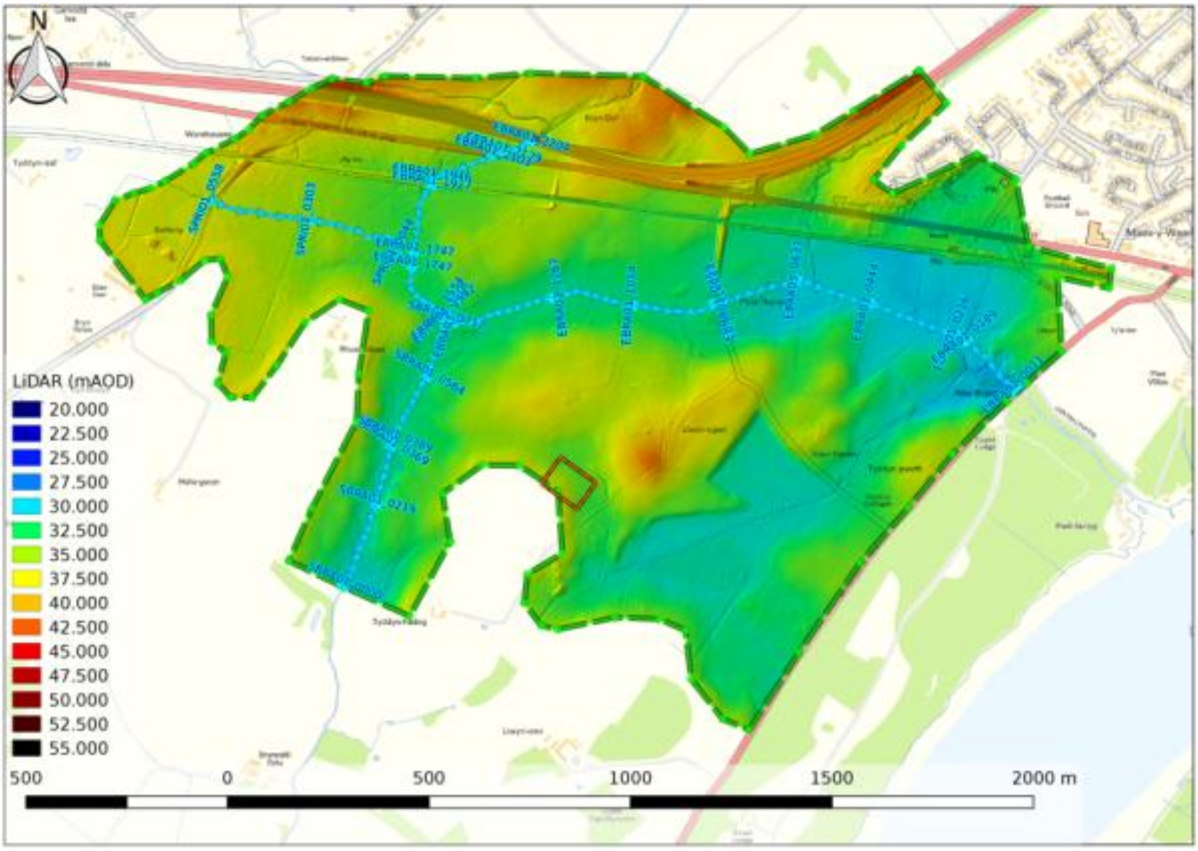

Image 5 - 1D model cross section locations

4.5.3 Of particular note is the bifurcation where the southern Afon Braint splits from the eastern Afon Braint. There is a structure on the southern Afon Braint which is intended to send the majority of river flows down the astern branch while still permitting a small quantity of flow down the southern branch even at low flows. There is a weir over this structure so that at high flows the capacity of the southern channel may be used to convey flow from the vicinity. This has been represented using a rectangular conduit running in parallel to a weir unit, with dimensions obtained from the new survey.

4.5.4 All the other structures within the model are bridges, which have been represented using conduit units. Where the bridge opening is not either circular or rectangular, a best fit has been generated with one of these where the width and area have been preserved with the invert and soffit levels set to an appropriate averaged level from the surveyed data. Where possible, bridge decks have been represented within the 2D domain, but where the deck is too thin for this to be appropriate, a 1D weir has been specified in parallel to the bridge opening, and the 2D area over the structure has been removed (coded out).

4.6 OPEN CHANNEL PARAMETERS

4.6.1 Aside from the geometry, there are a few other parameters that influence flow being passed through a 1D scheme; these were set as follows:

Channel Roughness

4.6.2 Roughness was applied using the Manning's 'n' parameterisation. Roughness is permitted to vary across the sections and was set to be 0.04 in the channel and 0.06 outside the channel, as specified by the surveyors in the supplied data. These are typical values for 1D channels with vegetation around the banks, and appear consistent with the photography from the site also supplied by the surveyors.

4.6.3 Structures were also assigned a Manning's 'n' roughness parameter of 0.04, as the 1D bed generally continued unimpeded beneath the structures.

Structure losses

4.6.4 The conduits representing bridges all have contraction, entrance and exit losses applied at default values as recommended within the TUFLOW manual. Such weirs as are present are represented using 'WW' units within ESTRY, which is an improved broad weir schematisation; parameters have been left at default in all cases.

4.7 BOUNDARY CONDITIONS

Inflows

4.7.1 As is presented in section 3, inflows have been determined for use both as point inflows for specific water courses flowing into the model domain and also as distributed inflows representing catchment areas contained within the model domain.

4.7.2 The locations of all inflows are shown in Image 2 above. It should be noted that the polygons denoting the distributed inflows are only indicative of their respective catchments; of more significance is their coverage of the 1D network, as they are distributed uniformly to the nodes contained within their outlines. For example, the catchment for the inflow 'AB@railway' actually extends both east and west along the strip of land between the A5 and the railway, but it is sufficient that it contains the 1D nodes that run between the A5 and the railway.

Outflows

4.7.3 Head/time boundaries have been applied at the downstream extent of both the eastern and southern Afon Braint watercourses (in both the 1D and 2D domains). The elevations of these boundaries have been set to be just below the bed of each watercourse (26.26 and 28.95 mAOD respectively). This causes the boundary to behave as a critical depth boundary. In the case of the eastern Afon Braint, there is a controlling structure just upstream of this boundary, reducing the influence of the boundary. On both the eastern and southern Afon Braint, it is considered the boundaries have been placed far enough away from the area of interest not to have any influence on the modelled results for the site.

4.8 INITIAL CONDITIONS

4.8.1 The 2D domain starts completely dry and the 1D domain has an initial water level set to be 0.25 m deep throughout. The exception to this is in the sensitivity run examining downstream boundary conditions (see 4.10) where the initial water levels near the boundaries have been adjusted to be consistent with these altered boundaries.

4.9 SIMULATION PARAMETERS

4.9.1 All simulation parameters have been left at their default values. The model timestep has been set to be 1 second for the 2D domain and 0.5 seconds for the 1D domain. This is in-line with the TUFLOW manual recommendations on appropriate timesteps (which states that "2D timestep in seconds should be somewhere between 1/2 to 1/5 of the 2D cell size in metres" and the 1D timestep is recommended as being half that of the 2D domain in linked simulations).

4.10 SENSITIVITIES

4.10.1 In any modelling exercise there are associated uncertainties. Often it is desirable to calibrate/verify the model to observed data, in order to either refine the selected schematisation/parameters or to demonstrate that they produce reasonable results by showing fit to the observed data. In this instance there is no observed data to fit for either calibration or verification. Instead, a number of sensitivities have been undertaken in order to assess the impact upon results that selecting different parameters or schematisation might have. It should be stressed that reasonable values and schematisation have been selected in all cases as the baseline case, in line with best practice; however, by adjusting these values a measure of confidence in the outputs might be obtained in the face of uncertainties.

4.10.2 Results from all these sensitivities are presented in section 6.

Blockage

4.10.3 Given the proximity to the area of interest, NRW requested that blockage analysis be undertaken on the structure at the bifurcation of the eastern and southern Afon Braint channels. According to their supplied guidance "OGN100 Blockage & Breach Guidance Note Nov 15 PDF.pdf" culverts should be blocked to one of 30, 67 or 100% (the guidance goes on to "Note that a 95% blockage is usually adopted over a 100% in the hydraulic model to maintain a minimum opening and ensure the model remains stable.") In this instance, to check the most extreme instance and the potential to effect modelled results, 100% blockage was selected (modelled as 95% blockage). In the model files and results, this is referred to as scenario B1.

4.10.4 Further to this, a second blockage scenario was constructed where all the structures at or downstream of the bifurcation were blocked to 100% (modelled as 95%) to present the greatest obstruction to flow moving away from the area of interest (and thus a precautionary case, if not necessarily conservative). In the model files and results, this is referred to as scenario B2.

1D roughness

4.10.5 While the roughness selected is within the range of suitable values, sensitivity runs were undertaken where 1D roughness parameters were all decreased and increased by a factor of 1.2. In the model files and results, these are referred to as scenarios C1 and C2 respectively.

2D roughness

4.10.6 While the roughness selected is within the range of suitable values, sensitivity runs were undertaken where 2D roughness parameters were all decreased and increased by a factor of 1.2. In the model files and results, these are referred to as scenarios D1 and D2 respectively.

Downstream boundaries

4.10.7 Rather than imposing a water level that is below bed level (causing outflow levels to be at critical depth), a sensitivity was undertaken where both rivers were set to have levels that were somewhat out of bank and higher than would be expected at these locations even under high flows (set to 31 mAOD at both boundaries). In the model files and results, this is referred to as scenario E.

Cell size

4.10.8 While the selected cell size was chosen as being able to represent flow routes and obstructions sufficiently, a sensitivity with cell size reduced to 2.5 m (half the original size) was undertaken to ensure this did not unduly affect results. To accommodate the reduced cell size, the timestep was also halved. In the model files and results, this is referred to as scenario F.

5 Model Results

5.1 MAPPED RESULTS

5.1.1 The following images show the peak modelled water level and flood depths, representing the 0.1% annual exceedance probability event with a 75% allowance for climate change, and model parameters set according to best practice within the limits of available data. Sensitivities to assess the impact of changing various model parameters have been undertaken, which are discussed in section 4.10 and results are presented in section 6.

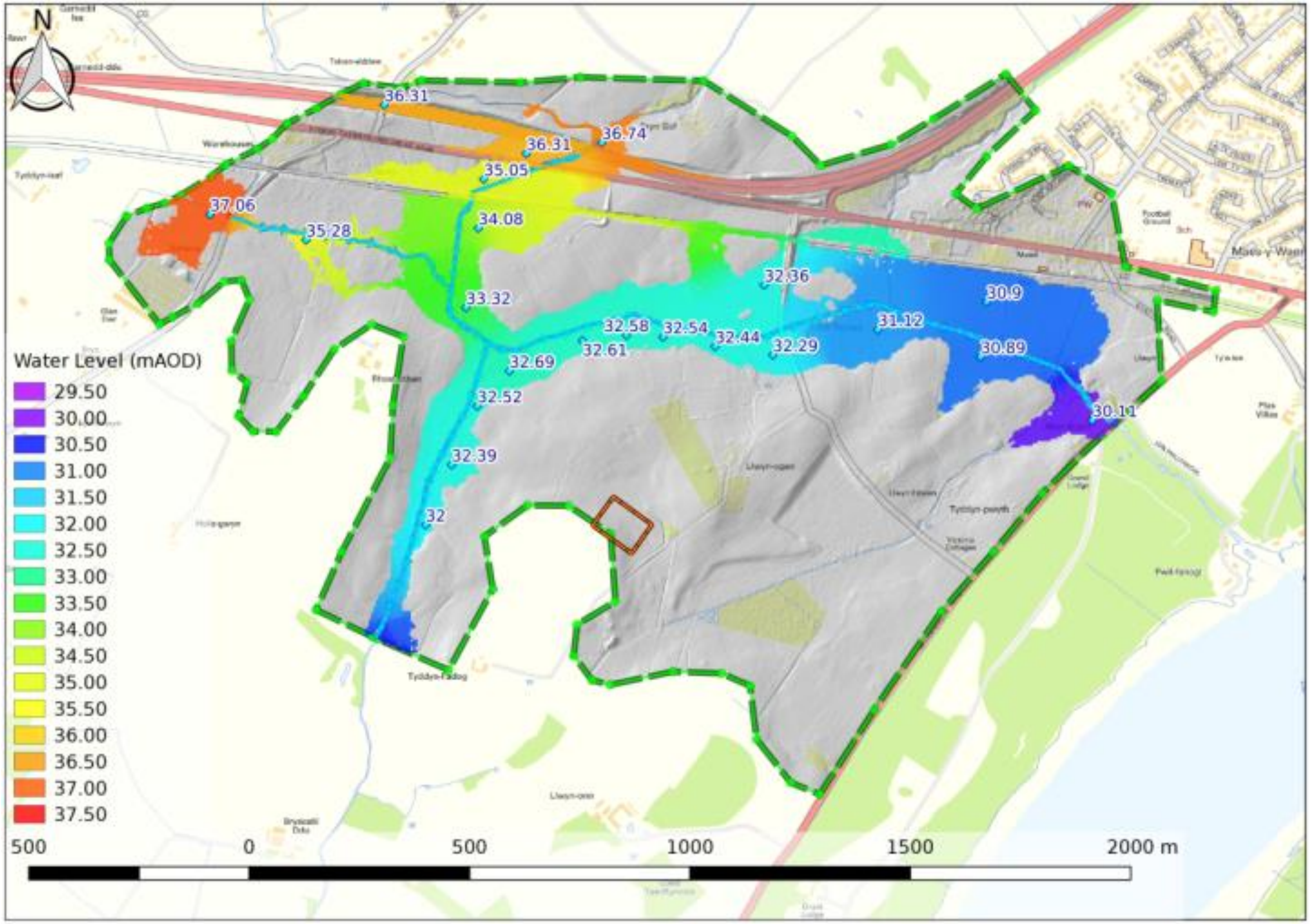

Image 6 - Peak modelled water levels

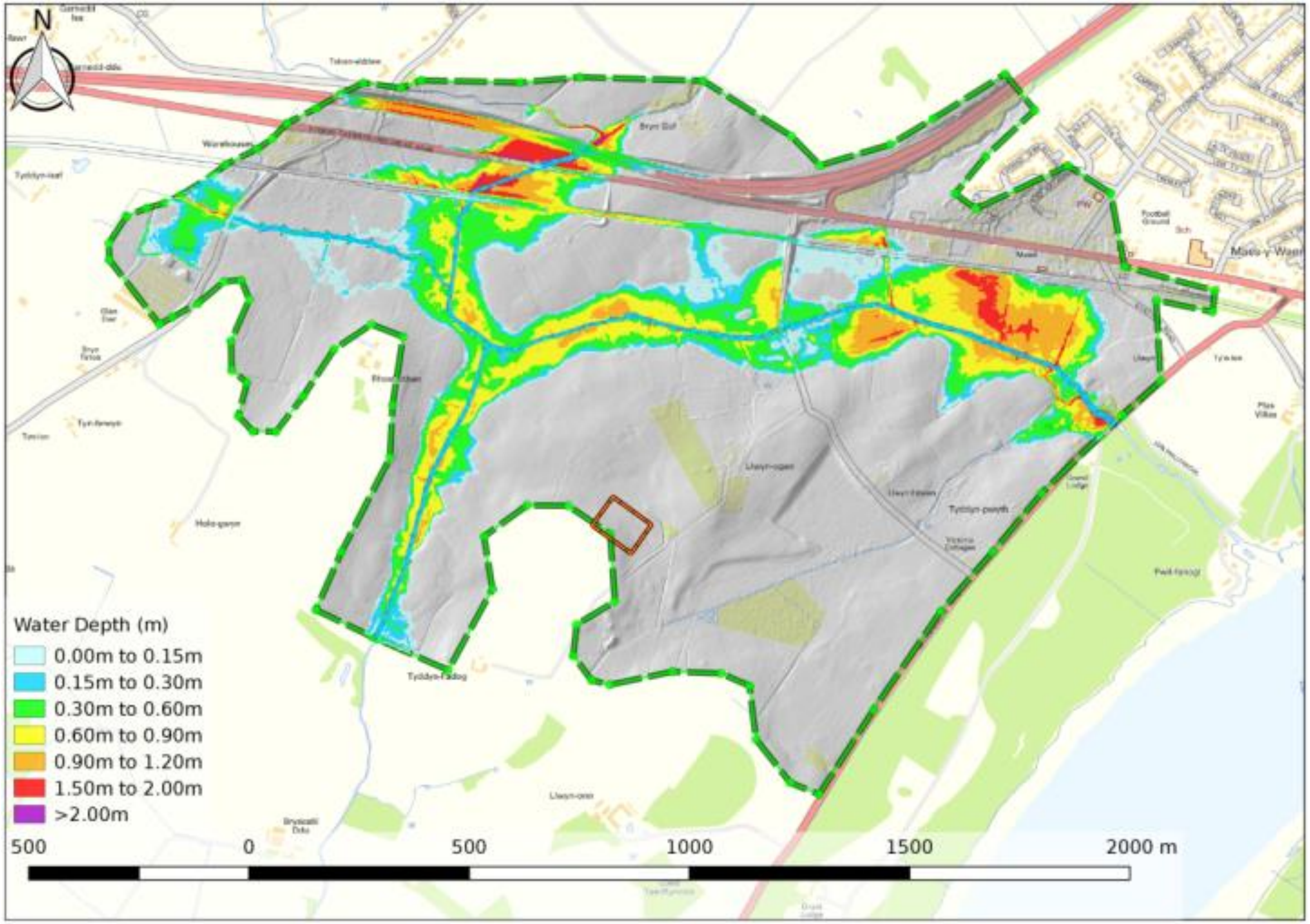

Image 7 - Peak modelled flood depths

5.2 ANALYSIS

5.2.1 As may be seen in Image 6 and Image 7 above, even in this extreme magnitude event the site remains flood free. Water levels on the southern Afon Braint would need to exceed about 35 m AOD, and from the eastern Afon Braint about 36 m AOD before water may approach the site; it may therefore be observed that there is still significant freeboard (greater than 2 m) before the site is at risk of flooding.

5.2.2 The floodplain is significant, generally exceeding 100 m wide where it is closest to the site, and wider elsewhere, providing both significant storage and conveyance. Flood depths in the area around the site are only infrequently in excess of 1 m, and so it would require a significantly large magnitude event to raise flood levels by over 2 m beyond the 0.1% AEP + 75% event, and threaten the site.

5.2.3 There is some ‘glass-walling’ (where modelled flooding goes up to the edge of the modelled domain) at the upstream limits of both the eastern Afon Braint and Spring channel. This could not be avoided in the modelling as there is no further elevation data to define the ground levels where the model domain would need to be increased (see Image 3 for available LiDAR coverage). The effect of such glass-walling is to reduce available storage, thus reducing the potential for attenuation at these locations; as they are both upstream of the area of interest, this would only serve to raise water levels near the site (albeit marginally) and so leaving it as it is may be considered a conservative approach.

6 Sensitivity Results

6.1 INTRODUCTION

6.1.1 As discussed in section 4.10, while the model has been built in line with best practice, with no data to calibrate or verify results there is some uncertainty about the model parameters applied. There is a range of acceptable values but the model can only be set to use a single value within that range.

6.1.2 Therefore, as laid out in section 4.10, a range of sensitivities have been undertaken to assess the impact of changing such parameters to see if they have any significant effect on model results which could alter the conclusions of the study.

6.2 MAPPED RESULTS

6.2.1 The following images show the peak modelled water level and flood depths, representing the 0.1% annual exceedance probability event with a 75% allowance for climate change and model parameters adjusted as described in section 4.10. The baseline case (with best-practice parameters) is presented in section 5.

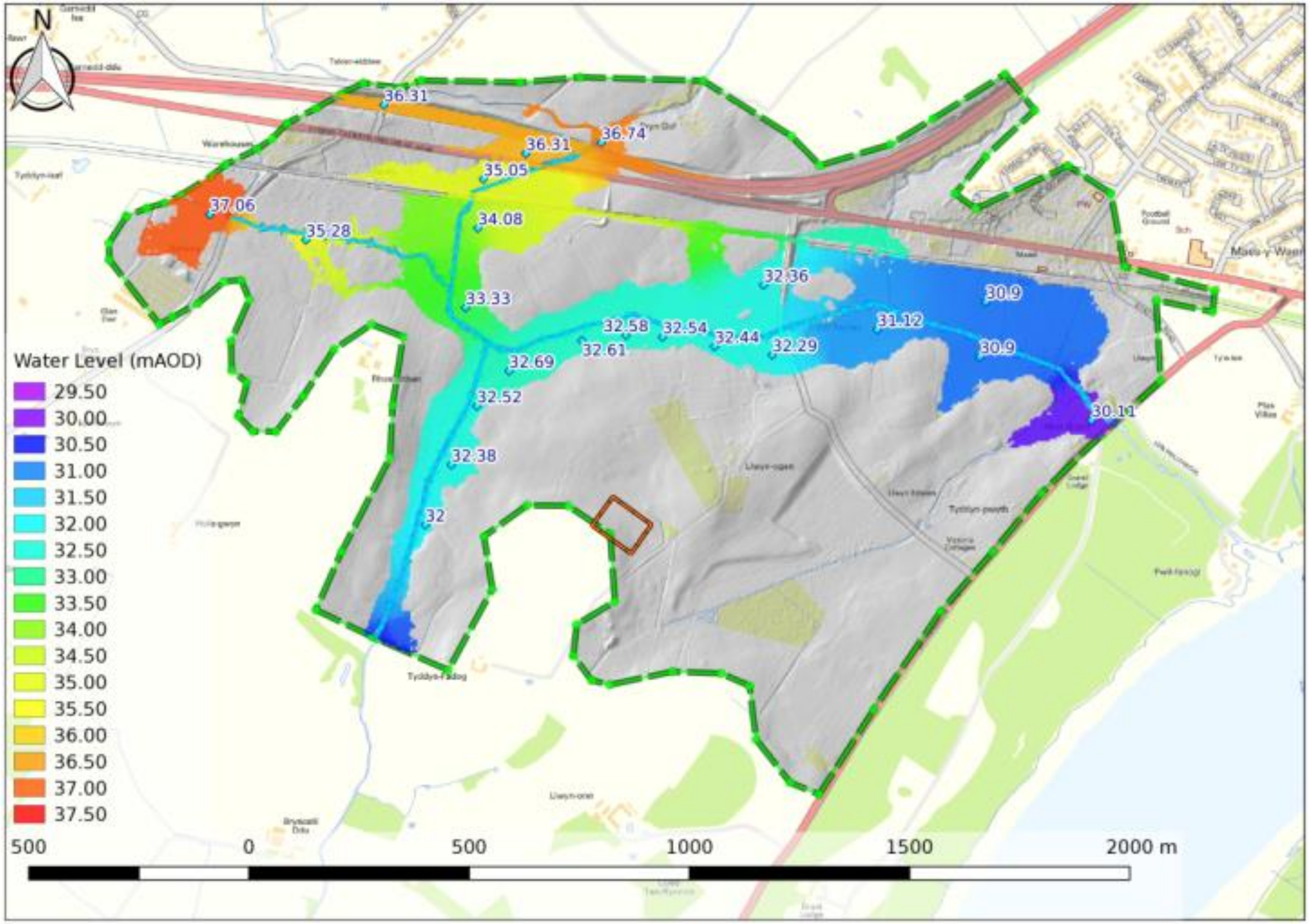

Image 8 - Peak modelled water levels with the structure at the bifurcation blocked (scenario B1)

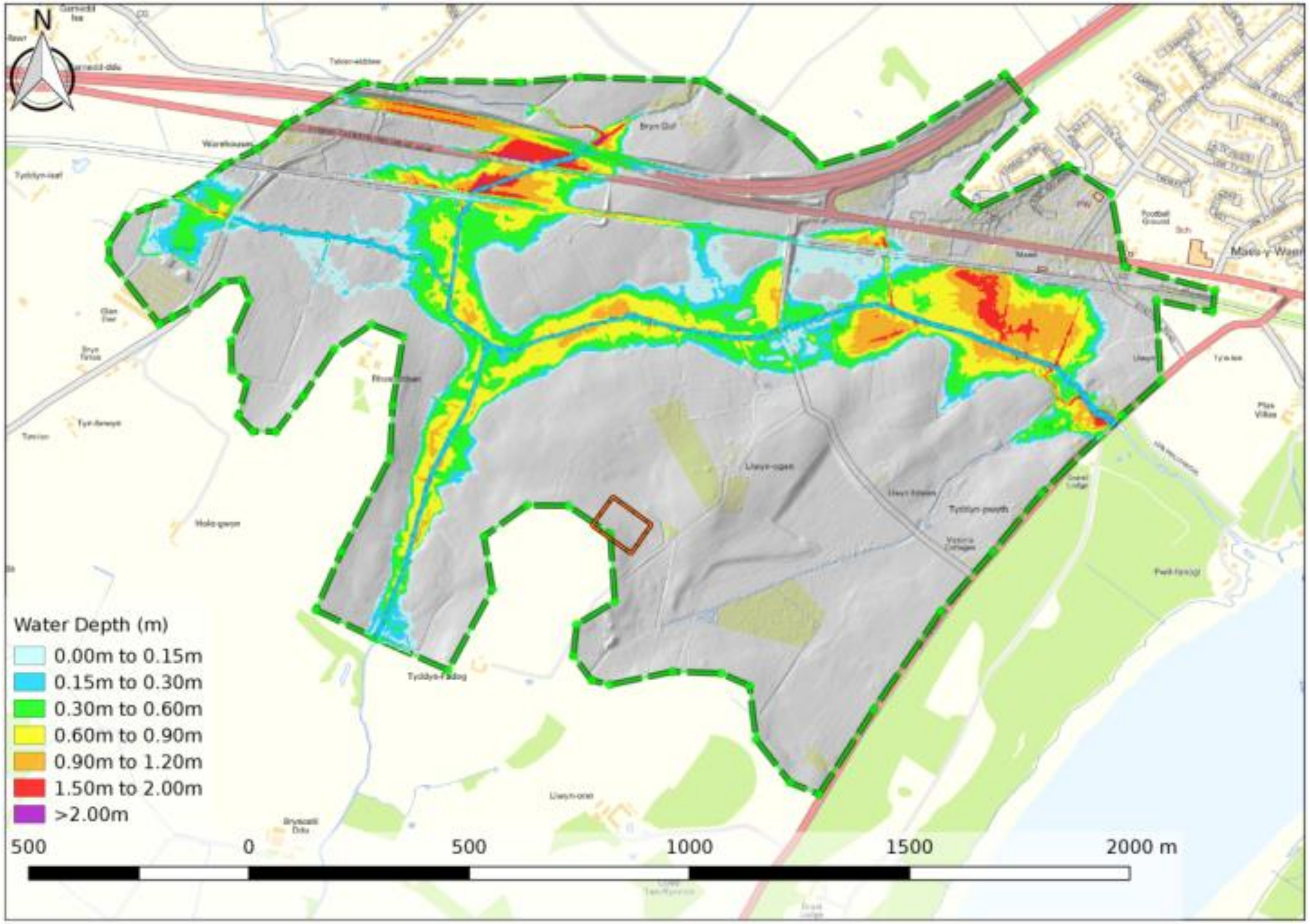

Image 9 - Peak modelled flood depths with the structure at the bifurcation blocked (scenario B1)

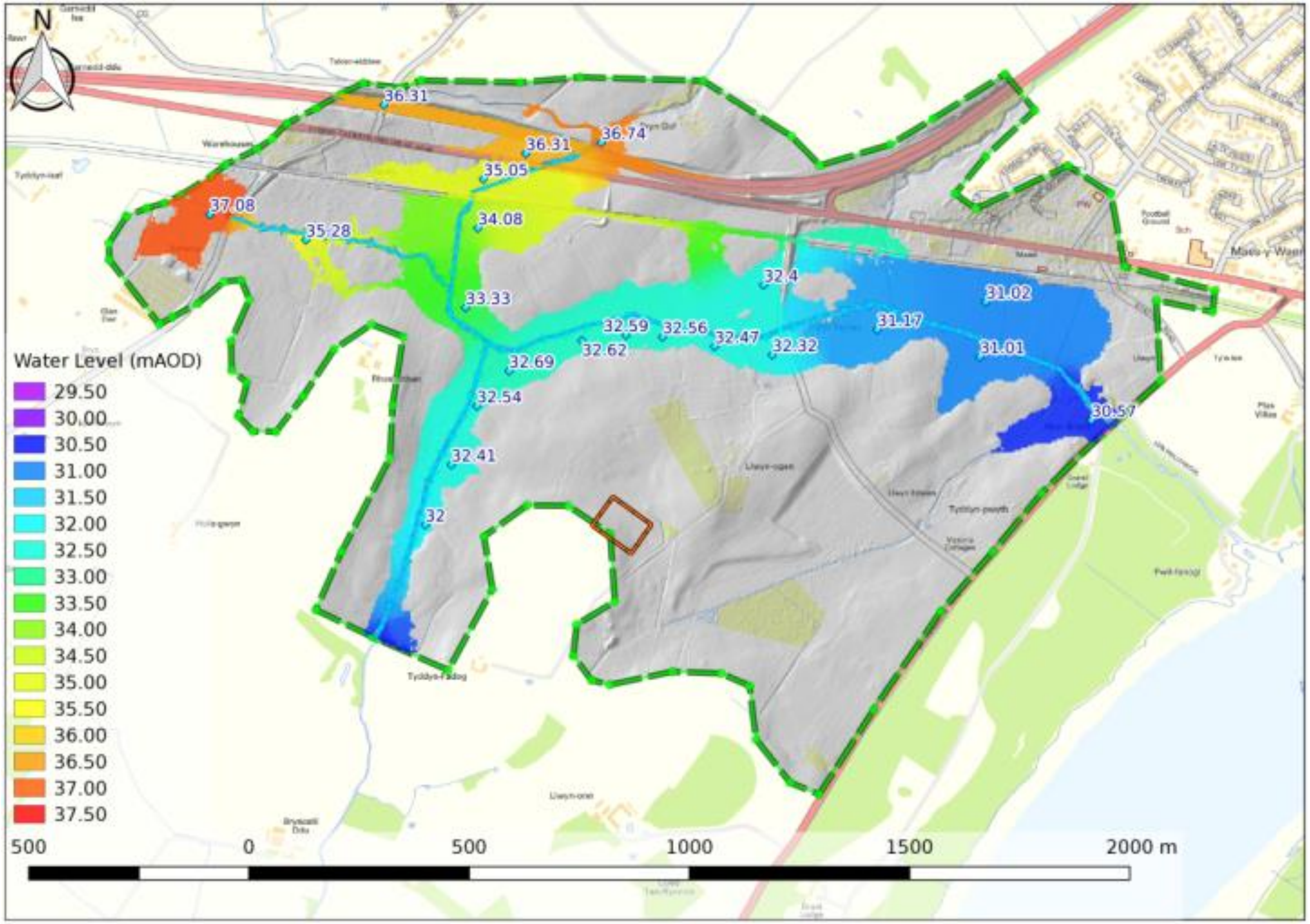

Image 10 - Peak modelled water levels with all structures downstream of the bifurcation blocked (scenario B2)

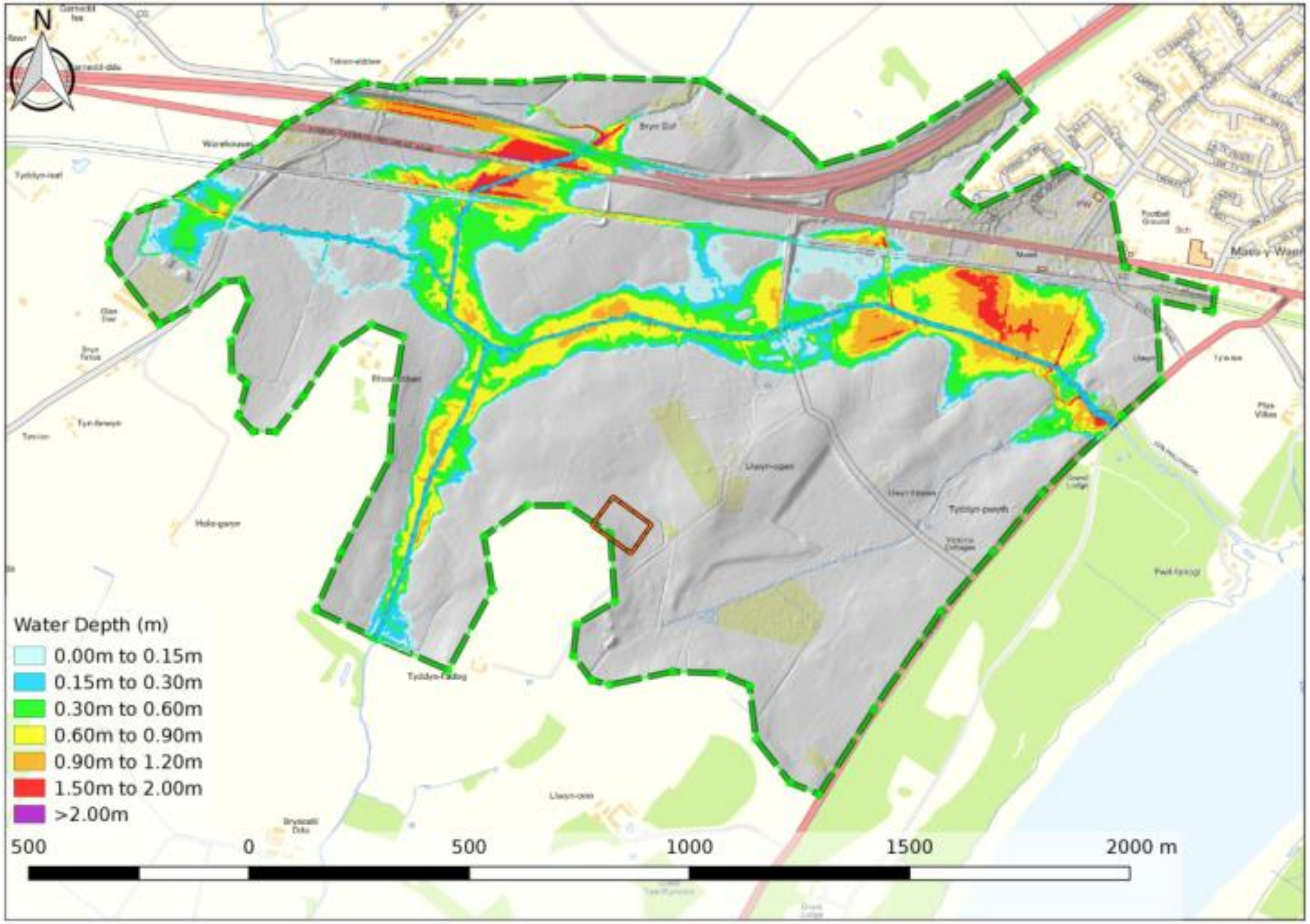

Image 11 - Peak modelled flood depths with all structures downstream of the bifurcation blocked (scenario B2)

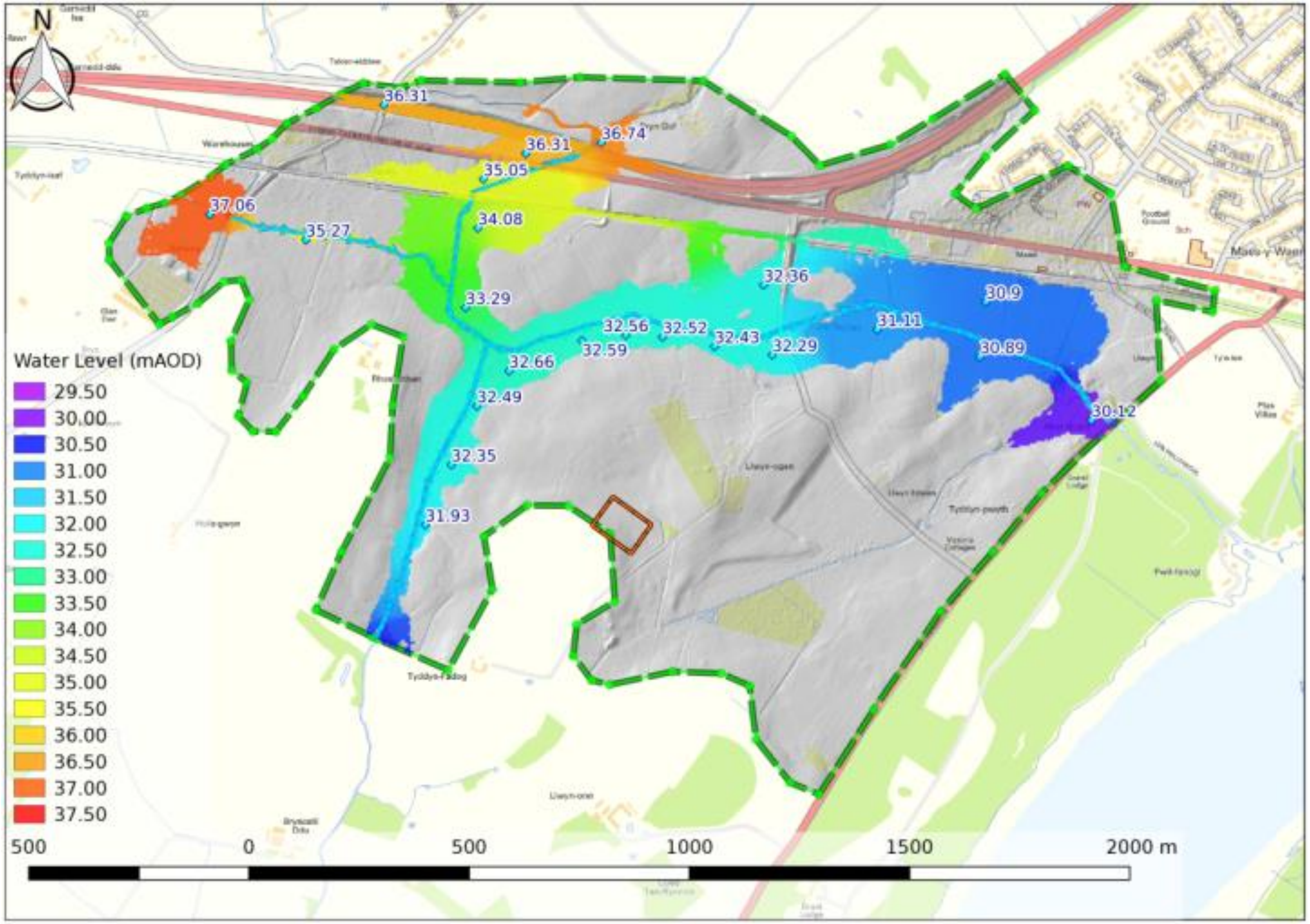

Image 12 - Peak modelled water levels with the 1D roughness decreased (scenario C1)

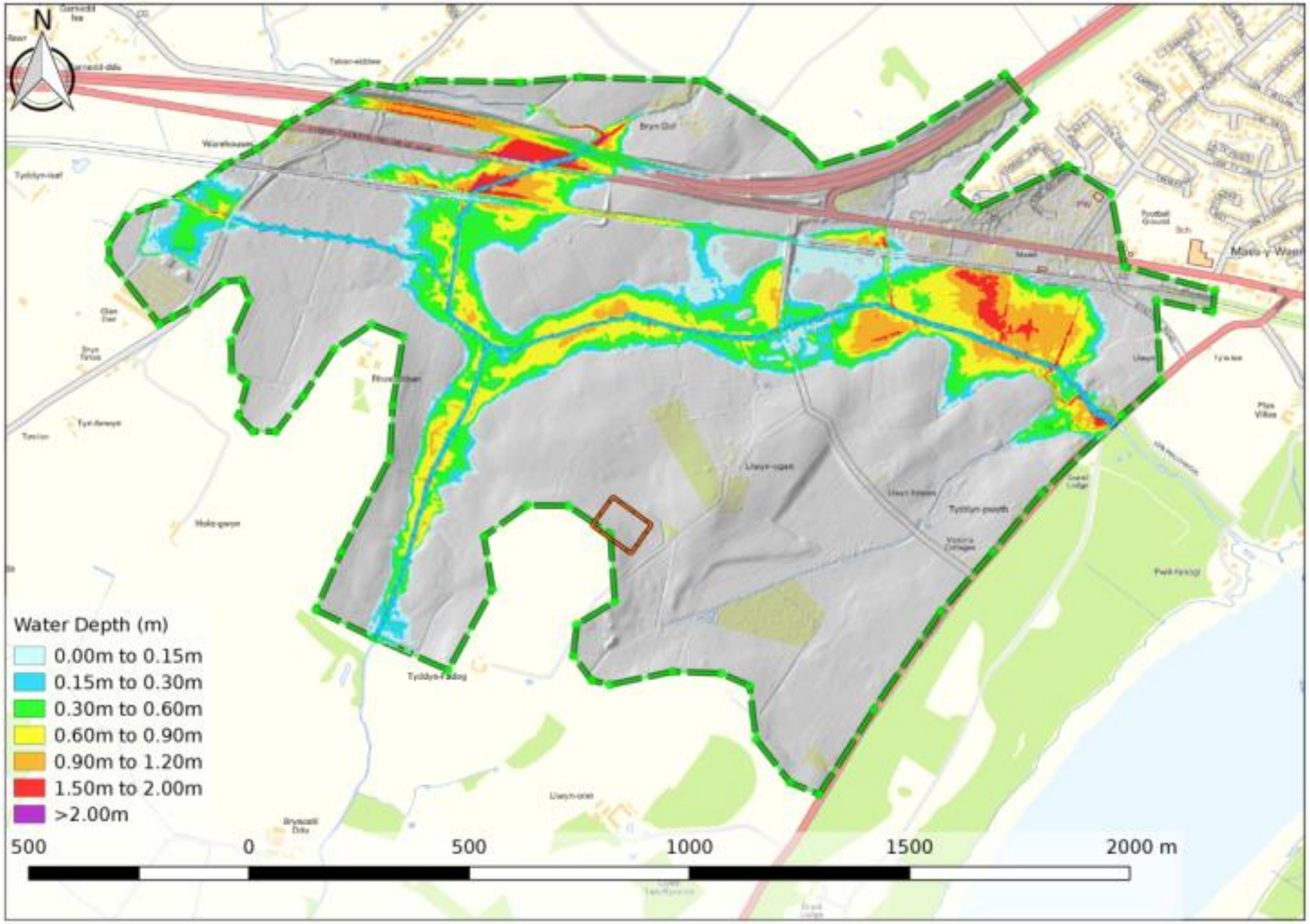

Image 13 - Peak modelled flood depths with the 1D roughness decreased (scenario C1)

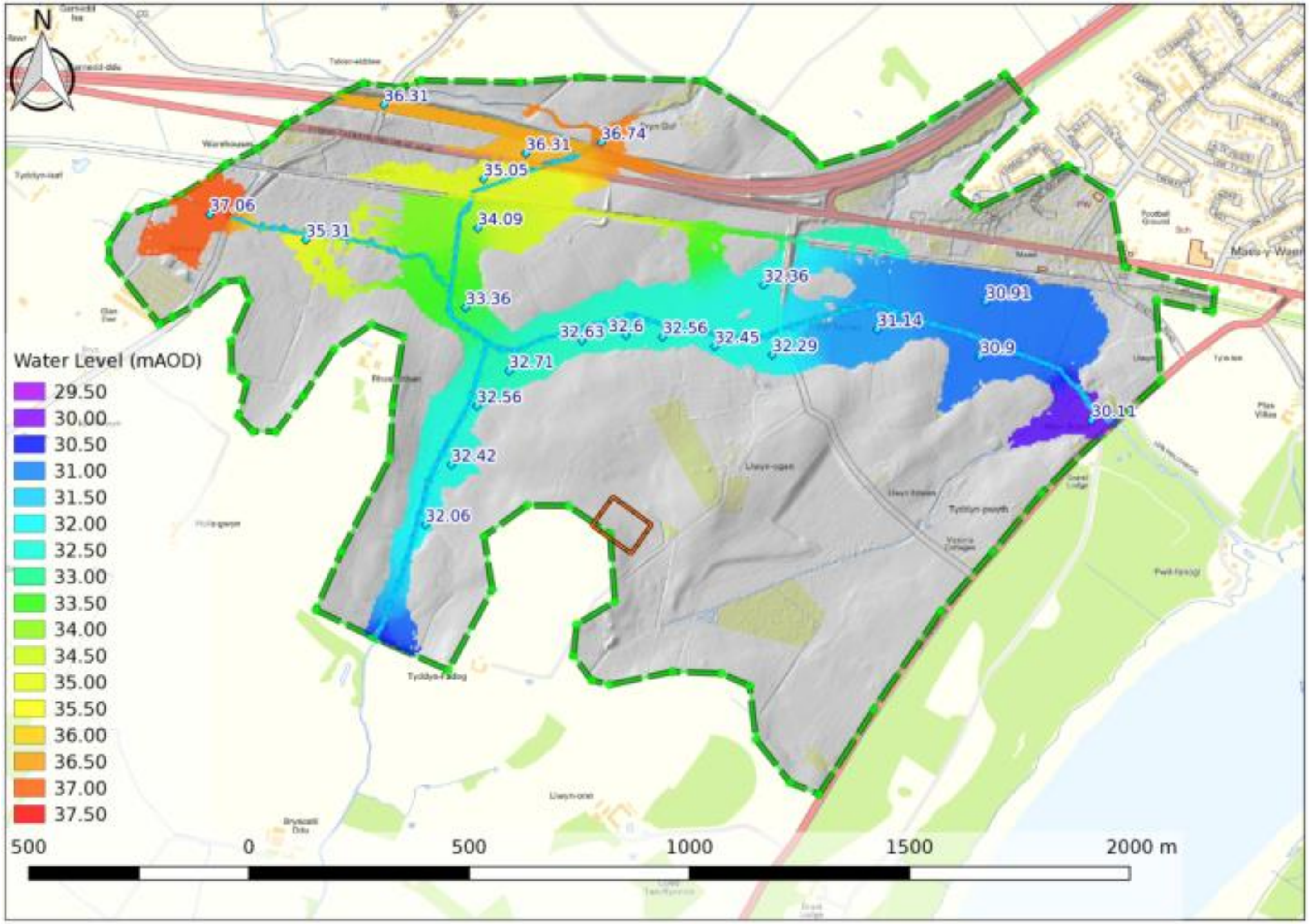

Image 14 - Peak modelled water levels with the 1D roughness increased (scenario C2)

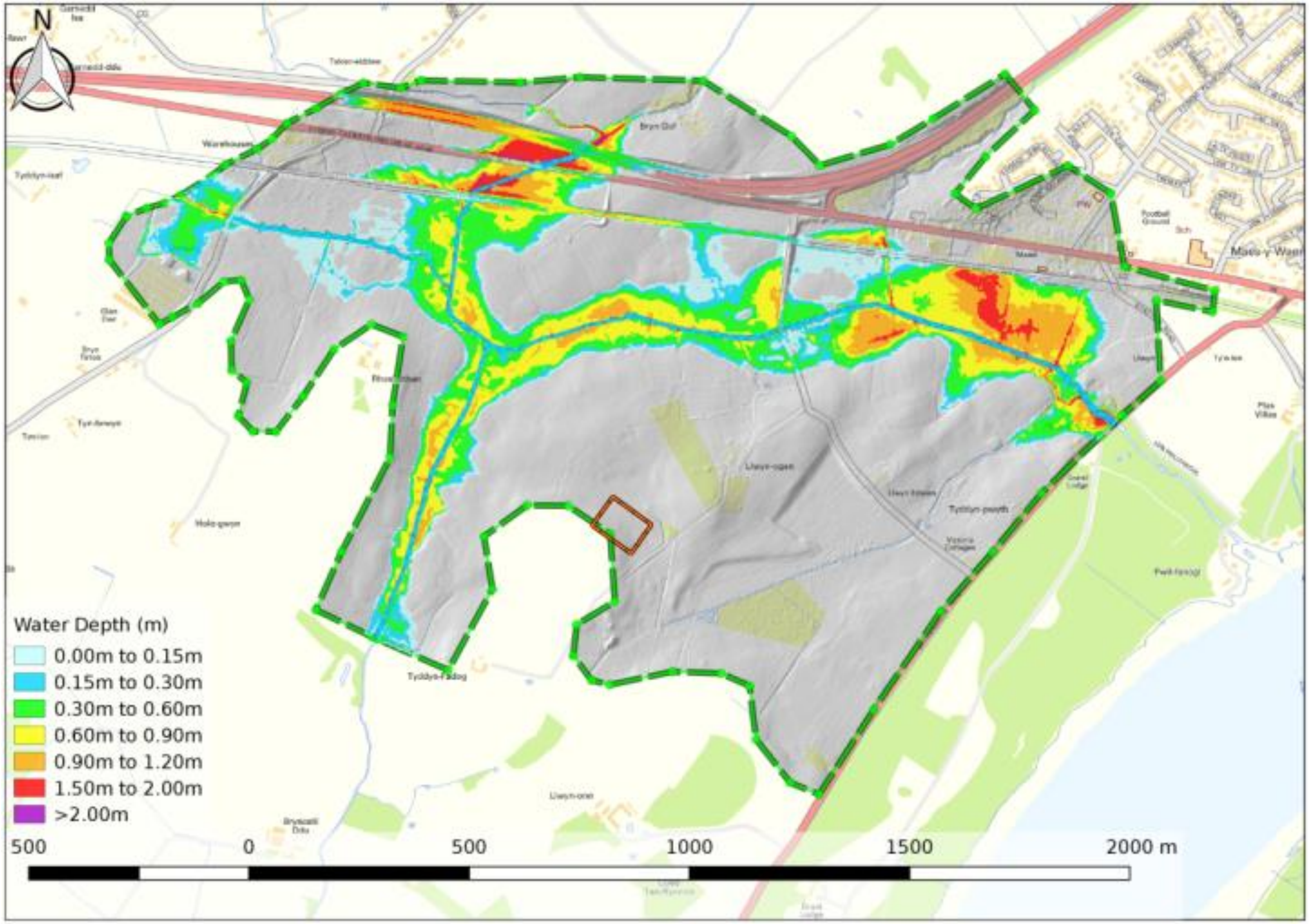

Image 15 - Peak modelled flood depths with the 1D roughness increased (scenario C2)

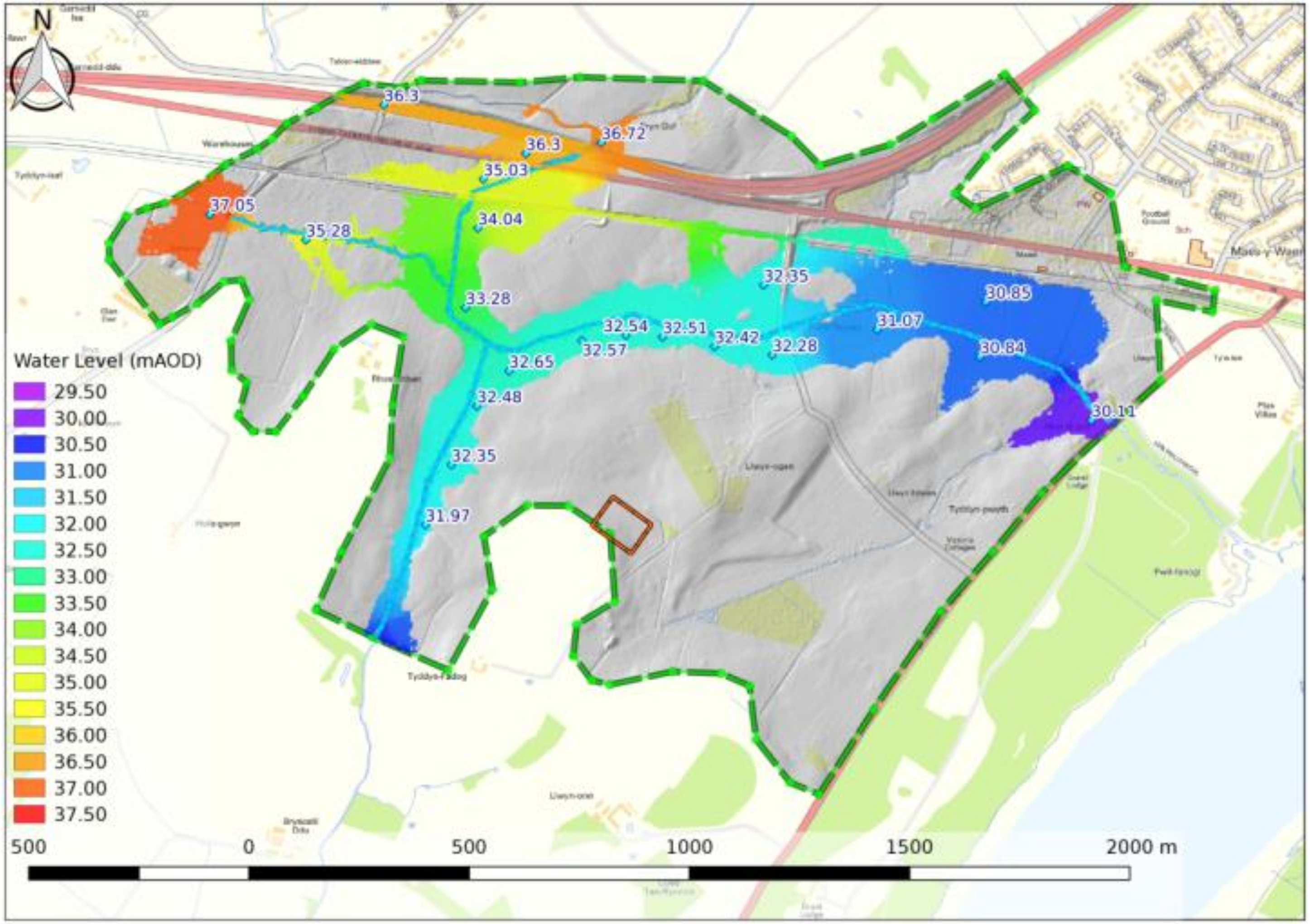

Image 16 - Peak modelled water levels with the 2D roughness decreased (scenario D1)

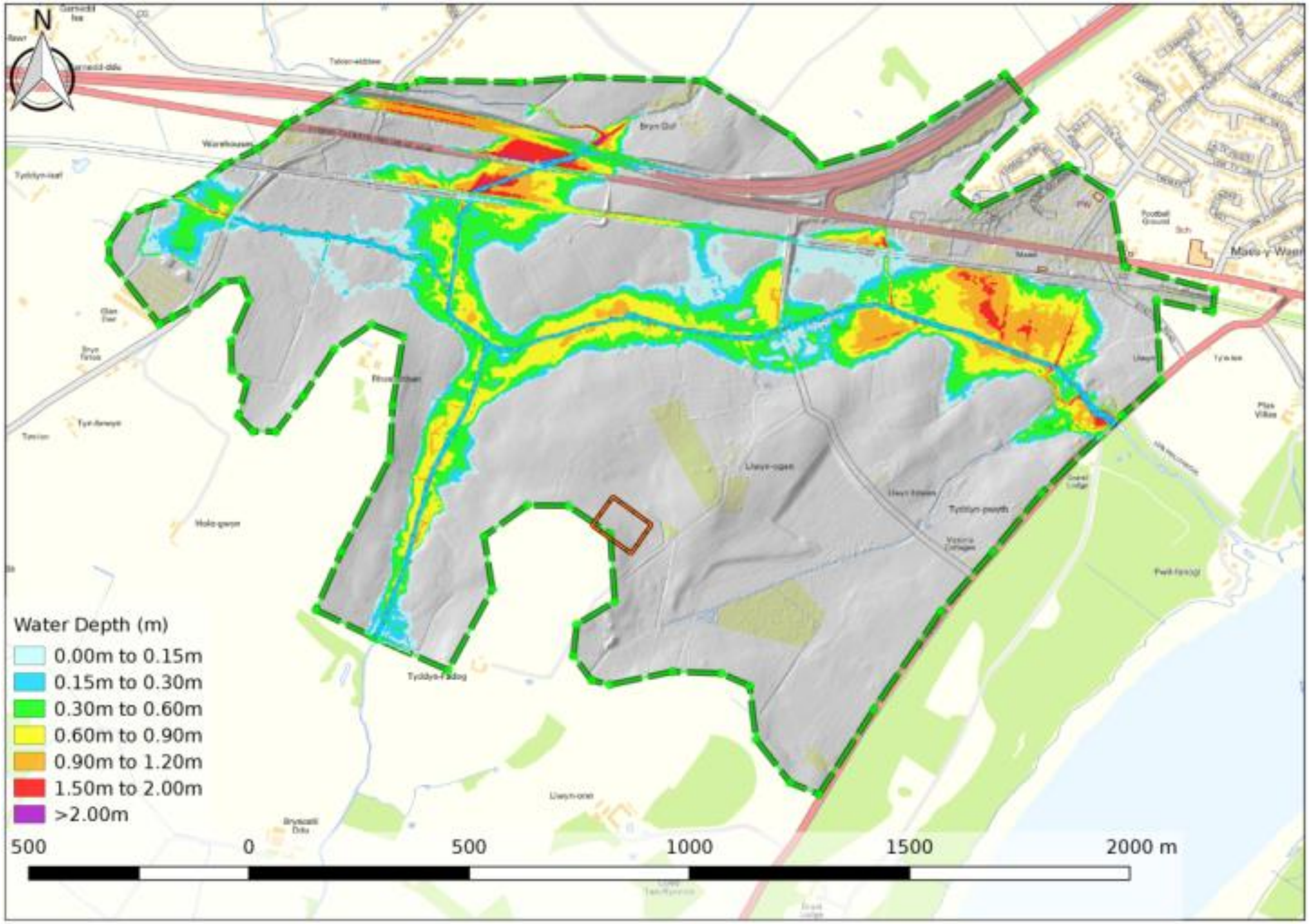

Image 17 - Peak modelled flood depths with the 2D roughness decreased (scenario D1)

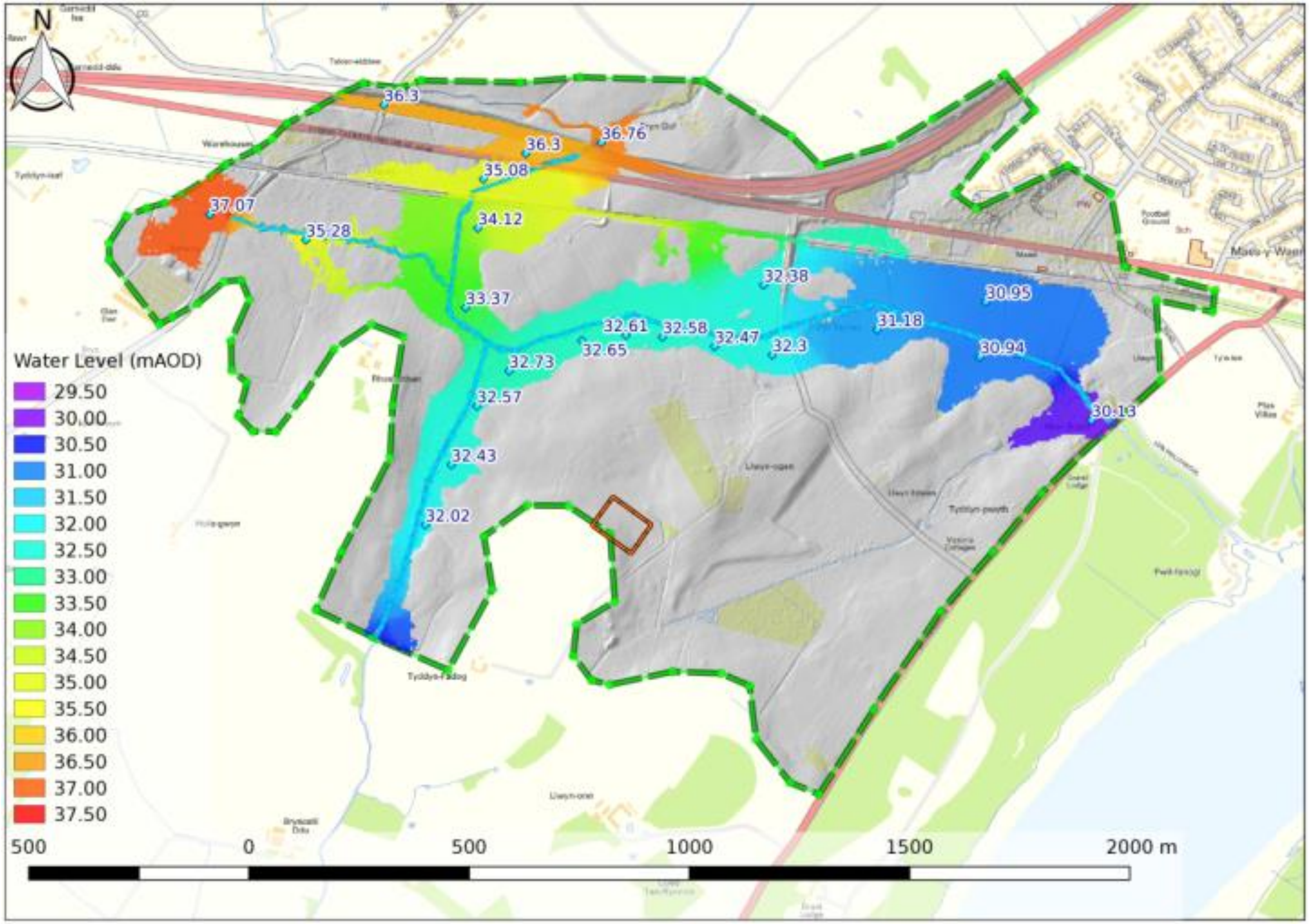

Image 18 - Peak modelled water levels with the 2D roughness increased (scenario D2)

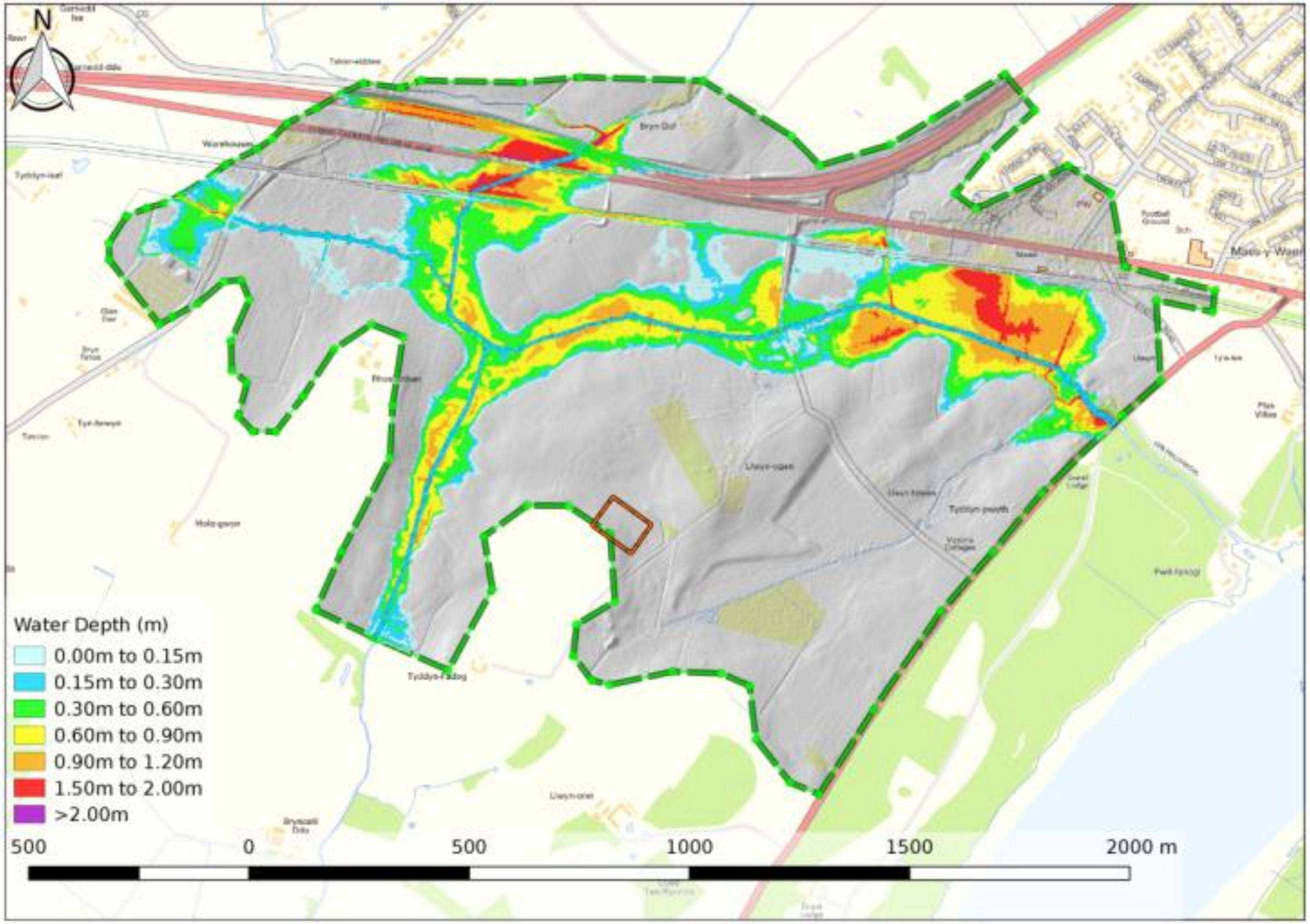

Image 19 - Peak modelled flood depths with the 2D roughness increased (scenario D2)

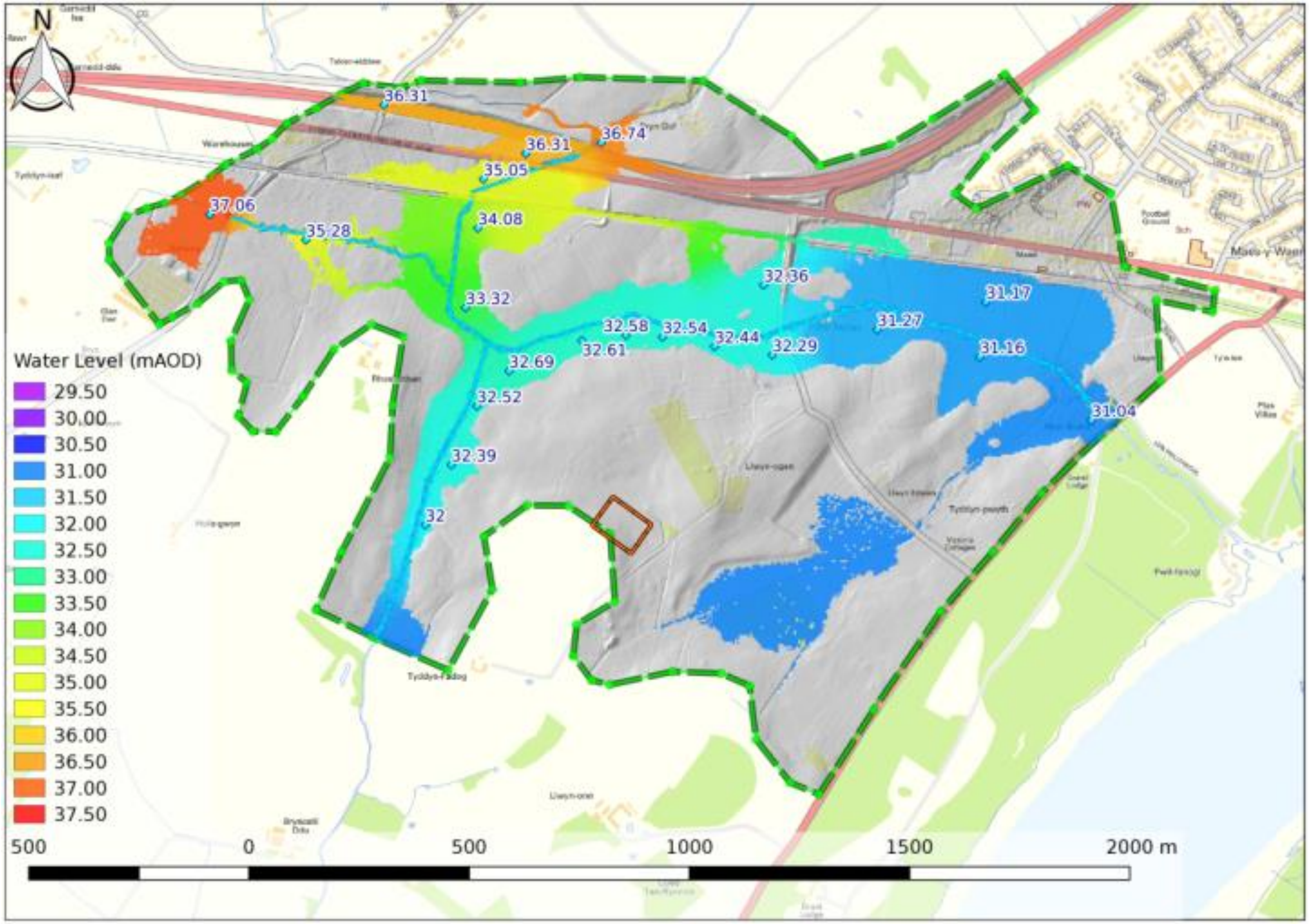

Image 20 - Peak modelled water levels with the downstream boundary levels increased (scenario E)

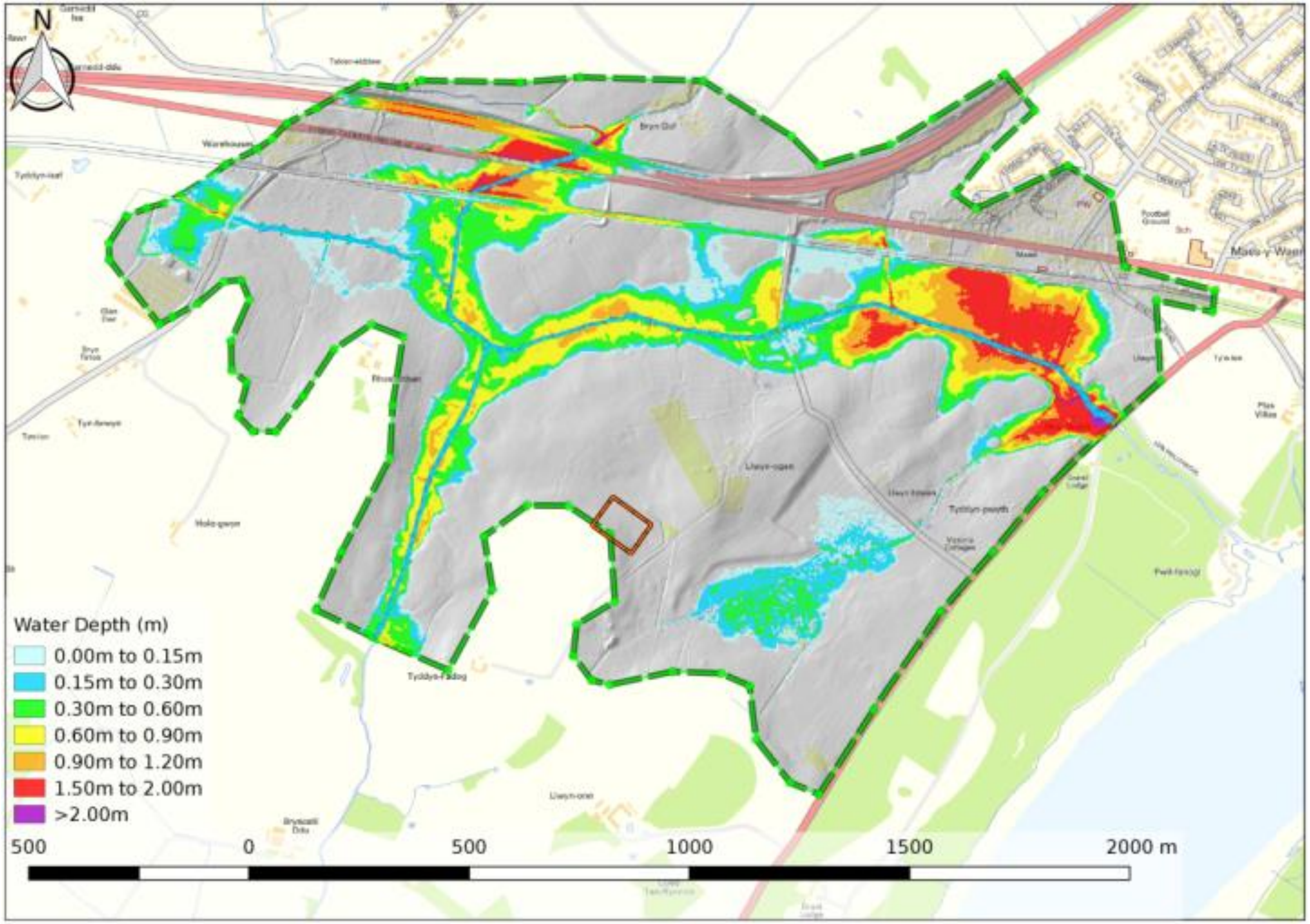

Image 21 - Peak modelled flood depths with the downstream boundary levels increased (scenario E)

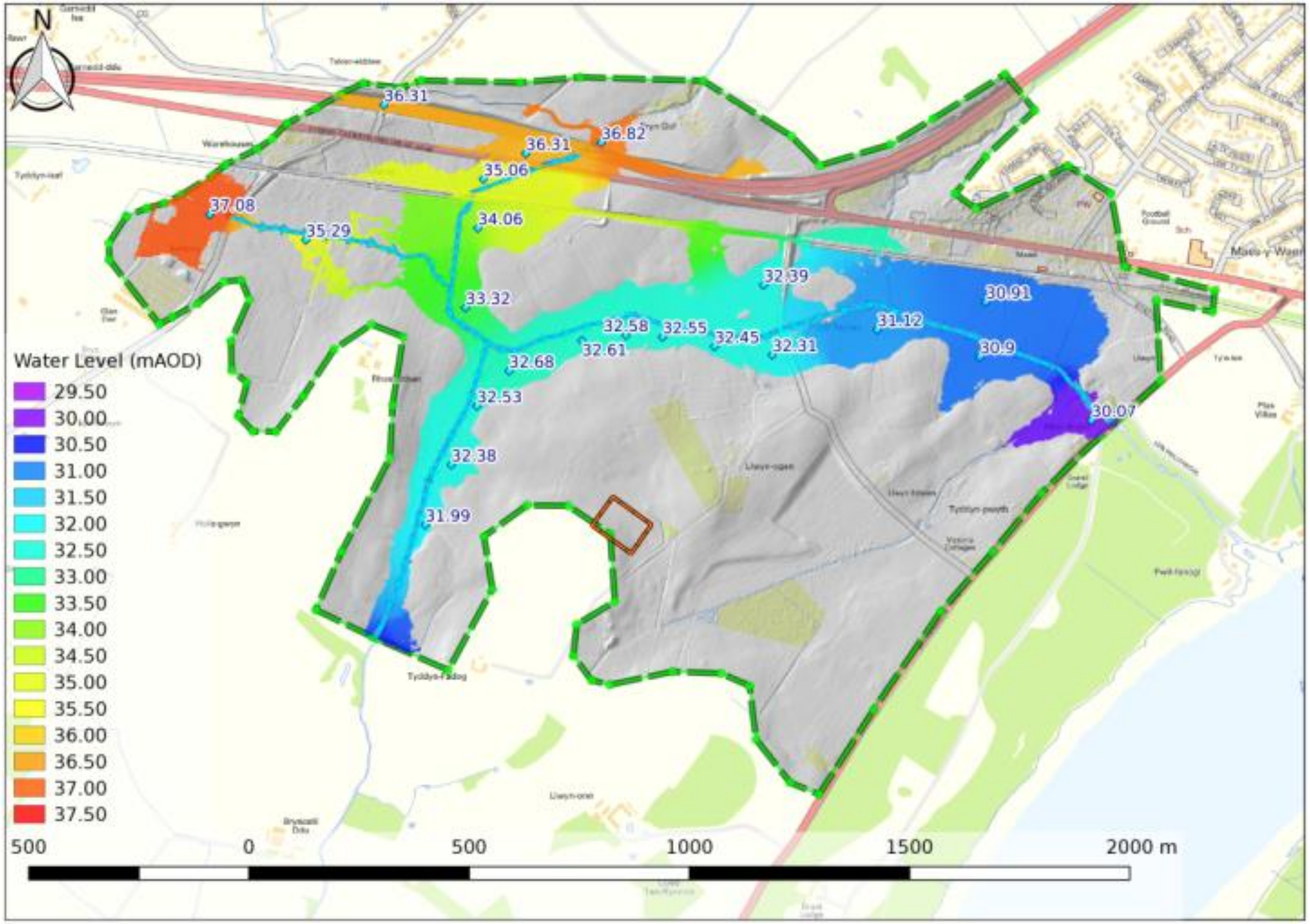

Image 22 - Peak modelled water levels with the 2D cell size reduced (scenario F)

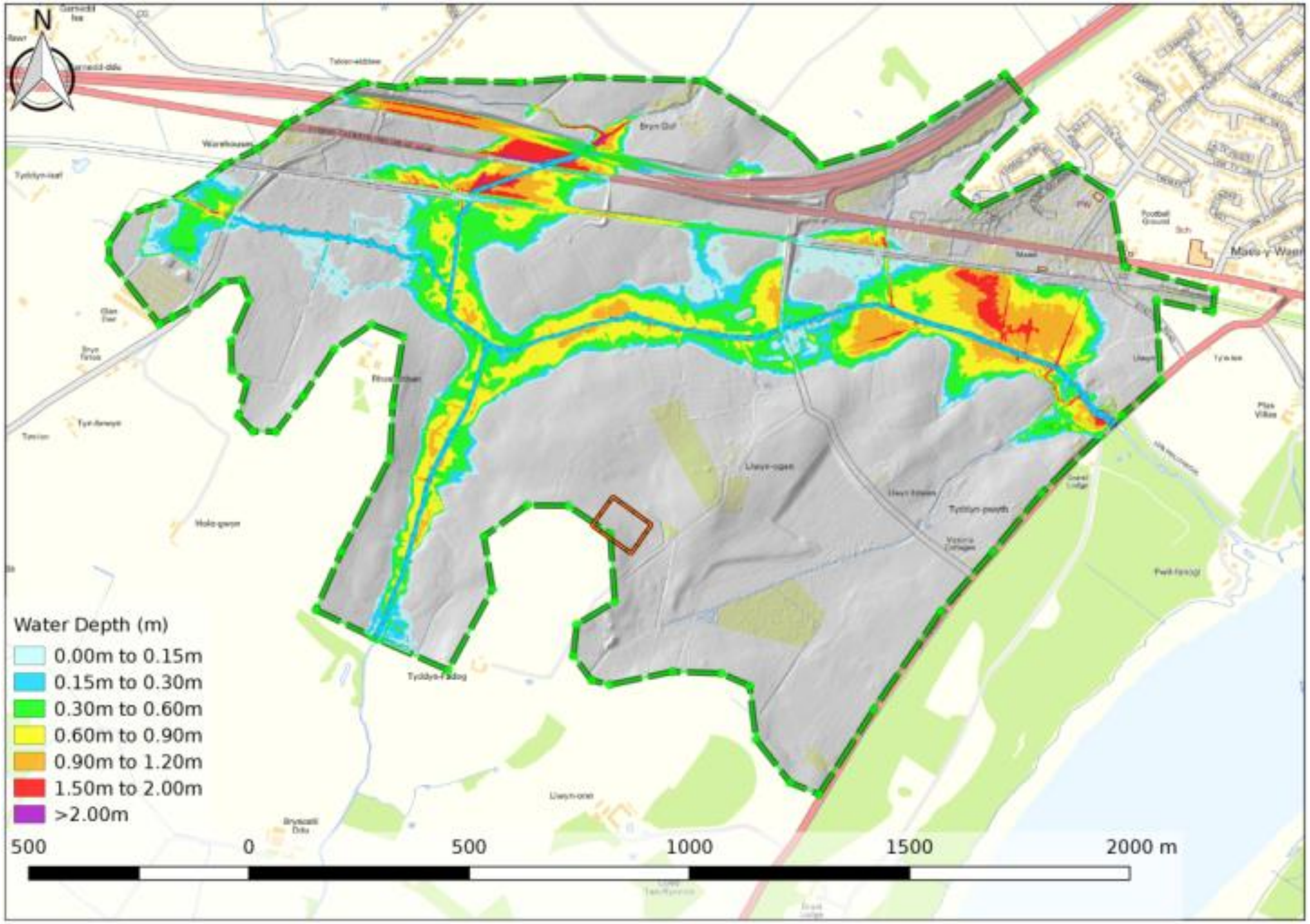

Image 23 - Peak modelled flood depths with the 2D cell size reduced (scenario F)

6.3 ANALYSIS

6.3.1 As may be seen in the above images, the site remains flood free for all of the parameter sensitivities undertaken. Furthermore, results near the site are largely unaffected, with variations in water level adjacent to the bifurcation limited to less than 0.04 m, as shown in Table 6 below.

Table 6 - Peak water levels adjacent to the bifurcation

Scenario	Description	Peak water level (mAOD)
A	Best-practice parameters	32.69
B1	Structure at the bifurcation blocked	32.69
B2	All structures downstream of the bifurcation blocked	32.69
C1	1D roughness decreased	32.66
C2	1D roughness increased	32.71
D1	2D roughness decreased	32.65
D2	2D roughness increased	32.73
E	Downstream boundary levels increased	32.69
F	2D cell size reduced	32.68

6.3.2 Adjusting model parameters within reasonable limits makes very little tangible to results near the Braint THH/CSEC. Therefore, there can be a high level of confidence that even if many of the selected model parameters were adjusted to increase flood levels near the site, Braint THH/CSEC would remain flood free.

7 Model Strengths/Limitations

7.1 STABILITY

7.1.1 The normal measure of model performance is mass balance error. Over the peak of the event, this is 1.5% in the worst case, which is within acceptable limits. The TUFLOW manual states that up to "3% can be acceptable, depending upon the objectives of the modelling"; in this instance we are not interested in particularly sensitive flow routes or flood levels, but simply to determine whether or not the site is susceptible to flooding in this extreme event. As such, this measure of mass error is entirely acceptable.

7.1.2 There are a few 1D negative depths at the start of the simulation in the B2 scenario, where all structures downstream of the bifurcation are blocked, as things settle out from the initial condition, but none are present after the first half hour. All the other simulations undertaken have no negative depths in either 1D or 2D.

7.1.3 In general, changing the simulation parameters as has been done in the sensitivity runs has very little effect on the stability/performance of the model. This should be taken as a positive indicator of the quality of the model.

7.2 CONFIDENCE IN RESULTS

7.2.1 As discussed in section 6.3, the sensitivities undertaken and their limited impact on modelled results give a high level of confidence in the outcomes of this study; in particular it is clear that Braint THH/CSEC should not be considered to be at risk from fluvial flooding.

8 Conclusions

8.1.1 A hydraulic model has been constructed of the Afon Braint using industry standard software.

8.1.2 The results using best practice model parameters show that Braint THH/CSEC is flood free for the 0.1% annual exceedance probability event including a 75% allowance for climate change.

8.1.3 Even in this extreme event there is significant freeboard available before Braint THH/CSEC would be at risk of flooding.

8.1.4 While there is some uncertainty associated with the model parameters applied, due to a lack of calibration/verification data, the sensitivities undertaken indicate that even with significant alteration of model parameters Braint THH/CSEC would still be shown to be flood free.

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9 FEH Calculation Record

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Flood estimation calculation record

Introduction

This document is a supporting document to the Environment Agency's flood estimation guidelines. It provides a record of the calculations and decisions made during flood estimation. It will often be complemented by more general hydrological information given in a project report. The information given here should enable the work to be reproduced in the future. This version of the record is for studies where flood estimates are needed at multiple locations.

Contents

Page

1 METHOD STATEMENT ---------- 3

2 LOCATIONS WHERE FLOOD ESTIMATES REQUIRED ---------- 9

3 STATISTICAL METHOD ---------- 12

4 REVITALISED FLOOD HYDROGRAPH (REFH) METHOD ---------- 18

5 FEH RAINFALL-RUNOFF METHOD ---------- 19

6 DISCUSSION AND SUMMARY OF RESULTS ---------- 20

7 ANNEX ---------- 23

Approval

	Signature	Name and qualifications	For Environment Agency staff: Competence level (see below)
Calculations prepared by:	Sara Liguori	Sara Liguori, PhD	
Calculations checked by:	Gerald CJ Morgan	Gerald Morgan, PhD	
Calculations approved by:	Gerald CJ Morgan	Gerald Morgan, PhD	

Environment Agency competence levels are covered in Section 2.1 of the flood estimation guidelines:

- Level 1 – Hydrologist with minimum approved experience in flood estimation
- Level 2 – Senior Hydrologist
- Level 3 – Senior Hydrologist with extensive experience of flood estimation

ABBREVIATIONS

AM	Annual Maximum
AREA	Catchment area (km^2)
BFI	Base Flow Index
BFIHOST	Base Flow Index derived using the HOST soil classification
CFMP	Catchment Flood Management Plan
CPRE	Council for the Protection of Rural England
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
FSR	Flood Studies Report
HOST	Hydrology of Soil Types
NRFA	National River Flow Archive
POT	Peaks Over a Threshold
QMED	Median Annual Flood (with return period 2 years)
ReFH	Revitalised Flood Hydrograph method
SAAR	Standard Average Annual Rainfall (mm)
SPR	Standard percentage runoff
SPRHOST	Standard percentage runoff derived using the HOST soil classification
Tp(0)	Time to peak of the instantaneous unit hydrograph
URBAN	Flood Studies Report index of fractional urban extent
URBEXT1990	FEH index of fractional urban extent
URBEXT2000	Revised index of urban extent, measured differently from URBEXT1990
WINFAP-FEH	Windows Frequency Analysis Package – used for FEH statistical method

1 Method statement

1.1 Overview of requirements for flood estimates

Item	Comments
Give an overview which includes: • Purpose of study • Approx. no. of flood estimates required • Peak flows or hydrographs? • Range of return periods and locations • Approx. time available	The purpose of this assessment is to derive hydrological estimates to assess flood risk to a National Grid development site in the lower Afon Braint catchment, in Anglesey, south-west of Llanfair. Flood estimates are required for the 1 in 1000 (0.1% AEP) plus 75% climate change allowance flood event. In addition, peak flow estimates have been derived for the following return periods: 1 in 2 (50% AEP), 1 in 5 (20% AEP), 1 in 10 (10% AEP), 1 in 25 (4% AEP), 1 in 50 (2% AEP), 1 in 100 (1% AEP), 1 in 200 (0.5% AEP), 1 in 500 (0.2% AEP) and 1 in 1000 (0.1% AEP). Full design hydrographs are required for use in hydraulic modelling.

1.2 Overview of catchment

Item	Comments
Brief description of catchment, or reference to section in accompanying report	The site of interest is located in the lower Afon Braint catchment, south-west of Llainfair. The Afon Braint rises in the hills to the south of Pentraeth Forest, east of Pentraeth and south-west of Llanddona; travels west/south-west passing north-west of Llanfair. Just west of Llainfair the Afon Braint passes under the A55, A5 and the railway. Downstream of the railway the watercourse bifurcates. The natural watercourse continues to the east flowing under the A4080 and into the Menai Strait, while the diverted watercourse flows south-west past Dwyran before flowing into the Menai Strait east of Pen-Ion. The whole natural catchment area of the Afon Braint is approximately 30km^2. The catchment is essentially rural and ungauged.

1.3 Source of flood peak data

Was the HiFlows UK dataset used? If so, which version? If not, why not? Record any changes made	Version 4.1, released May 2016. WINFAP-FEH release of HiFlows-UK from the NRFA database.

1.4 Gauging stations (flow or level)

(at the sites of flood estimates or nearby at potential donor sites)

Water-course	Station name	Gauging authority number	NRFA number (used in FEH)	Grid reference	Catch-ment area (km²)	Type (rated / ultrasoni c / level…)	Start and end of flow record
Seiont	Peblig Mill	65006	65006	SH494622	74.4	Rated section	1975-present
Gwyrfai	Bontnewy dd	65004	65004	SH483598	47.9	Wide non-standard shallow V crump weir	1970-present
Glaslyn	Beddgeler t	65001	65001	SH591477	68.6	20m wide river section	1961-present

Water-course	Station name	Gauging authority number	NRFA number (used in FEH)	Grid reference	Catch-ment area (km²)	Type (rated / ultrasonic / level…)	Start and end of flow record
Dwyfor	Garndolbenma	65007	65007	SH498429	52.4	Compound crump profile weir	1975-present
Conwy	Cwmlanerch	66011	66011	SH801580	344.5	Natural river section	1964-present
Erch	Pencaenewydd	65005	65005	SH400403	18.1	6m wide crump profile weir	1972-present
Give link/reference to any further data quality checks carried out			None				

1.5 Data available at each flow gauging station

Station name	Start and end of data in HiFlows-UK	Update for this study?	Suitable for QMED?	Suitable for pooling?	Data quality check needed?	Other comments on station and flow data quality – e.g. information from HiFlows-UK, trends in flood peaks, outliers.
Peblig Mill	1975-2014	No	Yes	No	Outside scope	Gauged to within 12% pf QMED, which remains in bank and is well gauged.
Bontnewydd	1970-2014	No	Yes	No	Outside scope	Gauged to within 18% of QMED. Uncertainty about rating as gaugings do not fit rating well.
Beddgelert	1961-2014	No	Yes	No	Outside scope	Gauged to within 9% of QMED. Multiple ratings applied across period of record as bed is unstable. Does not consider out of bank flow. No peak flow gaugings exist prior to 1987, therefore early ratings unverified.
Garndolbenma	1975-2014	No	Yes	No	Outside scope	Not gauged to within 30% of QMED. However, as a crump weir expected to perform well at QMED.
Cwmlanerch	1964-2014	No	Yes	No	Outside scope	Well gauged to QMED with no bypassing.
Pencaenewydd	1972-2014	No	Yes	No	Outside scope	Not gauged to within 30% of QMED. However, rating remains modular and thought to be reliable as QMED contained in bank.
Give link/reference to any further data quality checks carried out			NA			

1.6 Rating equations

Station name	Type of rating e.g. theoretical, empirical; degree of extrapolation	Rating review needed?	Reasons – e.g. availability of recent flow gaugings, amount of scatter in the rating.
For all stations in 1.4 and 1.5 information is provided by the NRFA			
Give link/reference to any rating reviews carried out		Outside scope	

1.7 Other data available and how it has been obtained

Type of data	Data relevant to this study?	Data available ?	Source of data and licence reference if from EA	Date obtained	Details
Check flow gaugings (if planned to review ratings)		No			
Historic flood data – give link to historic review if carried out.		No			
Flow data for events		No			
Rainfall data for events		No			
Potential evaporation data		No			
Results from previous studies		No			
Other data or information (e.g. groundwater, tides)		No			

1.8 Initial choice of approach

Is FEH appropriate? (it may not be for very small, heavily urbanised or complex catchments) If not, describe other methods to be used.	Standard FEH methods are applicable to the area of study. The Afon Braint catchment at the railway crossing has an area of 19.26km^2. Current guidelines recommend the use of standard FEH methods (Statistical and ReFH2) on small catchments (<25km^2).
Outline the conceptual model, addressing questions such as: • Where are the main sites of interest? • What is likely to cause flooding at those locations? (peak flows, flood volumes, combinations of peaks, groundwater, snowmelt, tides…) • Might those locations flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir? • Is there a need to consider temporary debris dams that could collapse?	The main site of interest is located in the south-east portion of the Afon Braint catchment, near Llwyn-Ogan. According to NRW flood risk map (see Figure 1), the site is not subject to risk of flooding from rivers and sea, while might be subject to surface flooding flood risk.

Any unusual catchment features to take into account? e.g. • highly permeable – avoid ReFH if BFIHOST>0.65, consider permeable catchment adjustment for statistical method if SPRHOST<20% • highly urbanised – avoid standard ReFH if URBEXT1990>0.125; consider FEH Statistical or other alternatives; consider method that can account for differing sewer and topographic catchments • pumped watercourse – consider lowland catchment version of rainfall-runoff method • major reservoir influence (FARL<0.90) – consider flood routing • extensive floodplain storage – consider choice of method carefully	The catchment of interest is relatively small (the total catchment area of the Afon Braint at the A4080 crossing is 29.378km^2). Permeability is not high (BFIHOST=0.471) and the catchment is essentially rural (URBEXT2000=0.014). The flood response is not affected by attenuation from reservoirs/lakes (FARL=0.996). The Afon Braint has been subject to artificial modifications to its natural path. The watercourse flows in a south westerly direction to the west of Llanfair, under the A55, A5 and the railway line before joining a west tributary just north of Rhosbothan and continuing in an easterly direction. A diversion to the south occurs at this location, thus the watercourse partly flows in a southerly direction. Towards the east, a field drain flows towards north-east, joining the Afon Braint just west of the A4080. The above configuration of the Afon Braint watercourse path has been taken in consideration in the hydrological model schematization.
Initial choice of method(s) and reasons Will the catchment be split into sub catchments? If so, how?	The hydrological model schematization takes account of the requirements of the hydraulic modelling and the characteristics of the catchment of interest. Design peak and hydrographs will be estimated at locations appropriate to the scale of the study and to the requirements of the hydraulic modelling. Specifically, lumped inflows will be derived for the: • Afon Braint catchment upstream of the A55; • Afon Braint intervening catchment between the A55 and the A5; • Afon Braint intervening catchment between the A5 and the railway line; • West tributary of the Afon Braint at NGR 250750, 371700; • North tributary of the Afon Braint flowing west of Llanfair and joining the Afon Braint at NGR 252250, 371550. • Field drain flowing in a north-east direction east of Llwyn-Ogan and joining the Afon Braint just west of the A4080. In addition, distributed inflows will be added to the model for the: • Intervening area in the Afon Braint catchment at the watercourse diversion between the railway line, the west tributary and Bryncelli Ddu; • Intervening area to the east, between the diversion and the A4080. A layout of the sub-catchments selected for the purpose of this assessment is provided in Figure 2. Both FEH statistical and rainfall-runoff analysis (using v2.2 of the ReFH model) will be undertaken for the Afon Braint catchment at the railway crossing location. This is just upstream of the watercourse diversion towards the south-west and has been deemed to be an appropriate location for statistical and lumped rainfall-runoff analysis. Growth factors estimated at this location will be applied to QMED estimated at all inflow locations, in order to ensure consistency across the catchment. Design hydrographs will be derived by scaling ReFH2

	hydrographs to match the appropriate peaks, with a consistent design storm applied to all sub-catchments and intervening areas.
Software to be used (with version numbers)	CEH FEH Web-Service WINFAP-FEH v4.0 ReFH2.2

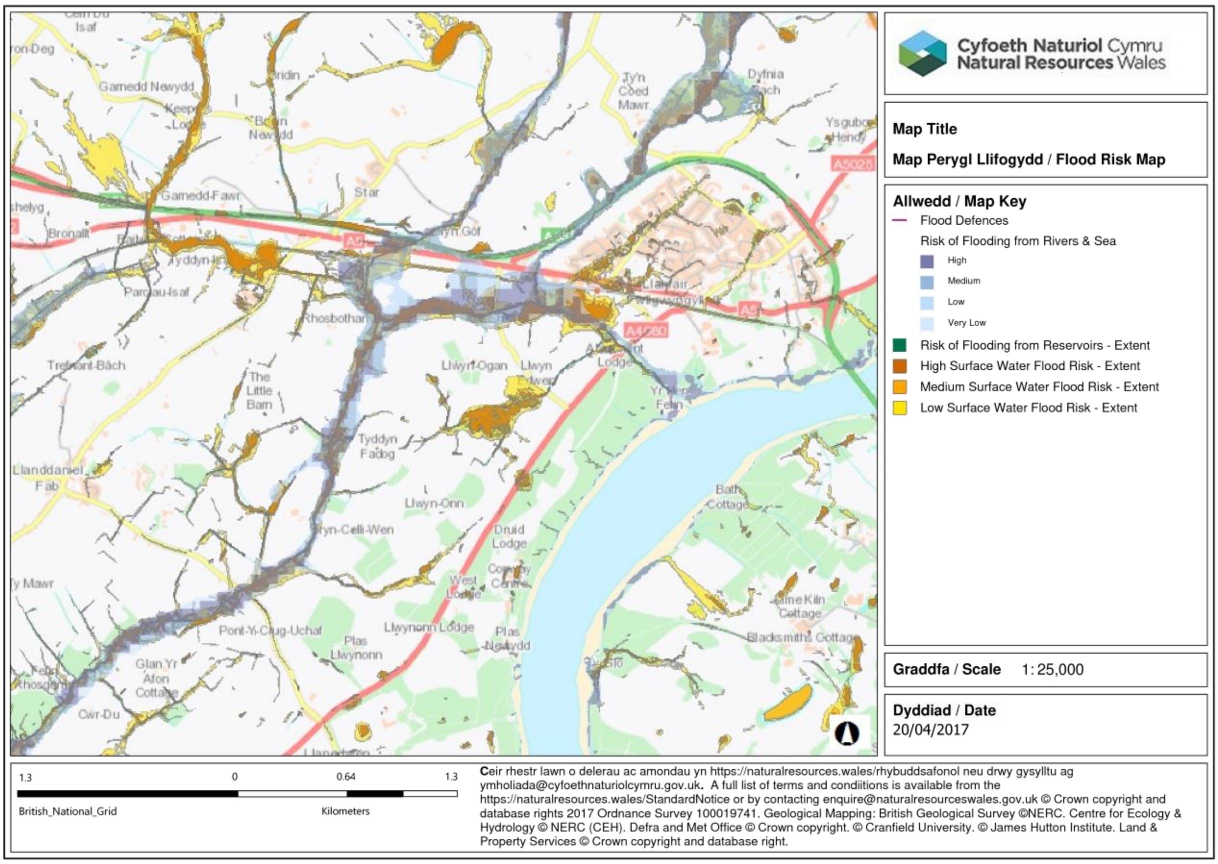

Figure 1 NRW flood risk map in the Afon Braint catchment. The site of interest is located near Llwyn-Ogan.

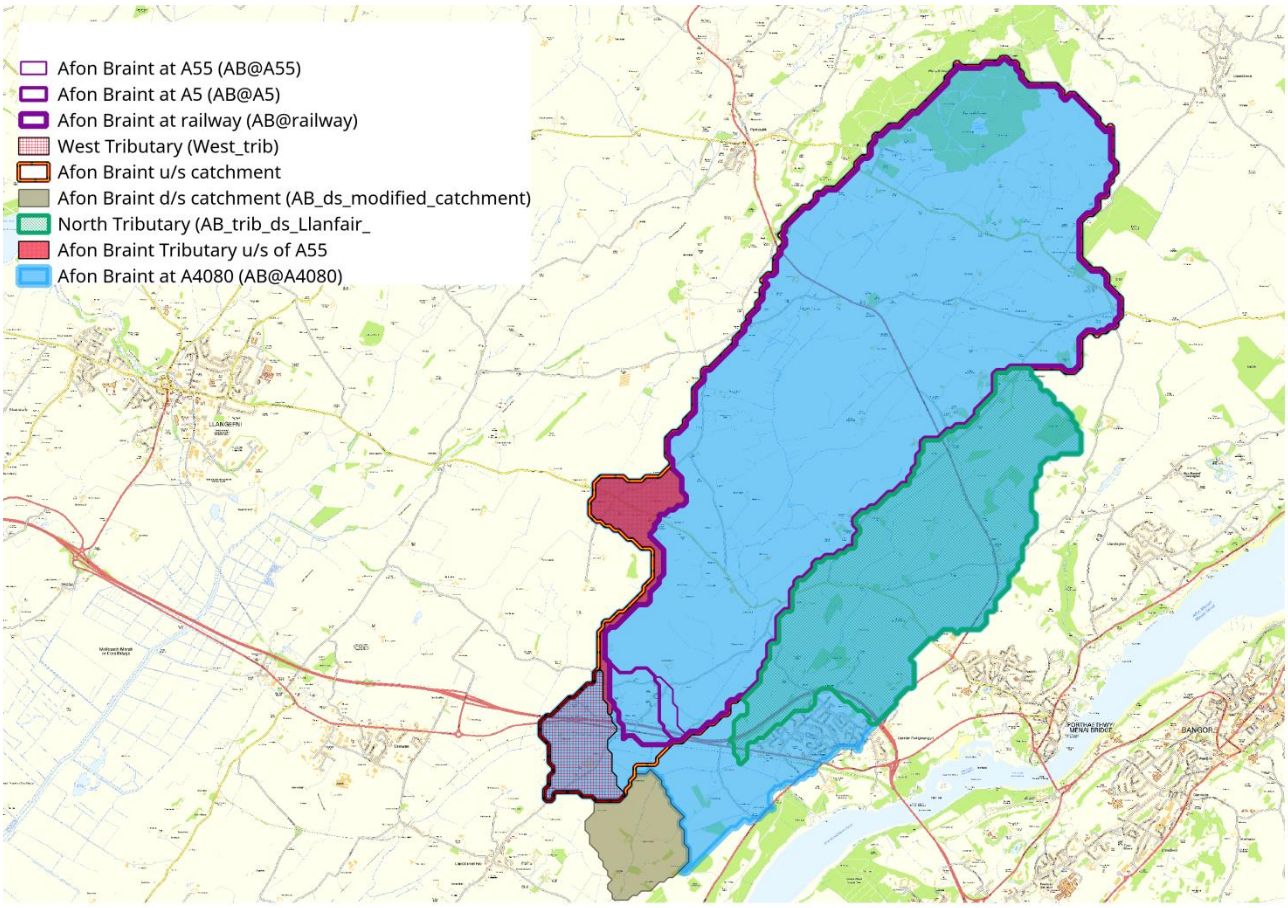

Figure 2 Schematization of FEH hydrological catchments in the area of interest.

2 Locations where flood estimates required

The table below lists the locations of subject sites. The site codes listed below are used in all subsequent tables to save space.

2.1 Summary of subject sites

Site code	Watercourse	Site	Easting	Northing	AREA on FEH CD-ROM (km^2)	Revised AREA if altered
Inflow estimation nodes						
AB@A55	Afon Braint	u/s of A55	251600	371900	18.743	19.428
AB@A5	Afon Braint	u/s of A5	251450	371850	18.858	0.115*
AB@railway	Afon Braint	u/s of railway	251250	371750	19.26	0.403*
West_trib	West tributary of the Afon Braint	West of road crossing	250750	371700	0.833	
AB_i	Afon Braint	Intervening area in the Afon Braint catchment at the location of the south-west diversion, between the railway, the west tributary and the southern boundary at Bryncelli Ddu	250850	370050		1.267
AB_trib_ds_Llanfair	North tributary of the Afon Braint	North tributary of the Afon Braint flowing west of Llanfair and confluence with Afon Braint	252250	371550	6.37	
Drain@A4080	Field drain	field drain flowing north-east through Llywyn Adwen, east of Llwyn-Ogan and joining the Afon Braint just west of the A4080	252637	371293		0.46
AB@A4060i	Afon Braint	Intervening area between the Afon Braint aggregated catchment at the south-west diversion, the north tributary and the A4080	252700	371300	0.963	0.503**
Additional catchments used in the assessment of catchment descriptors for the inflow estimation nodes						
AB_us_catchment	Afon Braint	Afon Braint u/s catchment at diversion	251250	371550	20.988	
AB_ds_modified_catchment	Afon Braint	Afon Braint d/s modified catchment south of diversion	250850	370050	1.058	

Site code	Watercourse	Site	Easting	Northing	AREA on FEH CD-ROM (km^2)	Revised AREA if altered
AB_aggregated	Afon Braint	Aggregated catchment including Afon Braint natural catchment at diversion and southern modified catchment at Bryncelli Ddu	250850	370050	22.045	
AB@A4080	Afon Braint	Afon Braint natural catchment u/s of A4080	252700	371300	29.378	
Reasons for choosing above locations		Appropriate to the scale of study and to the requirements of the hydraulic modelling.				
Comments		*Catchment areas at AB@A5 and AB@railway have been revised for the purpose of inflow estimation; the revised catchment areas are for the intervening areas from the u/s estimation points. **The intervening catchment area at AB@A4080i has been reduced to account for the catchment area (estimated from OSMapping and LiDAR) of the field drain flowing north-east through Llywyn Adwen, east of Llwyn-Ogan and joining the Afon Braint just west of the A4080 (Drain@A4080). The field drain catchment area has been considered separately in the inflow estimation process.				

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

Site code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPRHOST	URBEXT 2000	FPEXT
AB@A55	0.994	0.45	0.461	5.08	52.1	1054	40.2	0.0012	0.1379
AB@A5	0.994	0.45	0.461	6.31	52.1	1054	40.2	0.0012	0.1379
AB@railway	0.994	0.45	0.461	6.46	52.3	1054	40.19	0.0012	0.1369
West_trib	1	0.45	0.4	0.74	43.2	1067	40.47	0	0.0961
AB_i	0.994	0.45	0.429	1.14	28.7	1060	40.26	0	0.1217
AB_trib_ds_Llanfair	1	0.45	0.51	3.65	35	1084	39.98	0.0078	0.0938
Drain@A4080	0.996	0.45	0.511	0.653	16.5	1115	40.13	0.014	0.2673
AB@A4080i	0.996	0.45	0.511	0.686	16.5	1115	40.13	0.355	0.2673
AB_us_catchment	0.994	0.45	0.459	6.29	51.3	1056	40.2	0.0011	0.1325
AB_ds_modified_catchment	1	0.45	0.434	1.07	27.4	1066	40.3	0	0.1087

Site code	FARL	PROP WET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPRHOST	URBEXT 2000	FPEXT
AB_aggregated	0.994	0.45	0.458	5.45	50.2	1056	40.2	0.001	0.1314
AB@A4080	0.996	0.45	0.471	6.73	45.8	1064	40.15	0.014	0.1277

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (refer to maps if needed)	FEH catchment boundaries were checked using the LiDAR DTM and local knowledge of flow paths and artificial influences. The catchment area at AB@A55 has been modified to include the catchment area of a small tributary (A=0.685km^2) joining the Afon Braint u/s of the A55 as shown on the background OS map (see Figure 2). For model inflow estimation purposes the catchment area at AB@A5 and AB@railway has been modified to include only the intervening area from the u/s estimation node (see Figure 2). It should be noted that the FEH catchment area at AB@railway (d/s of A55) does not include the u/s tributary catchment area and, therefore, the revised catchment area at AB@A55 is larger than the unmodified FEH catchment areas at AB@A5 and AB@railway. The intervening catchment area between the railway and Bryncelli Ddu (AB_i) has been estimated from the total catchment area of the aggregated Afon Braint catchment at the diversion (Afon Braint upstream catchment at the location of the diversion plus downstream modified catchment), taking into account the u/s catchments explicitly accounted for in the inflow estimation process (AB@A55, intervening area at AB@A5, intervening area at AB@railway and West_trib). The catchment area of the field drain joining the Afon Braint west of the A4080 (Drain@A4080) has been estimated from LiDAR and OS mapping. The intervening catchment area west of the A4080 (AB@A4080i) has been estimated from the overall catchment area (AB@AB4080) and the u/s catchments AB_aggregated and AB_trib_ds_Llanfair (tributary flowing to the west of Llanfair), reduced by the catchment area of the field drain.
Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary.	URBEXT and FARL for FEH catchments have been checked against OS Open Data background map (1:10000) and found to be appropriate. Soil properties have not been explicitly checked against soil maps, but have been found to be regionally consistent. DPLBAR for the catchment at AB@A55 has been modified to account for the revised catchment area according to DPLBAR=A^0.548. Catchment descriptors for the intervening area between the railway and Bryncelli Ddu (AB_i) have been estimated by area weighting from the catchment descriptors of the d/s and u/s catchments. Similarly, catchment descriptors for the intervening catchment area west of the A4080 (AB@A4080i) have been estimated by area weighting from catchment descriptors of the u/s and d/s catchments, with DPLBAR modified to account for the reduced catchment area. According to its URBEXT2000 value of 0.355, this intervening area is very heavily urbanised, due to the presence of the urban area of Llanfair. Catchment descriptors for the drain field catchment have been set consistent with the intervening area at A4080 with the only exception of URBEXT2000 which has been set to the same value as the overall catchment value of 0.014.
Source of URBEXT	URBEXT2000 for Statistical and ReFH2
Method for updating of URBEXT	URBEXT2000 values in 2.2 are the FEH values updated according to Equation 5.5 of Technical Report FD1919/TR (URBEXT2000)

3 Statistical method

3.1 Search for donor sites for QMED (if applicable)

Comment on potential donor sites Mention: • Number of potential donor sites available • Distances from subject site • Similarity in terms of AREA, BFIHOST, FARL and other catchment descriptors • Quality of flood peak data Include a map if necessary. Note that donor catchments should usually be rural.	The following NRFA gauges have been assessed as potential donors for QMED estimation: 65006, 65004, 65001, 65007, 66011, 65005. The potentially suitable donor sites are all within a maximum distance of 35km from the subject sites. Sites 65006, 65004 and 65001 are characterized by a flood response affected by attenuation from reservoirs/lakes, as indicated by the low FARL values. FEH guidelines suggest caution in applying the donor transfer process to/from catchments with FARL<0.95. Despite the low FARL value, site 65006 has been gauged to within 12% of QMED and information provided by the NRFA supports its use as donor. For gauge 65004, information on the NRFA suggests uncertainty on rating as this does not fit gaugings well. Therefore, the gauge has been discarded as donor. For gauge 65001, information on the NRFA also suggests uncertainty on rating, with multiple ratings applied across period of record, early ratings unverified and ratings not considering out of bank flow (see also 1.5). Gauges 65007, 66011 and 65005 have also been further assessed as potential donors for the subject sites and found to be suitable (see also 1.5) according to their similarity with the subject sites and information provided by the NRFA. QMED adjustment by donor transfer has been carried out at AB@railway, West_trib, AB_trib_ds_Llanfair and AB@A4080. QMED at AB@railway has been estimated for the unrevised FEH catchment area at the estimation node (19.26km^2) and this is referred to as AB@railway(FEH) in table 3.3 below. For the purpose of inflow estimation, QMED at AB@A55, AB@A5, AB@railway (revised catchment area of 0.403km^2) and for the intervening area at ABi has been obtained by scaling QMED at AB@railway(FEH) by the ratio of catchment areas. Similarly, QMED for the intervening area at AB@A4080i and for the field drain Drain@A4080 has been obtained by scaling QMED at AB@A4080 by the ratio of catchment areas.

3.2 Donor sites chosen and QMED adjustment factors

NRFA no.	Reasons for choosing or rejecting	Method (AM or POT)	Adjust-ment for climatic variation?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjust-ment ratio (A/B)
65006	See 3.1	AM	No	48.007	40.004	1.200
65004	See 3.1	AM	No	20.888	32.233	0.648
65001	See 3.1	AM	No	89.942	63.065	1.426
65007	See 3.1	AM	No	41.160	51.753	0.795
66011	See 3.1	AM	No	378.062	291.218	1.298
65005	See 3.1	AM	No	10.848	15.597	0.696

<table>
<tr><th>NRFA no.</th><th>Reasons for choosing or rejecting</th><th>Method (AM or POT)</th><th>Adjust-ment for climatic variation?</th><th>QMED from flow data (A)</th><th>QMED from catchment descriptors (B)</th><th>Adjust-ment ratio (A/B)</th></tr>
<tr><td colspan="4">Which version of the urban adjustment was used for QMED at donor sites, and why?
Note: The guidelines recommend great caution in urban adjustment of QMED on catchments that are also highly permeable (BFIHOST>0.8).</td><td colspan="3">WINFAP 4 estimated UAF * urban adjustment was not carried out at donor sites and the rural estimate of QMED was used to estimate the adjustment ratio for the selected essentially rural donor sites (FEH Volume 3, 4.6.1).</td></tr>
</table>

3.3 Overview of estimation of QMED at each subject site

<table>
<tr><th rowspan="3">Site code</th><th rowspan="3">Method</th><th rowspan="3">Initial estimate of QMED (m^3/s)</th><th colspan="6">Data transfer</th><th rowspan="3">Final estimate of QMED (m^3/s)</th></tr>
<tr><th rowspan="2">NRFA numbers for donor sites used (see 3.3)</th><th rowspan="2">Distance between centroids d_{ij} (km)</th><th rowspan="2">Power term, a</th><th rowspan="2">Moderated QMED adjustment factor, (A/B)[a]</th><th colspan="2">If more than one donor</th></tr>
<tr><th>Weight</th><th>Weighted average adjustment factor</th></tr>
<tr><td colspan="10"></td></tr>
<tr><td rowspan="4">AB@railway (FEH)</td><td rowspan="4">DT</td><td rowspan="4">8.862</td><td>65006</td><td>16.14</td><td>0.333</td><td>1.063</td><td>1</td><td rowspan="4">1.012</td><td rowspan="4">8.978 (accounting for UAF=1.002)</td></tr>
<tr><td>65007</td><td>30.22</td><td>0.251</td><td>0.944</td><td>1</td></tr>
<tr><td>66011</td><td>34.19</td><td>0.232</td><td>1.062</td><td>1</td></tr>
<tr><td>65005</td><td>35.64</td><td>0.225</td><td>0.922</td><td>1</td></tr>
<tr><td rowspan="4">West_trib</td><td rowspan="4">DT</td><td rowspan="4">0.748</td><td>65006</td><td>13.59</td><td>0.351</td><td>1.066</td><td>1</td><td rowspan="4">1.003</td><td rowspan="4">0.750 (UAF=1)</td></tr>
<tr><td>65007</td><td>26.27</td><td>0.272</td><td>0.940</td><td>1</td></tr>
<tr><td>66011</td><td>30.62</td><td>0.249</td><td>1.067</td><td>1</td></tr>
<tr><td>65005</td><td>33.95</td><td>0.233</td><td>0.919</td><td>1</td></tr>
<tr><td rowspan="4">AB_trib_ds_Llanfair</td><td rowspan="4">DT</td><td rowspan="4">3.201</td><td>65006</td><td>13.94</td><td>0.349</td><td>1.066</td><td>1</td><td rowspan="4">1.013</td><td rowspan="4">3.272 (accounting for UAF=1.009)</td></tr>
<tr><td>65007</td><td>28.11</td><td>0.262</td><td>0.942</td><td>1</td></tr>
<tr><td>66011</td><td>32.31</td><td>0.241</td><td>1.065</td><td>1</td></tr>
<tr><td>65005</td><td>33.97</td><td>0.233</td><td>0.919</td><td>1</td></tr>
<tr><td rowspan="4">AB@A4080</td><td rowspan="4">DT</td><td rowspan="4"></td><td>65006</td><td>15.26</td><td>0.339</td><td>1.064</td><td>1</td><td rowspan="4">1.011</td><td rowspan="4">12.965 (accounting for UAF=1.015)</td></tr>
<tr><td>65007</td><td>29.27</td><td>0.256</td><td>0.943</td><td>1</td></tr>
<tr><td>66011</td><td>33.63</td><td>0.235</td><td>1.063</td><td>1</td></tr>
<tr><td>65005</td><td>34.72</td><td>0.230</td><td>0.920</td><td>1</td></tr>
<tr><td colspan="10"></td></tr>
<tr><td>AB@A55</td><td>Scaled by catchment area</td><td colspan="7">QMED = 8.978 * (19.428/19.26)</td><td>9.056</td></tr>
<tr><td>AB@A5</td><td>Scaled by catchment area</td><td colspan="7">QMED = 8.978 * (0.115/19.26)</td><td>0.054</td></tr>
<tr><td>AB@railway</td><td>Scaled by catchment area</td><td colspan="7">QMED = 8.978 * (0.403/19.26)</td><td>0.188</td></tr>
<tr><td>AB_i</td><td>Scaled by catchment area</td><td colspan="7">QMED = 8.978 * (1.268/19.26)</td><td>0.591</td></tr>
<tr><td>Drain@A4080</td><td>Scaled by catchment area</td><td colspan="7">QMED = 12.965 * (0.46/29.378)</td><td>0.203</td></tr>
<tr><td>AB@A4060i</td><td>Scaled by catchment area</td><td colspan="7">QMED = 12.965 * (0.503/29.378)</td><td>0.222</td></tr>
<tr><td colspan="6">Are the values of QMED consistent, for example at successive points along the watercourse and at confluences?</td><td colspan="4">Yes. QMED for AB_aggregated obtained by scaling QMED@railway(FEH) by ratio of catchment areas is 10.276 m^3/s, which summed to QMED for AB_trib_ds_Llanfair and</td></tr>
</table>

<table>
<tr><th rowspan="3">Site code</th><th rowspan="3">Method</th><th rowspan="3">Initial estimate of QMED (m^3/s)</th><th colspan="6">Data transfer</th><th rowspan="3">Final estimate of QMED (m^3/s)</th></tr>
<tr><th rowspan="2">NRFA numbers for donor sites used (see 3.3)</th><th rowspan="2">Distance between centroids d_{ij} (km)</th><th rowspan="2">Power term, a</th><th rowspan="2">Moderated QMED adjustment factor, $(A/B)^a$</th><th colspan="2">If more than one donor</th></tr>
<tr><th>Weight</th><th>Weighted average adjustment factor</th></tr>
<tr><td colspan="6"></td><td colspan="4">Drain@A4080 produces a total QMED of 13.751 m^3/s upstream of the A4080. This is larger than QMED at AB@A4080 of 12.965 m^3/s.</td></tr>
<tr><td colspan="6">Which version of the urban adjustment was used for QMED, and why?</td><td colspan="4">WINFAP 4 estimated UAF, latest update to recommended Kjeldsen (2010)</td></tr>
<tr><td colspan="10">Notes
Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer; CD – Catchment descriptors alone.
When QMED is estimated from POT data, it should also be adjusted for climatic variation. Details should be added.
When QMED is estimated from catchment descriptors, the revised 2008 equation from Science Report SC050050 should be used. If the original FEH equation has been used, say so and give the reason why.
The guidelines recommend great caution in urban adjustment of QMED on catchments that are also highly permeable (BFIHOST>0.8). The adjustment method used in WINFAP-FEH v3.0.003 is likely to overestimate adjustment factors for such catchments. In this case the only reliable flood estimates are likely to be derived from local flow data.
The data transfer procedure is from Science Report SC050050. The QMED adjustment factor A/B for each donor site is given in Table 3.3. This is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is $(A/B)^a$ times the initial estimate from catchment descriptors.
If more than one donor has been used, use multiple rows for the site and give the weights used in the averaging. Record the weighted average adjustment factor in the penultimate column.</td></tr>
</table>

3.4 Derivation of pooling groups

The composition of the pooling groups is given in the Annex. Several subject sites may use the same pooling group.

Name of group	**Site code from whose descriptors group was derived**	**Subject site treated as gauged?** (enhanced single site analysis)	**Changes made to default pooling group, with reasons** Note also any sites that were investigated but retained in the group.	**Weighted average L-moments**, L-CV and L-skew, (before urban adjustment)

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged? (enhanced single site analysis)	Changes made to default pooling group, with reasons Note also any sites that were investigated but retained in the group.	Weighted average L-moments, L-CV and L-skew, (before urban adjustment)
AB@railway(FEH)	AB@railway	No	The default pooling group is "possibly heterogeneous and a review is optional". None of the stations is discordant and station 20002 only is characterized by a discordancy value (2.595) close to the threshold (2.971). However, further analysis of the characteristics of the station and associated data at this site does not justify its removal from the default pooling group. The distribution of L-moments within the pooling group was examined and sites 203046, 72014, 73015, 76811, 44008 and 25019 were further assessed in terms of station and data characteristics/quality. Information provided by the NRFA on ratings and data supports the use of all sites except 25019 in pooling. For site 25019 the maximum gauged flow is well below QMED and the station does not appear to be reliable enough to be used in pooling. The station has, therefore, been removed from the default pooling group. Sites 48009 and 28041, selected on the basis of their hydrological similarity with the subject site, have been added to the pooling group. According to its heterogeneity value, a review of the revised pooling group is optional. None of the sites in the revised pooling group is discordant.	L-CV=0.230 L-Skew=0.207
Comments: the pooling group has been derived for the unrevised FEH catchment AB@railway (catchment area = 19.26km^2). Growth factors estimated at this location have been applied to QMED estimated at all inflow locations, in order to ensure consistency across the catchment.				
Notes Pooling groups were derived using the revised procedures from Science Report SC050050 (2008). Amend if not applicable. The weighted average L-moments, before urban adjustment, can be found at the bottom of the Pooling-group details window in WINFAP-FEH.				

3.5 Derivation of flood growth curves at subject sites

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group (3.4)	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution (location, scale and shape) after adjustments	Growth factor for 100-year return period
AB@railway (FEH)	P	AB@railway	GL, best fit (Z=-1.032). For GEV Z=-2.771.	Urban	Location=1 Scale=0.231 Shape=-0.207	2.774

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group (3.4)	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution (location, scale and shape) after adjustments	Growth factor for 100-year return period
Notes Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis A pooling group (or ESS analysis) derived at one gauge can be applied to estimate growth curves at a number of ungauged sites. Each site may have a different urban adjustment, and therefore different growth curve parameters. Urban adjustments to growth curves should use the version 3 option in WINFAP-FEH: Kjeldsen (2010). Growth curves were derived using the revised procedures from Science Report SC050050 (2008).						

3.6 Flood estimates from the statistical method

Site code	Flood peak (m^3/s) for the following return periods (in years)								
	2	5	10	25	50	100	200	500	1000
AB@railway(FEH)	8.978	12.309	14.751	18.306	21.386	24.905	28.936	35.212	40.814
AB@A55	9.056	12.416	14.879	18.465	21.572	25.122	29.188	35.518	41.169
AB@A5	0.054	0.073	0.088	0.109	0.128	0.149	0.173	0.210	0.244
AB@railway	0.188	0.257	0.308	0.383	0.447	0.520	0.605	0.736	0.853
West_Trib	0.750	1.028	1.232	1.529	1.787	2.081	2.417	2.942	3.410
AB_i	0.591	0.810	0.971	1.205	1.407	1.639	1.904	2.317	2.686
AB_trib_ds_Llanfair	3.272	4.486	5.376	6.672	7.794	9.077	10.546	12.833	14.875
AB@A4080i	0.222	0.304	0.364	0.452	0.528	0.615	0.715	0.870	1.008
Drain@A4080	0.203	0.278	0.334	0.414	0.484	0.563	0.654	0.796	0.923

4 Revitalised flood hydrograph (ReFH2.2) method

4.1 Parameters for ReFH2.2 model

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

Site code	Method: OPT: Optimisation BR: Baseflow recession fitting CD: Catchment descriptors DT: Data transfer (give details)	Tp (hours) Time to peak	C_{max} (mm) Maximum storage capacity	BL (hours) Baseflow lag	BR Baseflow recharge
AB@railway (FEH)	CD	3.94	347.94	41.99	1.25

Comments	Rainfall-runoff analysis has been carried out for the unrevised FEH catchment AB@railway.
Brief description of any flood event analysis carried out (further details should be given below or in a project report)	none

4.2 Design events for ReFH2.2 method

Site code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)	Storm area for ARF (if not catchment area)
AB@railway(FEH)	Rural	Winter	8.5 hr	
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?			A sensitivity analysis on the critical storm duration at the site of interest could be undertaken in the next stage of analysis, but this is not mandatory.	

4.3 Flood estimates from the ReFH2.2 method

Site code	Flood peak (m^3/s) for the following return periods (in years)								
	2	5	10	25	50	100	200	500	1000
AB@railway	6.625	8.507	10.399	13.718	16.59	19.669	22.947	27.585	31.343

5 FEH rainfall-runoff method

5.1 Parameters for FEH rainfall-runoff model

Methods:
FEA : Flood event analysis
LAG : Catchment lag
DT : Catchment descriptors with data transfer from donor catchment
CD : Catchment descriptors alone
BFI : SPR derived from baseflow index calculated from flow data

Site code	Rural (R) or urban (U)	Tp(0): method	Tp(0): value (hours)	SPR: method	SPR: value (%)	BF: method	BF: value (m^3/s)	If DT, numbers of donor sites used (see Section 5.2) and reasons

5.2 Donor sites for FEH rainfall-runoff parameters

No.	Watercourse	Station	Tp(0) from data (A)	Tp(0) from CDs (B)	Adjustment ratio for Tp(0) (A/B)	SPR from data (C)	SPR from CDs (D)	Adjust-ment ratio for SPR (C/D)
1								
2								

5.3 Inputs to and outputs from FEH rainfall-runoff model

Site code	Storm duration (hours)	Storm area for ARF (if not catchment area)	Flood peaks (m^3/s) or volumes (m^3) for the following return periods (in years)							
			2							
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?										

6 Discussion and summary of results

6.1 Comparison of results from different methods

This table compares peak flows from various methods with those from the FEH Statistical method at example sites for two key return periods. Blank cells indicate that results for a particular site were not calculated using that method.

Site code	Ratio of peak flow to FEH Statistical peak					
	Return period 2 years			Return period 100 years		
	ReFH2.2	Other method	Other method	ReFH2.2	Other method	Other method
AB@railway	6.625/8.978= 0.738			19.669/24.905=0.790		

6.2 Final choice of method

Choice of method and reasons – include reference to type of study, nature of catchment and type of data available.	QMED has been estimated from CDS and adjusted by donor transfer at AB@railway (FEH unrevised catchment), West_trib, AB_trib_ds_Llanfair and AB@A4080. For the purpose of inflow estimation, QMED at AB@A55, AB@A5, AB@railway (revised catchment area) and for the intervening area at ABi has been obtained by scaling QMED at AB@railway(FEH) by the ratio of catchment areas. Similarly, QMED for the intervening area at AB@A4080i and for the field drain Drain@A4080 has been obtained by scaling QMED at AB@A4080 by the ratio of catchment areas. Final peak flow estimates have been obtained by applying the ReFH ratio method, following best practice guidance from NRW[1]. Thus, the statistical peaks have been selected as final estimates for AEPs greater than and including the 1% AEP, while for less frequent events the growth curve from ReFH (version 2.2) is applied to the 1% AEP statistical peak estimate, i.e. for any AEP lower than 1%, the ratio of the ReFH2.2 peak flow to the 1% AEP ReFH peak flow is applied to the 1% AEP statistical peak flow. Design hydrographs at AB@A55, AB@A5, AB@railway, ABi, West_trib, AB_trib_ds_Llanfair have been obtained by scaling the ReFH2.2 hydrographs to match the final peak estimates and included as lumped inflows to the hydraulic model. Design hydrographs for ABi and AB@A4080i (also obtained by scaling the ReFH2.2 hydrographs to match the final peak estimate) have been added as lateral distributed inflows to the hydraulic model. A storm duration consistent with the recommended storm duration at AB@railway has been imposed across the catchment.

6.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	• Gauges used as donors are suitable for QMED according to the NRFA. • Suitability for pooling is based on HiFlows classification and the assessment of the quality of gauges is based on data and comments in the NRFA.
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed	• Statistical and ReFH2 method used up to the 1000 year return period. • ReFH model parameters are estimated from catchment descriptors; • Storm duration is set as uniform across all sub-catchments.

[1] NRW, 2016. Good Practice Guide. Technical Guidance: Flood Estimation.

Give what information you can on uncertainty in the results – e.g. confidence limits for the QMED estimates using FEH **3** 12.5 or the factorial standard error from Science Report SC050050 (2008).	Confidence intervals calculated according to SC050050[2] (4.6.2)

Node	QMED (m^3/s)	68% confidence		95% confidence	
		Lower	**Upper**	**Lower**	**Upper**
AB@railway(FEH)	8.978	6.274	12.848	4.384	18.385
West_trib	0.75	0.524	1.073	0.366	1.536
AB_trib_ds_Llanfair	3.272	2.287	4.682	1.598	6.700
AB@A4080	12.965	9.060	18.553	6.331	26.549

Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	The results are suitable for the purpose of flood risk assessment to the site of interest and generally in the area south-west of Llanfair in the lower Afon Braint catchment.
Give any other comments on the study, for example suggestions for additional work.	Estimates could be improved by local gauged data which is currently not available.

6.4 Checks

Are the results consistent, for example at confluences?	See 3.3
What do the results imply regarding the return periods of floods during the period of record?	Not applicable
What is the 100-year growth factor? Is this realistic? (The guidance suggests a typical range of 2.1 to 4.0)	**Node**: **AB@railway(FEH)**; **100yr flow/2yr flow**: 2.774
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	**Node**: **AB@railway(FEH)**; **1000yr flow/100yr flow**: 1.594
What range of specific runoffs (l/s/ha) do the results equate to? Are there any inconsistencies?	Not applicable
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	Not applicable, no data available
Are the results compatible with the longer-term flood history?	Not applicable, no data available
Describe any other checks on the results	No further checks were carried out

[2] DEFRA/EA, 2008. Improving the FEH statistical procedures for flood frequency estimation. Science Report: SC050050

6.5 Final results

Site code	Flood peak (m^3/s) for the following return periods (in years)								
	2	5	10	25	50	100	200	500	1000
AB@A55	9.056	12.416	14.879	18.465	21.572	25.122	29.310	35.233	40.030
AB@A5	0.054	0.073	0.088	0.109	0.128	0.149	0.173	0.209	0.237
AB@railway	0.188	0.257	0.308	0.383	0.447	0.520	0.607	0.730	0.829
West_Trib	0.750	1.028	1.232	1.529	1.787	2.081	2.427	2.918	3.315
AB_i	0.591	0.810	0.971	1.205	1.407	1.639	1.912	2.299	2.612
AB_trib_ds_Llanfair	3.272	4.486	5.376	6.672	7.794	9.077	10.590	12.730	14.463
AB@A4080i	0.222	0.304	0.364	0.452	0.528	0.615	0.718	0.863	0.980
Drain@A4080	0.203	0.278	0.334	0.414	0.484	0.563	0.657	0.790	0.897

Site code	1000+75 CC
AB@A55	70.053
AB@A5	0.415
AB@railway	1.451
West_Trib	5.802
AB_i	4.570
AB_trib_ds_Llanfair	25.310
AB@A4080i	1.715
Drain@A4080	1.570

If flood hydrographs are needed for the next stage of the study, where are they provided? (e.g. give filename of spreadsheet, name of ISIS model, or reference to table below)	Qt_f1000+75_Scaled_ReFHratio-Qpeaks.csv

7 ANNEX

Table 1 Default pooling group at AB@railway (FEH catchment). Sites highlighted in red have been removed.

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
203046 (Rathmore Burn @ Rathmore Bridge)	0.752	32	10.821	0.133	0.1	0.767
72014 (Conder @ Galgate)	0.874	47	17.703	0.196	0.049	0.765
73015 (Keer @ High Keer Weir)	0.958	24	12.187	0.164	0.008	1.182
20002 (West Peffer Burn @ Luffness)	1.12	41	3.299	0.292	0.015	2.595
41020 (Bevern Stream @ Clappers Bridge)	1.142	45	13.66	0.21	0.189	0.192
49003 (de Lank @ de Lank)	1.178	48	13.985	0.23	0.22	0.494
76811 (Dacre Beck @ Dacre Bridge)	1.219	14	35	0.194	0.263	2.326
72007 (Brock @ Upstream of a6)	1.259	36	29.438	0.193	0.236	1.559
48004 (Warleggan @ Trengoffe)	1.347	45	9.983	0.265	0.263	0.117
44008 (South Winterbourne @ Winterbourne Steepleton)	1.368	35	0.448	0.414	0.336	2.039
26802 (Gypsey Race @ Kirby Grindalythe)	1.375	15	0.109	0.284	0.27	0.153
27010 (Hodge Beck @ Bransdale Weir)	1.432	41	9.42	0.224	0.293	0.396
25019 (Leven @ Easby)	1.433	36	5.538	0.345	0.383	0.991
27032 (Hebden Beck @ Hebden)	1.44	48	3.923	0.206	0.265	0.424
Total		507				
Weighted means				0.237	0.205	

Table 2 Final pooling group at AB@railway (FEH catchment)

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
203046 (Rathmore Burn @ Rathmore Bridge)	0.752	32	10.821	0.133	0.1	0.87
72014 (Conder @ Galgate)	0.874	47	17.703	0.196	0.049	0.82
73015 (Keer @ High Keer Weir)	0.958	24	12.187	0.164	0.008	1.304
20002 (West Peffer Burn @ Luffness)	1.12	41	3.299	0.292	0.015	2.672
41020 (Bevern Stream @ Clappers Bridge)	1.142	45	13.66	0.21	0.189	0.127
49003 (de Lank @ de Lank)	1.178	48	13.985	0.23	0.22	0.506
76811 (Dacre Beck @ Dacre Bridge)	1.219	14	35	0.194	0.263	1.73
72007 (Brock @ Upstream of a6)	1.259	36	29.438	0.193	0.236	1.531
48004 (Warleggan @ Trengoffe)	1.347	45	9.983	0.265	0.263	0.126
44008 (South Winterbourne @ Winterbourne Steepleton)	1.368	35	0.448	0.414	0.336	2.79
26802 (Gypsey Race @ Kirby Grindalythe)	1.375	15	0.109	0.284	0.27	0.248
27010 (Hodge Beck @ Bransdale Weir)	1.432	41	9.42	0.224	0.293	0.323
27032 (Hebden Beck @ Hebden)	1.44	48	3.923	0.206	0.265	0.256
48009 (st Neot @ Craigshill Wood)	1.476	17	7.614	0.251	0.346	0.598
28041 (Hamps @ Waterhouses)	1.481	29	26.664	0.221	0.314	1.099
Total		517				
Weighted means				0.23	0.207	

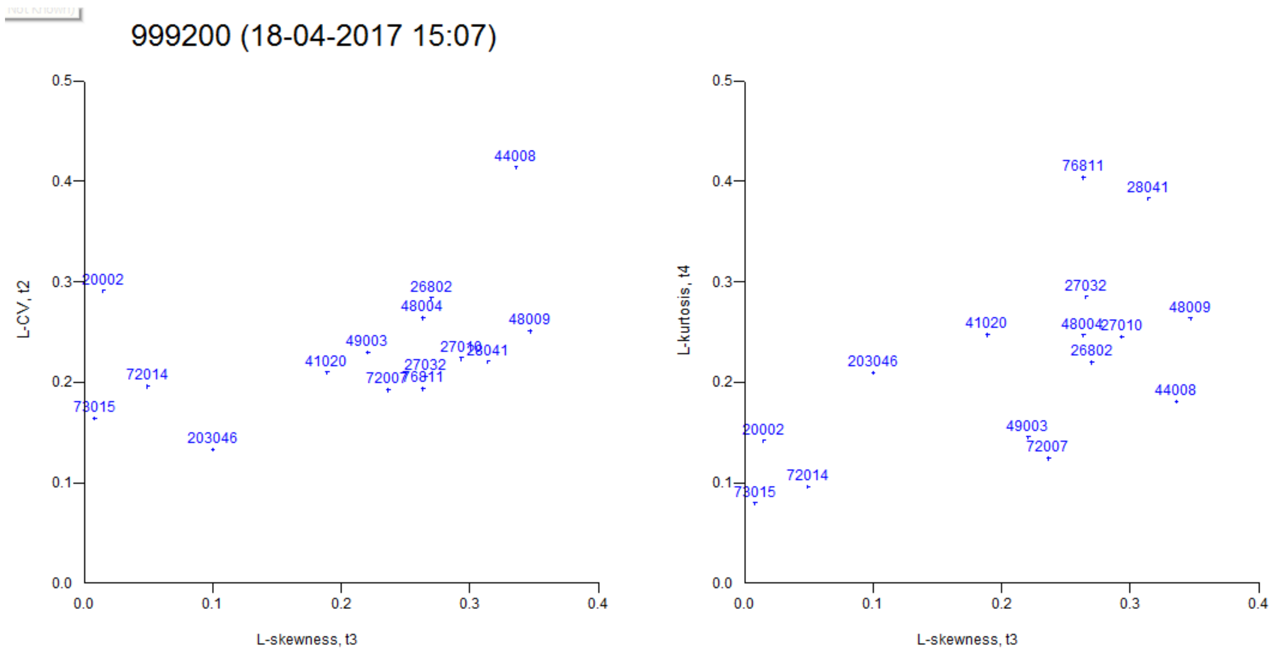

Figure 3 L-moments final pooling group at AB@railway (FEH catchment)

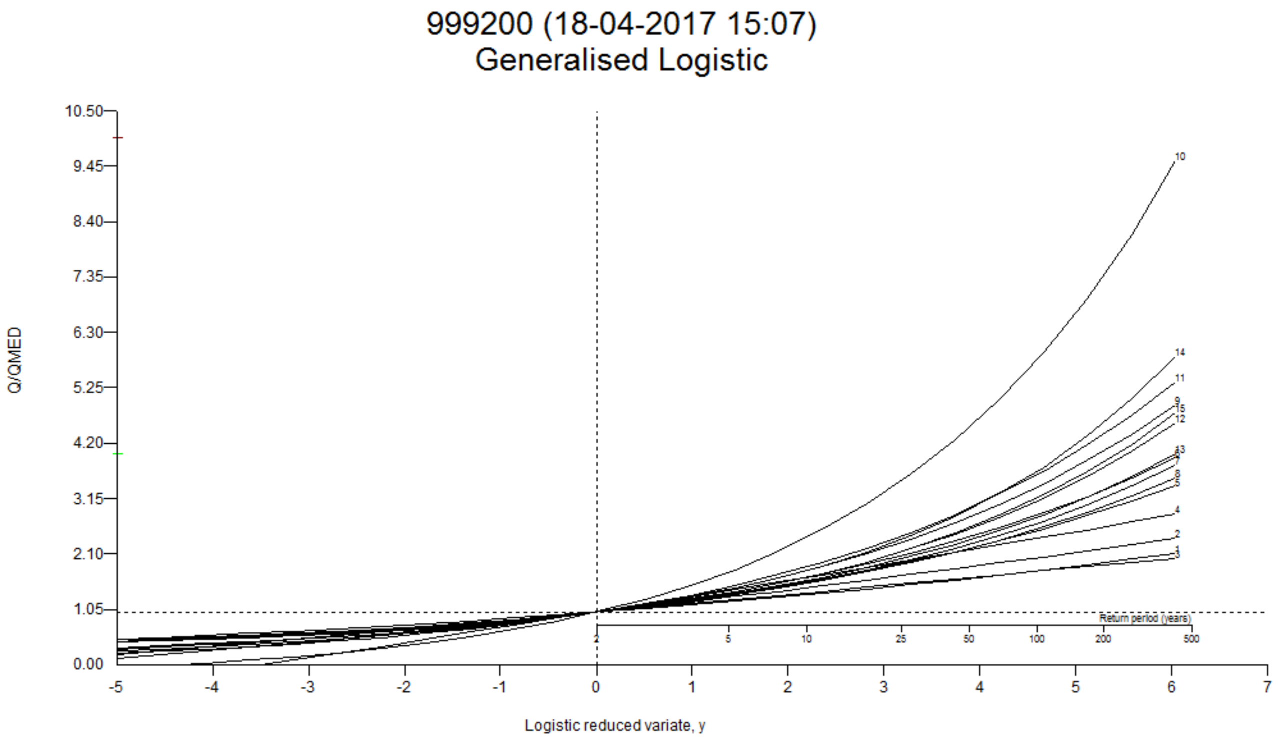

Figure 4 Growth curves final pooling group at AB@railway

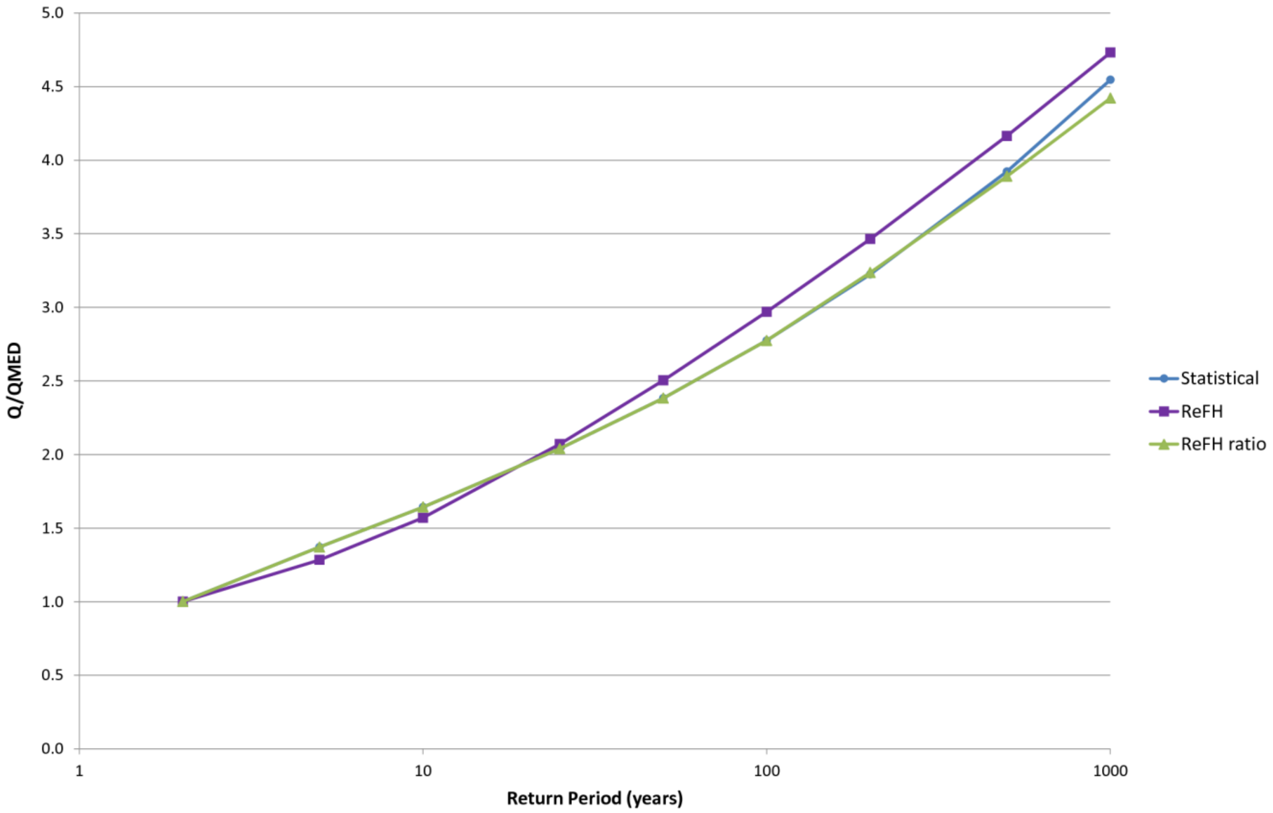

Figure 5 Growth curves from statistical analysis ReFH (2.2) rainfall-runoff analysis and ReFH ratio method at AB@railway (FEH catchment).

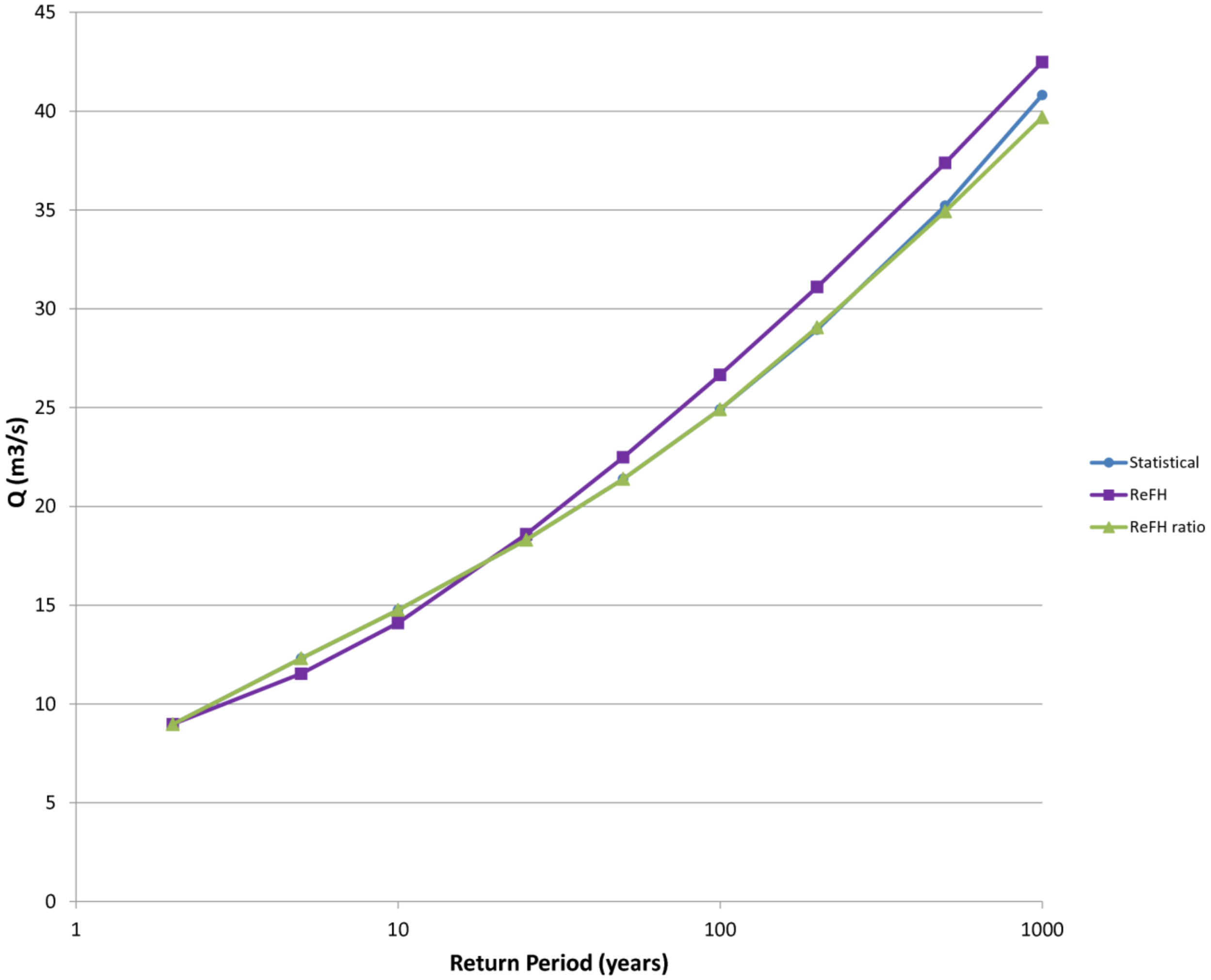

Figure 6 Flood frequency curves from statistical analysis ReFH (2.2) rainfall-runoff analysis and ReFH ratio method at AB@railway (FEH catchment).

Annex B

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nationalgrid

North Wales Connection Project

Volume 5

5.12.2.3 Annex B Outline Drainage Strategy

National Grid
National Grid House
Warwick Technology Park
Gallows Hill
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Final September 2018

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Document Control			
Document Properties			
Organisation	Mott MacDonald		
Author	E. Stanley		
Approved by	J Weeks		
Title	Outline Drainage Strategy		
Document Reference	356526/PWR/PTD/007		
Version History			
Date	**Version**	**Status**	**Description/Changes**
September 2018	Rev A	Final	Final for submission

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Contents

1 Introduction 1

1.1 Project overview

1.2 Disclaimer

1.3 Report scope 1

1.4 Ty Fodol and Braint Permanent Compound Components 1

2 Site Description 2

2.1 Site location 2

2.2 Site Description 2

3 Drainage Strategy 9

3.1 Surface water drainage strategy 9

3.2 Foul water drainage strategy 15

4 Conclusions and recommendations 17

4.1 Conclusions 17

4.2 Recommendations 18

IMAGES	
Image 1	Existing aerial imagery (Tŷ Fodol site)
Image 2	Existing aerial imagery (Braint site)
Image 3	Indicative watercourse route
Image 4	Contour Plan and Flow Direction for Existing Tŷ Fodol Site
Image 5	Contour Plan and Flow Direction for Existing Braint Site

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1 Introduction

1.1 REPORT SCOPE

1.1.1 The purpose of this report is to summarise the proposed drainage strategy (surface water, groundwater, and foul water) for the following works:

- Tunnel Head House and Sealing End Compounds THH/CSECs and associated access roads.
- Temporary construction compounds and associated haul roads.

1.1.2 This report is intended to be used to inform the Flood Consequence Assessment (FCA). The designs detailed within this report are preliminary and would be subject to detailed design.

1.2 TY FODOL AND BRAINT THH/CSECS

1.2.1 The permanent Sealing End Compounds include the following:

- Above-ground electrical equipment and gantries
- Modular building for Low Voltage Alternating Current (LVAC) and communications
- Distribution Network Operator (DNO) Supply
- Access road(s)

1.2.2 The permanent Tunnel Compounds include the following:

- Tunnel shaft / slab (finished above ground level)
- Tunnel headhouse
- Concrete culverts and troughs for electricity cables
- Transformers
- Access road(s)

2 Site Description

2.1 SITE LOCATION

2.1.1 The Proposed Development consists of two THH/CSEC site locations. The two sites are:

- Tŷ Fodol (Gwynedd) and
- Braint (Anglesey)

2.1.2 The Ordnance Survey Grid Reference for the proposed sites are listed below:

- Tŷ Fodol – SH 55215 68251
- Braint – SH 52391 71211

2.1.3 Site location plans are shown on Drawings DCO_DE/PS/09_02 and DCO_DE/PS/09_06 (**Document 4.13**) for Braint and Tŷ Fodol respectively.

2.2 SITE DESCRIPTION

Existing Site Conditions

2.2.1 The Tŷ Fodol site is currently two grass-covered fields, bordered with hedges, and is accessed off Fodolydd Lane. Aerial imagery of the existing Tŷ Fodol site is shown in Image 1.

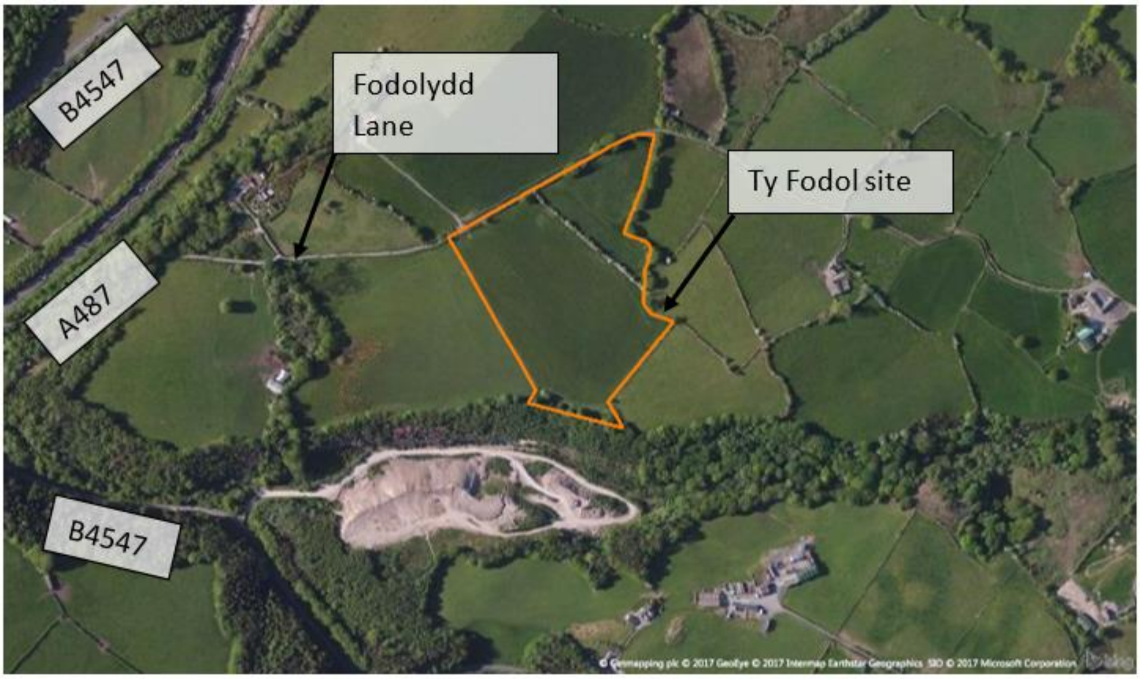

Image 1 Existing aerial imagery (Tŷ Fodol site)

2.2.2 The Braint site is currently a grass-covered field, bordered with hedges, and is accessed off A4080 Ffordd Brynsiencyn. Aerial imagery of the existing Braint site is shown in Inage 2.

Inage 2 Existing aerial imagery (Braint site)

Proposed Surface Finishes

2.2.3 The proposed construction materials for the permanent and construction compounds and access/haul roads are provided in Table 2.1.

Table 2.1: Indicative construction materials for proposed surface finishes

Section of works	Proposed surface finish
Permanent Compounds	Grass and porous granular material, with small areas of concrete troughing, a headhouse building structure located over the Tunnel shafts, and small buildings for LVAC and Communications.
Permanent Access Roads	Asphalt
Temporary Construction Compounds	Asphalt (at the contractor's discretion)
Temporary Haul Roads	Granular Material or asphalt (at the contractor's discretion)

Existing Topography

Tŷ Fodol

2.2.4 Existing levels across the site fall from east to west from approximately 90m AOD to 76 m AOD (taken from LiDAR).

Braint

2.2.5 Existing levels across the site fall from west to east from approximately 39m AOD to 34 m AOD (taken from LiDAR).

Existing Geology

2.2.6 Intrusive Ground Investigations (GI) and permeability testing have now been completed. In addition, one year of groundwater monitoring data has been collected and is still on-going at time of writing this report. Groundwater monitoring has been undertaken along the tunnel route and at the construction compounds, but it has not been undertaken for haul road routes. The GI logs indicate that there are superficial deposits on both sites, which are comprised of glacial till. The glacial till is variable both in composition and thickness. The till comprises of a mixture of clays, sands, gravels, and boulders. The thickness of the till also varies; boreholes indicate the thickness of glacial till around the Braint headhouse to range between 4.8 m and 10.2 m and boreholes proximal to the Tŷ Fodol headhouse indicate the glacial till to range from 0.9 to 4.35m thickness.

2.2.7 The bedrock differs between the two sites. The bedrock underlying the Tŷ Fodol headhouse is comprised of Tuff while the bedrock underlying the Braint Headhouse is comprised of Mica Schist.

2.2.8 Soakage tests were undertaken in general accordance with the recommended practice given in BRE Digest 365 at approximately 2m below ground level (bgl). Results in trial pits and boreholes suggest moderate to high infiltration potential (fast inflow to $1x10^{-6}$ m/s) at the Braint compound and moderate to high infiltration potential ($4x10^{-4}$ m/s to $1x10^{-6}$ m/s) at Tŷ Fodol. Infiltration results are provided in the Phase 2 Factual Report on Ground Investigation Report 732147 Groundwater levels are between about 0 and 3.5m bgl at the Braint compound and 0 and 2.8 m bgl at Tŷ Fodol compound.

Existing Hydrology

Tŷ Fodol

2.2.9 The nearest watercourse to the site is an unnamed drainage ditch which is located approximately 50 m south of the southern site perimeter, in a deep ravine (approximately 30 m deep, with a 1:1.5 approx. slope). The unnamed drainage ditch flows in a westerly direction where it outfalls into the Nant y Garth watercourse.

Braint

2.2.10 The nearest watercourse to the site is an unnamed watercourse which is located approximately 200 m south-east. The watercourse flows in a northeast direction where it outfalls into The Menai Strait. The Afon Braint (main river) is located approximately 300 m west of the site.

Existing Drainage

Tŷ Fodol

2.2.11 A site walkover survey was carried out on 4th May 2016 (dry weather) and it was observed that the existing site appeared to be free draining with no artificial systems evident at ground level. The presence of below ground land drainage could not be confirmed and should be investigated further during detailed design. Overland flow accumulated at a low point approximately 280 m from the proposed site location, where it was assumed to infiltrate into the ground.

2.2.12 Review of Ordinance Survey maps and a follow up site visit on 14th March 2017, highlighted the presence of a small watercourse in this location, which passes under Fodolydd Lane through a culvert. It is assumed that this watercourse eventually outfalls into the watercourse parallel to the B4547. See Image 3 for assumed watercourse route under Fodolydd Lane and to the watercourse parallel to the B4547.

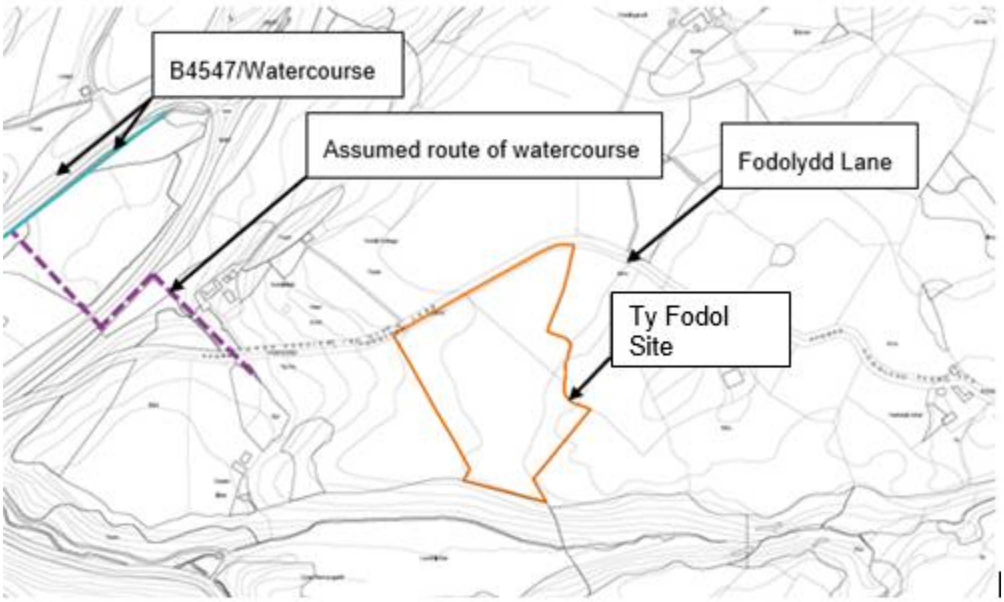

Image 3 Indicative watercourse route

2.2.13 Existing contours (taken from LiDAR in November 2015) and assumed overland flow routes for the site are shown in Image 4:

Image 4 Contour Plan and Flow Direction for Existing Tŷ Fodol Site

<u>Braint</u>

2.2.14 A site walkover survey was carried out on 4th May 2016 (dry weather) and it was observed that the existing site appeared to be free draining with no artificial systems evident at ground level. The presence of below ground land drainage could not be confirmed and should be investigated further during detailed design. A further site visit on 14th March 2017 revealed localised areas of ponding in some fields and a hand-dug trench collecting water across a field near the proposed northern haul road. Overland flow accumulates at a low point 20 m from the proposed site location, where it was assumed to infiltrate into the ground. Existing contours (taken from LiDAR in November 2015) and assumed overland flow routes are shown in Image 5.

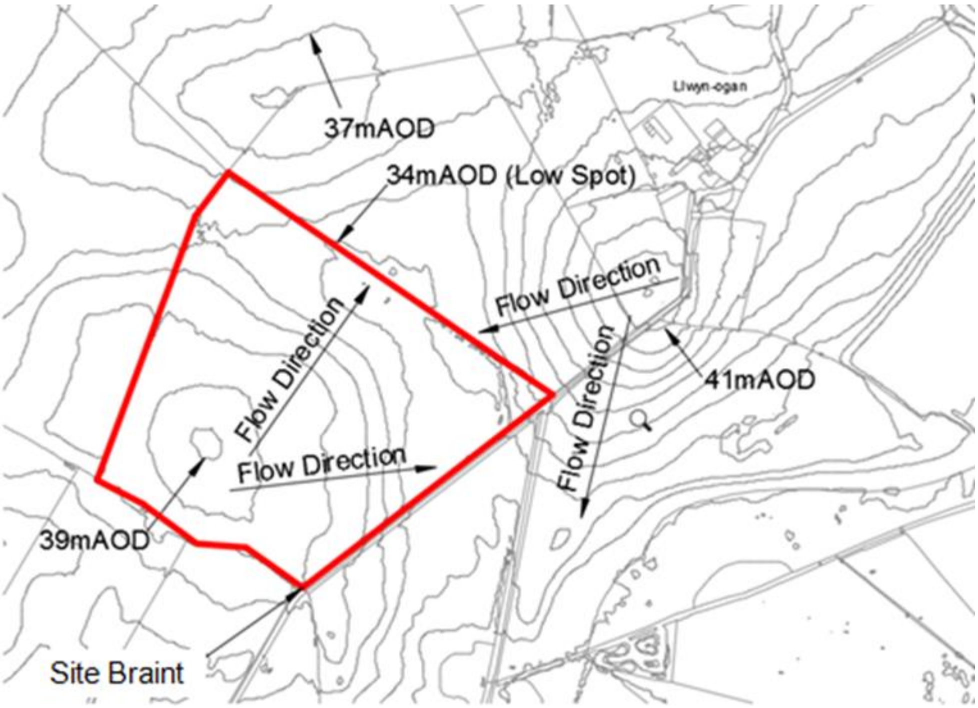

Image 5 Contour Plan and Flow Direction for Existing Braint Site

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3 Drainage Strategy

3.1 SURFACE WATER DRAINAGE STRATEGY

Permanent Sealing End compounds and tunnel compounds

Drainage principle

3.1.1 The proposed drainage layout for the permanent sites are shown on drawings DCO_DE/PS/09_02 and DCO_DE/PS/09_06 for Braint and Tŷ Fodol respectively. The drainage design completed to date is preliminary and subject to detailed design.

3.1.2 The new hardstanding areas in the form of access roads, multiple structures, and impermeable ground below the porous granular material, would increase surface water runoff. To effectively manage the quality and quantity of discharge offsite sustainable drainage features have been proposed, including attenuation basins and filter drains, coupled with traditional systems where necessary.

3.1.3 Flow control devices, storage and permanent pond volumes are proposed to attenuate and treat surface water prior to discharging into nearby watercourses. Infiltration was not considered viable when initially sizing the attenuation features to allow for adequate land take at master planning phase.

3.1.4 Subsequent soakaway tests have shown that there is a moderate to high infiltration potential at both Braint and Tŷ Fodol compound sites. However, seasonal groundwater monitoring shows that groundwater levels are high in both locations (0m-3.5 m bgl at Braint and 0m-2.8m bgl at Tŷ Fodol) which would make infiltration unfeasible as the sole means of discharge (note: infiltration features require a minimum clearance of 1 m above the groundwater table (CIRIA C753 The SUDS Manual). It may be necessary to line the ponds in order to exclude groundwater.

3.1.5 The potential for infiltration is to be reviewed further during detailed design stages, with emphasis on design exceedance routing should infiltration be considered.

3.1.6 Surface water entering the ponds would come from numerous sources:

- Runoff from the THH/CSEC would be collected in filter drains and downpipes respectively, before combining in a closed pipe system and discharging directly into the ponds.

- Runoff collected from the internal access roads would also drain directly to the ponds via a combination of gullies, filter drains, and open channels where practicable.

- Groundwater from the tunnel and shafts and surface water collecting in the transformer bunds would pass through oil separators (see paragraphs 3.1.9-11 for more information on oily water drainage) before discharging to the ponds or alternative treatment.

3.1.7 From the ponds, the water would discharge to the nearby watercourse via a flow control device and pollution control, such as an automated penstock or similar. The outfall would be retained from the construction phase to minimise construction costs and materials.

3.1.8 Runoff from the natural catchment is to be managed with ditches or land drains.

Oily drainage

3.1.9 Transformers have been located within the tunnel compound at both sites. These are oil-filled and therefore require a separate oily water drainage network. The transformers would be surrounded by a concrete bund, which would drain to the pond via a full retention Class 1 oil separator at both sites in accordance with National Grid Technical Specification T 2.20 *Oil containment at electricity substations and other operational sites*.

3.1.10 In accordance with National Grid Technical Specification T 2.20 *Oil containment at electricity substations and other operational sites,* a catastrophic failure main has been specified to drain the bund in the event of a failure. This is to be located 40 m-50 m away from the transformer bund. In addition, a Bund Water Control Unit shall be used to manage the quality of discharge.

3.1.11 Oil separators are to be positioned the recommended distance from the plant and headhouse in accordance with relevant standards/guidance, including National Grid Technical Specifications TS 2.20 and TS 3.01.03. These state that the location of penstock valves, surface inspection hatch covers, and access roads for oil separators shall be positioned outside the fire damage zone (TS 2.20), which is linked to the length and width of the bund (TS 3.01.03). Penstocks which couple as sampling points would be positioned either side of the oil separator for pollution control.

Groundwater ingress and saline handling

3.1.12 Groundwater ingress into the tunnel/shafts during the permanent (operational) phase is estimated to be between approximately 6.3 m^3/day and 1.6m^3 /day, for Braint and Tŷ Fodol respectively, for undrained shafts and 35 m^3/day and 30m^3/day for drained shafts. Any groundwater that enters the tunnel or shafts would drain to the base of the shafts where it would be collected in a sump and pumped up to ground level. Pumped water would discharge at ground level into a gravity drainage system.

3.1.13 Due to the close-proximity to the Menai Strait in both locations, there is the potential for the groundwater to be saline. Following Ground Investigations, no saline water has been found up to 250 m of the Menai Strait shoreline. However, there is still a risk 250 m either side of the Menai Strait. It is estimated that 1m3/day of saline water could enter the tunnel under the Menai Strait during the operational phase. As a conservative approach, it has been assumed that any saline concentrations in the groundwater would be greater than acceptable concentrations for discharging into freshwater; therefore, an area has been made available within the tunnel compounds for either a pond to dilute saline water or tanks to store saline water for removal by a tanker.

3.1.14 If testing indicates that the groundwater has acceptably low concentrations of saline, then the water would drain to the site treatment (settlement) and attenuation pond.

3.1.15 The groundwater would need to pass through an oil separator before entering either the saline pond, saline tank, or the site treatment (settlement) and attenuation ponds. This is to intercept any residual hydrocarbons in the water resulting from previous construction activities in the tunnel. Oil separators are to be nominally sized in accordance with Building Regulations Approved Document H *Drainage and waste disposal.* In accordance with PPG3, it may be necessary for the pumps in the shafts to be low shear pumps to mitigate the risk of oil emulsification during pumping – which could allow oils to bypass the separator. This requirement is to be confirmed during detailed design.

Treatment and attenuation pond sizing

3.1.16 The ponds are to be designed in accordance with CIRIA C753 *The SUDS Manual* and will allow settlement of surface water and attenuation of flood flows. In the permanent phase, the flood storage capacity of the ponds has been indicatively sized to store the 1 in 100 year flood in accordance with National Grid Technical Specification TS_2.10.13. The sizing also accounts for a 20% climate change allowance (change factor for 2080s) and a discharge rate of Qbar, which is equivalent to the greenfield runoff rate for the 1:2.3 year event, in accordance with the North Wales Connection Project Flood Consequences Assessment Methodology (Feb 2017).

3.1.17 The UK Sustainable Drainage Greenfield Runoff Estimation Tool defaults to a minimum discharge rate of 5l/s due to the risk of blockage. A minimum discharge rate of 5l/s will therefore be applied to the ponds. This will be utilised in the permanent phase due to the small size of the permanent compound, which has a greenfield runoff rate <5l/s.

3.1.18 The permanent pool within the ponds have been sized in accordance with CIRIA C753 *The SUDS Manual Section 23.5*. An allowance has also been made for the leakage from the tunnel if saline concentrations are sufficiently low.

Permanent Paved Access Roads for Tŷ Fodol and Braint

3.1.19 The indicative drainage layouts for permanent access roads are shown on Drawings DCO_DE/PS/09_02 and DCO_DE/PS/09_06 for Braint and Tŷ Fodol respectively.

3.1.20 At both sites, surface water runoff from the permanent access roads would be discharged to existing watercourses via open drainage ditches parallel to the road, treatment (settlement) and attenuation ponds, and outfall pipes/channels.

3.1.21 As with the permanent site compound, the ponds have been sized with a permanent treatment volume (pool) in accordance with the CIRIA SuDS Manual and an additional volume to accommodate the 1 in 100 year flood. A 20% climate change allowance (change factor for 2080s) and a discharge rate of Qbar have been selected in accordance with National Grid Technical Specification TS_2.10.13 and the North Wales Connection Project Flood Consequences Assessment Methodology document.

3.1.22 Runoff from natural catchment to be managed with ditches or land drains. This is to be further reviewed during detailed design.

Temporary Construction Compounds

Drainage principle

3.1.23 The indicative drainage layout for the temporary construction compounds are shown on Drawings DCO_DE/PS/12_02 and DCO_DE/PS/12_03 for Braint and Tŷ Fodol respectively.

3.1.24 These plans have been prepared to illustrate possible site layouts for the principle construction phases. Contractors may choose to lay out sites differently during construction depending on their preferred construction methods, subject to any controls on layout imposed through the planning submission and approval process.

3.1.25 It is advised that surface water runoff from the site, construction wastewater, and groundwater ingress pumped from the tunnel and shafts (if it is not saline) passes through an oil interceptor before discharging to an area for treatment (settlement) and attenuation, before eventually discharging to an existing watercourse via the site outfall. If the groundwater entering the tunnel and shafts is saline, provision is to be made on site to treat this. Provision has also been made for additional proprietary treatment if required.

3.1.26 Oil separators are to be nominally sized in accordance with Building Regulations 2010 Approved Document H *Drainage and waste disposal.* If pumps are used during the construction of the shafts, and once the shafts are constructed, it may be necessary for pumps to be low shear pumps. This is to mitigate the risk of oil emulsification during pumping, which could allow oils to bypass the separator. This requirement is to be confirmed during detailed design.

3.1.27 Runoff from natural catchment to be managed with ditches or land drains.

Treatment and attenuation pond sizing

3.1.28 Ponds are to be designed in accordance with CIRIA C532 *Control of Water Pollution from Construction Sites*, which recommends having three ponds in series to allow filling, settling, and emptying in parallel.

3.1.29 Each individual pond is indicatively sized for a runoff volume (CIRIA C648 *Control of water pollution from linear construction sites*), which has been scaled up for contingency; construction wastewater volume; and groundwater ingress volume. The flood storage volume is divided equally across the three ponds.

3.1.30 In the construction phase, the flood storage capacity of the ponds has been indicatively sized to store the 1 in 100 year flood with a 5% climate change allowance and a discharge rate of Qbar, which is equivalent to the greenfield runoff rate for the 1:2.3 year event, in accordance with the North Wales Connection Project Flood Consequences Assessment Methodology (Feb 2017). Indicative greenfield runoff rates for both sites have been estimated using *HR Wallingford Greenfield Runoff Estimation for Sites*.

3.1.31 It may be necessary to line the ponds to prevent risks to underlying groundwater from infiltration of contaminated water and / or to exclude groundwater from the ponds.

Groundwater ingress and saline handling

3.1.32 Groundwater ingress into the tunnel during the construction phase will vary depending on the construction technique used. If tunnel boring is utilised, a permanent lining would be installed as the tunnel boring machine (TBM) progresses. This would result in a groundwater ingress rate of approximately $5m^3$/day from the Braint shaft.

3.1.33 Alternatively, if Drill and Blast (D&B) is used, groundwater ingress rates will increase steadily as the tunnel is excavated and would decrease down to 5 m^3/day as the secondary lining is installed. Inflow rates could reach 560 m^3/day (prior to D&B breakthrough) and 900m3/day (following D&B breakthrough) at Braint and 335 m^3/day (prior to D&B breakthrough) and 0 m^3/day (following D&B breakthrough) at Tŷ Fodol. These values are in addition to $30m^3$/day from each shaft (drained shaft rates).

3.1.34 Any groundwater that enters the tunnel or shafts would drain to the base of the shafts where it would be collected in a sump and pumped up to ground level for treatment and eventual discharge.

Material waste drainage

3.1.35 Construction wastewater would be recycled where possible and volumes have been incorporated when sizing the treatment (settlement) and attenuation ponds.

Temporary Haul Roads for Tŷ Fodol and Braint

3.1.36 The indicative drainage layout for temporary haul roads are shown on drawings DCO_DE/PS/12_02 and DCO_DE/PS/12_03 (**Document 4.13**) for Braint and Ty Fodol respectively.

3.1.37 Surface water runoff from the temporary haul roads would be discharged to existing watercourses via open drainage ditches parallel to the road, treatment (settlement) and attenuation ponds, and outfall pipes/channels. Simple gravel banks can be used between the road and open channel to filter the surface water runoff from the haul roads before it enters the channels.

3.1.38 The ponds have been sized with a permanent pool in accordance with the CIRIA SuDS Manual and has a flood storage capacity to hold the 1 in 100 year flood, with 5% climate change allowance, and a discharge rate of Qbar in accordance with the Flood Consequences Assessment Methodology document.

3.1.39 The northern haul road route at Braint, north of the Afon Braint, falls within Environment Agency Flood Zone 3 (1 in 100 year or greater chance of flooding from rivers)/Welsh (TAN 15) Flood Zone C2 (Areas of the floodplain without significant flood defence infrastructure) and therefore an attenuation pond is not suitable. A vegetated swale will be used in this location to convey water to the Afon Braint.

3.1.40 Overland flow from the upstream rural catchment has not been reviewed. This is to be reviewed during detailed design.

3.2 FOUL WATER DRAINAGE STRATEGY

Permanent Tunnel Compounds

3.2.1 As with the drainage design, foul water design is preliminary and subject to detailed design. Foul water would be discharged from the headhouse mess facilities. Due to the absence of public sewers in the local area, a sealed tank (cesspool) would to be used to store foul water for removal and disposal in accordance with National Grid *Electricity Substation Construction Civil, Structural and Building Engineering Design Handbook* (DH10) for unmanned sites (section 2.10.6). Foul water would be drained via a gravity pipework system to the tanks and effluent would be tankered off-site for authorised disposal at regular intervals.

3.2.2 The tanks would be located outside of the operational compound and beside the access road to facilitate emptying by third parties. The tanks are shown on drawings DCO_DE/PS/09_02 and DCO_DE/PS/09_06 (**Document 4.13**) for Braint and Tŷ Fodol respectively.

3.2.3 The tanks would be designed in accordance with Building Regulations and National Grid Electricity Substation Construction Civil, Structural and Building Engineering Design Handbook.

Temporary construction compounds

3.2.4 Within the construction phase, package treatment plants would be utilised to treat foul water from the contractor's mess facilities, in accordance with National Grid Civil, Structural and Building Engineering Design Handbook (DH10) for manned sites (section 2.10.6). Indicative locations of the package treatment plants are shown on drawings DCO_DE/PS/12_02 and DCO_DE/PS/12_03 (**Document 4.13**) for Braint and Tŷ Fodol respectively.

3.2.5 Foul water would be drained via a gravity pipework system to the package treatment works and the treated water would be discharged to an existing watercourse via the site outfall.

4 Conclusions and recommendations

4.1 CONCLUSIONS

4.1.1 Permanent

- Groundwater ingress into the shafts would be pumped from sumps at the base of the shafts. Groundwater ingress from the tunnel would flow to one shaft only. Pumped water would discharge at ground level into a gravity drainage system including an oil separator. Groundwater would either discharge to the treatment (settlement) and attenuation feature or to an area for saline treatment as required.
- Surface water runoff would discharge to existing watercourses, via treatment (settlement) and attenuation features.
- Foul water from the headhouse mess facilities would be drained via a gravity pipework system to sealed tanks where it would be stored before being tankered off-site for authorised disposal.
- Surface water runoff from the permanent access roads would be discharged to existing watercourses via drainage ditches and treatment (settlement) and attenuation ponds.

4.1.2 Temporary

- Surface water runoff from the temporary construction compounds would be drained via an oil separator into treatment (settlement) and attenuation features before discharging to an existing watercourse.
- Groundwater ingress into the shafts would be pumped from sumps at the base of the shafts. Groundwater ingress from the tunnel would flow to one shaft only. Pumped water would discharge at ground level into a gravity drainage system including an oil separator. Groundwater would either discharge to the treatment (settlement) and attenuation features or to an area for saline treatment as required.
- Foul water from the contractor’s mess facilities would be drained via a gravity pipework system to a package treatment plant, before discharging into an existing watercourse.

- Surface water runoff from the temporary haul roads would pass through drainage ditches, and treatment (settlement) and attenuation features, before being discharged to existing watercourses. Gravel banks can be used between the road and open channel to filter the surface water runoff.

4.2 RECOMMENDATIONS

4.2.1 Topographical surveys of existing watercourses and culverts are required to determine capacity and suitability. Ecological surveys have now been completed. Please refer to the Ecology Chapter of the Environmental Statement (**Document 5.9**) and the Biodiversity Mitigation Strategy (**Document 7.7**).

4.2.2 Groundwater monitoring has been undertaken along the tunnel route and at the construction compounds, but it has not been undertaken for the haul road routes. Monitoring would be required along the length of the haul road routes, at the locations of the proposed ponds, to determine requirements for liners within treatment and attenuation features; this additional monitoring is likely to be undertaken during detailed design.

4.2.3 The potential for infiltration is to be reviewed further during detailed design, with emphasis on design exceedance routing should infiltration be considered.

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