Appendix K.1 – Flood Consequence Assessment

A487 CAERNARFON & BONTNEWYDD BYPASS

FLOOD CONSEQUENCE ASSESSMENT

Final

A487 Caernarfon & Bontnewydd Bypass

Flood Consequence Assessment

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EXECUTIVE SUMMARY

Background	This Flood Consequence Assessment (FCA) has been prepared to support the proposed A487 Caernarfon & Bontnewydd Bypass scheme. The FCA assesses the flood risks and consequences posed to the Scheme and any changes to flood risk and consequences of that which may occur because of the Scheme. The FCA has been completed in accordance with the requirements of Technical Advice Note 15: Development and Flood Risk (TAN15). The A487 Caernarfon & Bontnewydd bypass is approximately 9.5 km in length starting south of Llanwnda (NGR SH 4724 5775) and joining the existing A487 north of Caernarfon (NGR SH 5052 6573). The proposed road runs to the west of Bontnewydd and the east of Caernarfon. The Scheme includes a number of watercourse crossings and diversions of both Main Rivers and ordinary watercourses. Natural Resources Wales and Gwynedd Council have been consulted to inform the approach to the FCA and specific requirements of the Scheme. The FCA is based on qualitative assessment of flood consequences scheme-wide and detailed hydrological / hydraulic assessment (including hydraulic modelling) of the larger river crossings.
Existing flood risk	The existing flood risk to the site from fluvial, tidal, groundwater, overland flow and artificial sources has been assessed. The majority of the Scheme is assessed at low risk of flooding from any source. The main areas where flooding may present a constraint are where the Scheme crosses or runs close to existing watercourses. The following sources of flooding are assessed to present a potential constraint to the Scheme, or have the potential to be affected by the Scheme: • Fluvial flooding from Main Rivers and local watercourses; • Overland flows from surface water flooding; • Groundwater flooding where the Scheme is in cutting.
Post development flood risk and surface water management proposals	The Scheme design includes a range of mitigation to manage flood risks posed to the Scheme and the impact of the Scheme on flood risks elsewhere. These include the design of new culverts to carry the 100 year flow (including suitable climate change and freeboard allowances); viaducts spanning the larger river floodplains; diversion of watercourses and ditches to maintain flow routes; and control of surface water runoff to manage flood risk to the Scheme and mitigate an increase in flood risk downstream. The Scheme is considered at low risk of fluvial flooding. There are some locations where flooding may occur during larger events; however, the flooding is not expected to exceed TAN15 thresholds for acceptable flood consequences. The flood risk associated with the larger river crossings (Rhyd, Gwyrfai, Seiont and Cadnant) has been assessed in detail and demonstrates that the risk of fluvial flooding to the Scheme is low and meets TAN15 guidance. Aside from the rivers subject to detailed assessment, the Afon Rhosdican is considered to pose the most significant risk to the Scheme and potential to be affected by the Scheme. It is recommended that

	further assessment of flood risk from this watercourse is undertaken during detailed design to confirm the flood consequences are acceptable. The Scheme includes a number of new watercourse crossings and diversions. These will potentially have small localised impacts, due to effects on floodplain storage and conveyance, but are not expected to lead to an increase in flooding elsewhere as existing flow routes are maintained and the proposed crossings will be designed to convey the 100 year flow (with climate change). Based on the current available information it is considered that groundwater flows may enter the deeper cuttings (near Llanwnda and Plas Menai). However provided appropriate drainage is in place to capture any groundwater flows it is unlikely that flood depths would exceed TAN15 thresholds. Details of temporary works were not available for this assessment; however, with the exception of the Afon Gwyrfai, they are unlikely to significantly affect flood flows. The temporary works required during construction of the Afon Gwyrfai are likely to have a more significant impact, should a large flood occur during the 18 month construction period. It is expected that the proposed haul road would lead to an increase in flood depths upstream for a distance of around 100m. The haul road would increase the flow across the northern part of the floodplain and could potentially increase the flooding to the existing properties located close to the river on the right bank of the meander. However it is anticipated that this would only be the case for the larger events and the likelihood of this occurring during the 18 month construction period is low. The Scheme will result in an increase in surface water runoff, due to the additional impermeable area. The proposed drainage scheme includes flow controls and attenuation to limit the peak surface water discharge rate and control the discharge rate of the additional runoff volume. For the majority of events this will represent a decrease in peak runoff rate and therefore an improvement in terms of reduced flood risk downstream. For smaller events the peak discharge rate may slightly increase; however, it is anticipated that this will be small, and any infiltration which occurs within the drainage system will further reduce the runoff. The proposed drainage strategy includes measures to manage exceedance flows to avoid an increase in flood risk elsewhere during events which exceed the design capacity of the surface water drainage system.
Compliance with TAN15	The majority of the Scheme is located on land within Zone A and B but the Scheme will involve works within Zone C where the Scheme crosses or lies close to existing watercourses. The Scheme is considered “less vulnerable” to flooding, according to the TAN15 classifications, and is therefore acceptable within Zone C1 and C2 subject to the Justification test and acceptable flood consequences. The Scheme is promoted by Welsh Government and it is considered will therefore pass part 1 and / or 2 of the Justification test. Contrary to the requirement of part 3 of the Justification test, the Scheme crosses largely greenfield land. However, considering the location of the Scheme, it is unlikely this could be avoided. The proposed route has been selected following an appraisal of alternatives. It is considered that flood consequences to the Scheme will meet TAN15 guidelines and the Scheme will not result in a significant increase in flood

	risk elsewhere. It is therefore considered the Scheme meets the requirements of the Justification test and TAN15.

SECTION 1

INTRODUCTION

1 INTRODUCTION

1.1 Project Background

1.1.1 The JV Team has prepared this Flood Consequence Assessment (FCA) to support the proposed A487 Caernarfon & Bontnewydd Bypass scheme (the Scheme). The FCA assesses the flood risks and consequences posed to the Scheme and any changes to flood risk and consequences that may occur because of the Scheme.

1.1.2 The FCA has been completed in accordance with the requirements of Technical Advice Note 15: Development and Flood Risk (TAN15)[1]. The assessment includes the following:

- Confirmation of the sources of flooding which may affect the Scheme;
- Review of the availability and adequacy of existing information;
- A qualitative assessment of the risk of flooding from all sources to the site and to adjacent sites as a result of the Scheme;
- A quantitative assessment of the risk of flooding to the Scheme and the impact of the Scheme on flooding at selected Main River crossings; and
- Identification of possible measures which could reduce flood risk to acceptable levels.

1.2 Development Proposals

1.2.1 A full description of the Scheme is included in the Environmental Statement and illustrated in the accompanying Scheme drawings. Figure 14.1 (Appendix A) shows an overview of the Scheme. The main features of relevance to this assessment are outlined below:

- The Scheme is approximately 9.5 km in length, predominantly new road construction through undeveloped land. The road alignment requires a combination of embankment, cutting and at-grade construction which may locally affect drainage routes and flow regimes.
- The Scheme includes a number of watercourse crossings and diversions. Six Main Rivers and tributaries are affected by the Scheme (Afon Rhyd, Afon Plas, Afon Gwyrfai, Afon Rhosdican, Afon Seiont and Afon Cadnant) as well as a number of ordinary watercourses.
- The Scheme will result in an increase in the total impermeable area due to the new road construction (the existing road will largely remain in place). A new sustainable drainage system will be provided.

1.3 Consultation

1.3.1 Natural Resources Wales (NRW) and Gwynedd Council have been consulted on the proposals and specific requirements of the FCA as detailed in Tables 1.1 and 1.2. Consultation has taken place through the Environmental Liaison Group meetings, a separate meeting held with NRW and Gwynedd Council on the 18th February 2015 to discuss flood risk and drainage matters and email / telephone consultation with Iwan

[1] Planning Policy Wakes, Technical Advice Note 15: Development and Flood Risk, Welsh Assembly Government, July 2004

Huws (NRW) and Alun Williams (Gwynedd Council). Consultation has continued through the preparation of the FCA to discuss Scheme changes, assumptions and model results. This includes technical reviews of the hydrological assessments and hydraulic models by NRW.

Table 1.1 Summary of consultation with NRW

Topic	Comment
Scope & approach to the FCA	A Flood Consequence Assessment is to be prepared in accordance with TAN15. The FCA should consider a range of flood flows for the watercourse crossings up to and including that of the 1000 year. Climate change allowances should be made but climate change allowances are not applicable for the 1000 year fluvial event. Climate change allowances of +20% (river flows) and +30% (drainage design) are acceptable. Hydraulic modelling is required for the larger Main River crossings (Afon Rhyd, Afon Gwyrfai, Afon Seiont, Afon Cadnant). NRW agreed that hydraulic modelling of the smaller Main River crossings would not be required and that a qualitative assessment would be sufficient if suitable freeboard is provided above the 100 year (climate change) flood level. 1D hydraulic models are acceptable for clear spanning structures (2D models have been used for the Afon Gwyrfai, Afon Rhyd and Afon Cadnant). Hydrology and models should be submitted to NRW for review. Flood consequences to the Scheme should be in line with TAN15. The FCA should consider scour risks, particularly potential impact on 3rd parties. New channel sections should seek to keep as close to existing as possible. The FCA should include comment on temporary works. Full assessment / hydraulic modelling is unlikely to be required at this stage unless the impacts are deemed significant. It is suggested that the locations of balancing ponds/embankments within identified flood risk areas consider not only loss of floodplain (which would need to be compensated) but also conveyance. Balancing ponds that are located in floodplains may need to be modelled to ensure they do not displace flood waters or affect conveyance. Tidal flooding is unlikely to be an issue but it should be covered in the FCA.
Main River Crossings	Structures crossing Main Rivers should have a minimum freeboard of 600mm above the design flood level (1 in 100 year return period + 20% for climate change). Trash screens are unlikely to be required given the size and length of the proposed culverts and it is preferable not to have screens. Reference should be made to the DEFRA/EA Trash and Security Screen Guide 2009. Flood Defence Consents will need to be submitted under the requirements of Section 210 of the Water Resources Act 1991 for the main rivers crossings/diversions. All river and stream crossings should be designed to minimise disruption to the watercourse and maintain a natural bed to the watercourse and, wherever practicable, be clear span structures. Where culverts are required to accommodate wildlife e.g. otters, bats etc. these should not compromise the primary watercourse requirements and features. A natural bed depth of 150 -300mm is considered appropriate. A set back for access at least 7m from either side of watercourses where crossings are proposed is encouraged wherever possible. However, it was confirmed this could be relaxed at the Afon Gwyrfai.
Ordinary watercourse crossings	With regards to the ordinary watercourse crossings, these will require consent from the LLFA and we would suggest that the method of sizing the crossings should be agreed with the LLFA.

	A bifurcation occurs on the Afon Cadnant tributary at NGR SH 50991 64773. A percentage of the flow is directed towards the proposed culverts at Chainage 8900.Therefore culvert sizing at this location(s) for the bypass and associated road should ensure that the catchment is adjusted to consider this. It is understood that the bifurcation is to relieve flood risk issues in the town of Caernarfon. There is no formal bifurcation structure but the flow splits due to the natural ground and bed levels of the watercourses.
Surface water management	Drainage should mimic existing rates/volumes for a range of events up to the 1 in 100 year rainfall event. Balancing ponds should be designed to cater for the 1 in 100 year rainfall event (with due consideration given to climate change) with greenfield run off rates maintained. When designing the drainage system for the road it must be designed to maintain catchment separation i.e. not take run-off from one catchment and drain it to another. NRW encourages the use of soft SuDS in the management and treatment of run-off as close to source as possible. This could be through the use of filter strips, filter drains, swales, over edge drainage, retention ponds and detention basins these will also assist with balancing of run-off from the drainage.
Temporary works	Site compounds etc. should be located outside of any flood zones. Any temporary structures (e.g. bailey bridges) likely to affect the flow should be supported by hydraulic assessment to demonstrate the flood risk is acceptable. Bailey bridges will be subject to flood defence consent and should pass the 100 year flow with freeboard.
Afon Gwyrfai	NRW would be unlikely to support value engineered option with embankments extending into the floodplain. NRW may object to the increase in flood depths shown, above usual tolerances, due to the embankment extending into the floodplain as they consider this an increase in flood risk contrary to TAN15. If the landowner accepts the impacts (to farmland) then NRW would probably not object. NRW is unlikely to object to increased flooding shown around piers; it is accepted that the model accuracy is limited in this respect and there is no mitigation that could be provided. Floodplain compensation storage would not be required if the hydraulic modelling shows increases in flood depth within acceptable tolerances. The temporary bridge for the Gwyrfai should pass the 100 year flow with a suitable freeboard. The bridge & haul road should be modelled and included in the FCA due to the potential significance of impacts. A range of events up to the 100 year should be considered.
Afon Seiont	The road embankment on the southern land (shown as within current EA Flood Zones) is acceptable as the detailed modelling undertaken for the FCA shows this land lies outside of the 1000 year flood extent.
Afon Cadnant	Introduction of additional flows into the Afon Cadnant would not be acceptable due to existing flood risk in Caernarfon.
Afon Rhyd	The proposed diversion may be acceptable subject to hydraulic modelling showing the effects are acceptable. The channel should not be trapezoidal and should include riffles etc. to slow flow, alongside any necessary bank / bed protection.

Table 1.2 Summary of consultation with Gwynedd Council

Topic	**Comment**
General Flood Risk	Culvert design where 3rd party flooding is a possibility is for a 1 in 100 year event plus 20% for climate change.

	Ordinary watercourse crossings should have a 300mm freeboard above the 100 year return period flow, including an allowance for climate change.

SECTION 2

ASSESSMENT METHODOLOGY

2 ASSESSMENT METHODOLOGY

2.1 Overview

2.1.1 The assessment has been conducted in accordance with TAN15 which provides guidance on how new developments must take into account flood risk, including making allowance for climate change impacts.

2.1.2 TAN15 encourages decision makers to:

- Steer new development to lower risk locations that are appropriate to the proposed use and ensure development is safe, enforced through the Development Advice Map and application of the Justification Test;
- Prevent any increase in flood risk elsewhere and reduce flood risk through the layout and form of the development and the appropriate application of sustainable drainage systems;
- Reduce flood risk by making space for water by creating flood flow paths and identifying, allocating and safeguarding space for flood storage;
- Use regeneration to help relocate development to lower risk locations when climate change is expected to mean that some existing development may not be sustainable in the long-term.

2.1.3 The methodology adopted in this FCA comprises:

- Review of available flood risk data to identify existing flood risk from fluvial, tidal, groundwater, overland flow and artificial sources;
- Hydrological and hydraulic assessment (including development of hydraulic models at selected river crossings) to determine flood levels and flows and assess the impact of the Scheme on fluvial flooding;
- Qualitative assessment of the impact of the Scheme on other sources of flooding, including overland flows and smaller river crossings;
- Consideration of existing ground conditions on-site to determine the potential for groundwater flooding through review of information available from NRW, the British Geological Survey (BGS), Soil Survey of England & Wales maps (1:50000 series, 1983) and site Ground Investigation report;
- Review of the Scheme in terms of the requirements of the Justification test and acceptable flood consequences as set out in TAN15;
- Consideration of how the Scheme may affect flood risk to the site and surrounding land; and
- Proposals for the appropriate management of flood risks to facilitate the Scheme whilst not increasing risks elsewhere.

2.1.4 Following the consultation with NRW and Gwynedd Council the following approach was agreed and adopted for the assessment of specific aspects of the Scheme:

- Afon Rhyd crossing (S102) - full hydrological assessment and 1D/2D ISIS - TUFLOW model used to obtain flood levels at the site and test the impact of the proposed crossing and diversion on flood levels and flows in the vicinity.
- Afon Gwyrfai crossing (S106) - full hydrological assessment and 1D/2D ISIS - TUFLOW model used to obtain flood levels at the site and test the impact of the

proposed crossing on flood levels and flows in the vicinity. The temporary works have also been tested with the model due to the potential effects on flood risk;

- Afon Seiont crossing (S112) - full hydrological assessment and 1D ISIS model used to obtain flood levels at the site and test the impact of the proposed crossing on flood levels and flows in the vicinity. The Afon Seiont flows through a confined valley at the proposed crossing location therefore a 1D hydraulic model is appropriate;
- Afon Cadnant crossings (S114, S114A, S115A, S115B) - full hydrological assessment and 1D/2D TUFLOW model used to obtain flood levels at the site and test the impact of the proposed crossing on flood levels and flows in the vicinity;
- Other watercourse crossings and diversions - qualitative assessment based on the design principles adopted and design criteria;
- Other sources of flooding and potential impacts (e.g. loss of floodplain storage) - qualitative assessment based on the design information and online flood risk maps;
- Surface water runoff - qualitative assessment based on the design principles adopted and design criteria.

2.1.5 Data regarding flood risk relevant to the Scheme and surrounding area has been obtained from the following sources:

- NRW indicative flood risk maps and groundwater maps;
- Gwynedd and Anglesey Strategic Flood Consequence Assessment (SFCA)[2];
- Gwynedd Council Local Flood Risk Management Strategy (LFRMS)[3];
- North West Wales Catchment Flood Management Plan (CFMP)[4];
- Western Wales Flood Risk Management Plan (FRMP)[5];
- Direct consultation with NRW and Gwynedd Council as discussed in Section 1.

2.2 Potential sources of flooding

2.2.1 The following sources of flooding have been considered in this assessment:

- Fluvial flood risk from watercourses;
- Overland surface water flooding;
- Surface water runoff from the Scheme;
- Surcharging of sewers;
- Groundwater flooding; and
- Tidal flooding.

[2] Anglesey & Gwynedd Joint Local Development Plan, Strategic Flood Consequence Assessment (Level 1), Isle of Anglesey County Council / Gwynedd Council, February 2015
[3] Gwynedd Council Local Flood Risk Management Strategy, Gwynedd Council, February 2013
[4] North West Wales Catchment Flood Management Plan Summary Report, Environment Agency Wales, January 2010
[5] Managing the risk of flooding in the Western Wales River Basin District: What's being planned and when, Natural Resources Wales

2.3 Potential effects of climate change

2.3.1 Scientific consensus is that the global climate is changing as a result of human activity. While there remain uncertainties in how a changing climate will affect areas already vulnerable to flooding, it is expected to increase risk significantly over time. For the UK, projections of future climate change indicate that more frequent short-duration high-intensity rainfall events and more frequent periods of long-duration rainfall could be expected.

2.3.2 Following consultation with NRW peak river flows have been increased by 20% to account for climate change effects over the lifetime of the Scheme and rainfall intensities used in the surface water drainage design have been assumed to increase by 30%.

2.4 Legislation, policy and guidance

Planning Policy Wales and Technical Advice Note 15: Development and Flood Risk

2.4.2 Planning Policy Wales (PPW) (Welsh Government, 2014) sets outs the land use planning policies of the Welsh Government. PPW is supported by Technical Advice Notes (TANs). TAN 15 (Welsh Assembly Government, 2004) considers development and flood risk and is accompanied by a Development Advice Map (DAM) containing three zones of flood risk. TAN 15 aims to locate new development away from those areas that are at high risk of flooding. Considering the vulnerability of development and the risk of flooding, justification must be given for the chosen location of new development in flood risk areas and the consequences of flooding to a development must be considered in the planning process.

2.4.3 Flood risk is the product of the likelihood or chance of a flood occurring (flood frequency) and the consequence or impact of the flooding (flood consequence).

2.4.4 Flood frequency is identified in terms of the return period and annual probability. For example, a 1 in 100 year flood event has a 1% annual probability of occurring. Table 2.1 below provides a conversion between return periods and annual flood probabilities.

Table 2.1 – Flood probability conversion table

Return Period (years)	2	5	10	20	50	100	200	1000
Annual Flood Probability (%)	50	20	10	5	2	1	0.5	0.1

2.4.5 TAN15 identifies Flood Zones based on the likelihood of flooding. The zones refer to the probability of river (fluvial) and sea (tidal) flooding. Table 2.2 below summarises the relationship between Flood Zone category and the identified flood risk.

Table 2.2 – Flood Zones

Flood Zone	**Description**
Zone A	Considered to be at little or no risk of fluvial or tidal / coastal flooding.
Zone B	Areas known to have flooded in the past based on sedimentary deposits.

Zone C1	Based on the NRW extreme flood outline, equal to or greater than 0.1% AEP (river, tidal or coastal).	Areas which are developed and served by significant infrastructure, including flood defences.
Zone C2		Areas of the floodplain without significant flood defence infrastructure.

2.4.6 The consequence of a flood event describes the potential damage, danger and disruption caused by flooding. This is dependent on the mechanism and characteristics of the flood event and the vulnerability of the affected land and land use.

2.4.7 TAN15 identifies three classifications of flood risk vulnerability and provides recommendations on the acceptability of each vulnerability classification with the Flood Zones, as shown in Table 2.3.

2.4.8 Full details of the Flood Zones and flood risk vulnerability classifications can be found in TAN15. Within Zone C1, plan allocations and development applications for most types of development can only proceed subject to justification and acceptable flood consequences. Within Zone C2 the flood consequences associated with Emergency Services and Highly vulnerable development are not considered to be appropriate.

Table 2.3 – Flood risk vulnerability and flood zone compatibility

Flood Zone	Emergency Services	Highly Vulnerable	Less Vulnerable	Other
Zone A	✓	✓	✓	✓
Zone B	✓	✓	✓	✓
Zone C1	Justification test required	Justification test required	Justification test required	Subject to acceptable flood consequences
Zone C2	×	×	Justification test required	Subject to acceptable flood consequences

2.4.9 TAN15 provides guidance on acceptable flood consequences for different types of development. This includes a number of general conditions to ensure that the flood risks can be effectively managed, for example provision of flood warnings, flood emergency plans and escape / evacuation routes. In addition to these general conditions TAN15 provides indicative guidance on particular flooding consequences which may not be considered acceptable for particular types of development as detailed in Tables 2.4 and 2.5.

Table 2.4 – TAN15 Guidance Values: Flood Frequency Threshold (TAN15 A1.14)

Type of Development	Threshold Frequency (AEP)	
	Fluvial	Tidal
Residential	1%	0.5%
Commercial / Retail	1%	0.5%
Industrial	1%	0.5%
Emergency Services	0.1%	0.1%
General Infrastructure	1%	0.5%

Table 2.5 – TAN15 Guidance Values: Tolerable Flood Conditions (TAN15 A1.15)

Type of Development	Maximum depth (mm)	Maxium rate of rise (m/hr)	Maximum speed of inundation (hrs)	Maximum velocity (m/s)
	Property Access			Property Access
Residential (habitable rooms)	600 600	0.1	4	0.15 0.3
Commercial / Retail	600 600	0.3	2	0.15 0.3
Industrial	1000 1000	0.3	2	0.3 0.45
Emergency Services	450 600	0.1	4	0.15 0.3
General Infrastructure	600 600	0.3	2	0.3 0.3

The Flood and Water Management Act 2010

2.4.10 The Flood and Water Management Act 2010 (FWMA) introduces new responsibilities for flood risk management for local authorities and sets out new requirements for the management of sustainable drainage.

2.4.11 The FWMA Act is still being implemented and this report will provide guidance on how its implementation will impact on the management of surface water and flood risk for the proposed development.

Lead Local Flood Authorities

2.4.12 Under the FWMA the unitary authority or county council for an area is designated the 'Lead Local Flood Authority' (LLFA), with responsibility for managing flood risk from surface water, ground water and ordinary watercourses within their area. The LLFA (Gwynedd Council) is also the consenting authority for works near or within ordinary watercourses.

Sustainable drainage

2.4.13 Schedule 3 of the FWMA introduces new National Standards for Sustainable Drainage Systems (SuDS) against which proposed drainage systems should comply. Under Schedule 3 of the FWMA, LLFAs will become the SUDS Approving Body (SAB) for surface water drainage systems for new development. Approval from the SAB for drainage proposals must be agreed prior to construction. For drainage systems that serve more than one property, the SAB will have responsibility for maintenance of adopted SUDS schemes that meet SAB requirements.

2.4.14 Schedule 3 is still to be enacted and it is unclear when this will take place. In the meantime it is expected that the North and Mid Wales Trunk Road Agency (NMWTRA) will be responsible for maintenance.

2.4.15 The Welsh Government produced draft non-statutory standards for sustainable drainage for consultation in February 2015. The draft standards introduce a set of Principles which underpin the design of surface water management schemes the national Standards.

2.4.16 Standard S1 introduces the SUDS hierarchy that states that the following methods of surface water disposal must be considered in order of preference:

- Collected for use;
- Infiltrated to ground;
- Discharged to a surface water body;
- Discharged to a surface water sewer;
- Discharged to a combined sewer.

2.4.17 Standard S2 aims to control the surface water runoff from rainfall. It requires that surface water runoff is managed to prevent any discharge for the first 5mm of event rainfall and that runoff for all events up to approximately the 1 in 1 year return period should be controlled to mitigate the morphological effects of development runoff on the environment. Surface water runoff for events up to the 1 in 100 year return period should be managed to protect people and property on the site from flooding and controlled to mitigate the effects of development on increasing flood risk in the receiving waterbody and downstream. Risks associated with surface water runoff for events greater than the 1 in 100 year return period should be evaluated for their impact and appropriate mitigation provided if necessary. Drainage design proposals should also consider the likelihood and consequences of failure and associate flood risks reduced where possible.

2.4.18 Standards S3, S4, S5 and S6 relate to water quality, amenity, biodiversity and construction, operation and maintenance which are not specifically relevant to this assessment.

2.4.19 The proposed drainage strategy (section 8) has been prepared in accordance with the design standards for highway drainage systems as set out in the Design Manual for Roads and Bridges (DMRB). However the proposals broadly follow the principles of the draft non-statutory standards produced by Welsh Government.

Gwynedd Unitary Development Plan (2001 - 2016)

2.4.20 Gywnedd Council is in the process of preparing a Local Development Plan (LDP) for the area. Until this is adopted the existing Unitary Development Plan (UDP) is the primary documentation referred to by the Council when determining planning applications.

2.4.21 Several policies within the UDP are relevant to this FCA, as follows:

- Policy B29 – 'Development on land at risk from flooding' which reinforces the national policy set out in TAN15.
- Policy B32 – 'Increasing Surface Water' which states that "Proposals that do not include flood minimisation or mitigation measures that will reduce the volume and rate at which run off reaches rivers and other watercourses will be refused…"

Gwynedd Local Development Plan (2011 - 2026)

2.4.22 The joint Isle of Anglesey and Gwynedd Council Local Development Plan has not yet been adopted by the council. Once adopted it will set out the councils' plans for development. The deposit plan is available and includes the following policies relevant to this assessment:

- Policy PCYFF2: 'Design & Place shaping' which states that drainage systems for new developments should limit surface water run-off and flood risk and prevent pollution;
- Policy PCYFF5: 'Water Conservation' which requires that development proposals incorporate water conservation measures, including SuDS and should implement flood minimisation or mitigation where possible, to reduce surface water run-off and minimise its contribution to flood risk elsewhere.
- Policy PS8: 'Proposals for large infrastructure projects'. The council will aim to ensure proposals include provision of flood protection measures to manage flood risk and, where feasible, deliver improvements in the locality.

Level 1 Strategic Flood Consequence Assessment February 2015

2.4.23 The Gwynedd and Anglesey Strategic Flood Consequence Assessment (SFCA) Stage 1 is a desk-based study compiling all the existing information on flooding from all sources. The SFCA includes an assessment of flooding issues in the main settlements within the area, using information contained in the Catchment Flood Management Plan, Shoreline Management Plan and Preliminary Flood Risk Assessment.

2.4.24 The SFCA focussed on the assessment of flood risk to the main settlements. Flooding issues in Caernarfon were assessed in the SFCA. This highlighted that Caernarfon has suffered from surface water and sewer flooding in the past although this is not considered significant. The Afon Cadnant has caused flooding problemns in the past where it is culverted through the town. Development within Zone C1 for the Afon Cadnant and Afon Seiont is highlighted as an issue to be considered in the local plan.

2.4.25 The SFCA states that in general groundwater flooding is not considered a significant issue although it may be a local consideration.

Gwynedd Local Flood Risk Management Strategy

2.4.26 The Local Flood Risk Management Strategy (LFRMS) has been prepared by Gywnedd Council to meet its responsibilities as Lead Local Flood Authority (LLFA) under the requirements of the Flood and Water Management Act (2010). The LFRMS outlines how Gywnedd Council proposes to manage local flood risk. The LFRMS reinforces how the council will comply with PPW and TAN15 through the Local Development Plan.

2.4.27 The LFRMS described how the Council will implement the National objectives:

- Reducing the consequences for individuals, communities, businesses and the environment from flooding and coastal erosion;
- Raising awareness of and engaging people in the response to flood and coastal erosion risk;
- Providing an effective and sustained response to flood and coastal erosion events; and
- Prioritising investments in the most at risk communities.

2.4.28 Of specific relevance to this assessment the LFRMS states that the council will oppose the culverting of watercourses and take action against any unconsented works. Applications for culverts will be considered on their own merits and approved only if there is no reasonably practicable alternative, or the detrimental effects are so minor that a more costly alternative cannot be justified.

2.4.29 The LFRMS does not include any further information on flood risk to add to that obtained from other sources.

North West Wales Catchment Flood Management Plan (CFMP)

2.4.30 The CFMP was prepared by Environment Ageney Wales (now NRW) to set policies for how flood risk will be managed at a catchment scale. The CFMP divides the North West Wales catchments into a number of sub areas, which have similar characteristics, and where it is appropriate to set the same policy. The Scheme passes through the Bangor and Caernarfon sub-area which has been assigned policy option 3. Policy option 3 is applied to areas of low to moderate flood risk where NRW are generally managing flood risk effectively.

2.4.31 The CFMP highlights that flooding in the Bangor and Caernarfon area is often the result of complex interactions of flooding sources, including localised run-off, rapid onset of river flooding and tidal influences in the lower reaches of the Afon Cadnant and Seiont. None of the identified actions are of specific relevance to this assessment.

Western Wales Flood Risk Management Plan

2.4.32 This plan describes how NRW propose to meet their obligations under the Flood Risk Regulations within the Western Wales River Basin District to manage flooding from rivers, the sea and reservoirs. No specific information is included in the draft plan that is relevant to this assessment.

SECTION 3

SITE DESCRIPTION

3 SITE DESCRIPTION

3.1 Site Location

3.1.1 The Scheme extends approximately 9.5km from south of Llanwnda (NGR SH 4724 5775) to join the existing A487 north of Caernarfon (NGR SH 5052 6573). The Scheme runs to the west of Bontnewydd and the east of Caernarfon. Figure 3.1 shows the location of the Scheme.

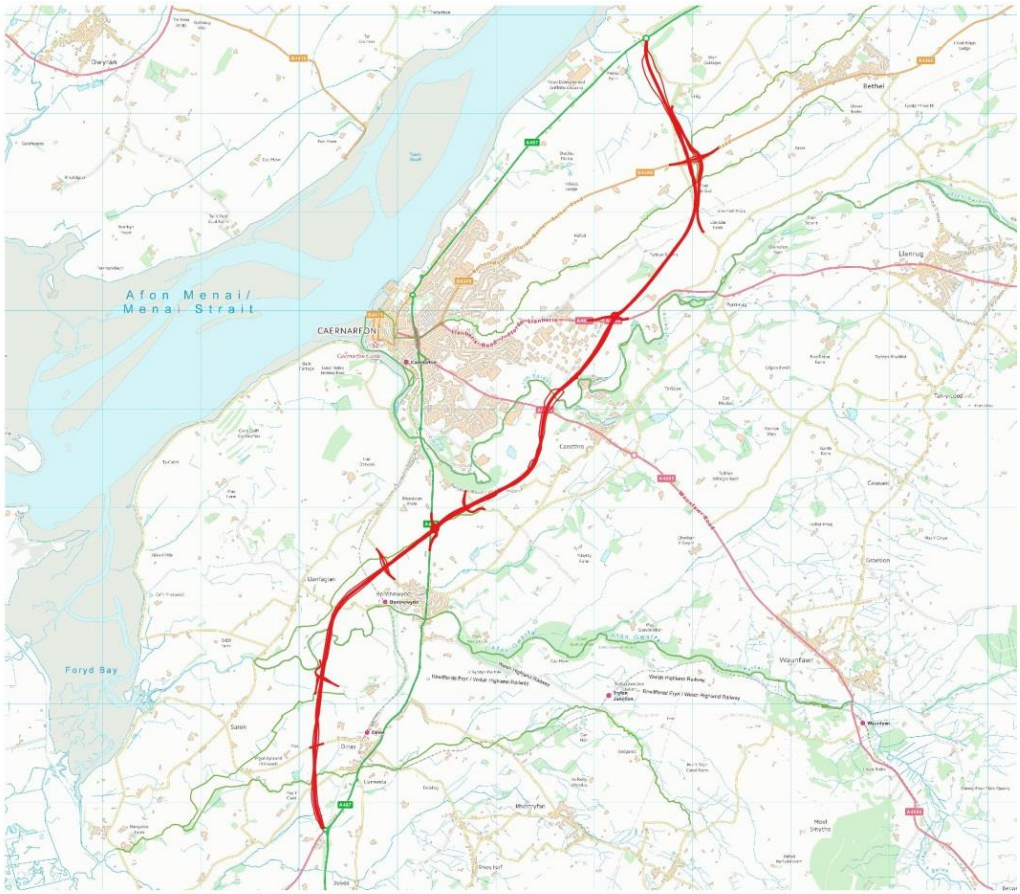

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Figure 3.1 – Site Location

3.2 Site Description

3.2.1 The Scheme is generally located on undeveloped land used for agricultural and animal grazing situated between the Menai Strait and the mountainous area around Snowdon. The Scheme is located on the lower lying land that slopes more gently towards the Menai Strait. Caernarfon is the main urban area in the vicinity although there are a number of smaller towns and villages in the wider catchment.

Geology and Hydrogeology

3.2.2 The bedrock geology at the site and surrounding area is mostly mudstone, siltstone and sandstone however the Scheme crosses an area of igneous bedrock north of Caernarfon. The geology is more varied in the wider area and river catchments that

include Snowdonia, with igneous rocks generally underlying the hills and mountains and sedimentary rocks in the valleys. There are limited superficial deposits in the upper catchments. The superficial geology at the site and vicinity is mostly till.

3.2.3 Soils Survey of England and Wales maps indicate that soils in the area are a mixture of 'deep, well drained, coarse loamy and sandy soils locally over gravel' and 'slowly permeable seasonally waterlogged fine loamy soils'. North of Caernarfon the Scheme area is dominated by the well drained soils whereas soils are more variable to the south.

3.2.4 The geology and soil maps suggest moderate infiltration potential for the soils and underlying geology along the route although this will vary depending on the specific location. The underlying geology would not generally support major aquifers. There is potential for minor aquifers and groundwater flows through the underlying soils and geology. Some lower lying areas may be susceptible to groundwater flooding but this is likely to be related to migration of surface water flows rather than groundwater aquifers rising to the ground surface.

Hydrology and Surface Water Features

3.2.5 The Scheme crosses through five Main River catchments: the Afon Carrog, Afon Rhyd, Afon Gwyrfai, Afon Seiont and Afon Cadnant as described in the following sections and illustrated in Figure 14.1 (Appendix A). These catchments incorporate a number of main rivers, their tributaries and smaller watercourses. The rivers generally flow in a westerly direction, with their source in higher land on the western area of Snowdonia and drain largely rural catchments before discharging to the Menai Strait. The rivers are tidally influenced in their lower reaches but this does not extend to the Scheme location. The other main surface water feature in the vicinity is the Menai Strait. The Scheme is generally located approximately 2km east of the Menai Strait which is a narrow stretch of tidal water between Anglesey and mainland Wales. At its northern end, near Goat roundabout, the Scheme is located approximately 400m from the Menai Strait.

Afon Carrog

3.2.6 The Afon Carrog is a designated Main River located to the south of the Scheme. The road alignment crosses tributaries of the Carrog in the northern part of the catchment. The Carrog has a reasonably small and rural catchment with its source near Rhosgadfan to the east. The Afon Carrog continues through largely rural areas to discharge to Foryd Bay and then to the Menai Strait.

Afon Rhyd

3.2.7 The Scheme crosses the Afon Rhyd (a designated Main River) approximately 500m west of Dinas. The Scheme also crosses tributaries of the Rhyd. The Rhyd is a reasonably small watercourse which has been engineered in places; its source is in Moel Tryfan Quarry south east of the Scheme and it has a largely rural catchment area of approximately 5 km^2. According to the Flood Estimation Handbook (FEH) CD-ROM the catchment has moderate permeability.

Afon Gwyrfai

3.2.8 The Afon Gwyrfai is a designated Main River and is one of the larger rivers flowing through the study area. The Scheme crosses the Gwyrfai approximately 800m south-west of Bontnewydd. At this location the Gwyrfai has a wide floodplain. The Scheme also crosses tributaries of the Gwyrfai, notably the Afon Rhosdican.

3.2.9 At the proposed crossing the Afon Gwyrfai and its tributary, the Afon Bueno, have a combined catchment area of approximately 50 km^2. The catchment is largely rural with the main urban areas being Bontnewydd and Waunfawr. The source of the Gwyrfai is in Snowdonia with the upper catchment dominated by steep, mountainous areas.

3.2.10 According to the FEH CD-ROM the permeability of the catchment soils is reasonably low. Runoff from the catchment is likely to be high due to the limited soil cover and permeability, steep topography and high rainfall. However there are a number of lakes and reservoirs in the upper catchment which will help to attenuate peak flows reaching the lower lying ground.

3.2.11 The Afon Rhosdican is a tributary of the Afon Gwyrfai that joins the larger river downstream of the Scheme. It is a designated Main River with a reasonably small catchment to the south of Caernarfon. The Scheme runs close to the Afon Rhosdican for approximately 1.5km and crosses it in places.

Afon Seiont

3.2.12 The Afon Seiont is a designated Main River and is another of the larger rivers flowing through the study area. The Scheme crosses the Seiont east of Caernarfon. At this location the Seiont has a reasonably confined floodplain. The Scheme also crosses minor drains which outfall to the Seiont.

3.2.13 The Afon Seiont has a catchment area of approximately 82 km^2. The upper catchment includes steep, mountainous areas west of Snowdon. These areas are largely rural although there have been some significant works in the past due to mining and hydropower operations. There are two large glacial lakes in the upper catchment, Llyn Peris and Llyn Padarn; the Llyn Peris forms part of the Dinorwig hydropower scheme. The upper catchment is exceptionally west with impermeable geology and much bare rock exposure. Runoff from this area will be high, although the lakes will provide some attenuation of flows continuing downstream.

3.2.14 Downstream of Llyn Peris the catchment is much less steep. It remains largely rural until Caernarfon with the soils and geology suggesting moderate permeability and therefore a moderate runoff response. Downstream of the Scheme the Afon Seiont flows south of Caernarfon to the Menai Strait. The Scheme is upstream of the tidal limit.

Afon Cadnant

3.2.15 The Afon Cadnant and its tributary are designated Main Rivers which drain the area around Bethel and flow in a south westerly direction through Caernarfon to discharge to the Menai Strait. The Scheme crosses the Cadnant in the upper reaches of the catchment; the catchment is reasonably small at this point (approximately 4 km^2) and largely rural, with the exception of Bethel village.

3.2.16 For the area, the catchment is reasonably flat with soils of moderate permeability. Site observations indicated potential soil saturation and, as the Scheme is located in the upper catchment, it is expected that the overall response from direct runoff and baseflows is similar.

3.2.17 NRW has advised that the Cadnant is a significant source of flooding in Caernarfon, particularly where it is culverted through the urban area.

3.2.18 The Scheme also crosses an un-named watercourse which drains to the Menai Strait at the northern end of the Scheme. This watercourse originates as a bifurcation of the Cadnant close to the Scheme, before heading in a north west direction.

Soil Infiltration

3.2.19 The available information indicates soils and geology of varying permeability throughout the Scheme. However infiltration testing undertaken for the scheme in accordance with BRE365 showed very low infiltration rates; the majority of test pits did not drain sufficiently for the infiltration rate to be calculated.

3.2.20 As detailed in the drainage strategy (Appendix C), the very low infiltration rates would not support the use of infiltration as the sole means of surface water disposal.

Existing Drainage

3.2.21 The proposed Scheme crosses land that is largely undeveloped with no formal drainage.

SECTION 4

EXISTING FLOOD RISK

4 EXISTING FLOOD RISK

4.1 Tidal Flooding

4.1.1 The Scheme is generally located approximately 2km inland from the Menai Strait, a shallow tidal water separating the Isle of Anglesey from mainland Wales. The rivers flowing through the study area eventually discharge to the Menai Strait and are tidal in their lower reaches.

4.1.2 Figure 4.1 shows the extent of NRW Flood Zone 2 which is derived from tidal flood models or tidal / coastal flood risk information and represents land potentially at risk from tidal flooding in the 1000 year flood event. This indicates that the Scheme is not at risk of tidal flooding and the rivers are not tidally influenced within the study area.

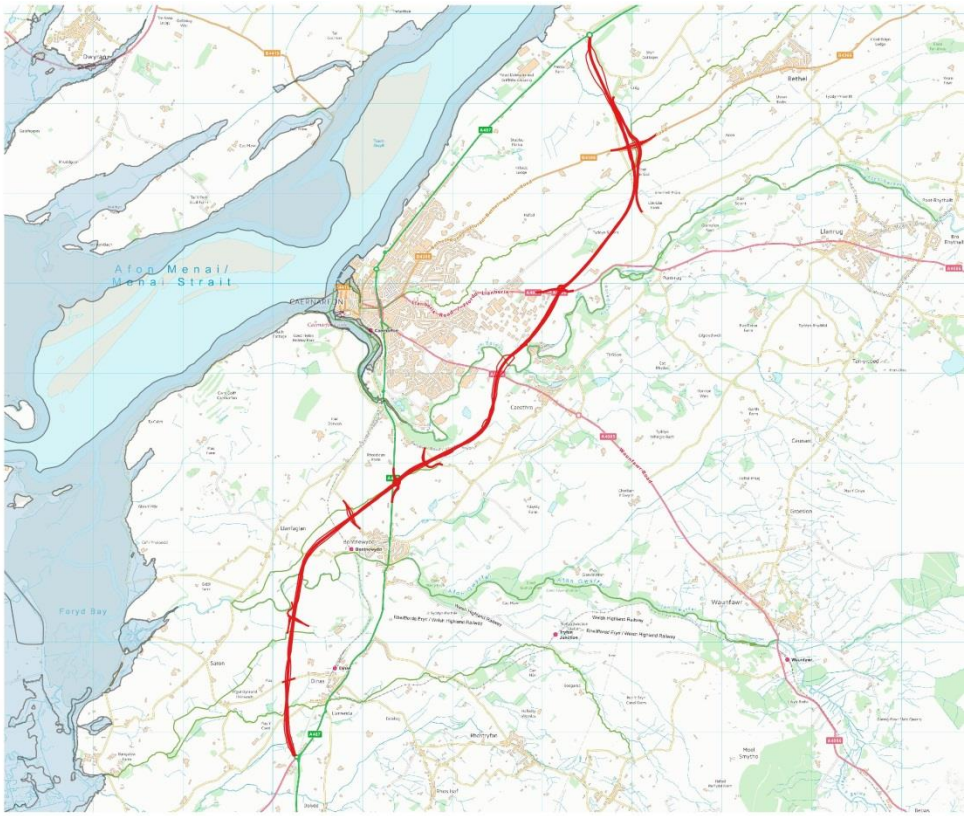

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Figure 4.1 - NRW Tidal Flood Zone 2

4.1.3 NRW also provided extreme sea level estimates at Foryd Bay in the vicinity of the site (NGR SH 43944 61311). Allowances for sea level rise in accordance with Defra 2006 guidance were included in the estimates. The 95% confidence bound 1000 year extreme sea level estimate, including for sea level rise to 2115, is 5.0 mAOD. The ground levels at the site are all above this level.

4.1.4 The Scheme is therefore not considered at risk of tidal flooding, even accounting for climate change effects. Tidal flooding has not been considered further in this assessment.

4.2 Fluvial Flooding

4.2.1 This section provides an overview of fluvial flood risk throughout the Scheme. Further details on existing and post development flood risks for the Afon Rhyd, Afon Gwyrfai, Afon Seiont and Afon Cadnant are provided in Section 6 of this report.

4.2.2 Figures 4.2 a - c show extracts from the NRW Flood Zones and updated flood map for surface water provided by NRW. Both sets of data are largely based on generalised modelling techniques that do not take account of local influences and hydraulic features; however, they provide a good indication of areas that may be at risk of fluvial flooding. The map shows the following layers:

- Flood Zone 3 - Defined as land with an annual probability of flooding of 1% or greater (the 100 year flood extent), ignoring the presence of defences;
- Flood Zone 2 - Defined as land with an annual probability of flooding of between 1% and 0.1% (the 1000 year flood extent), ignoring the presence of defences;
- 1000 year surface water flood risk area - land which may flood during a storm with a return period of 1000 years. This layer includes areas at risk from overland flows in addition to rivers and watercourses. It has however been included as it provides an indication of areas at risk from smaller watercourses where Flood Zones have not been defined.

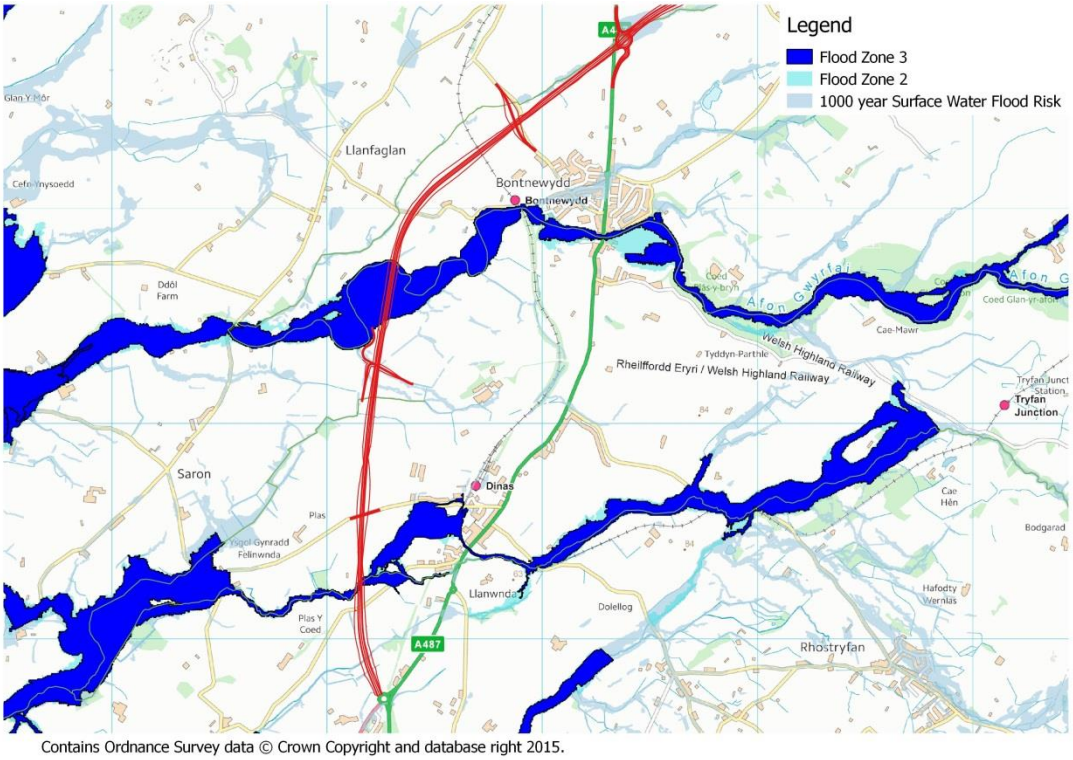

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Figure 4.2a - Fluvial Flood Risk Areas (South)

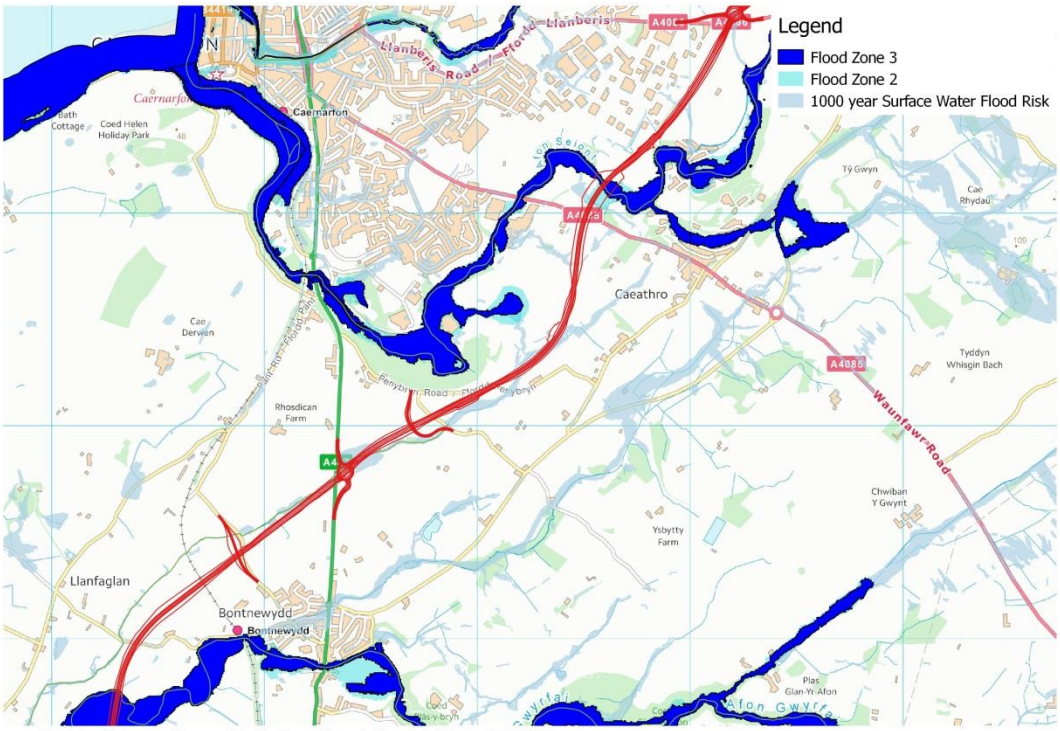


Figure 4.2b - Fluvial Flood Risk Areas (Mid)

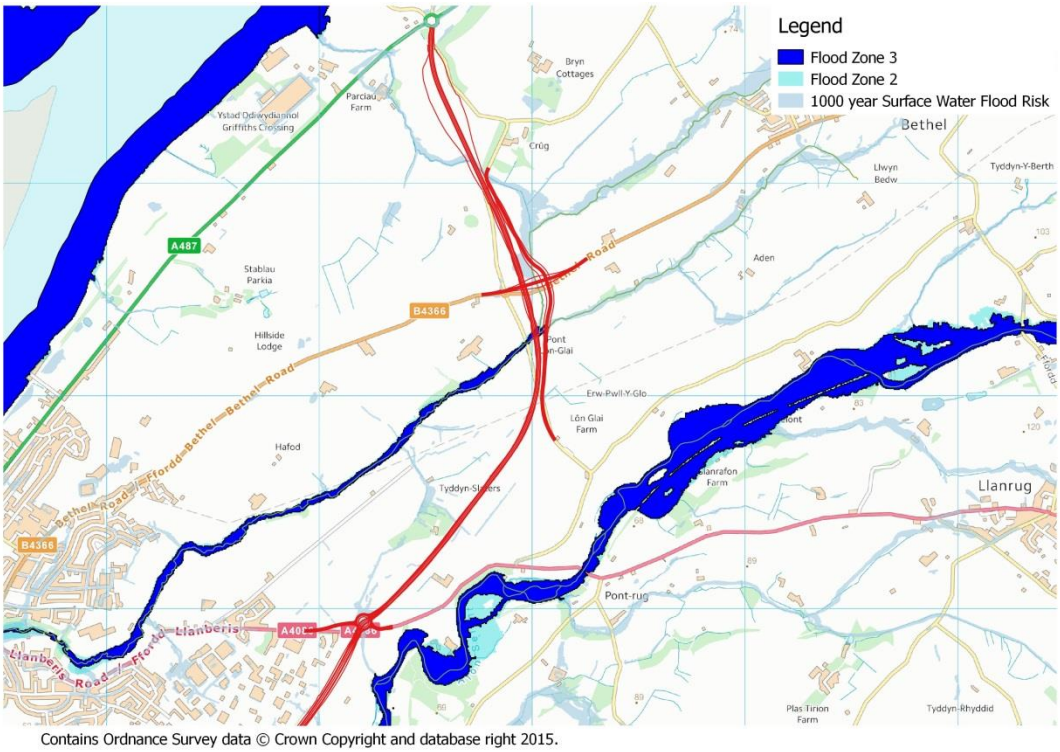


Figure 4.2c - Fluvial Flood Risk Areas (North)

4.2.3 Land outside of Flood Zones 2 and 3 is designated Flood Zone 1 and considered at low risk of fluvial flooding. This is equivalent to TAN15 Zones A & B. Flood Zone 2 is equivalent to TAN15 Zone C.

4.2.4 Figure 4.2 shows that the majority of the Scheme is at low risk of fluvial flooding. As would be expected, the main areas where fluvial flooding may affect or be affected by the Scheme are the proposed watercourse crossings. The fluvial flood extents are generally reasonably confined and limited to the immediate vicinity of the watercourse although the Afon Gwyrfai has a more extensive floodplain.

4.2.5 Fluvial flooding has been considered in the Scheme design and appropriate mitigation included to manage risks to the Scheme and potential impacts of the Scheme on flooding elsewhere. This is described in more detail in Sections 5 and 6 of this report.

4.3 Other Sources of Flooding

Groundwater Flood Risk

4.3.2 Groundwater flooding occurs when water stored below ground reaches the surface. It is commonly associated with porous underlying geology, such as chalk, limestone and gravels. The available information on geology at the site suggests groundwater flooding is unlikely to be a significant issue but may be a problem locally. A number of springs are shown on OS mapping which also indicate potential for groundwater emergence. This is supported by information in the SFCA and other previous studies. There is likely to be some interaction between groundwater and river flows and potential for flooding from shallow groundwater in low lying land close to rivers. Locations where the Scheme is in cutting will also be more susceptible to groundwater flooding.

4.3.3 NRW provided mapping showing Areas Susceptible to Groundwater Flooding (AStGWF). This classifies land in 1km grid squares based on what proportion of the square has geological and hydrogeological conditions in which groundwater might emerge. The assessment is based on the underlying geology. The AStGWF map does not provide any information on the likelihood of groundwater emergence in these areas. Only isolated areas within the overall susceptible area are likely to suffer the consequences of groundwater flooding. There are no known incidents of groundwater flooding at the site; however, as much of the area is rural this does not necessarily imply that no groundwater flooding has occurred.

4.3.4 Figure 4.3 shows the AStGWF across the study area. The majority of the Scheme passes through land where the susceptibility to groundwater flooding is due to superficial deposits as the bedrock geology does not support large aquifers. North of Caernarfon the classification is mostly <25% or 25 - 50%, indicating low to moderate susceptibility to groundwater flooding. South of the town the classification is mostly 50 - 75% although the area around the Afon Gwyrfai is classified as >75% which would indicate moderate to high susceptibility.

4.3.5 Borehole records from the ground investigation report have been reviewed to assess current groundwater levels at the site. The majority of the borehole records do not show a groundwater strike, indicating the groundwater level is below the base of the borehole. Some of the boreholes recorded groundwater nearer the surface. Where information is available the recorded borehole levels have been considered for proposed cuttings as noted in Table 4.1.

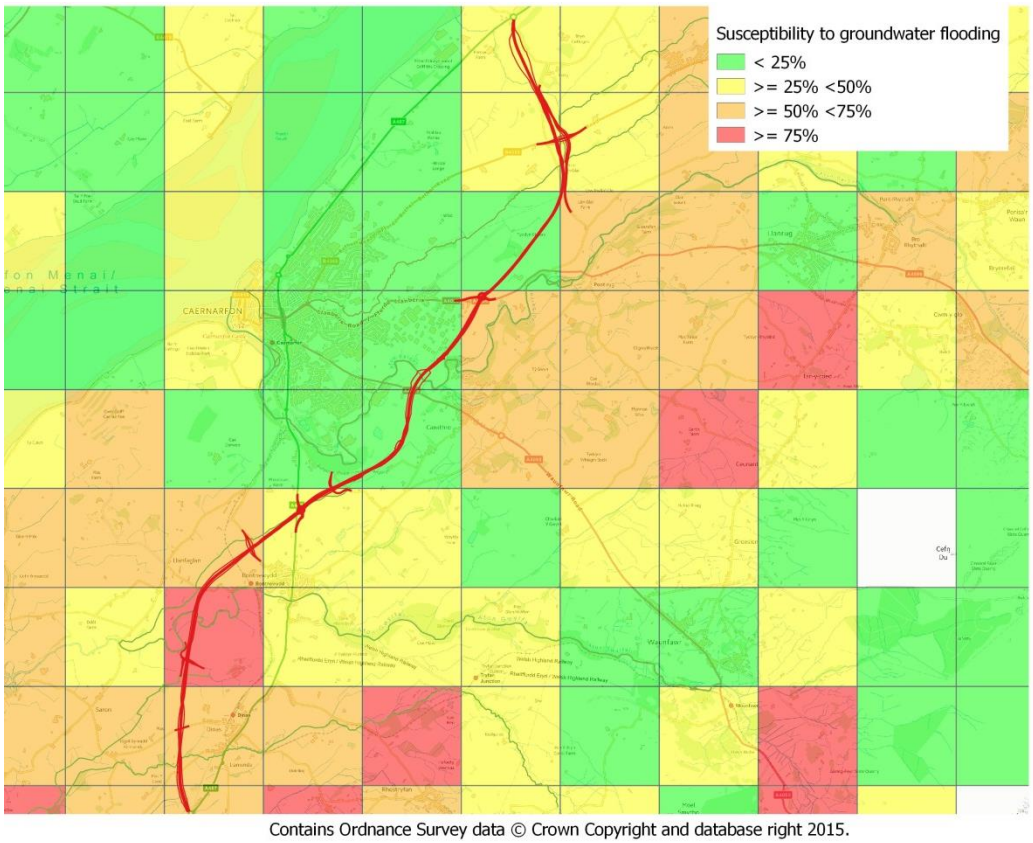


Figure 4.3 - Areas Susceptible to Groundwater Flooding (map shows proportion of grid square classified as susceptible)

4.3.6 Groundwater flooding is not considered a significant constraint to the Scheme; however, it should be considered where the Scheme is located in cutting as detailed in Table 4.1.

Table 4.1. Locations where potential groundwater flooding should be considered

Chainage	Location	Groundwater flood risk
650 - 1100	Near Llanwnda	Moderate / high susceptibility (50 - 75%). Boreholes did not record groundwater (terminated ~ 10 - 10.8 mbgl) Some potential for groundwater flooding dependent on depth of cutting and groundwater levels.
4300 - 4450	Near old quarry south of Caernarfon	Low susceptibility (<25%). Borehole records south of this location indicate groundwater levels ~ 35.5 - 37.9 mAOD. Lower likelihood of groundwater flooding as cutting is shallow and groundwater levels are likely to be similar to water levels in the quarry which is at a lower level than the site.

Chainage	Location	Groundwater flood risk
4800 - 5000	Near old quarry south of Caernarfon	Low susceptibility (<25%). Borehole records show highly variable groundwater levels in the vicinity (~ 36.8 - 46.6 mAOD). Some potential for groundwater flooding; however, groundwater levels are likely to be similar to water levels in the quarry which is at a lower level than the site.
5600 - 6500	Near Cibyn Industrial Estate (near Caernarfon)	Low (<25%) and moderate / high susceptibility (50 - 75%). Borehole records indicate groundwater levels in the vicinity ~48.2 - 48.6 mAOD. Potential for groundwater flooding dependent on depth of cutting and groundwater levels.
7180	Footpath near Tiddyn Bistle	Low susceptibility (<25%). No recorded groundwater levels in vicinity. Some potential for groundwater flooding depending on depth of cutting & groundwater levels. Impacts likely to be limited to footpath.
8250 - 9700	Bethel Road to existing A487 tie-in (Plas Menai)	Low / moderate susceptibility (25 - 50%). Borehole records indicate variable groundwater levels in vicinity ~ 48.2 - 52.4 mAOD. Some potential for groundwater flooding depending on depth of cutting & groundwater levels.

Overland Flow

4.3.7 For the purpose of this FCA, flood risk from overland flow includes flooding from surface water runoff and surcharging of the sewerage network.

4.3.8 Figures 4.4 a - c show the updated flood map for surface water at the study area. The map shows areas at risk from storms with return periods of 30, 100 and 1000 years. The map has been produced from generalised modelling and uses a simplified approach. In particular, the modelling technique often does not account for culverts which carry smaller watercourses under roads and similar linear features on embankments. The extent of flooding can frequently be overestimated in these areas as floodwater builds up behind the embankments. Despite this, the maps provide a good indication of areas that may be subject to more rapid flows or ponding of runoff.

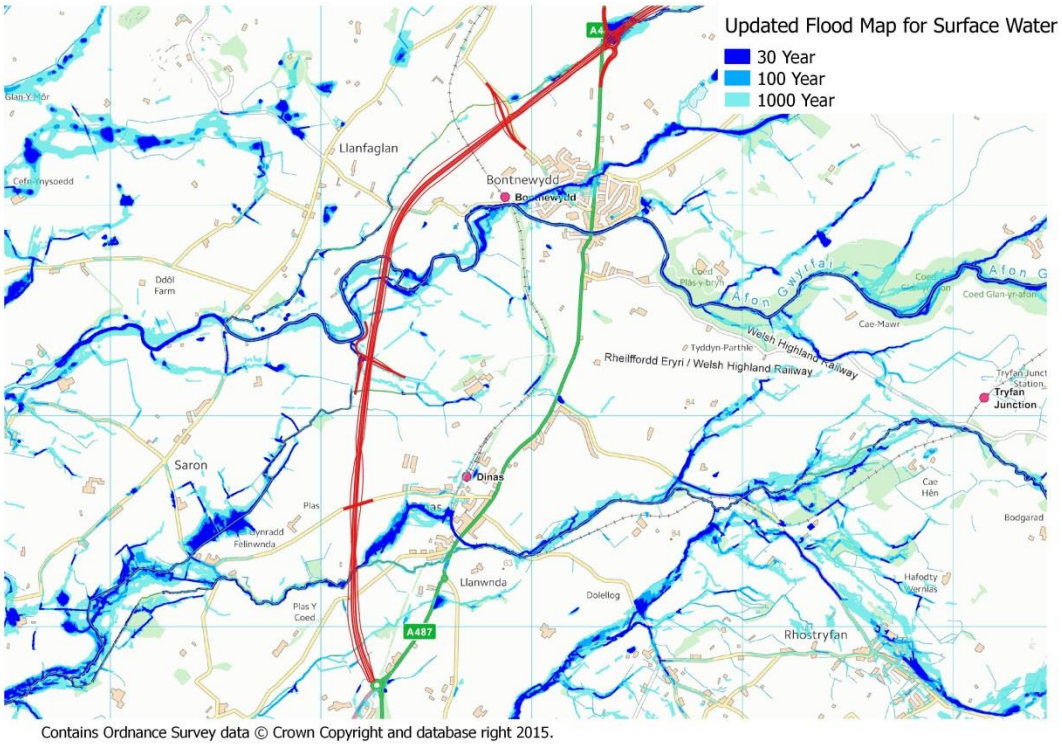


Figure 4.4a - Surface Water Flood Risk Areas (South)

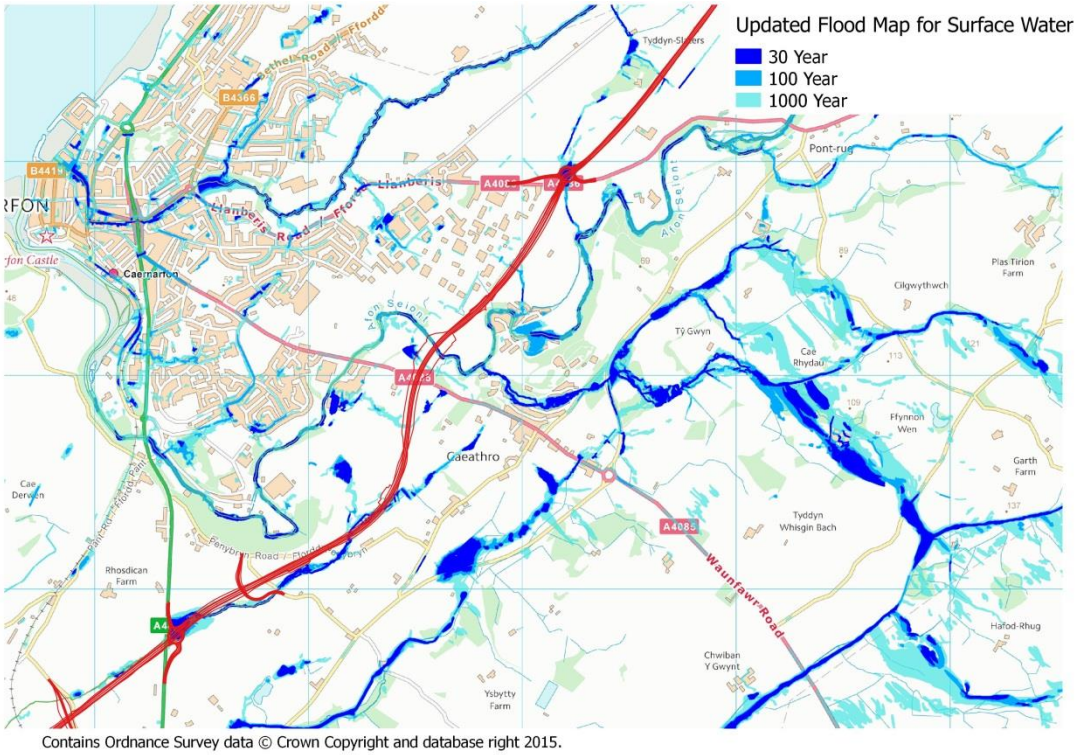


Figure 4.4b - Surface Water Flood Risk Areas (Mid)

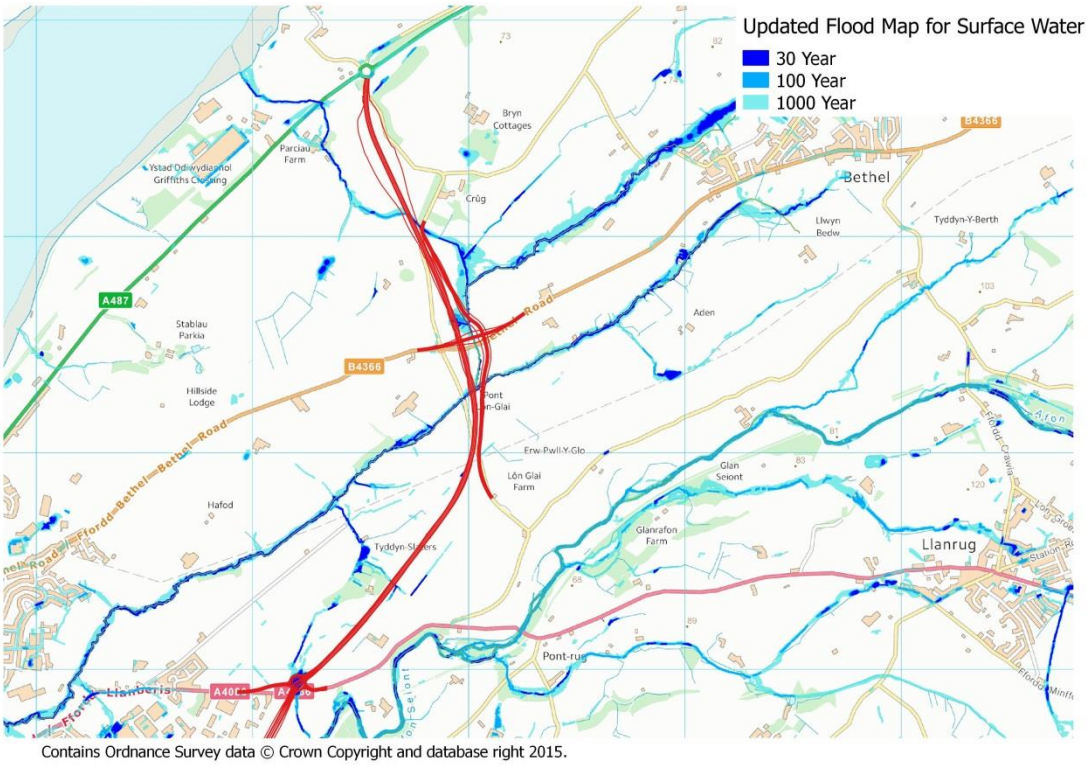


Figure 4.4c - Surface Water Flood Risk Areas (North)

4.3.9 In general the areas shown at risk follow drains and watercourses shown on OS mapping. Flooding from local watercourses has been considered in the Scheme design and appropriate mitigation included to manage risks to the Scheme and potential impacts of the Scheme on flooding elsewhere. This is described in more detail in Sections 5 and 6 of this report.

4.3.10 The majority of the Scheme is at low risk of surface water flooding. Table 4.2 indicates locations identified as potentially at risk from surface water flooding that may not be directly related to local watercourses. As the Scheme is largely located in a rural area flooding from sewers is unlikely to present a significant constraint.

Table 4.2. Locations identified at risk of surface water flooding

Chainage	Location	Surface Water Flood Risk
1450	Close to Afon Gwyrfai	Flood map indicates potential flow path across the Scheme during the 1000 year event. Unlikely to present a significant constraint.
2100	Close to Afon Gwyrfai	Flood map indicates potential flow path across the Scheme during the 1000 year event. Unlikely to present a significant constraint.

Chainage	Location	Surface Water Flood Risk
2300	Near Bontnewydd	Flood map indicates minor flow path along existing road (1000 year). Unlikely to present a significant constraint as new road cross the existing on embankment.
4500 - 4700	Afon Rhosdican near Penybryn Road	OS mapping and SW flood map indicates Scheme crosses the Afon Rhosdican; however, topographic survey indicates the watercourse remains on the eastern side of the proposed road. Flood map indicates flow path towards the Afon Rhosdican. Unlikely to present a significant constraint as new road cross the existing on embankment.
5100	South of A485 near Caeathro	Flood map indicates a surface water flow path (1000 year) which crosses the Scheme. The Scheme is on raised embankment at this location.
5400	North of A485 near Caeathro	Flood map indicates a surface water flow path (1000 year) which crosses the Scheme. The Scheme is on raised embankment at this location.
6000 & 6100	Near Cibyn Industrial Estate	Flood map indicates a surface water flow path (100 year) along the existing access track. The Scheme is in cutting at this location.
6500	Cibyn roundabout	Flood map indicates significant surface water ponding north of the A4086. It is likely that a ditch or small watercourse is present which carries runoff under the existing road.
7150	Near Tiddyn Slaters	Flood map indicates a surface water flow path crossing the Scheme. Although not shown on mapping a ditch is present which will be diverted through the pedestrian underpass.
7800	Near Lon Glai farm	Flood map indicates surface water flooding along the existing ditch. The Scheme crosses the ditch which will be diverted.

4.3.11 Flood risk from overland flows is considered in further details in Section 5 of the report.

Flooding from artificial sources

4.3.12 For the purpose of this assessment, artificial sources of flooding include raised reservoirs and canals that may cause flooding through failure of embankments. There are several large lakes and reservoirs located in the upper catchments of the watercourses.

4.3.13 The NRW online Flood Risk map shows areas at risk from failure of larger reservoirs, due to a breach in the embankments. The map indicates that the Gwyrfai and Seiont river valleys are at risk from a dam failure at upstream reservoirs. For the Seiont, the

area at risk is generally less than that from fluvial flooding (smaller than Flood Zone 2); however, for the Gwyrfai it is slightly larger in places. Flood flows from breach can be rapid with little warning. However as the Scheme is located some distance downstream of the reservoirs it is anticipated that breach flows will be slower and present a lower hazard than immediately downstream of the reservoir.

4.3.14 Reservoirs are subject to strict management and control therefore the likelihood of a dam failure is very low. The Scheme is located on embankment where it crosses the Afon Gwyrfai and Afon Seiont therefore reservoir failure is not considered to present a significant constraint to the Scheme.

4.3.15 No other artificial sources of flooding have been identified from OS mapping therefore artificial flooding has not been considered further.

4.4 Summary of Existing Flood Risk

4.4.1 The majority of the Scheme is assessed at low risk of flooding from any source. The main areas where flooding may present a constraint are where the Scheme crosses or runs close to existing watercourses. The following sources of flooding are considered to present a potential constraint to the Scheme, or have the potential to be affected by the Scheme:

- Fluvial flooding from Main Rivers and local watercourses;
- Overland flows from surface water flooding;
- Groundwater flooding where the Scheme is in cutting.

4.4.2 The impacts of flooding on the Scheme and impact of the Scheme on flood risk elsewhere, including assessment of appropriate mitigation, is discussed further in Sections 5 and 6.

SECTION 5

POST DEVELOPMENT FLOOD RISK

5 POST DEVELOPMENT FLOOD RISK

5.1 Mitigation measures included in the Scheme

5.1.1 The majority of the Scheme is assessed at low risk of flooding from any source. The main areas where flooding may present a constraint are where the Scheme crosses or runs close to existing watercourses. The following sources of flooding are considered to present a potential constraint to the Scheme, or have the potential to be affected by the Scheme:

- Fluvial flooding from Main Rivers and local watercourses;
- Overland flows from surface water flooding;
- Groundwater flooding where the Scheme is in cutting.

5.1.2 The following mitigation measures will be included to manage flood risks posed to the Scheme and the impact of the Scheme on flood risks elsewhere:

- New Main River crossings have been designed to carry the 100 year flow (with climate change) with a minimum 600mm freeboard to reduce the likelihood of floodwaters spilling onto the new road or increasing flood risk upstream of the Scheme.
- New Ordinary Watercourse crossings have been designed to carry the 100 year flow (with climate change) with a minimum 300mm freeboard to reduce the likelihood of floodwaters spilling onto the new road or increasing flood risk upstream of the Scheme. A 300mm freeboard was agreed with Gwynedd Council appropriate to the size of the watercourses and nature of the catchments. In many places the culverts have a larger capacity / freeboard as this is dictated by other constraints.
- The proposed crossings of the Afon Seiont and Afon Gwyrfai are viaducts, which largely span the floodplain to reduce the impacts on river flows and flood risks.
- The requirement for trash/debris screens has been assessed in accordance with current EA/Defra guidance, which considers both blockage risk and the risk of the potential for non-permitted access by members of the public. Based on the results of this assessment, it is only proposed to apply a security screen to the inlet of the 0.6m diameter culvert S118 (chainage 8900 near Crug). Limiting the number of screens reduces the risk of flooding due to blockage of trash screens.
- Generally, existing ditches and watercourses have been diverted as necessary to maintain existing flow routes and the current drainage regime. Diverted watercourses will be designed to maintain the existing capacity based on matching cross-sectional area.
- Generally, where the Scheme passes close to existing or proposed watercourses, appropriate buffers (minimum 2m) have been provided to cater for flood flows and reduce the likelihood of flooding affecting the Scheme or the Scheme increasing flood risk elsewhere through loss of conveyance of floodplain storage.
- Cut-off ditches or filter drains have been provided where runoff is likely to flow towards the route corridor to capture runoff and direct this towards existing watercourses. The existing drainage regime has been maintained to prevent “cross-transfer” of flows between catchments.

- The proposed drainage strategy includes slope drainage for the Plas Menai cutting and toe drainage at the base of cuttings to capture any groundwater ingress to the highway.
- The proposed drainage strategy includes appropriate measures to limit additional runoff from the Scheme up to and including the 100 year event (with climate change allowance). Further details of the proposed drainage strategy are provided in Section 7.
- Attenuation ponds have generally been located outside of the floodplain so that fluvial flooding does not compromise their effectiveness and the ponds do not impact flood risks through loss of conveyance or floodplain storage. Where necessary ponds will be bunded to prevent flooding from watercourses during a 100 year event (with climate change).

5.2 Fluvial Flood Risk

5.2.1 Table 5.1 summarises the locations where fluvial flood risk has been identified as a constraint to the Scheme. The table includes an assessment of the impact of flooding to the Scheme and the impact of the Scheme on flooding elsewhere. The assessment for the larger Main Rivers (Rhyd, Gwyrfai, Seiont and Cadnant) is provided separately (Section 6).

5.2.2 The assessment is qualitative and based on the design information and methodology used in the design. The proposed culverts have been designed in accordance with the hydraulic requirements of HA 107/00 and CIRIA C689. Design flows have been determined using the IH124 small catchments approach for the 100 year event (including a 20% climate change allowance) as stipulated in HA106/04. Culverts have been sized using simplified steady state 1D hydraulic models (ISIS).

5.2.3 Watercourse diversions have been sized to maintain the existing capacity based on the upstream cross section. A minimum 2m buffer has generally been provided to watercourses.

5.2.4 The approach adopted in the design is considered appropriate, therefore the assessment assumes that all new culverts will take the 100 year flow (with climate change) and provide a minimum 300mm freeboard, and that diverted watercourses will, as a minimum, match the capacity of existing watercourses.

5.2.5 As detailed in Table 5.1 the fluvial flood risk to the Scheme is considered low. There are some locations where flooding may occur during larger events, however this is not expected to exceed TAN15 thresholds in respect of acceptable flood consequences (Table 2.5) and is therefore considered acceptable at these locations.

5.2.6 The Scheme includes a number of new watercourse crossings and diversions. These will potentially have small localised impacts due to effects on floodplain storage and conveyance, but are not expected to lead to an increase in flooding elsewhere as existing flow routes are maintained and the proposed crossings will be designed to convey the 100 year flow (with climate change).

5.3 In general proposed temporary works are unlikely to significantly affect flood flows. It is assumed that appropriate temporary diversions and pumping will be put in place to maintain watercourse flows whilst new channel and structures are being built. The potential impacts associated with temporary works for the Afon Gwyrfai and Afon Seiont are described in Section 6.

Table 5.1. Assessment of post-development fluvial flood risk

Chainage	Location	Description	Impact of flooding to the Scheme	Impact of the Scheme on flooding elsewhere
17	Roundabout south of Llanwnda	Small watercourse crosses Scheme. Existing culverts to be extended.	Low risk - road is on embankment and culverts will maintain flow to reduce the likelihood of flows backing up behind embankment.	Nominal - culvert extensions will maintain existing flow route
122	South of Llanwnda	Small watercourse crosses Scheme. Existing ditch will be infilled and diverted to culvert S101	Low risk - road is on embankment and culverts / diversions will maintain flow to reduce the likelihood of flows backing up behind embankment.	Nominal - culvert S101 and diversion will maintain existing flow route
185	South of Llanwnda	Ordinary watercourse crosses Scheme. New 1.8m dia. culvert proposed (S101).	Low risk - road is on embankment and culverts will maintain flow to reduce the likelihood of flows backing up behind embankment. Approx. 7m freeboard before flows would spill onto highway	Nominal - culvert S101 will maintain existing flow route. SW flood map indicates flows confined even for 1000 year event therefore flood storage loss will be nominal.
317	Near Afon Rhyd	Small watercourse located west of road. Scheme encroaches on upstream end.	Low risk - road is on embankment and upstream ditch diverted to culvert S101.	Small impact - upstream runoff diverted through culvert S101 so flow route maintained. Minor loss of storage at ditch but existing ditch maintained downstream.
500 - 600	Afon Rhyd	Refer Section 6		
1300	West of Dinas	Small watercourse crosses Scheme. Existing ditch to be diverted to culvert S104	Low risk - road is on embankment and culverts / diversions will maintain flow to reduce the likelihood of flows backing up behind embankment.	Nominal - culvert S104 and diversion will maintain existing flow route
1400	West of Dinas	Ordinary watercourse crosses Scheme. New 1.8m dia. culvert proposed (S104). Attenuation pond located adjacent to watercourse.	Low risk - road is on embankment and culvert will maintain flow to reduce the likelihood of flows backing up behind embankment. Approx. 1.3m freeboard before flows would spill onto highway. Pond is raised above watercourse and slightly bunded therefore flooding is unlikely.	Nominal - culvert S104 will maintain existing flow route. SW flood map indicates flows reasonably confined even for 1000 year event therefore flood storage loss will be nominal. Pond is located outside of 100 year surface water flood extent.

Chainage	Location	Description	Impact of flooding to the Scheme	Impact of the Scheme on flooding elsewhere
1550	Near Afon Gwyrfai	Ordinary watercourse crosses Scheme. Existing ditch will be diverted through underpass S105. Attenuation pond located between underpass and Gwyrfai, shown to slightly encroach into 1000 year surface water extent.	Low risk to A487. Moderate risk to proposed underpass in cutting. Flood depths unlikely to exceed TAN15 thresholds due to size of catchment. Pond is raised above watercourse and slightly bunded therefore flooding is unlikely.	Small impact - flood risk may slightly increase to existing access track where it crosses under the new road. Ditch diversion will maintain existing flow route. Pond is located outside of 100 year surface water flood extent.
1700 - 2000	Afon Gwyrfai	Refer Section 6.		
2900	Afon Rhosdican near Bontnewydd	Afon Rhosdican crosses existing highway in culvert (retained). Side road diverted slightly west, additional 1.8m dia culvert proposed where side road crosses the Rhosdican (S109A)	Low risk - road is on embankment and culvert will maintain flow to reduce the likelihood of flows backing up behind embankment. Approx. 6m freeboard before flows would spill onto new side road. Flood risk to side road reduced. Surface water flood map indicates low risk of flooding to A487.	Small impact - flood risk will reduce to highway. Proposed culvert will maintain existing flow route. SW flood map indicates flows reasonably confined even for 1000 year event therefore flood storage loss will be nominal. Existing upstream culvert is also likely to be a flow constriction.
3100 - 3500	Afon Rhosdican north of Bontnewydd	Afon Rhosdican flows close to Scheme. The river will be diverted to the west away from the Scheme where the road encroaches into the existing watercourse. 2m buffer provided from watercourse to toe of embankment.	Low risk - road is on slight embankment and higher than surrounding ground. Assumed that ditch will be designed to maintain existing capacity. Flooding of watercourse is likely to extend onto lower ground to the west rather than the embankment. Embankment design should consider higher water levels but it is assumed this can be managed.	Small impact - proposed diversion should maintain flow route. Scheme may result in minor loss of floodplain storage and conveyance although this is not expected to result in increased flooding elsewhere.
3150	Near Afon Rhosdican	Small watercourse crosses Scheme. Proposed pipe crossing S109B (0.6m diameter) to maintain existing flow route	Low risk - culvert will maintain flow to reduce the likelihood of flows backing up behind embankment.	Nominal - culvert S109B will maintain existing flow route

Chainage	Location	Description	Impact of flooding to the Scheme	Impact of the Scheme on flooding elsewhere
3500 - 3700	Afon Rhosdican near existing A487	Afon Rhosdican crosses existing highway in culvert. Proposed roundabout is located on existing river course. Attenuation pond proposed. River will be diverted under new road at culverts S110 and S110A (1.8m dia.). SW flood map indicates reasonably extensive floodplain; however, it is expected that this does not account for the existing A487 culvert.	Moderate risk - road is on embankment and diversions / culverts will maintain flow to reduce the likelihood of flows backing up behind embankment. Approx. 1.3 - 2.4m freeboard provided at culverts before flows would spill onto highway. Local topography will direct flows through culverts prior to flooding of road. It is expected that flood depths will meet TAN15 thresholds therefore flood risks deemed acceptable. Pond will be bunded to prevent flooding for the 100CC event (currently shown within 1000 year SW flood extent). It is recommended that detailed hydraulic assessment or modelling is undertaken to confirm flood extents design detailed design.	Small impact - proposed diversion and culverts should maintain flow route. Scheme will likely result in some loss of floodplain storage and conveyance although this is not expected to result in increased flooding elsewhere. It is recommended that detailed hydraulic assessment or modelling is undertaken to confirm flood extents at detailed design stage.
3700 - 3900	Afon Rhosdican south of Caernarfon	Afon Rhosdican flows close to Scheme. Proposed embankment slightly encroaches into SW map extents. 2m buffer provided from watercourse to toe of embankment.	Low risk - road is on embankment and higher than surrounding ground. Embankment design should consider higher water levels but it is assumed this can be managed. Some potential for flood flows onto proposed side road underpass; however, SW flood map indicates this will be minor and unlikely to exceed TAN15 thresholds.	Small impact - flow route maintained. Scheme may result in minor loss of floodplain storage but this is not expected to lead to increased flooding elsewhere.

Chainage	Location	Description	Impact of flooding to the Scheme	Impact of the Scheme on flooding elsewhere
4100	Afon Rhosdican at road crossing	Afon Rhosdican crosses existing highway in culvert. Existing culvert will be removed and new culvert proposed under realigned road (1.5m dia.) (S111B). SW flood map indicates backing up behind road; however, it is expected that this does not account for the existing culvert.	Low risk - road is on embankment and culvert will maintain flow to reduce the likelihood of flows backing up behind embankment. Approx. 1.3m freeboard before flows would spill onto new side road. Flood risk to side road reduced.	Small impact - flow route maintained. Scheme may result in increased flows through culvert and reduced flooding upstream but this is not expected to have a significant impact in the wider area. Flood risk to side road likely to reduce.
4300 - 4400	Afon Rhosdican near Penybryn Road	SW Flood map indicates proposed attenuation pond may slightly encroach into flood extent	Low risk - potential for flooding of attenuation pond during extreme events; however, this is not considered to significantly affect the performance in terms of available storage volume as pond likely to be full and rate of ingress assumed to be reasonably small.	Small impact - potential for minor loss of floodplain storage but this is not expected to increase flooding elsewhere.
4500 - 4800	Afon Rhosdican near Penybryn Road	OS mapping and SW flood map indicates Scheme crosses the Afon Rhosdican however, topographic survey indicates the watercourse remains on the eastern side of the proposed road. Proposed embankment may slightly encroach on existing watercourse and flood extents.	Low / moderate risk - road is on embankment and higher than surrounding ground. Embankment design should consider higher water levels but it is assumed this can be managed. Some potential for flooding during extreme events; however, it is unlikely this will exceed TAN15 thresholds due to catchment size.	Small impact - flow route maintained. Scheme may result in minor loss of floodplain storage but this is not expected to lead to increased flooding elsewhere.
5500	Afon Seiont Crossing	Refer Section 6		

Chainage	Location	Description	Impact of flooding to the Scheme	Impact of the Scheme on flooding elsewhere
5850	Near Caernarfon	Scheme crosses small watercourse. Proposed pipe crossing S112C (0.6m diameter) to maintain existing flow route	Low risk - culvert will maintain flow to reduce the likelihood of flows backing up behind embankment. If the culvert surcharges flows will enter the cut-off drain. Culvert will have min 900mm cover therefore low risk of flooding to road for 100CC event. Some flooding may occur to road during 1000 year event but unlikely to exceed TAN15 thresholds due to catchment size and embedded mitigation.	Nominal - culvert S112C will maintain existing flow route
8100 - 8600	Bethel Road Roundabout	Refer Section 6.		
8900 - 9000	Near Crug	Scheme crosses ordinary watercourse which is culverted under existing road. Watercourse will be diverted through culverts S118 and S116 (0.6m diameter) and new channel.	Low / moderate risk - culverts and diversion will maintain flow to reduce the likelihood of flows spilling onto highway. Proposed roads are in cutting therefore flow exceeding culvert capacity may flood highway. However as culverts are designed for 100CC flow it is not expected that flooding will exceed TAN15 thresholds.	Small impact - flow route maintained. Scheme may result in minor loss of floodplain storage but this is not expected to lead to increased flooding elsewhere. SW flood map indicates flooding is reasonably confined to watercourse. Scheme may result in increased flows through culvert and reduced flooding upstream but this is not expected to have a significant impact in the wider area. Flood risk to side road likely to reduce.

5.4 Surface water flood risk

5.4.1 Table 5.2 summarises the locations where overland flows and surface water flood risk has been identified as a constraint to the Scheme. The table includes an assessment of the impact of flooding to the Scheme and the impact of the Scheme on flooding elsewhere.

5.4.2 The assessment is qualitative based on the design information and methodology used in the design. The Scheme includes provision for land drainage in accordance with the requirements of HD33/06 and cut-off ditches designed to the requirements of HA 106/04. Proposed culverts have been designed in accordance with the hydraulic requirements of HA 107/00 and CIRIA C689. Design flows have been determined using the IH124 small catchments approach for the 100 year event (including a 20% climate change allowance) as stipulated in HA106/04. Culverts have been sized using simplified steady state 1D hydraulic models (ISIS).

5.4.3 Watercourse diversions have been sized to maintain the existing capacity based on the upstream cross section. A minimum 2m buffer has generally been provided to watercourses.

5.4.4 The approach adopted in the design is considered appropriate therefore the assessment assumes that all new culverts will take the 100 year flow (with climate change) and provide a minimum 300mm freeboard, and that diverted watercourses / ditches will as a minimum match the capacity of existing watercourses.

5.4.5 As detailed in Table 5.2, the surface water flood risk to the Scheme is considered low. Flooding may occur in some areas during larger events however it is not expected to exceed TAN15 thresholds in respect of acceptable flood consequences (Table 2.5) and is therefore considered acceptable.

5.4.6 The Scheme includes a number of new ditch crossings and diversions. These will potentially have small localised impacts, due to effects on floodplain storage and conveyance, but are not expected to lead to an increase in flooding elsewhere as existing flow routes are generally maintained and flows are likely to be small.

Table 5.2. Assessment of post-development surface water flood risk

Chainage	Location	Description	Impact of flooding to the Scheme	Impact of the Scheme on flooding elsewhere
1450	Close to Afon Gwyrfai	Flood map indicates potential flow path across the Scheme during the 1000 year event. Cut-off ditch provided to underpass.	Low risk - main road is on embankment therefore unlikely that runoff would be sufficient to flood the highway. It is likely that overland flows would be captured either by existing watercourse culverted at S104 or proposed cut-off ditch at top of underpass cutting	Small impact - the proposed embankment may interrupt flow path; however, this is only shown for the 1000 year event and overland flows would be captured either by existing watercourse culverted at S104 or proposed cut-off ditch at top of underpass cutting.
2100	Close to Afon Gwyrfai	Flood map indicates potential flow path across the Scheme during the 1000 year event.	Low risk - main road is on embankment therefore unlikely that runoff would be sufficient to flood the highway. It is likely that overland flows would flow towards the Gwyrfai east of the road.	Small impact - the proposed embankment may interrupt flow path; however, this is only shown for the 1000 year event and overland flows can continue towards the Gwyrfai east of the road.
2300	Near Bontnewydd	Flood map indicates minor flow path along existing road (1000 year).	Low risk - main road is on embankment therefore unlikely that runoff would be sufficient to flood the highway. Potential flood risk to existing road remains.	Nominal - no change to existing road proposed.
4500 - 4700	Afon Rhosdican near Penybryn Road	OS mapping and SW flood map indicates Scheme crosses the Afon Rhosdican; however, topographic survey indicates the watercourse remains on the eastern side of the proposed road. The topography indicates low lying land west of the Scheme may be susceptible to ponding of runoff	Low risk - road is on a slight embankment and ground levels are generally lower to the west therefore unlikely that significant ponding will occur sufficient to flood the road. The embankment design should consider the potential for ponded water; however, it is expected this could be managed. It may be advisable to include additional cut-off drains to manage overland flows.	Small impact - the Scheme may interrupt runoff flows towards the Afon Rhosdican; however, any effects will be localised and there are no properties in the vicinity.
5100	South of A485 near Caeathro	Flood map indicates a surface water flow path (1000 year) which crosses the Scheme. The	Low risk - main road is on embankment therefore unlikely that runoff would be	Small impact - the proposed embankment may interrupt flow path; however, this is only shown for the

		Scheme is on raised embankment at this location. Cut off ditch provided along embankment toe	sufficient to flood the highway. Cut-off ditch should intercept runoff.	1000 year event and overland flows would be captured by proposed cut-off ditch
5400	North of A485 near Caeathro	Flood map indicates a surface water flow path (1000 year) which crosses the Scheme. The Scheme is on raised embankment at this location.	Low risk - road is on embankment therefore unlikely that significant ponding will occur sufficient to flood the road. The embankment design should consider the potential for ponded water however it is expected this could be managed.	Small impact - the proposed embankment may interrupt flow path; however, this is only shown for the 1000 year event and overland flows can continue towards the Seiont east of the road.
6000 & 6100	Near Cibyn Industrial Estate	Flood map indicates a surface water flow path (100 year) along the existing access track. The Scheme is in cutting at this location.	Low / moderate risk - road is in cutting; however, cut-off ditch is provided to capture overland flows and runoff catchment is small. It is unlikely that flooding to the road would exceed TAN15 thresholds therefore risk is deemed acceptable	Nominal - the proposed cut-off ditch will be designed to capture runoff and as the road is in cutting flooding should not increase upstream.
6500	Cibyn roundabout	Flood map indicates significant surface water ponding north of the A4086. Topographic survey shows a ditch and culvert under the existing road. It is likely the culvert is not accounted for in the SW flood map. The ditch will be diverted and 1.5m dia culverts are proposed (S112A and S112B)	Moderate risk - road is on slight embankment and diversions / culverts will maintain flow to reduce the likelihood of flows backing up behind embankment. Approx. 1.2 - 1.4m freeboard provided at culverts before flows would spill onto highway. It is expected that flood depths will meet TAN15 thresholds therefore flood risks deemed acceptable. The attenuation ponds are located outside the flood extent.	Small impact - proposed diversion and culverts should maintain flow route. Scheme will likely result in some loss of floodplain storage and conveyance although this is not expected to result in increased flooding elsewhere.
7150	Near Tiddyn Slaters	Flood map indicates a surface water flow path crossing the Scheme. Although not shown on mapping a ditch is present which will be diverted through the pedestrian underpass (S113A).	Low risk - road is on embankment therefore unlikely that significant ponding will occur sufficient to flood the road. The underpass may be susceptible to flooding where it goes under the road; however, the flood depths are not expected to exceed TAN15 thresholds therefore this is deemed acceptable.	Small impact - proposed ditch diversion will maintain existing flow route. Flood risk to footpath may increase where it crosses under the road; however, this is not expected to exceed TAN15 thresholds.
7800	Near Lon Glai farm	Flood map indicates surface water flooding along the existing ditch. The Scheme crosses the ditch which will be diverted.	Low risk - The existing ditch will be diverted towards the Cadnant therefore flow route maintained. Road is on embankment	Small impact- the proposed ditch diversion will maintain a flow route towards the Afon Cadnant. Flows will enter the Cadnant earlier; however, the

			therefore unlikely that significant ponding will occur sufficient to flood the road.	additional flow is unlikely to be sufficient to increase flooding.

5.5 Groundwater Flood risk

5.5.1 Table 5.3 summarises the locations where the Scheme is in cutting and therefore may be more susceptible to groundwater flooding. Whilst groundwater flows into cuttings may present a risk to the Scheme it is not considered that the Scheme will affect groundwater flooding in the wider catchment as the drainage strategy seeks to maintain the existing hydrological regime and catchment boundaries.

5.5.2 Cut-off drains provided at the top of cut-slopes will be lined to prevent the ingress of surface runoff into the slope. The drainage strategy includes slope drainage for the Plas Menai cutting and toe drainage at the base of cut slopes to intercept any groundwater flows

5.5.3 Based on the current available information, it is considered that groundwater flows may enter the deeper cuttings (near Llanwnda and Plas Menai); however, provided appropriate drainage is in place to capture any groundwater flows it is unlikely that flood depths would exceed TAN15 thresholds. Groundwater flood risks are therefore considered acceptable.

Table 5.3. Assessment of groundwater flood risk

Chainage	Location	Groundwater flood risk
650 - 1100	Near Llanwnda	Moderate / high susceptibility (50 - 75%). Potential for groundwater flooding dependent on and groundwater levels. Maximum cutting depth is approximately 10m. Boreholes did not record groundwater (terminated ~ 10 - 10.8 mbgl) Moderate risk - provided appropriate mitigation is in place to capture any groundwater flows it is unlikely that flood depths will exceed TAN15 thresholds therefore the risk is deemed acceptable.
4300 - 4450	Near old quarry south of Caernarfon	Low susceptibility (<25%). Lower likelihood of groundwater flooding as cutting is shallow (<2m) and groundwater levels are likely to be similar to water levels in the quarry which is at a lower level than the site. Borehole records south of this location indicate groundwater levels ~ 35.5 - 37.9 mAOD which is a few metres below road level at this point. Low risk.
4800 - 5000	Near old quarry south of Caernarfon	Low susceptibility (<25%). Some potential for groundwater flooding; however, groundwater levels are likely to be similar to water levels in the quarry which is at a lower level than the site. Maximum cutting depth is approximately 5.5m. Borehole records show highly variable groundwater levels in the vicinity (~ 36.8 - 46.6 mAOD). Higher groundwater levels exceed proposed cutting level. Moderate risk - provided appropriate mitigation is in place to capture any groundwater flows it is unlikely that flood depths will exceed TAN15 thresholds therefore the risk is deemed acceptable.

Chainage	Location	Groundwater flood risk
5600 - 6500	Near Cibyn Industrial Estate (near Caernarfon)	Low (<25%) and moderate / high susceptibility (50 - 75%). Potential for groundwater flooding dependent on groundwater levels. Maximum cutting depth is approximately 2.5m. Borehole records indicate groundwater levels in the vicinity ~48.2 - 48.6 mAOD. Groundwater levels exceed proposed cutting level. Moderate risk - provided appropriate mitigation is in place to capture any groundwater flows it is unlikely that flood depths will exceed TAN15 thresholds therefore the risk is deemed acceptable.
7180	Footpath near Tiddyn Bistle	Low susceptibility (<25%). Some potential for groundwater flooding depending on depth of cutting & groundwater levels. Impacts likely to be limited to footpath. Proposed ditch diversion will help to capture any groundwater flows. No recorded groundwater levels in vicinity. Low / moderate risk - provided appropriate mitigation is in place to capture any groundwater flows it is unlikely that flood depths will exceed TAN15 thresholds therefore the risk is deemed acceptable.
8250 - 9700	Bethel Road to existing A487 tie-in (Plas Menai)	Low / moderate susceptibility (25 - 50%). Some potential for groundwater flooding depending on groundwater levels. Maximum cutting depth approximately 20m. Borehole records indicate variable groundwater levels in vicinity ~ 48.2 - 52.4 mAOD. Spring line is present in cut area however drainage design includes slope drainage to capture groundwater ingress. Moderate risk - provided appropriate mitigation is in place to capture any groundwater flows it is unlikely that flood depths will exceed TAN15 thresholds therefore the risk is deemed acceptable.

SECTION 6

FLOOD RISK FROM THE AFON RHYD, AFON GWYRFAI, AFON SEIONT & AFON CADNANT

6 FLOOD RISK FROM THE AFON RHYD, AFON GWYRFAI, AFON SEIONT & AFON CADNANT

6.1 Afon Rhyd

6.1.1 This section provides an overview of existing and post-development fluvial flood risk associated with the Afon Rhyd. The assessment is based on the results of a 1D-2D ISIS Tuflow model developed specifically for the Scheme.

Methodology

6.1.2 A summary of the approach to the hydrological assessment and hydraulic modelling underlying this FCA is provided here. Full details of the technical methodology, alongside flood risk maps, are provided in Appendix D.

6.1.3 Flood flows were estimated using the FEH Statistical and Revitalised Flood Hydrograph (ReFH) methods as both were considered applicable for the catchment. There are no flow gauges in the catchment; however, a suitable donor site (Erch at Pencaenewydd) was identified and used to adjust the Statistical QMED estimate. No suitable donor was identified to improve the ReFH model parameters. The peak flow estimates obtained using the Pooled Statistical method were selected for all events up to the 100 year (climate change) event. For larger events the hybrid method was adopted, where the ratio of the ReFH X-year / 100 year peak flow is applied to the Statistical 100 year flow estimate. As full hydrographs were required for the model the ReFH hydrographs were fitted to the derived peak flow estimates.

6.1.4 A 1D-2D ISIS-Tuflow model was used to assess existing flood risk from the Afon Rhyd and the impacts of the Scheme. The model extends covers a 1.85km reach, from the Rhos Isaf road bridge east of Llanwnda to the Felinwnda road bridge approximately 900m downstream of the proposed crossing. The model has been developed using a combination of channel survey and LIDAR data.

6.1.5 Sensitivity tests were completed to check the robustness of the model and sensitivity to assumed parameters. The tests indicate that the downstream boundary assumption does not affect the results at the site. Changes to the Manning's n (roughness) values generally resulted in a change of +/- 100mm throughout the model. A blockage of the Glanrhyd road bridge upstream was shown to increase flooding as flows overtop and bypass the bridge however the flows return to the channel by the proposed crossing location, with no significant impact on modelled flood levels and flows at the crossing.

6.1.6 Simulations (baseline and post-Scheme) have been completed for a range of events up to the 1000 year.

Scheme proposals

6.1.7 The Scheme proposals are shown on drawing 3513874-PB-05-102-SK-D-00002, Appendix D. The Afon Rhyd will be diverted from its current course a short distance upstream of the crossing and enter a 3.2 x 2.4m box culvert under the proposed road (total length approximately 53m). A natural bed (200mm) will be maintained through the structure and the channel diversion will also include riffles and localised meanders to reduce flow velocities and maintain existing habitats. A small watercourse enters the Afon Rhyd upstream of the road. This will be extended to flow into the diverted river channel upstream of the culvert.

6.1.8 Fish baffles, in the form of v-weirs, are also proposed in the culvert. These will be subject to detailed design however for the purposes of this assessment are assumed to be at approximate 4m spacings, with a minimum height of 200mm and maximum height of 400mm. Typically the weirs will protrude a height of 100 - 200mm above the natural culvert bed.

6.1.9 A culvert structure is proposed considering the overall Scheme feasibility. The culvert length is dictated by the river diversion (necessary for potential land blight) and the embankment slopes which are dictated by ground conditions.

Existing flood risk

6.1.10 The model results show broadly similar flood extents to the NRW Flood Zones and identify the same flow paths.

6.1.11 A full suite of flood maps and results are included in Appendix D. The key findings are summarised below.

6.1.12 For all events up to the 100 year (with climate change) water remains in channel at the proposed crossing location. Floodwater is shown to spill out of bank at the Rhos Isaf bridge, approximately 800 upstream of the site, and follow the railway line to re-enter the Afon Rhyd via a ditch a short distance upstream of the crossing. Flooding at the crossing is shown to occur in the 1,000 year event with maximum flood depths generally less than 50mm. The modelled flood velocities and flood hazard (a combination of depth and velocity) are generally low except in the channel and along the route of the incoming ditch.

Post-development flood risk

6.1.13 The hydraulic model was adapted to include the Scheme. In respect of flood risk the significant aspects of the Scheme include the new road embankment and Afon Rhyd culvert, diversion of the Afon Rhyd and extension of the incoming ditch to the new channel location.

Impacts of flooding on the Scheme

6.1.14 The model results indicate that flooding from the Afon Rhyd will have little to no impact on the Scheme. The proposed road is well above the modelled flood levels, even for the 1000 year event. The modelled in-channel flood level at the culvert entrance is 42.58 mAOD (100CC) and 43.14 mAOD (1000) providing minimum freeboard allowances of 708mm and 145mm respectively. This meets the 600mm minimum required by the NRW for the 100CC event. Flooding of the Rhyd will not pose a risk to the road. Blockage of the structure or damage due to debris impact is also not considered a significant risk due to the size of the structure and freeboard provided.

6.1.15 The proposed surface water attenuation pond is positioned outside the floodplain therefore flooding will not compromise the road drainage.

6.1.16 The model results indicate that maximum flow velocities at the culvert will likely be in the region of 2.5 - 3 m/s for the 100CC and 1000 year events. There may also be turbulent flows and locally higher velocities at the entrance and exit that the model is unable to accurately represent. There is potential for some scour, particularly in larger events; however provided adequate scour protection is included it is not considered this will pose a significant risk to the structural stability. The requirement for scour protection

will be assessed during detailed design. Similarly the embankment design should consider the potential for ponded floodwater against the embankment.

Impacts of the Scheme on flooding elsewhere

6.1.17 The model results show that the scheme will not have a significant impact on flooding elsewhere. The modelled peak flows show slight increases of 0.01 m^3/s (100CC) and 0.32 m^3/s (1000), equivalent to 0.1% and 2.3% of the existing peak flow. The Scheme will not result in any significant loss of floodplain storage as the flows are contained in channel at this location.

6.1.18 The model shows increased in-channel peak levels upstream of the culvert of approximately 300mm at the start of the diversion however this reduces to a negligible amount over a distance of approximately 100m. Downstream of the crossing the results show slight increases in peak level of 10 - 20mm.

6.1.19 The model shows increased flood extent and flood depths immediately upstream of the embankment, at the existing channel location, which occurs when overland flows exceed the capacity of the incoming ditch. Although the existing channel is to be filled in the natural topography directs overland flows to this location. The increase in flood depth reaches approximately 1m for the 1000 year event but the vast majority of the land affected is owned by Welsh Government therefore the increased flood depths do not particularly affect third party land. OS mapping shows an outbuilding in the area affected but it is understood that this will be removed as part of the Scheme. For the 1000 year event the results also show a slight increase in flood depth downstream of the crossing, which extends close to an existing property. Inspection of the results shows this is small, around 10mm, and is unlikely to represent an increase in risk compared with existing flood depths. If necessary minor bank works or ground reprofiling will be undertaken to direct flows towards the channel away from the property.

6.1.20 The model results indicate the Scheme will not particularly affect flow velocities aside from the culvert itself therefore the Scheme is not expected to lead to additional scour in the area.

6.1.21 The Scheme will not significantly increase the area at risk of flooding. It is recommended that the ground levels at the old channel location are reviewed during detailed design and amended to direct the overland flow away from the embankment and reduce the likelihood of standing floodwater for long periods of time. It is not expected that the increased flood depths shown by the model will materially affect the use of the land in respect of flooding.

Temporary Works

6.1.22 It is understood that temporary works are unlikely to affect flood flows as the flow route can be maintained through appropriate sequencing of works. It is assumed that the proposed culvert and diversion will be constructed prior to removal of the existing channel.

Summary

6.1.23 The proposed Scheme is not considered at risk from flooding of the Afon Rhyd. The proposed road sits well above the maximum flood levels, even for the extreme events (1000 year), with a minimum freeboard of approximately 5m. Debris carried by floodwaters is therefore unlikely to have significant impact through blockage of the

structure or through structure damage. There is some potential for localised scour around the culvert but it is expected that this can be managed with appropriate scour protection included in the detailed design.

6.1.24 The proposed Scheme results in some increases in the flood depth and extent in the immediate vicinity, where the natural topography directs overland flows towards the existing channel location. The majority of the land affected is owned by Welsh Government. The Scheme is not expected to lead to a significant increase in flooding to third party land. During detailed design it is recommended that the ground levels at the old channel location are amended to direct the overland flow away from the embankment and reduce the likelihood of standing floodwater for long periods of time. Minor bank works or ground reprofilng is also recommended downstream of the crossing to direct overland flows towards the channel and away from the existing property. The Scheme will not result in any significant loss of flood storage or increased flows downstream.

6.1.25 Temporary works are not expected to have a significant impact on flooding in the area.

6.2 Afon Gwyrfai

6.2.1 This section provides an overview of existing and post-development fluvial flood risk associated with the Afon Gwyrfai. The assessment is based on the results of a 1D-2D ISIS Tuflow model developed specifically for the Scheme.

Methodology

6.2.2 A summary of the approach to the hydrological assessment and hydraulic modelling underlying this FCA is provided here. Full details of the technical methodology, alongside flood risk maps, are provided in Appendix E.

6.2.3 Flood flows were estimated using the FEH Statistical and Revitalised Flood Hydrograph (ReFH) methods as both were considered applicable for the catchment. Two inflows were calculated, for the catchment draining directly to the Afon Gwyrfai and for its tributary, the Afon Bueno. The FEH Statistical estimates were improved using data from the Bontnewydd gauging station (Gwyrfai) and Erch at Pencaenewydd (Bueno). The ReFH model parameters have been based on catchment descriptors. The peak flow estimates obtained using the Statistical method were selected for all events up to the 100 year (climate change) event. For larger events the hybrid method was adopted, where the ratio of the ReFH X-year / 100 year peak flow is applied to the Statistical 100 year flow estimate. As full hydrographs were required for the model the ReFH hydrographs were fitted to the derived peak flow estimates.

6.2.4 A 1D-2D ISIS-Tuflow model was used to assess existing flood risk from the Afon Gwyrfai and the impacts of the Scheme. The model covers a 3.5km reach, from upstream of Bontnewydd village to Pont Faen bridge. A150m length of the Afon Bueno has also been included at the confluence with the Gwyrfai. The model has been developed using a combination of channel survey and LIDAR data. A flood defence wall located to the west of Bontnewydd has been included in the model using data supplied by NRW.

6.2.5 Sensitivity tests were completed to check the robustness of the model and sensitivity to assumed parameters. The tests indicate that the downstream boundary assumption does not affect the results at the site. Changes to the Manning's n (roughness) values generally resulted in a change of +/- 80mm throughout the model.

6.2.6 Simulations (baseline and post-Scheme) have been completed for a range of events up to the 1000 year.

Scheme proposals

6.2.7 The Scheme proposals are shown in drawing 3513874-PB-SBR-106-DR-S-00001, Appendix B. The proposed road is on an embankment on the approaches to the Afon Gwyrfai and will cross the floodplain on an 8-span viaduct structure with total length approximately 260m. Where it crosses the floodplain the proposed road level varies from approximately 25.4 to 27.0 mAOD. The minimum soffit level varies from approximately 23.7 to 24.8 mAOD which at its minimum height is approximately 3.9m above the floodplain level. No changes are proposed to the Gwyrfai channel or the ditch which cuts across the floodplain. The viaduct will be supported by 7 no. piers of width 800mm as it crosses the floodplain.

Existing flood risk

6.2.8 The model results show broadly similar flood extents to the NRW Flood Zones although the modelled flood extents are generally smaller. As would be expected in this location the flood extents for the larger events are largely dictated by the local topography as the Gwyrfai has an extensive and well defined floodplain at this location. NRW noted recent flooding to Glanrafon Estate, Bontnewydd on 26th December 2015 however details of the event and flooding which occurred are not available to inform this assessment. Bontnewydd is upstream of the area affected by the Scheme.

6.2.9 A full suite of flood maps and results are included in Appendix E. The key findings are summarised below.

6.2.10 At this location the Afon Gwyrfai has a large and active floodplain. Flooding is shown to occur across the northern part of the floodplain between the ditch and the river channel for the 2 year event (the smallest modelled event). For larger events flooding also occurs to the southern part of the floodplain as flow leaves the channel upstream and bypasses the channel meander. The floodplain topography initially directs flows to the south west (away from the river); however, for the 20 year event and larger, almost the entire area is shown flooded. Flood extents do not increase significantly for larger events although the flood depth increases. For the 1000 year event approximately 75% (55 m^3/s) of the flow passes across the floodplain rather than in the channel.

6.2.11 The maximum flood depths remain reasonably shallow due to the extensive floodplain. For events up to the 100 year, with climate change (100CC), flood depths across the majority of the floodplain remain below 300mm. Deeper flooding is shown close to the channel and in the ditch, generally up to a maximum of 600 - 900mm. Larger areas of the floodplain experience higher flood depths in the 1000 year event, particularly the southern extent where ground levels are lower. However, the depths remain below 300mm across the majority of the area and, except in small areas, are less than 600mm.

6.2.12 As would be expected for an active floodplain the flow velocities are relatively high. For the smaller events the floodplain velocities are generally less than 1 m/s but for the 100CC event much of the floodplain experiences velocities in the range 1.2 - 2.4 m/s.

6.2.13 The modelled flood hazard (a combination of depth and velocity) is low across much of the floodplain; however, for the 100 year event and higher significant areas show significant (danger for most) and extreme (danger for all) hazard ratings.

Post-development flood risk

6.2.14 The hydraulic model was adapted to include the Scheme. In respect of flood risk the significant aspects of the Scheme include the southern embankment, which encroaches slightly into the floodplain (modelled 10 year event and greater) and the piers. It should be noted that the model is limited in the accuracy to which it can represent the effects of the piers due to their size in relation to the model grid resolution (2m). However the model provides a basis for an assessment of the likely effects on flood flows and maximum water levels.

Impacts of flooding on the Scheme

6.2.15 The model results indicate that flooding from the Afon Gwyrfai will have little to no impact on the Scheme. The proposed road is well above the modelled flood levels, even for the 1000 year event. The modelled in-channel flood level at this point is 20.08 mAOD (100CC) and 20.15 mAOD (1000) providing minimum freeboard allowances of 4.7m. This is well in excess of the 600mm minimum required by the NRW for the 100CC event. The minimum freeboard along the length of the crossing is approximately 3.6m. Flooding of the Gwyrfai will not pose a risk to the road. Blockage of the structure or damage due to debris impact is also not considered a significant risk due to the large freeboard provided.

6.2.16 The proposed surface water attenuation ponds are positioned well outside the floodplain therefore flooding will not compromise the road drainage.

6.2.17 The model results indicate that maximum flow velocities at the piers will likely be in the region of 2 m/s for the 100CC and 1000 year events. There may also be turbulent flows around the piers and locally higher velocities that the model is unable to accurately represent. There is potential for some scour, particularly in larger events; however, provided adequate scour protection is included, it is not considered this will pose a significant risk to the structural stability. The requirement for scour protection will be assessed during detailed design. Similarly the embankment design should consider the potential for ponded floodwater against the embankment.

Impacts of the Scheme on flooding elsewhere

6.2.18 The proposed structure and embankments sit largely outside the Afon Gwyrfai floodplain and therefore the proposals have limited effects on flooding elsewhere.

6.2.19 The southern embankment extends slightly into the floodplain; as a result during the larger events floodwaters back up behind the embankment and are diverted slightly to the north to flow around the embankment. The results indicate that this has only a limited effect for the moderate events as the flood plain flow at this location is limited. For the 100CC event the results show increases in flood depth ~250 - 300mm immediately upstream of the embankment; however, generally the increases are less than 100mm across the affected area. The results indicate some isolated locations with a greater increase, this is likely to be due to undulations in the underlying topography.

6.2.20 For the 1000 year event the results are similar with a slightly larger area of the floodplain experiencing higher flood depths and the effects extending over a wider area. The maximum increase in flood depth is approximately 400mm immediately upstream of the embankment. The flood maps show the majority of increased flood depths are in the 5 - 100mm band. Inspection of the model results shows that downstream of the river meander this increase is generally 20 - 50mm or less. A property lies close to river and area affected. The model results indicate the increased flood depths will not increase

risk to this property. Existing flood depths are in the region of 200mm and the increase within the property boundary is approximately 1 - 2mm and 10 - 15mm in adjacent land.

6.2.21 The model results indicate the Scheme will not particularly affect flow velocities. For the 1000 year event flow velocities around the southern embankment increase from approximately 1 to 2 m/s. This is similar to the existing flow velocities for the event, it is simply the location that is changed. As noted above there is some potential for scour around the piers and abutment; however, it is expected this can be managed with appropriate scour protection. The Scheme is not expected to lead to additional scour across the floodplain.

6.2.22 The southern embankment will lead to a slight loss of flood storage volume where it extends into the southern floodplain, approximately 200m^3 for the 100CC event. This is small compared with the total flow and the current flood storage volume. As the floodplain is "active", the slight reduction in storage volume does not significantly affect the flows continuing downstream. Comparison of modelled flows shows an increase in peak flow of approximately 0.1 m^3/s (1000 year) equivalent to around 0.1% of the flow.

6.2.23 The Scheme will not increase the area at risk. Nor does it affect the frequency or duration of flooding in this area. However, as the embankment is positioned at a natural low point in the floodplain it is recommended that the ground levels are designed to direct this flow away from the embankment and reduce the likelihood of standing floodwater for long periods of time. It is not expected that the increased flood depths shown by the model will materially affect the use of the land in respect of flooding.

Temporary works

6.2.24 During construction a temporary Bailey bridge will be constructed across the Afon Gwyrfai channel and a haul road and crane hardstandings will be laid across the floodplain (refer drawing included in Appendix B which shows proposed ground levels). The JV Team has confirmed appropriate assumptions for the temporary works as follows:

- Bailey bridge span length 22m, deck level 22 mAOD, soffit level 21 mAOD, top of truss level 23 mAOD;
- A 900mm pipe will be provided to maintain the flow route through the ditch.

6.2.25 The haul road is approximately 400 - 700mm above the floodplain and therefore will be a temporary embankment. Should a flood occur during the construction period (~ 18 months) it is expected that floodwaters would back up behind the embankment.

6.2.26 As would be expected the model results show that floodwater ponds behind the haul road embankment with maximum depths approximately 600mm (2 year), 800mm (20 year) and 1m (100 year). Flooding of the haul road is also shown. This is minor for the 2 year event with a maximum depth of approximately 30mm and velocities of 0.15 m/s. The corresponding flood hazard is generally low (caution). Flooding to the embankment increases for larger events. For the 20 year event the maximum depth is generally 150 - 200mm, reaching 280mm in places, with maximum velocities approximately 2 m/s. The flood hazard is generally low (caution) but is classified as significant (danger for most) where water is channelled across the embankment and the flood depths and velocities are highest. A similar pattern is shown for the 100 year event with maximum depths of around 350mm and velocities of 2.5 m/s.

6.2.27 As the proposals change the flow regime there is a change in flood depths in the vicinity. The results show this is mostly restricted to the immediate area upstream of the

embankment and in the river channel through the meander. For the 2 year event the increase in flood depths is less than 100mm apart from immediately upstream of the platform where the maximum increase is around 150mm. Elsewhere flood depths are reduced as the continuing flow is restricted by the embankment. For the 20 year event the maximum increase is approximately 800mm and 800 - 900mm for the 100 year event. The flood depths generally increase upstream of the embankment and in the southern half of the floodplain. A slight reduction in flood depths is shown adjacent to the closest property.

6.2.28 The modelled flood levels show a minimum freeboard for the 100 year event of approximately 1.2m (modelled flood level 19.8 mAOD). Specific blockage scenarios have not been modelled. The results show that the pipe (for the ditch) takes a very small proportion of the flow (~ 0.8 m^3/s for the 100 year event compared with a total flow of approximately 50 m^3/s. Should a blockage occur to the pipe it will therefore make little difference to the flooding in the vicinity. The size of the Bailey bridge is such that blockage is unlikely however if a blockage were to occur it is likely that this would simply divert more flow over the raised platform.

6.2.29 Considering the model results it is considered the Temporary Works proposals are acceptable. Whilst the proposals increase flood depths in the vicinity this is mostly restricted to land that would likely be significantly affected by the works in any case. The results indicate the effects are localised and will not increase risk to people or properties or land in the wider area. The proposed Bailey bridge is set well above the modelled flood levels providing a freeboard in excess of NRW's minimum requirement of 600mm.

6.2.30 As expected the results show that flooding in the area during the works could present a risk to construction personnel and plant which reinforces the requirement for a robust construction flood management plan.

Summary

6.2.31 The Afon Gwyrfai has a large and active floodplain at the proposed crossing location. Flooding is predicted to occur for the 2 year event, with much of the area shown to flood for events with return periods of 20 years and greater. Maximum flood depths across the area are generally less than 300mm although some areas experience depths of up to 600 - 900mm during the larger events.

6.2.32 The Scheme is not considered at risk from flooding of the Afon Gwyrfai. The proposed road sits well above the maximum flood levels, even for the extreme events (1000 year), with a minimum freeboard of approximately 3.6m. Debris carried by floodwaters is therefore unlikely to have significant impact through blockage of the structure or due to structure impact. There is some potential for localised scour around the bridge piers and southern abutment; however, it is expected that this can be managed with appropriate scour protection included in the detailed design.

6.2.33 The southern embankment extends slightly into the floodplain. As a result, flood depths are expected to increase on the upstream side of the embankment and there are some increases shown in the localised area as the embankment redirects a proportion of the floodplain flow. However, the area affected is localised and the majority only sees an increase in depth of <100mm. The Scheme is not shown to increase flow velocities and therefore increase scour risk across the majority of the floodplain. There may be some potential for local scour at the structures as noted above. The Scheme does not increase flooding to any properties and is not considered to materially affect flood risk to the farm land affected.

6.2.34 The temporary works required during construction are likely to have a more significant impact, should a large flood occur during the 18 month construction period. The proposed haul road would lead to an increase in flood depths upstream. However no properties are expected to be affected. A flood management plan will be in place for the construction works to mitigate the risks to site personnel and plant. .

6.3 Afon Seiont

6.3.1 This section provides an overview of existing and post-development fluvial flood risk associated with the Afon Seiont. The assessment is based on the results of a 1D ISIS model developed specifically for the Scheme.

Methodology

6.3.2 A summary of the approach to the hydrological assessment and hydraulic modelling underlying this FCA is provided here. Full details of the technical methodology, alongside flood extent maps, are provided in Appendix F.

6.3.3 Flood flows were estimated using the FEH Statistical and Revitalised Flood Hydrographs (ReFH) methods as both were considered applicable for the catchment. Inflows were calculated for the catchment draining directly to the Afon Seiont and its tributary. The FEH Statistical estimates were improved using data from the Peblig Mill gauging station for the Afon Seiont. The ReFH model parameters have been based on catchment descriptors. The peak flow estimates obtained using the Statistical method were selected for all events up to the 100 year (climate change) event. For larger events the hybrid method was adopted, where the ratio of the ReFH X-year / 100 year peak flow is applied to the Statistical 100 year flow estimate. As full hydrographs were required for the model the ReFH hydrographs were fitted to the derived peak flow estimates.

6.3.4 A 1D ISIS model was used to assess existing flood risk from the Afon Seiont and the impacts of the Scheme. The model covers a 1.9km reach, from Glan Gwna holiday park to Peblig Industrial estate. The model also includes a 200m length of the tributary which flows in to the Seiont within the holiday park. The model has been developed using a combination of channel survey and LIDAR data.

6.3.5 Sensitivity tests were completed to check the robustness of the model and sensitivity to assumed parameters. The tests indicate that the downstream boundary assumption does not affect the results at the site. Changes to the Manning's n (roughness) values generally resulted in a change of +200 to 300mm and -30 to 40mm throughout the model. The results show an increase in flood level of approximately 200mm at the site (100CC event) for a higher Mannings n.

6.3.6 Simulations (baseline and post-Scheme) have been completed for a range of events up to the 1000 year.

Scheme proposals

6.3.7 The Scheme proposals are shown in drawing 3513874-PB-SBR-SD-SK-S-00024, Appendix B. The proposed road is on an embankment on the approaches to the Afon Seiont and will cross the floodplain on a 4-span viaduct structure with total length approximately 150m. Where it crosses the floodplain the proposed road level is approximately 42.2 mAOD. The minimum soffit level varies and is approximately 39.7 mAOD which is approximately 15.6m above the current ground level. No changes are

proposed to the Seiont channel. The viaduct will be supported by 3 no. rows of piers of width 1.8m as it crosses the floodplain.

Existing flood risk

6.3.8 The model results show broadly similar flood extents to the NRW Flood Zones although are generally less extensive, particularly for the 100 year event. The model results do not show flooding on the left bank upstream of the crossing (contrary to NRW Flood Map), however, the survey and LIDAR show the ground levels are higher which would explain the reduced flood extent.

6.3.9 Appendix F includes a map showing the modelled flood extents and model results at the proposed crossing.

6.3.10 At this location the Afon Seiont has a relatively confined floodplain, with flows for all events except the 1000 year largely remaining in bank. The results for the 1000 year event show flooding of the slightly lower lying plateau on the right bank, immediately upstream of the proposed crossing. Flooding is shown to be more extensive upstream and downstream of the site however this only affects undeveloped land except for the larger events (100 year and above) where properties in the holiday park are shown at risk.

Post-development flood risk

6.3.11 The hydraulic model was adapted to include the Scheme. The soffit and embankments of the proposed structure are positioned outside of the floodplain, therefore the only effect of the structure on flood flows is the pier on the right bank, which is within the 1000 year flood extent. The floodplain width reduces on the downstream side of the structure, therefore the pier does not particularly affect the flow area; however, there may be energy losses at the pier itself. The pier is above the 100CC flood level therefore will only affect flows during the 1000 year event. The expected energy losses were calculated using methods outlined in Hydraulics of Bridge Waterways and applied to the model using an energy loss unit.

Impacts of flooding on the Scheme

6.3.12 The model results indicate that flooding from the Afon Seiont will have little to no impact on the Scheme. The proposed road is well above the modelled flood levels, even for the 1000 year event. The modelled flood level at this point is 21.91 mAOD (100CC) and 22.46 mAOD (1000) providing minimum freeboard allowances of 17.8m and 17.3m respectively. This is well in excess of the 600mm minimum required by the NRW for the 100CC event. Flooding of the Seiont will not pose a risk to the road. Debris carried by floodwaters is not expected to be a significant risk to the structure, either through blockage or structure damage, due to the large freeboard provided.

6.3.13 The proposed surface water attenuation ponds are positioned well outside the floodplain therefore flooding will not compromise the road drainage.

6.3.14 There may be turbulent flows around the piers and locally higher velocities and therefore potential for some scour during the 1000 year event. However provided adequate scour protection is included it is not considered this will pose a significant risk to the structural stability. The requirement for scour protection will be assessed during detailed design.

Impacts of the Scheme on flooding elsewhere

6.3.15 The proposed structure and embankments sit outside the Afon Seiont floodplain and therefore the proposals have a limited effect on flooding elsewhere.

6.3.16 The model results indicate that peak flood levels at the structure for the 1000 year event may increase by approximately 15mm due to energy losses at the pier. The results show this reduces to 3mm over a distance of ~ 130m upstream. The flood depths on the right bank immediately upstream of the structure, within the Glan Gwna holiday park, may increase marginally (between 8 and 15mm) but this is negligible compared with the existing depths of up to around 750mm. The Scheme will not result in any loss of floodplain storage or affect flood flows.

Temporary Works

6.3.17 The JV Team provided information on the likely temporary works as shown on the drawing included in Appendix F. The relevant features are the raised areas of hard standing and haul road on both banks in the vicinity of the proposed crossing and a Bailey bridge crossing the channel downstream of the proposed crossing. From the available information it is assumed the bridge will have a minimum soffit level of around 24 mAOD.

6.3.18 The proposed Bailey bridge is above the modelled 1000 year flood level and is therefore not expected to be impacted by, or have an impact on flooding. The raised area on the right bank upstream of the crossing encroaches into the 1000 year flood extent, and that on the left bank downstream of the crossing encroaches into the 100 year extent. The likelihood of a 1000 year event occurring during the construction period is very remote and therefore does not require detailed consideration for temporary works (as confirmed with NRW in relation to the Afon Gwyrfai).

6.3.19 The proposed ground levels downstream of the crossing are approximately 24.2 - 25.2 mAOD, well above the modelled 100 year level (approximately 21.5 mAOD). The platform / haul road is therefore not considered at significant risk of flooding. The raised ground will result in a slight loss of floodplain storage and may have some localised impacts on flooding as flow is diverted around the raised area however this is not expected to lead to any significant increase in flood depths or flows continuing downstream. The model results indicate this would not be an area of active flow and would flood from backing up downstream. The model results indicate the 100 year flood depths are around 100mm, therefore the loss of storage volume will be in the region of 40 - 50 m^3.

Summary

6.3.20 The proposed Scheme is not considered at risk from flooding of the Afon Seiont. The proposed road sits well above the maximum flood levels, even for the extreme events (1000 year), with a minimum freeboard of approximately 17.3m. Debris carried by floodwaters is therefore unlikely to have significant impact through blockage of the structure or through structure damage. There is some potential for localised scour around the bridge piers; however, it is expected that this can be managed with appropriate scour protection included in the detailed design.

6.3.21 The proposed Scheme includes a pier located within the 1000 year flood extent which may lead to local energy losses. As a result flood depths may slightly increase on the upstream side of the structure, within the Glan Gwna holiday park, by around 8 - 15mm. The effect is restricted to the immediate area and the predicted increase is insignificant

compared with existing flood depths (up to ~ 750mm). The Scheme will not result in any loss of floodplain storage or affect flood flows.

6.3.22 Temporary works are not expected to have a significant impact on flooding in the area.

6.4 Afon Cadnant

6.4.1 This section provides an overview of existing and post-development fluvial flood risk associated with the Afon Cadnant and the unnamed watercourse which bifurcates from the Cadnant and flows in a northerly direction to the Menai Strait. The assessment is based on the results of a 1D/2D Estry Tuflow model developed specifically for the Scheme.

Methodology

6.4.2 A summary of the approach to the hydrological assessment and hydraulic modelling underlying this FCA is provided here. Full details of the technical methodology, alongside flood maps, are provided in Appendix G.

6.4.3 Flood flows were estimated using the FEH Statistical and Revitalised Flood Hydrograph (ReFH) methods as both were considered applicable for the catchment. Inflows were calculated for the catchment draining directly to the Afon Cadnant, its tributary and the unnamed northern watercourse. Appropriate adjustments were made to the catchment descriptors obtained from the FEH CD-Rom to reflect the actual catchment boundaries assessed using LiDAR and OS mapping. No suitable donor sites were identified therefore the flow estimates were based solely on catchment descriptors. The peak flow estimates obtained using the Statistical method were selected. As full hydrographs were required for the model the ReFH hydrographs were fitted to the derived peak flow estimates.

6.4.4 A 1D/2D Estry Tuflow model was used to assess existing flood risk from the Afon Cadnant watercourses and the impacts of the Scheme. The model covers a total watercourse length of approximately 1.9km, upstream and downstream of Crug Lane. The model has been developed using a combination of channel survey, topographic survey and LiDAR data.

6.4.5 Sensitivity tests were completed to check the robustness of the model and sensitivity to assumed parameters. The tests indicate that the downstream boundary assumption does not affect the results at the site. Changes to the Manning's n (roughness) values of 20% generally resulted in a change of +/- 50mm throughout the model. Changes in flows of 20% generally resulted in a change in water level of +/- 70 - 80mm.

6.4.6 Simulations (baseline and post-Scheme) have been completed for a range of events up to the 1000 year.

Scheme proposals

6.4.7 The Scheme proposals are illustrated by the drawings included in Appendix G (drawings 3513874-PB-SBR-114-DR-S-00001, 3513874-PB-06-XX-DR-J-00007, 3513874-PB-06-XX-DR-J-00008 and the "Drainage Layouts Model" sketch). Changes were made to the initial design following preliminary model runs. The main features of the Scheme relevant to this assessment are as follows:

- The proposed A487 bypass, which generally runs at grade or in cutting through the area. The proposed road level varies from approximately 44.8 to 55.2 mAOD.

- A diversion of Crug Lane and Bethel Road, with new roundabout, to accommodate the proposed bypass. The diversion runs on embankment, at grade and in cutting. The proposed road levels vary from approximately 54 mAOD where the northern watercourse crosses under the road to 63.6 mAOD at the new roundabout.
- A new rectangular culvert (S114), incorporating a cattle creep, to carry the Afon Cadnant under the A487. The culvert dimensions are 3.4 x 3.4m, although part of this area is taken up by the cattle creep. A 700 x 700mm channel is included to carry normal flows adjacent to the cattle creep with a natural bed depth of 300mm. Drawing 3513874-PB-SBR-114-DR-S-00001, Appendix G, shows details of the culvert.
- Four 1.8m diameter pipe culverts where the Afon Cadnant and its tributary are crossed by the Scheme. A 300mm depth of natural bed is proposed for all the Cadnant culverts.
- Diversion of the Afon Cadnant to accommodate the proposed roads. The diversion follows a similar route to the existing channel and will be designed to replicate the existing natural channel.
- Proposed surface water attenuation pond located between the proposed bypass and Crug Lane diversion.
- Diversion of the northern watercourse (ordinary watercourse) to the south and west to provide sufficient headroom where the watercourses cross the proposed roads. The new channel will be designed to replicate the existing natural channel as far as possible, however immediately west of the bypass a more engineered channel is required for stability adjacent to the road cutting.
- Twin 600mm diameter pipe culverts for the northern watercourse crossing of Crug Lane and the proposed bypass. A natural bed depth of 100mm has been assumed for this culvert. A 600mm mammal crossing is also provided in the vicinity. Manholes are located on the route of these culverts but will be sealed to prevent flood water escaping the manholes when surcharged.
- A small wall or earth bund (expected to be approximately 200mm high) between Crug Lane and the bypass near the watercourse crossing. This is proposed to prevent floodwater spilling into the bypass cutting in the 1000 year flood event.

Existing flood risk

6.4.8 Appendix G includes maps showing the modelled flood extents, depths and velocities.

6.4.9 The lower modelled reaches of the Afon Cadnant and its tributary show that flood flows are largely contained in the channel however north of Bethel Road and east of Crug Lane the flood extents are larger, with areas of ponding near to the Bethel Road / Crug Lane junction and upstream of Crug Lane. Downstream of Crug Lane the northern watercourse is quite steep, and flood flows are shown to largely remain in bank. Some flooding of Crug Lane is predicted for the 1000 year event where the existing culvert crosses under the road.

6.4.10 The modelled flood depths are generally reasonably shallow, less than 300mm for the 100CC event, except the northern watercourse upstream of Crug Lane where depths exceed 600mm. The flooding of Crug Lane in the 1000 year event is shallow, with depths less than 100mm. The flat topography and shallow flows mean that flow velocities in the floodplain are generally low, less than 0.15 m/s.

Post-development flood risk

6.4.11 The hydraulic model was adapted to include the Scheme and a range of events modelled. Flood maps are included in Appendix G.

Impacts of flooding on the Scheme

6.4.12 The model results indicate that flooding from the Cadnant watercourses will have little to no impact on the Scheme. The results show the roads remain flood free for events up to the 100CC. Flooding occurs to land east and north of the Scheme, similar to the existing situation. Flooding is shown to Crug Lane in the 1000 year event, however the maximum flood depth is approximately 170mm with velocities less than 0.01 m/s and remain well within TAN15 guidelines.

6.4.13 The NRW requirement for 600mm freeboard in the 100CC event is met at all structures on the Afon Cadnant and its tributary. The northern watercourse crossing (S116/S118) is surcharged to a depth of around 1.7m at the upstream end. Gwynedd Council were consulted and confirmed this was acceptable, considering the constraints which apply to the Scheme. This culvert is surcharged downstream due to the flat gradient of the downstream diversion channel. Constraints on the available land restrict the gradient of this channel and the existing culverts are similarly surcharged.

6.4.14 The cattle creep through structure S114 is shown to flood for a flow of around 250 l/s. Comparison with the flow duration curve, obtained using the Low Flows2 software, indicates this would equate to an approximate annual flow. Maximum flood depths at the creep reach around 1m for the 100CC event, however it is unlikely the creep would be required in these larger floods. It is considered the impacts of flooding on the movement of cattle are likely to be similar to the existing situation. The otter pass is shown to flood for flows between the 10 and 20 year event flows.

6.4.15 The proposed attenuation pond lies outside of the modelled flood extents and therefore flooding is not expected to compromise its operation.

6.4.16 The majority of the proposed culverts are large enough that blockage is not a significant concern. A 50% blockage of the northern watercourse culvert was tested for the 100 year event, which led to a 120mm increase in water level at the upstream face. The blockage also diverts more flow along the Cadnant, rather than the northern watercourse, however the flow in the Cadnant is lower than the baseline flow.

Impacts of the Scheme on flooding elsewhere

6.4.17 The proposed Scheme is not considered to have a significant impact on flooding to third party property and people. The existing watercourses and flow routes are maintained with minor diversions.

6.4.18 Appendix G includes maps showing the difference in maximum flood depth for the 100, 100CC and 1000 year events. These show that for events up to the 100CC the depth of flooding in the fields upstream of Crug Lane is, in general, slightly reduced. This is likely due to the larger culverts proposed for the northern watercourse crossing Crug Lane (the existing twin pipes are 450mm diameter). Localised increases in flood depth are shown upstream of the new Crug Lane culverts on the Cadnant however this is generally less than 300mm and is restricted to the channels and local floodplain. The impacts are restricted to a small area of the fields. An increase in flood depth is also shown for the northern watercourse downstream of the bypass. This is due to the

increased flow in this watercourse (refer below). It is restricted to the channel and is shown less than 300mm.

6.4.19 For the 1000 year event the general increase in flood depth is shown upstream of Crug Lane of around 200 - 300mm. A greater increase is shown immediately upstream of the Cadnant Crug Lane crossings. This is likely due to backing up behind the Cadnant culvert when this reaches capacity and ponding upstream of Crug Lane as overland flows along this route are restricted by the proposed wall / bund between Crug Lane and the bypass. The increases in flood depth on the Cadnant between Bethel Road and the bypass are similar to the smaller events, although slightly more extensive. As for the smaller events the land affected is restricted to the local fields.

6.4.20 The model results show a change in the flows in the Afon Cadnant and the northern watercourse. A decrease in peak flow is shown on the Afon Cadnant of approximately 1.3 m^3/s (20%) for the 100CC event and 2.4 m^3/s (25%) for the 1000 year event. A corresponding increase in peak flow is shown for the northern watercourse; approximately 1.1 m^3/s (80%) and 1.2 m^3/s (80%) for the 1000 year. This is likely due to a combination of attenuation behind the proposed Afon Cadnant culverts and the increased capacity of the northern watercourse culvert.

6.4.21 NRW advised of existing flooding problems on the Afon Cadnant downstream of the Scheme therefore the reduction in flow in this watercourse may be of benefit in reducing downstream flood risk. Gwynedd Council were consulted in respect of the increased flow in the northern watercourse and advised this was acceptable as the natural channel has capacity for these flows. This is supported by the model results which show flow largely contained in bank through the modelled reach.

Temporary Works

6.4.22 It is understood that temporary works are unlikely to affect flood flows as the flow routes can be maintained through appropriate sequencing of works. It is assumed that the proposed culverts and diversions will be constructed prior to removal of the existing channel.

Summary

6.4.23 The proposed Scheme is not considered at significant risk from flooding of the Afon Cadnant watercourses. The majority of the Scheme is shown to remain flood free in the 100 year event. Some flooding is shown to the realigned Crug Lane for this event but is well within TAN15 guidelines.

6.4.24 The Scheme results in some localised changes in flooding in the vicinity of the Scheme. This varies with areas of reduced and increased flood depths. The change is relatively modest and restricted to the immediate channels and fields. No properties are affected.

6.4.25 The proposed Scheme leads to a reduction in peak flow in the Afon Cadnant, which may lead to reduced flood risk downstream. An increase in peak flow is shown for the northern watercourse however Gwynedd Council advised this was acceptable and the natural channel has capacity for these flows.

6.4.26 Temporary works are not expected to have a significant impact on flooding in the area.

SECTION 7

OUTLINE SURFACE WATER DRAINAGE STRATEGY

7 OUTLINE SURFACE WATER DRAINAGE STRATEGY

7.1 Surface Water Management Approach

7.1.1 Appendix C includes a copy of the drainage strategy prepared for the Scheme.

7.1.2 Surface water management proposals for the new development have been prepared to meet the following principles:

- No increase in the rate of surface water runoff from the site for all events up to an including the 100 year return period event (with 30% climate change allowance);
- Controlled release of additional runoff volume generated from the Scheme for all events up to the 100 year return period event (with climate change allowance);
- No increase in flooding to people and property elsewhere as a result of the development;
- Where groundwater levels permit, drainage features are unlined to allow an element of infiltration during low flows. Site specific ground investigations have determined that infiltration rates are very low and preclude the use of infiltration as the sole means of surface water disposal. Surface waters will be discharged to surface watercourses; no discharges to sewers are expected. This is deemed to meet the preferred surface water discharge hierarchy.
- Management of exceedance flows so that runoff for events up to the 100 year return period event are contained within the Scheme.

7.2 Surface Water Management Strategy

7.2.1 The proposed drainage strategy is summarised as follows:

- Carriageway runoff will drain 'over the edge' to vegetated swales designed to accommodate, without surcharge, a 1 year return period rainfall event with 30% climate change allowance. Surcharging that occurs during a 5 year return period event will be restricted to the verge and hard strip and not extend onto a running lane.
- The swales will outfall to combined filter/carrier drains running directly beneath the swales. Where on embankments, swales and filter/carrier drains will (where required) be lined to prevent infiltration into the underlying embankment earthwork. Where in cut or at-grade, the viability of utilising infiltration will be assessed considering local geotechnical and topographical conditions.
- The drainage of both the Afon Seiont and Afon Gwyrfai viaducts will be via combined kerb and drainage bridge-deck compatible units which will outfall into the mainline carrier drains.
- Traditional kerb and gully systems will be used to drain runoff from gyratory carriageways and kerbed elements of approach and departure arms.
- Attenuation ponds will be provided for each of the carriageway drainage sub-catchments to mitigate for the increased rates and volume of runoff that will arise from the Scheme. The attenuation strategy will comply with current UK best-practice guidelines[6], considering both discharge and volumetric criteria. Discharge rates for any return period event up to and including the 100 year event (with an

[6] Kellagher (2012) *Preliminary rainfall runoff management for developers – R & D Technical Report W5-074/A/TR/1*. Defra/EA, Bristol. January 2012.

allowance for climate change) will be limited to the greenfield mean annual peak rate of runoff. Formal means of mitigating for the increase in discharge volume criteria will therefore not be provided.

- Flow control from the attenuation ponds will be provided in the form of a vortex flow control device. In order to provide an allowance for a potential failure/blockage of this device, or the requirement to route above-design-event storms through the pond, a high-level overflow/embankment spillway and appropriate erosion protection measures will be provided for controlled overtopping of each pond into an appropriate receptor.
- Exceedance routes will be contained within the verge/hard-strip/nearside running lane and routed to intermediate outfall points. These flows will then be re-introduced into the positive drainage system, or routed directly to an attenuation pond.
- Cut-off ditches will be provided where runoff from adjoining land is likely to flow towards the Scheme. Cut-off drains provided at the crest of cut-slopes will be lined to prevent the ingress of water into the slope. Those that are provided at the toe of embankments, or in natural ground will be left unlined (subject to ground conditions and groundwater levels). Drainage at the base of cut slopes will be provided to intercept groundwater ingress.
- Highway drainage assets and land drainage elements required to protect highway assets will become the responsibility of NMWTRA. In general, diverted watercourses will remain the responsibility of the (pre-Scheme) riparian owners. However, under certain instances these watercourses will become the responsibility of NMWTRA.

7.2.2 The proposed drainage scheme will limit the peak surface water discharge rate to the equivalent mean annual runoff rate for the greenfield site for all events up to the 100 year return period event (with climate change). For the majority of events this will represent a decrease in peak runoff rate and therefore an improvement in terms of reduced flood risk downstream. For events smaller than the mean annual flood (e.g. 1 year and 2 year) the peak discharge rate may slightly increase. However, it is anticipated that this will be small, and any infiltration which occurs within the drainage system will further reduce the runoff. It is not expected that this will lead to an increase in flood risk elsewhere.

7.2.3 The Scheme will result in an overall increase in runoff volume due to the additional impermeable area. However, as discharge rates will be limited to the greenfield mean annual runoff rate, this additional volume will be discharged at a controlled rate and is not expected to lead to a significant increase in flood risks downstream on the local watercourses.

7.2.4 The proposed drainage strategy includes measures to manage exceedance flows to avoid an increase in flood risk elsewhere during events which exceed the design capacity of the surface water drainage system.

7.2.5 The proposed surface water drainage provides appropriate mitigation to avoid an increase in flood risk elsewhere as a result of the Scheme and therefore is considered to meet the requirements of TAN 15.

SECTION 6

JUSTIFICATION TEST

8 JUSTIFICATION TEST

8.1.1 TAN15 requires that all development proposed within Zone C, with the exception of water compatible development, is subject to the Justification test.

8.1.2 To pass the test, it must be demonstrated that:

1. Its location within Zone C is necessary to assist, or be part of, a local authority regeneration initiative or a local authority strategy required to sustain an existing settlement; **or**
2. Its location in Zone C is necessary to contribute to key employment objectives supported by the local authority, and other key partners, to sustain an existing settlement or region; **and**
3. It concurs with the aims of PPW and meets the definition of previously developed land; **and**,
4. The potential consequences of a flooding event for the particular type of development have been considered, and in terms of the criteria contained in sections 5 & 7 and Appendix 1 (of TAN15) found to be acceptable.

8.1.3 The majority of the Scheme is located on land within Zone A and B. However, the Scheme will involve works within Zone C where the Scheme crosses or lies close to existing watercourses. The proposed Scheme is promoted by Welsh Government and it is considered that it will therefore pass part 1 and / or 2 of the test. The Scheme crosses largely greenfield land however, considering the nature of the Scheme, it is unlikely this could be avoided. The proposed route has been selected following an appraisal of alternatives.

8.1.4 The proposed Scheme is considered “less vulnerable” to flooding, according to the TAN15 classifications, and is therefore acceptable within Zone C1 and C2 subject to acceptable flood consequences.

8.1.5 As described previously, the proposed Scheme is generally at low risk of flooding from any source. There is some potential for flooding where the Scheme crosses existing watercourses; however, this is considered low risk. Proposed culverts have been designed to accommodate the 100 year return period flow, including climate change and freeboard allowances, and watercourse diversions have been designed to maintain existing flow capacities. In many cases the proposed culverts have larger capacities than the design standard. On this basis it is deemed unlikely that fluvial flooding will occur to the Scheme for the 100 year return period event and any flooding that occurs for larger events is unlikely to exceed TAN15 thresholds. The detailed hydraulic analyses confirm the flood risks meet TAN15 guidance for the larger Main River crossings (Rhyd, Gwyrfai, Seiont and Cadnant).

8.1.6 There is also potential for flooding of the Scheme due to exceedance of the road drainage system and / or groundwater ingress at the deeper cuttings. The proposed drainage meets the appropriate design criteria and exceedance flows, for events up to the 100 year event, will be contained to the verge / hard strip and nearside running lane. It is unlikely that flood depths will exceed the maximum values suggested in TAN15 for the 1000 year return period event. The flood consequences to the Scheme are therefore considered acceptable.

8.1.7 The proposals include appropriate restriction of surface runoff to mitigate an increase in flood risk elsewhere. As detailed in sections 5 and 6, the Scheme will result in some changes in flooding in the immediate vicinity and may cause localised increases in

flooding. However this is not expected to affect any properties or to materially change the flood risk in the vicinity of the Scheme or the wider area.

8.1.8 It is therefore considered the Scheme meets the requirements of the Justification test.

SECTION 7

CONCLUSION

9 CONCLUSION

9.1 Introduction

9.1.1 This Flood Consequence Assessment (FCA) has been prepared to support the proposed A487 Caernarfon & Bontnewydd Bypass Scheme. The FCA assesses the flood risks and consequences posed to the Scheme and any changes to flood risk and consequences that may occur because of the Scheme.

9.1.2 The main features of the Scheme of relevance to this assessment are outlined below:

- The Scheme is approximately 9.5 km in length, predominantly new road construction through undeveloped land. The road alignment requires a combination of embankment, cutting and at-grade construction, which may locally affect drainage routes and flow regimes.
- The Scheme includes a number of watercourse crossings and diversions of both Main Rivers and ordinary watercourses.
- The Scheme will result in an increase in the total impermeable area due to the new road construction (the existing road will largely remain in place). A new sustainable drainage system will be provided.

9.1.3 NRW and Gwynedd Council have been consulted to inform the approach to the FCA and specific requirements of the Scheme. The FCA is based on qualitative assessment of flood consequences Scheme-wide and detailed hydrological / hydraulic assessment (including hydraulic modelling) of the larger river crossings.

9.2 Summary of Existing Flood Risk

9.2.1 The majority of the Scheme is assessed at low risk of flooding from any source. The main areas where flooding may present a constraint are where the Scheme crosses or runs close to existing watercourses. The following sources of flooding are assessed to present a potential constraint to the Scheme, or have the potential to be affected by the Scheme:

- Fluvial flooding from Main Rivers and local watercourses;
- Overland flows from surface water flooding;
- Groundwater flooding where the Scheme is in cutting.

9.3 Summary of Post Development Flood Risk

9.3.1 The Scheme design includes a range of mitigation to manage flood risks posed to the Scheme and the impact of the Scheme on flood risks elsewhere. These include the design of new culverts to carry the 100 year return period flow (including suitable climate change and freeboard allowances); viaducts spanning the larger river floodplains; diversion of watercourses and ditches to maintain flow routes; and control of surface water runoff to manage flood risk to the Scheme and mitigate an increase in flood risk downstream.

9.3.2 The fluvial flood risk to the Scheme is considered low. There are some locations where flooding may occur during larger events; however, the flooding is not expected to exceed TAN15 thresholds and is therefore considered acceptable. Aside from the rivers subject to detailed assessment, the Afon Rhosdican is considered to pose the most significant risk to the Scheme and potential to be affected by the Scheme. It is

recommended that further assessment of flood risk from this watercourse is undertaken during detailed design to confirm the flood consequences are acceptable.

9.3.3 The Scheme includes a number of new watercourse crossings and diversions. These will potentially have small localised impacts, due to effects on floodplain storage and conveyance, but are not expected to lead to an increase in flooding elsewhere as existing flow routes are maintained and the proposed crossings will be designed to convey the 100 year flow (with climate change).

9.3.4 The flood risk associated with the larger river crossings has been assessed in detail and summarised as follows:

- Afon Rhyd - The Scheme is not at risk of flooding from the Afon Rhyd. The proposals result in localised increases in flood depth as the natural topography directs overland flows towards the current channel alignment. The increased flood depths do not affect any properties and the majority of the land affected is owned by Welsh Government.
- Afon Gwyrfai - The Scheme is not at risk from flooding of the Afon Gwyrfai. The proposals result in localised increases in flood depth due to the portion of embankment and piers located in the floodplain but this does not affect any properties and is not considered to materially affect the flood risk to the affected farm land.
- Afon Seiont - The Scheme is not at risk from flooding of the Afon Seiont. The proposals may result in small, localised increases in flood depth for the 1000 year event due to pier located in the floodplain but this does not materially affect the flood risk to the affected land.
- Afon Cadnant - The Scheme is not at significant risk of flooding from the Cadnant watercourses. The proposals results in some changes in flows and localised increases in flood depth but this does not affect any properties and is not considered to materially affect flood risk to the affected land.

9.3.5 Details of proposed temporary works have been provided for the Afon Gwyrfai and Afon Seiont. With the exception of the Afon Gwyrfai, they are unlikely to significantly affect flood flows. It is assumed that appropriate temporary diversions and pumping will be put in place to maintain watercourse flows whist new channel and structures are being built.

9.3.6 The temporary works required during construction of the Afon Gwyrfai are likely to have a more significant impact, should a large flood occur during the 18 month construction period. It is expected that the proposed haul road would lead to an increase in flood depths upstream for a distance of around 100m. However no properties are expected to be affected. The haul road would increase the flow across the northern part of the floodplain and could potentially increase the flooding to the existing properties located close to the river on the right bank of the meander. However, it is anticipated that this would only be the case for the larger events and any increase in flood depth is unlikely to be significant. The likelihood of this occurring during the 18 month construction period is low.

9.3.7 The surface water flood risk to the Scheme is considered low. Flooding may occur in some areas during larger events; however, the flooding is not expected to exceed TAN15 thresholds and is therefore considered acceptable. The Scheme includes a number of new ditch crossings and diversions which will potentially have small localised impacts but these are not expected to lead to an increase in flooding elsewhere as existing flow routes are generally maintained and flows are likely to be small.

9.3.8 Based on the current available information it is considered that groundwater flows may enter the deeper cuttings (near Llanwnda and Plas Menai); however, provided appropriate drainage is in place to capture any groundwater flows it is unlikely that flood depths would exceed TAN15 thresholds. Groundwater flood risks are therefore considered acceptable.

9.3.9 The Scheme will result in an increase in surface water runoff, due to the additional impermeable area. The proposed drainage scheme will limit the peak surface water discharge rate and control the discharge rate of the additional runoff volume. For the majority of events this will represent a decrease in peak runoff rate and therefore an improvement in terms of reduced flood risk downstream. For smaller events the peak discharge rate may slightly increase; however, it is anticipated that this will be small, and any infiltration that occurs within the drainage system will further reduce the runoff.

9.3.10 The proposed drainage strategy includes measures to manage exceedance flows to avoid an increase in flood risk elsewhere during events which exceed the design capacity of the surface water drainage system.

9.3.11 The proposed surface water drainage provides appropriate mitigation to avoid an increase in flood risk elsewhere as a result of the Scheme and therefore is considered to meet the requirements of TAN 15.

9.4 Compliance with TAN15

9.4.1 The majority of the Scheme is located on land within Zone A and B. The Scheme will involve works within Zone C where the Scheme crosses or lies close to existing watercourses.

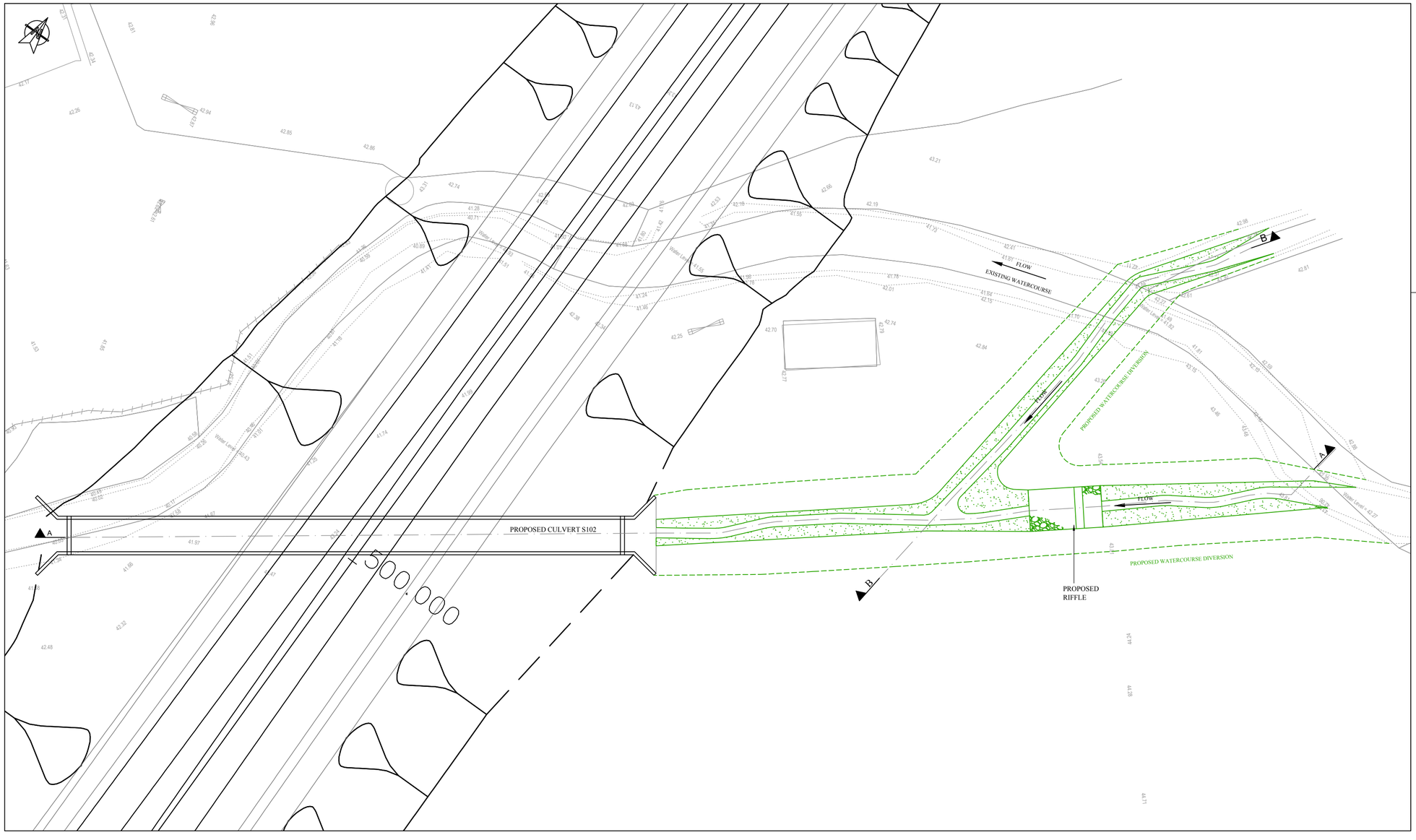
9.4.2 The Scheme is considered “less vulnerable” to flooding, according to the TAN15 classifications, and is therefore acceptable within Zone C1 and C2 subject to the Justification test and acceptable flood consequences. The Scheme is promoted by Welsh Government and it is considered will therefore pass part 1 and / or 2 of the Justification test. The Scheme crosses largely greenfield land which is Contrary to the requirement of part 3 of the Justification test. However, considering the nature of the Scheme, it is unlikely this could be avoided. The proposed route has been selected following an appraisal of alternatives.

9.4.3 The Scheme is generally at low risk of flooding from any source. It is deemed unlikely that fluvial flooding will occur to the Scheme for the 100 year return period event and any flooding that occurs for larger events is unlikely to exceed TAN15 thresholds. There is potential for flooding of the Scheme due to exceedance of the road drainage system and / or groundwater ingress at the deeper cuttings. However the proposed drainage meets the appropriate design criteria and exceedance flows for events up to the 100 year return period event will be contained to the verge / hard strip and nearside running lane. It is unlikely that flood depths will exceed the maximum values suggested in TAN15 for the 1000 year event. The flood consequences to the Scheme are therefore considered acceptable.

9.4.4 The proposals include appropriate restriction of surface runoff to mitigate an increase in flood risk elsewhere. The Scheme will result in some changes in flooding in the immediate vicinity and may cause localised increases in flooding. This is not expected to affect any properties or to materially change the flood risk in the vicinity of the Scheme or the wider area.

9.4.5 It is therefore considered the Scheme meets the requirements of the Justification test and TAN15.

Appendix K.2 – Scheme Proposals



PLAN (EXTENTS OF DIVERTED WATERCOURSE SHOWN INDICATIVELY)

SCALE 1:200

DRAFT TO INFORM INITIAL HYDRAULIC MODELLING ONLY

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INLET HEADWALL PARAMETERS:

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M	1.0
C	0.0385
Y	0.670
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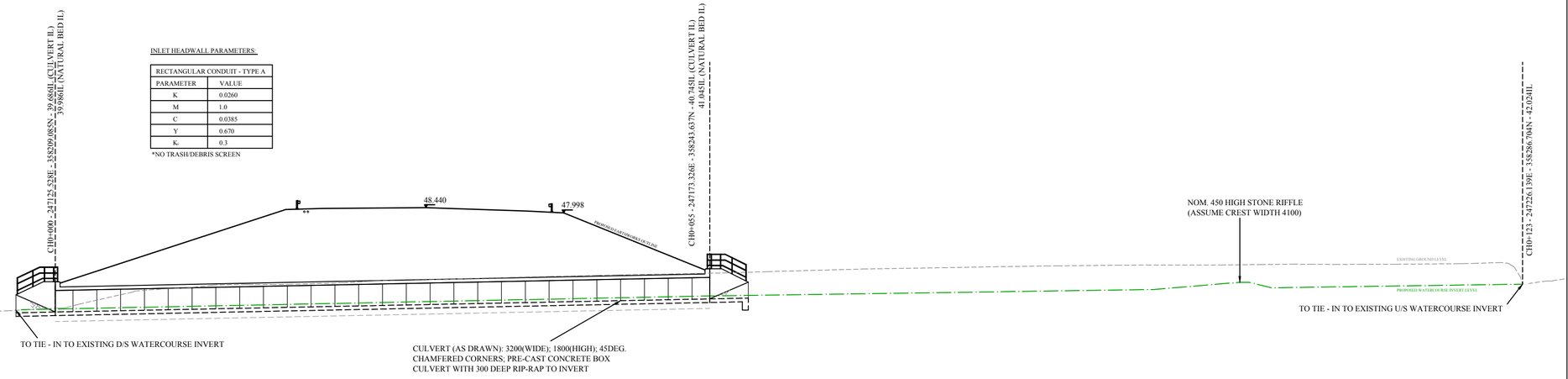
*NO TRASH/DEBRIS SCREEN



SECTION A-A

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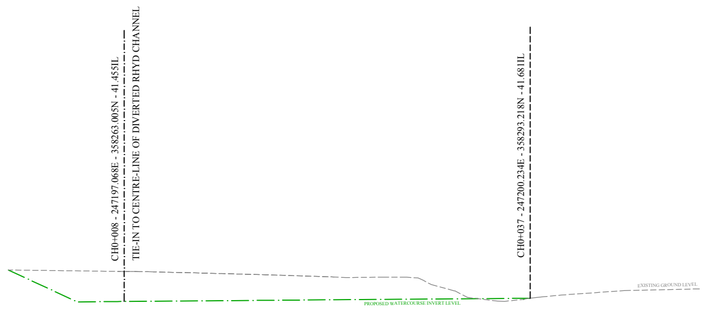

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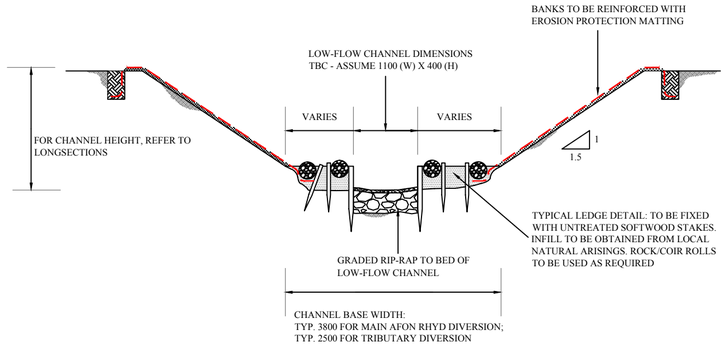

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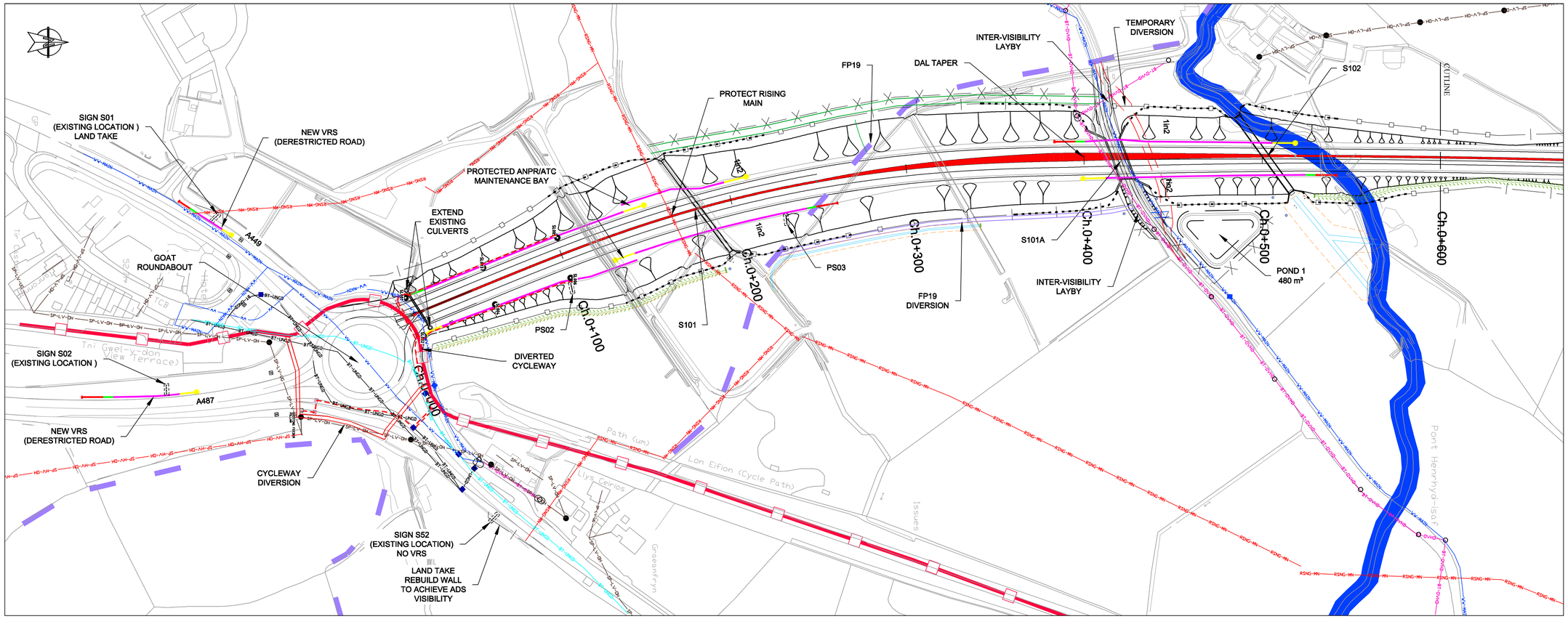

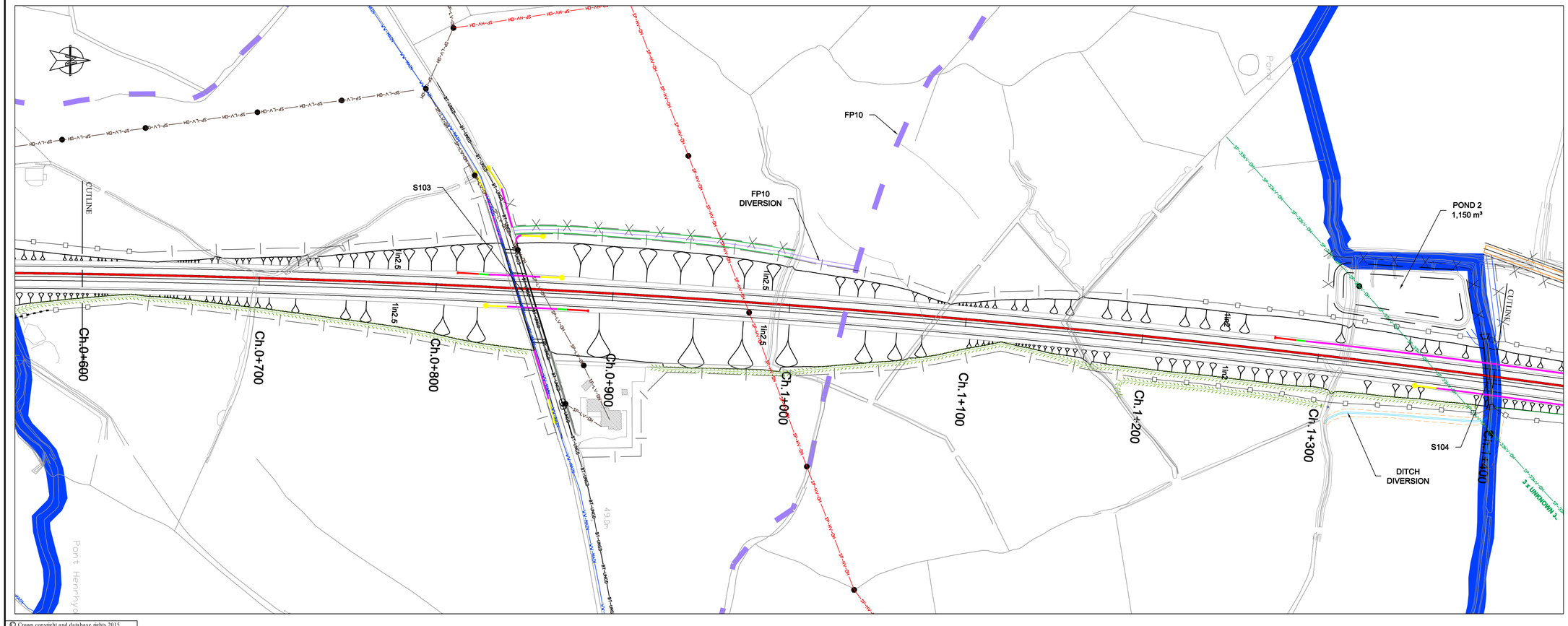

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KEY

- 2+1 CARRIAGEWAY
- EARTHWORKS
- ATTENUATION POND
- BAT FENCE
- OTTER FENCE
- HIGHWAY BOUNDARY
- STOCK PROOF FENCE
- VEHICLE RESTRAINT SYSTEM
- TRAFFIC SIGN (ADS)
- TRAFFIC SIGN (REGULATION)
- STREET LIGHTING COLUMN
- SHARED USED PMA (CONTRETE)
- PMA (GRANULAR)
- POND ACCESS (GRANULAR)
- EXISTING FOOTPATH
- FOOTPATH DIVERSION (GRANULAR)
- EXISTING RECREATIONAL ROUTE
- RECREATIONAL ROUTE DIVERSION (ASPHALT)
- MAIN RIVER OR TRIBUTARY
- RIVER TRAINING/DITCH WORKS
- CUT-OFF DITCH

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Rev.	Date	Description	By	Chk	App

INITIAL STATUS OR WIP

EC HARRIS BUILT ASSET CONSULTANCY
Llywodraeth Cymru Welsh Government
RAMBOLL
Balfour Beatty
JONES BROS CIVIL ENGINEERING UK
PARSONS BRINCKERHOFF
Ty Glyn, Canol Y Dre, Ruthin Denbighshire Tel 01824 703661
TACP

Site/Project:

A487 CAERNARFON TO BONTNEWYDD BYPASS

Title:

LAYOUT APPROVAL PLAN

Drawn: R.Boyle		Checked: S.Carr	
Designed: M.Godfrey		Approved: S.Carr	
Date: 23/02/15	Scale: 1:1250	A1	Sheet: 1 of 9

Container Number: 3513874-PB-06-XX-DR-J-00001

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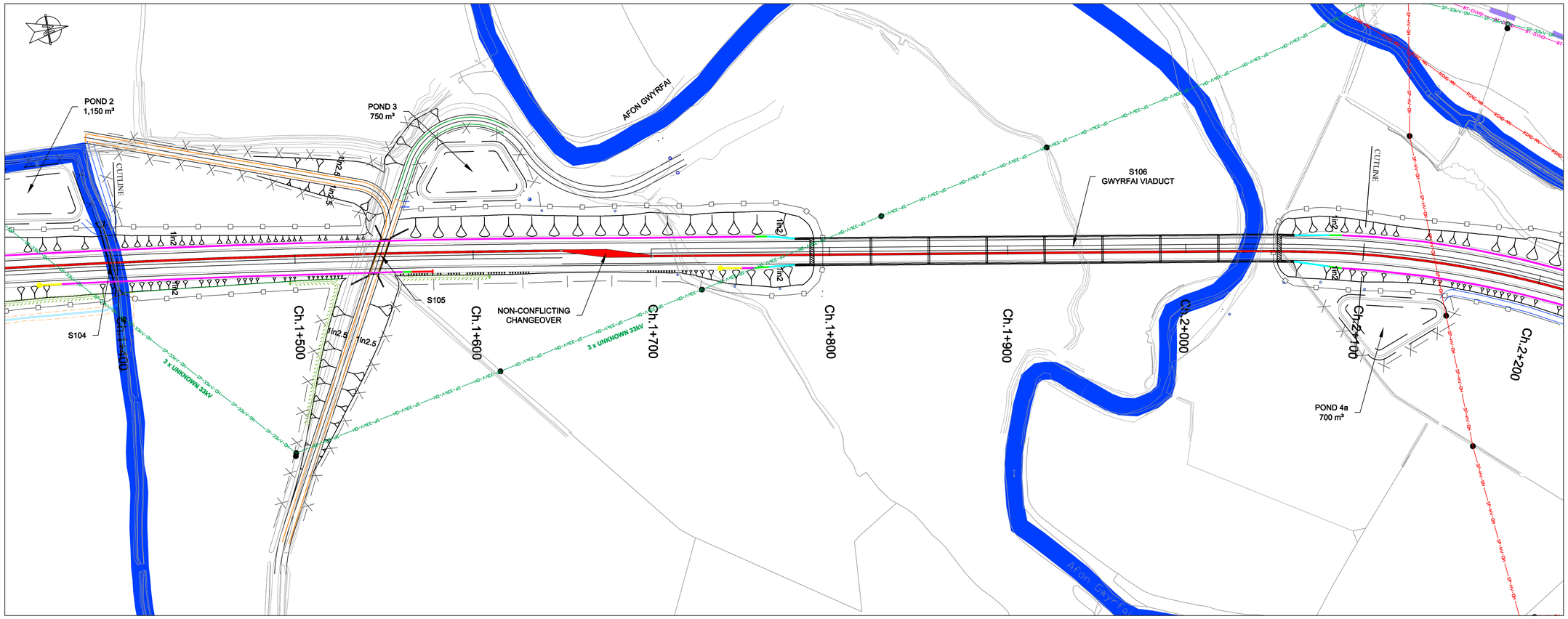

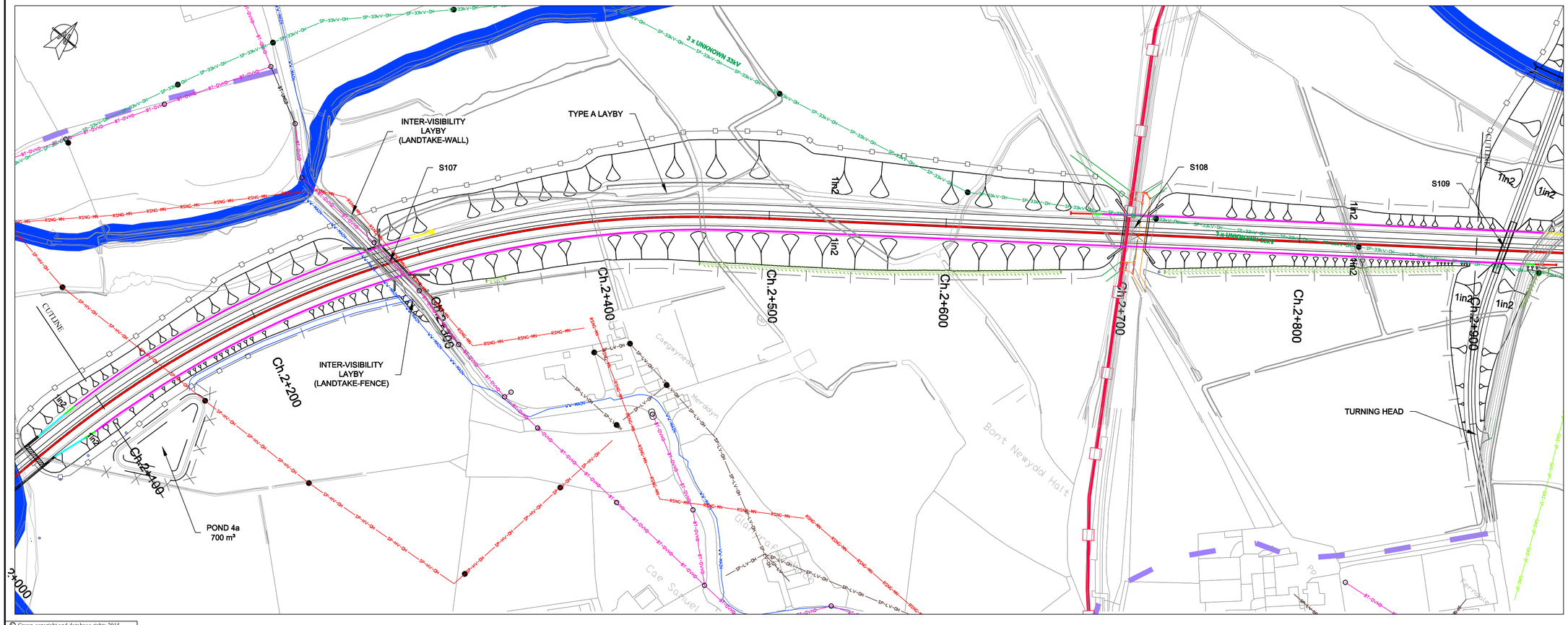

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- 2+1 CARRIAGEWAY
- EARTHWORKS
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- BAT FENCE
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- HIGHWAY BOUNDARY
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- TRAFFIC SIGN (ADS)
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- STREET LIGHTING COLUMN
- SHARED USED PMA (CONTRETE)
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Container Number: 3513874-PB-06-XX-DR-J-00002

Revision: P11

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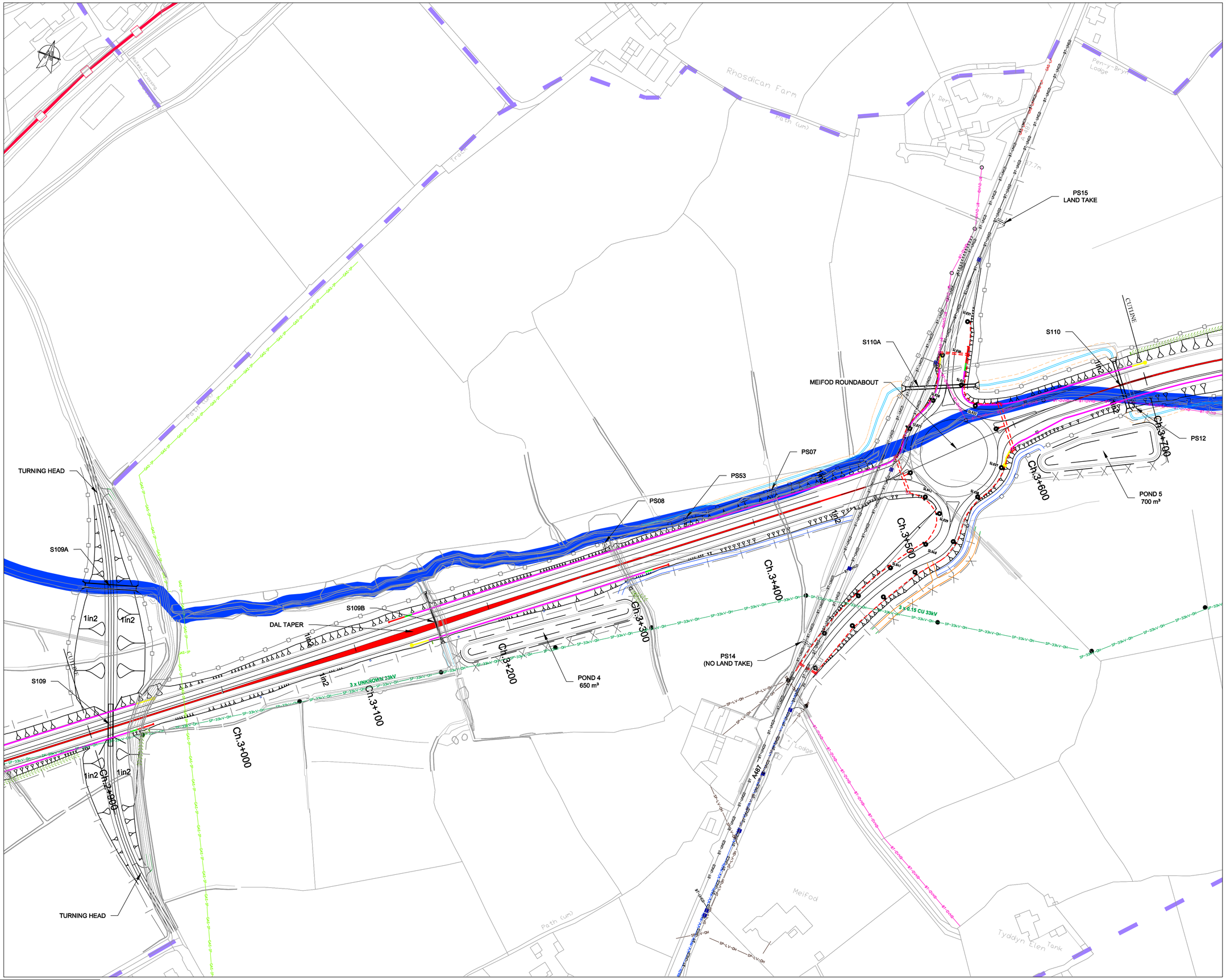

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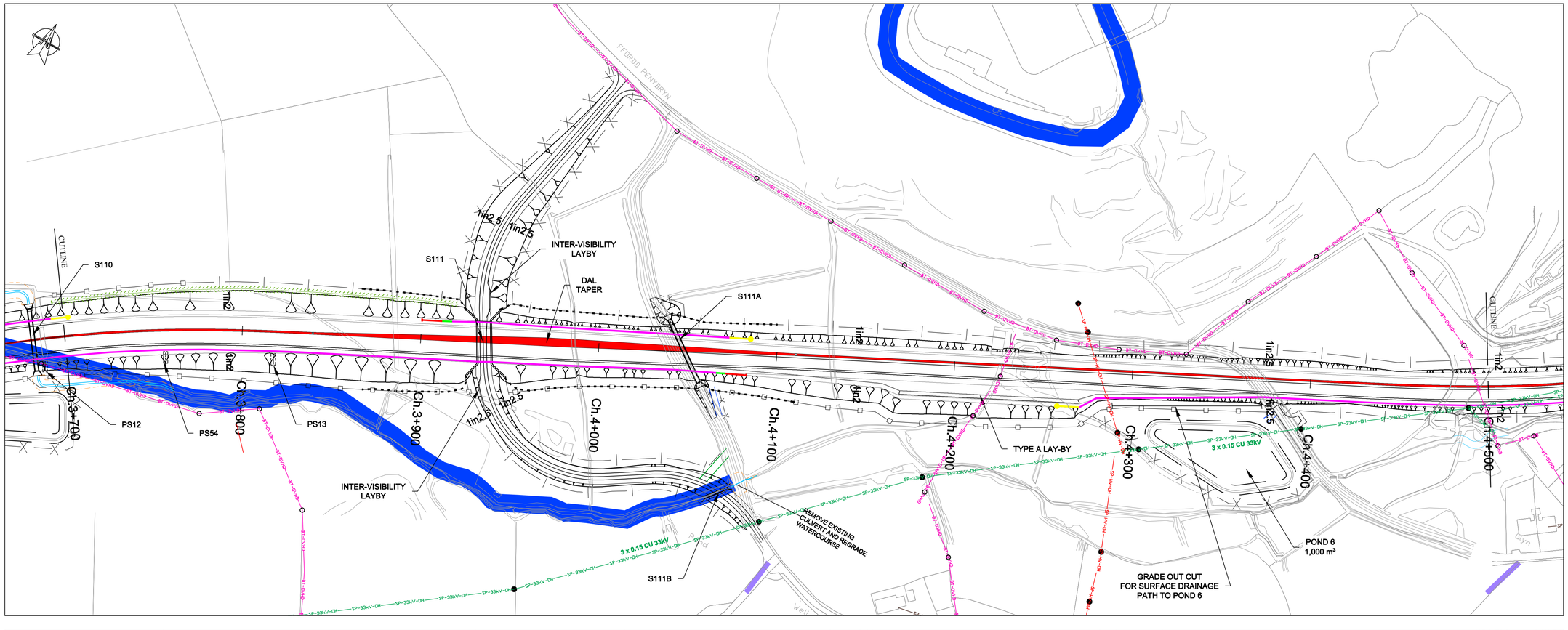

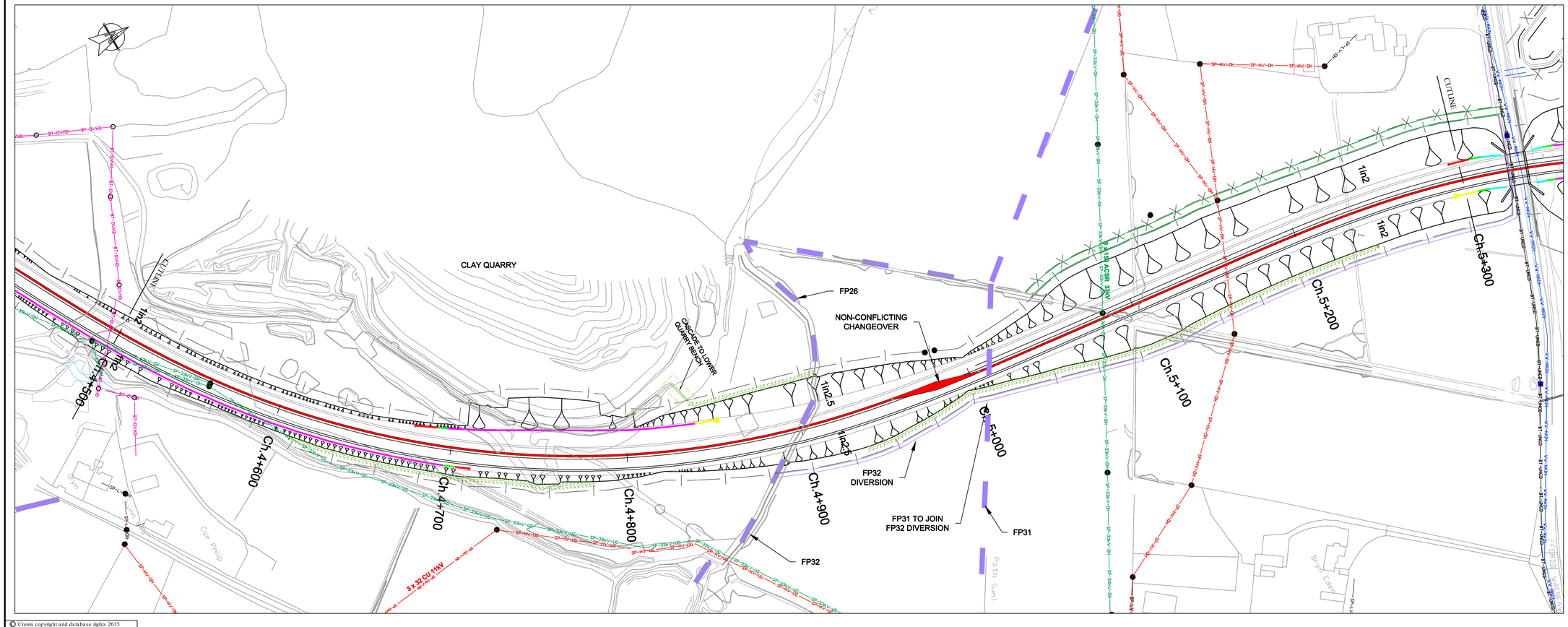

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Balfour Beatty
JONES BROS CIVIL ENGINEERING UK
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TACP
Ty Glyn, Canol Y Dre, Ruthin Denbighshire Tel 01824 703661

Site/Project:

A487 CAERNARFON TO BONTNEWYDD BYPASS

Title:

LAYOUT APPROVAL PLAN

Drawn: R.Boyle		Checked: S.Carr	
Designed: M.Godfrey		Approved: S.Carr	
Date: 24/02/15	Scale: 1:1250	A1	Sheet: 4 of 9

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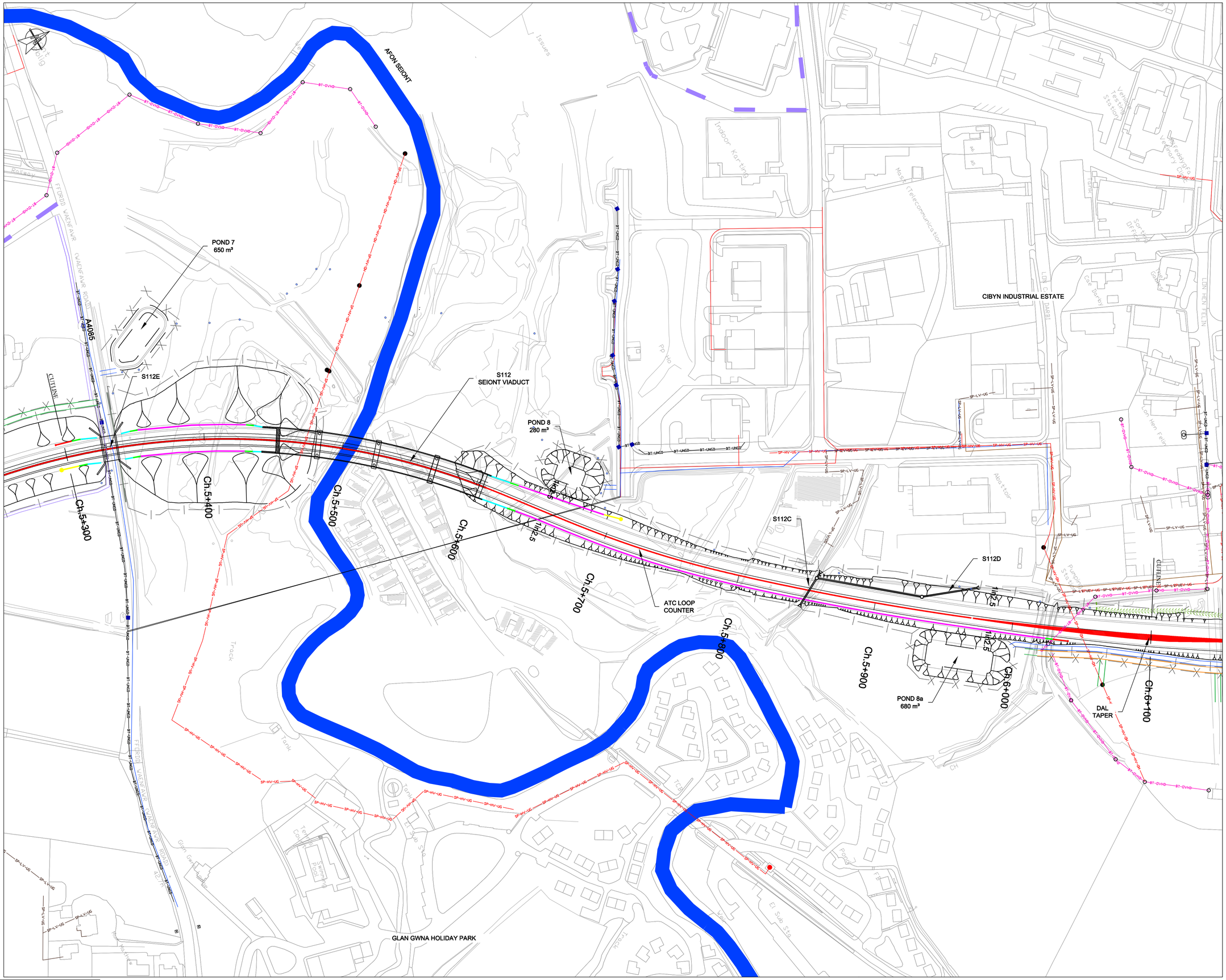
AFON SEIONT
POND 7
650 m³
S112E
S112
SEIONT VIADUCT
POND 8
280 m³
CUTTING
A4085
FFORDD WAENFAWR (WAENFAWR ROAD)
Ch.5+300
Ch.5+400
Ch.5+500
Ch.5+600
Ch.5+700
Ch.5+800
Ch.5+900
Ch.6+000
Ch.6+100
S112C
S112D
ATC LOOP COUNTER
POND 8a
680 m³
DAL TAPER
CIBYN INDUSTRIAL ESTATE
GLAN GWNA HOLIDAY PARK
Indoor Karting
Mast (Telecommunication)
Veterinary Testing Station
Veterinary Clinic
Sports Ground
Pumping Station
Abattoir
Tennis Courts
Swimming Pool
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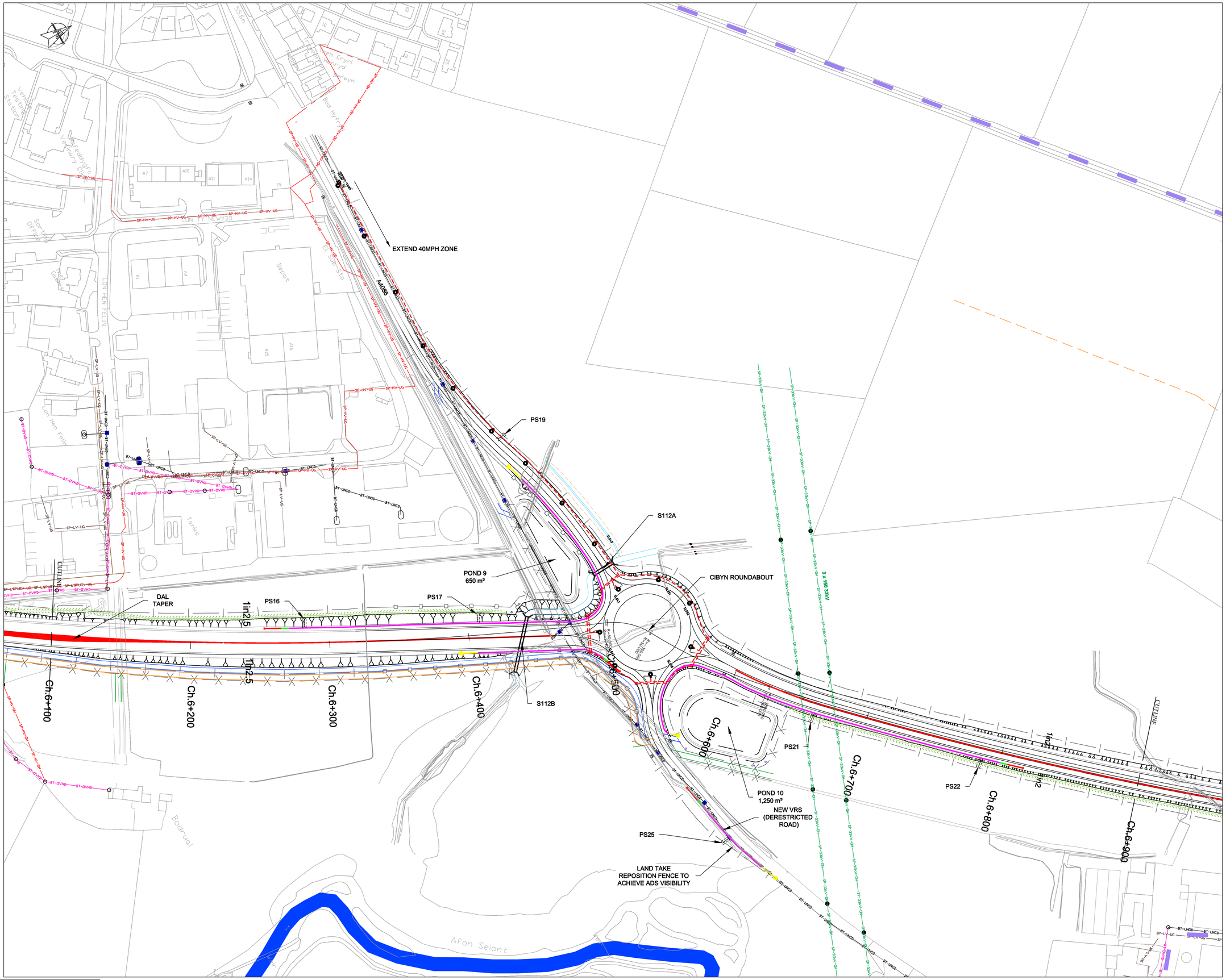
Ll/2.5
Ll/2.5



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Title:

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Drawn: R.Boyle		Checked: S.Carr	
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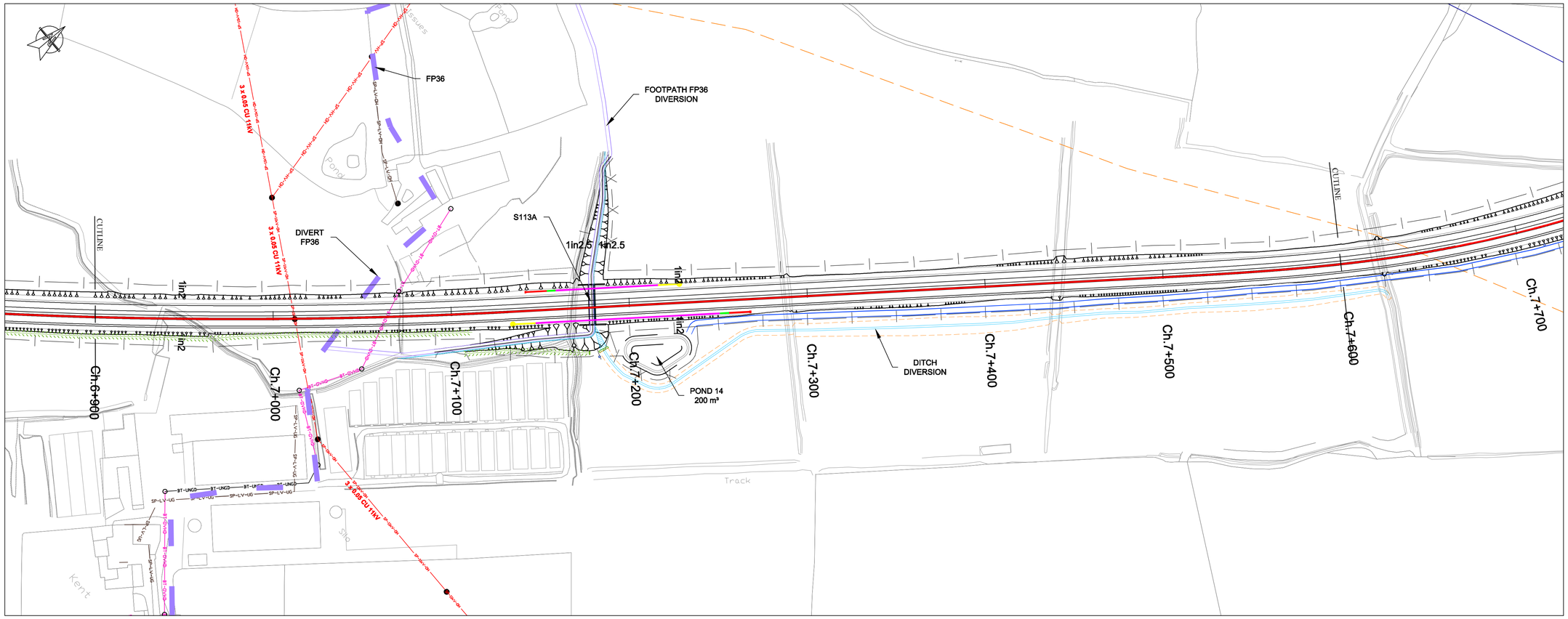

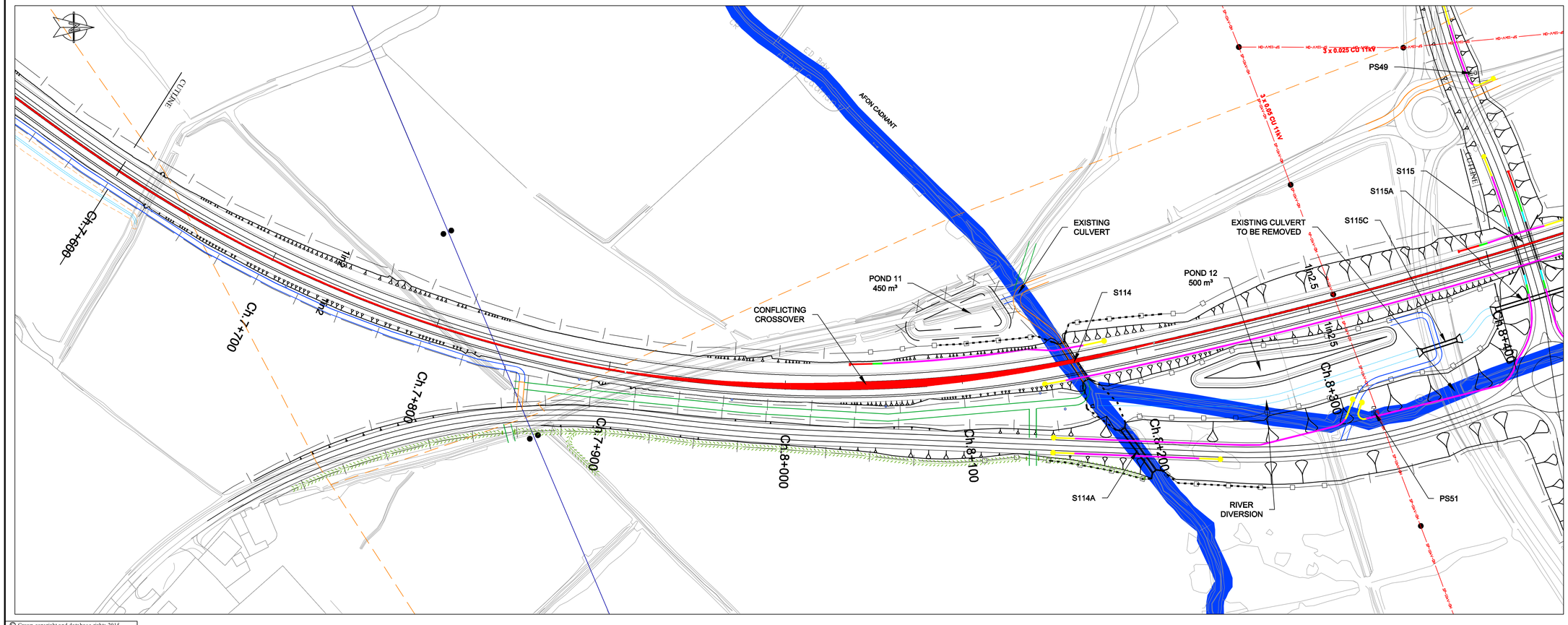

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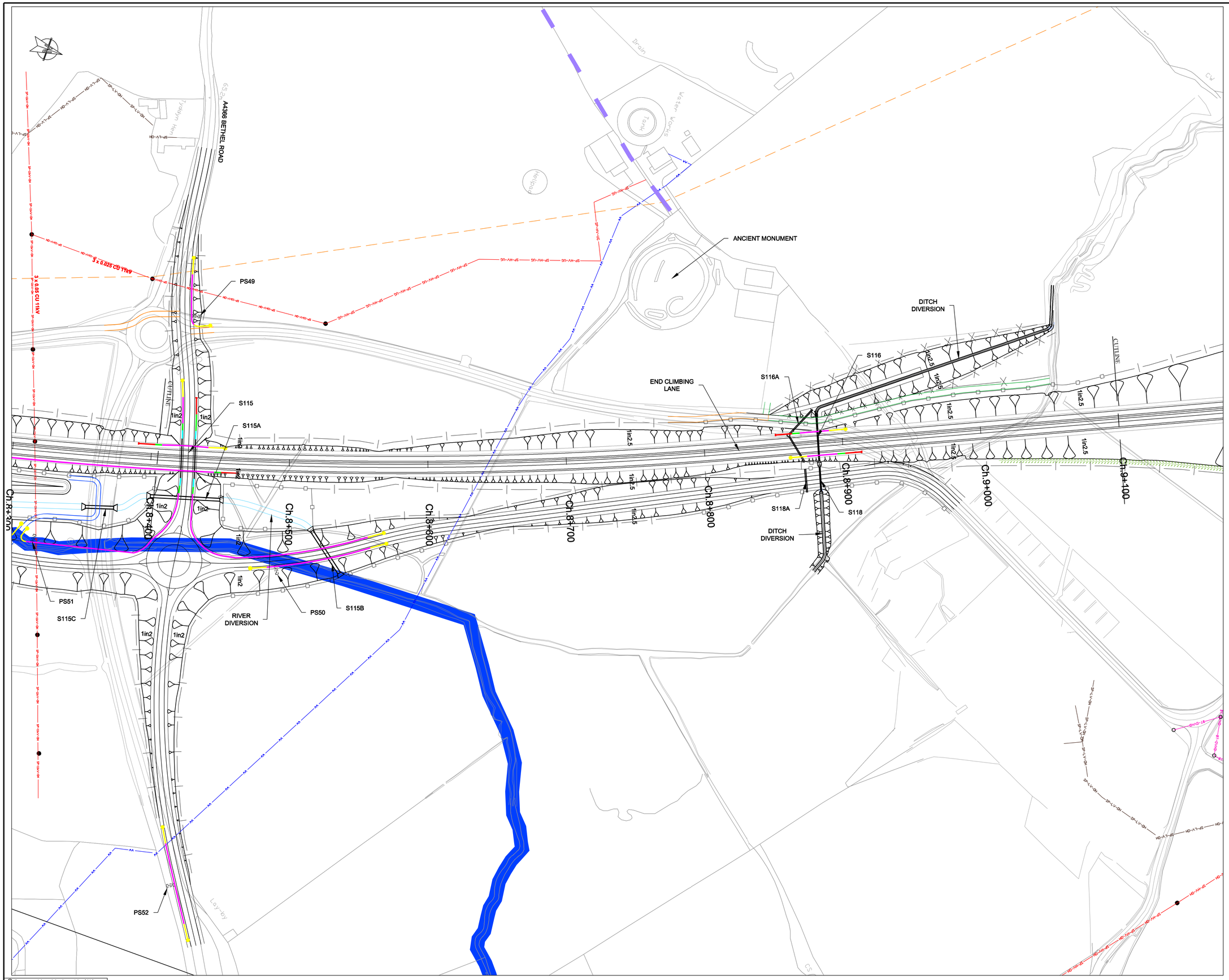

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LAYOUT APPROVAL PLAN

Drawn: R.Boyle		Checked: S.Carr	
Designed: M.Godfrey		Approved: S.Carr	
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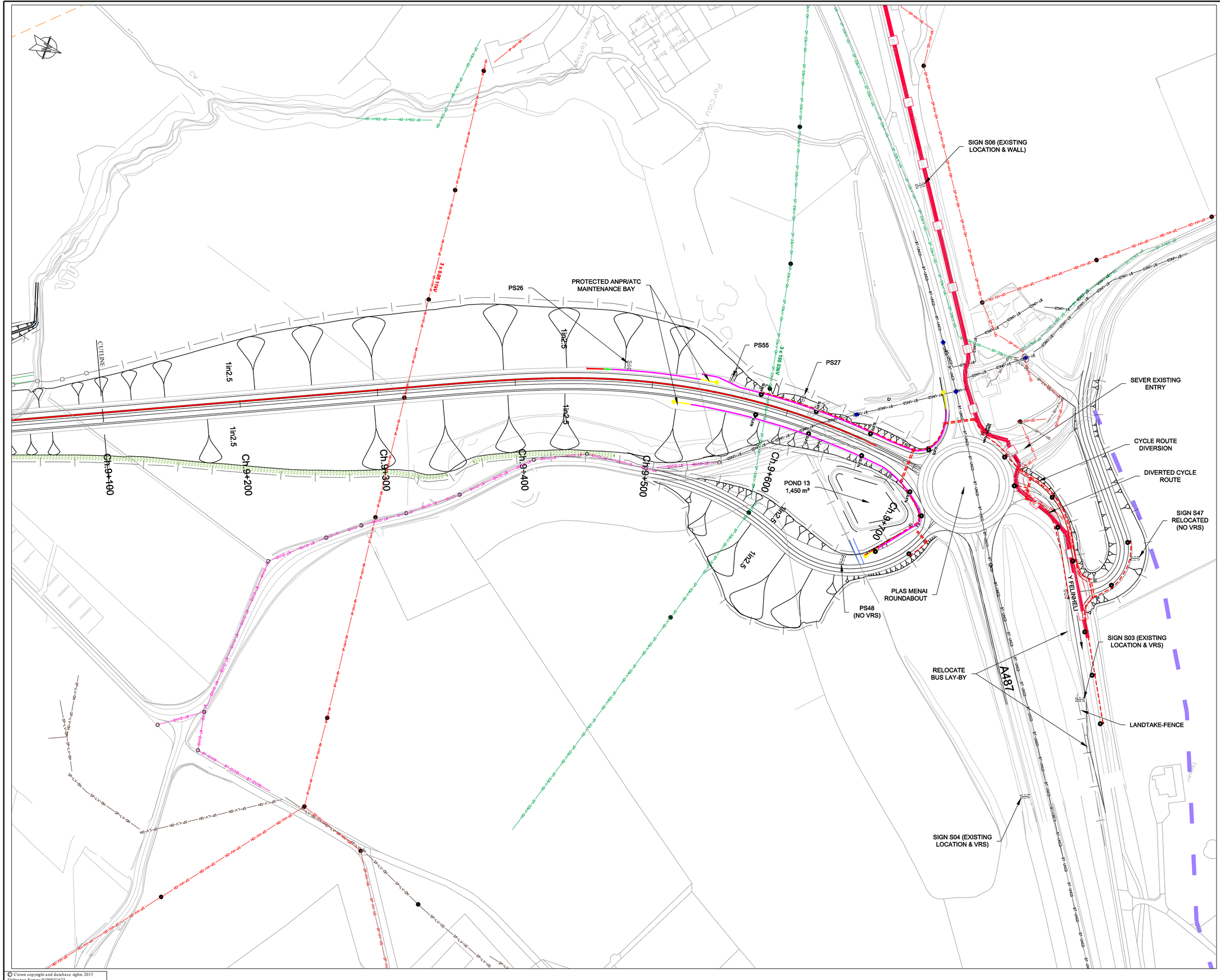

NOTES

A1

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KEY

- 2+1 CARRIAGEWAY
- EARTHWORKS
- ATTENUATION POND
- BAT FENCE
- OTTER FENCE
- HIGHWAY BOUNDARY
- STOCK PROOF FENCE
- VEHICLE RESTRAINT SYSTEM (TRANSITION, P1, VRS, P4)
- TRAFFIC SIGN (ADS)
- TRAFFIC SIGN (REGULATION)
- STREET LIGHTING COLUMN
- SHARED USED PMA (CONTRETE)
- PMA (GRANULAR)
- POND ACCESS (GRANULAR)
- EXISTING FOOTPATH
- FOOTPATH DIVERSION (GRANULAR)
- EXISTING RECREATIONAL ROUTE
- RECREATIONAL ROUTE DIVERSION (ASPHALT)
- MAIN RIVER OR TRIBUTARY
- RIVER TRAINING/DITCH WORKS
- CUT-OFF DITCH

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TACP

Site/Project:

A487 CAERNARFON TO BONTNEWYDD BYPASS

Title:

LAYOUT APPROVAL PLAN

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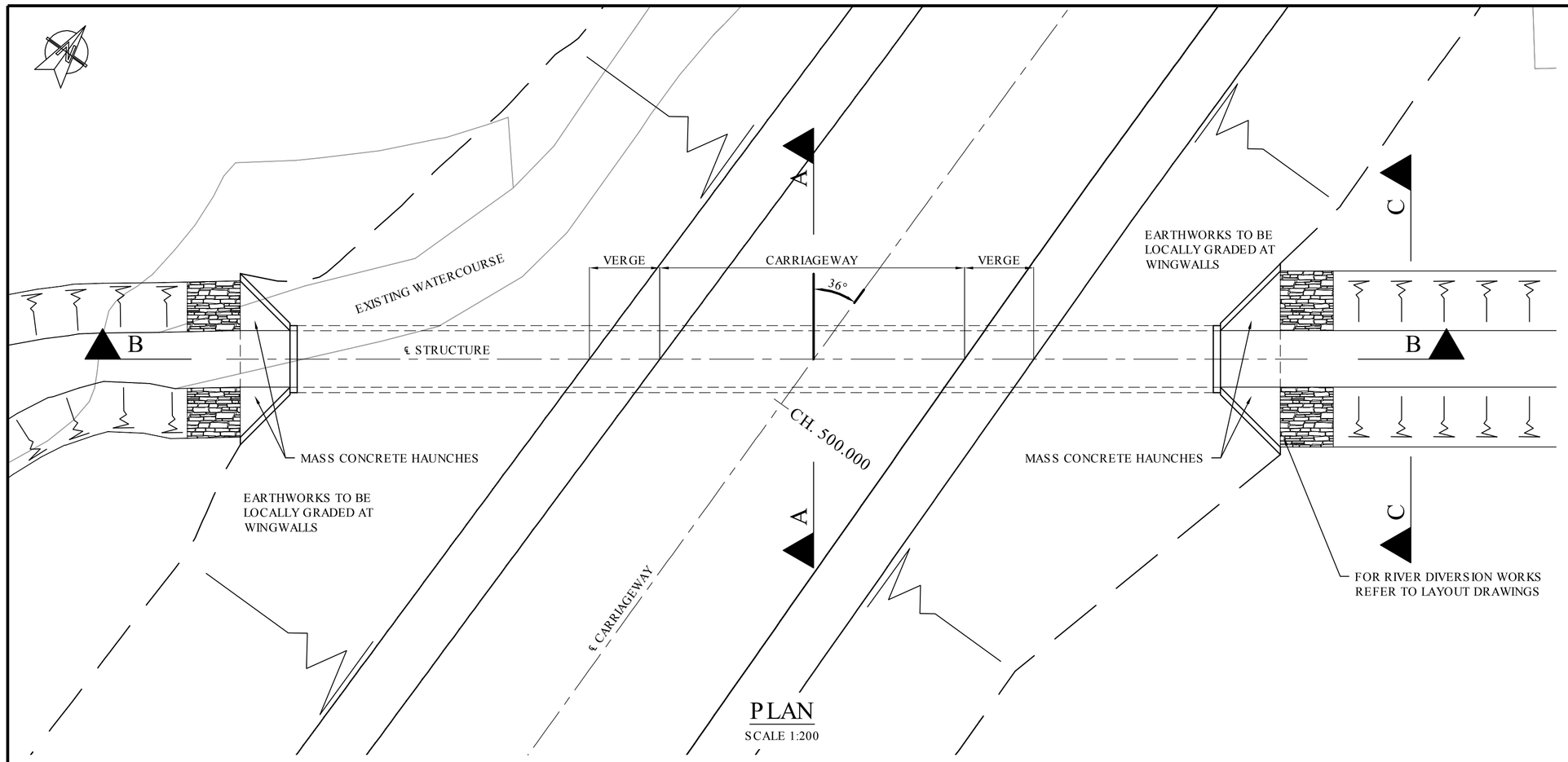

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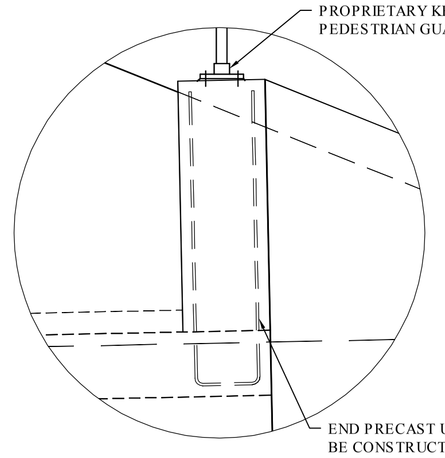

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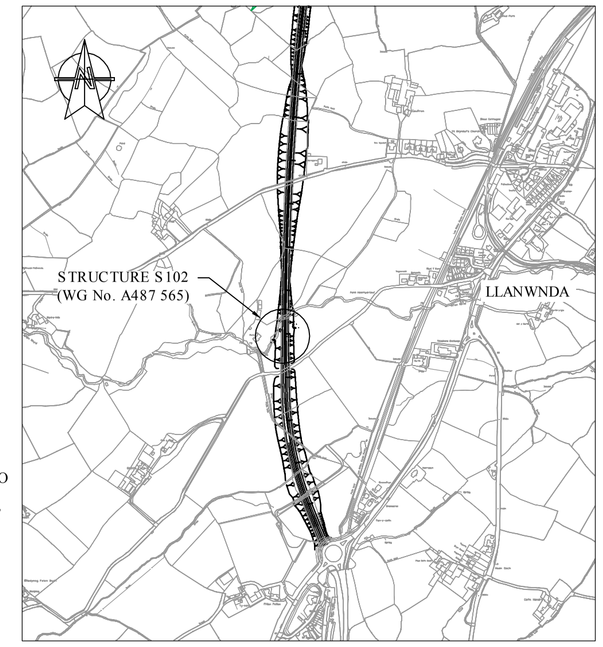

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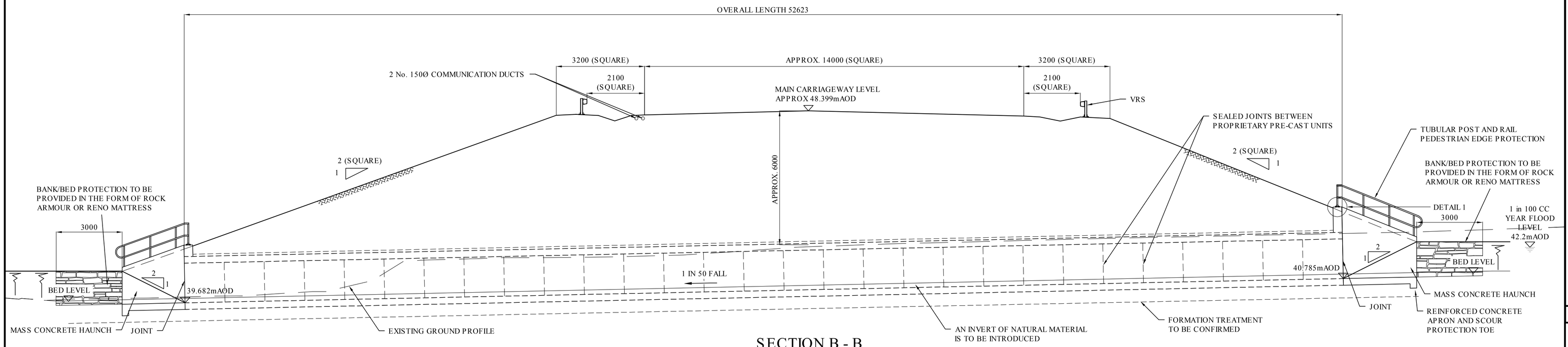

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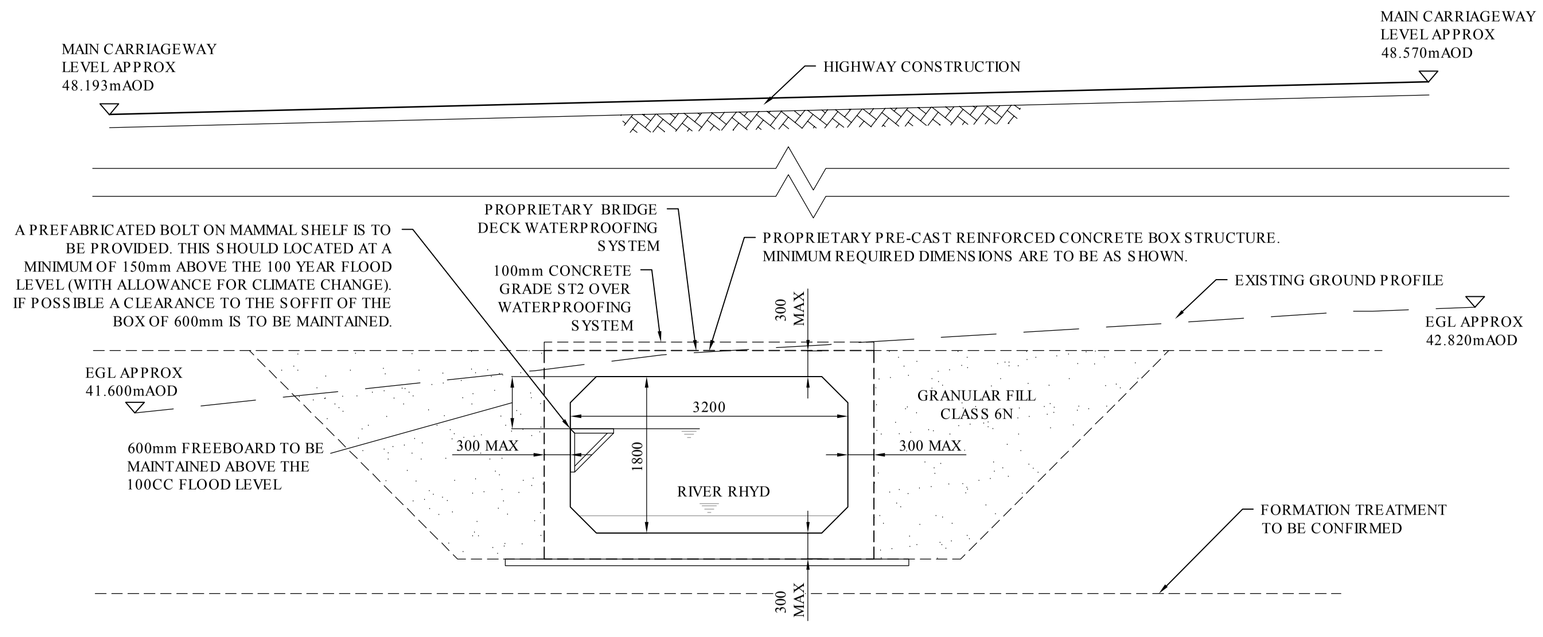

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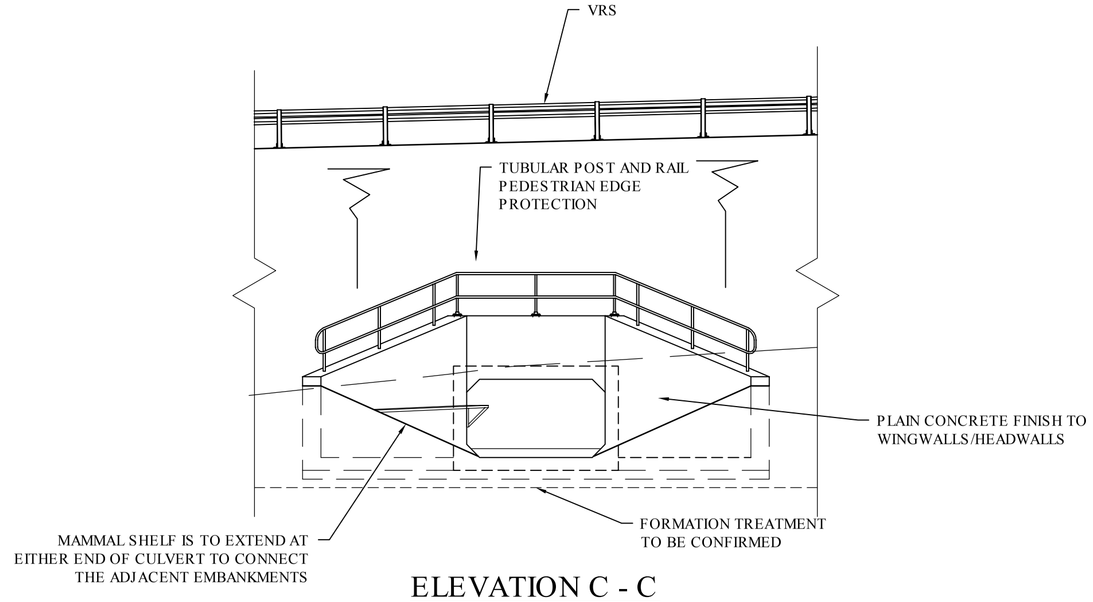

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TACP

Site/Project:

A487 CAERNARFON TO BONTNEWYDD BYPASS

Title:

S102 AFON RHYD CULVERT APPROVAL IN PRINCIPLE GENERAL ARRANGEMENT (WG No. A487 565)

Drawn: D.Parslow		Checked: S.Spence	
Designed: A GROVES		Approved: S.Spence	
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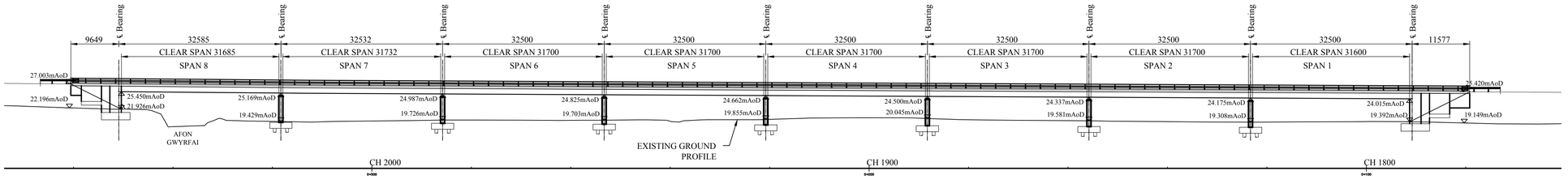

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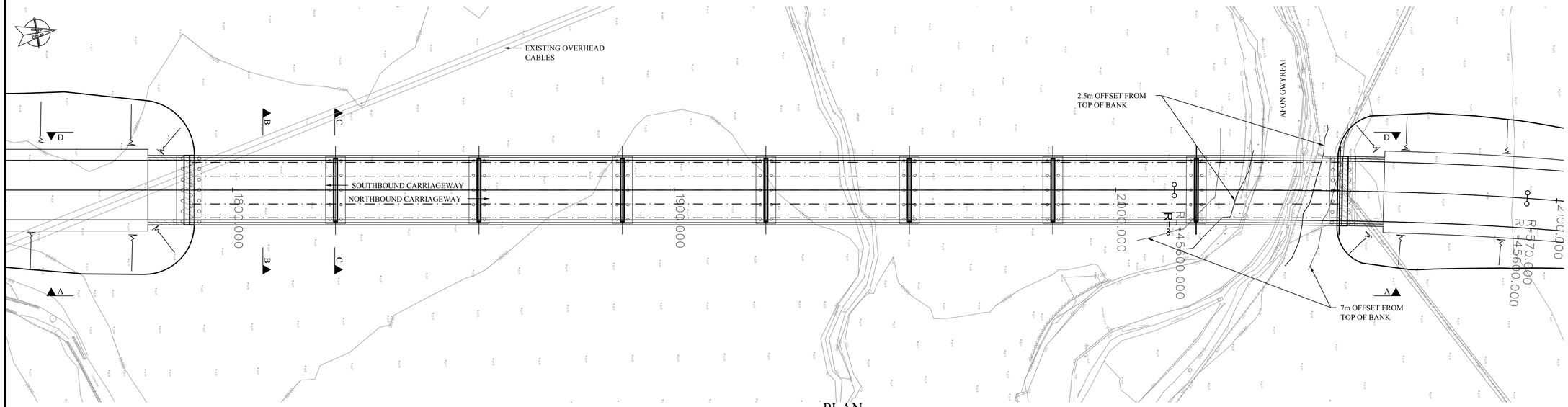

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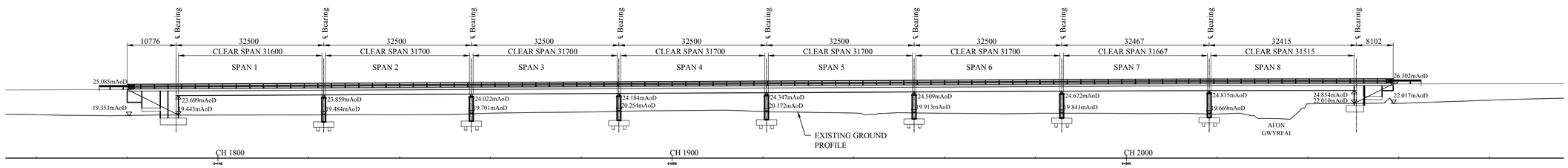

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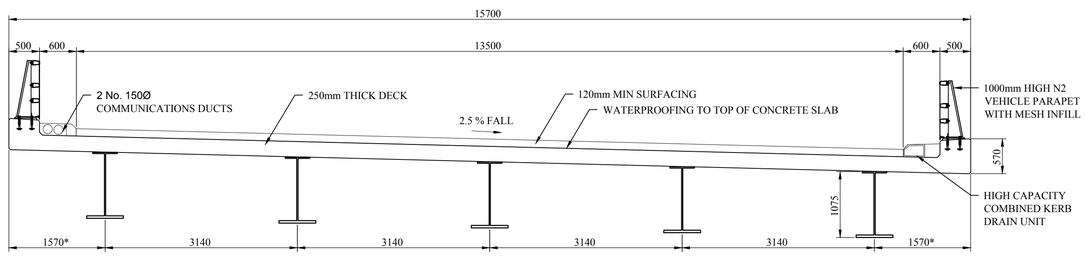

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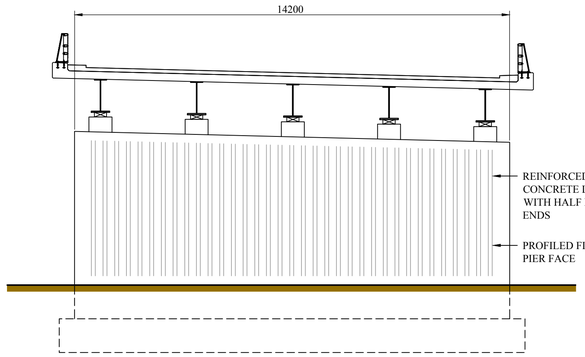
* CANTILEVER VARIES FOR SPANS 7 & 8



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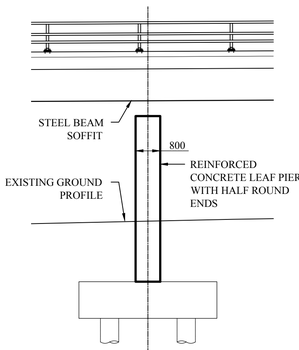

TYPICAL PIER END ELEVATION
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   (Topographical survey Ch.840 to Ch.2050)
   HIGHWAY:3513874-PB-XX-XX-M3-J-00006 VER P01.1
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P01.2	15/05/2015	UPDATED TO NEW ALIGNMENT	MB	AKG	AKG
P01.1	29/04/2015	ISSUED INITIAL FLOOD MODELLING	MB		

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Site/Project:
A487 CAERNARFON TO BONTNEWYDD BYPASS

Title:
STRUCTURE S106
GENERAL ARRANGEMENT

Drawn: M. BARKA		Checked: A. GROVES	
Designed: A. JARMAN		Approved: A. GROVES	
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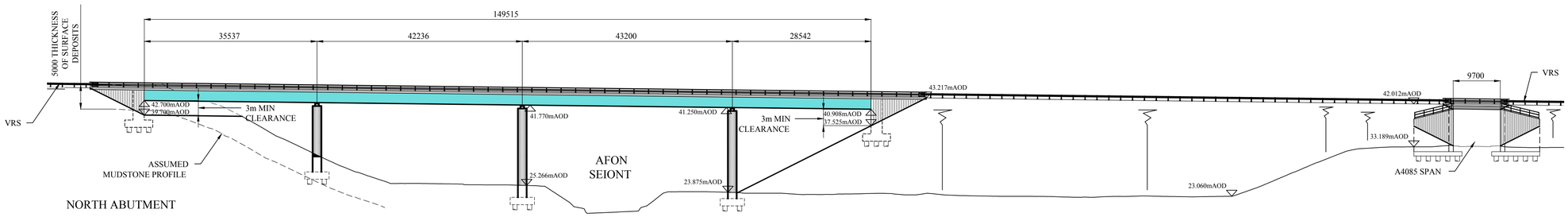

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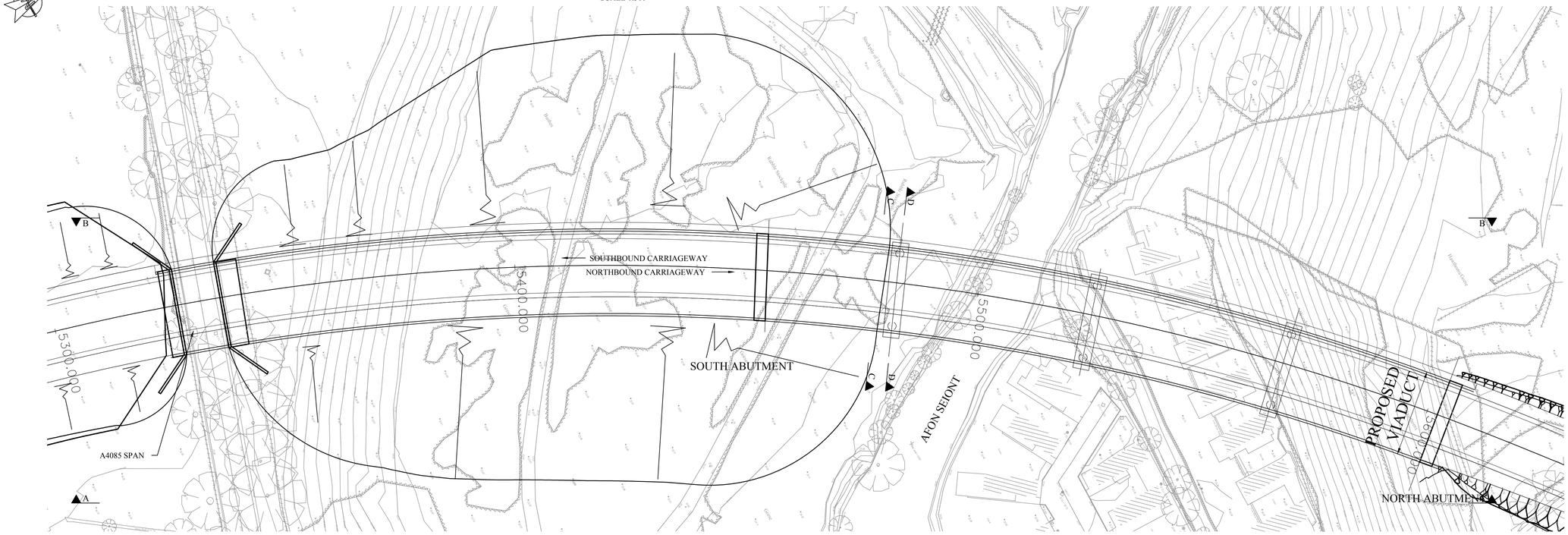

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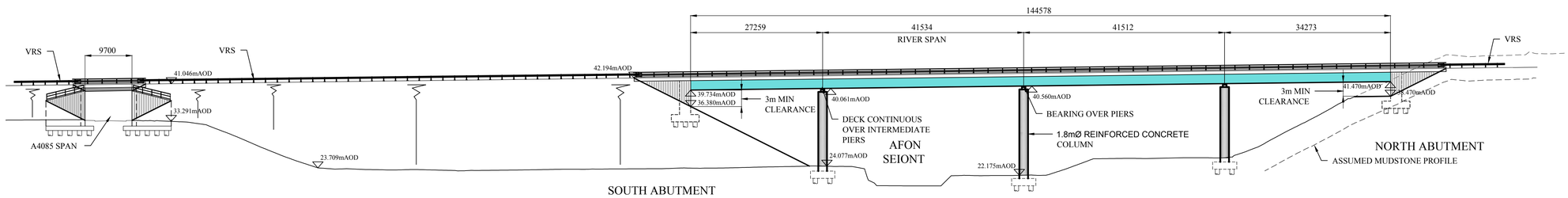

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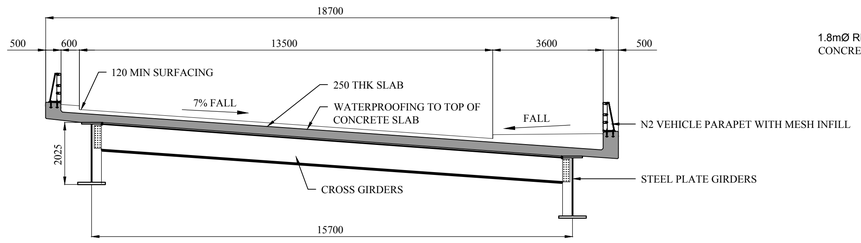

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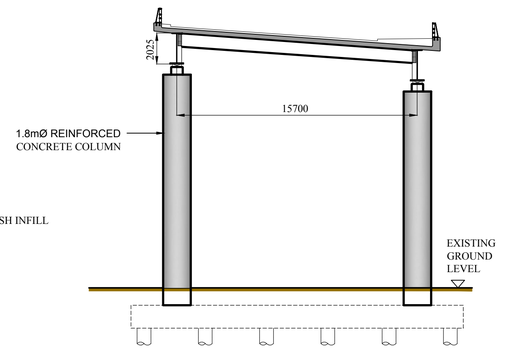

SECTION D-D

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A487 CAERNARFON TO BONTNEWYDD BYPASS

Title:

S112 OPTION 6

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Date: 18/05/15	Scale: AS SHOWN	A1	Sheet:

Container Number:	Revision:
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Appendix K.3 – Drainage Strategy

Subject:	**DRAINAGE STRATEGY**	**BIM Ref:**	3513874-PB-05-XX-D-00002	Ver. 0
Prepared:	Steve Burke	**Approved:**		
Date:	14/10/15	**Date:**	20/010/2015	

This technical note covers the proposed scheme drainage strategy including attenuated carriageway drainage; formation/earthworks drainage; land drainage; and the diversion and culverting of ordinary watercourses.

1 EXISTING SITE DRAINAGE REGIME

1.1.1 The existing site, both along the proposed highway corridor and the wider affected catchments are predominantly rural, typical of upland-lowland transition topography found in the UK.

1.1.2 Desk-based sources[1] indicate that catchment annual rainfall totals are above average, but generally typical of the catchment typologies (1190-1390mm/year).

1.1.3 Multiple watercourses, ranging in size and discharge - from the larger main river classified Afon Gwyfrai and Afon Seiont, to the numerous small un-named natural watercourses and man-made ditches - cross the alignment of the proposed route.

2 HIGHWAY DRAINAGE STRATEGY

2.1 Surface Water Management Approach

2.1.1 In line with best-practice surface water management guidance, the following precepts have been used in the surface water drainage strategy for the A487:

- No increase in the rate of runoff from the site for rainfall events up to and including the 1% Annual Exceedance Probability (AEP) event (1 in 100 year) with an appropriate factor applied to allow for potential future climate change (30% increase in rainfall intensity/20% increase in fluvial flows).
- No significant increase in flooding to people and property elsewhere as a result of the scheme;
- Overland flows arising from exceedance of the design standard of the positive surface water drainage systems will be contained and managed within the confines of the site boundary.
- Site-specific ground investigations have determined that infiltration rates scheme-wide are very low and would preclude the use of infiltration as a sole means of surface water disposal. However, where groundwater levels permit, surface drainage features (i.e. ponds and channels which are at-grade or in cut) will be unlined to allow an element of infiltration during low-flow; or periods where antecedent conditions are relatively dry. Thus, within the context of the 'discharge hierarchy' approach to surface water disposal, the preferred method of discharge will be to surface watercourses. It is not anticipated that discharge to any surface water sewers will be required.

2.2 Mainline carriageway drainage

2.2.1 The proposed carriageway drainage strategy has been formulated to be, as far as possible, consistent along the entire route, varying only where site constraints dictate. The strategy can be summarised thus:

[1] FEH catchment database - CD-ROM v3.0

- Carriageway runoff will drain 'over the edge' to vegetated swales of scheme-standard dimensions (150mm deep, 1 in 5 side slopes);

- Swales will be designed to accommodate, without surcharge, a 100% AEP (1 in 1 year) rainfall event with 30% uplift in rainfall in intensity to accommodate future climate change. Swales will also be designed to ensure that lateral surcharge extents do not encroach onto the nearside running lane during a 20% AEP (1 in 5 year) plus 30% rainfall event in accordance with the requirements of HA37/97[2] and HA119/06[3];

- Initial swale runs at the head of catchments will have no underlying carrier drainage. However, once either of the hydraulic design thresholds referenced in the preceding bullet-point have been reached, an in-line outlet chamber (Ref. MCHW Highway Construction Detail F22) will be provided as an intermediate outfall point, discharging to a combined filter/carrier drain running directly beneath the remainder of the swale run. It is envisaged, that where required, the filter material of this under-drain will be extended such that it is contiguous with the adjacent carriageway sub-base, providing formation drainage – eliminating the requirement for a separate fin drain;

- Where on embankment, swales and attendant filter/carrier drains will (where required) be provided with a lining system to prevent infiltration into the underlying embankment earthwork. Where present in cut or at-grade, the viability of utilising infiltration will be assessed taking heed of local geotechnical and topographical conditions.

2.3 Viaduct drainage

2.3.1 The drainage of both the Afon Seiont and Afon Gwyrfai viaducts will be via combined kerb and drainage bridge-deck compatible units.

2.3.2 Hydraulic analysis indicates that both of the proposed viaduct decks can be drained without the use of intermediate outfall points, thus reducing the requirements for the provision of external carrier pipework attached to the bridge superstructure.

2.3.3 Combined kerb and drainage units will outfall into the carrier drain element of the system outlined in section 2.2.

2.4 Drainage provision at proposed roundabouts

2.4.1 Traditional kerb and gully systems will be used to drain runoff from gyratory carriageways and kerbed elements of approach and departure arms. Gully spacing will be designed to the requirements of HA102/00[4]. Where required (due to flat longitudinal gradients or the necessity to pass over culverts) combined kerb drainage systems will be utilised.

2.4.2 It is envisaged that a circumferential combined carrier/filter drain will be provided to roundabout islands as a means of preventing runoff onto the carriageway from the island and as a common carrier system for the island gullies.

2.4.3 Supplementary gullies will be placed immediately upstream of proposed pedestrian/cycle crossing points and at tangent points of splitter islands where flow concentration and subsequent discharge onto the adjacent carriageway is of concern.

---

[2] HMSO (1997) *HA37/97 Hydraulic Design of Road-edge Surface Water Channels*. Design Manual for Roads and Bridges, Volume 4, Section 2, Part 4.
[3] HMSO (2006) *HA119/06 Grassed Surface Water Channels for Highway Runoff*. Design Manual for Roads and Bridges, Volume 4, Section 2, Part 9.
[4] HMSO (2000) *HA102/00 Spacing of Road Gullies.* Design Manual for Roads and Bridges, Volume 4, Section 2, Part 3.

2.5 Attenuation ponds

2.5.1 Attenuation ponds will be provided for each of the carriageway drainage sub-catchments to mitigate for the increased rates and volume of runoff that will arise post-scheme construction. The attenuation strategy will comply with current UK best-practice guidelines[5], considering both discharge and volumetric criteria to the following hierarchy. Discharge rates for any return period event up to and including the 1% AEP (1 in 100 year) plus climate change, will be limited to the greenfield mean annual peak rate of runoff; and formal means of mitigating for the increase in discharge volume criteria will not be provided.

2.5.2 Flow control from the attenuation ponds will be provided in the form of a vortex flow control device. In order to provide an allowance for a potential failure/blockage of this device, or the requirement to route above design-event storms through the pond, a high-level overflow/embankment spillway, and appropriate erosion protection measures will be provided for controlled overtopping of each pond into an appropriate receptor.

2.5.3 The scheme runoff pollution prevention and control strategy is discussed further in section 4.5.1, but it is foreseen that the attenuation ponds would be provided with appropriate containment mechanisms (i.e. penstock outlets) to provide a means of mitigating any potential spillage. Low-level and chronic pollution issues will also be somewhat mitigated by the allowance for containment and treatment of 'first-flush' flows within a permanently wet sump area of the attenuation ponds or the use of pre-treatment chambers if the maintaining authority (North and Mid-Wales Trunk Road Agency [NMWTRA]) require that the pond remain dry as a maintenance preference.

2.5.4 Pond landforms will aim to reflect the overall character, shape and scale of the prevailing local topography. Geometric shapes and steep, uniform banks will be avoided. Typically side-slopes will be no steeper than 1 in 3 and allow for ease of access for future maintenance. The strategy assumes that all scheme attenuation ponds will be appropriately fenced – the use of vegetative barrier screening is not currently being considered.

2.6 Drainage interfaces at structures

2.6.1 At under-bridges and culvert crossings where insufficient cover exists to allow mainline carrier drainage systems through and over the interface, the carrier system will be terminated and routed to an attenuation pond.

2.6.2 At over-bridges, swale runs beneath these structures will be temporarily terminated up-grade, with the drainage continued through in a traditional carrier drain. Dependent on the final choice of potential bridge pier/abutment configurations, the introduction of lateral offsets to the carrier system to 'dog-leg' around pier foundations may be required.

2.7 Exceedance flow routes

2.7.1 In order to adhere to the requirements of HD45/096 (i.e. that the scheme should not increase flood risk to third-parties for events up to and including the 1 in 100 year event) consideration has been given to the nature of exceedance flow routes (i.e. those in excess of the nominal Design Manual for Roads and Bridges (DMRB)

[5] Kellagher (2012) *Preliminary rainfall runoff management for developers – R & D Technical Report W5-074/A/TR/1*. Defra/EA, Bristol. January 2012.

[6] HMSO (2009) *Road Drainage and the Water Environment.* Design Manual for Roads and Bridges, Volume 11, Section 3, Part 10.

standard of 20% AEP (1 in 5 years) and that these are contained within the site environs and managed appropriately.

2.7.2 It is proposed that exceedance routes are contained within the verge/hard-strip/nearside running lane and routed to intermediate outfall points. These flows will then be re-introduced into the positive drainage system, or routed directly to an attenuation pond.

3 LAND DRAINAGE STRATEGY

3.1.1 In line with the requirements of HD33/06[7], separate provision will be made to accommodate runoff from adjoining land where runoff is likely to flow towards the route corridor. This provision will take the form of cut-off ditches, designed to the requirements of HA106/04[8].

3.1.2 Cut-off ditches provided at the crest of cut-slopes will be lined to prevent the ingress of water into the slope. Those that are provided at the toe of embankments, or in natural ground will be left unlined (subject to ground conditions and groundwater levels).

3.1.3 The cut-off ditches will generally flow according to the natural topography but where undulating topography is encountered, piped filter drains will be used in lieu of open ditches. Land drainage elements will discharge to watercourses that cross the highway corridor, ensuring that there is no 'cross-transfer' of flows from sub-catchment to another sub-catchment.

4 CULVERTING STRATEGY

4.1 General

4.1.1 It should be noted that the requirements for the scheme culverting strategy for ordinary watercourses and minor main river crossings are not solely governed by the required hydraulic parameters. Constraints such as the minimum culvert dimensions acceptable to the maintaining authority and environmental factors are likely, for most of the culvert crossings, to ultimately provide the governing controls.

4.1.2 Piped culverts will be used as the preferred conduit with diameters standardised to 1.8m; 1.5m; 1.05m and 0.6m.

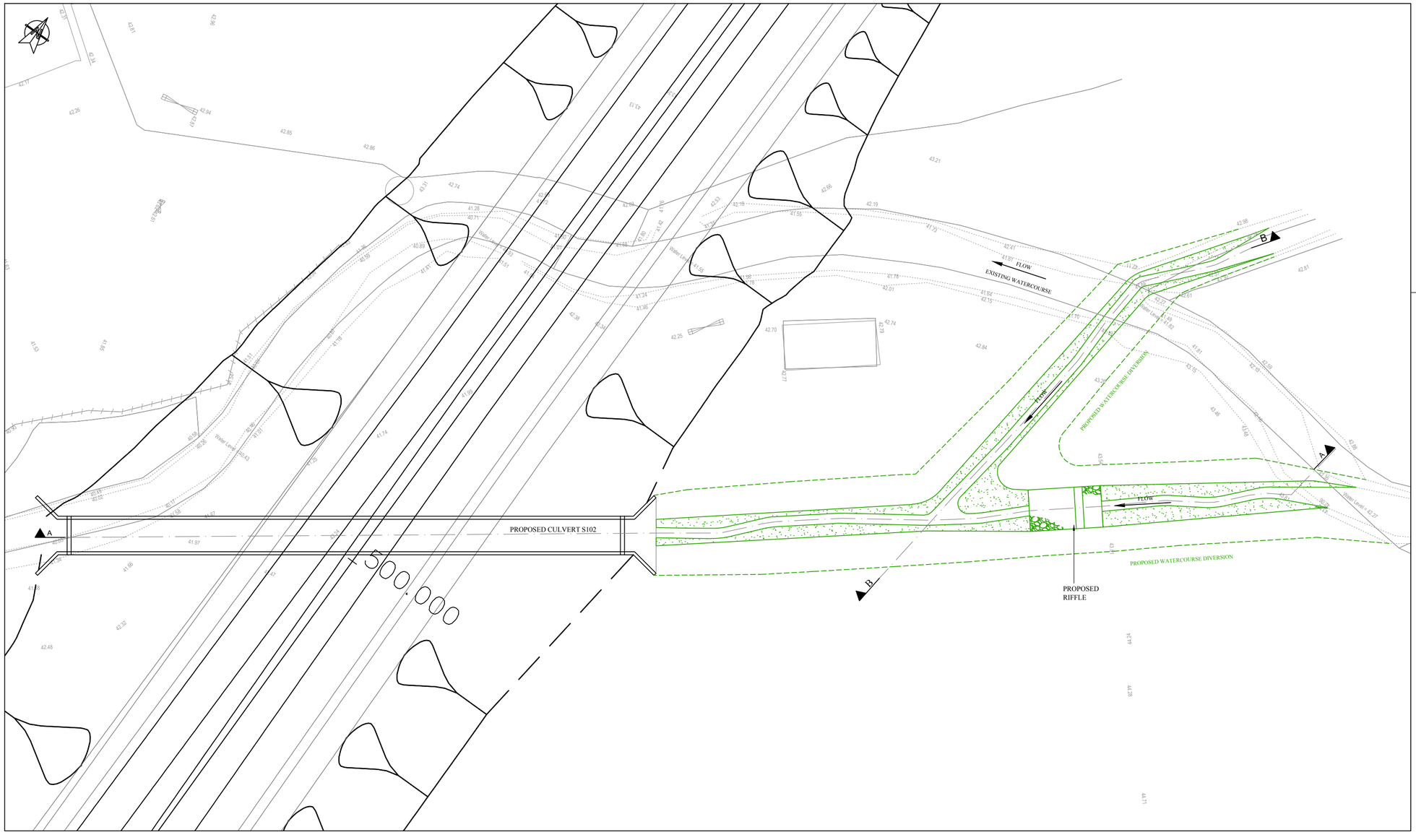
4.2 Freeboard requirements

4.2.1 Natural Resources Wales (NRW) require that all culvert crossings on main rivers be designed to accommodate a 1%AEP (1 in 100 year) plus 20% increase in peak flow (climate change allowance) event with a minimum 0.6m freeboard allowance.

4.2.2 Gwynedd County Council (GCC) require that all culvert crossings on ordinary watercourses be designed to accommodate a 1%AEP (1 in 100 year) plus 20% increase in peak flow (climate change allowance) event with a minimum 0.3m freeboard allowance.

[7] HMSO (2006) *Surface and Sub-Surface Drainage Systems for Highways.* Design Manual for Roads and Bridges, Volume 4, Section 2, Part 3.
[8] HMSO (2004) *Drainage of Runoff from Natural Catchments.* Design Manual for Roads and Bridges, Volume 4, Section 2, Part 1.

Appendix K.4 – Afon Rhyd Assessment



PLAN (EXTENTS OF DIVERTED WATERCOURSE SHOWN INDICATIVELY)

SCALE 1:200

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INLET HEADWALL PARAMETERS:

RECTANGULAR CONDUIT - TYPE A	
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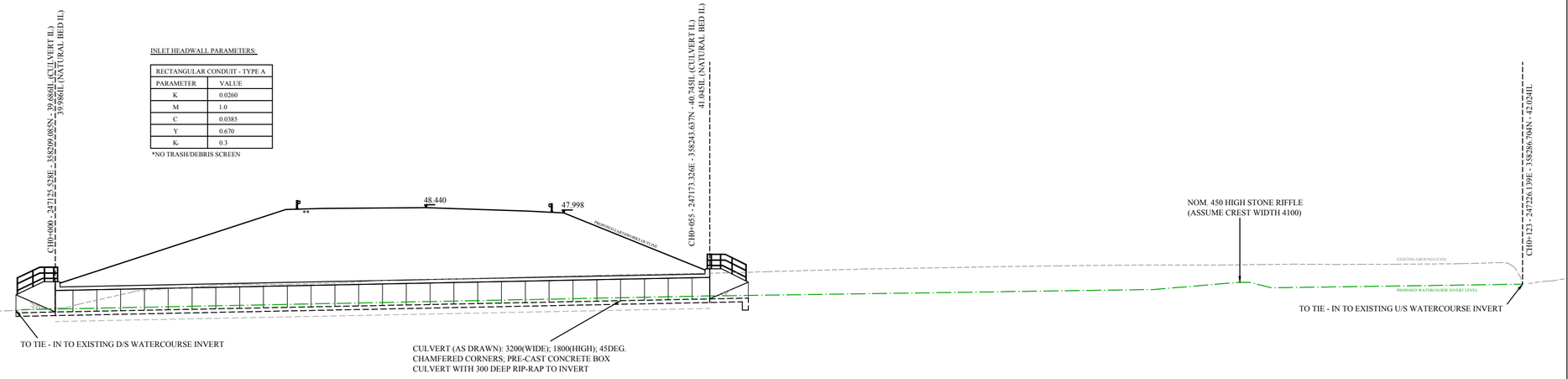
M	1.0
C	0.0385
Y	0.670
K_e	0.3

*NO TRASH/DEBRIS SCREEN



SECTION A-A

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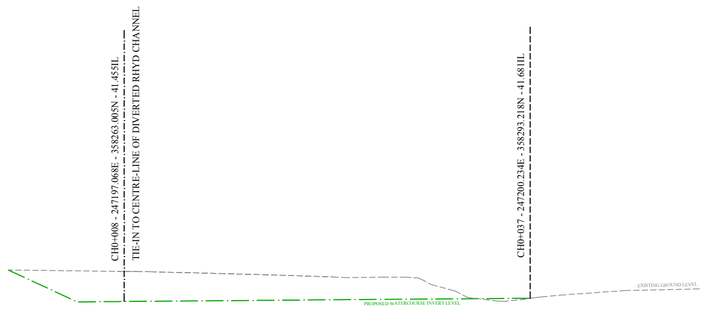

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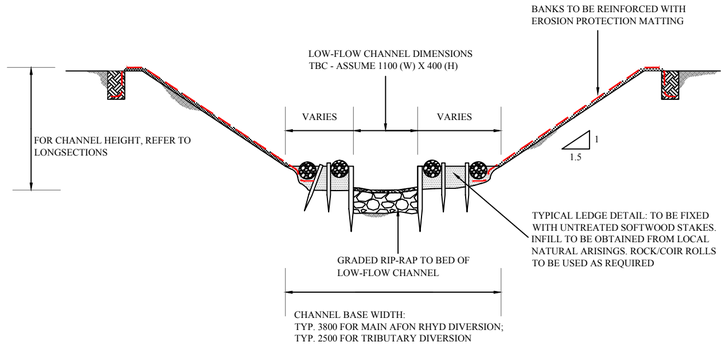

TYPICAL CROSS-SECTION

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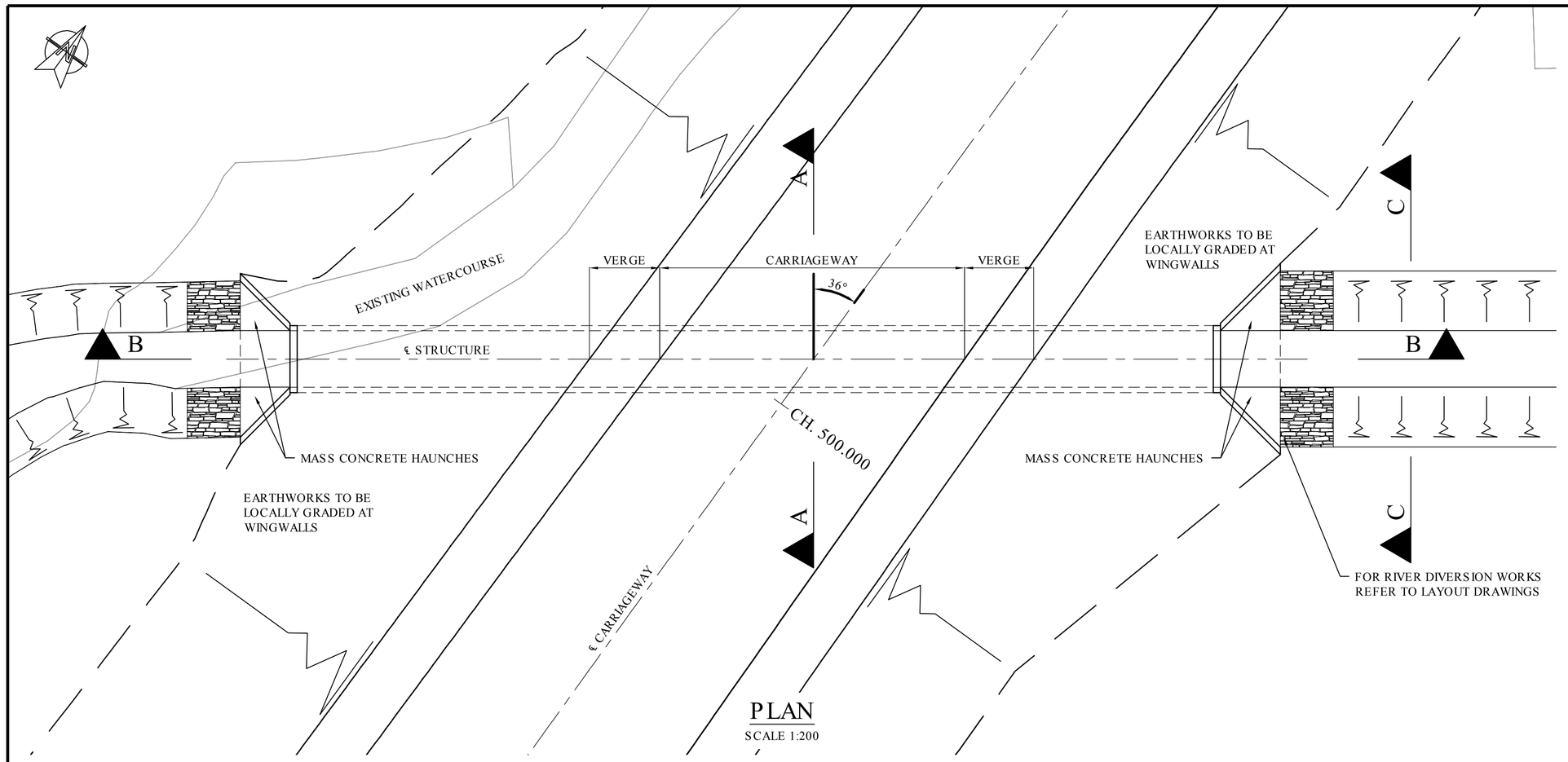

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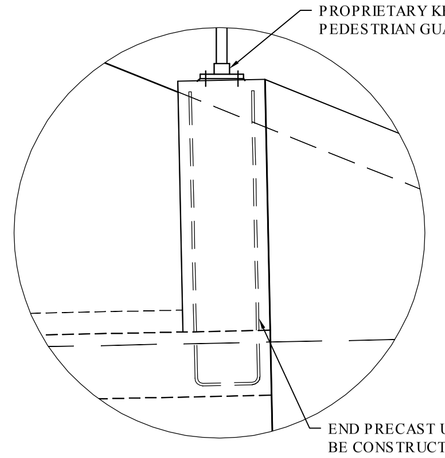

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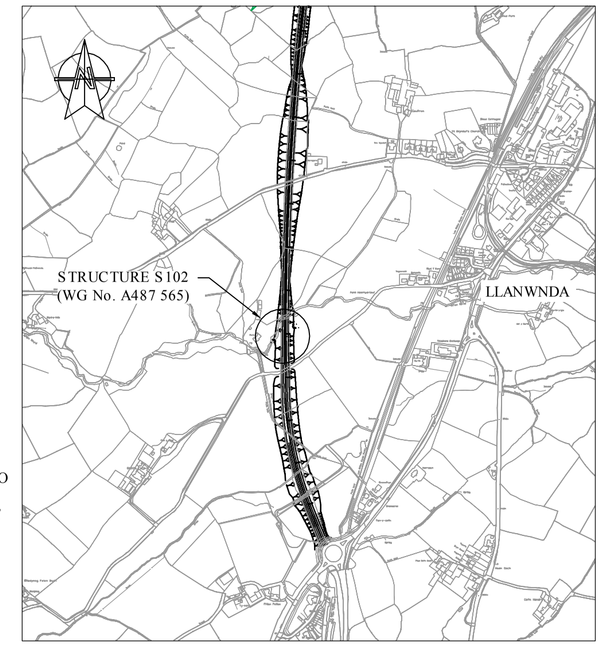

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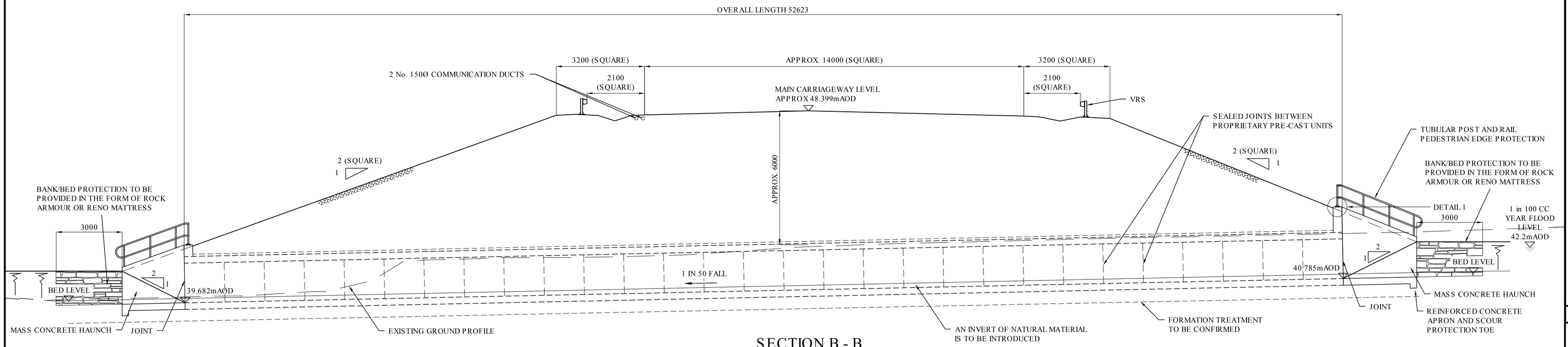

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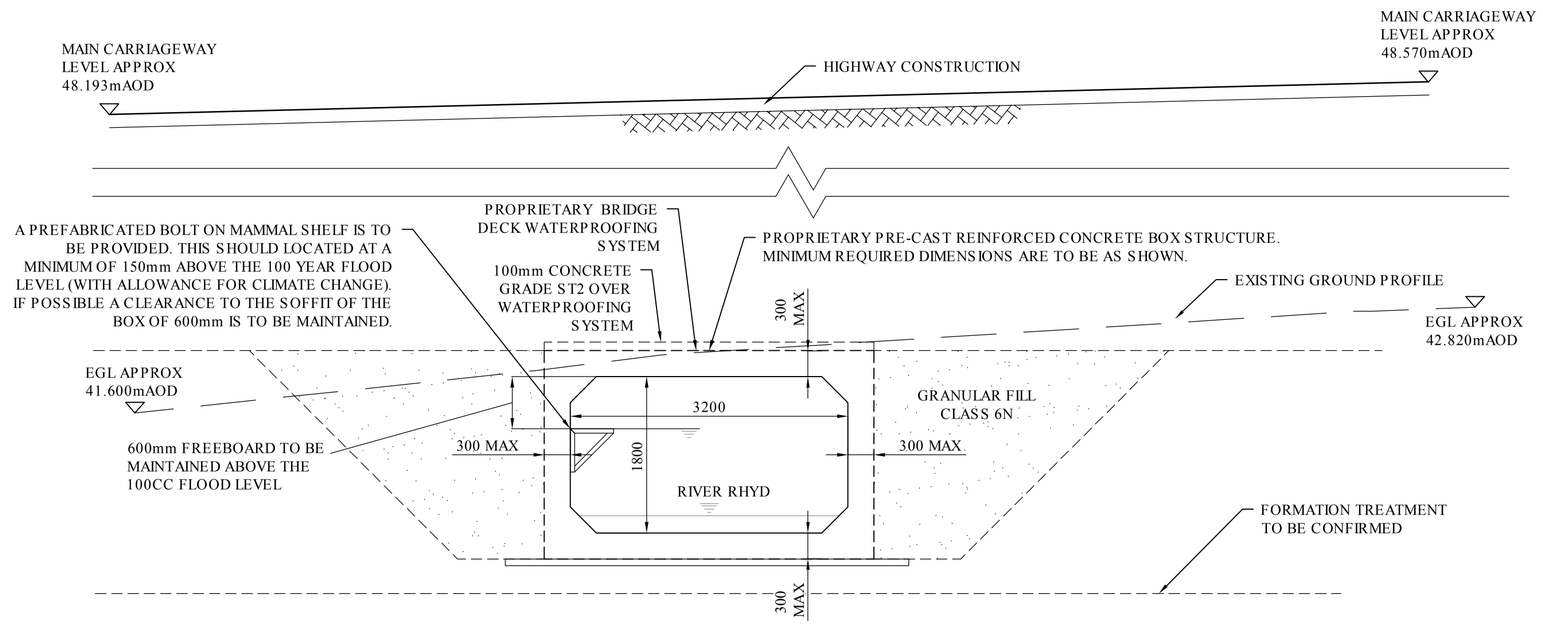

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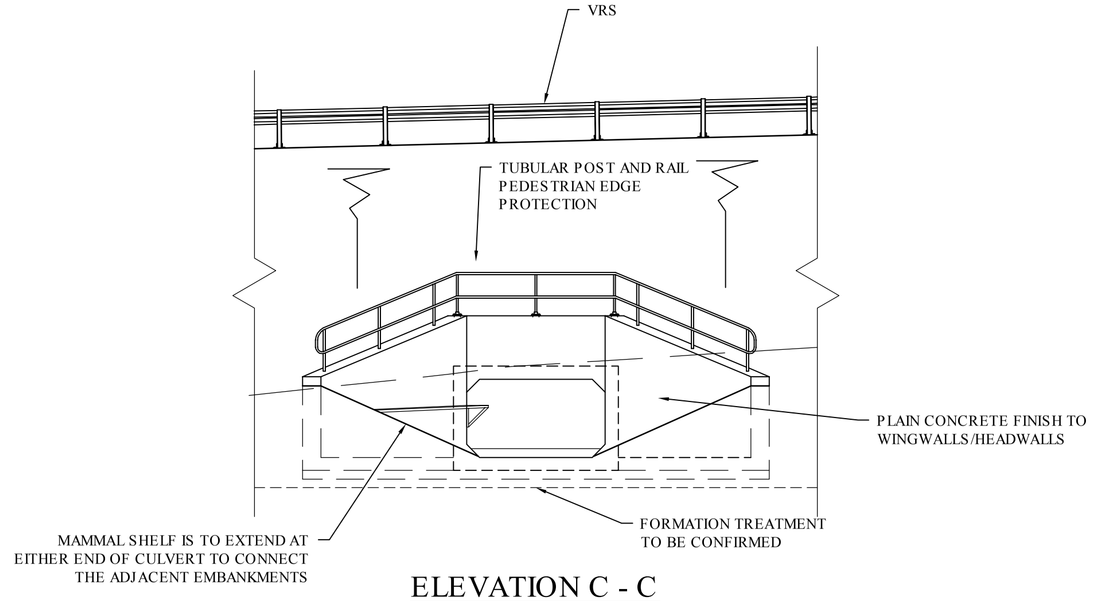

ELEVATION C - C
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S102 AFON RHYD CULVERT APPROVAL IN PRINCIPLE GENERAL ARRANGEMENT (WG No. A487 565)

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3513874-PB-SBR-102-DR-S-00011			P02

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TECHNICAL NOTE

Project :	A487 Caernarfon and Bontnewydd Bypass	**Project No. :**	w3172
Subject :	Hydraulic Modelling – Afon Rhyd Crossing	**Date :**	24/11/15
Author :	DH **Checker :** BY **Approver :** RCL	**Rev :**	B

Introduction

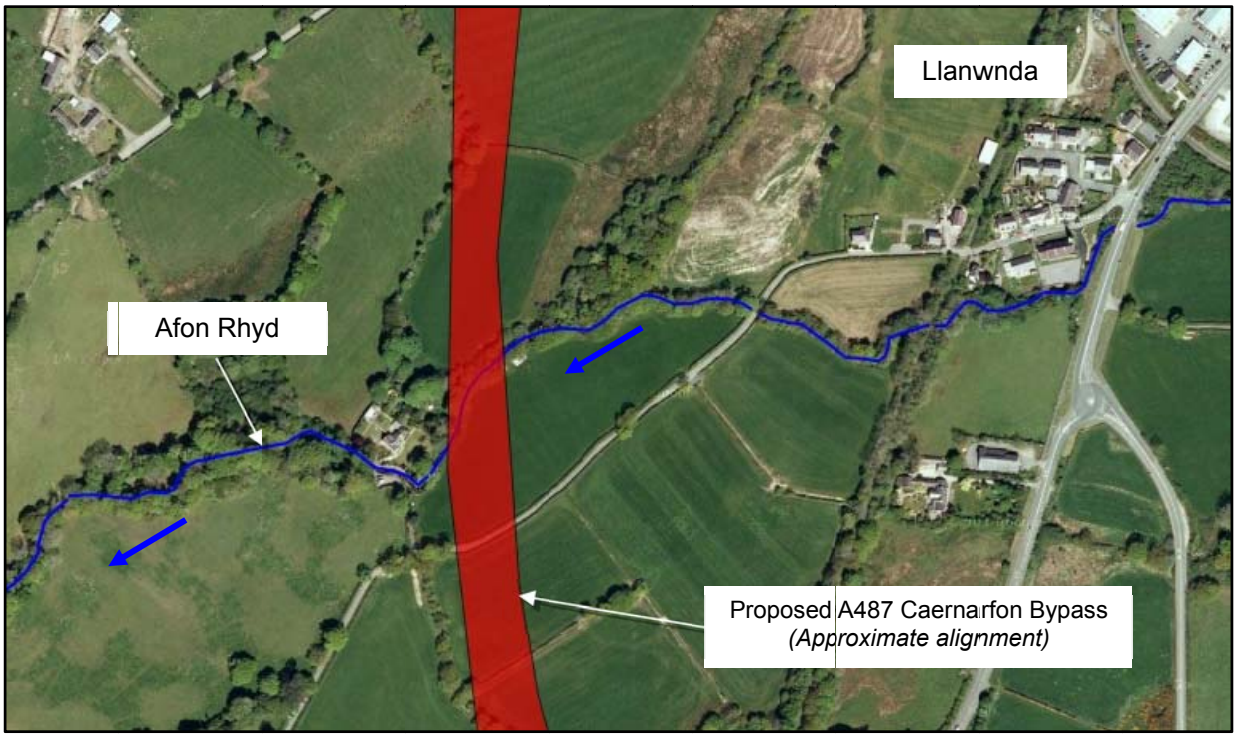
Waterco Consultants have been commissioned to undertake 1D/2D hydraulic modelling of the Afon Rhyd watercourse through Llanwnda, North Wales to investigate fluvial flood risk at the location of a proposed highway crossing as part of the planned A487 Caernarfon and Bontnewydd Bypass Project. The crossing proposals include construction of an earth embankment across the watercourse, associated channel realignment and concrete culvert installation. A location plan is provided in Appendix A with an extract provided in Figure 1 below. Details of the proposed structure / watercourse arrangement are given in Appendix B.

The objectives of the modelling study are to:

1) Assess existing (EXG) fluvial flood risk (depth, velocity, hazard and extent) at the proposed highway crossing location and throughout the wider floodplain
2) Investigate and quantify the impact of the proposed works (DEV1) on flood risk elsewhere (if any)

This hydraulic modelling technical note provides a basic overview of the methodology adopted, specific parameters used and simulation results for review / analysis.

Figure 1 – Location Plan



Methodology and Model Parameters

Natural Resources Wales (NRW) do not have any existing hydraulic model data available for this project. As such, a new 1D/2D ISIS-TUFLOW model of the Afon Rhyd has been constructed from surveyed channel cross sections and 1m LiDAR coverage. The latest versions of ISIS[1] and TUFLOW available at the start of the project have been used for all simulations; 3.7 and 2013-12 respectively.

1D ISIS Model

A 2.1km stretch of the Afon Rhyd has been modelled, starting 150m upstream of Rhos Isaf Road Bridge (bridge NGR 247960 358358) down to the Felinwnda road bridge (NGR 246487 358207). The Afon Rhyd generally flows east to west at this location. A model extent plot has been included in Appendix C for information.

Inflow hydrographs for the watercourses have been calculated and applied to the upstream boundary of the 1D model as a QT boundary. A detailed hydrological assessment was undertaken and is documented in the associated Hydrology Technical Note[2]. The final design flows and hydrographs were approved by NRW in July 2015.

The downstream boundary of the 1D network has been set using a normal depth boundary unit – a reasonable condition given the study area is situated above the nearest tidal range and is relatively steep at this location. Based on standard backwater effect equation below, the minimum required downstream distance of this boundary from the study area is ≈50m. The 1D model boundary has been established ≈900m downstream of the proposed viaduct – a sufficient distance to have minimal effect on flood levels in the area of interest. To verify this assumption, model sensitivity testing of the boundary location has been undertaken.

Backwater Effect Equation:

$$L = 0.7\,\frac{D}{s}$$

L = extension of backwater effects (m)
D = approximate channel depth (m)
s = channel slope (m/m)

$$L = 0.7 \times \frac{2.0}{39.49 - 13.88/892} = 48.8m \text{ (significantly less than the 900m to the area of interest)}$$

A total of twelve structures along the watercourse were surveyed. The majority of these structures are deemed to be hydraulically significant and have been included within the 1D ISIS network model – one culvert, one railway bridge, three road bridges, three site access bridges and one weir. A number of small, slender footbridge structures along the watercourse have not been included within the model due to their minimal deck depth and local topography which indicates they would be easily bypassed.

[1] Flood Modeller superseded ISIS 3.7 in late 2014 after the project was underway, but was primarily a GUI update. As such, the ISIS 3.7 engine has been used for consistency.
[2] Doc ref: w3172-150618-Hydrology Tech Note - Rhyd Rev A

The Glanrhyd Road bridge (model node RHYD_1228), located upstream of the proposed crossing location, is considered potentially critical to flooding at the site due to its close proximity. To investigate any increase in flood risk at the site associated with a significant blockage of this structure, a 67% blockage scenario has been simulated as a sensitivity test.

Manning's n coefficients have been used to represent the roughness of the channel and structures. Coefficients between 0.03$sm^{-1/3}$ and 0.055$sm^{-1/3}$ throughout the 1D network to represent the channel bed and banks based on Chow (1959)[3] and survey photography. To investigate the validity of this roughness value, sensitivity testing on this parameter has been performed with a significant variation in channel and floodplain roughness being considered i.e. +/-20% - discussed in detail below.

2D TUFLOW Model

The 1D network has been hydrodynamically linked to a new 2D TUFLOW domain, constructed from 1m LiDAR data – see model extent plot in Appendix A. The cell size of the 2D model has been set at 2m. This is sufficient to accurately represent flowpaths within the floodplain whilst maintaining reasonable simulation times.

Additional elevation points have been applied along the 1D/2D links in order to ensure that the elevations along the interface between the 1D network and 2D floodplain models are appropriately represented. The elevations of these additional points have been taken from the LiDAR data. Where possible, comparison of the LiDAR data against surveyed cross sections showed the bank levels are in good agreement.

OS MasterMap data has been used to classify land use and assign Manning's n roughness coefficients throughout the floodplain. The coefficients used are given in Table 1.

Table 1 – 2D Model Manning's n Roughness Coefficients

Land Use	Manning's n Roughness Coefficient ($sm^{-1/3}$)
Default	0.035
Buildings	1.0
Land (gardens / fields)	0.03 - 0.035
Woodland	0.06
Inland / tidal water	0.03
Roads, paths, rail	0.02

An automatic HQ relationship downstream boundary has been applied to the 2D domain with a slope of 20m/km based on the underlying LiDAR data.

[3] Chow, V.T., 1959, Open-channel hydraulics: New York, McGraw-Hill, 680 p.

Proposed Development Model (DEV1)

In addition to modelling the existing (EXG) fluvial flood risk at the site, a post-development model (DEV1) representing the proposed highway crossing works, watercourse realignment and culvert arrangement has been run to investigate and quantify any changes in flood risk elsewhere due to the development. Details of the proposed structure / watercourse arrangement are given in Appendix B.

The proposed arrangement includes realignment of a 150m stretch of the Afon Rhyd, which is to be culverted beneath the new carriageway. The abandoned section of the existing channel will be filled in. The cross section of the diverted channel is to be trapezoidal, approximately 1.5m deep and with a similar cross sectional area to the existing channel.

The proposed carriageway underpass utilises a 3.2m wide by 1.8m high concrete box culvert, the lower 300mm being filled with rip-rap leaving a 1.5m high opening.

Primary Simulations

In order to fully investigate the fluvial flooding mechanisms through the study area, a range of fluvial events have been simulated for both the existing (EXG) and development (DEV1) scenarios – namely the 50% (Q2), 20% (Q5), 10% (Q10), 5% (Q20), 1% (Q100) and 0.1% (Q1000) annual exceedance probability (AEP) events. The effect of future climate change has also been investigated during the 1% AEP event as a 20% increase in flows. The complete list of events is summarised in Table 2.

Table 2 – Simulation Summary

Modelled Scenario	Annual Exceedance Probability (AEP)	Return Period
EXG *(Existing site arrangement)*	50%	Q2
	20%	Q5
	10%	Q10
	5%	Q20
	1%	Q100
	1% + CC	Q100CC
	0.1%	Q1000
DEV1 *(Including proposed crossing)*	50%	Q2
	20%	Q5
	10%	Q10
	5%	Q20
	1%	Q100
	1% + CC	Q100CC
	0.1%	Q1000

Model Sensitivity Testing

In the absence of available calibration data, increased significance has been placed on sensitivity testing to improve confidence in the model outputs and assess the sensitivity of the model parameters. A total of five sensitivity tests have been carried out (ST1-5) with respect to the 1% AEP + CC fluvial event.

Sensitivity tests “ST1” and “ST2” investigate variations (+/- 20%) of Manning’s roughness coefficients in both the channel and across the floodplain.

Sensitivity tests “ST3” and “ST4” investigate a +/-20% variation in the slope curve used in both the downstream boundary of the 1D model and 2D domain.

Sensitivity test “ST5” investigates a 67% blockage of Glanrhyd Road bridge (RHYD_1228) located upstream of the proposed bypass road location.

To enable an assessment of overall sensitivity to flows at the study site, the model has been tested for a wide range of fluvial events from the 50% AEP event to the 0.1% AEP. Confidence in the approved watercourse inflows is discussed in the associated Hydrology Technical Note.

Simulation Results

Maximum flood depth, velocity and flood hazard mapping has been provided for each simulation, EXG and DEV1 in Appendix D. For additional information, calculated maximum water levels for all simulations have been extracted from each 1D model node, tabulated and compared in Appendix E.

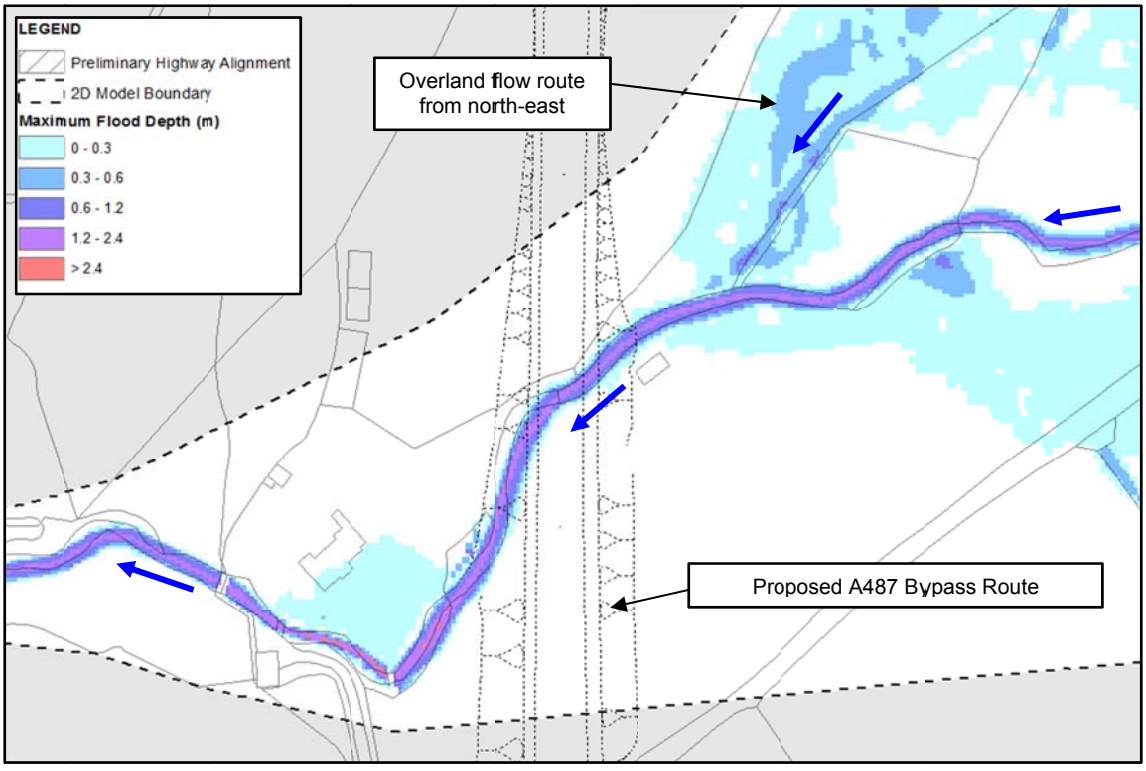
Flood hazard ratings have been calculated in accordance with DEFRA document 'FD2320: Flood Risks to People' and EA guidance document 'Supplementary Note on Flood Hazard Ratings and Thresholds'.

EXG Simulations

During all events up to and including the 1% AEP + CC event, water is shown to remain in channel at the location of the proposed crossing. Model outputs show the Afon Rhyd to spill out of bank approximately 800m upstream of the development site at Rhos Isaf Road Bridge, leading to a shallow depth flow route along the railway line running through Llanwnda. Although this overland flow affects areas to the north-east of the site, the proposed crossing location area remains unaffected with this spill water re-entering the Afon Rhyd upstream of the works.

During the 0.1% AEP event a small portion of the site at the proposed carriageway location immediately adjacent to the watercourse is affected by shallow depth flooding with maximum flood depth values generally less than 50mm. An extract of the 0.1% AEP EXG simulation flood depth map is given in Figure 2 for information. The maximum water level at the site (model node RHYD_1018i) during this event is 42.0m AOD. The maximum velocity and flood hazard rating (FD2320) are both low (velocity <0.15m/s).

Figure 2 – Maximum flood depth - 0.1% AEP fluvial event (existing site layout)



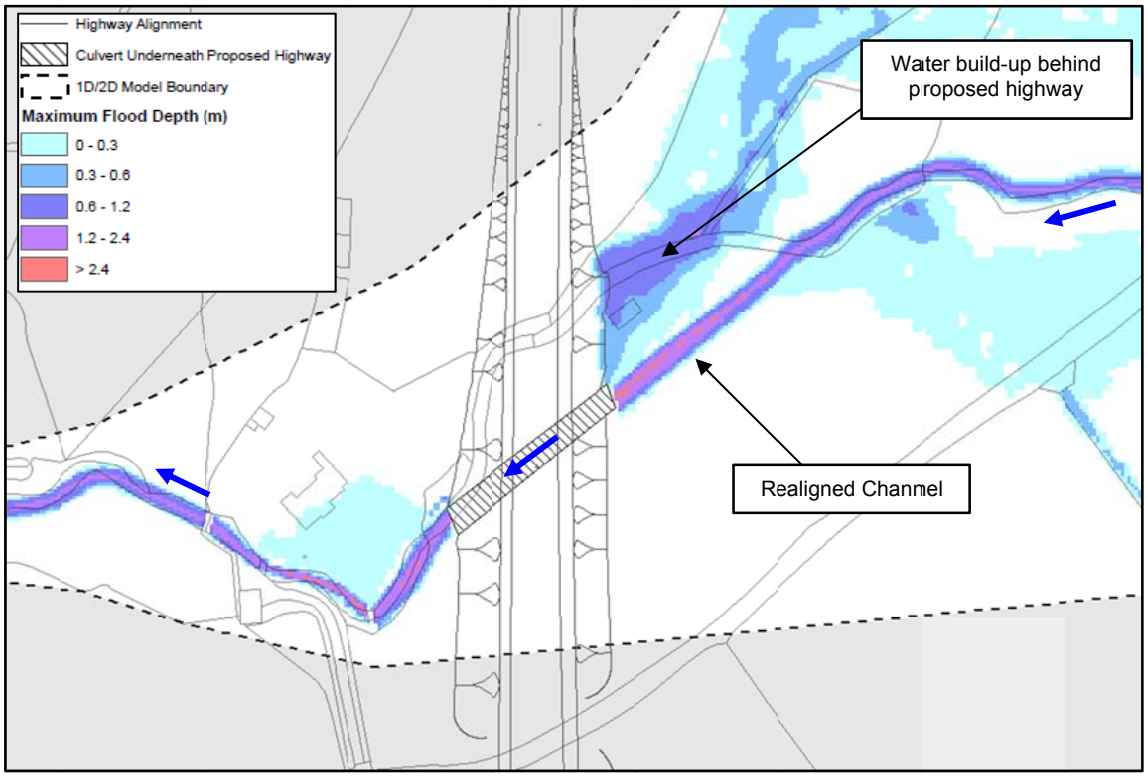
DEV1 Simulations

The potential impact of the proposed development on flood risk elsewhere has been quantified by comparing the results of the existing (EXG) site layout simulations with the proposed (DEV1). To provide a detailed assessment of the relative changes in flood depths throughout the floodplain, a series of water level difference maps comparing the pre- and post-development maximum water levels have been created and are included in the DEV1 section of Appendix D for information.

The generated DEV1 flood maps show that change to flood risk in the wider floodplain is minimal for all events. Whilst there are localised variations, both increases and decreases to flood depths, immediately upstream of the proposed crossing, they are generally confined to the work area. The significance of these variations increases with the severity of the considered fluvial event.

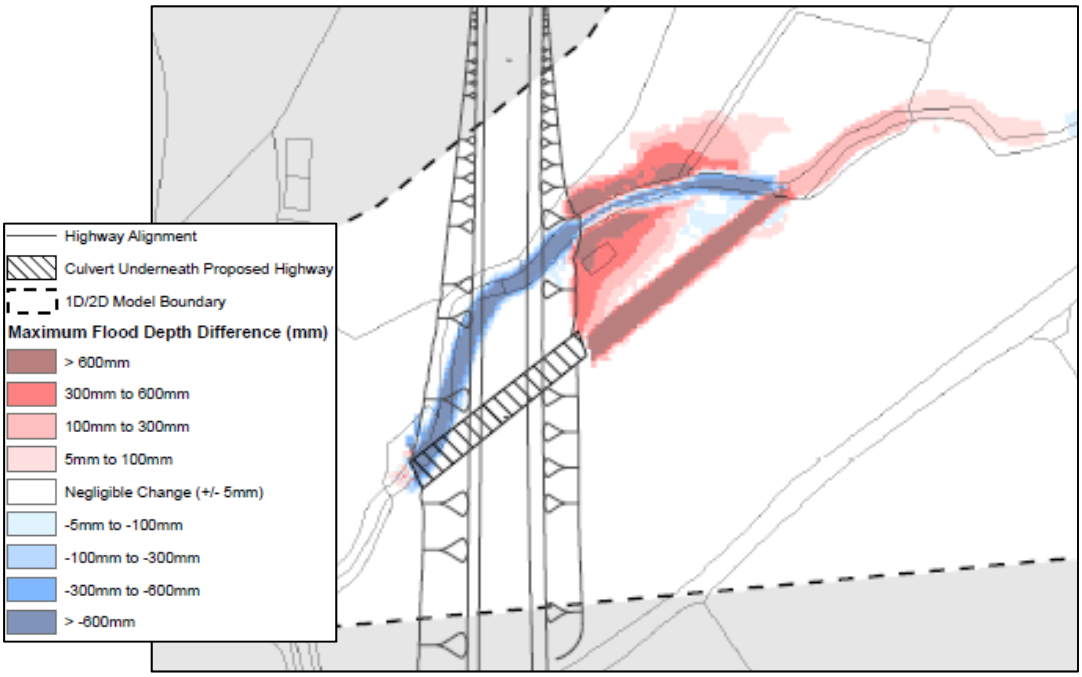
For all events simulated, the proposed channel realignment and culvert perform well, containing the majority of flood water in channel up to and including the 0.1% AEP event. Water levels at the location of existing channel infill are shown to experience a relative increase as water builds up behind the highway embankment before continuing south to converge with the newly realigned channel and pass through the proposed box culvert. An extract of the 0.1% AEP DEV1 simulation flood depth map is given in Figure 3 for information.

Figure 3 – Maximum flood depth - 0.1% AEP fluvial event (post-development site layout)



During the 0.1% (Q1000) AEP event, the changes in relative flood depth arising as a consequence of the proposed works reach +1m (43.39m AOD) immediately upstream of the works but are restricted to a small area local to the channel profiling works and the site of the old channel. An extract of the 0.1% AEP Maximum Depth Difference map is provided in Figure 4 for reference. Variations in water levels throughout the extended floodplain, including downstream of the proposed works are negligible.

Figure 4 – 0.1% (Q1000) AEP Maximum Depth Difference Map Extract



To further investigate the impact of the proposals on flood risk elsewhere, discharge data downstream of the proposed crossing has been extracted from the EXG and DEV1 simulations to determine any variation in flow arising as a result of the development. Data taken from 1D model node RHYD_672 shows the proposals have negligible effect on downstream flows. At this location the flow is contained entirely within channel providing a good point for comparison. A summary of the relative peak flows and differences is presented in Table 3.

Table 3 – Peak Flow Comparison at RHYD_672

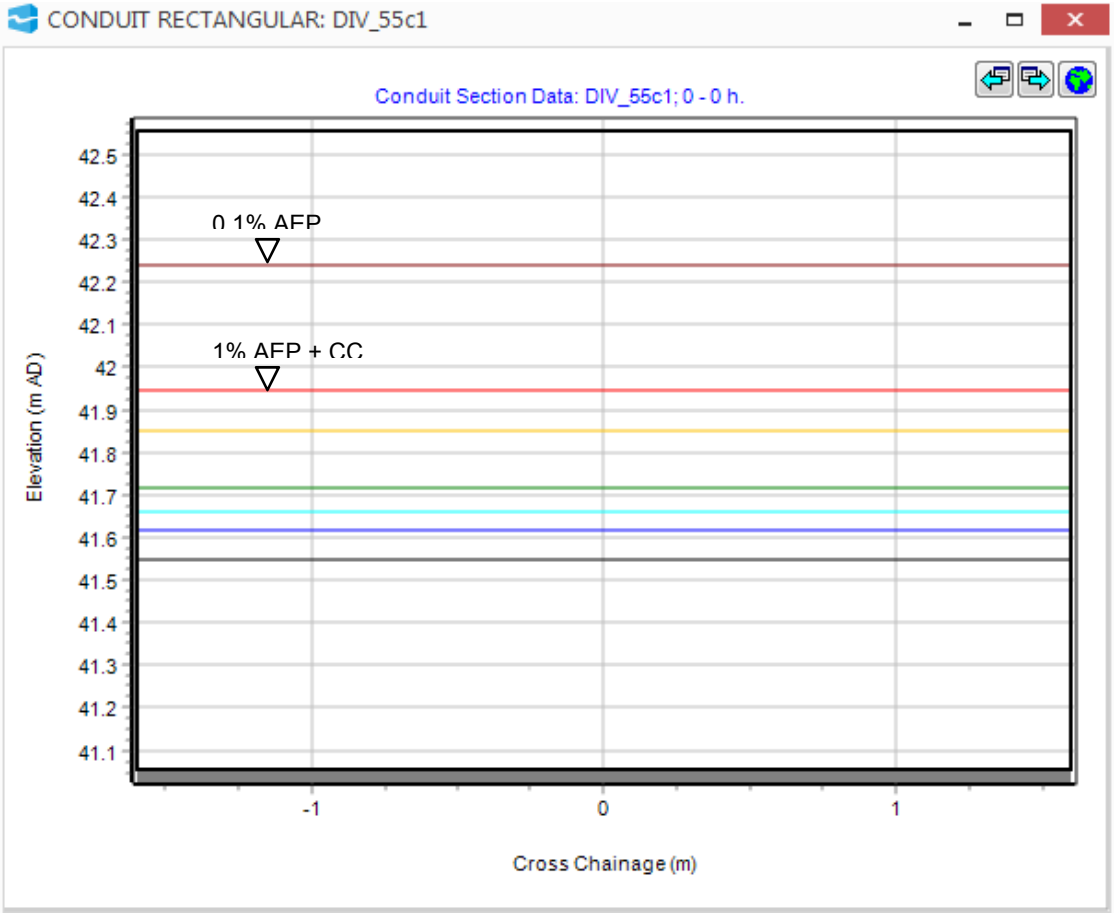
Rhyd Fluvial Event (AEP)	EXG Peak Flow (m^3/s)	DEV1 Peak Flow (m^3/s)	Difference (+/-m^3/s)	Difference (%)
1%	7.733	7.736	+0.003	+0.04
1%+CC	9.228	9.241	+0.013	+0.14
0.1%	14.229	14.355	+0.126	+0.88

Peak water level data extracted from the upstream face of the proposed box culvert shows the structure opening to have a clearance freeboard in excess of 600mm for all events up to and including the 1% AEP + CC event. During the 0.1% AEP the freeboard is 315mm. The freeboard allowances achieved by the proposed arrangement significantly reduce the probability of structure blockage. Tabulated freeboard data is given in Table 4 with a graphical representation presented in Figure 5.

Table 4 – Simulation Summary

Rhyd Fluvial Event (AEP)	Max WL at Culvert Entrance (mAOD)	Freeboard (mm)
50%	41.546	1009
20%	41.617	938
10%	41.658	897
5%	41.717	838
1%	41.851	704
1%+CC	41.945	610
0.1%	42.240	315

Figure 5 – 0.1% (Q1000) AEP Maximum Depth Difference Map Extract



Model Sensitivity

The results of sensitivity tests ST1 and ST2 show that varying the Manning's n coefficients within the channel and floodplain does not have a significant effect on maximum water levels throughout the model (differences of water levels generally +/-150mm). As such the roughness coefficients used (channel and floodplain) are considered reasonable.

The results of sensitivity tests ST3 and ST4 show that varying the slope value used within the downstream boundary calculations (both 1D and 2D) does not have any significant effect on the maximum water levels throughout the majority of the model. Water levels local to the boundary only are shown to vary and rise by a maximum of 55mm (during ST4). Water level increases propagate just some 100m upstream; still 840m downstream of the proposed bypass road location.

Sensitivity test ST5 simulation results show that 67% blockage to Glanrhyd Road Bridge has a significant effect on flow paths upstream of the site location with both maximum depth and extent increasing relative to the unblocked scenario. Model outputs show the blockage to cause localised overtopping of the watercourse banks upstream of the bridge, leading to overland flow through downstream areas towards the proposed carriageway location. Maximum flood depths rise to 800mm in places. The flood extent and in-channel levels return to "normal" at the carriageway location.

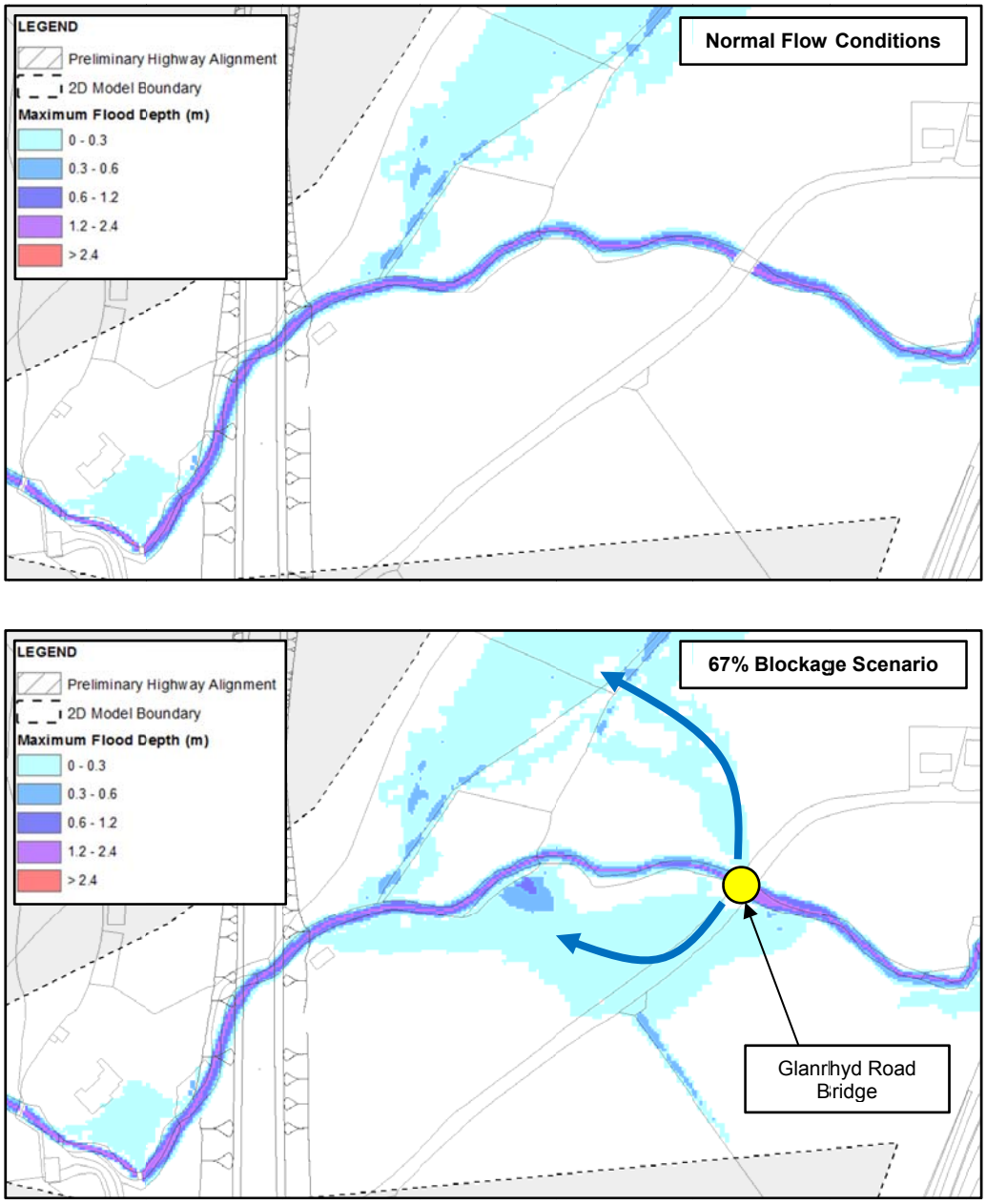
To enable an assessment of overall model sensitivity to flows at the study site, the model was tested for a wide range of fluvial events. Although the relative water levels associated with larger events increase as expected, analysis of the model outputs show the model is not significantly sensitive to flow. This can be partially attributed to the relatively steep nature of the watercourse with flow being largely contained within channel, particularly downstream of the site. At the location of the proposed crossing the range of maximum water level (Appendix E) between the 5% AEP and 0.1% AEP events is <400mm. Confidence in the approved watercourse inflows is discussed in the associated Hydrology Technical Note.

Model Stability

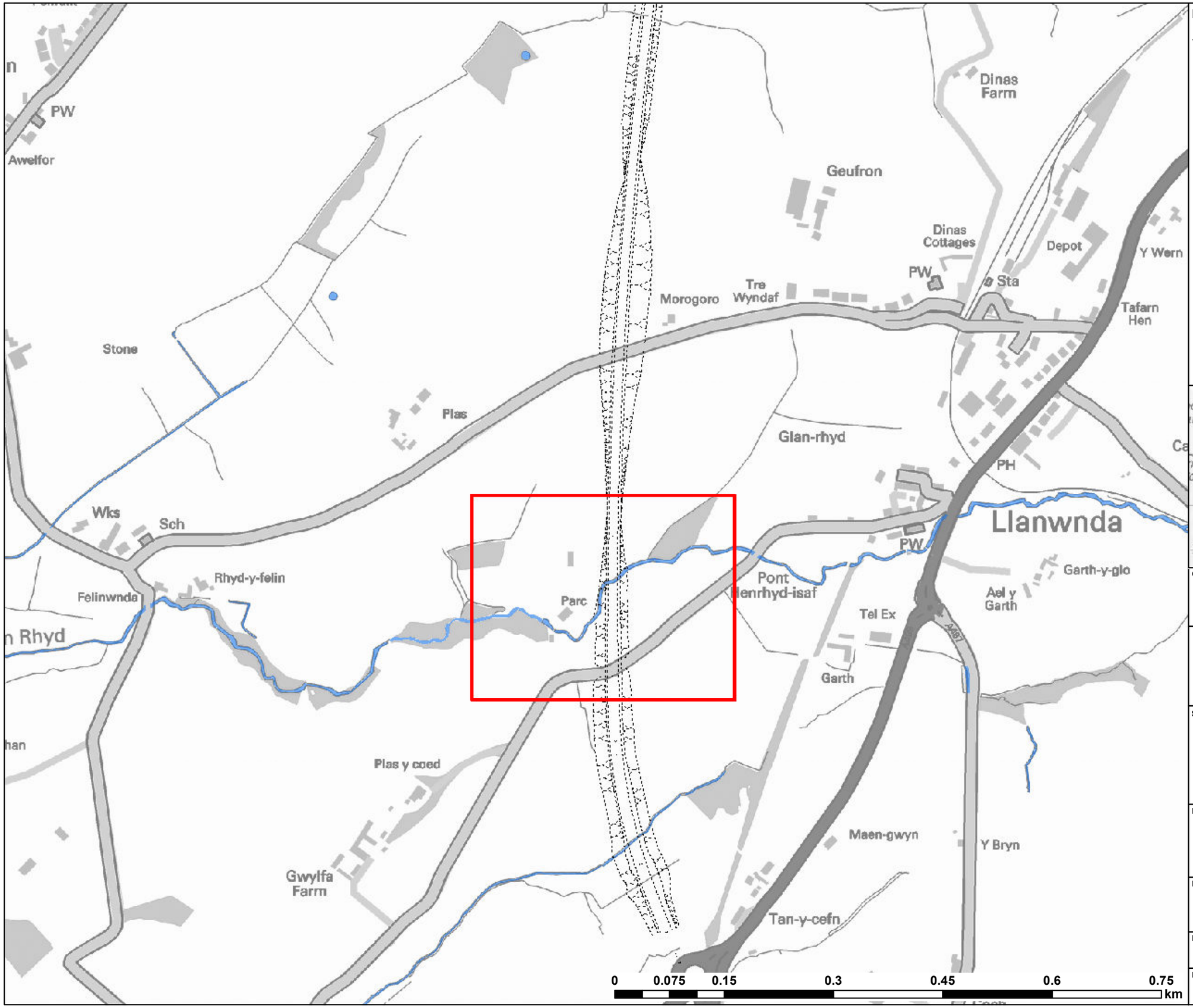
Stability of all simulations has been reviewed to assess confidence in model outputs. For all events and scenarios considered model stability is good with no significant observed peculiarities or stability issues noted. More detail is provided in the associated model log.

Stage and flow profiles for all model nodes, including structures, have been reviewed for all events and are smooth. Analysis of the 1D and 2D log files indicate no convergence issues or negative depth recorded. The average cumulative mass balance of the models is <0.6 % indicating good overall stability.

Figure 6 – Max Flood Depth Comparison - 1% AEP + CC fluvial event; 67% blockage Glanrhyd Rd Bridge

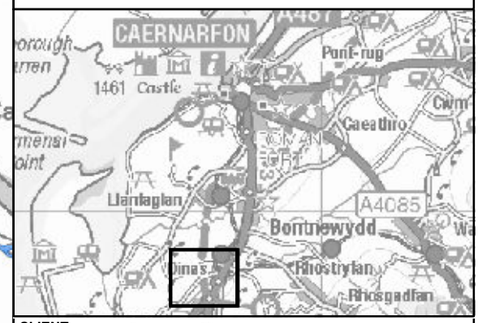


Appendix A – Location Map



LEGEND

------- Highway Alignment



CLIENT:

Llywodraeth Cymru
Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

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AFON RHYD CROSSING

PLOT TITLE:

LOCATION PLAN

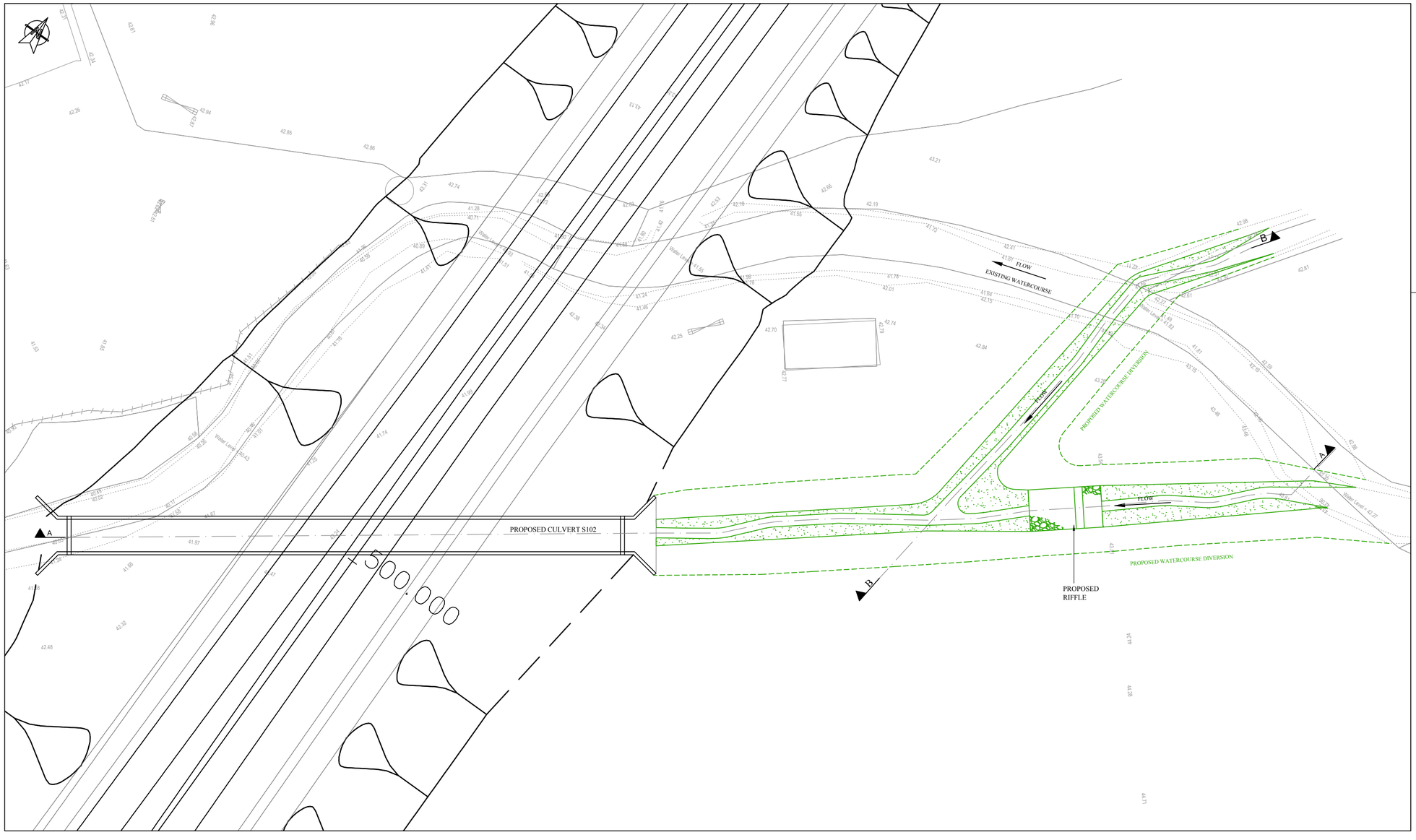
PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:5,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_LOCATION_PLAN	-

Appendix B – Proposed Crossing Details



PLAN (EXTENTS OF DIVERTED WATERCOURSE SHOWN INDICATIVELY)

SCALE 1:200

DRAFT TO INFORM INITIAL HYDRAULIC MODELLING ONLY

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Container Number: 3513874-PB-05-102-SK-D-00002

Revision: P01.1

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INLET HEADWALL PARAMETERS:

RECTANGULAR CONDUIT - TYPE A	
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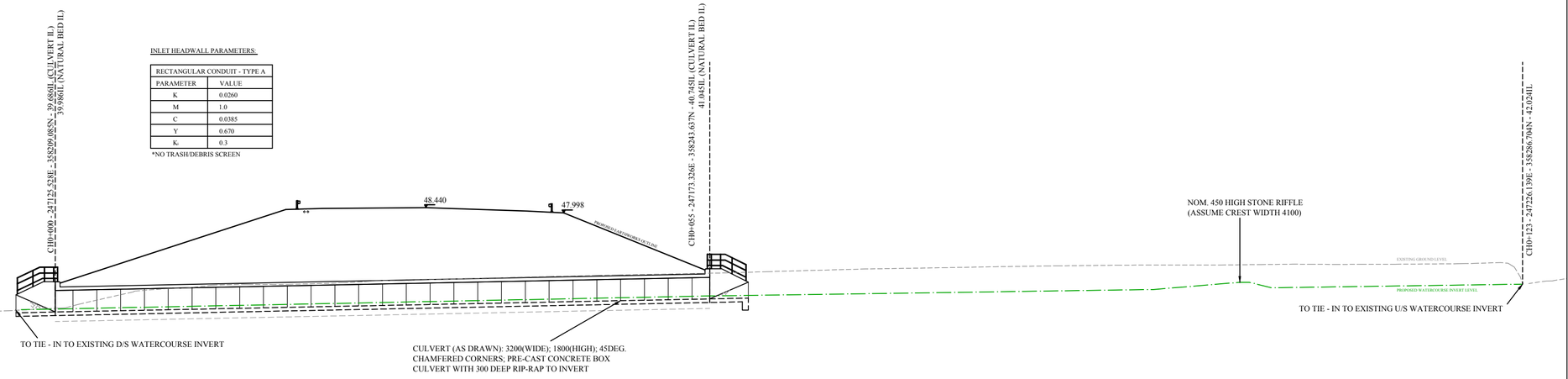
M	1.0
C	0.0385
Y	0.670
K_e	0.3

*NO TRASH/DEBRIS SCREEN



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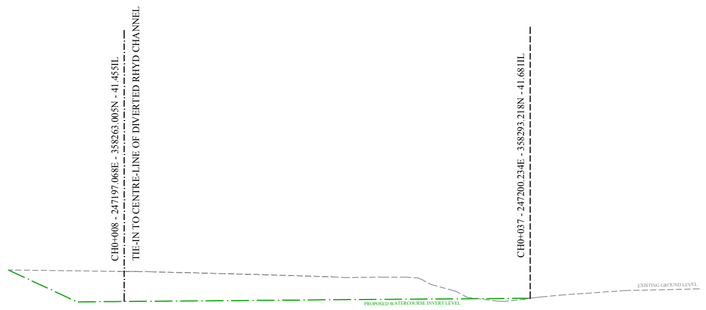

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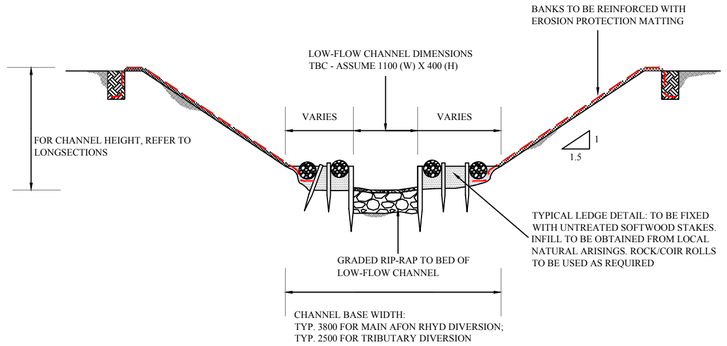

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Revision: P01.1

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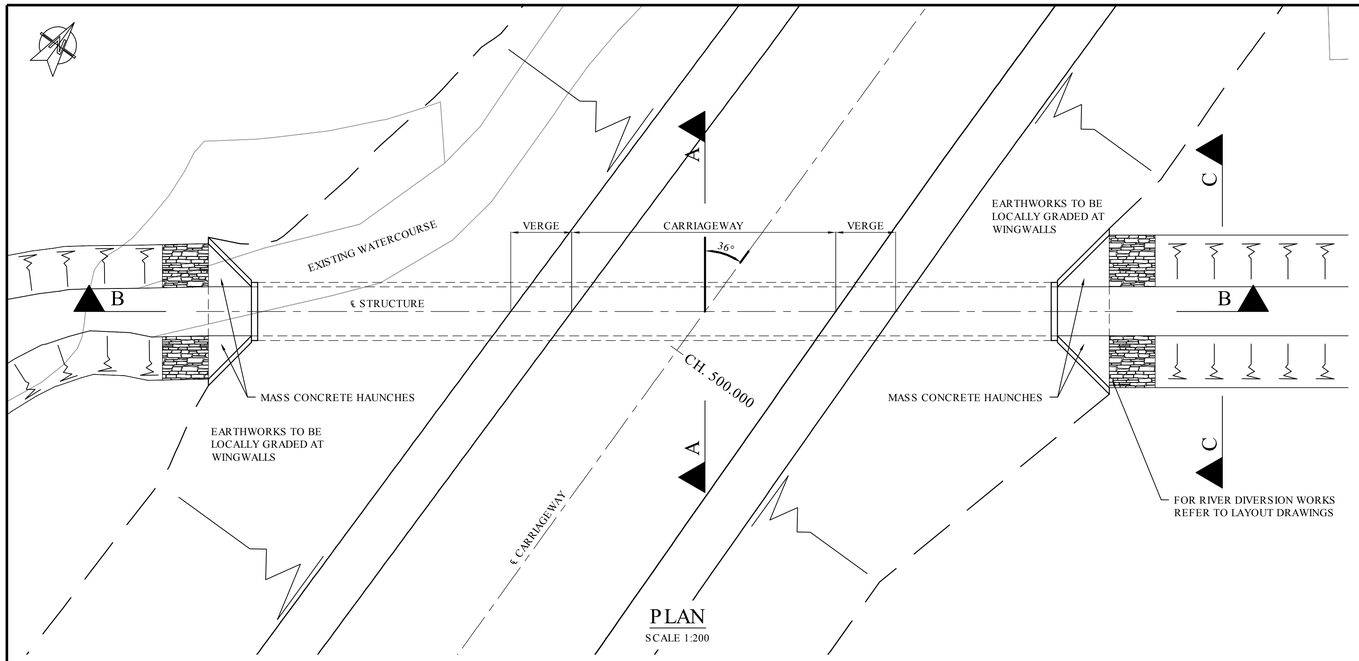

PLAN
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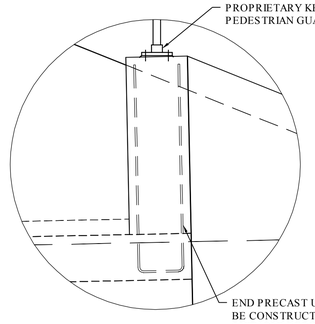

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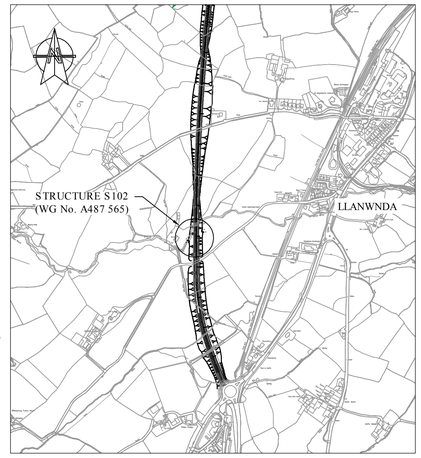

LOCATION PLAN
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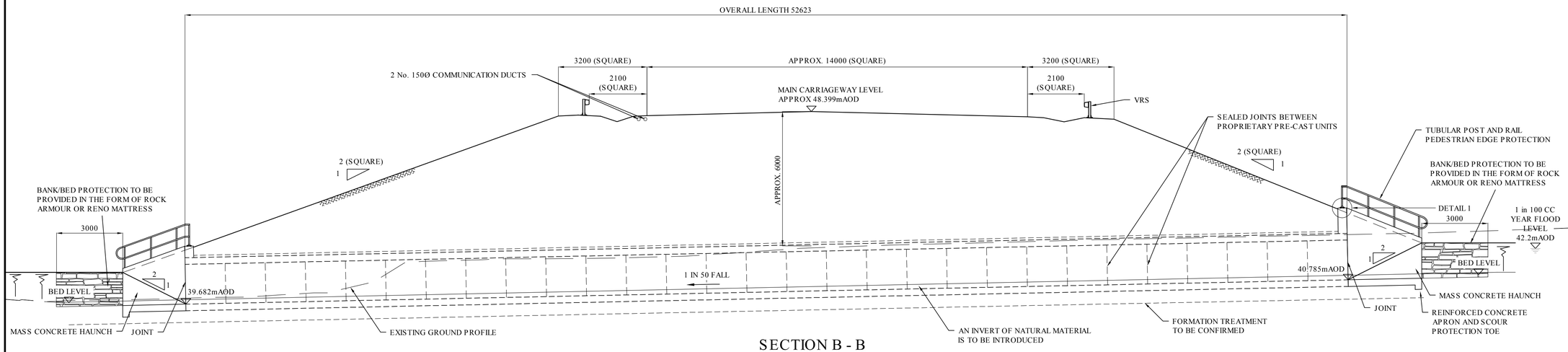

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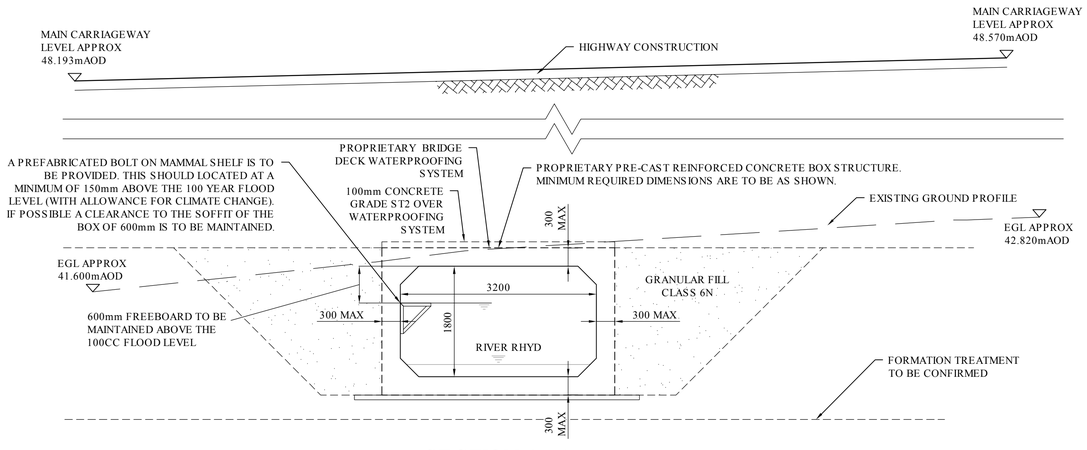

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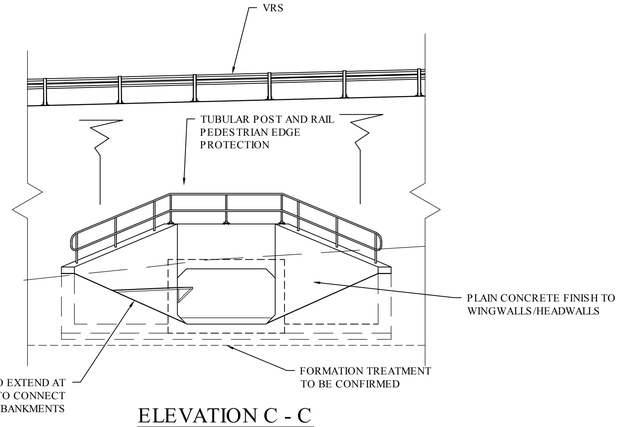

ELEVATION C - C
SCALE 1:100

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Site/Project:

A487 CAERNARFON TO BONTNEWYDD BYPASS

Title:

S102 AFON RHYD CULVERT APPROVAL IN PRINCIPLE GENERAL ARRANGEMENT (WG No. A487 565)

Drawn: D.Parslow		Checked: S.Spence	
Designed: A GROVES		Approved: S.Spence	
Date: 17/08/15	Scale: AS SHOWN	A1	Sheet:
Container Number:			Revision:
3513874-PB-SBR-102-DR-S-00011			P02

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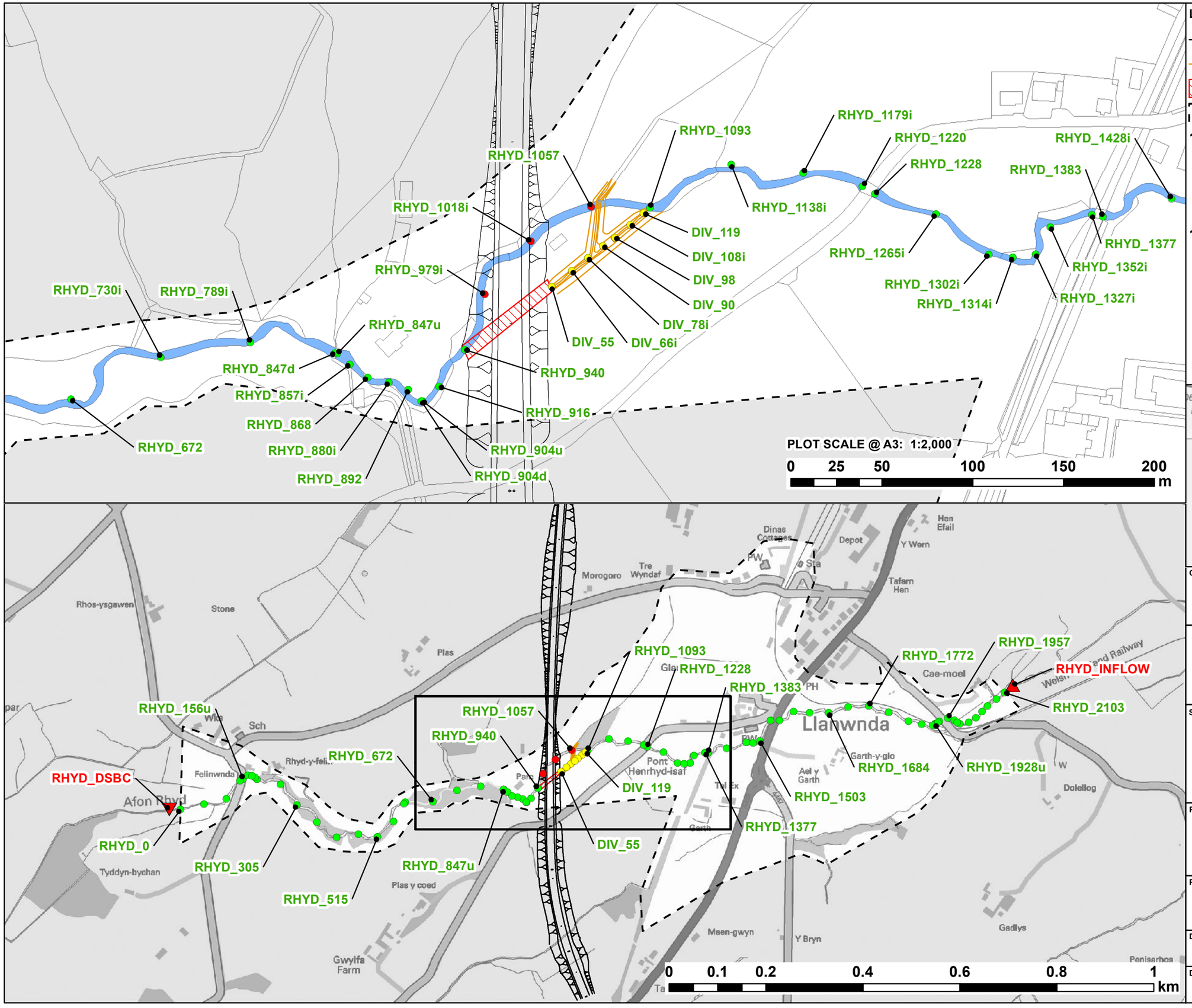
Appendix C – 1D/2D Model Extent



LEGEND

- Proposed Highway Alignment
- Proposed Channel Diversion
- Proposed Culvert Location
- 1D/2D Model Extent

1D Model Nodes

- Channel to be Filled
- Proposed Channel Diversion
- No Change

1D Model Boundaries

- Flow-Time (QT)
- Flow-Level (QH)

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

PLOT TITLE:

1D/2D MODEL EXTENT

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:7,500 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
20/11/2015	w3172-RHYD_Model_Extent	A

Appendix D – Flood Mapping

Existing Site Arrangement (EXG)

AREA OF INTEREST

PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tafarn Hen
Tre Wyndaf
PW
Sta
Stone
Plas
Glan-rhyd
Cae-moel
PH
Wks
Sch
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
Llanwnda
Garth-y-glo
Ael y Garth
Tel Ex
Garth
A487
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

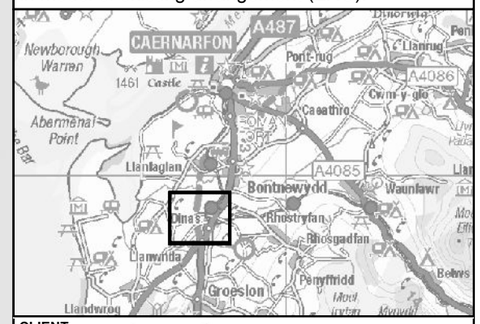
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included in model of existing arrangement (EXG).



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waterco consultants

SCHEME:
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AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD DEPTH
50% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q2_EXG_D	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tre Wyndaf
Tafarn Hen
Stone
Plas
Glan-rhyd
Cae-moel
Llanwnda
Wks
Sch
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
Garth-y-glo
Ael y Garth
Tel Ex
Garth
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

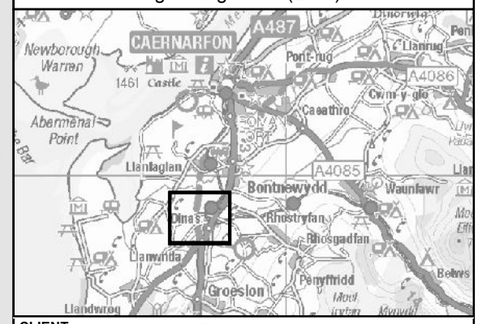
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT:
Llywodraeth Cymru
Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD DEPTH
20% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q5_EXG_D	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tafarn Hen
Tre Wyndaf
PW
Sta
Stone
Plas
Glan-rhyd
Cae-moel
PH
Wks
Sch
Llanwnda
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
Garth-y-glo
Ael y Garth
Tel Ex
Garth
A487
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

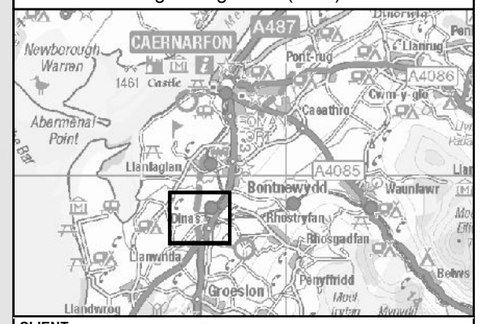
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD DEPTH
10% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q10_EXG_D	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tafarn Hen
Tre Wyndaf
PW
Sta
Stone
Plas
Glan-rhyd
Cae-moel
PH
Wks
Sch
Llanwnda
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
PW
Garth-y-glo
Ael y Garth
Tel Ex
A487
Garth
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

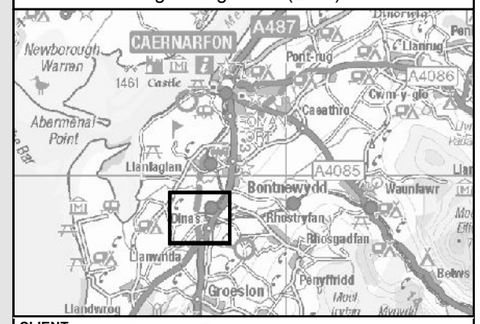
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT:
Llywodraeth Cymru
Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD DEPTH
5% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q20_EXG_D	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tafarn Hen
Tre Wyndaf
PW
Sta
Stone
Plas
Glan-rhyd
Cae-moel
PH
Llanwnda
Wks
Sch
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
Garth-y-glo
Ael y Garth
Tel Ex
Garth
A487
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

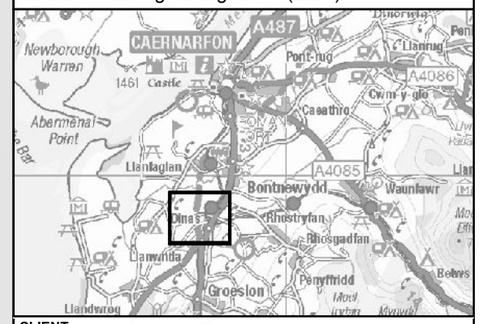
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD DEPTH
1% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q100_EXG_D	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tafarn Hen
Tre Wyndaf
PW
Sta
Stone
Plas
Glan-rhyd
Cae-moel
PH
Llanwnda
Wks
Sch
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
PW
Garth-y-glo
Ael y Garth
Tel Ex
A487
Garth
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

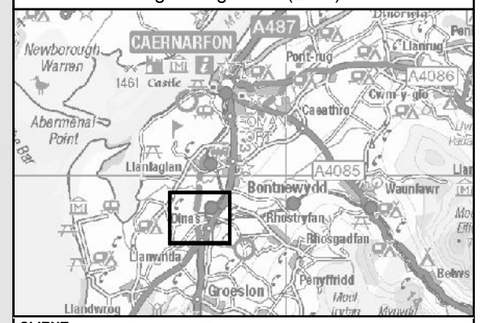
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT:
Llywodraeth Cymru
Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD DEPTH
1% AEP + CC FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q100CC_EXG_D	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

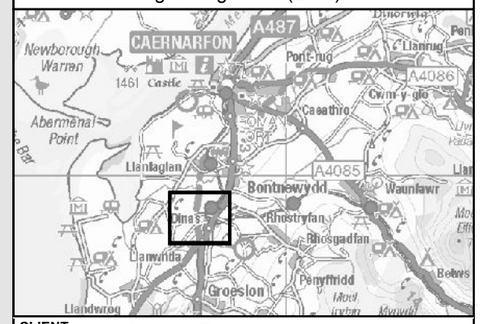
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD DEPTH
0.1% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q1000_EXG_D	B

AREA OF INTEREST

PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tre Wyndaf
Tafarn Hen
Stone
Plas
Glan-rhyd
Cae-moel
Wks
Sch
Llanwnda
Rhyd-y-felin
Felinwnda
Pont Henrhyd-isaf
Parc
Afon Rhyd
Tel Ex
Garth-y-glo
Ael y Garth
Garth
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

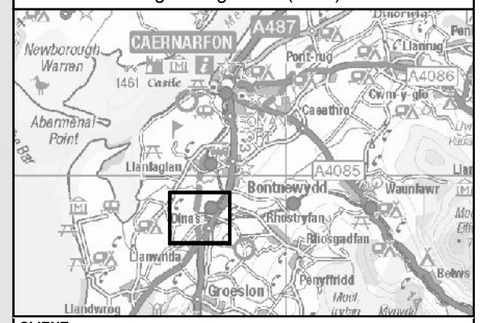
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM VELOCITY
50% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q2_EXG_V	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tre Wyndaf
Tafarn Hen
Stone
Plas
Glan-rhyd
Cae-moel
Llanwnda
Wks
Sch
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
Garth-y-glo
Ael y Garth
Tel Ex
Garth
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

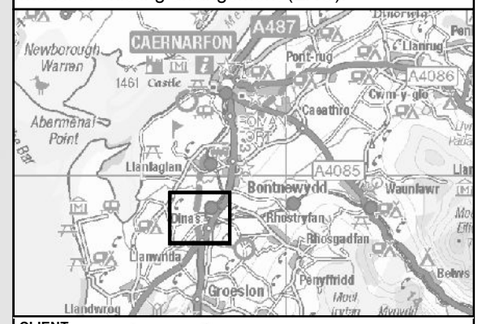
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM VELOCITY
20% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q5_EXG_V	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tafarn Hen
Tre Wyndaf
PW
Sta
Stone
Plas
Glan-rhyd
Cae-moel
PH
Wks
Sch
Llanwnda
Rhyd-y-felin
Felinwnda
Pont Henrhyd-isaf
Parc
Afon Rhyd
Tel Ex
Garth-y-glo
Ael y Garth
Garth
A487
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

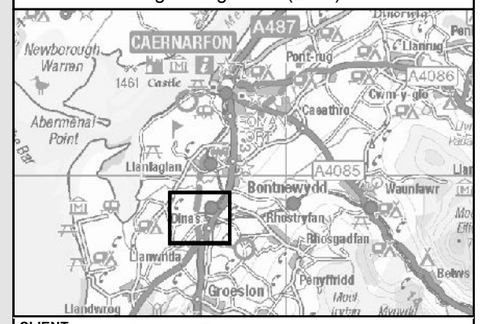
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM VELOCITY
10% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q10_EXG_V	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tafarn Hen
Tre Wyndaf
PW
Sta
Stone
Plas
Glan-rhyd
Cae-moel
PH
Llanwnda
Wks
Sch
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
Tel Ex
Garth-y-glo
Ael y Garth
Garth
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

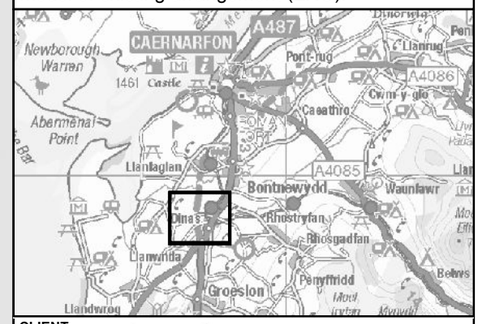
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM VELOCITY
5% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q20_EXG_V	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tre Wyndaf
Tafarn Hen
Stone
Plas
Glan-rhyd
Cae-moel
Llanwnda
Wks
Sch
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
Garth-y-glo
Ael y Garth
Tel Ex
Garth
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

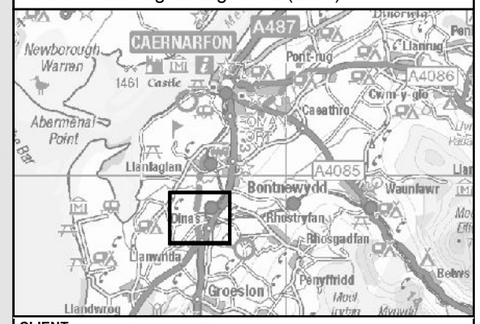
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM VELOCITY
1% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q100_EXG_V	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tafarn Hen
Tre Wyndaf
PW
Sta
Stone
Plas
Glan-rhyd
Cae-moel
PH
Wks
Sch
Llanwnda
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
Garth-y-glo
Ael y Garth
Tel Ex
Garth
A487
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

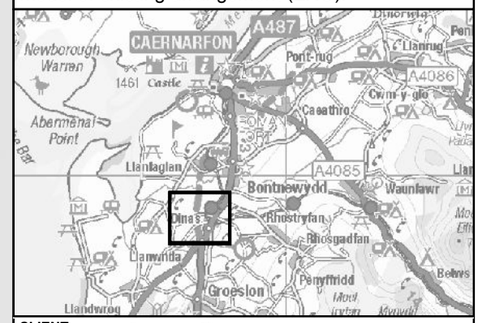
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

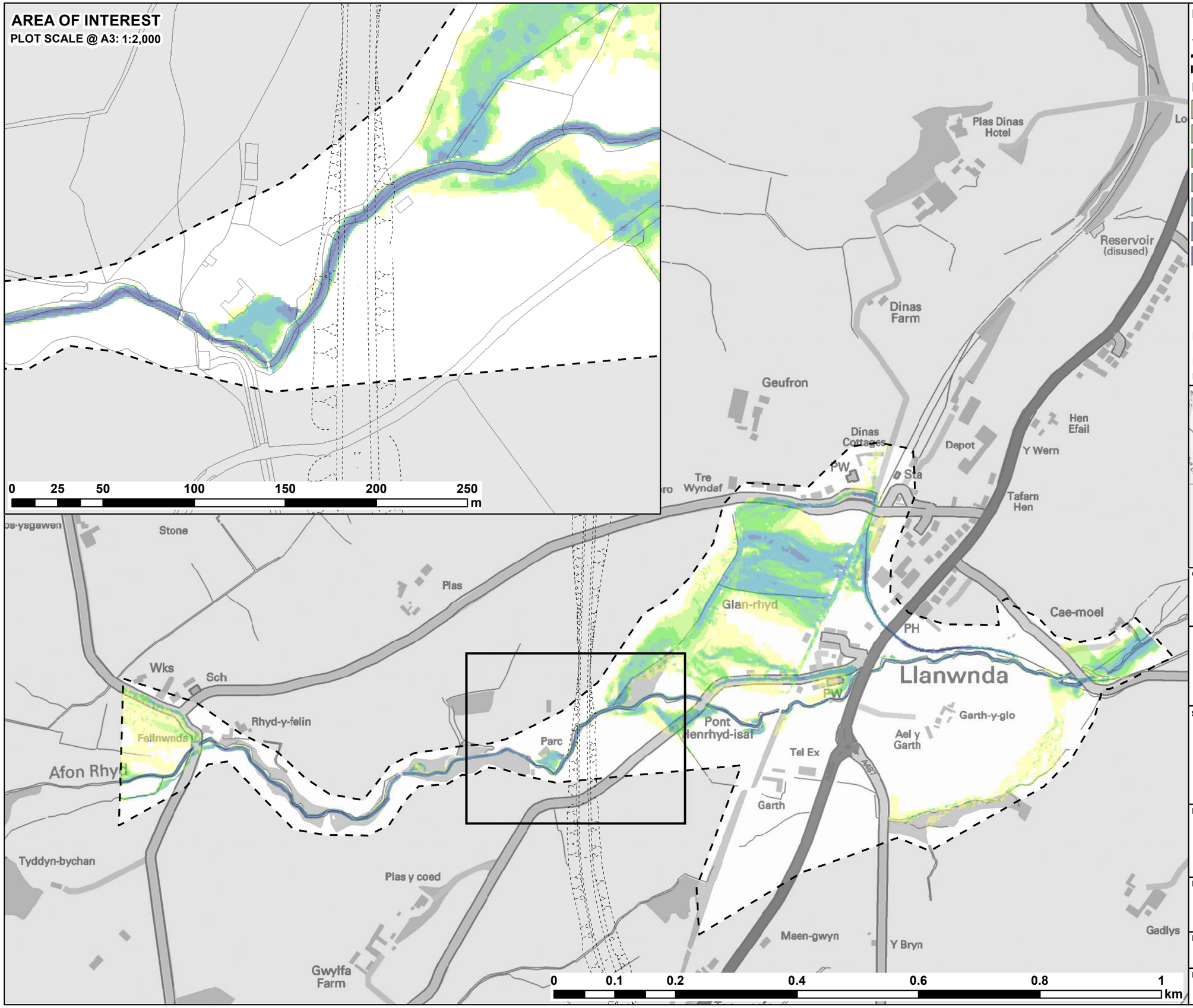
SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM VELOCITY
1% AEP + CC FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q100CC_EXG_V	B



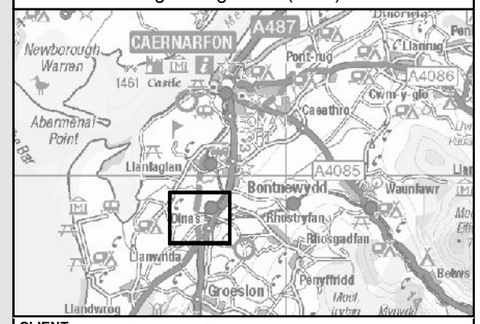
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM VELOCITY
0.1% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q1000_EXG_V	B

AREA OF INTEREST

PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tafarn Hen
Tre Wyndaf
PW
Sta
Stone
Plas
Glan-rhyd
Cae-moel
PH
Wks
Sch
Llanwnda
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
PW
Garth-y-glo
Ael y Garth
Tel Ex
A487
Garth
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

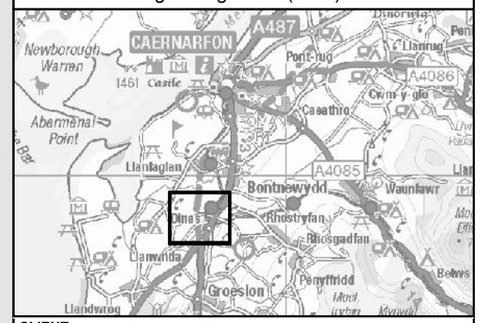
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

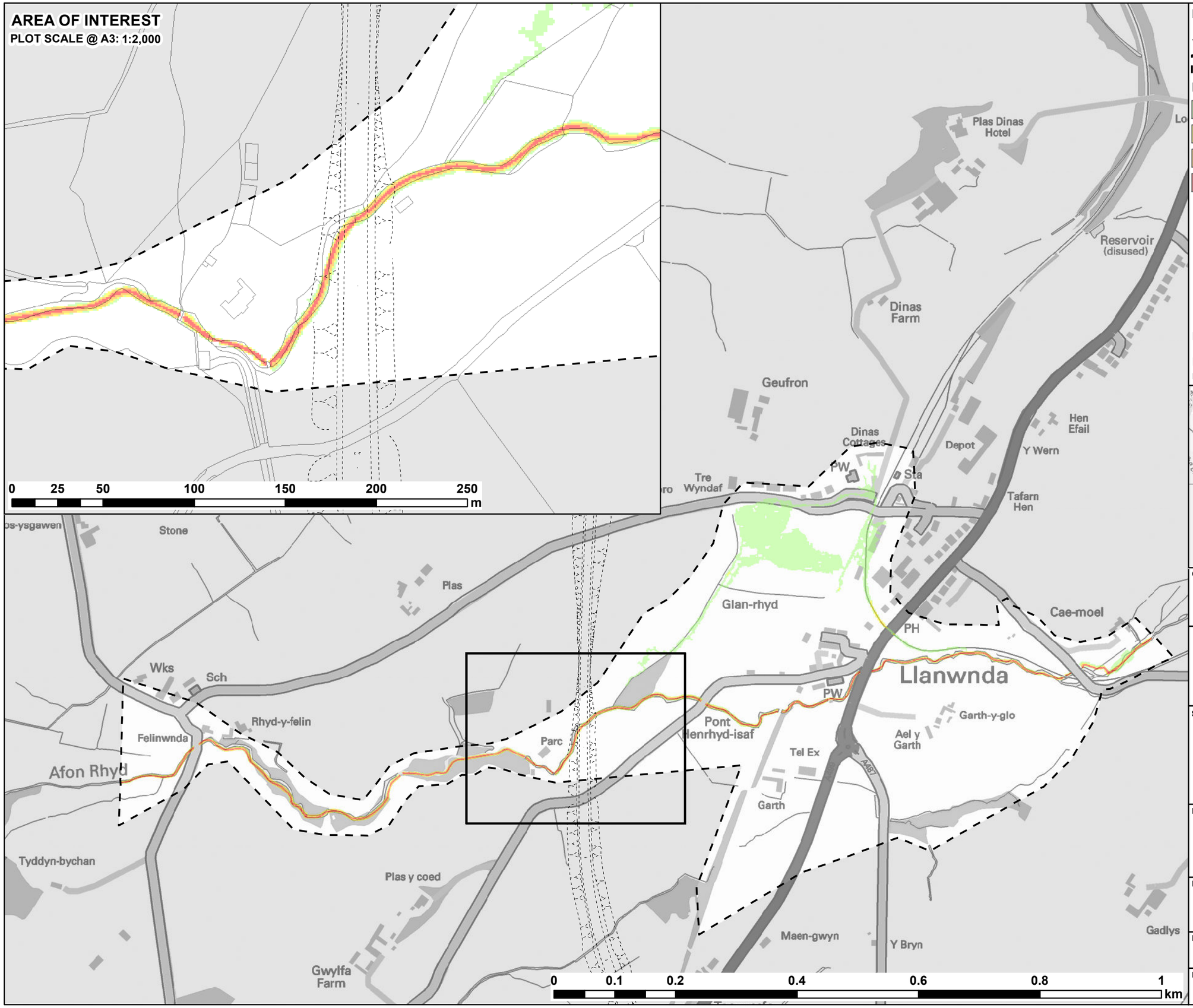
SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD HAZARD
50% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q2_EXG_H	B



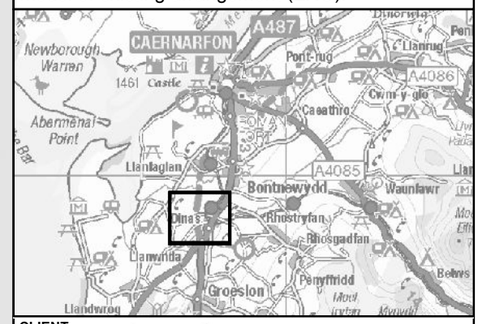
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

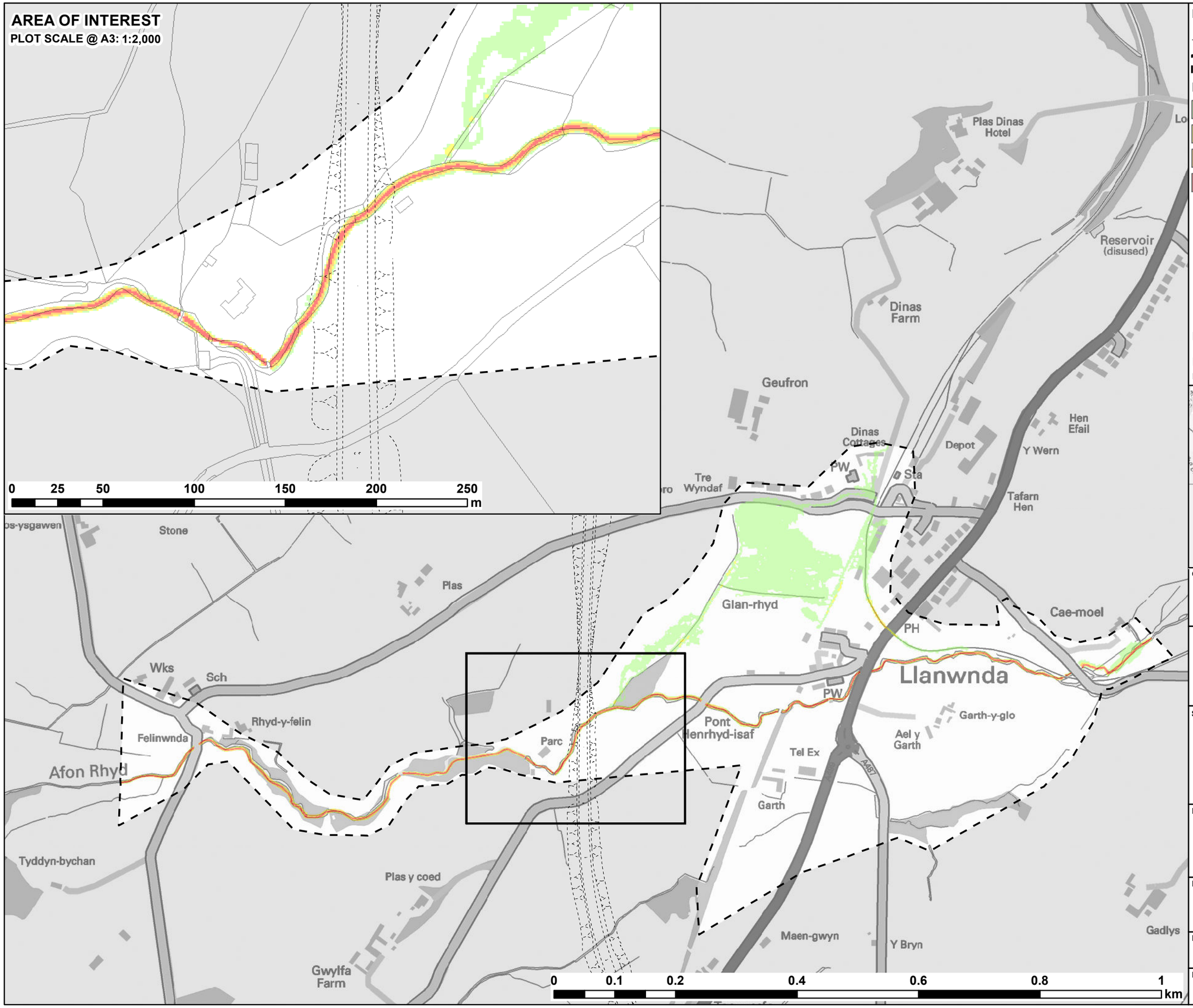
SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD HAZARD
20% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q5_EXG_H	B



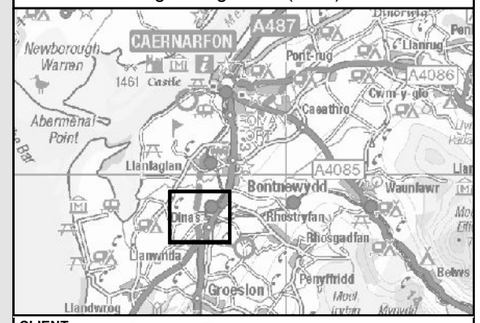
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD HAZARD
10% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q10_EXG_H	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tafarn Hen
Tre Wyndaf
PW
Sta
Stone
Plas
Glan-rhyd
Cae-moel
PH
Wks
Sch
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
Llanwnda
Garth-y-glo
Ael y Garth
Tel Ex
Garth
A487
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

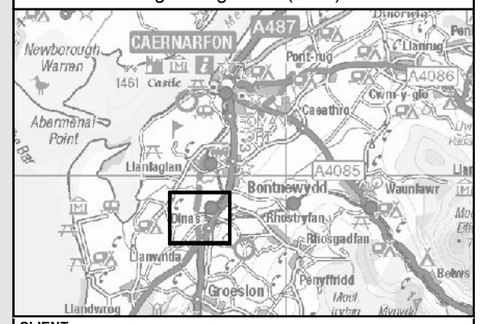
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

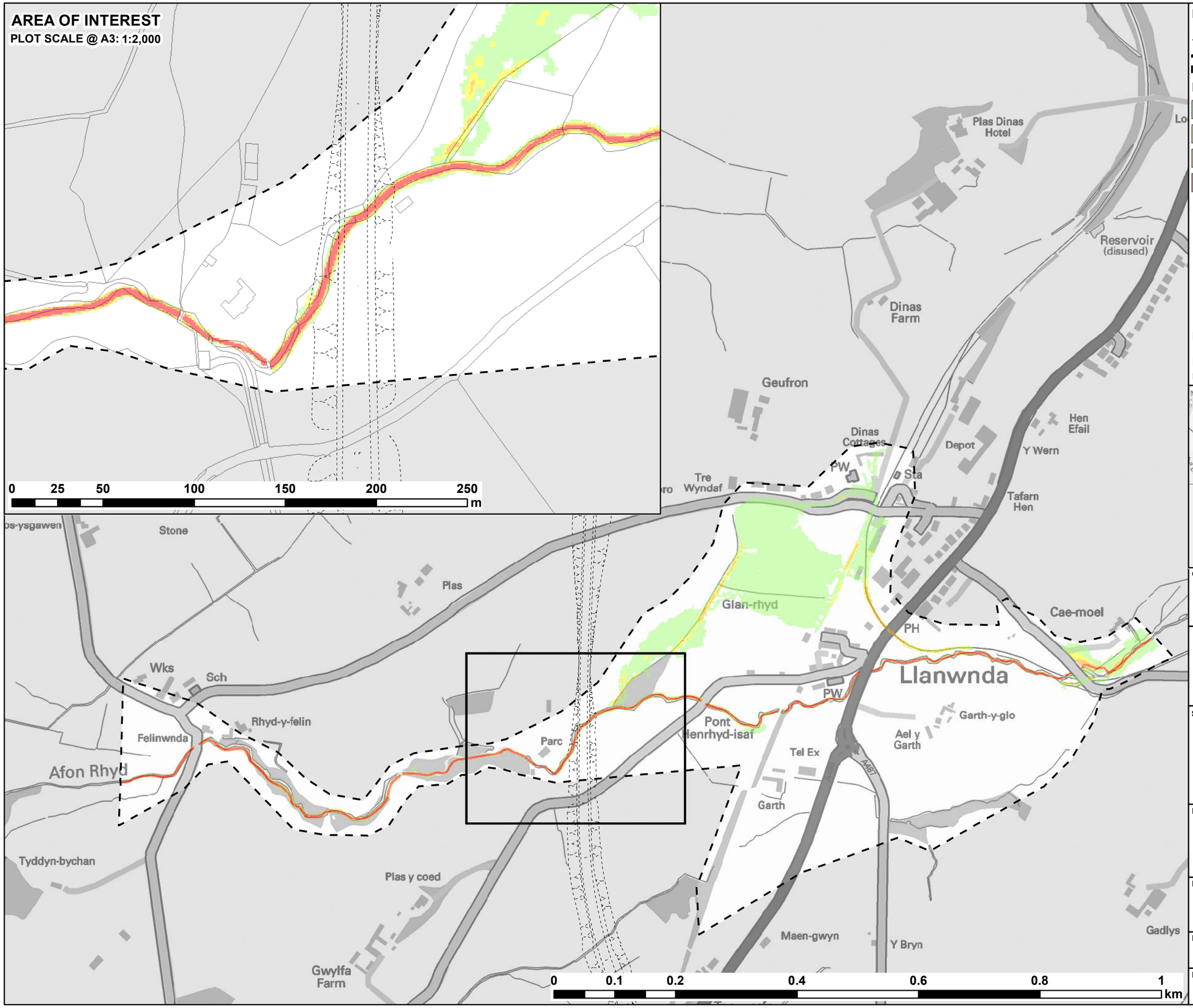
SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD HAZARD
5% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q20_EXG_H	B



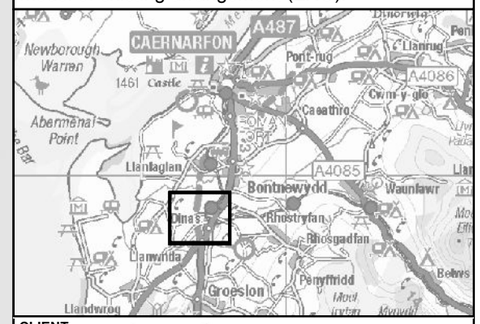
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD HAZARD
1% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q100_EXG_H	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

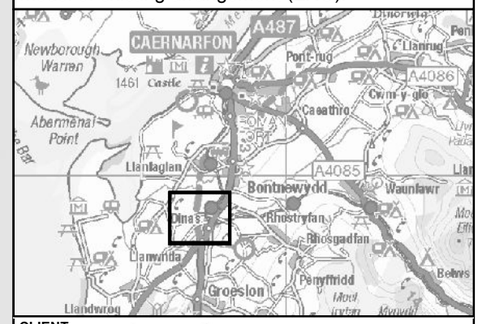
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD HAZARD
1% AEP + CC FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q100CC_EXG_H	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tre Wyndaf
Tafarn Hen
Stone
Plas
Glan-rhyd
Cae-moel
Llanwnda
Wks
Sch
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
Garth-y-glo
Ael y Garth
Tel Ex
Garth
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

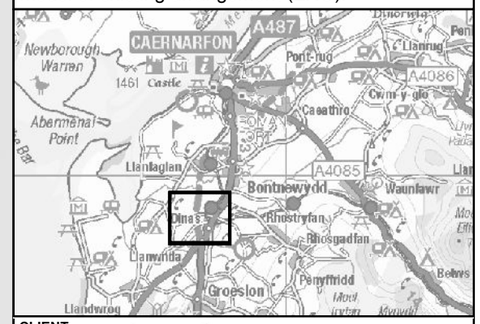
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD HAZARD
0.1% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q1000_EXG_H	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tre Wyndaf
Tafarn Hen
Stone
Plas
Glan-rhyd
Cae-moel
Llanwnda
Wks
Sch
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
Garth-y-glo
Ael y Garth
Tel Ex
Garth
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

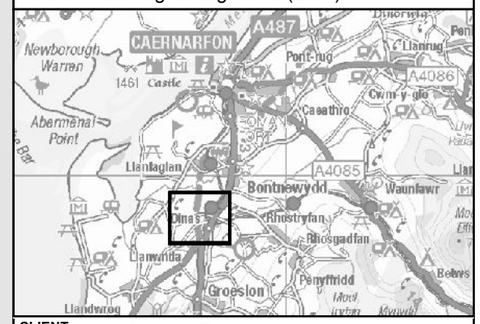
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

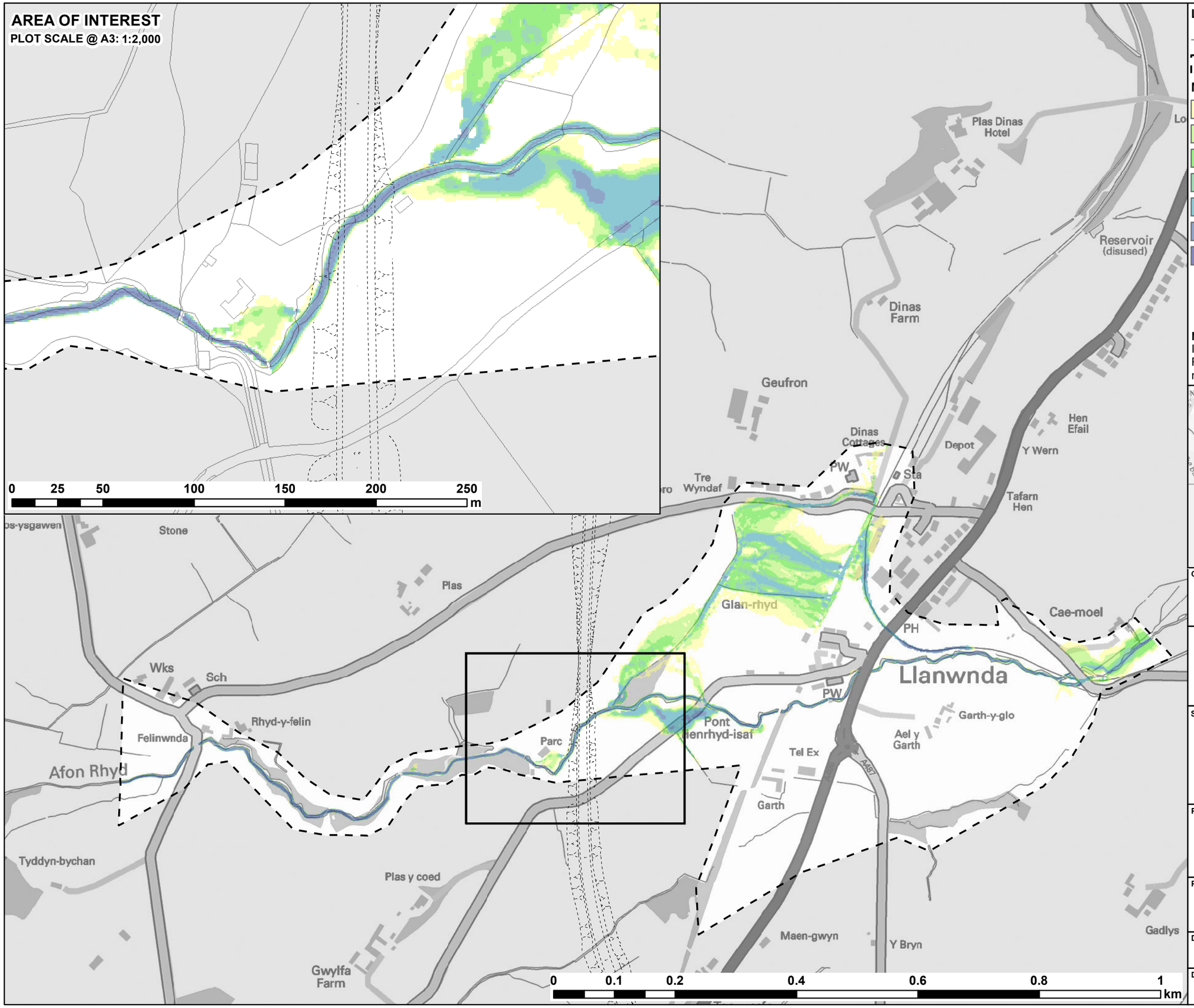
SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD DEPTH
1% AEP + CC FLUVIAL EVENT
ST5 - 67% GLANRHYD BRIDGE BLOCKAGE

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q100CC_ST5_D	B



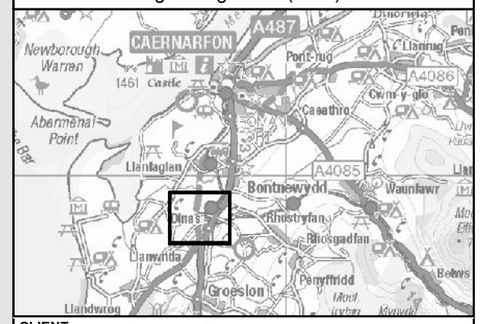
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM VELOCITY
1% AEP + CC FLUVIAL EVENT
ST5 - 67% GLANRHYD BRIDGE BLOCKAGE

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q100CC_ST5_V	B

AREA OF INTEREST

PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tre Wyndaf
Sta
Tafarn Hen
Stone
Plas
Glan-rhyd
Cae-moel
PH
Wks
Sch
Llanwnda
PW
Rhyd-y-felin
Felinwnda
Pont Henrhyd-isaf
Parc
Garth-y-glo
Ael y Garth
Afon Rhyd
Tel Ex
Garth
A487
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

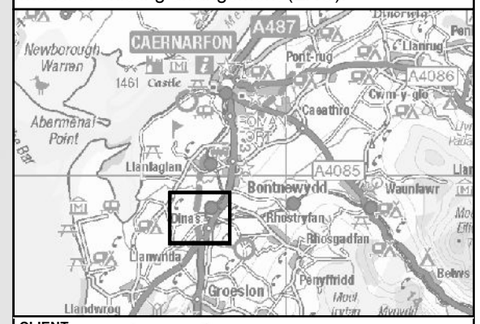
LEGEND

- Highway Alignment
- 1D/2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

NOTE:
Indicative highway route included for information. Proposed embankments and culvert not included model of existing arrangement (EXG).



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WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD HAZARD
1% AEP + CC FLUVIAL EVENT
ST5 - 67% GLANRHYD BRIDGE BLOCKAGE

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q100CC_ST5_H	B

Proposed Development Arrangement (DEV1)

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

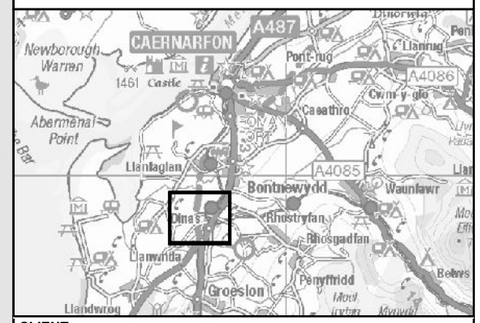
0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

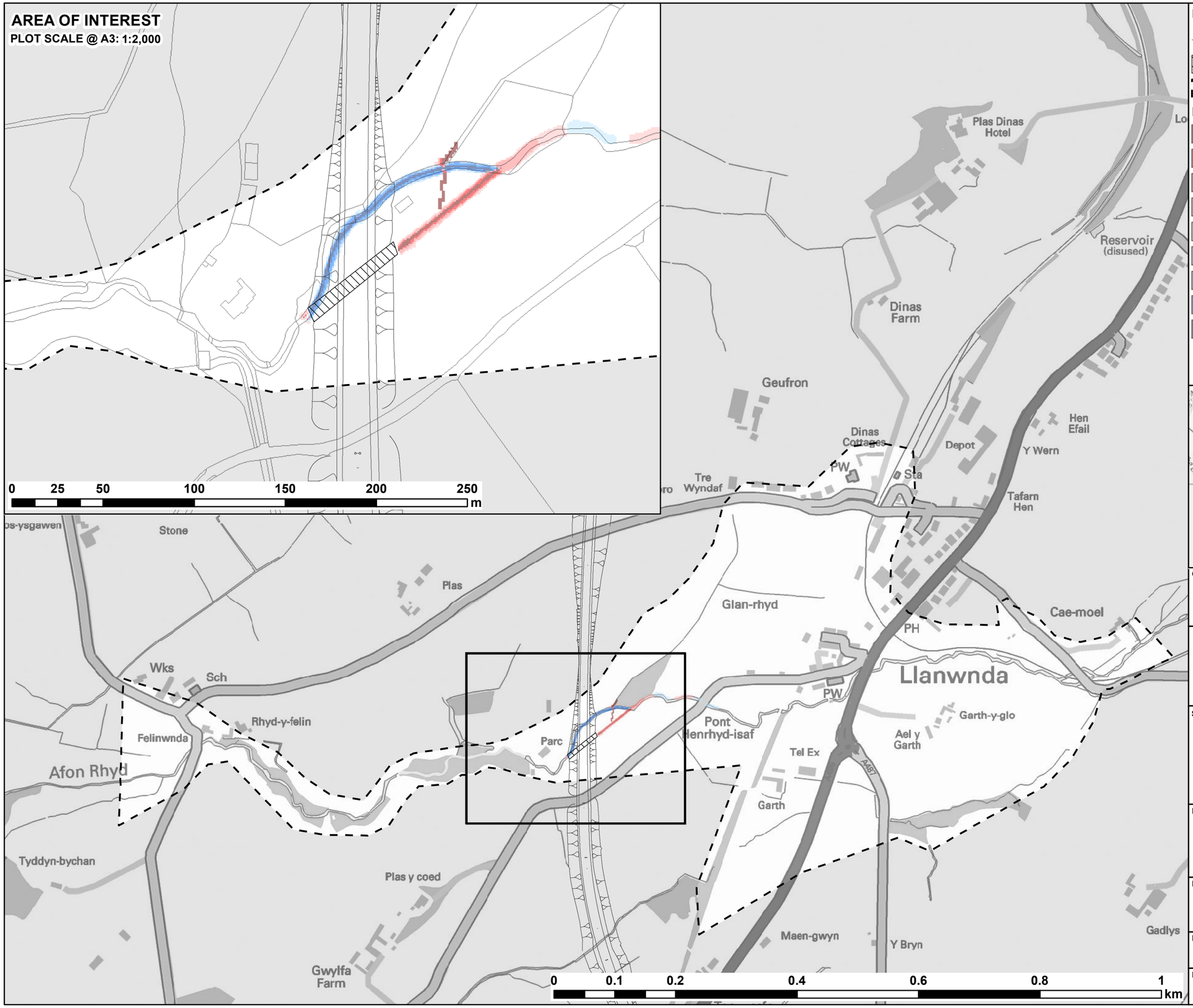
PLOT TITLE:

MAXIMUM FLOOD DEPTH
50% AEP FLUVIAL EVENT
PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q2_DEV1_D	B

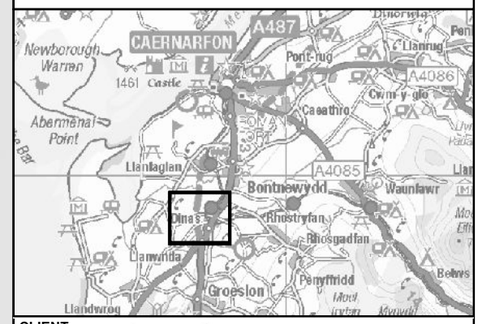


LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Depth Difference

- > 600mm
- 300mm to 600mm
- 100mm to 300mm
- 5mm to 100mm
- Negligible Change (+/- 5mm)
- -5mm to -100mm
- -100mm to -300mm
- 300mm to -600mm
- > -600mm



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

PLOT TITLE:

MAXIMUM DEPTH DIFFERENCE

50% AEP FLUVIAL EVENT

DEV1 vs EXG

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q2_DEV1-EXG_D	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

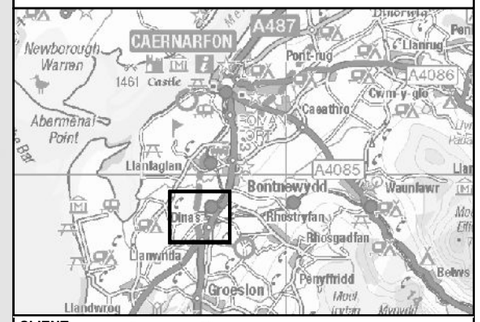
Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tre Wyndaf
Tafarn Hen
Stone
Plas
Glan-rhyd
Cae-moel
Llanwnda
Wks
Sch
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
Garth-y-glo
Ael y Garth
Tel Ex
Garth
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD DEPTH
20% AEP FLUVIAL EVENT
PROPOSED SITE LAYOUT (DEV1)

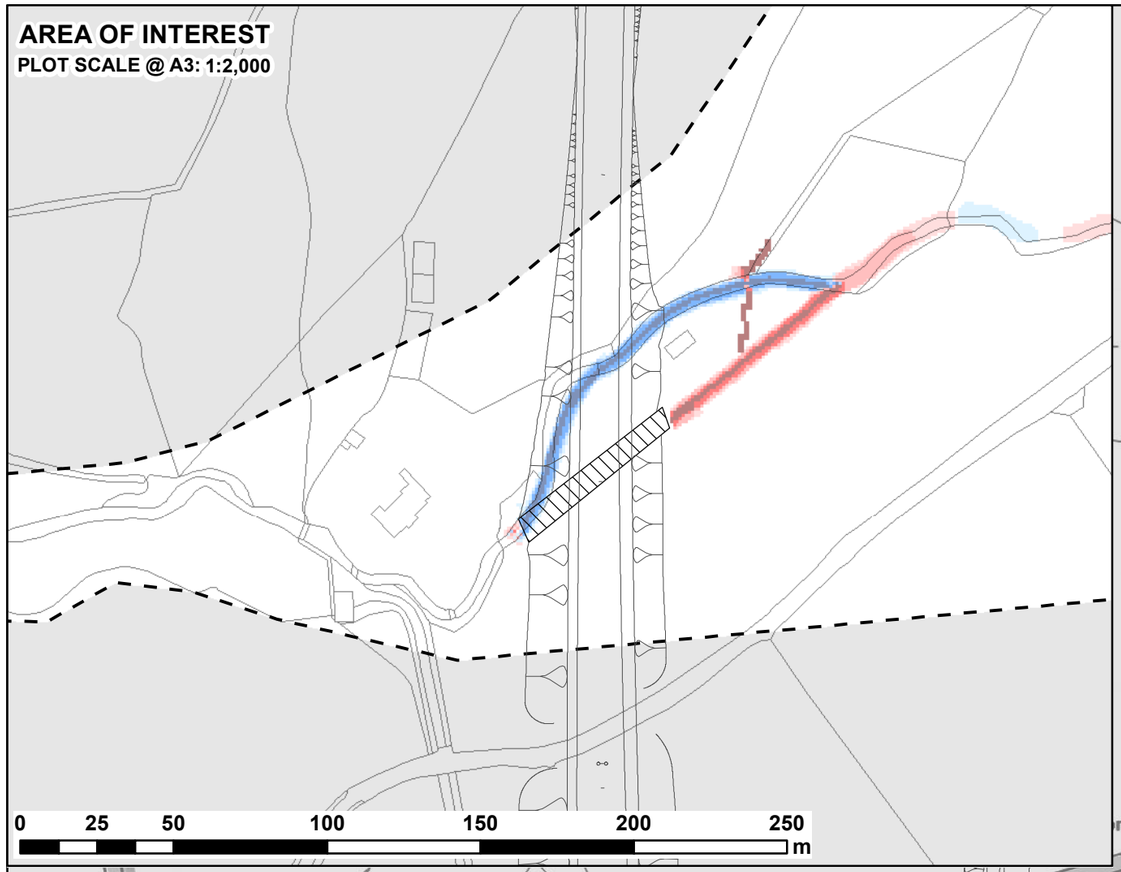
PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q5_DEV1_D	B

AREA OF INTEREST

PLOT SCALE @ A3: 1:2,000

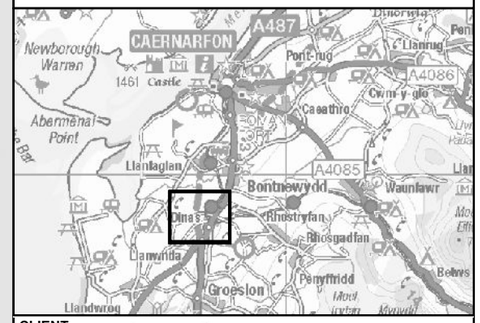


LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Depth Difference

- > 600mm
- 300mm to 600mm
- 100mm to 300mm
- 5mm to 100mm
- Negligible Change (+/- 5mm)
- -5mm to -100mm
- -100mm to -300mm
- 300mm to -600mm
- > -600mm



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

PLOT TITLE:

MAXIMUM DEPTH DIFFERENCE

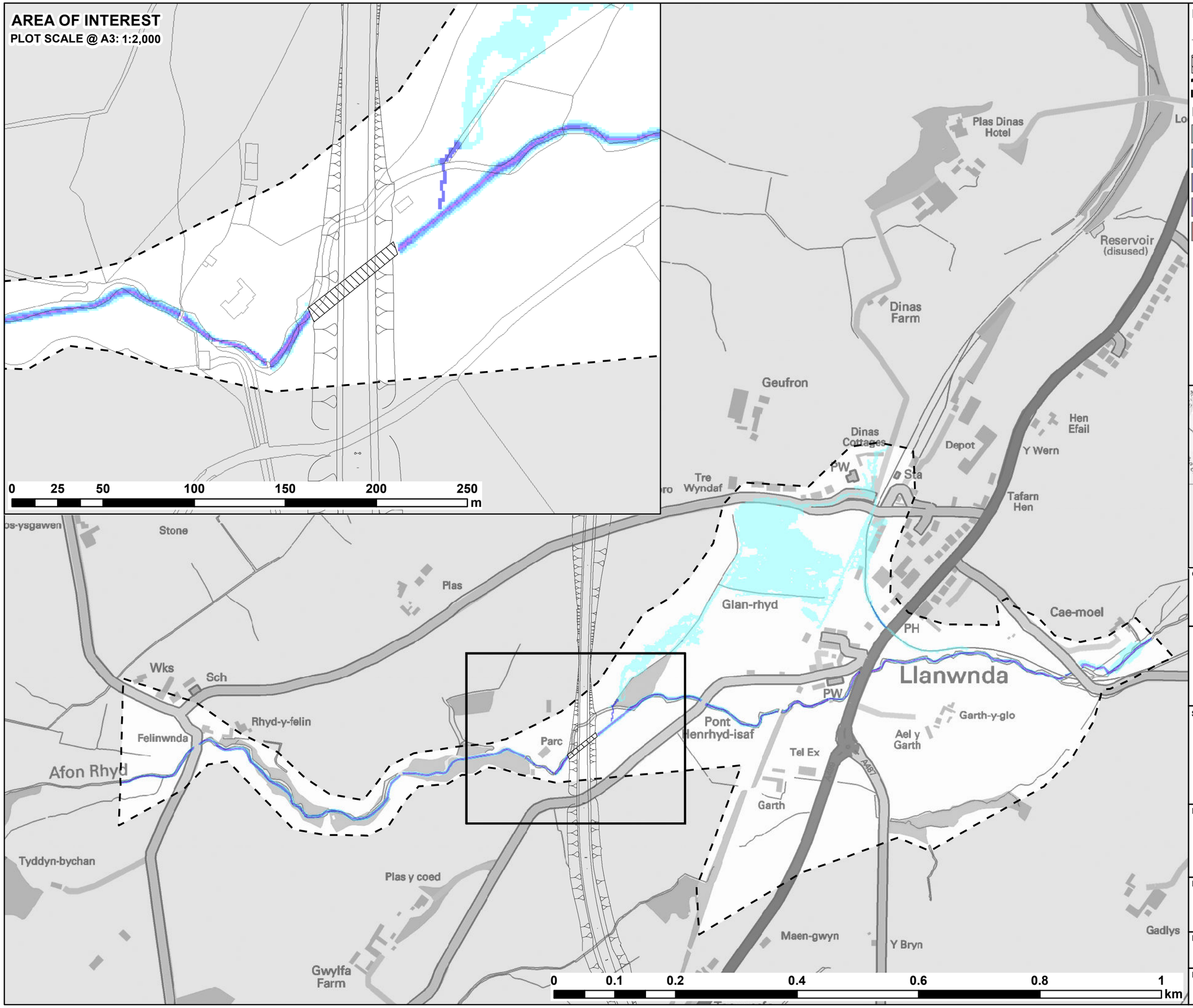
20% AEP FLUVIAL EVENT

DEV1 vs EXG

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q5_DEV1-EXG_D	B

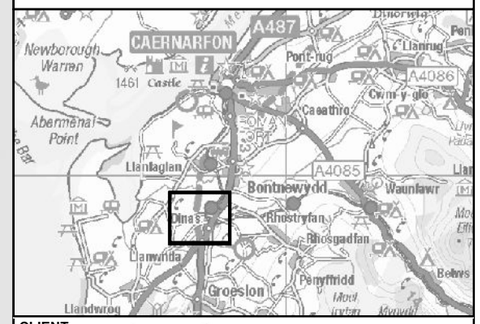


LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4



CLIENT:

Llywodraeth Cymru
Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

PLOT TITLE:

MAXIMUM FLOOD DEPTH

10% AEP FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:

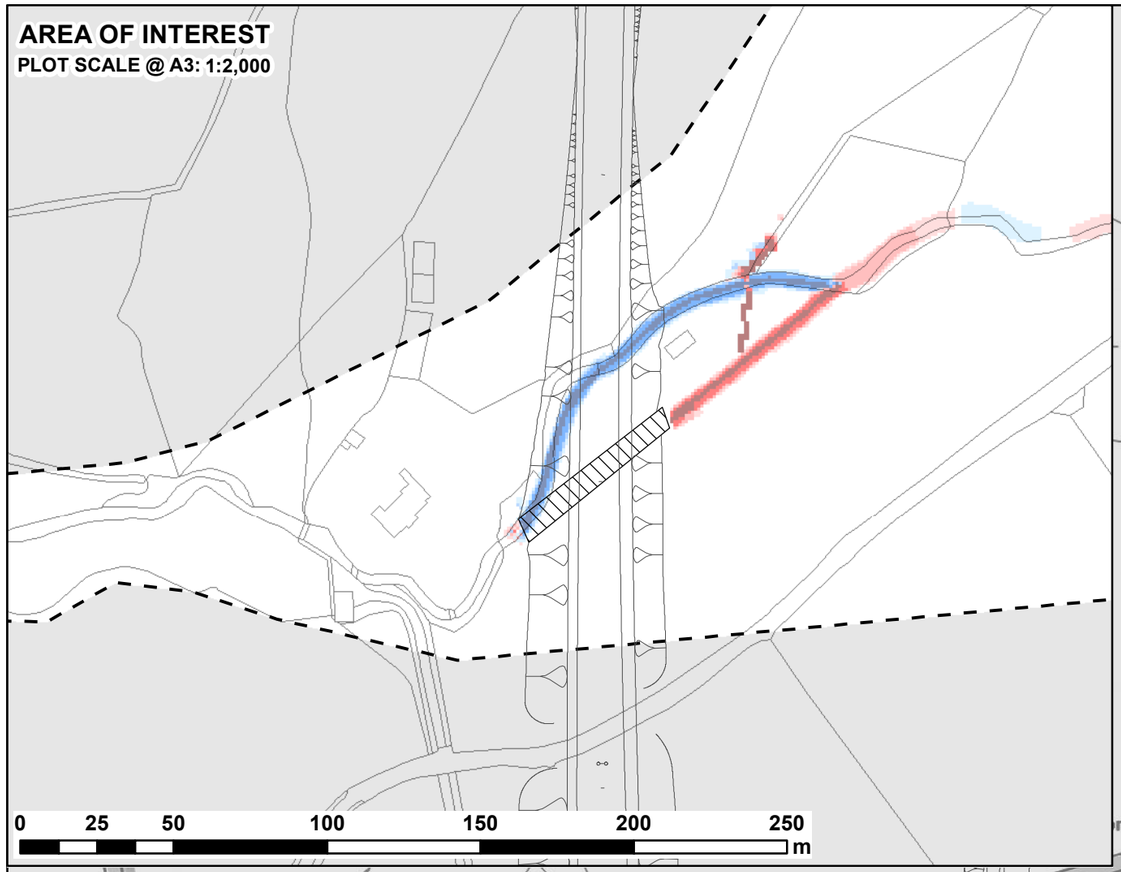
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q10_DEV1_D	B

AREA OF INTEREST

PLOT SCALE @ A3: 1:2,000

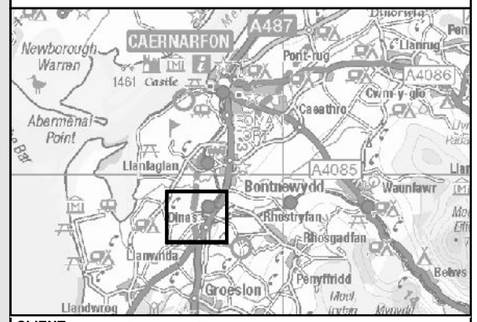


LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Depth Difference

- > 600mm
- 300mm to 600mm
- 100mm to 300mm
- 5mm to 100mm
- Negligible Change (+/- 5mm)
- -5mm to -100mm
- -100mm to -300mm
- 300mm to -600mm
- > -600mm



CLIENT:
Llywodraeth Cymru
Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM DEPTH DIFFERENCE
10% AEP FLUVIAL EVENT
DEV1 vs EXG

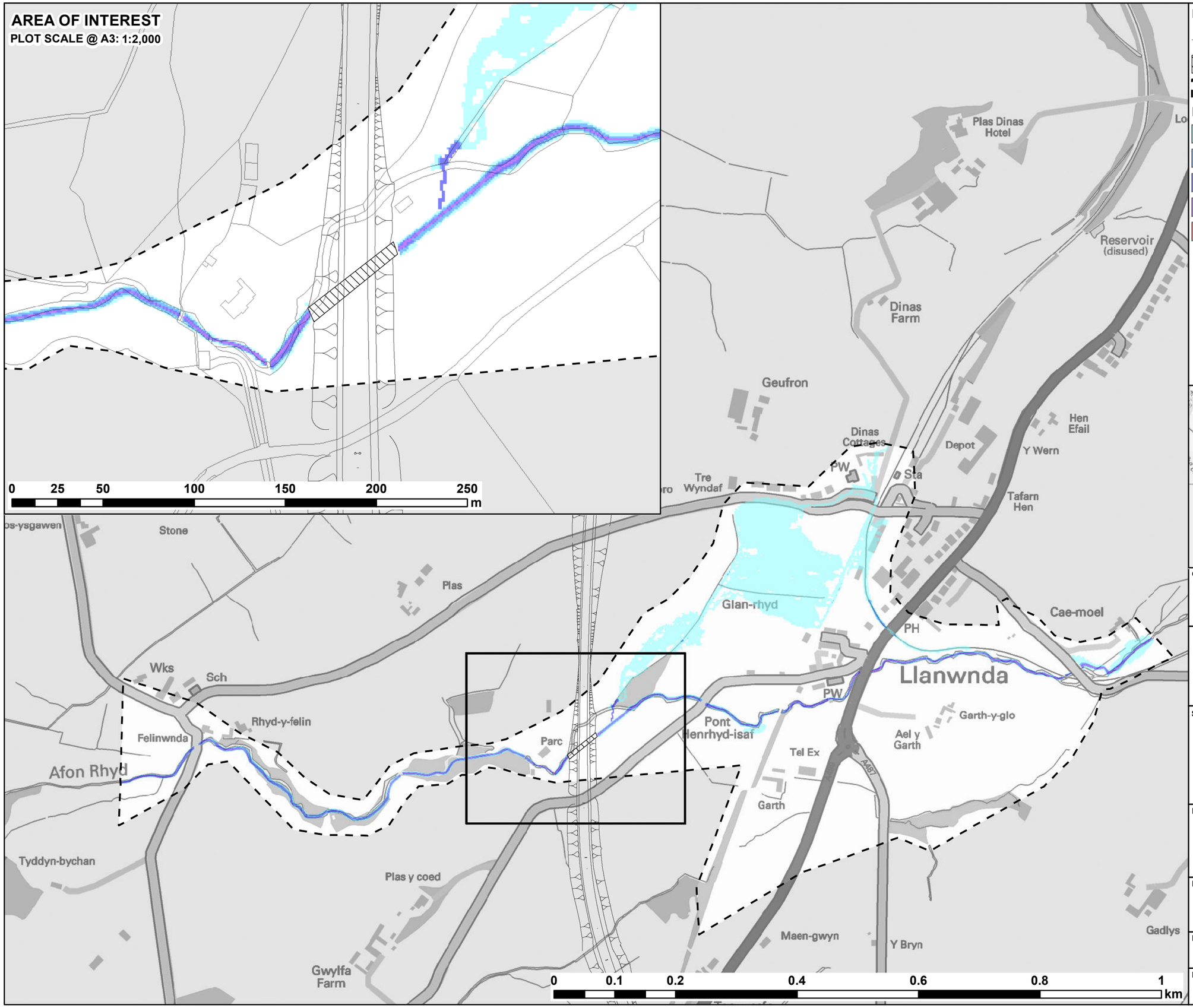
PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q10_DEV1-EXG_D	B

AREA OF INTEREST

PLOT SCALE @ A3: 1:2,000

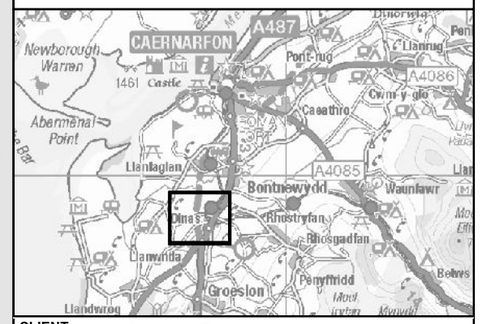


LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

PLOT TITLE:

MAXIMUM FLOOD DEPTH

5% AEP FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q20_DEV1_D	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

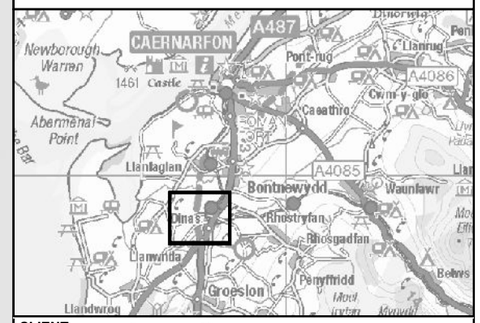
Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tre Wyndaf
Tafarn Hen
Stone
Plas
Glan-rhyd
Cae-moel
Wks
Sch
Llanwnda
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
Tel Ex
Garth-y-glo
Ael y Garth
Garth
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Depth Difference

- > 600mm
- 300mm to 600mm
- 100mm to 300mm
- 5mm to 100mm
- Negligible Change (+/- 5mm)
- -5mm to -100mm
- -100mm to -300mm
- 300mm to -600mm
- > -600mm



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM DEPTH DIFFERENCE
5% AEP FLUVIAL EVENT
DEV1 vs EXG

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q20_DEV1-EXG_D	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

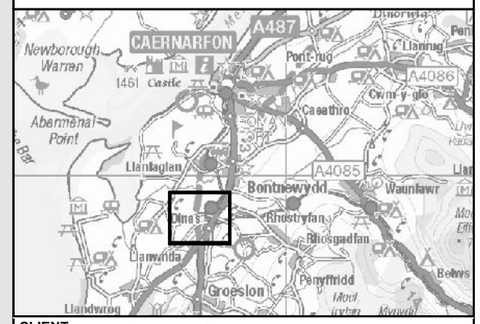
Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tafarn Hen
Tre Wyndaf
PW
Sta
Stone
Plas
Glan-rhyd
Cae-moel
PH
Llanwnda
Wks
Sch
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
Garth-y-glo
Ael y Garth
Tel Ex
Garth
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD DEPTH
1% AEP FLUVIAL EVENT
PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q100_DEV1_D	B

AREA OF INTEREST

PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

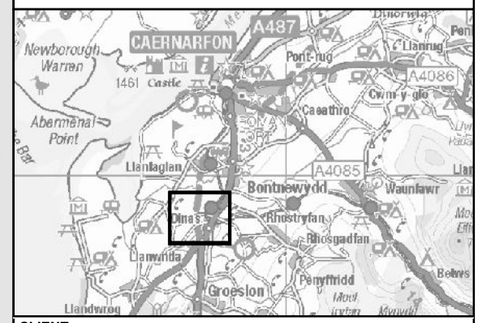
Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tre Wyndaf
PW
Sta
Tafarn Hen
Stone
Plas
Glan-rhyd
Cae-moel
PH
Wks
Sch
Llanwnda
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
Garth-y-glo
Ael y Garth
Tel Ex
Garth
A487
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Depth Difference

- > 600mm
- 300mm to 600mm
- 100mm to 300mm
- 5mm to 100mm
- Negligible Change (+/- 5mm)
- -5mm to -100mm
- -100mm to -300mm
- 300mm to -600mm
- > -600mm



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

PLOT TITLE:

MAXIMUM DEPTH DIFFERENCE

1% AEP FLUVIAL EVENT

DEV1 vs EXG

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q100_DEV1-EXG_D	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

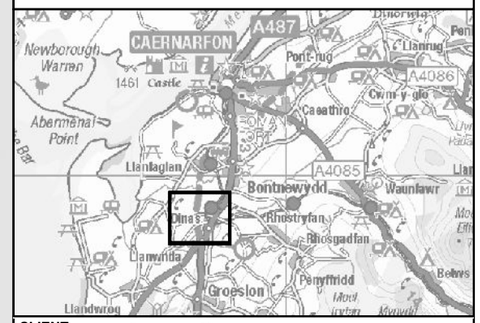
Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tafarn Hen
Tre Wyndaf
PW
Sta
Stone
Plas
Glan-rhyd
Cae-moel
PH
Llanwnda
Wks
Sch
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
PW
Garth-y-glo
Ael y Garth
Tel Ex
Garth
A487
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD DEPTH
1% AEP + CC FLUVIAL EVENT
PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q100CC_DEV1_D	B

AREA OF INTEREST

PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

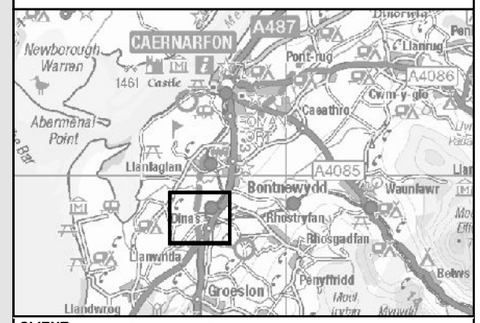
Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tafarn Hen
Tre Wyndaf
PW
Sta
Stone
Plas
Glan-rhyd
Cae-moel
PH
Wks
Sch
Llanwnda
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
Garth-y-glo
Ael y Garth
Tel Ex
Garth
A487
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Depth Difference

- > 600mm
- 300mm to 600mm
- 100mm to 300mm
- 5mm to 100mm
- Negligible Change (+/- 5mm)
- -5mm to -100mm
- -100mm to -300mm
- 300mm to -600mm
- > -600mm



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

PLOT TITLE:

MAXIMUM DEPTH DIFFERENCE

1% AEP + CC FLUVIAL EVENT

DEV1 vs EXG

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q100CC_DEV1-EXG_D	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

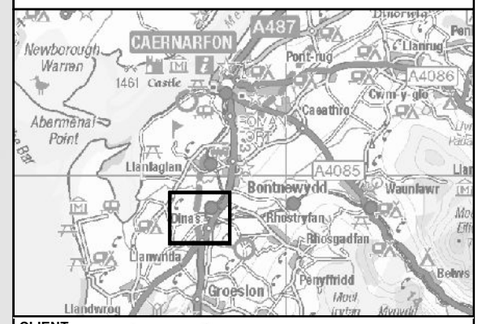
0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4



CLIENT:
Llywodraeth Cymru
Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD DEPTH
0.1% AEP FLUVIAL EVENT
PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q1000_DEV1_D	B

AREA OF INTEREST

PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

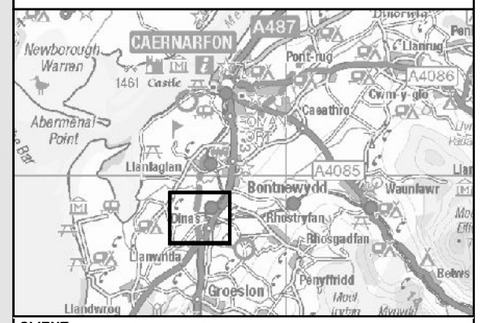
Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tafarn Hen
Tre Wyndaf
PW
Sta
Stone
Plas
Glan-rhyd
Cae-moel
PH
Wks
Sch
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Llanwnda
Pont Henrhyd-isaf
Garth-y-glo
Ael y Garth
Tel Ex
Garth
A487
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Depth Difference

- > 600mm
- 300mm to 600mm
- 100mm to 300mm
- 5mm to 100mm
- Negligible Change (+/- 5mm)
- -5mm to -100mm
- -100mm to -300mm
- 300mm to -600mm
- > -600mm



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

PLOT TITLE:

MAXIMUM DEPTH DIFFERENCE

0.1% AEP FLUVIAL EVENT

DEV1 vs EXG

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q1000_DEV1-EXG_D	B

AREA OF INTEREST

PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

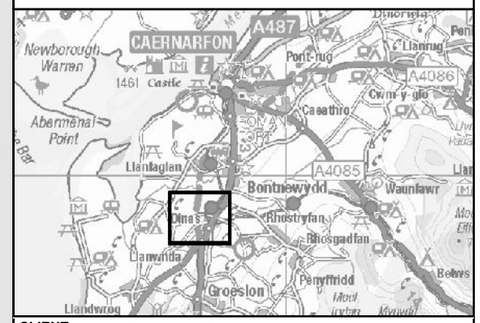
Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tafarn Hen
Tre Wyndaf
PW
Sta
Stone
Plas
Glan-rhyd
Cae-moel
PH
Llanwnda
Wks
Sch
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
PW
Garth-y-glo
Ael y Garth
Tel Ex
A487
Garth
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

PLOT TITLE:

MAXIMUM VELOCITY

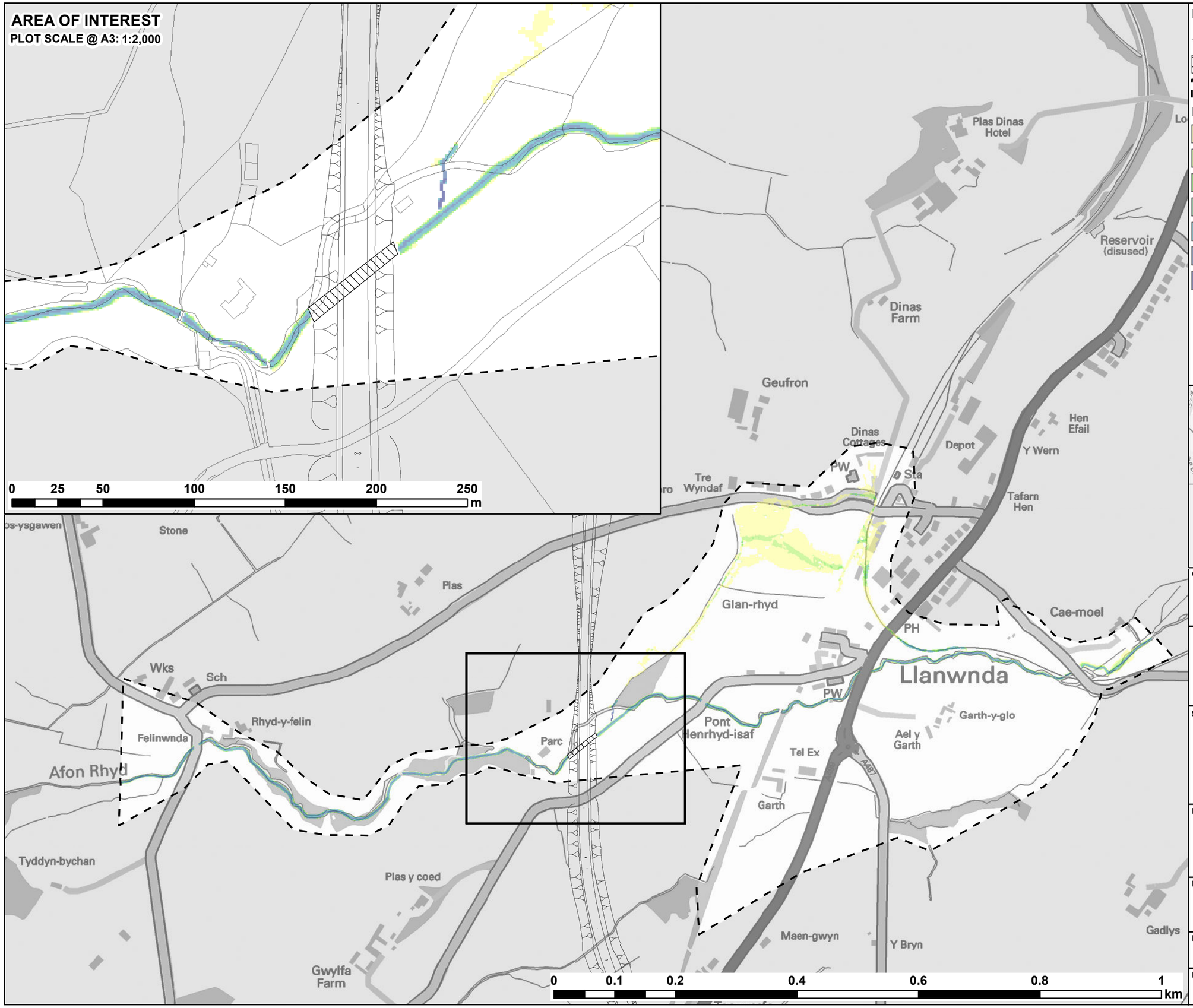
50% AEP FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q2_DEV1_V	B

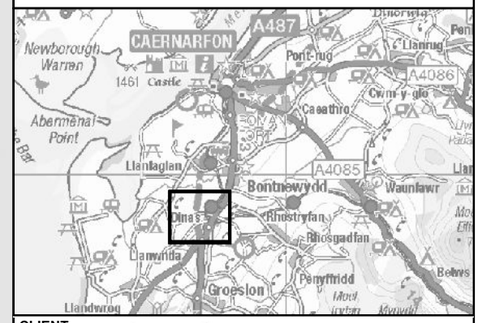


LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

PLOT TITLE:

MAXIMUM VELOCITY

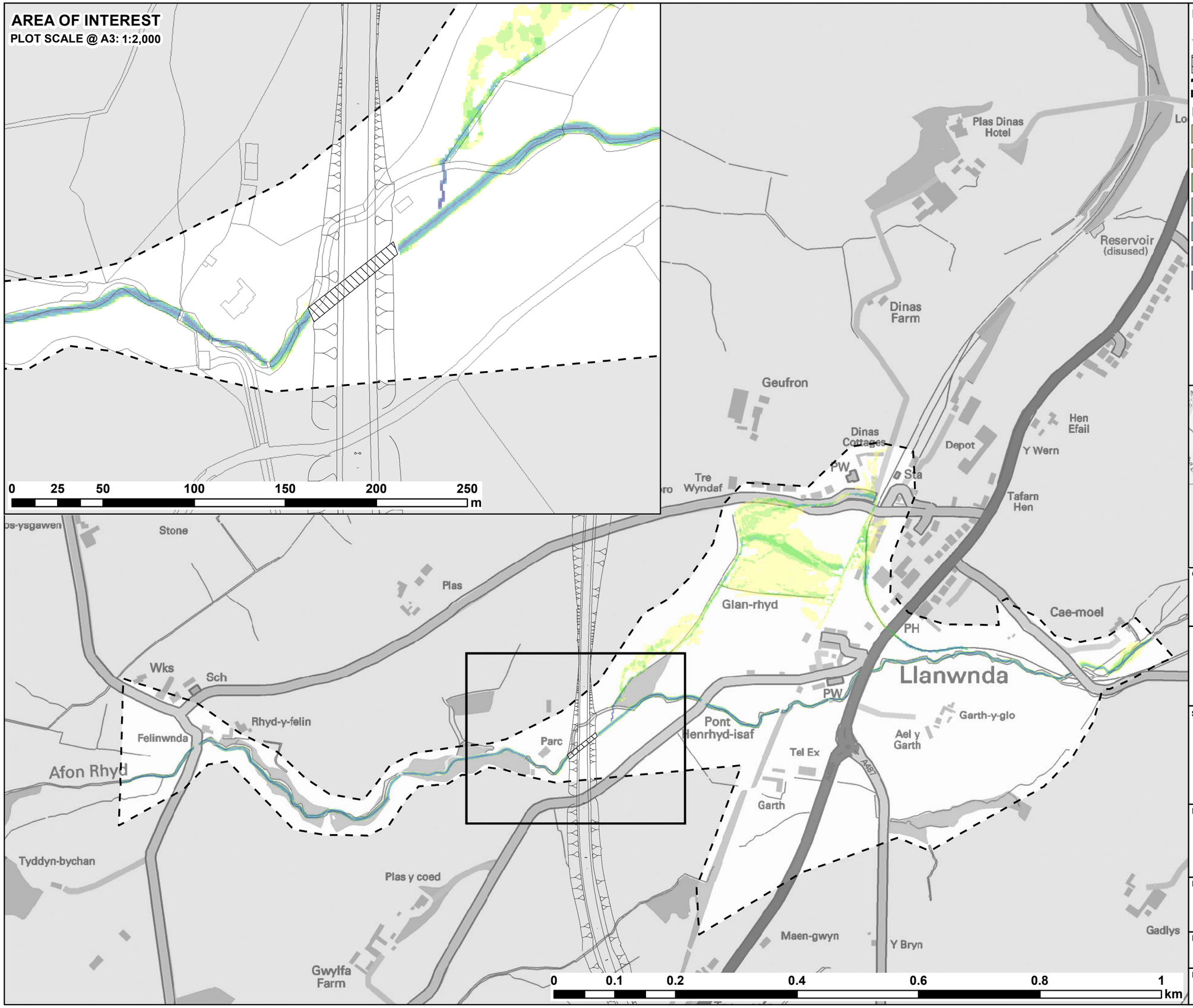
20% AEP FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q5_DEV1_V	B



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

PLOT TITLE:

MAXIMUM VELOCITY

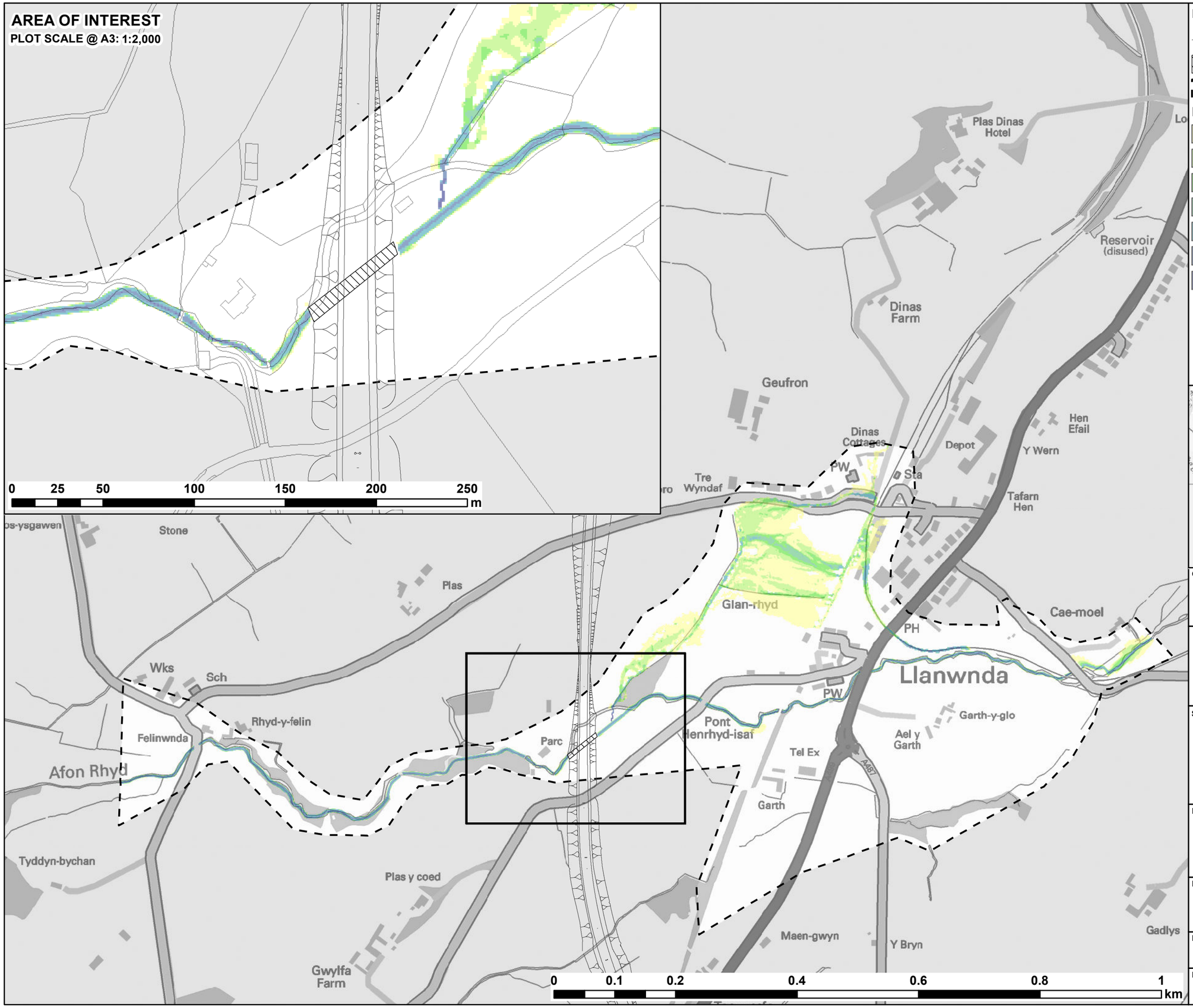
10% AEP FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q10_DEV1_V	B

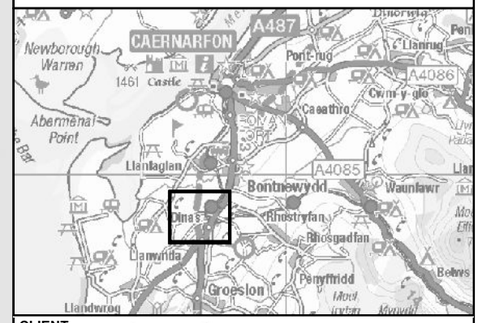


LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

PLOT TITLE:

MAXIMUM VELOCITY

5% AEP FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q20_DEV1_V	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

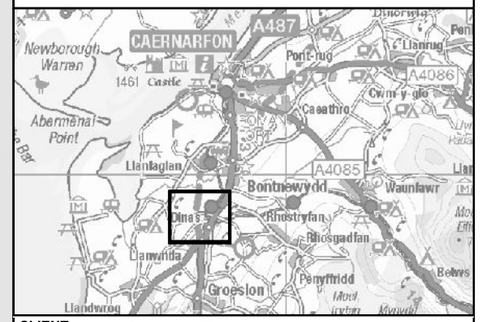
0 25 50 100 150 200 250 m

LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

PLOT TITLE:

MAXIMUM VELOCITY
1% AEP FLUVIAL EVENT
PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q100_DEV1_V	B

0 0.1 0.2 0.4 0.6 0.8 1 km

Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Y Wern
Hen Efail
Tafarn Hen
Tre Wyndaf
PW
Sta
Stone
Plas
Glan-rhyd
Cae-moel
PH
Llanwnda
Wks
Sch
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
Garth-y-glo
Ael y Garth
Tel Ex
Garth
A487
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

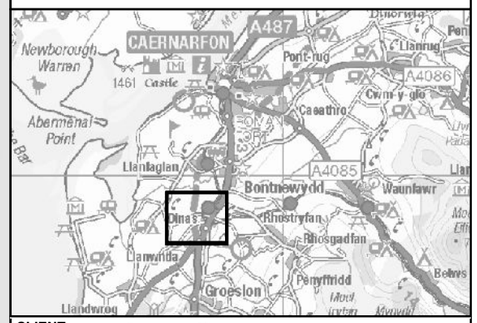
0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

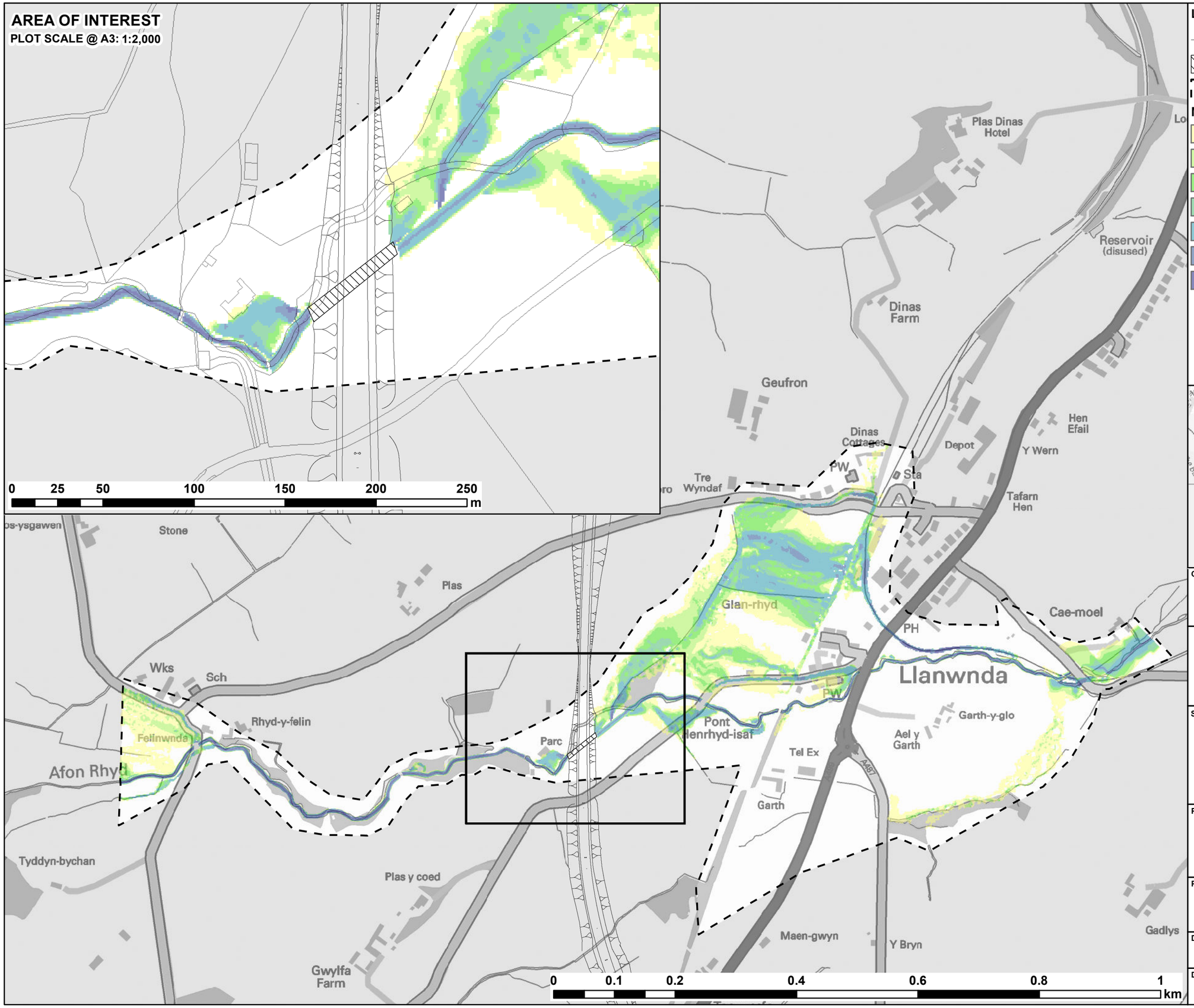
SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM VELOCITY
1% AEP + CC FLUVIAL EVENT
PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q100CC_DEV1_V	B



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

PLOT TITLE:

MAXIMUM VELOCITY

0.1% AEP FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q1000_DEV1_V	B

AREA OF INTEREST

PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

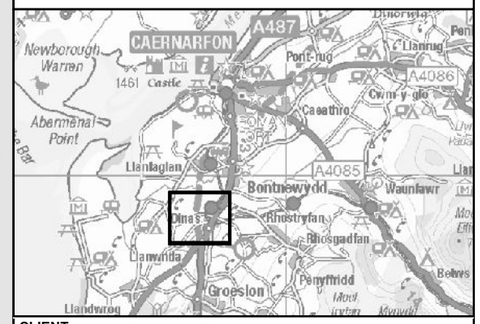
Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tafarn Hen
Tre Wyndaf
PW
Sta
Stone
Plas
Glan-rhyd
Cae-moel
PH
Wks
Sch
Llanwnda
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
PW
Garth-y-glo
Ael y Garth
Tel Ex
A487
Garth
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

PLOT TITLE:

MAXIMUM FLOOD HAZARD

50% AEP FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q2_DEV1_H	B

AREA OF INTEREST

PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

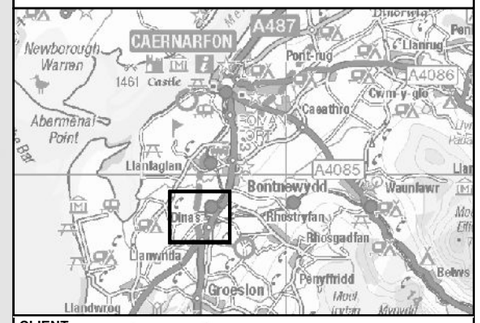
Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Y Wern
Hen Efail
Tre Wyndaf
PW
Sta
Tafarn Hen
Stone
Plas
Glan-rhyd
Cae-moel
PH
Wks
Sch
Llanwnda
Rhyd-y-felin
Felinwnda
Pont Henrhyd-isaf
Parc
Afon Rhyd
Tel Ex
Garth-y-glo
Ael y Garth
Garth
A487
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

PLOT TITLE:

MAXIMUM FLOOD HAZARD

20% AEP FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q5_DEV1_H	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

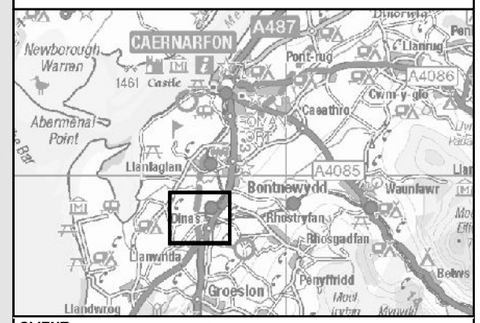
0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD HAZARD
10% AEP FLUVIAL EVENT
PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q10_DEV1_H	B

AREA OF INTEREST

PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

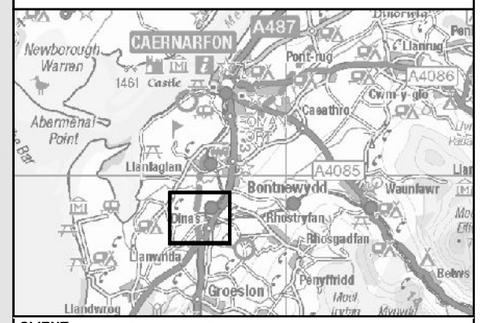
0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

PLOT TITLE:

MAXIMUM FLOOD HAZARD

5% AEP FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q20_DEV1_H	B

AREA OF INTEREST
PLOT SCALE @ A3: 1:2,000

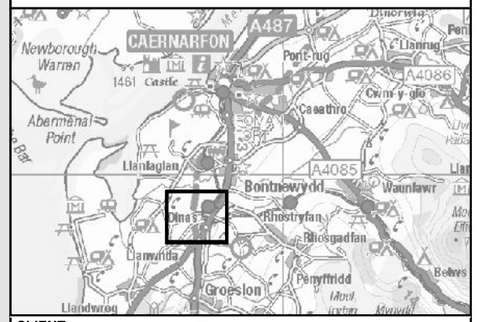
0 25 50 100 150 200 250 m

LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON RHYD CROSSING

PLOT TITLE:
MAXIMUM FLOOD HAZARD
1% AEP FLUVIAL EVENT
PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q100_DEV1_H	B

0 0.1 0.2 0.4 0.6 0.8 1 km

AREA OF INTEREST

PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

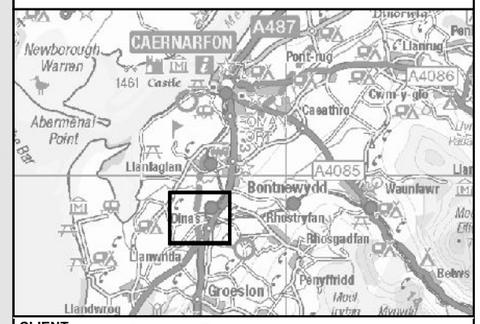
Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tafarn Hen
Tre Wyndaf
PW
Sta
Stone
Plas
Glan-rhyd
Cae-moel
PH
Wks
Sch
Llanwnda
Rhyd-y-felin
Felinwnda
Pont Henrhyd-isaf
Parc
Afon Rhyd
Tel Ex
Garth-y-glo
Ael y Garth
Garth
A487
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

PLOT TITLE:

MAXIMUM FLOOD HAZARD

1% AEP + CC FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q100CC_DEV1_H	B

AREA OF INTEREST

PLOT SCALE @ A3: 1:2,000

0 25 50 100 150 200 250 m

0 0.1 0.2 0.4 0.6 0.8 1 km

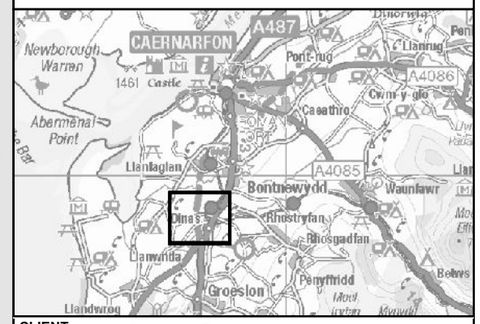
Plas Dinas Hotel
Reservoir (disused)
Dinas Farm
Geufron
Dinas Cottages
Depot
Hen Efail
Y Wern
Tre Wyndaf
Tafarn Hen
Stone
Plas
Glan-rhyd
Cae-moel
Llanwnda
Wks
Sch
Rhyd-y-felin
Felinwnda
Afon Rhyd
Parc
Pont Henrhyd-isaf
Garth-y-glo
Ael y Garth
Tel Ex
Garth
Tyddyn-bychan
Plas y coed
Maen-gwyn
Y Bryn
Gadlys
Gwylfa Farm

LEGEND

- Highway Alignment
- Culvert Underneath Proposed Highway
- 1D/2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON RHYD CROSSING

PLOT TITLE:

MAXIMUM FLOOD HAZARD

0.1% AEP FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	RCL	RCL	1:6,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
16/07/2015	w3172-RHYD_Q1000_DEV1_H	B

Appendix E – Tabulated 1D Maximum Water Levels

Proposed A487 Caernarfon and Bontnewydd - Afon Rhyd Crossing

Hydraulic Model Results - Afon Rhyd
1D ISIS Model Results - Maximum Water Levels (mAOD) and Depths (m)

Job Name: A487 Caernarfon and Bontnewydd Bypass
Job Number: w3172
Date: 23/11/15
Model Type: ISIS-TUFLOW
ISIS Build: 3.7
TUFLOW Build: 2013-12

Notes:

Waterco model build 015
Nodes highlighted in yellow are diverted as part of the proposed development

				EXISTING SITE LAYOUT (EXG)													
				Q2		Q5		Q10		Q20		Q100		Q100CC		Q1000	
	Node Label	Bed Elevation (mAOD)	Notable Features / Structures	Max WL (mAOD)	Max Flood Depth (m)	Max WL (mAOD)	Max Flood Depth (m)	Max WL (mAOD)	Max Flood Depth (m)	Max WL (mAOD)	Max Flood Depth (m)	Max WL (mAOD)	Max Flood Depth (m)	Max WL (mAOD)	Max Flood Depth (m)	Max WL (mAOD)	Max Flood Depth (m)
AFON RHYD	RHYD_2103	60.69		61.31	0.62	61.42	0.73	61.49	0.80	61.54	0.85	61.61	0.92	61.65	0.96	61.74	1.05
	RHYD_2083i	60.37		61.05	0.68	61.16	0.79	61.23	0.85	61.26	0.89	61.33	0.96	61.37	1.00	61.48	1.10
	RHYD_2063i	60.06		60.80	0.74	60.91	0.85	60.97	0.91	61.01	0.95	61.08	1.03	61.14	1.08	61.24	1.18
	RHYD_2043i	59.74		60.57	0.83	60.68	0.94	60.76	1.02	60.82	1.08	60.88	1.14	61.00	1.26	61.07	1.33
	RHYD_2024i	59.44		60.34	0.90	60.45	1.01	60.51	1.07	60.56	1.12	60.66	1.22	60.76	1.32	60.85	1.41
	RHYD_2004i	59.12		60.00	0.87	60.11	0.98	60.17	1.04	60.23	1.10	60.37	1.25	60.43	1.31	60.58	1.46
	RHYD_1985i	58.82		59.66	0.84	59.78	0.96	59.86	1.03	59.93	1.10	60.15	1.33	60.24	1.41	60.52	1.70
	RHYD_1978i	58.71		59.56	0.84	59.69	0.97	59.78	1.06	59.86	1.15	60.14	1.42	60.24	1.52	60.52	1.81
	RHYD_1971i	58.60		59.48	0.88	59.62	1.02	59.74	1.14	59.85	1.24	60.15	1.55	60.25	1.65	60.53	1.93
	RHYD_1957	58.38	Rhos Isaf Road bridge (U/S)	59.44	1.06	59.60	1.22	59.73	1.35	59.85	1.47	60.15	1.77	60.25	1.87	60.53	2.15
	RHYD_1939	58.38	Rhos Isaf Road bridge (D/S)	58.80	0.42	58.86	0.48	58.90	0.52	58.95	0.57	59.05	0.67	59.09	0.71	59.25	0.87
	RHYD_1935i	57.92		58.32	0.40	58.39	0.47	58.44	0.52	58.50	0.58	58.64	0.72	58.73	0.81	59.05	1.13
	RHYD_1931	57.46		57.97	0.51	58.08	0.62	58.16	0.70	58.25	0.78	58.46	1.00	58.58	1.12	58.93	1.47
	RHYD_1928u	57.07	Welsh Highland Railway bridge (U/S)	57.90	0.83	58.02	0.95	58.11	1.04	58.20	1.13	58.42	1.35	58.57	1.50	59.10	2.03
	RHYD_1928d	57.07	Welsh Highland Railway bridge (D/S)	57.84	0.77	57.93	0.86	57.99	0.92	58.06	0.98	58.23	1.16	58.38	1.31	58.82	1.75
	RHYD_1902i	56.84		57.59	0.75	57.69	0.84	57.75	0.91	57.81	0.97	57.96	1.11	58.05	1.21	58.34	1.50
	RHYD_1876i	56.61		57.32	0.70	57.42	0.80	57.48	0.87	57.54	0.93	57.70	1.09	57.81	1.20	58.11	1.50
	RHYD_1824i	56.16		56.90	0.74	57.00	0.85	57.08	0.92	57.15	0.99	57.37	1.21	57.52	1.36	57.93	1.77
	RHYD_1772	55.70		56.22	0.52	56.30	0.60	56.34	0.64	56.38	0.68	56.45	0.75	56.50	0.80	56.62	0.92
	RHYD_1728i	54.78		55.35	0.57	55.43	0.65	55.47	0.69	55.52	0.74	55.60	0.82	55.66	0.88	55.83	1.05
	RHYD_1684	53.86		54.51	0.65	54.58	0.72	54.62	0.76	54.66	0.80	54.74	0.88	54.80	0.94	54.98	1.12
	RHYD_1645i	53.13		53.72	0.59	53.80	0.67	53.86	0.73	53.91	0.78	54.02	0.89	54.10	0.97	54.35	1.22
	RHYD_1607i	52.42		53.08	0.66	53.22	0.80	53.30	0.88	53.38	0.96	53.55	1.13	53.65	1.23	53.97	1.55
	RHYD_1569	51.71	A487 Road culvert, Llandwnda (U/S)	52.94	1.23	53.12	1.41	53.21	1.50	53.30	1.59	53.46	1.75	53.57	1.86	53.88	2.17
	RHYD_1549	51.71	A487 Road culvert, Llandwnda (D/S)	52.87	1.16	53.02	1.31	53.10	1.39	53.18	1.47	53.31	1.60	53.39	1.68	53.54	1.83
	RHYD_1539i	51.64		52.85	1.21	53.00	1.36	53.08	1.43	53.15	1.51	53.28	1.64	53.36	1.72	53.56	1.92
	RHYD_1503	51.40	Concrete footbridge (not modelled)	51.90	0.50	51.98	0.58	52.02	0.62	52.06	0.66	52.15	0.75	52.21	0.81	52.36	0.96
	RHYD_1488i	50.64		51.09	0.45	51.17	0.53	51.22	0.58	51.26	0.62	51.36	0.72	51.42	0.78	51.61	0.97
	RHYD_1474	49.93	Concrete footbridge (not modelled)	50.63	0.70	50.74	0.81	50.80	0.87	50.86	0.93	50.97	1.04	51.05	1.12	51.27	1.34
	RHYD_1428i	49.55		50.41	0.87	50.50	0.95	50.55	1.01	50.60	1.05	50.69	1.15	50.75	1.20	50.85	1.30
	RHYD_1383	49.17	Cycle path bridge (U/S)	49.67	0.50	49.73	0.56	49.77	0.60	49.81	0.64	49.88	0.71	49.94	0.77	50.18	1.01
	RHYD_1377	49.17	Cycle path bridge (D/S)	49.67	0.50	49.73	0.56	49.77	0.60	49.81	0.63	49.88	0.71	49.93	0.76	50.17	1.00
	RHYD_1352i	48.44		48.91	0.48	48.98	0.54	49.01	0.58	49.05	0.61	49.11	0.67	49.14	0.71	49.17	0.73
	RHYD_1327i	47.70		48.17	0.46	48.23	0.52	48.26	0.56	48.29	0.59	48.36	0.66	48.41	0.71	48.61	0.91
	RHYD_1314i	47.32		47.77	0.45	47.83	0.51	47.86	0.55	47.90	0.58	47.96	0.64	48.01	0.69	48.15	0.84
	RHYD_1302i	46.97		47.45	0.48	47.50	0.54	47.53	0.57	47.56	0.59	47.61	0.64	47.64	0.67	47.73	0.77
	RHYD_1265i	45.88		46.28	0.40	46.33	0.45	46.36	0.49	46.40	0.52	46.47	0.59	46.53	0.65	46.67	0.79
	RHYD_1228	44.79	Glanrhyd Road bridge (U/S)	45.35	0.56	45.48	0.69	45.55	0.76	45.63	0.84	45.79	1.00	45.92	1.13	46.22	1.43
	RHYD_1220	44.79	Glanrhyd Road bridge (D/S)	45.25	0.46	45.31	0.52	45.34	0.55	45.37	0.58	45.43	0.64	45.48	0.69	45.55	0.76
	RHYD_1179i	43.95		44.43	0.48	44.49	0.54	44.53	0.57	44.56	0.61	44.63	0.68	44.68	0.73	44.75	0.80
	RHYD_1138i	43.11		43.64	0.53	43.70	0.59	43.74	0.63	43.77	0.66	43.81	0.70	43.85	0.74	43.95	0.84
	RHYD_1093	42.19	Start of proposed channel diversion	42.72	0.54	42.79	0.60	42.82	0.63	42.86	0.67	42.97	0.78	43.04	0.85	43.25	1.06
	RHYD_1057	41.45		42.05	0.60	42.12	0.67	42.16	0.71	42.21	0.76	42.33	0.88	42.41	0.96	42.63	1.18
	RHYD_1018i	40.93		41.52	0.59	41.59	0.66	41.63	0.70	41.69	0.76	41.80	0.87	41.88	0.95	42.09	1.16
	RHYD_979i	40.41		40.97	0.56	41.05	0.64	41.10	0.69	41.16	0.75	41.29	0.88	41.38	0.97	41.58	1.17
	RHYD_940	39.89	End of proposed channel diversion	40.49	0.60	40.59	0.70	40.65	0.76	40.73	0.84	40.89	1.00	40.99	1.10	41.16	1.27
	RHYD_916	39.57		40.42	0.84	40.53	0.96	40.60	1.03	40.69	1.12	40.87	1.30	40.98	1.41	41.17	1.60
	RHYD_904u	39.40	Weir (U/S) + metal footbridge (not modelled)	40.31	0.91	40.42	1.02	40.49	1.09	40.57	1.17	40.75	1.35	40.85	1.46	41.06	1.66
	RHYD_904d	38.20	Weir (D/S) + metal footbridge (not modelled)	39.16	0.96	39.28	1.08	39.35	1.15	39.44	1.24	39.65	1.45	39.78	1.58	40.15	1.95
	RHYD_892	38.20		38.92	0.72	39.03	0.83	39.10	0.90	39.19	0.98	39.38	1.18	39.51	1.31	39.95	1.75
	RHYD_880i	37.83		38.57	0.75	38.68	0.86	38.74	0.92	38.83	1.00	39.01	1.18	39.13	1.31	39.57	1.74
	RHYD_868	37.45	Iron footbridge (not modelled)	38.10	0.65	38.18	0.73	38.23	0.77	38.29	0.84	38.43	0.98	38.52	1.07	38.79	1.34
	RHYD_857i	37.17		37.61	0.44	37.67	0.50	37.71	0.54	37.76	0.59	37.87	0.70	37.95	0.78	38.20	1.02
	RHYD_847u	36.92	Wooden bridge (U/S)	37.33	0.41	37.40	0.48	37.44	0.52	37.50	0.58	37.63	0.70	37.71	0.79	37.99	1.07
	RHYD_847d	36.92	Wooden bridge (D/S)	37.30	0.38	37.36	0.44	37.39	0.47	37.44	0.52	37.54	0.62	37.60	0.68	37.79	0.87
	RHYD_789i	35.48		35.91	0.43	35.97	0.49	36.00	0.52	36.05	0.57	36.15	0.67	36.22	0.74	36.43	0.95
	RHYD_730i	34.01		34.46	0.45	34.54	0.52	34.58	0.57	34.64	0.63	34.78	0.76	34.86	0.85	35.11	1.10
	RHYD_672	32.57		33.13	0.56	33.21	0.64	33.25	0.67	33.31	0.73	33.43	0.86	33.52	0.95	33.74	1.17
	RHYD_611	31.24	Concrete bridge (U/S)	31.73	0.49	31.79	0.55	31.83	0.59	31.89	0.65	32.02	0.78	32.11	0.87	32.40	1.16
	RHYD_608	31.24	Concrete bridge (D/S)	31.72	0.48	31.79	0.55	31.82	0.58	31.87	0.63	31.98	0.74	32.05	0.81	32.27	1.03
	RHYD_561i	30.10		30.57	0.47	30.64	0.54	30.68	0.58	30.74	0.64	30.86	0.76	30.94	0.84	31.16	1.05
	RHYD_515	28.99		29.39	0.40	29.44	0.45	29.47	0.48	29.51	0.52	29.60	0.61	29.66	0.67	29.82	0.83
	RHYD_463i	26.75		27.08	0.33	27.13	0.38	27.16	0.41	27.20	0.44	27.29	0.53	27.34	0.59	27.51	0.75
	RHYD_410i	24.48		24.88	0.41	24.93	0.46	24.96	0.49	25.01	0.53	25.09	0.61	25.15	0.67	25.31	0.83
	RHYD_357i	22.20		22.51	0.31	22.55	0.35	22.58	0.38	22.62	0.42	22.69	0.49	22.74	0.55	22.89	0.69
	RHYD_305	19.96		20.41	0.45	20.47	0.50	20.50	0.54	20.54	0.58	20.65	0.69	20.71	0.75	20.92	0.95
	RHYD_247i	18.90		19.35	0.45	19.42	0.53	19.47	0.57	19.52	0.63	19.66	0.76	19.75	0.85	20.00	1.10
	RHYD_190	17.85		18.54	0.69	18.59	0.74	18.62	0.77	18.66	0.81	18.75	0.90	18.81	0.96	18.95	1.10
	RHYD_185	18.00		18.32	0.32	18.37	0.37	18.41	0.41	18.45	0.45	18.55	0.55	18.62	0.62	18.80	0.80
	RHYD_176	17.26	Wooden footbridge (not modelled)	17.74	0.48	17.82	0.56	17.87	0.61	17.96	0.70	18.09	0.83	18.17	0.91	18.40	1.14
	RHYD_168	16.75		17.43	0.68	17.51	0.76	17.56	0.81	17.66	0.91	17.79	1.04	17.87	1.12	18.16	1.41
	RHYD_156u	16.61	Felinwnda Road bridge (U/S)	17.16	0.55	17.23	0.62	17.27	0.66	17.33	0.72	17.47	0.86	17.56	0.95	17.97	1.36
	RHYD_156d	16.61	Felinwnda Road bridge (D/S)	17.15	0.54	17.23	0.62	17.27	0.66	17.33	0.72	17.47	0.86	17.56	0.95	17.78	1.17
	RHYD_104i	15.70		16.27	0.57	16.35	0.65	16.39	0.69	16.46	0.76	16.60	0.90	16.70	1.00	16.93	1.23
	RHYD_52i	14.79		15.40	0.61	15.49	0.70	15.54	0.75	15.61	0.82	15.76	0.97	15.85	1.06	16.06	1.27
	RHYD_0	13.88		14.52	0.64	14.61	0.73	14.66	0.78	14.73	0.85	14.89	1.01	14.98	1.10	15.20	1.32
DIVERSION	DIV_119	42.20		-	-	-	-	-	-	-	-	-	-	-	-	-	-
	DIV_98	41.83	Proposed riffle	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	DIV_90	41.70		-	-	-	-	-	-	-	-	-	-	-	-	-	-
	DIV_55	41.09	Proposed culvert under new carriageway (U/S)	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Proposed A487 Caernarfon and Bontnewydd - Afon Rhyd Crossing

Hydraulic Model Results - Afon Rhyd
1D ISIS Model Results - Maximum Water Levels (mAOD) and Depths (m)

Job Name: A487 Caernarfon and Bontnewydd Bypass
Job Number: w3172
Date: 23/11/15
Model Type: ISIS-TUFLOW
ISIS Build: 3.7
TUFLOW Build: 2013-12

Notes:

Waterco model build 015
Nodes highlighted in yellow are diverted as part of the proposed development

				POST-DEVELOPMENT SITE LAYOUT 1 (DEV1)																				
				Q2			Q5			Q10			Q20			Q100			Q100CC			Q1000		
	Node Label	Bed Elevation (mAOD)	Notable Features / Structures	Max WL (mAOD)	Max Flood Depth (m)	WL Diff vs EXG (m)	Max WL (mAOD)	Max Flood Depth (m)	WL Diff vs EXG (m)	Max WL (mAOD)	Max Flood Depth (m)	WL Diff vs EXG (m)	Max WL (mAOD)	Max Flood Depth (m)	WL Diff vs EXG (m)	Max WL (mAOD)	Max Flood Depth (m)	WL Diff vs EXG (m)	Max WL (mAOD)	Max Flood Depth (m)	WL Diff vs EXG (m)	Max WL (mAOD)	Max Flood Depth (m)	WL Diff vs EXG (m)
AFON RHYD	RHYD_2103	60.69		61.31	0.62	0.00	61.42	0.73	0.00	61.49	0.80	0.00	61.54	0.85	0.00	61.61	0.92	0.00	61.65	0.96	0.00	61.74	1.05	0.00	
	RHYD_2083i	60.37		61.05	0.68	0.00	61.16	0.79	0.00	61.23	0.85	0.00	61.26	0.89	0.00	61.33	0.96	0.00	61.37	1.00	0.00	61.48	1.10	0.00	
	RHYD_2063i	60.06		60.80	0.74	0.00	60.91	0.85	0.00	60.97	0.91	0.00	61.01	0.95	0.00	61.08	1.03	0.00	61.14	1.08	0.00	61.24	1.18	0.00	
	RHYD_2043i	59.74		60.57	0.83	0.00	60.68	0.94	0.00	60.76	1.02	0.00	60.82	1.08	0.00	60.88	1.14	0.00	60.90	1.26	0.00	61.07	1.33	0.00	
	RHYD_2024i	59.44		60.34	0.90	0.00	60.45	1.01	0.00	60.51	1.07	0.00	60.56	1.12	0.00	60.66	1.22	0.00	60.76	1.32	0.00	60.85	1.41	0.00	
	RHYD_2004i	59.12		60.00	0.87	0.00	60.11	0.98	0.00	60.17	1.04	0.00	60.23	1.10	0.00	60.37	1.25	0.00	60.43	1.31	0.00	60.53	1.46	0.00	
	RHYD_1985i	58.82		59.66	0.84	0.00	59.78	0.96	0.00	59.86	1.03	0.00	59.93	1.10	0.00	60.15	1.33	0.00	60.24	1.41	0.00	60.52	1.70	0.00	
	RHYD_1978i	58.71		59.56	0.84	0.00	59.69	0.97	0.00	59.78	1.06	0.00	59.86	1.15	0.00	60.14	1.42	0.00	60.24	1.52	0.00	60.52	1.81	0.00	
	RHYD_1971i	58.60		59.48	0.88	0.00	59.62	1.02	0.00	59.74	1.14	0.00	59.85	1.24	0.00	60.15	1.55	0.00	60.25	1.65	0.00	60.53	1.93	0.00	
	RHYD_1957	58.38	Rhos Isaf Road bridge (U/S)	59.44	1.06	0.00	59.60	1.22	0.00	59.73	1.35	0.00	59.85	1.47	0.00	60.15	1.77	0.00	60.25	1.87	0.00	60.53	2.1	5	0.00
	RHYD_1939	58.38	Rhos Isaf Road bridge (D/S)	58.80	0.42	0.00	58.86	0.48	0.00	58.90	0.52	0.00	58.95	0.57	0.00	59.03	0.67	0.00	59.09	0.71	0.00	59.25	0.8	7	0.00
	RHYD_1935i	57.92		58.32	0.40	0.00	58.39	0.47	0.00	58.44	0.52	0.00	58.50	0.58	0.00	58.64	0.72	0.00	58.73	0.81	0.00	59.05	1.13	0.00	
	RHYD_1931	57.46		57.97	0.51	0.00	58.08	0.62	0.00	58.16	0.70	0.00	58.25	0.78	0.00	58.46	1.00	0.00	58.58	1.12	0.00	58.93	1.47	0.00	
	RHYD_1928u	57.07	Welsh Highland Railway bridge (U/S)	57.90	0.83	0.00	58.02	0.95	0.00	58.11	1.04	0.00	58.20	1.13	0.00	58.42	1.35	0.00	58.57	1.50	0.0	0	59.10	2.03	0.00
	RHYD_1928d	57.07	Welsh Highland Railway bridge (D/S)	57.84	0.77	0.00	57.93	0.86	0.00	57.99	0.92	0.00	58.06	0.98	0.00	58.23	1.16	0.00	58.38	1.31	0.0	0	58.82	1.75	0.00
	RHYD_1902i	56.84		57.59	0.75	0.00	57.69	0.84	0.00	57.75	0.91	0.00	57.81	0.97	0.00	57.96	1.11	0.00	58.05	1.21	0.00	58.34	1.50	0.00	
	RHYD_1876i	56.61		57.32	0.70	0.00	57.42	0.80	0.00	57.48	0.87	0.00	57.54	0.93	0.00	57.70	1.09	0.00	57.81	1.20	0.00	58.1	1.50	0.00	
	RHYD_1824i	56.16		56.90	0.74	0.00	57.00	0.85	0.00	57.08	0.92	0.00	57.15	0.99	0.00	57.37	1.21	0.00	57.52	1.36	0.00	57.93	1.77	0.00	
	RHYD_1772	55.70		56.22	0.52	0.00	56.30	0.60	0.00	56.34	0.64	0.00	56.38	0.68	0.00	56.45	0.75	0.00	56.50	0.80	0.00	56.62	0.92	0.00	
	RHYD_1728i	54.78		55.35	0.57	0.00	55.43	0.65	0.00	55.47	0.69	0.00	55.52	0.74	0.00	55.60	0.82	0.00	55.66	0.88	0.00	55.83	1.05	0.00	
	RHYD_1684	53.86		54.51	0.65	0.00	54.58	0.72	0.00	54.62	0.76	0.00	54.66	0.80	0.00	54.74	0.88	0.00	54.80	0.94	0.00	54.98	1.12	0.00	
	RHYD_1645i	53.13		53.72	0.59	0.00	53.80	0.67	0.00	53.86	0.73	0.00	53.91	0.78	0.00	54.02	0.89	0.00	54.10	0.97	0.00	54.35	1.22	0.00	
	RHYD_1607i	52.42		53.08	0.66	0.00	53.22	0.80	0.00	53.30	0.88	0.00	53.38	0.96	0.00	53.55	1.13	0.00	53.65	1.23	0.00	53.97	1.55	0.00	
	RHYD_1569	51.71	A487 Road culvert, Llandwnda (U/S)	52.94	1.23	0.00	53.12	1.41	0.00	53.21	1.50	0.00	53.30	1.59	0.00	53.46	1.75	0.00	53.57	1.86	0.00	5	3.88	2.17	0.00
	RHYD_1549	51.71	A487 Road culvert, Llandwnda (D/S)	52.87	1.16	0.00	53.02	1.31	0.00	53.10	1.39	0.00	53.18	1.47	0.00	53.3	1.60	0.00	53.39	1.68	0.00	5	3.54	1.83	0.00
	RHYD_1539i	51.64		52.85	1.21	0.00	53.00	1.36	0.00	53.08	1.43	0.00	53.15	1.51	0.00	53.28	1.64	0.00	53.36	1.72	0.00	53.56	1.92	0.00	
	RHYD_1503	51.40	Concrete footbridge (not modelled)	51.90	0.50	0.00	51.98	0.58	0.00	52.02	0.62	0.00	52.06	0.66	0.00	52.15	0.75	0.00	52.21	0.81	0.00	5	2.36	0.96	0.00
	RHYD_1488i	50.64		51.09	0.45	0.00	51.17	0.53	0.00	51.22	0.58	0.00	51.26	0.62	0.00	51.36	0.72	0.00	51.42	0.78	0.00	51.6	0.97	0.00	
	RHYD_1474	49.93	Concrete footbridge (not modelled)	50.63	0.70	0.00	50.74	0.81	0.00	50.80	0.87	0.00	50.86	0.93	0.00	50.97	1.04	0.00	51.05	1.12	0.00	5	1.27	1.34	0.00
	RHYD_1428i	49.55		50.41	0.87	0.00	50.50	0.95	0.00	50.55	1.01	0.00	50.60	1.05	0.00	50.69	1.15	0.00	50.75	1.20	0.00	50.85	1.30	0.00	
	RHYD_1383	49.17	Cycle path bridge (U/S)	49.67	0.50	0.00	49.73	0.56	0.00	49.77	0.60	0.00	45.81	0.64	0.00	49.88	0.71	0.00	49.94	0.77	0.00	50.18	1.01	0.0	0
	RHYD_1377	49.17	Cycle path bridge (D/S)	49.67	0.50	0.00	49.73	0.56	0.00	49.77	0.60	0.00	45.81	0.63	0.00	49.88	0.71	0.00	49.93	0.76	0.00	50.17	1.00	0.0	0
	RHYD_1352i	48.44		48.91	0.48	0.00	48.98	0.54	0.00	49.01	0.58	0.00	49.05	0.61	0.00	49.11	0.67	0.00	49.14	0.71	0.00	49.17	0.73	0.00	
	RHYD_1327i	47.70		48.17	0.46	0.00	48.23	0.52	0.00	48.26	0.56	0.00	48.29	0.59	0.00	48.36	0.66	0.00	48.41	0.71	0.00	48.6	0.91	0.00	
	RHYD_1314i	47.32		47.77	0.45	0.00	47.83	0.51	0.00	47.86	0.55	0.00	47.90	0.58	0.00	47.96	0.64	0.00	48.01	0.69	0.00	48.15	0.84	0.00	
	RHYD_1302i	46.97		47.45	0.48	0.00	47.51	0.54	0.00	47.53	0.57	0.00	47.56	0.59	0.00	47.61	0.64	0.00	47.64	0.67	0.00	47.72	0.77	0.00	
	RHYD_1265i	45.88		46.28	0.40	0.00	46.33	0.45	0.00	46.36	0.49	0.00	46.40	0.52	0.00	46.47	0.59	0.00	46.53	0.65	0.00	46.67	0.79	0.00	
	RHYD_1228	44.79	Glanrhyd Road bridge (U/S)	45.34	0.55	-0.02	45.47	0.68	-0.01	45.55	0.76	-0.01	45.63	0.84	0.00	45.79	1.00	0.00	45.92	1.13	0.00	46.22	1	.43	0.00
	RHYD_1220	44.79	Glanrhyd Road bridge (D/S)	45.24	0.45	-0.01	45.30	0.51	-0.01	45.34	0.55	-0.01	45.37	0.58	-0.01	45.44	0.65	0.00	45.48	0.69	0.00	45.56		0.77	0.00
	RHYD_1179i	43.95		44.45	0.50	0.02	44.51	0.56	0.02	44.54	0.59	0.01	44.57	0.62	0.01	44.63	0.68	0.00	44.67	0.72	0.00	44.73	0.78	-0.01	
	RHYD_1138i	43.11		43.61	0.50	-0.04	43.67	0.56	-0.03	43.71	0.60	-0.03	43.74	0.63	-0.03	43.81	0.70	0.00	43.86	0.75	0.01	44.00	0.89	0.05	
	RHYD_1093	42.19	Start of proposed channel diversion	42.99	0.80	0.26	43.08	0.89	0.29	43.13	0.94	0.31	43.17	0.98	0.31	43.26	1.08	0.30	43.33	1.14	0.29		43.57	1.38	0.32
	RHYD_1057	41.45		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	RHYD_1018i	40.93		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	RHYD_979i	40.41		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	RHYD_940	39.89	End of proposed channel diversion	40.49	0.60	0.00	40.59	0.70	0.00	40.65	0.76	0.00	40.73	0.84	0.00	40.89	1.00	0.00	40.99	1.10	0.00	41.	16	1.27	0.00
	RHYD_916	39.57		40.42	0.84	0.00	40.53	0.96	0.00	40.60	1.03	0.00	40.69	1.12	0.00	40.87	1.30	0.00	40.98	1.41	0.00	41.18	1.61	0.00	
	RHYD_904u	39.40	Weir (U/S) + metal footbridge (not modelled)	40.31	0.91	0.00	40.42	1.02	0.00	40.49	1.09	0.00	40.57	1.17	0.00	40.75	1.35	0.00	40.8	6	1.46	0.00	41.07	1.67	0.01
	RHYD_904d	38.20	Weir (D/S) + metal footbridge (not modelled)	39.16	0.96	0.00	39.28	1.08	0.00	39.35	1.15	0.00	39.45	1.25	0.00	39.65	1.45	0.00	39.7	8	1.58	0.00	40.16	1.96	0.01
	RHYD_892	38.20		38.92	0.72	0.00	39.03	0.83	0.00	39.10	0.90	0.00	39.19	0.99	0.00	39.38	1.18	0.00	39.51	1.31	0.00	39.96	1.76	0.01	
	RHYD_880i	37.83		38.57	0.75	0.00	38.68	0.86	0.00	38.74	0.92	0.00	38.83	1.00	0.00	39.01	1.18	0.00	39.13	1.31	0.00	39.58	1.75	0.01	
	RHYD_868	37.45	Iron footbridge (not modelled)	38.10	0.65	0.00	38.18	0.73	0.00	38.23	0.77	0.00	38.29	0.84	0.00	38.43	0.98	0.00	38.52	1.07	0.00	38.79	1	.34	0.01
	RHYD_857i	37.17		37.61	0.44	0.00	37.67	0.50	0.00	37.71	0.54	0.00	37.76	0.59	0.00	37.88	0.70	0.00	37.95	0.78	0.00	38.20	1.03	0.01	
	RHYD_847u	36.92	Wooden bridge (U/S)	37.33	0.41	0.00	37.40	0.48	0.00	37.44	0.52	0.00	37.50	0.58	0.00	37.63	0.70	0.00	37.71	0.79	0.00	37.99	1.07	0.01	
	RHYD_847d	36.92	Wooden bridge (D/S)	37.30	0.38	0.00	37.36	0.44	0.00	37.39	0.47	0.00	37.44	0.52	0.00	37.54	0.62	0.00	37.60	0.68	0.00	37.80	0.88	0.00	
	RHYD_789i	35.48		35.91	0.43	0.00	35.97	0.49	0.00	36.00	0.52	0.00	36.05	0.57	0.00	36.15	0.67	0.00	36.22	0.74	0.00	36.43	0.95	0.01	
	RHYD_730i	34.01		34.46	0.45	0.00	34.54	0.52	0.00	34.58	0.57	0.00	34.64	0.63	0.00	34.78	0.76	0.00	34.87	0.85	0.00	35.12	1.11	0.01	
	RHYD_672	32.57		33.13	0.56	0.00	33.21	0.64	0.00	33.25	0.67	0.00	33.31	0.74	0.00	33.43	0.86	0.00	33.52	0.95	0.00	33.74	1.17	0.00	
	RHYD_611	31.24	Concrete bridge (U/S)	31.73	0.49	0.00	31.79	0.55	0.00	31.83	0.59	0.00	31.89	0.65	0.00	32.02	0.78	0.00	32.11	0.87	0.00	32.41	1.17	0.01	
	RHYD_608	31.24	Concrete bridge (D/S)	31.72	0.48	0.00	31.79	0.55	0.00	31.82	0.58	0.00	31.87	0.63	0.00	31.98	0.74	0.00	32.05	0.81	0.00	32.27	1.03	0.01	
	RHYD_561i	30.10		30.57	0.47	0.00	30.64	0.54	0.00	30.68	0.58	0.00	30.74	0.64	0.00	30.86	0.76	0.00	30.94	0.84	0.00	31.16	1.06	0.00	
	RHYD_515	28.99		29.39	0.40	0.00	29.44	0.45	0.00	29.47	0.48	0.00	29.51	0.52	0.00	29.60	0.61	0.00	29.66	0.67	0.00	29.83	0.84	0.00	
	RHYD_463i	26.75		27.08	0.33	0.00	27.13	0.38	0.00	27.16	0.41	0.00	27.20	0.44	0.00	27.29	0.53	0.00	27.34	0.59	0.00	27.5	0.76	0.00	
	RHYD_410i	24.48		24.88	0.41	0.00	24.93	0.46	0.00	24.96	0.49	0.00	25.01	0.53	0.00	25.09	0.62	0.00	25.15	0.67	0.00	25.3	0.84	0.00	
	RHYD_357i	22.20		22.51	0.31	0.00	22.55	0.35	0.00	22.58	0.38	0.00	22.62	0.42	0.00	22.69	0.49	0.00	22.75	0.55	0.00	22.89	0.70	0.00	
	RHYD_305	19.96		20.41	0.45	0.00	20.47	0.50	0.00	20.50	0.54	0.00	20.54	0.58	0.00	20.65	0.69	0.00	20.72	0.75	0.00	20.92	0.96	0.01	
	RHYD_247i	18.90		19.35	0.45	0.00	19.42	0.53	0.00	19.47	0.57	0.00	19.52	0.63	0.00	19.66	0.76	0.00	19.75	0.85	0.00	20.0	1.11	0.01	
	RHYD_190	17.85		18.54	0.69	0.00	18.59	0.74	0.00	18.62	0.77	0.00	18.66	0.81	0.00	18.75	0.90	0.00	18.81	0.96	0.00	18.95	1.10	0.00	
	RHYD_185	18.00		18.32	0.32	0.00	18.37	0.37	0.00	18.41	0.41	0.00	18.45	0.45	0.00	18.55	0.55	0.00	18.62	0.62	0.00	18.8	0.81	0.00	
	RHYD_176	17.26	Wooden footbridge (not modelled)	17.74	0.48	0.00	17.82	0.56	0.00	17.87	0.61	0.00	17.96	0.70	0.00	18.09	0.83	0.00	18.17	0.91	0.00	18.4	1	1.15	0.00
	RHYD_168	16.75		17.43	0.68	0.00	17.51	0.76	0.00	17.56	0.81	0.00	17.66	0.91	0.00	17.79	1.04	0.00	17.87	1.12	0.00	18.16	1.41	0.01	
	RHYD_156u	16.61	Felinwnda Road bridge (U/S)	17.16	0.55	0.00	17.23	0.62	0.00	17.27	0.66	0.00	17.33	0.72	0.00	17.47	0.86	0.00	17.56	0.95	0.00	17.98	1.3	7	0.01
	RHYD_156d	16.61	Felinwnda Road bridge (D/S)	17.15	0.54	0.00	17.23	0.62	0.00	17.27	0.66	0.00	17.33	0.72	0.00	17.47	0.86	0.00	17.56	0.95	0.00	17.78	1.1	7	0.00
	RHYD_104i	15.70		16.27	0.57	0.00	16.35	0.65	0.00	16.39	0.69	0.00	16.46	0.76	0.00	16.60	0.90	0.00	16.70	1.00	0.00	16.93	1.23	0.00	
	RHYD_52i	14.79		15.40	0.61	0.00	15.49	0.70	0.00	15.54	0.75	0.00	15.61	0.82	0.00	15.76	0.97	0.00	15.85	1.06	0.00	16.06	1.27	0.00	
	RHYD_0	13.88		14.52	0.64	0.00	14.61	0.73	0.00	14.66	0.78	0.00	14.73	0.85	0.00	14.89	1.01	0.00	14.98	1.10	0.00	15.20	1.32	0.00	
DIVERSION	DIV_119	42.20		42.88	0.68	-	42.96	0.76	-	43.01	0.81	-	43.06	0.86	-	43.14	0.94	-	43.20	1.00	-	43.45	1.25	-	
	DIV_98	41.83	Proposed riffle	42.55	0.72	-	42.63	0.79	-	42.67	0.83	-	42.73	0.90	-	42.86	1.03	-	42.96	1.13	-	43.35	1.52	-	
	DIV_90	41.70		42.35	0.66	-	42.43	0.73	-	42.48	0.78	-	42.55	0.86	-	42.74	1.05	-	42.88	1.18	-	43.33	1.63	-	
	DIV_55	41.09	Proposed culvert under new carriageway (U/S)	41.79	0.70	-	41.93	0.85	-	42.02	0.93	-	42.13	1.05	-	42.40	1.31	-	42.57	1.49	-	43.19	2.11	-	

Proposed A487 Caernarfon and Bontnewydd - Afon Rhyd Crossing

Hydraulic Model Results - Afon Rhyd
1D ISIS Model Results - Maximum Water Levels (mAOD) and Depths (m)

Job Name: A487 Caernarfon and Bontnewydd Bypass
Job Number: w3172
Date: 23/11/15
Model Type: ISIS-TUFLOW
ISIS Build: 3.7
TUFLOW Build: 2013-12

Notes:

Waterco model build 015
Nodes highlighted in yellow are diverted as part of the proposed development

				SENSITIVITY TESTING (vs Q100CC/EXG)																
				EXG	ST1 (Mannings n +20%)			ST2 (Mannings n -20%)			ST3 (DSBC Slope +20%)			ST4 (DSBC Slope -20%)			ST5 (Glan Rhyd Rd 67% blockage)		
	Node Label	Bed Elevation (mAOD)	Notable Features / Structures	Max WL (mAOD)	Max WL (mAOD)	Max Flood Depth (m)	WL Diff vs EXG (m)	Max WL (mAOD)	Max Flood Depth (m)	WL Diff vs EXG (m)	Max WL (mAOD)	Max Flood Depth (m)	WL Diff vs EXG (m)	Max WL (mAOD)	Max Flood Depth (m)	WL Diff vs EXG (m)	Max WL (mAOD)	Max Flood Depth (m)	WL Diff vs EXG (m)
AFON RHYD	RHYD_2103	60.69		61.65	61.69	1.00	0.04	61.61	0.92	-0.04	61.65	0.96	0.00	61.65	0.96	0.00	61.65	0.96	0.00
AFON RHYD	RHYD_2083i	60.37		61.37	61.41	1.04	0.04	61.32	0.95	-0.05	61.37	1.00	0.00	61.37	1.00	0.00	61.37	1.00	0.00
AFON RHYD	RHYD_2063i	60.06		61.14	61.19	1.13	0.05	61.07	1.02	-0.06	61.14	1.08	0.00	61.14	1.08	0.00	61.14	1.08	0.00
AFON RHYD	RHYD_2043i	59.74		61.00	61.02	1.28	0.03	60.87	1.13	-0.13	61.00	1.26	0.00	61.00	1.26	0.00	61.00	1.26	0.00
AFON RHYD	RHYD_2024i	59.44		60.76	60.80	1.36	0.04	60.65	1.21	-0.11	60.76	1.32	0.00	60.76	1.32	0.00	60.76	1.32	0.00
AFON RHYD	RHYD_2004i	59.12		60.43	60.47	1.35	0.04	60.38	1.25	-0.05	60.43	1.31	0.00	60.43	1.31	0.00	60.43	1.31	0.00
AFON RHYD	RHYD_1985i	58.82		60.24	60.26	1.44	0.03	60.21	1.39	-0.03	60.24	1.41	0.00	60.24	1.41	0.00	60.24	1.41	0.00
AFON RHYD	RHYD_1978i	58.71		60.24	60.25	1.53	0.01	60.22	1.51	-0.01	60.24	1.52	0.00	60.24	1.52	0.00	60.24	1.52	0.00
AFON RHYD	RHYD_1971i	58.60		60.25	60.25	1.65	0.00	60.25	1.65	0.00	60.25	1.65	0.00	60.25	1.65	0.00	60.25	1.65	0.00
AFON RHYD	RHYD_1957	58.38	Rhos Isaf Road bridge (U/S)	60.25	60.24	1.86	-0.01	60.25	1.87	0.00	60.25	1.87	0.00	60.25	1.87	0.00	60.25	1.87	0.00
AFON RHYD	RHYD_1939	58.38	Rhos Isaf Road bridge (D/S)	59.09	59.16	0.78	0.07	59.00	0.62	-0.09	59.09	0.71	0.00	59.09	0.71	0.00	59.09	0.71	0.00
AFON RHYD	RHYD_1935i	57.92		58.73	58.78	0.86	0.05	58.67	0.74	-0.07	58.73	0.81	0.00	58.73	0.81	0.00	58.73	0.81	0.00
AFON RHYD	RHYD_1931	57.46		58.58	58.60	1.14	0.03	58.52	1.06	-0.06	58.58	1.12	0.00	58.58	1.12	0.00	58.58	1.12	0.00
AFON RHYD	RHYD_1928u	57.07	Welsh Highland Railway bridge (U/S)	58.57	58.63	1.56	0.06	58.49	1.42	-0.08	58.57	1.50	0.00	58.57	1.50	0.00	58.57	1.50	0.00
AFON RHYD	RHYD_1928d	57.07	Welsh Highland Railway bridge (D/S)	58.38	58.46	1.39	0.08	58.27	1.20	-0.11	58.38	1.31	0.00	58.38	1.31	0.00	58.38	1.31	0.00
AFON RHYD	RHYD_1902i	56.84		58.05	58.17	1.33	0.12	57.95	1.10	-0.10	58.05	1.21	0.00	58.05	1.21	0.00	58.05	1.21	0.00
AFON RHYD	RHYD_1876i	56.61		57.81	57.94	1.33	0.13	57.72	1.10	-0.09	57.81	1.20	0.00	57.81	1.20	0.00	57.81	1.20	0.00
AFON RHYD	RHYD_1824i	56.16		57.52	57.63	1.48	0.12	57.37	1.22	-0.14	57.52	1.36	0.00	57.52	1.36	0.00	57.52	1.36	0.00
AFON RHYD	RHYD_1772	55.70		56.50	56.57	0.87	0.07	56.42	0.72	-0.08	56.50	0.80	0.00	56.50	0.80	0.00	56.50	0.80	0.00
AFON RHYD	RHYD_1728i	54.78		55.66	55.71	0.93	0.05	55.60	0.81	-0.06	55.66	0.88	0.00	55.66	0.88	0.00	55.66	0.88	0.00
AFON RHYD	RHYD_1684	53.86		54.80	54.86	1.00	0.06	54.73	0.87	-0.06	54.80	0.94	0.00	54.80	0.94	0.00	54.80	0.94	0.00
AFON RHYD	RHYD_1645i	53.13		54.10	54.14	1.01	0.04	54.02	0.89	-0.08	54.10	0.97	0.00	54.10	0.97	0.00	54.10	0.97	0.00
AFON RHYD	RHYD_1607i	52.42		53.65	53.74	1.32	0.09	53.55	1.13	-0.10	53.65	1.23	0.00	53.65	1.23	0.00	53.65	1.23	0.00
AFON RHYD	RHYD_1569	51.71	A487 Road culvert, Llandwnda (U/S)	53.57	53.62	1.91	0.05	53.52	1.81	-0.05	53.57	1.86	0.00	53.57	1.86	0.00	53.57	1.86	0.00
AFON RHYD	RHYD_1549	51.71	A487 Road culvert, Llandwnda (D/S)	53.39	53.47	1.76	0.08	53.30	1.59	-0.09	53.39	1.68	0.00	53.39	1.68	0.00	53.39	1.68	0.00
AFON RHYD	RHYD_1539i	51.64		53.36	53.44	1.80	0.08	53.27	1.63	-0.09	53.36	1.72	0.00	53.36	1.72	0.00	53.36	1.72	0.00
AFON RHYD	RHYD_1503	51.40	Concrete footbridge (not modelled)	52.21	52.26	0.86	0.06	52.14	0.74	-0.07	52.21	0.81	0.00	52.21	0.81	0.00	52.21	0.81	0.00
AFON RHYD	RHYD_1488i	50.64		51.42	51.49	0.85	0.07	51.35	0.71	-0.07	51.42	0.78	0.00	51.42	0.78	0.00	51.42	0.78	0.00
AFON RHYD	RHYD_1474	49.93	Concrete footbridge (not modelled)	51.05	51.15	1.22	0.09	50.97	1.04	-0.08	51.05	1.12	0.00	51.05	1.12	0.00	51.05	1.12	0.00
AFON RHYD	RHYD_1428i	49.55		50.75	50.81	1.27	0.06	50.68	1.13	-0.07	50.75	1.20	0.00	50.75	1.20	0.00	50.75	1.20	0.00
AFON RHYD	RHYD_1383	49.17	Cycle path bridge (U/S)	49.94	49.98	0.81	0.05	49.88	0.71	-0.05	49.94	0.77	0.00	49.94	0.77	0.00	49.94	0.77	0.00
AFON RHYD	RHYD_1377	49.17	Cycle path bridge (D/S)	49.93	49.98	0.81	0.05	49.88	0.70	-0.06	49.93	0.76	0.00	49.93	0.76	0.00	49.93	0.76	0.00
AFON RHYD	RHYD_1352i	48.44		49.14	49.18	0.74	0.04	49.10	0.67	-0.04	49.14	0.71	0.00	49.14	0.71	0.00	49.14	0.71	0.00
AFON RHYD	RHYD_1327i	47.70		48.41	48.45	0.75	0.04	48.36	0.65	-0.05	48.41	0.71	0.00	48.41	0.71	0.00	48.41	0.71	0.00
AFON RHYD	RHYD_1314i	47.32		48.01	48.05	0.73	0.04	47.96	0.64	-0.05	48.01	0.69	0.00	48.01	0.69	0.00	48.01	0.69	0.00
AFON RHYD	RHYD_1302i	46.97		47.64	47.69	0.72	0.05	47.60	0.63	-0.04	47.64	0.67	0.00	47.64	0.67	0.00	47.61	0.65	-0.03
AFON RHYD	RHYD_1265i	45.88		46.53	46.55	0.67	0.02	46.48	0.60	-0.05	46.53	0.65	0.00	46.53	0.65	0.00	46.62	0.74	0.10
AFON RHYD	RHYD_1228	44.79	Glanrhyd Road bridge (U/S)	45.92	45.88	1.09	-0.04	45.86	1.07	-0.06	45.92	1.13	0.00	45.92	1.13	0.00	46.39	1.60	0.47
AFON RHYD	RHYD_1220	44.79	Glanrhyd Road bridge (D/S)	45.48	45.52	0.73	0.04	45.43	0.64	-0.05	45.48	0.69	0.00	45.48	0.69	0.00	45.36	0.56	-0.12
AFON RHYD	RHYD_1179i	43.95		44.68	44.72	0.77	0.04	44.63	0.68	-0.05	44.68	0.73	0.00	44.68	0.73	0.00	44.51	0.56	-0.17
AFON RHYD	RHYD_1138i	43.11		43.85	43.89	0.78	0.04	43.81	0.70	-0.04	43.85	0.74	0.00	43.85	0.74	0.00	43.82	0.71	-0.03
AFON RHYD	RHYD_1093	42.19	Start of proposed channel diversion	43.04	43.07	0.89	0.04	42.97	0.78	-0.07	43.04	0.85	0.00	43.04	0.85	0.00	43.04	0.85	0.00
AFON RHYD	RHYD_1057	41.45		42.41	42.49	1.04	0.08	42.32	0.87	-0.09	42.41	0.96	0.00	42.41	0.96	0.00	42.41	0.96	0.00
AFON RHYD	RHYD_1018i	40.93		41.88	41.96	1.03	0.09	41.79	0.85	-0.09	41.88	0.95	0.00	41.88	0.95	0.00	41.88	0.95	0.00
AFON RHYD	RHYD_979i	40.41		41.38	41.44	1.03	0.07	41.29	0.88	-0.08	41.38	0.97	0.00	41.38	0.97	0.00	41.37	0.96	0.00
AFON RHYD	RHYD_940	39.89	End of proposed channel diversion	40.99	41.04	1.15	0.05	40.96	1.07	-0.03	40.99	1.10	0.00	40.99	1.10	0.00	40.98	1.09	0.00
AFON RHYD	RHYD_916	39.57		40.98	40.99	1.42	0.02	40.96	1.39	-0.02	40.98	1.41	0.00	40.98	1.41	0.00	40.97	1.40	0.00
AFON RHYD	RHYD_904u	39.40	Weir (U/S) + metal footbridge (not modelled)	40.86	40.84	1.44	-0.01	40.86	1.46	0.01	40.86	1.46	0.00	40.86	1.46	0.00	40.85	1.45	0.00
AFON RHYD	RHYD_904d	38.20	Weir (D/S) + metal footbridge (not modelled)	39.78	39.91	1.71	0.13	39.62	1.42	-0.16	39.78	1.58	0.00	39.78	1.58	0.00	39.77	1.57	0.00
AFON RHYD	RHYD_892	38.20		39.51	39.65	1.45	0.14	39.35	1.15	-0.15	39.51	1.31	0.00	39.51	1.31	0.00	39.50	1.30	0.00
AFON RHYD	RHYD_880i	37.83		39.13	39.26	1.43	0.13	38.99	1.16	-0.14	39.13	1.31	0.00	39.13	1.31	0.00	39.13	1.30	0.00
AFON RHYD	RHYD_868	37.45	Iron footbridge (not modelled)	38.52	38.62	1.17	0.10	38.41	0.96	-0.11	38.52	1.07	0.00	38.52	1.07	0.00	38.51	1.06	0.00
AFON RHYD	RHYD_857i	37.17		37.95	38.02	0.85	0.07	37.89	0.72	-0.06	37.95	0.78	0.00	37.95	0.78	0.00	37.95	0.78	0.00
AFON RHYD	RHYD_847u	36.92	Wooden bridge (U/S)	37.71	37.76	0.84	0.04	37.69	0.77	-0.02	37.71	0.79	0.00	37.71	0.79	0.00	37.71	0.79	0.00
AFON RHYD	RHYD_847d	36.92	Wooden bridge (D/S)	37.60	37.67	0.75	0.07	37.53	0.61	-0.08	37.60	0.68	0.00	37.60	0.68	0.00	37.60	0.68	0.00
AFON RHYD	RHYD_789i	35.48		36.22	36.30	0.82	0.08	36.13	0.65	-0.09	36.22	0.74	0.00	36.22	0.74	0.00	36.22	0.74	0.00
AFON RHYD	RHYD_730i	34.01		34.86	34.95	0.94	0.09	34.77	0.75	-0.10	34.86	0.85	0.00	34.86	0.85	0.00	34.86	0.85	0.00
AFON RHYD	RHYD_672	32.57		33.52	33.62	1.05	0.10	33.39	0.82	-0.12	33.52	0.95	0.00	33.52	0.95	0.00	33.51	0.94	0.00
AFON RHYD	RHYD_611	31.24	Concrete bridge (U/S)	32.11	32.19	0.95	0.07	32.04	0.80	-0.07	32.11	0.87	0.00	32.11	0.87	0.00	32.11	0.87	0.00
AFON RHYD	RHYD_608	31.24	Concrete bridge (D/S)	32.05	32.13	0.89	0.08	31.96	0.72	-0.09	32.05	0.81	0.00	32.05	0.81	0.00	32.05	0.81	0.00
AFON RHYD	RHYD_561i	30.10		30.94	31.02	0.92	0.08	30.84	0.74	-0.10	30.94	0.84	0.00	30.94	0.84	0.00	30.94	0.83	0.00
AFON RHYD	RHYD_515	28.99		29.66	29.72	0.73	0.06	29.58	0.59	-0.07	29.66	0.67	0.00	29.66	0.67	0.00	29.66	0.67	0.00
AFON RHYD	RHYD_463i	26.75		27.34	27.41	0.65	0.06	27.27	0.52	-0.07	27.34	0.59	0.00	27.34	0.59	0.00	27.34	0.58	0.00
AFON RHYD	RHYD_410i	24.48		25.15	25.21	0.73	0.06	25.08	0.60	-0.07	25.15	0.67	0.00	25.15	0.67	0.00	25.15	0.67	0.00
AFON RHYD	RHYD_357i	22.20		22.74	22.80	0.60	0.05	22.68	0.48	-0.07	22.74	0.55	0.00	22.74	0.55	0.00	22.74	0.55	0.00
AFON RHYD	RHYD_305	19.96		20.71	20.79	0.83	0.08	20.63	0.67	-0.08	20.71	0.75	0.00	20.71	0.75	0.00	20.71	0.75	0.00
AFON RHYD	RHYD_247i	18.90		19.75	19.84	0.95	0.10	19.64	0.74	-0.11	19.75	0.85	0.00	19.75	0.85	0.00	19.74	0.85	0.00
AFON RHYD	RHYD_190	17.85		18.81	18.88	1.03	0.07	18.74	0.89	-0.07	18.81	0.96	0.00	18.81	0.96	0.00	18.81	0.96	0.00
AFON RHYD	RHYD_185	18.00		18.62	18.70	0.70	0.08	18.54	0.54	-0.08	18.62	0.62	0.00	18.62	0.62	0.00	18.62	0.62	0.00
AFON RHYD	RHYD_176	17.26	Wooden footbridge (not modelled)	18.17	18.26	1.00	0.09	18.07	0.81	-0.10	18.17	0.91	0.00	18.17	0.91	0.00	18.17	0.91	0.00
AFON RHYD	RHYD_168	16.75		17.87	17.96	1.21	0.09	17.77	1.02	-0.10	17.87	1.12	0.00	17.87	1.12	0.00	17.87	1.12	0.00
AFON RHYD	RHYD_156u	16.61	Felinwnda Road bridge (U/S)	17.56	17.66	1.05	0.10	17.45	0.84	-0.11	17.56	0.95	0.00	17.55	0.94	0.00	17.55	0.94	0.00
AFON RHYD	RHYD_156d	16.61	Felinwnda Road bridge (D/S)	17.56	17.66	1.05	0.10	17.44	0.83	-0.11	17.56	0.95	0.00	17.55	0.94	0.00	17.55	0.94	0.00
AFON RHYD	RHYD_104i	15.70		16.70	16.79	1.09	0.09	16.58	0.88	-0.12	16.69	0.99	-0.01	16.71	1.01	0.01	16.70	1.00	0.00
AFON RHYD	RHYD_52i	14.79		15.85	15.95	1.16	0.10	15.74	0.95	-0.12	15.87	1.08	0.02	15.82	1.03	-0.04	15.85	1.06	0.00
AFON RHYD	RHYD_0	13.88		14.98	15.08	1.20	0.10	14.86	0.98	-0.12	14.94	1.06	-0.05	15.52	1.64	0.54	14.98	1.10	0.00
DIVERSION	DIV_119	42.20		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DIVERSION	DIV_98	41.83	Proposed riffle	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DIVERSION	DIV_90	41.70		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DIVERSION	DIV_55	41.09	Proposed culvert under new carriageway (U/S)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

4.3 Hydraulic and hydrological requirements

4.3.1 Culverts have been designed in accordance with the hydraulic requirements presented in HA107/00[9] and CIRIA C689[10].

4.3.2 Design flows have been determined according to the 'small-catchment' IH124 methodology as stipulated in HA106/04. Peak flows have been estimated for 1% AEP (1 in 100 year) events and a 20% increase to the derived flow has been applied to allow for the future effects of climate change.

4.3.3 Culverts have been sized using a simplified steady-state 1-D hydraulic model (using ISIS/Flood Modeller software).

4.4 Water Framework Directive Requirements

4.4.1 NRW and GCC have requested that culvert inverts be depressed to allow the creation of a natural bed through proposed culverts, with depths ranging from 150mm to 300mm depending on the nature and size of the proposed culvert.

4.5 Trash/debris screen strategy

4.5.1 The requirement for trash/debris screens has been assessed in accordance with current EA/Defra guidance which considers both blockage risk and the risk of the potential for non-permitted access by members of the public. Based on the results of this assessment, it is only proposed to apply a security screen to the inlet of culvert S118 (0.6m diameter).

5 POLLUTION PREVENTION CONTROL

5.1 General

5.1.1 The highway runoff elements of the pollution prevention control strategy will take into consideration the results of the HD45/09 assessment undertaken as part of the scheme Environmental Statement.

5.1.2 However, given the relatively low predicted traffic flows of the constructed route, it is not anticipated that formal, engineered pollution prevention control devices, such as by-pass separators, will be required unless constraining environmental conditions govern.

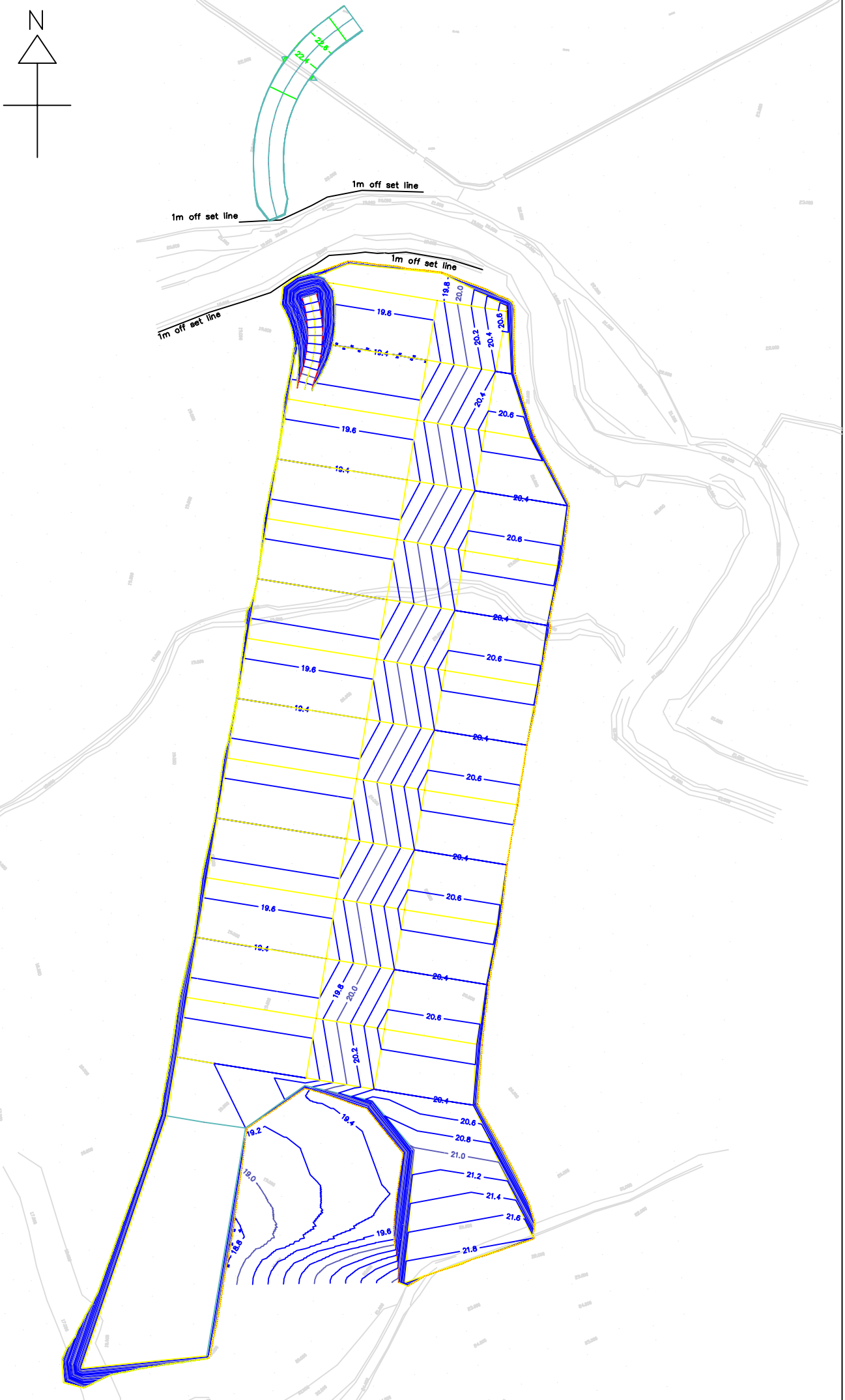
6 ADOPTION AND MAINTENANCE

6.1.1 Highway drainage assets and land drainage elements required to protect highway assets will become the responsibility of NMWTRA.

6.1.2 In general, diverted watercourses will remain the responsibility of the (pre-scheme) riparian owners. However, under certain instances these watercourses will become the responsibility of NMWTRA.

[9] HMSO (2004) *Design of Outfall and Culvert Details.* Design Manual for Roads and Bridges, Volume 4, Section 2, Part 7.
[10] Balkham, Fosbeary *et al* (2010) *Culvert design and operation guide,* CIRIA C689, London 2010.

Appendix K.5 – Afon Gwyrfai Assessment


N
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22.4
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1m off set line
1m off set line
1m off set line
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20.0
20.2
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20.6
19.6
19.4
19.2
19.0
18.8
20.8
21.0
21.2
21.4
21.6

TECHNICAL NOTE

Project :	A487 Caernarfon and Bontnewydd	**Project No. :**	w3172
Subject :	Hydraulic Modelling – Afon Gwyrfai Crossing	**Date :**	26/11/15
Author :	DH **Checker :** BY **Approver :** RCL	**Rev :**	B

Introduction

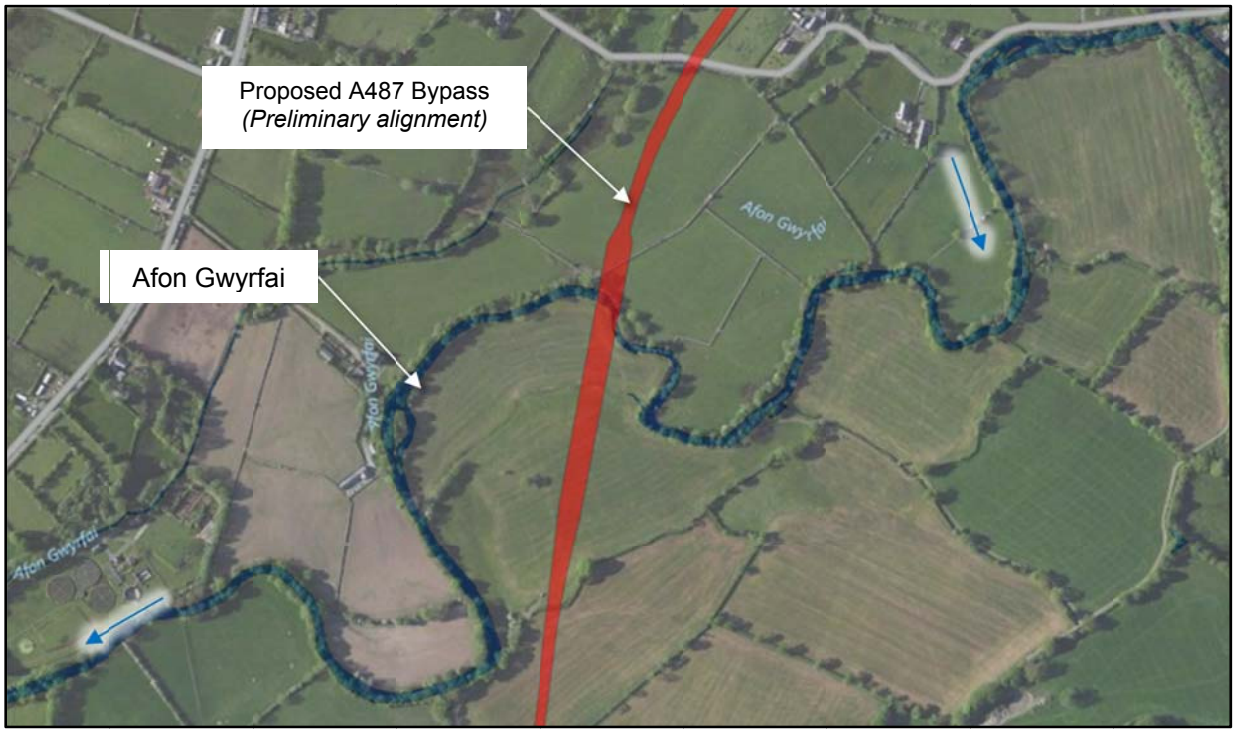
Waterco Consultants have been commissioned to undertake detailed 1D/2D hydraulic modelling of the Afon Gwyrfai watercourse near Bontnewydd, North Wales, investigating fluvial flood risk at the location of a proposed highway viaduct spanning the river as part of the proposed A487 Caernarfon and Bontnewydd Bypass Project. A location plan is provided in Appendix A with an extract provided in Figure 1 below. Details of the proposed structure are given in Appendix B.

The objectives of the modelling study are to:

1) Assess existing fluvial flood risk (depth, velocity and extent) at the proposed highway viaduct location and throughout the wider floodplain.
2) Investigate and quantify the impact of the proposed viaduct arrangement on flood risk elsewhere as a consequence of the development.

This Hydraulic Modelling Technical Note provides a basic overview of the methodology adopted, specific parameters used and simulation results for review / analysis.

Figure 1 – Site Location Detail



Methodology and Model Parameters

Natural Resources Wales (NRW) do not have any existing hydraulic model data available for this project. As such, a new 1D/2D ISIS-TUFLOW model of the Afon Gwyrfai and its tributary, the Afon Beuno has been constructed from surveyed channel cross sections and 1m LiDAR coverage. The latest versions of ISIS and TUFLOW available at the start of the project have been used for all simulations; 3.7 and 2013-12-AD respectively.

1D ISIS Model

A 3.5km stretch of the Afon Gwyrfai has been modelled, starting approximately 300m upstream of Bontnewydd village (NGR 248630 359740) down to Pont Faen (bridge) on Ffordd Pant (road) (NGR 246490 359480). The Gwyrfai generally flows east to west at this location. A 150m length of the Afon Beuno north of Bontnewydd has also been included down to its confluence with the Afon Gwyrfai. A model extent plot has been included in Appendix C for information.

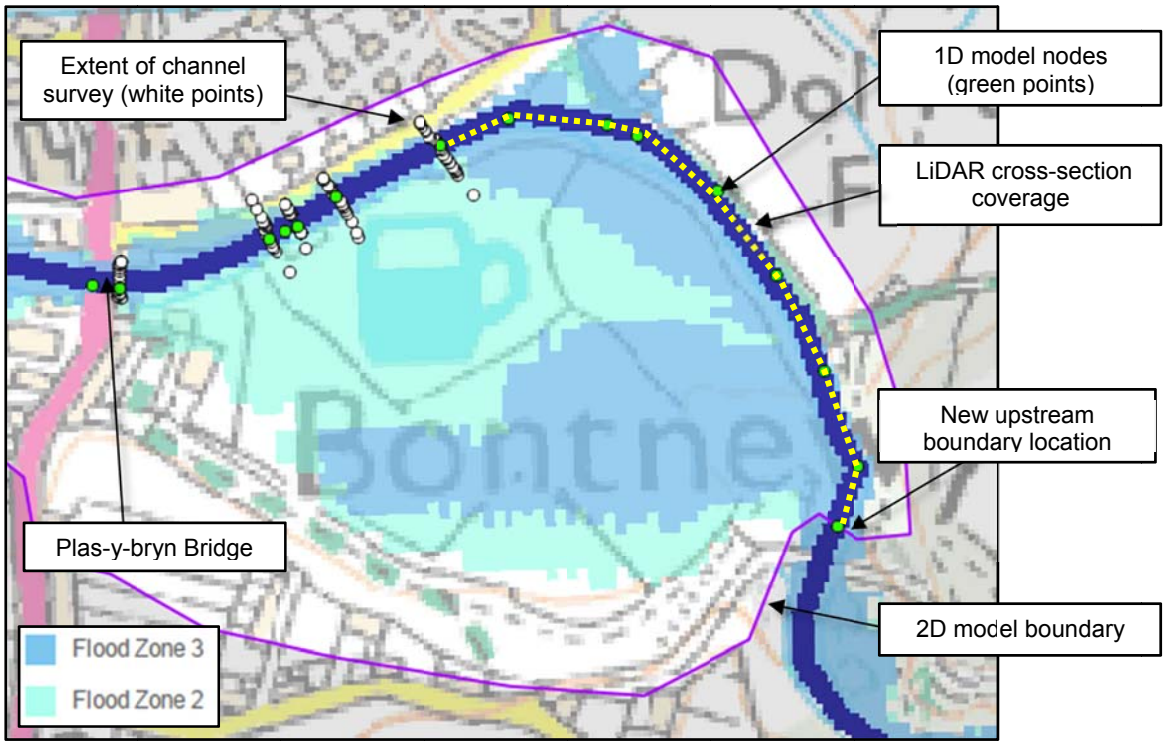
The Gwyrfai channel survey coverage begins 1.8km upstream of the proposed bypass location in an area shown on current NRW Flood Maps to be within Flood Zones 2/ 3 and out of channel. Following a detailed review of these flood maps, it was considered important to represent the adjacent floodplain storage to account for any attenuation effect. To achieve this, the 1D model was extended 350m upstream of the watercourse survey extent near Plas-y-bryn Access Bridge as illustrated in Figure 2. Survey data was not available in this area so sections have been extracted from 1m LiDAR and the channel bed levels dropped as required (by up to 400mm) through extrapolation of the surveyed downstream slope. Comparison of the LiDAR data against downstream survey data showed that bank levels are in good agreement.

A total of six structures were surveyed and included within the 1D ISIS network model – two weirs, two road bridges and two railway bridges. A high level footbridge on the Afon Beuno was not picked up during the survey works and so is not included within the 1D network due to a lack of available data. However, given the distance of this minor structure from the area of interest, exclusion of this structure from the 1D model is unlikely to have a significant effect on results at the proposed viaduct location.

Approximately 90m upstream of the watercourse survey extent, a 1m drop in elevation within the channel was shown in the LiDAR dataset - see Figure 3 below. A review of online mapping and photography suggests there may be a weir at this location. Although no survey data was available, a weir has been included within the 1D ISIS network (GWY_3290) with geometry taken from nearby cross sections and the crest level being set at 34.5mAOD (based on nearby LiDAR elevations).

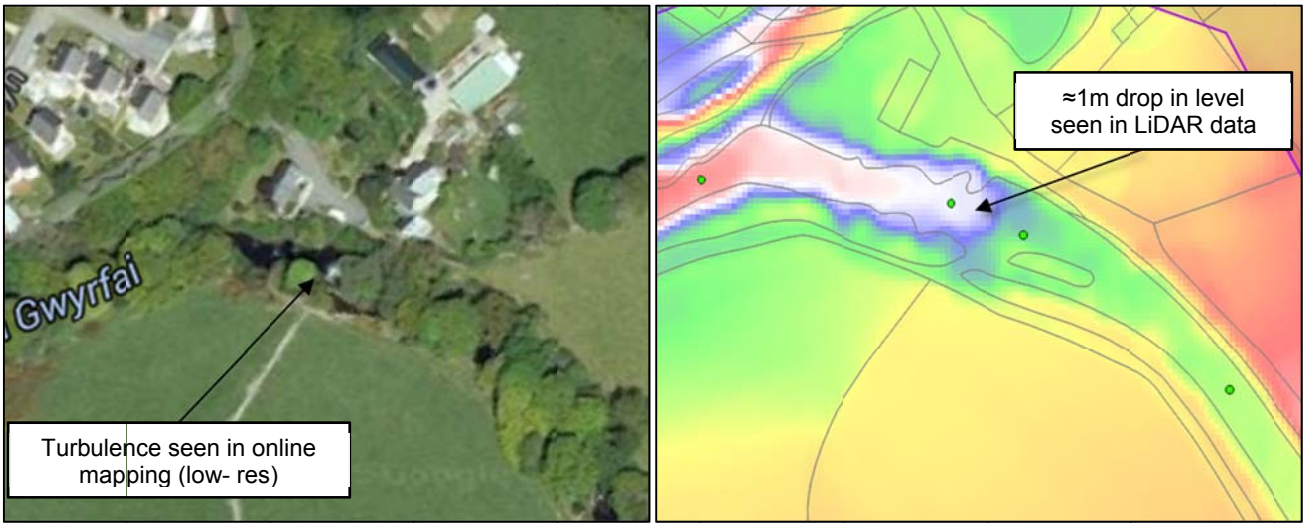
It should be noted that the existing NRW Bontnewydd flood defence wall has been represented within the 2D model and is discussed in detail later in this document.

Figure 2 – Upstream model extension



(NRW Flood Map – April 2015)

Figure 3 – Location of weir upstream of survey extent



Manning's n coefficients have been used to represent the roughness of the channel and structures, set to 0.035sm$^{-1/3}$ throughout the network based on Chow (1959)[1] and survey photography. To investigate the validity of this roughness value sensitivity testing on this parameter has been performed with a significant variation in channel and floodplain roughness being considered i.e. +/-20% - discussed in detail below.

Inflow hydrographs for both watercourses have been calculated and applied to the upstream extent of each watercourse. A detailed hydrological assessment was undertaken and is documented in the associated Hydrology Technical Note[2]. The final design flows and hydrographs were approved by NRW in July 2015. To ensure all flows within the modelled catchment are taken into account, additional lateral inflows have been applied along the Afon Gwyrfai between the Afon Beuno confluence, the proposed viaduct location and the downstream boundary.

The downstream boundary of the 1D network has been set using a normal depth boundary unit – a reasonable condition given the study area is situated above the tidal range and located sufficiently downstream (1.4km) of the proposed viaduct to have minimal effect on flood levels in the area of interest – minimum required distance ≈200m based on standard backwater effect equation below. To verify this assumption and investigate its impact on model results in the area of interest (if any), model sensitivity testing has been undertaken.

Backwater Effect Equation:

$$L = 0.7\,\frac{D}{s}$$

L = extension of backwater effects (m)
D = approximate channel depth (m)
s = channel slope (m/m)

$$L = 0.7 \times \frac{2.0}{18.24 - 7.84/1397} = 188.1m \text{ (significantly less than the 1.4km to the area of interest)}$$

2D TUFLOW Model

The 1D network has been hydrodynamically linked to a new 2D TUFLOW model domain, constructed primarily from 1m LiDAR data – see model extent plot is Appendix C. The cell size of the 2D model has been set at 2m. This is sufficient to accurately represent flowpaths within the floodplain whilst maintaining reasonable simulation times.

The existing NRW flood defence wall to the west of Bontnewydd has been surveyed and included within the 2D domain using a thick z-line. No further structures have been identified and included within the 2D domain.

Additional ZP points have been applied along the HX links in order to ensure that the elevations along the interface between the 1D network and 2D floodplain models are appropriately represented. The elevations of these points have been taken from the LiDAR data as no top of bank survey was available.

[1] Chow, V.T., 1959, Open-channel hydraulics: New York, McGraw-Hill, 680 p.
[2] Doc ref: w3172-150508-Hydrology Tech Note - Gwyrfai Rev A

OS MasterMap data has been used to classify land use and assign Manning's n roughness coefficients throughout the floodplain. The coefficients used are given in Table 1. Localised alterations have been made to some 1D/2D link cells to improve model stability.

Table 1 – 2D Model Manning's n Roughness Coefficients

Land Use	Manning's n Roughness Coefficient ($sm^{-1/3}$)
Default	0.035
Buildings	1.0
Land (gardens / fields)	0.03 - 0.035
Woodland	0.06
Inland / tidal water	0.03
Roads, paths, rail	0.02

An automatic HQ relationship downstream boundary has been applied to the 2D domain with a slope of 10m/km based on the underlying LiDAR data.

Proposed Development Model

In addition to modelling the existing (EXG) fluvial flood risk at the site, a development model (DEV1) representing the proposed site arrangement has also been run to quantify any changes in flood risk elsewhere due to the development.

Given the high level of the proposed viaduct above the watercourse and floodplain, the structure has been included within the 2D DTM through use of z-shapes to represent the proposed southern approach embankment and the seven bridge support piers – see proposed structure details in Appendix B.

Simulations

In order to fully investigate the fluvial flooding mechanisms through the study area, a range of fluvial events have been simulated for both the existing (EXG) and development (DEV1) scenarios – namely the 50% (Q2), 20% (Q5), 10% (Q10), 5% (Q20), 1% (Q100) and 0.1% (Q1000) annual exceedance probability (AEP) events. The effect of future climate change has also been investigated during the 1% AEP event as a 20% increase in flows. The complete list of events is summarised in Table 2.

Table 2 – Simulation Summary

Modelled Scenario	Annual Exceedance Probability (AEP)	Return Period
EXG *(Existing site arrangement)*	50%	Q2
	20%	Q5
	10%	Q10
	5%	Q20
	1%	Q100
	1% + CC[3]	Q100CC
	0.1%	Q1000
DEV1 *(Including proposed viaduct)*	50%	Q2
	20%	Q5
	10%	Q10
	5%	Q20
	1%	Q100
	1% + CC	Q100CC
	0.1%	Q1000

Model Sensitivity Tests

In the absence of available calibration data, increased significance has been placed on sensitivity testing to improve confidence in the model outputs and assess the sensitivity of the model parameters. A total of four sensitivity tests have been carried out (ST1-4) with respect to the 1% AEP + CC fluvial event and EXG scenario.

Sensitivity tests “ST1” and “ST2” investigate variations (+/- 20%) of Manning’s roughness coefficients in both the channel and across the floodplain.

Sensitivity tests “ST3” and “ST4” investigate a +/-20% variation in the slope curve used in both the downstream boundary of the 1D model and 2D domain.

Sensitivity testing of the influence of structures was considered, however there are no structures along the stretch of the Afon Gwrfai in the vicinity of the proposed viaduct location and so it was not deemed necessary.

To enable an assessment of overall sensitivity to flows at the study site, the model has been tested for a wide range of fluvial events from the 50% AEP event to the 0.1% AEP. Confidence in the approved watercourse inflows is discussed in the associated Hydrology Technical Note.

[3] CC – Climate Change Allowance

Simulation Results

Maximum flood depth, velocity and flood hazard mapping has been provided for each simulation, EXG and DEV1 in Appendix D. For additional information, calculated maximum water levels for all simulations have been extracted from each 1D model node, tabulated and compared in Appendix E.

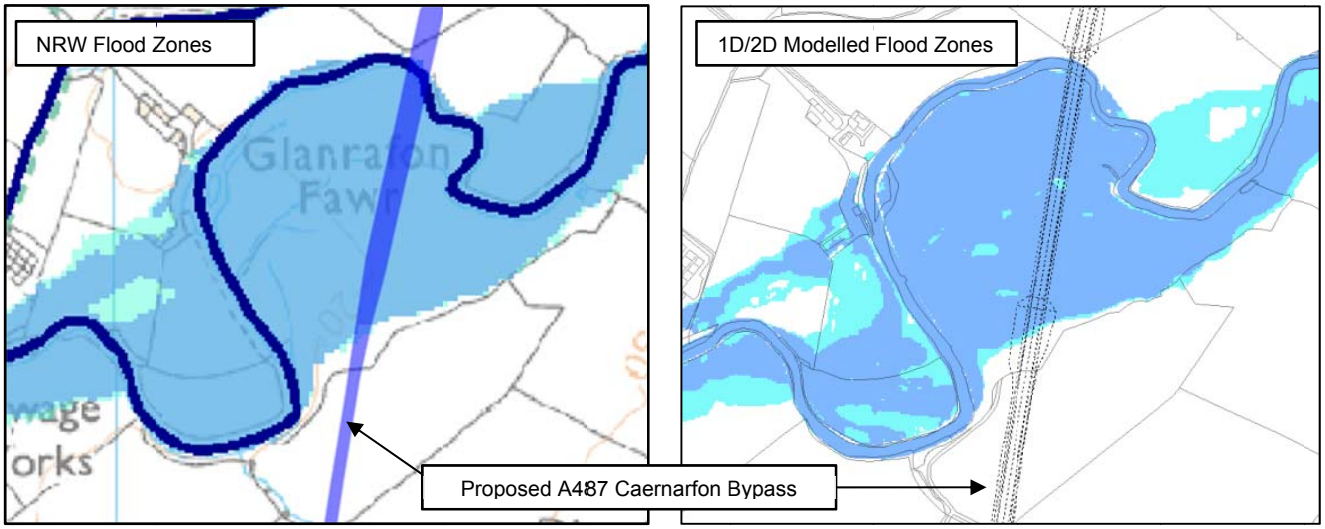
Flood hazard ratings have been calculated in accordance with DEFRA document 'FD2320: Flood Risks to People' and EA guidance document 'Supplementary Note on Flood Hazard Ratings and Thresholds'.

EXG Simulations

During all EXG events considered, the floodplain local to the proposed viaduct site is shown to flood, with shallow depth flooding of approximately 200mm occurring at this location during the 50% AEP fluvial event. During the 1% AEP + CC event the extent and depth of flooding is increased to around 600mm in places. Maximum velocity values through the area of interest range from 0.1m/s to 2.5m/s.

The 1D/2D ISIS-TUFLOW model of the existing (EXG) arrangement is shown to produce broadly similar flood extents to the current NRW flood zones albeit with generally smaller extents. This is illustrated by the comparison plots included in Figure 4.

Figure 4 – Flood Zone Comparison



It was noted during results analysis that the Bontnewydd flood wall offers protection up to and including the 0.1% AEP event – a standard of protection greater than expected. However on further inspection, model outputs show an old railway bridge just upstream of the flood wall to hold back flows in the Afon Gwrfai leading to upstream flooding. This attenuation effect appears to result in lower water levels adjacent to the flood wall than expected.

DEV1 Simulations

The potential impact of the proposed development on flood risk elsewhere has been quantified by comparing the results of the existing (EXG) site layout simulations with the proposed (DEV1). To provide a detailed assessment of the relative changes in flood depths throughout the floodplain, a series of water level difference maps comparing the pre- and post-development maximum water levels have been created and are included in the DEV1 section of Appendix D for information.

The generated DEV1 flood maps show there is negligible change in the modelled flood extents relative to existing site arrangement for all events considered. However, local changes, both increases and decreases, to flood depths in the immediate vicinity of the proposed structure were simulated to varying degrees for all considered events.

During the 50% (Q2) and 20% (Q5) AEP events, the changes in relative flood depth are small (< +/- 25mm) and concentrated around the proposed viaduct support piers to the north of the floodplain. The impact of the proposed southern viaduct approach embankment is first felt during the 10% (Q10) AEP event with some depth variations (+/- 100mm) in the immediate vicinity of the embankment. All variations in floodplain depths isolated to within the existing watercourse meander in the study area. An extract of the 10% AEP Maximum Depth Difference map is provided in Figure 5 for reference.

As the return period of the simulated events increase, so does the relative impact of the proposed site arrangement on flood risk elsewhere. When the 5% (Q20), 1% (Q100), 1% plus climate change (Q100CC) and 0.1% (Q1000) AEP events are considered areas experiencing variations in maximum flood depth, both increases and decreases, become progressively pronounced, particularly local to the southern viaduct approach embankment. During the 0.1% AEP event, the maximum relative increase in flood depth occurs immediately upstream of the embankment and peaks at +400mm. Immediately downstream of the embankment the maximum relative decrease in flood depth is approximately -400mm. An extract of the 0.1% AEP Maximum Depth Difference map is provided in Figure 6 for information. During this most extreme event simulated the variations in maximum flood depth remain isolated within the existing watercourse meanders in the study area. General increases downstream are ≈15mm.

To further investigate the impact of the proposals on flood risk elsewhere, discharge data downstream of the proposed crossing has been extracted from the EXG and DEV1 simulations. Combined flow data taken from both within the channel (1D node GWY_398) and across the floodplain (2D PO line MAIN_OUT) shows the proposals have negligible effect on downstream flows. A summary of the relative peak flows is presented in Table 3.

Table 3 – Combined Peak Flow Comparison (1D-GWY_398 and 2D-MAIN_OUT)

Rhyd Fluvial Event (AEP)	EXG Peak Flow (m^3/s)	DEV1 Peak Flow (m^3/s)	Difference (+/-m^3/s)	Difference (%)
1%	54.015	53.994	-0.021	-0.04
1%+CC	66.544	66.552	0.008	-0.012
0.1%	109.102	109.222	+0.121	+0.11

Figure 5 – 10% (Q10) AEP Maximum Depth Difference Map Extract

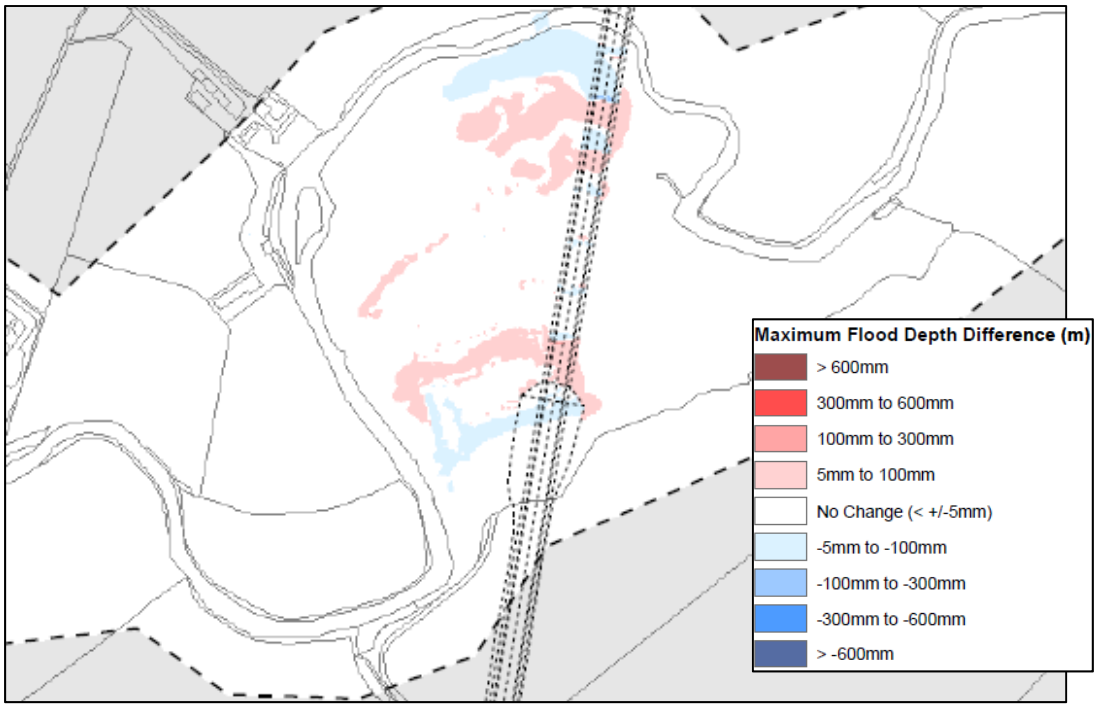
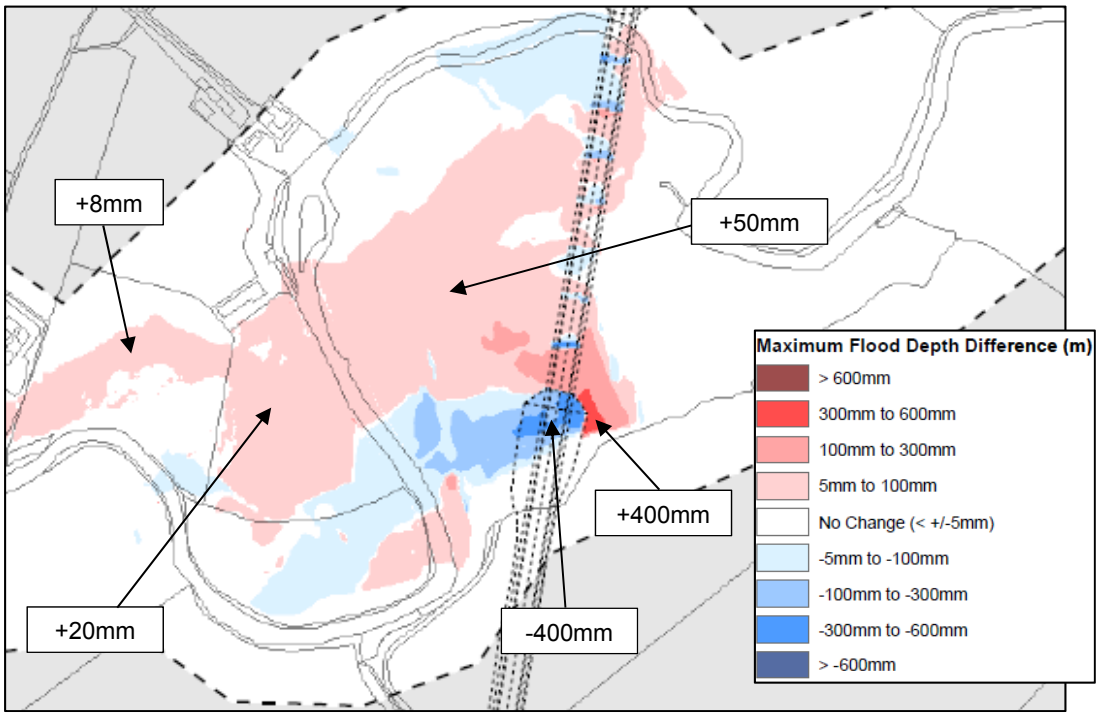


Figure 6 – 0.1% (Q1000) AEP Maximum Depth Difference Map Extract



Model Sensitivity

The results of sensitivity tests ST1 and ST2 show that varying the Manning's n coefficients within the channel and floodplain does not have any considerable effect on the maximum water levels throughout the model (differences of water levels +/-50mm).

The results of sensitivity tests ST3 and ST4 show that varying the slope value used within the downstream boundary calculations (both 1D and 2D) does not have any considerable effect on the maximum water levels throughout the model. Water levels local to the boundary rise by a maximum of 70mm (during ST3) with increases in water levels only propagating some 150m upstream; still over 1km downstream of the proposed viaduct location and approximately 9m lower.

To enable an assessment of overall model sensitivity to flows at the study site, the model was tested for a wide range of fluvial events. Although the relative water levels associated with larger events increase as expected, analysis of the model outputs show the model is not significantly sensitive to flow. This can be partially attributed to the relatively steep nature of the watercourse with flow being largely contained within channel, particularly downstream of the site. At the location of the proposed crossing the range of maximum water level (Appendix E) between the 5% AEP and 0.1% AEP events is <270mm. Confidence in the approved watercourse inflows is discussed in the associated Hydrology Technical Note.

Model Stability

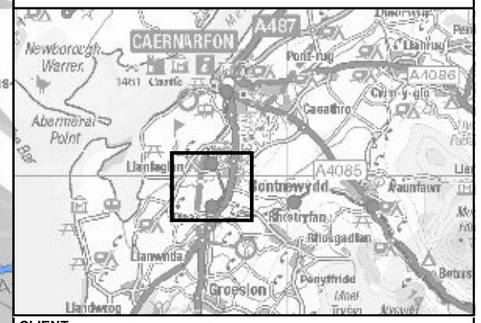
Stability of all simulations has been reviewed to assess confidence in model outputs. For all events and scenarios considered model stability is good with no significant observed peculiarities or stability issues noted. More detail is provided in the associated model log.

Stage and flow profiles for model nodes, including structures, have been reviewed for all events and are smooth. Analysis of the 1D and 2D log files indicate no convergence issues or negative depth recorded. The average cumulative mass balance of the models is <0.08% indicating good overall stability.

Appendix A – Location Map

LEGEND

Highway Alignment



CLIENT:

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Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

LOCATION PLAN

PLOT STATUS:

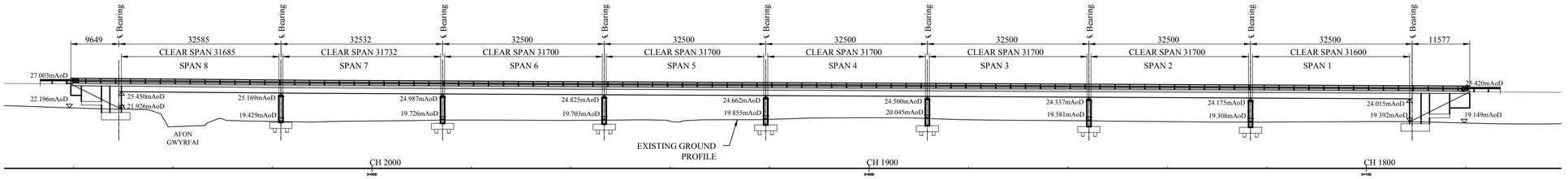
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

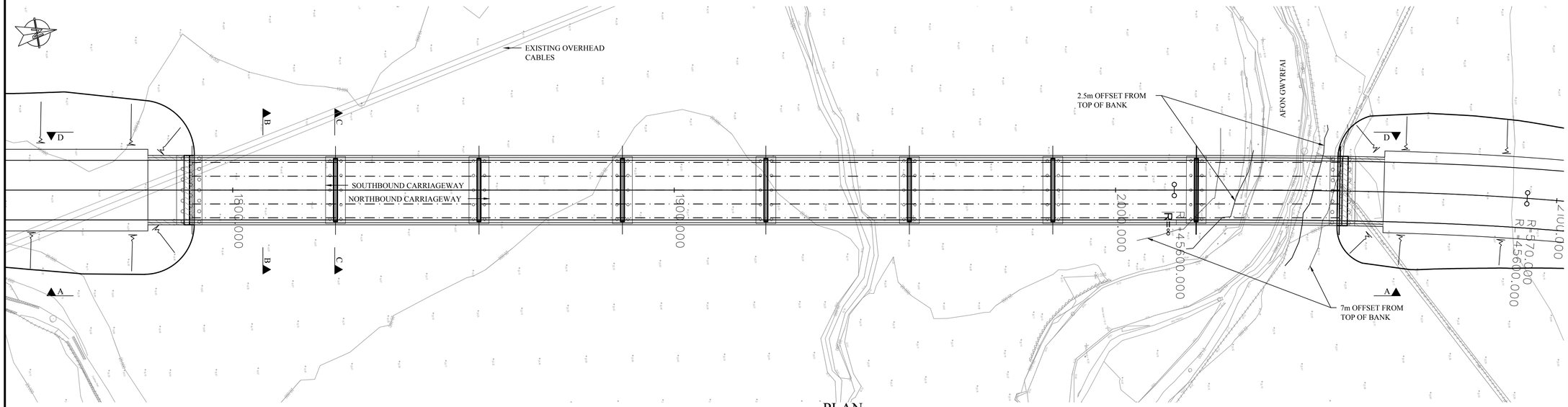
DATE:	PLOT NAME:	REV:
26/10/2015	w3172-GWY_LOCATION_PLAN	-

0 0.1 0.2 0.4 0.6 0.8 1 km

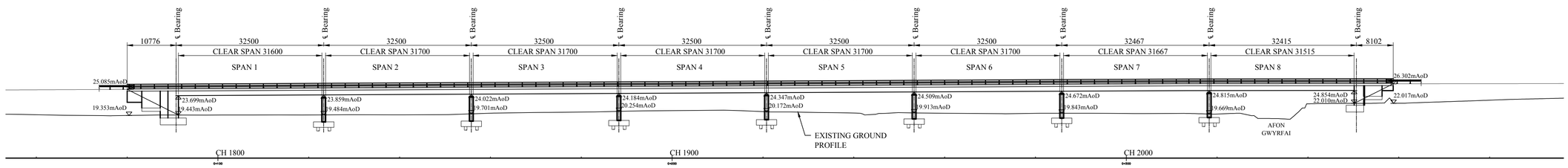
Appendix B – Proposed Viaduct Details



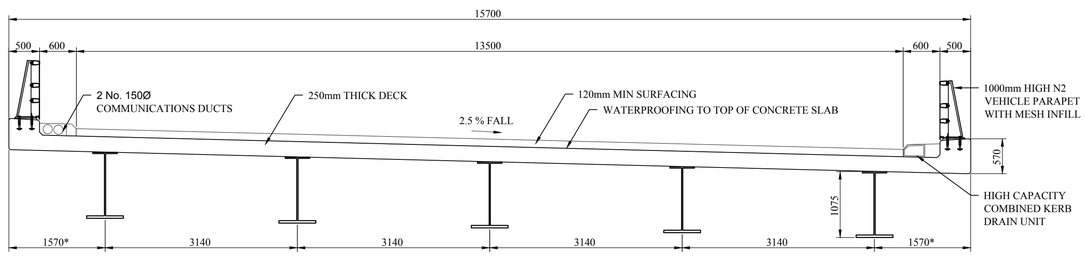
ELEVATION D-D
SCALE 1:500



PLAN
SCALE 1:500

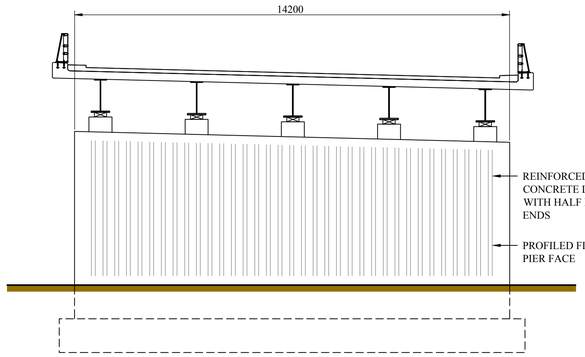


ELEVATION A-A
SCALE 1:500

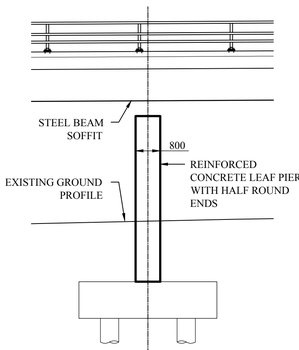


SECTION B-B
SCALE 1:50

* CANTILEVER VARIES FOR SPANS 7 & 8



ELEVATION C-C
SCALE 1:100



TYPICAL PIER END ELEVATION
SCALE 1:100

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Ordnance Survey 0100031673
© Getmapping plc.

NOTES

1. THIS IS A C.A.D. DRAWING AND SHOULD NOT BE AMENDED BY HAND.
2. ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED.
3. THE LEVEL AND HIGHWAY ALIGNMENT INFORMATION ON THIS DRAWING USE THE FOLLOWING MODELS.
   TOPO: 3513874-EXT-XX-XX-M3-Z-00007 VER. A
   (Topographical survey Ch.2050 to Ch.2950)
   3513874-EXT-XX-XX-M3-Z-00010 VER. A
   (Topographical survey Ch.840 to Ch.2050)
   HIGHWAY:3513874-PB-XX-XX-M3-J-00006 VER P01.1
   (Mainline Proposed strings Design Freeze 14.05.15)

HEALTH AND SAFETY INFORMATION

SIGNIFICANT OR EXCEPTIONAL RISKS ARE IDENTIFIED BELOW

CONSTRUCTION PHASE

1. PLEASE REFER TO THE HAZARD RISK REGISTER AND THE WORKS INFORMATION FOR DETAILS OF THE RISKS ASSOCIATED WITH THIS WORK.
2. IN PREPARATION OF CONSTRUCTION METHOD STATEMENTS CONSIDERATION SHOULD BE GIVEN TO THE CLOSE PROXIMITY OF ANY STRUCTURES THAT MAY BE AFFECTED BY CONSTRUCTION.
3. RESIDUAL HAZARDS ARE LISTED HERE AND REFERENCED ON THE DRAWING.
   i. NOTHING SIGNIFICANT OR UNUSUAL.
4. THE CONTRACTOR SHALL REFER TO STATUTORY UNDERTAKERS LAYOUT DRAWINGS AND IDENTIFY LOCATIONS OF EXISTING UNDERGROUND SERVICES PRIOR TO CARRYING OUT EXCAVATION WORKS.

MAINTENANCE / OPERATION / DECOMMISSIONING / DEMOLITION PHASES

1. PLEASE REFER TO THE HAZARD RISK REGISTER AND THE MAINTENANCE AND REPAIR STRATEGY FOR DETAILS OF THE RISKS ASSOCIATED WITH THE MAINTENANCE, OPERATION, DECOMMISSIONING AND DEMOLITION PHASES.
2. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE HEALTH AND SAFETY FILE(S) PRODUCED AND HANDED OVER ON COMPLETION OF THIS PROJECT.
3. RESIDUAL HAZARDS ARE LISTED HERE AND REFERENCED ON THE AS-BUILT DRAWING.
   i. NOTHING SIGNIFICANT OR UNUSUAL.

Rev	Date	Description	By	Chk	App
P01.2	15/05/2015	UPDATED TO NEW ALIGNMENT	MB	AKG	AKG
P01.1	29/04/2015	ISSUED INITIAL FLOOD MODELLING	MB		

Initial Status or WIP

EC HARRIS BUILT ASSET CONSULTANCY
Llywodraeth Cymru Welsh Government
RAMBOLL
Balfour Beatty
JONES BROS CIVIL ENGINEERING UK
PARSONS BRINCKERHOFF
Ty Glyn, Canol Y Dre, Ruthin Denbighshire Tel: 01824 703661
TACP

Site/Project:
A487 CAERNARFON TO BONTNEWYDD BYPASS

Title:
STRUCTURE S106
GENERAL ARRANGEMENT

Drawn: M. BARKA		Checked: A. GROVES	
Designed: A. JARMAN		Approved: A. GROVES	
Date: 29/04/15	Scale: AS SHOWN	A1	Sheet:

Container Number: 3513874-PB-SBR-106-DR-S-00001 — Revision: P01.2

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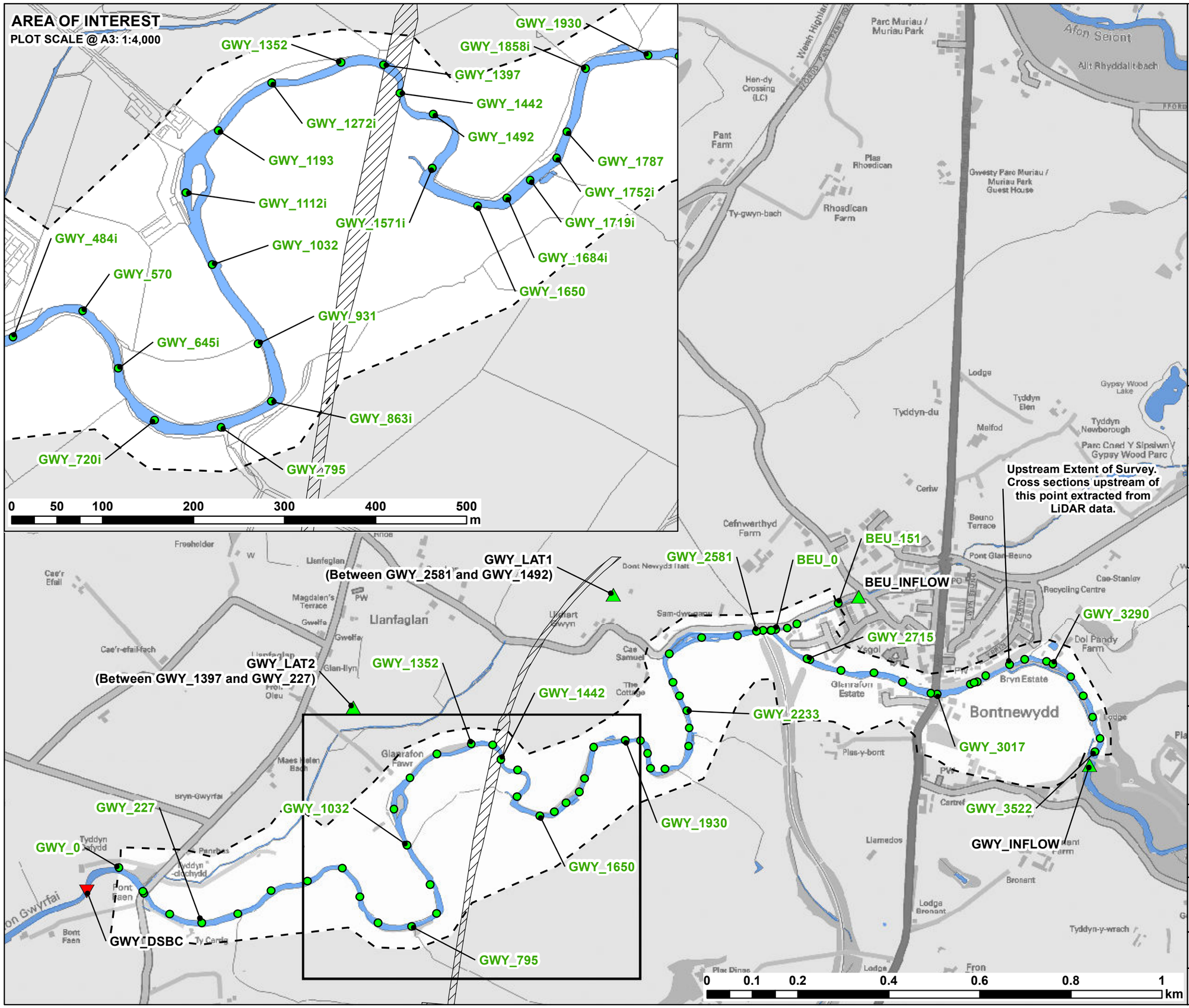
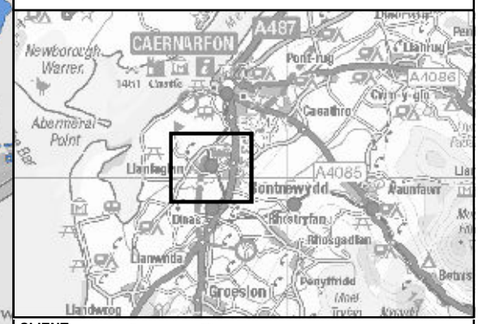
Appendix C – 1D/2D Model Extent



LEGEND

- Preliminary Highway Alignment
- 2D Model Boundary
- 1D Flow-Time (QT) Boundary
- 1D Flow-Level (QH) Boundary
- 1D Model Nodes

NOTE:
Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.



CLIENT:
Llywodraeth Cymru
Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

PLOT TITLE:
1D/2D MODEL EXTENT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
27/07/15	w3172-GWY_MODEL_EXTENT	-

Appendix D – Flood Mapping

Existing Site Arrangement (EXG)

AREA OF INTEREST
PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.

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PLOT TITLE:
MAXIMUM FLOOD DEPTH
50% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q2_EXG_D	G

AREA OF INTEREST
PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.

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SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

PLOT TITLE:
MAXIMUM FLOOD DEPTH
20% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
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DATE:	PLOT NAME:	REV:
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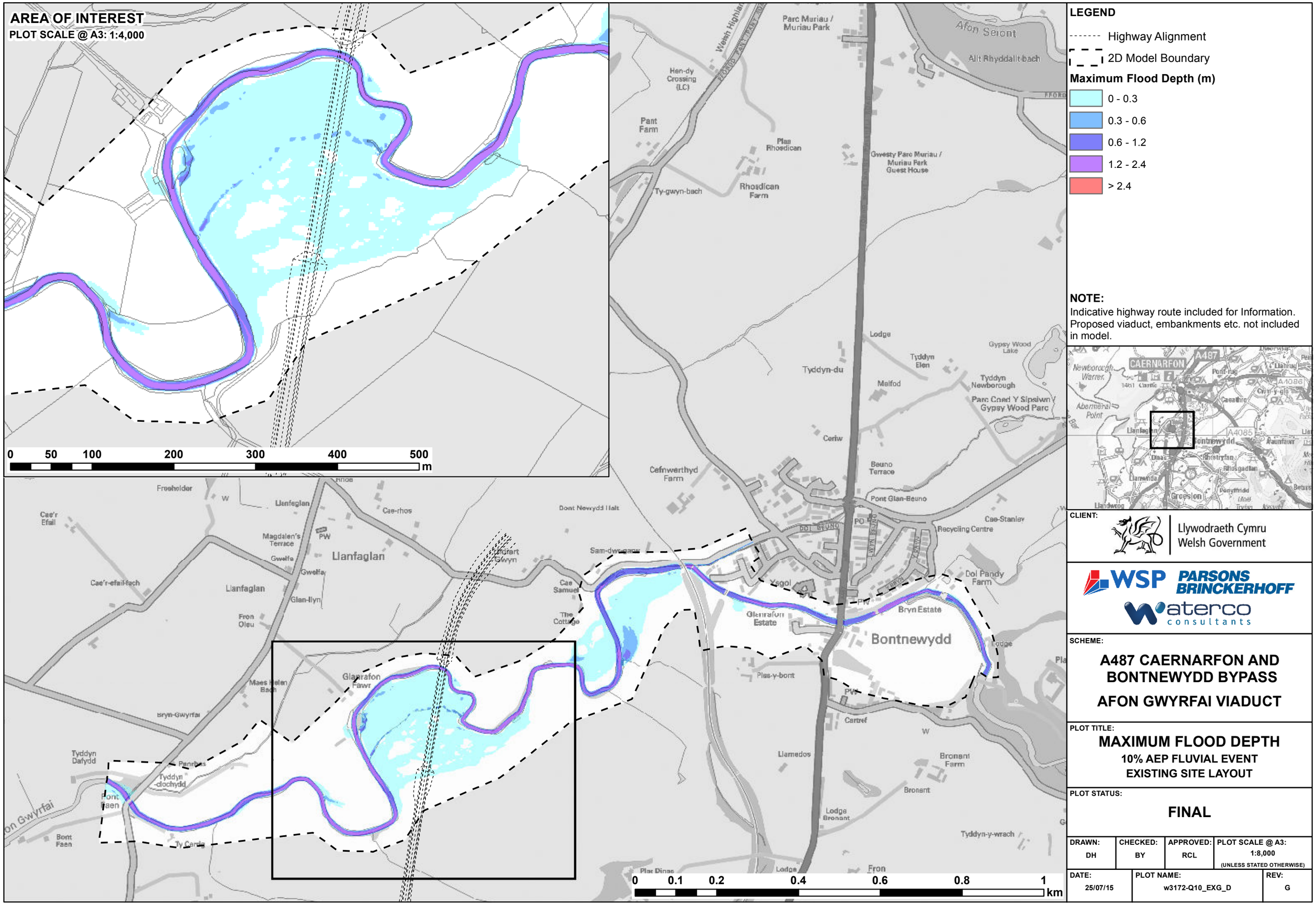

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.

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Waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD DEPTH

10% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q10_EXG_D	G

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

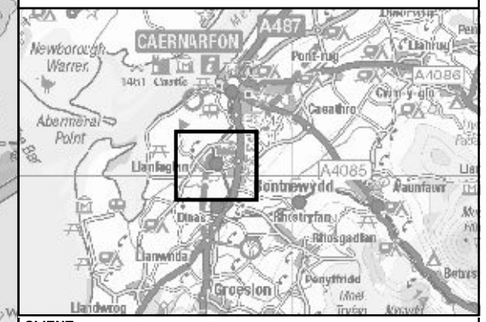
- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:

Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.



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Waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD DEPTH

5% AEP FLUVIAL EVENT

EXISTING SITE LAYOUT

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q20_EXG_D	G

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

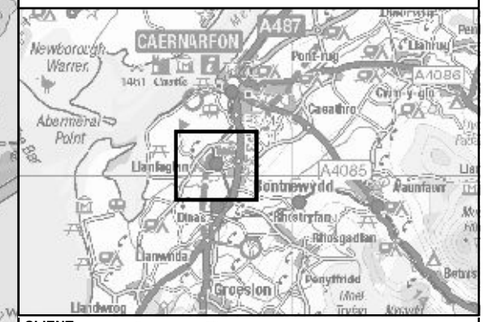
- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:

Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF

Waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD DEPTH

1% AEP FLUVIAL EVENT

EXISTING SITE LAYOUT

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q100_EXG_D	G

AREA OF INTEREST
PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

PLOT TITLE:
MAXIMUM FLOOD DEPTH
1% AEP + CCA FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q100CC_EXG_D	G

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

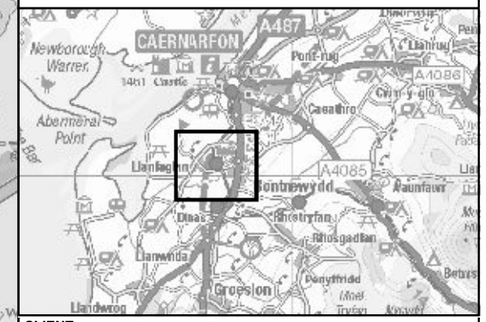
- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:

Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF

waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD DEPTH

0.1% AEP FLUVIAL EVENT

EXISTING SITE LAYOUT

PLOT STATUS:

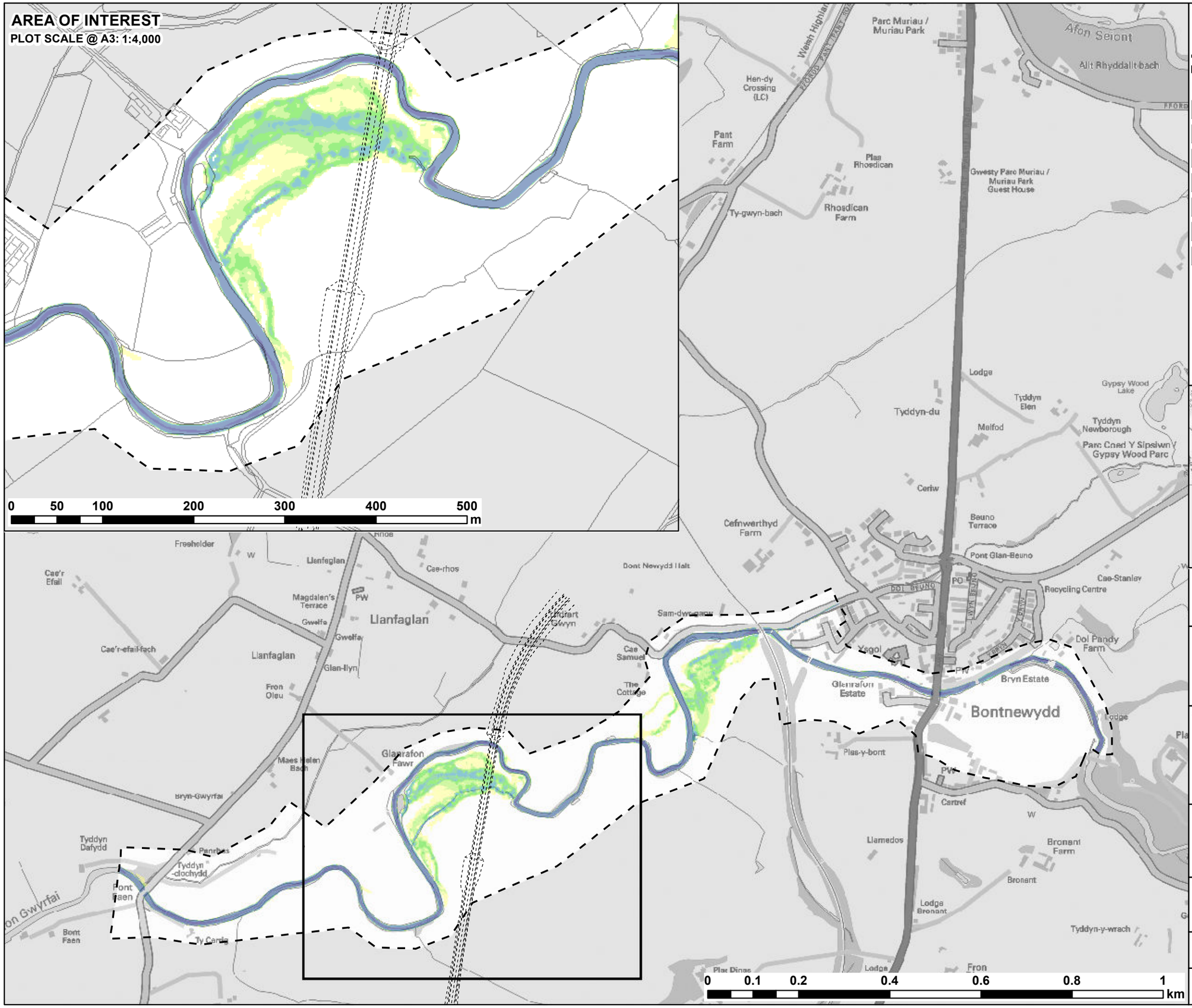
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q1000_EXG_D	G

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000



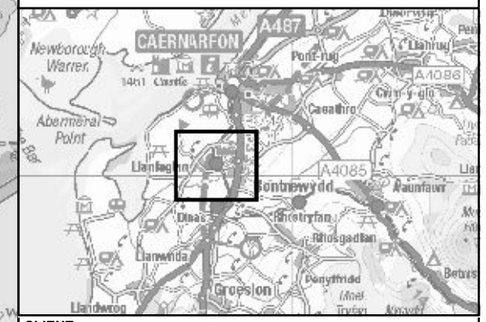
LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

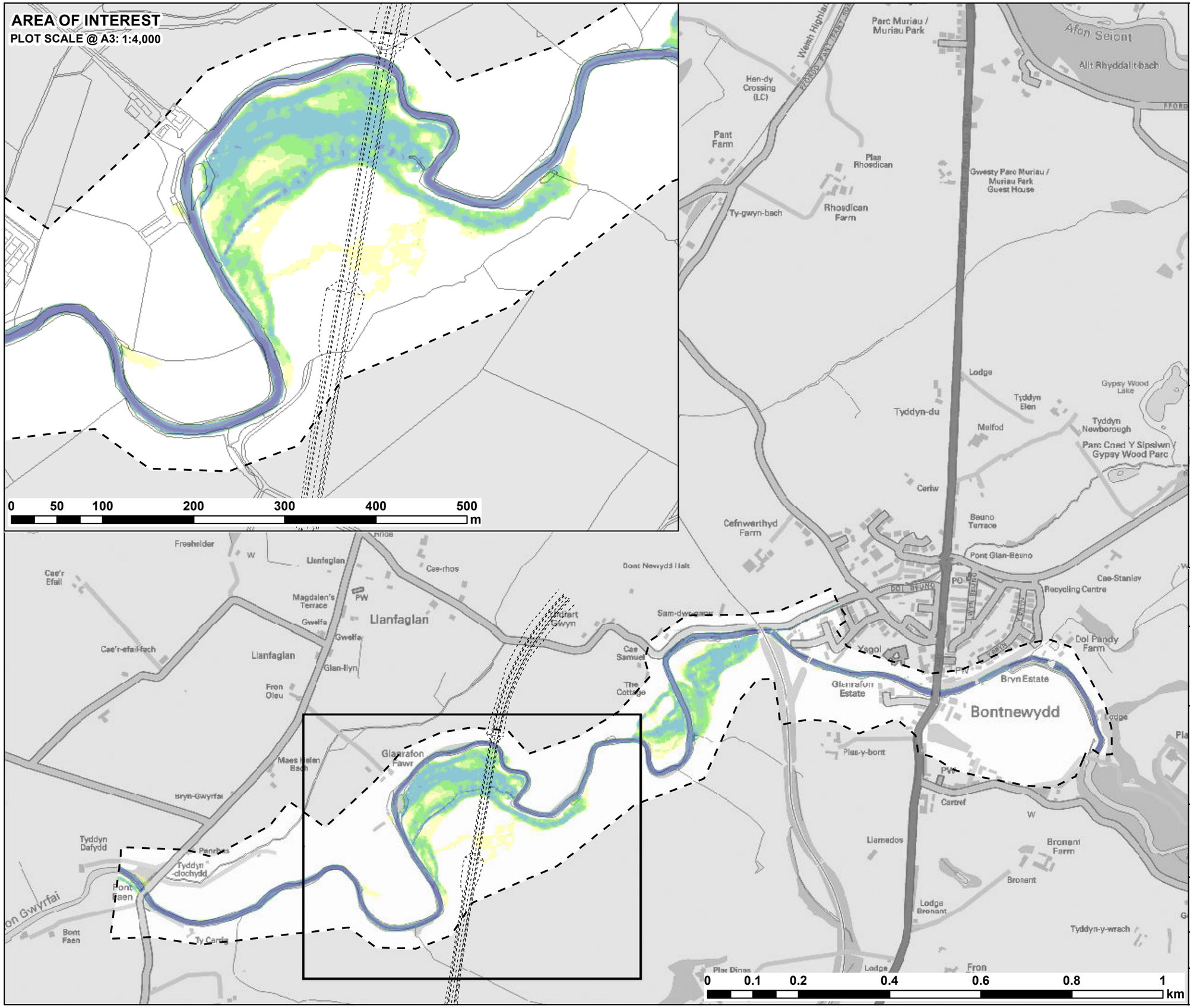
PLOT TITLE:

MAXIMUM VELOCITY
50% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q2_EXG_V	G



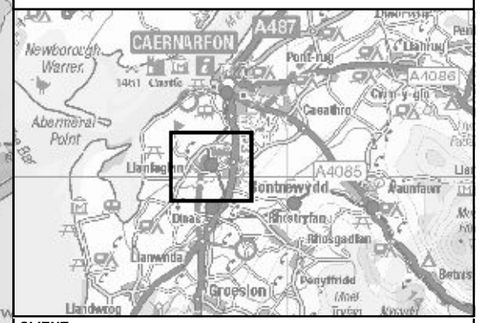
LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.



CLIENT:
Llywodraeth Cymru
Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

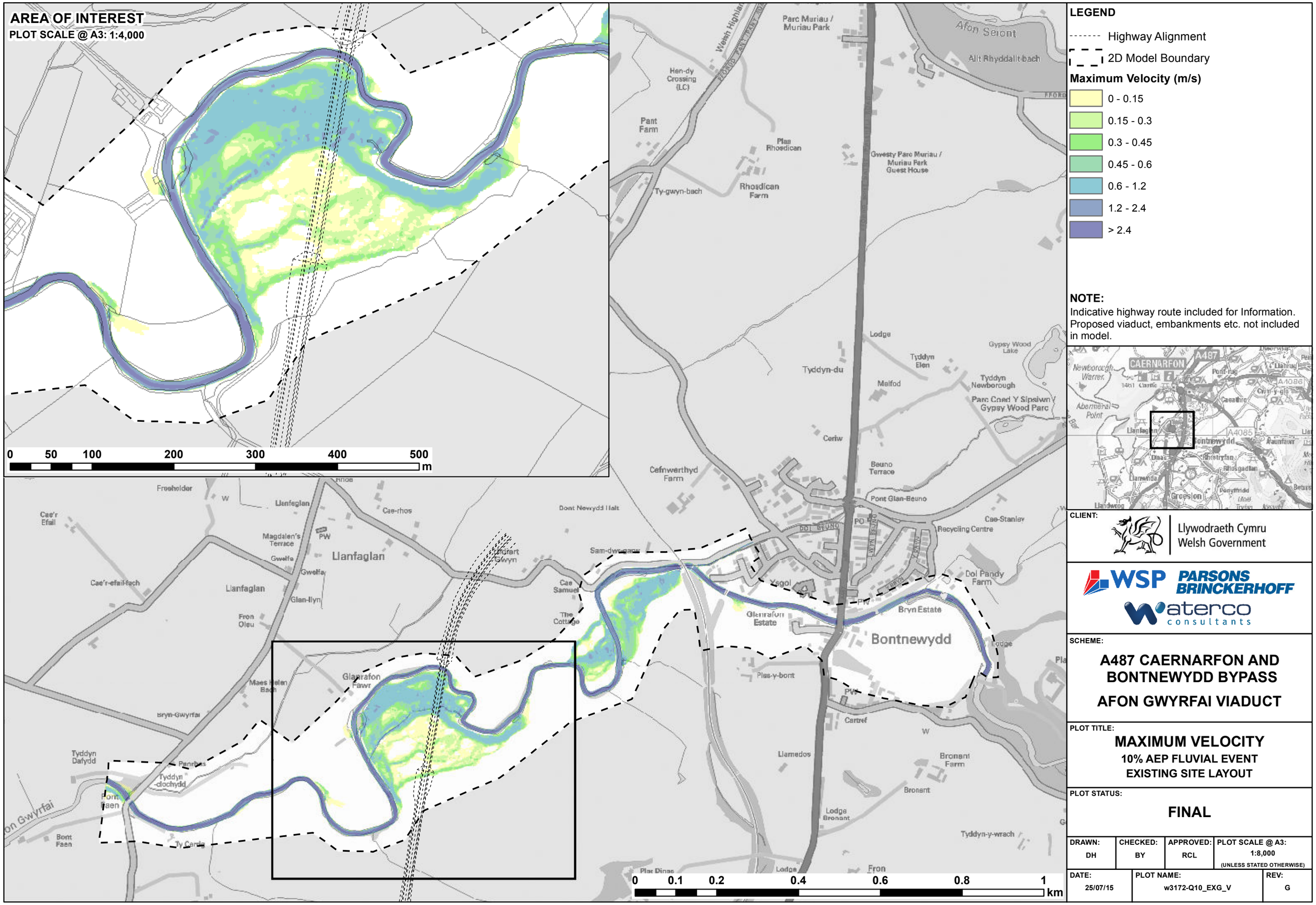
SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

PLOT TITLE:
MAXIMUM VELOCITY
20% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q5_EXG_V	G



CLIENT: Llywodraeth Cymru / Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM VELOCITY

10% AEP FLUVIAL EVENT

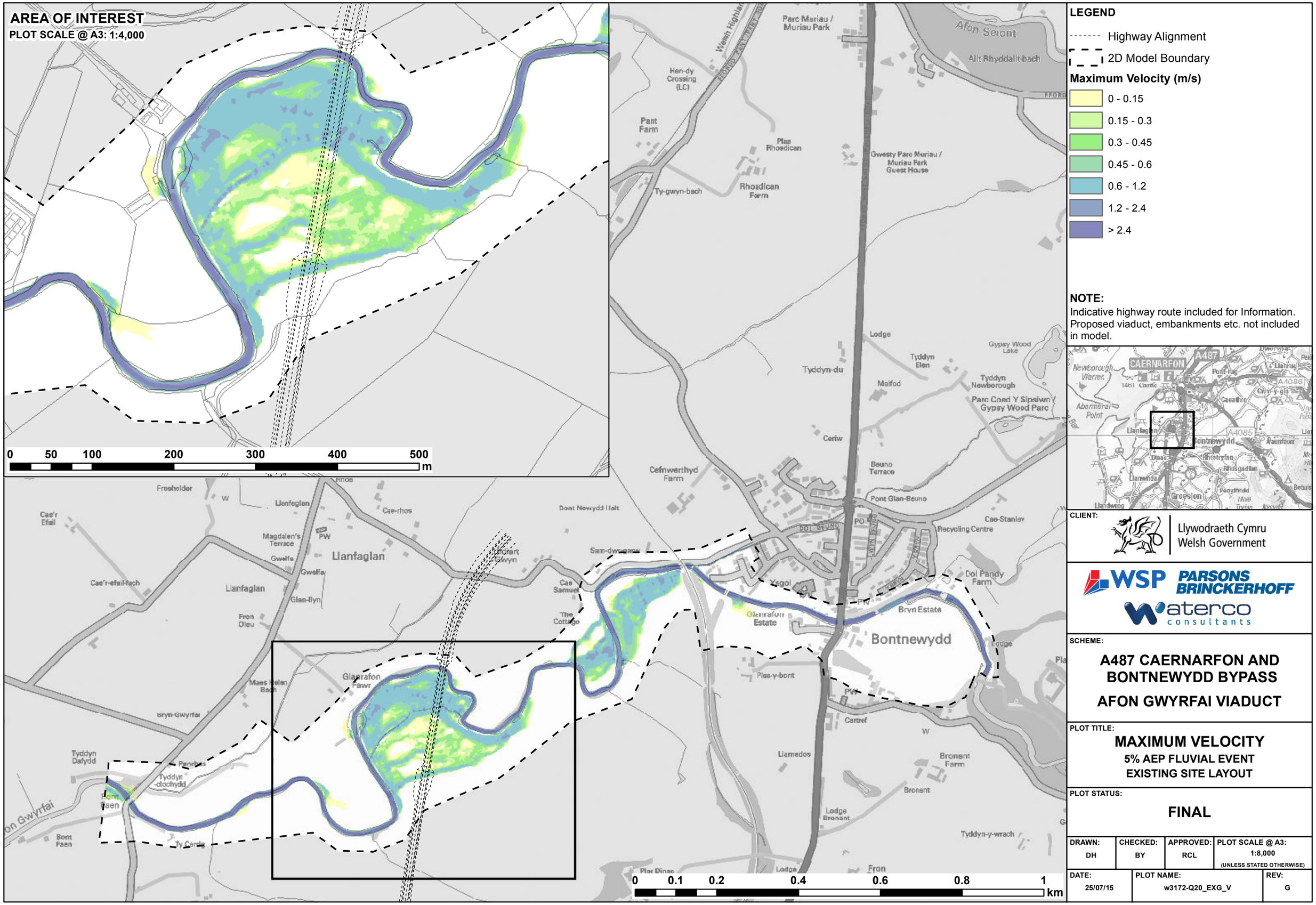
EXISTING SITE LAYOUT

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q10_EXG_V	G



LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

PLOT TITLE:
MAXIMUM VELOCITY
5% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

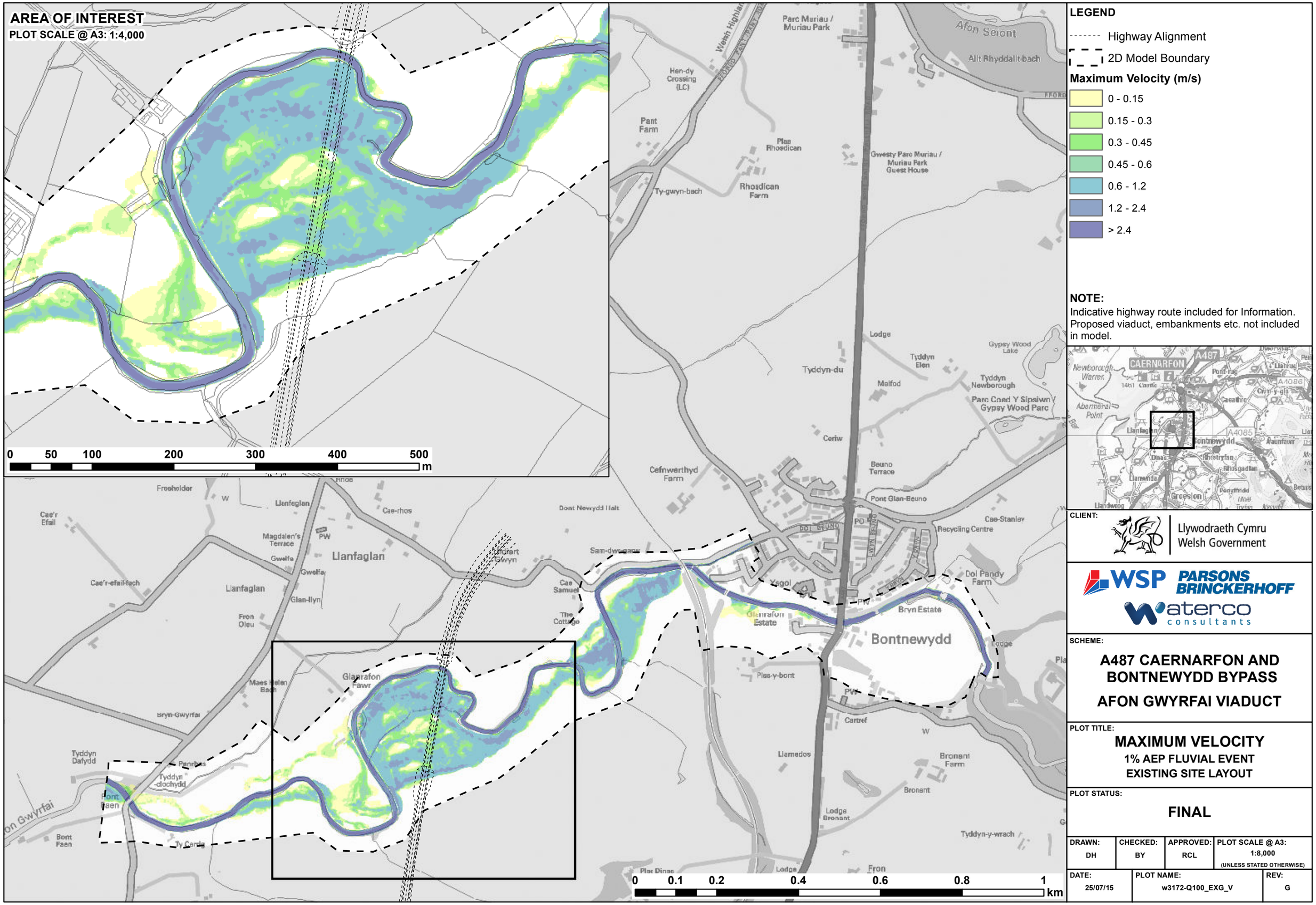
PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q20_EXG_V	G

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000



LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

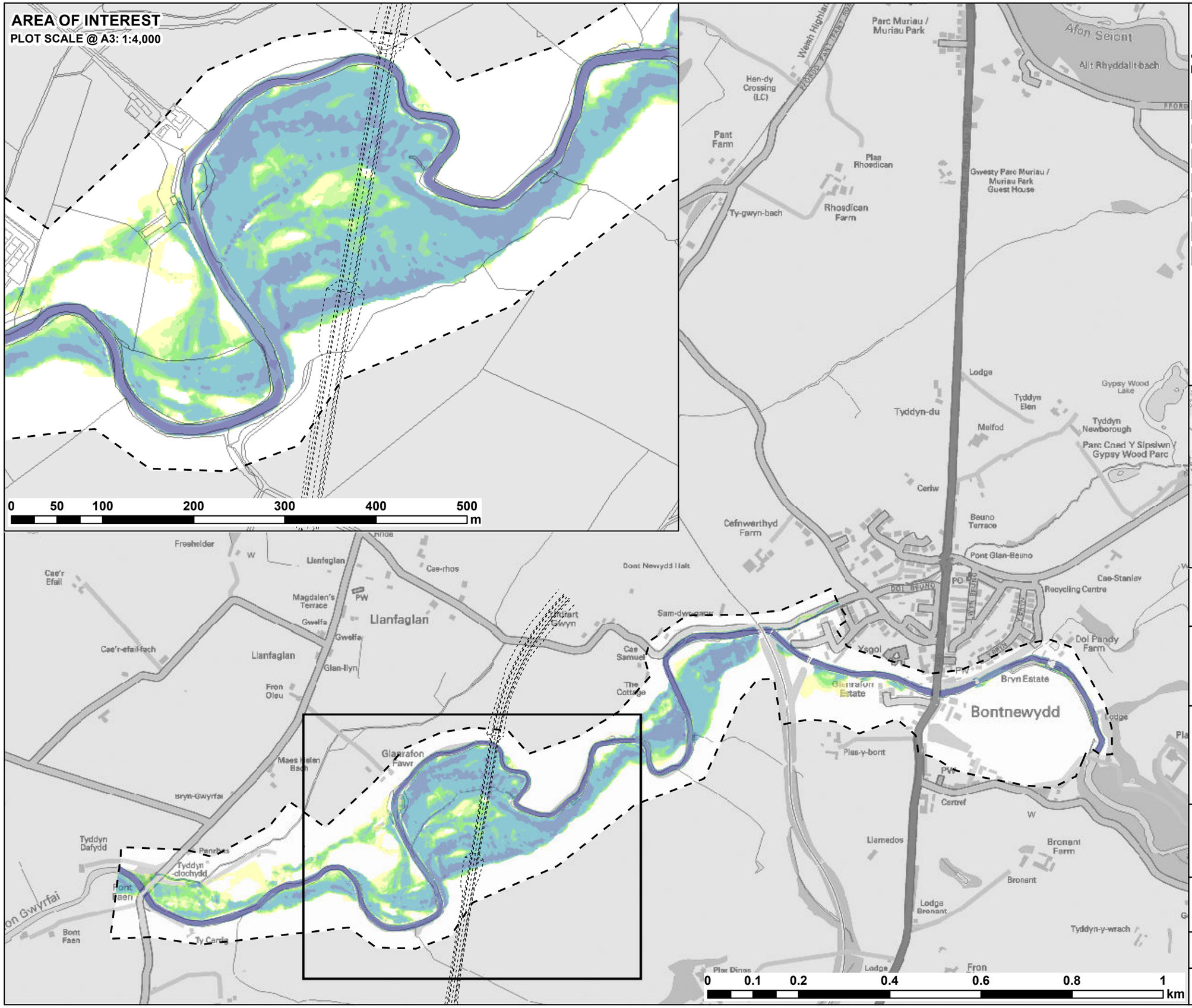
PLOT TITLE:

MAXIMUM VELOCITY
1% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q100_EXG_V	G



LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM VELOCITY

1% AEP + CCA FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q100CC_EXG_V	G

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

NOTE:
Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

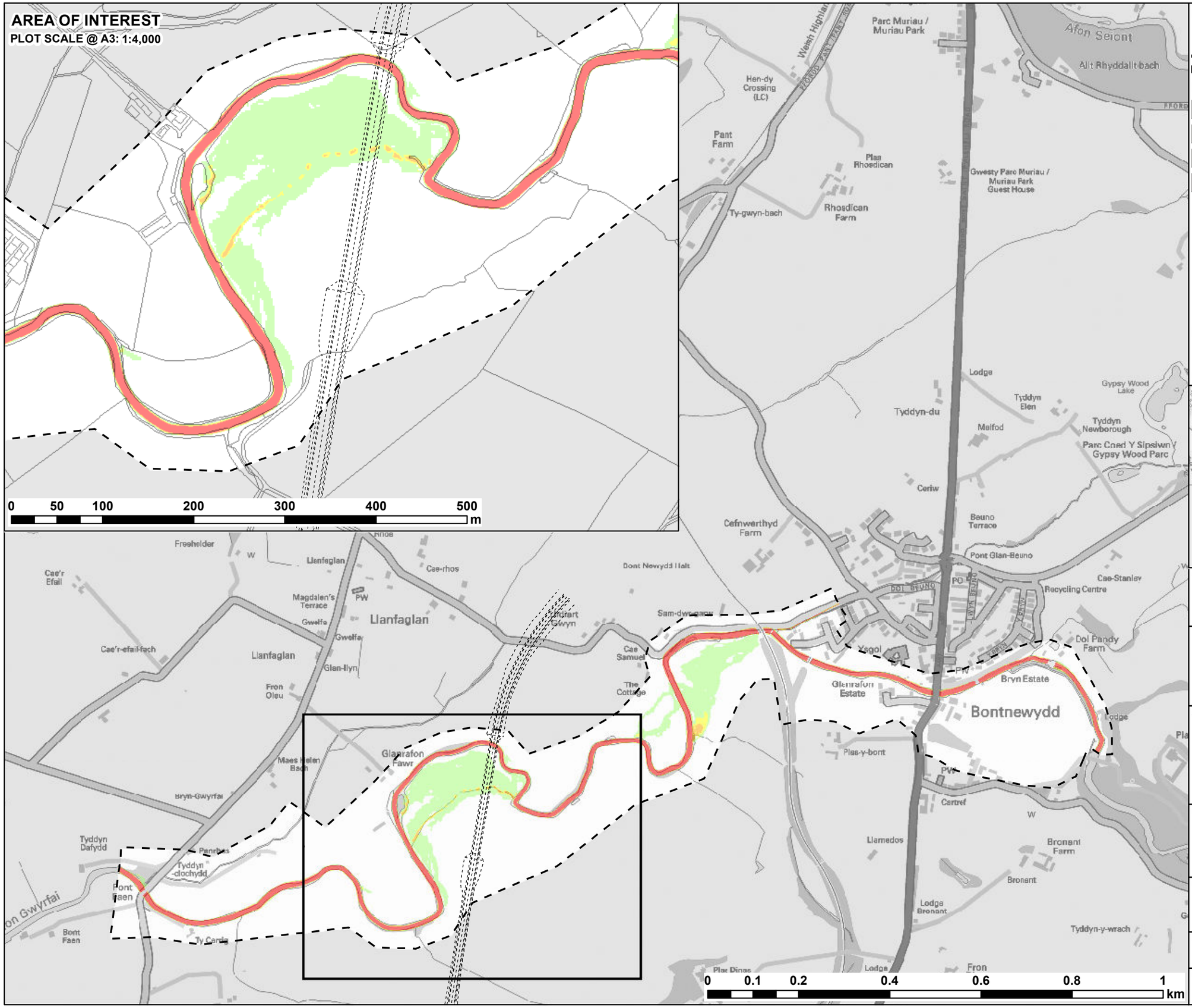
PLOT TITLE:

MAXIMUM VELOCITY
0.1% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q1000_EXG_V	G



LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

NOTE:
Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

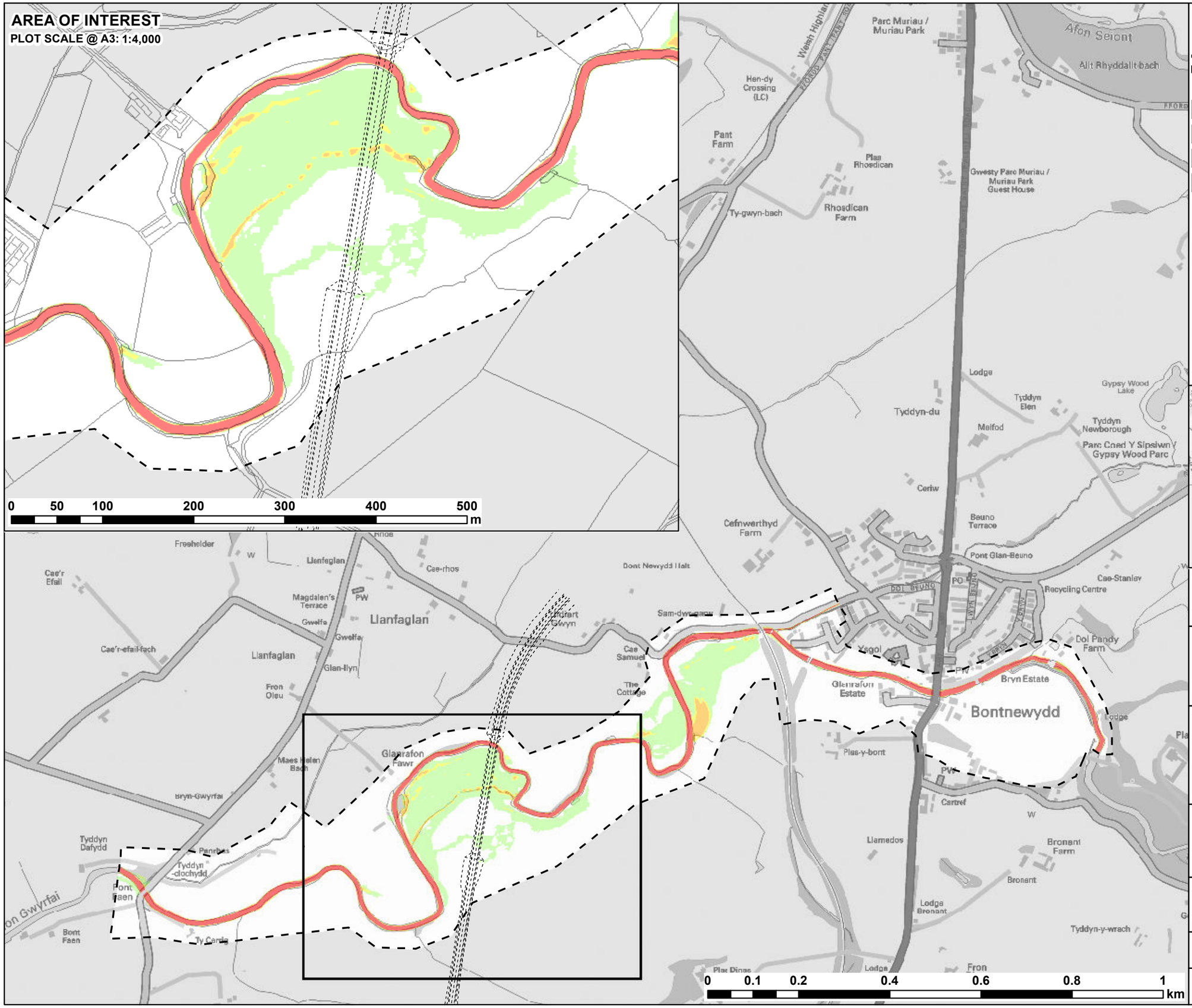
SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

PLOT TITLE:
MAXIMUM FLOOD HAZARD
50% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q2_EXG_H	G



LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

NOTE:
Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

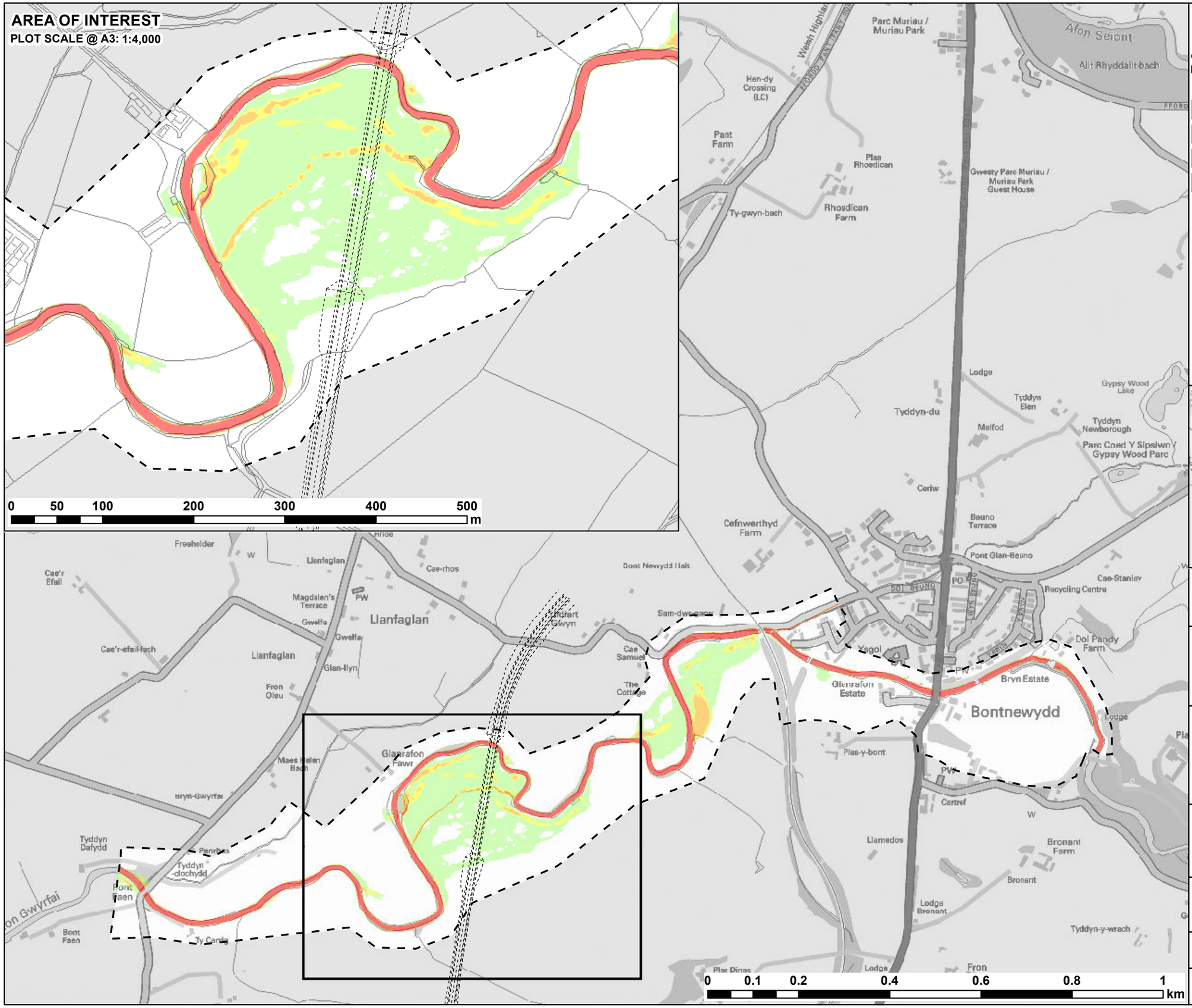
SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

PLOT TITLE:
MAXIMUM FLOOD HAZARD
20% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q5_EXG_H	G



LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

NOTE:
Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

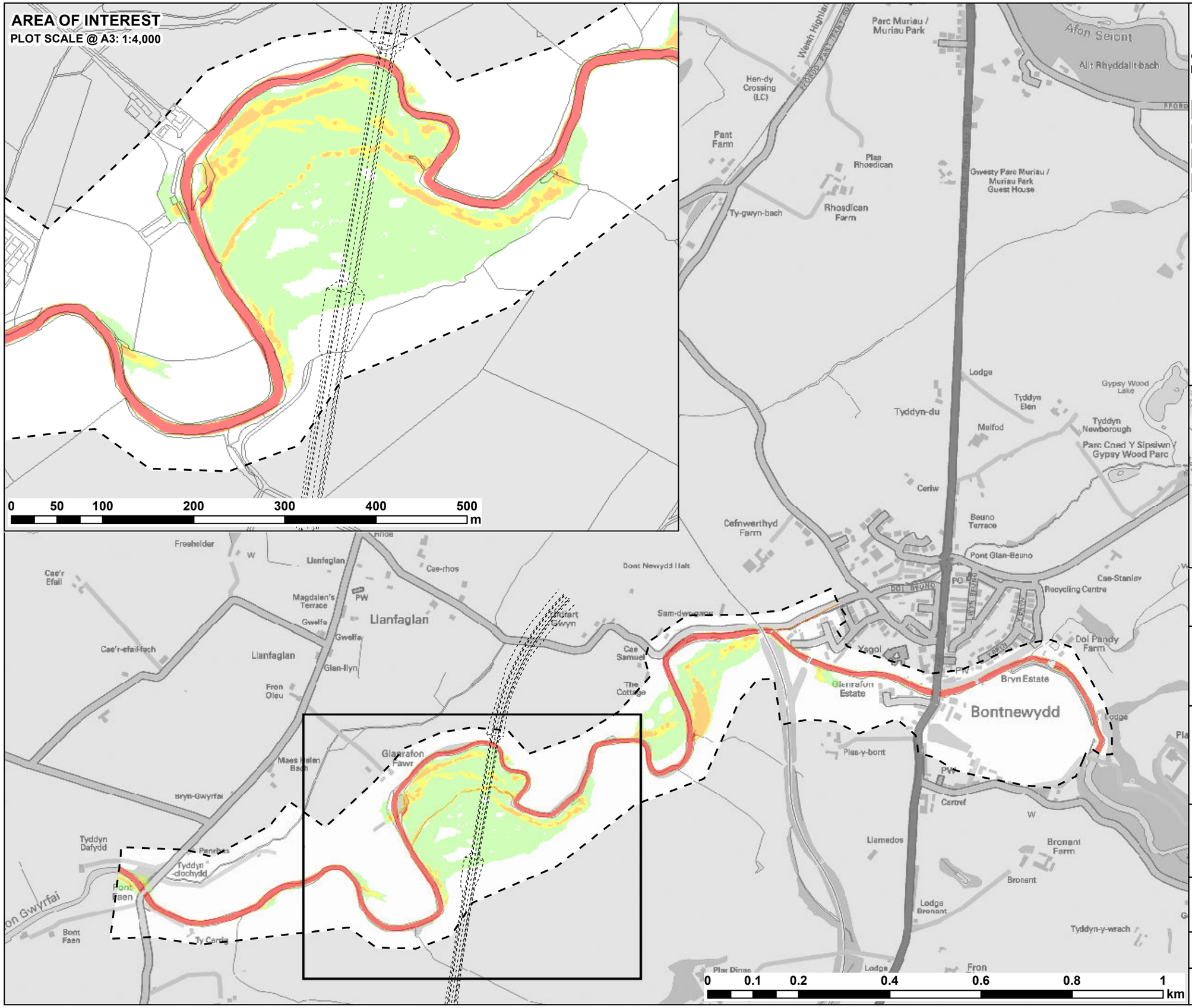
SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

PLOT TITLE:
MAXIMUM FLOOD HAZARD
10% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q10_EXG_H	G



LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

NOTE:
Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

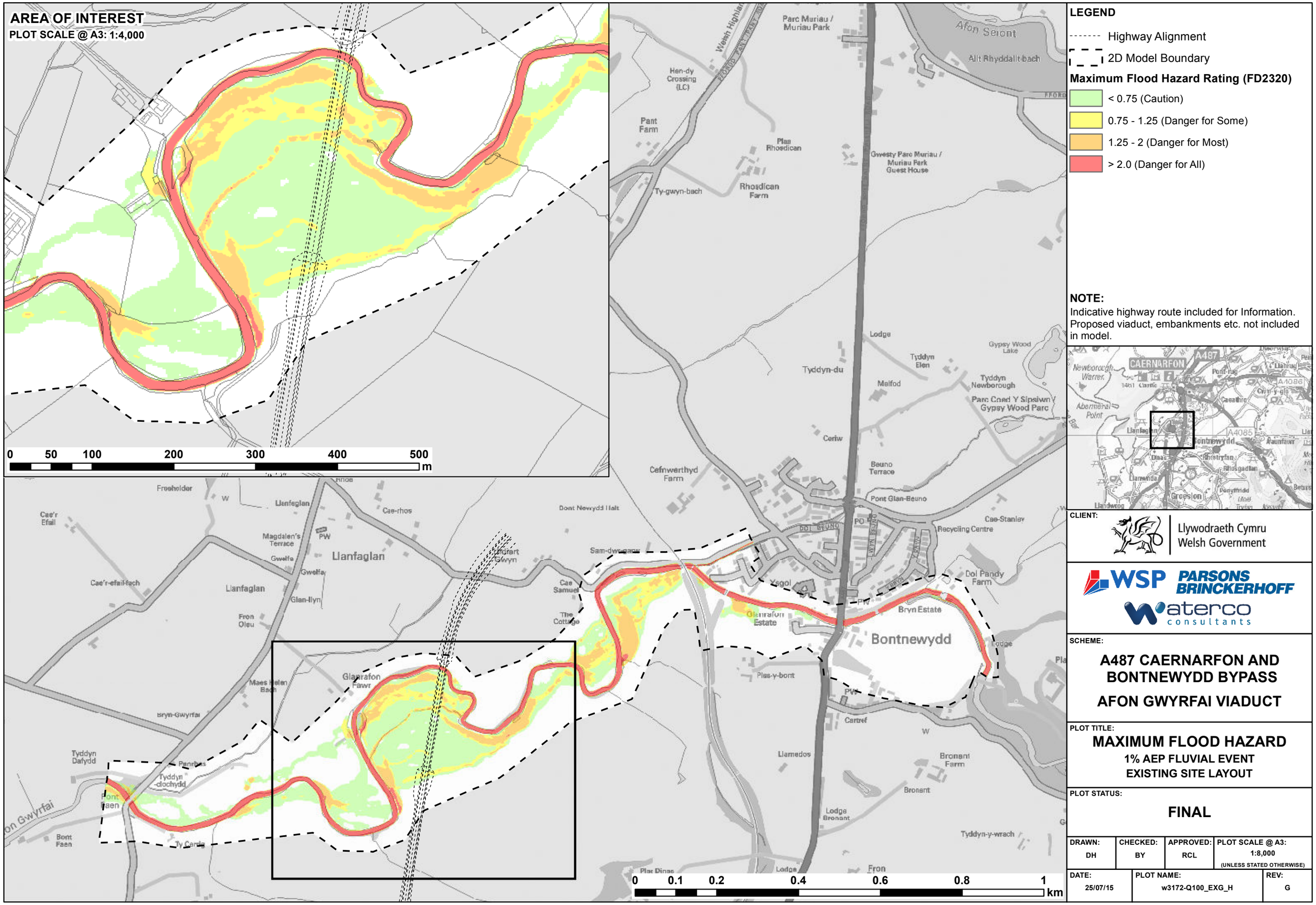
SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

PLOT TITLE:
MAXIMUM FLOOD HAZARD
5% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q20_EXG_H	G



LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

NOTE:
Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

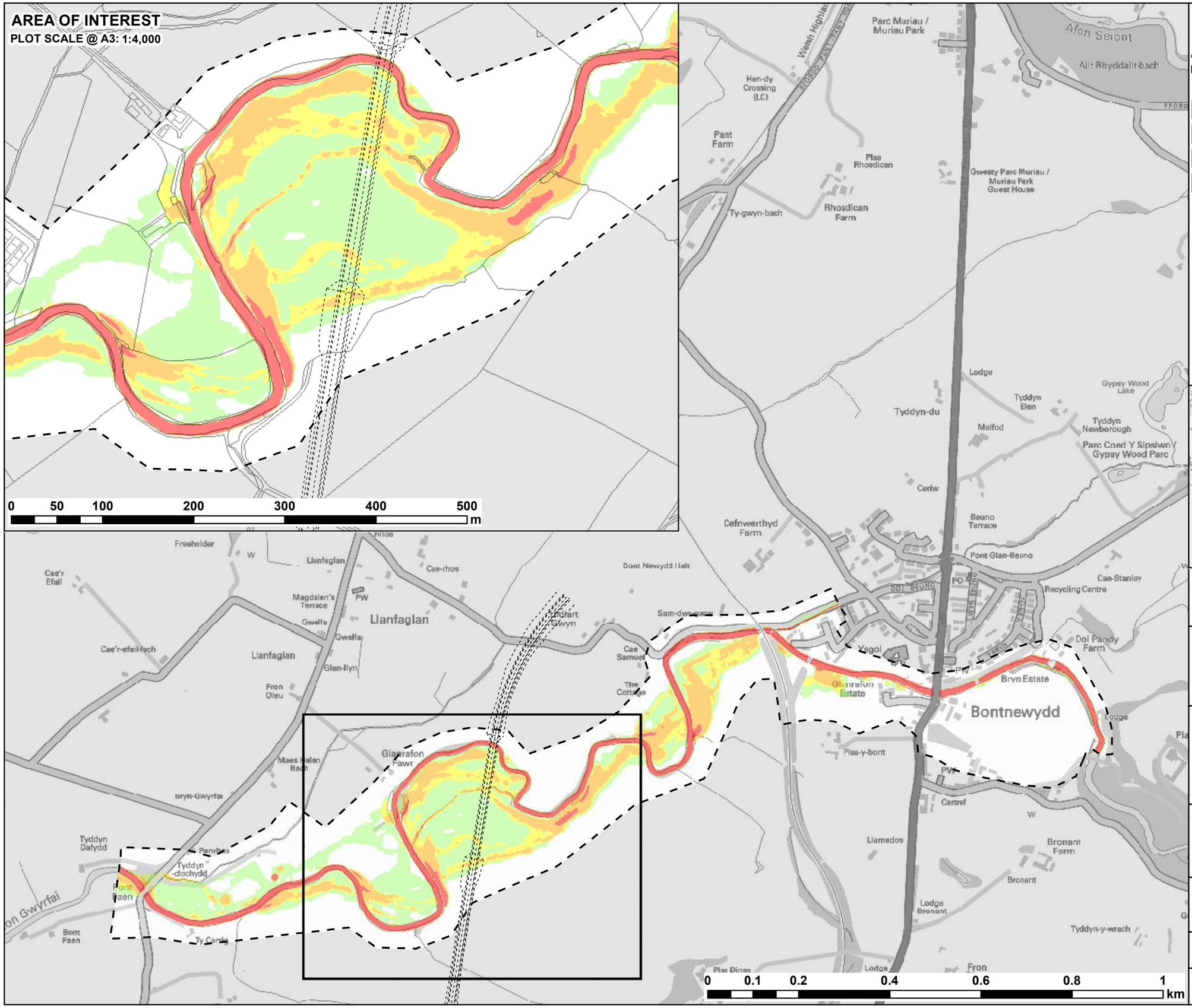
SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

PLOT TITLE:
MAXIMUM FLOOD HAZARD
1% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q100_EXG_H	G



NOTE:
Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

PLOT TITLE:
MAXIMUM FLOOD HAZARD
1% AEP + CCA FLUVIAL EVENT
EXISTING SITE LAYOUT

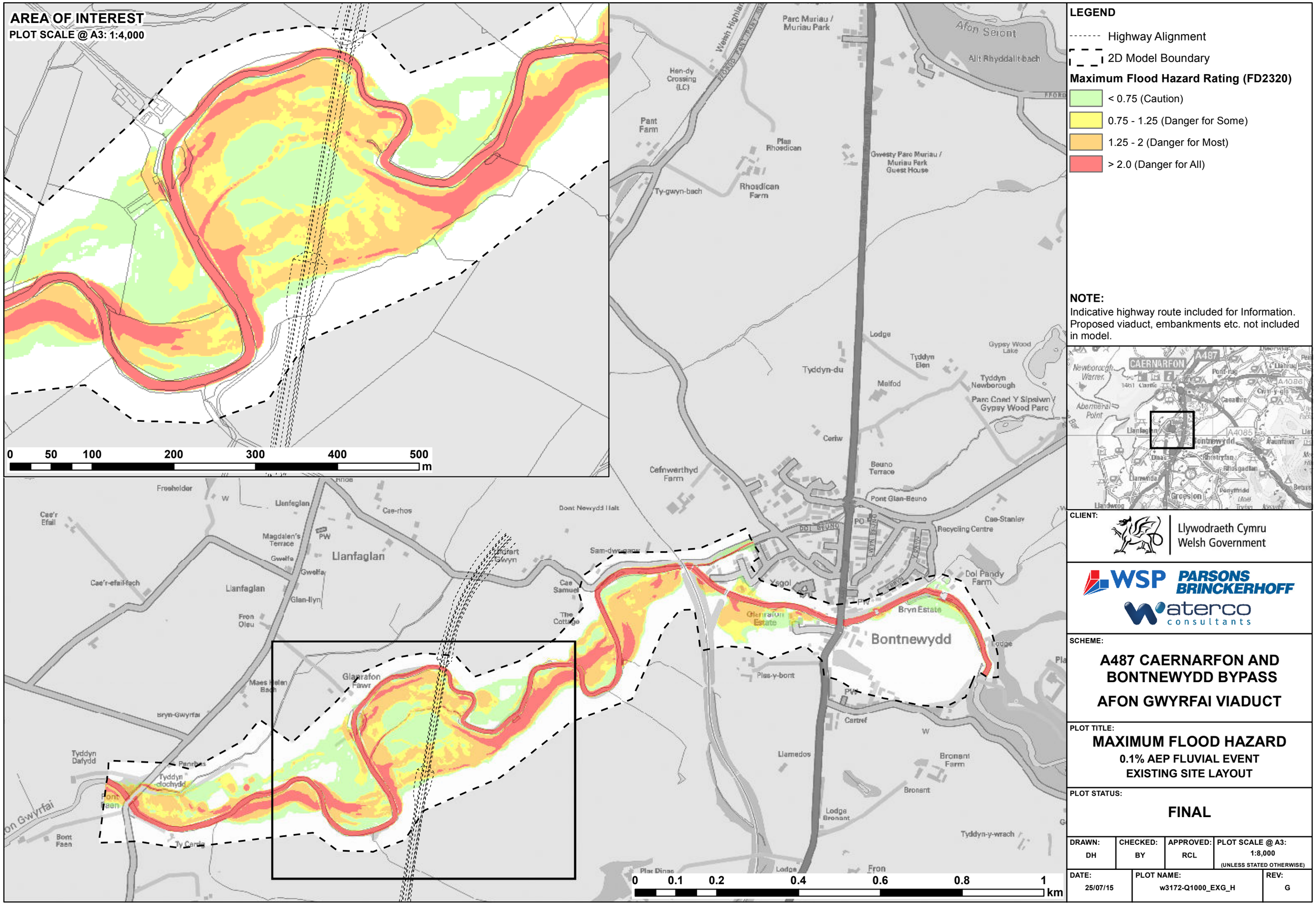
PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q100CC_EXG_H	G

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000



LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

NOTE:
Indicative highway route included for Information. Proposed viaduct, embankments etc. not included in model.

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD HAZARD

0.1% AEP FLUVIAL EVENT
EXISTING SITE LAYOUT

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q1000_EXG_H	G

Proposed Development Arrangement (DEV1)

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

CLIENT: Llywodraeth Cymru / Welsh Government

WSP PARSONS BRINCKERHOFF

Waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD DEPTH

50% AEP FLUVIAL EVENT

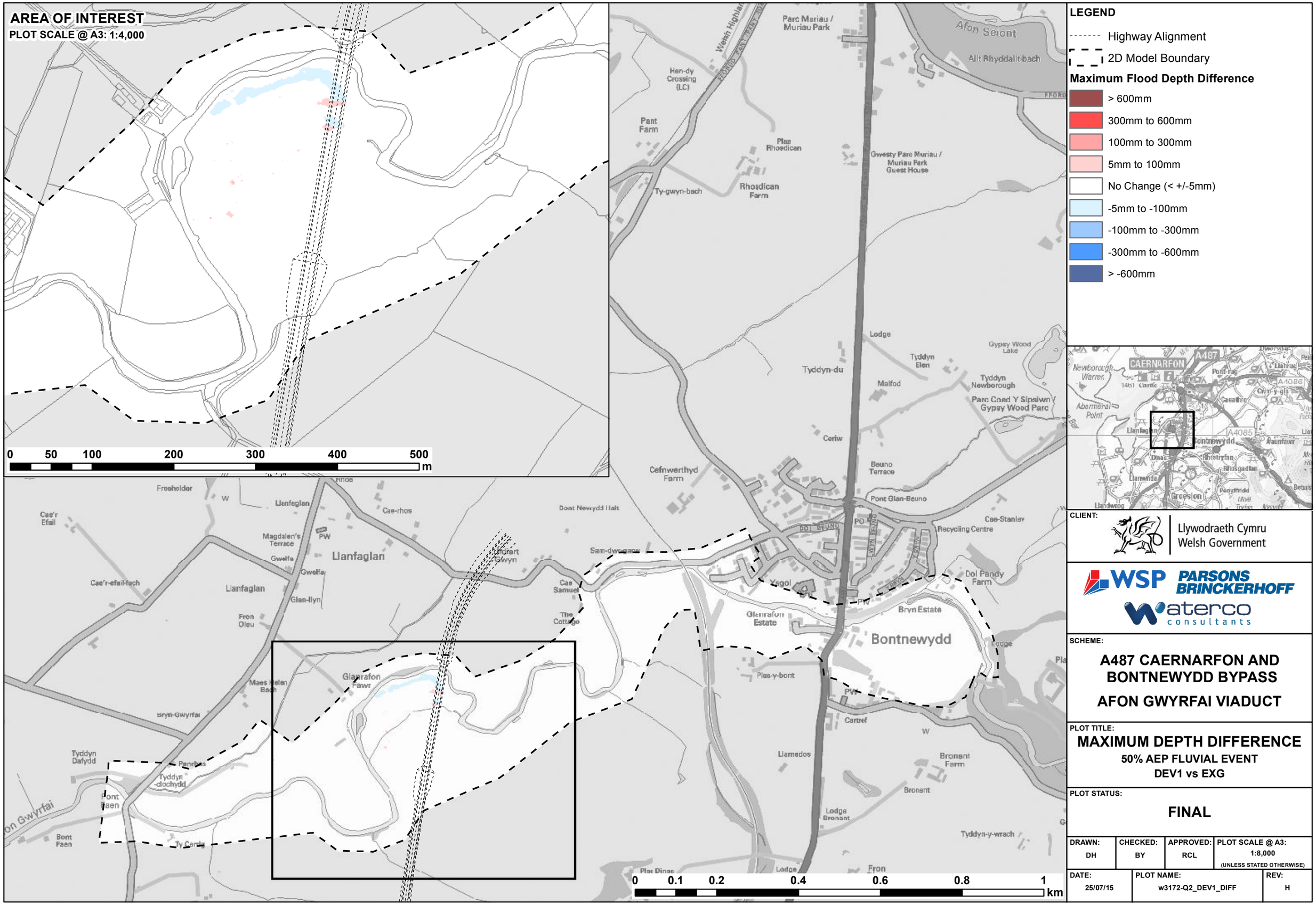
PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q2_DEV1_D	G



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM DEPTH DIFFERENCE

50% AEP FLUVIAL EVENT

DEV1 vs EXG

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q2_DEV1_DIFF	H

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF

waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD DEPTH

20% AEP FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q5_DEV1_D	G

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth Difference

- > 600mm
- 300mm to 600mm
- 100mm to 300mm
- 5mm to 100mm
- No Change (< +/-5mm)
- -5mm to -100mm
- -100mm to -300mm
- -300mm to -600mm
- > -600mm

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF

Waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM DEPTH DIFFERENCE

20% AEP FLUVIAL EVENT

DEV1 vs EXG

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q5_DEV1_DIFF	H

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

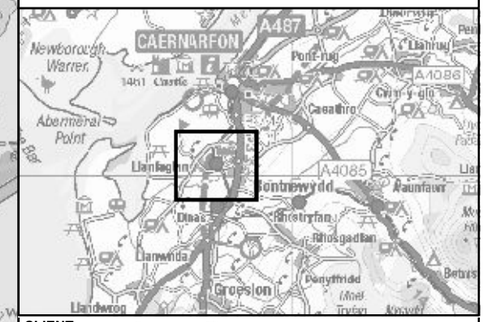
0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD DEPTH

10% AEP FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q10_DEV1_D	G

AREA OF INTEREST
PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth Difference

- > 600mm
- 300mm to 600mm
- 100mm to 300mm
- 5mm to 100mm
- No Change (< +/-5mm)
- -5mm to -100mm
- -100mm to -300mm
- -300mm to -600mm
- > -600mm

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

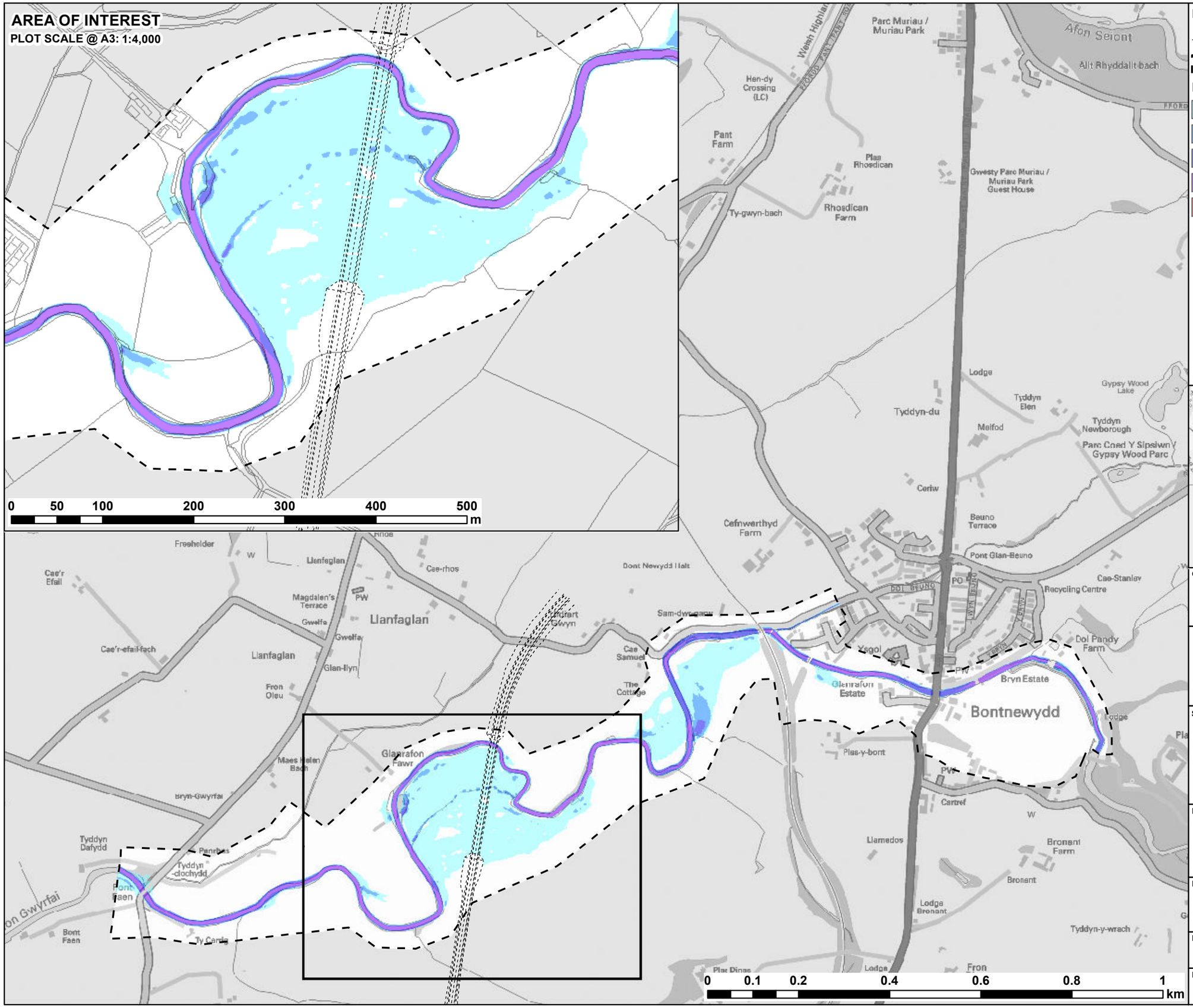
SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

PLOT TITLE:
MAXIMUM DEPTH DIFFERENCE
10% AEP FLUVIAL EVENT
DEV1 vs EXG

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q10_DEV1_DIFF	H



LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

CLIENT:

Llywodraeth Cymru
Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD DEPTH

5% AEP FLUVIAL EVENT

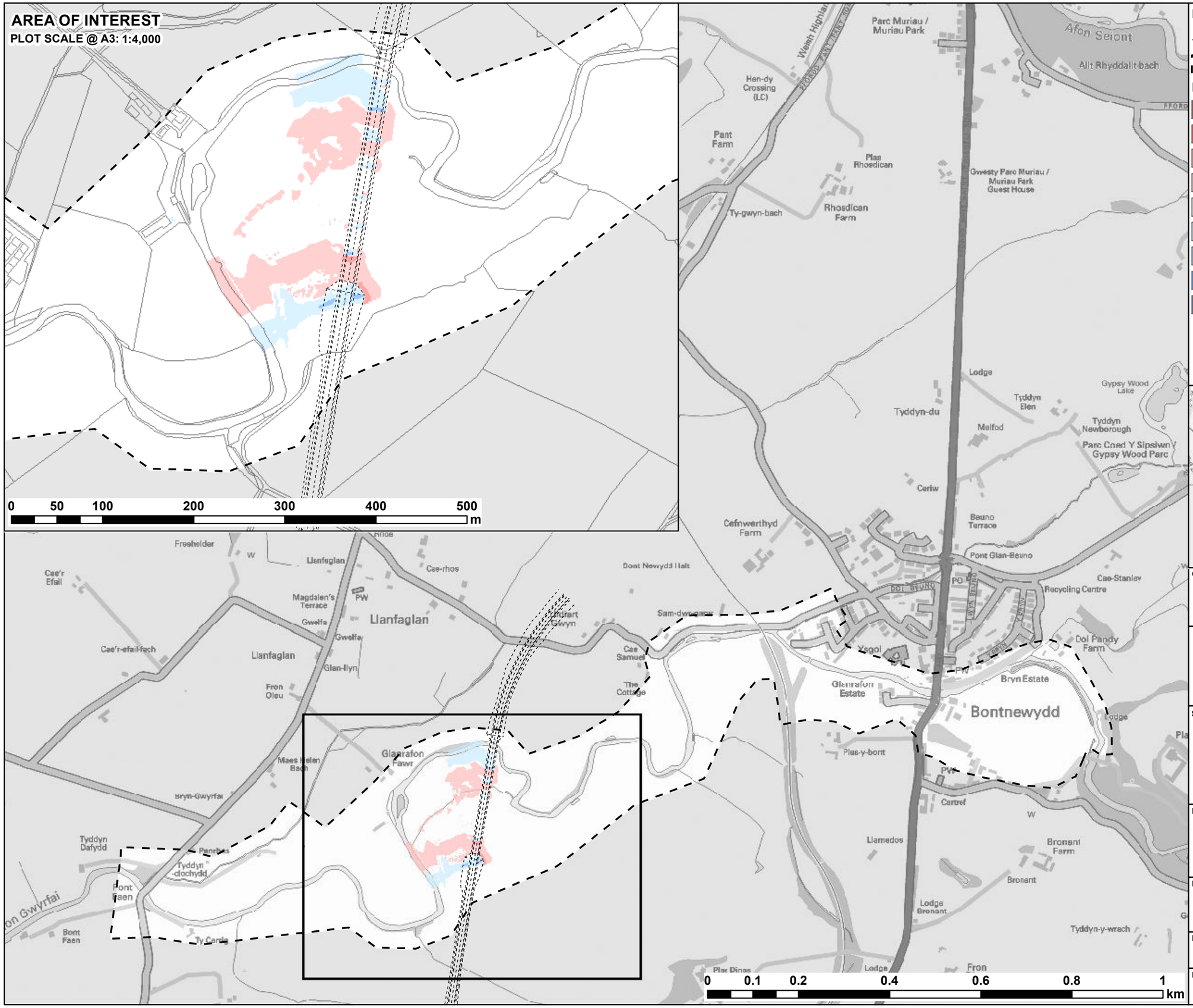
PROPOSED SITE LAYOUT (DEV1)

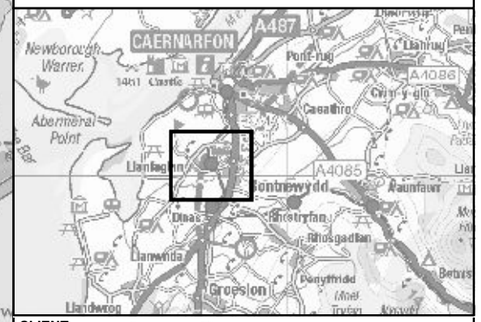
PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q20_DEV1_D	G





LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth Difference

- > 600mm
- 300mm to 600mm
- 100mm to 300mm
- 5mm to 100mm
- No Change (< +/-5mm)
- -5mm to -100mm
- -100mm to -300mm
- -300mm to -600mm
- > -600mm

CLIENT:

Llywodraeth Cymru
Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM DEPTH DIFFERENCE

5% AEP FLUVIAL EVENT

DEV1 vs EXG

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q20_DEV1_DIFF	H

AREA OF INTEREST
PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

PLOT TITLE:
MAXIMUM FLOOD DEPTH
1% AEP FLUVIAL EVENT
PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q100_DEV1_D	G

AREA OF INTEREST
PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth Difference

- > 600mm
- 300mm to 600mm
- 100mm to 300mm
- 5mm to 100mm
- No Change (< +/-5mm)
- -5mm to -100mm
- -100mm to -300mm
- -300mm to -600mm
- > -600mm

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

PLOT TITLE:
MAXIMUM DEPTH DIFFERENCE
1% AEP FLUVIAL EVENT
DEV1 vs EXG

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q100_DEV1_DIFF	H

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF

waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD DEPTH

1% AEP + CCA FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q100CC_DEV1_D	G

AREA OF INTEREST
PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth Difference

- > 600mm
- 300mm to 600mm
- 100mm to 300mm
- 5mm to 100mm
- No Change (< +/-5mm)
- -5mm to -100mm
- -100mm to -300mm
- -300mm to -600mm
- > -600mm

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

PLOT TITLE:
MAXIMUM DEPTH DIFFERENCE
1% AEP + CCA FLUVIAL EVENT
DEV1 vs EXG

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q100CC_DEV1_DIFF	H

AREA OF INTEREST
PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

PLOT TITLE:
MAXIMUM FLOOD DEPTH
0.1% AEP FLUVIAL EVENT
PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q1000_DEV1_D	G

AREA OF INTEREST
PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Depth Difference

- > 600mm
- 300mm to 600mm
- 100mm to 300mm
- 5mm to 100mm
- No Change (< +/-5mm)
- -5mm to -100mm
- -100mm to -300mm
- -300mm to -600mm
- > -600mm

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

PLOT TITLE:
MAXIMUM DEPTH DIFFERENCE
0.1% AEP FLUVIAL EVENT
DEV1 vs EXG

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q1000_DEV1_DIFF	H

AREA OF INTEREST
PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

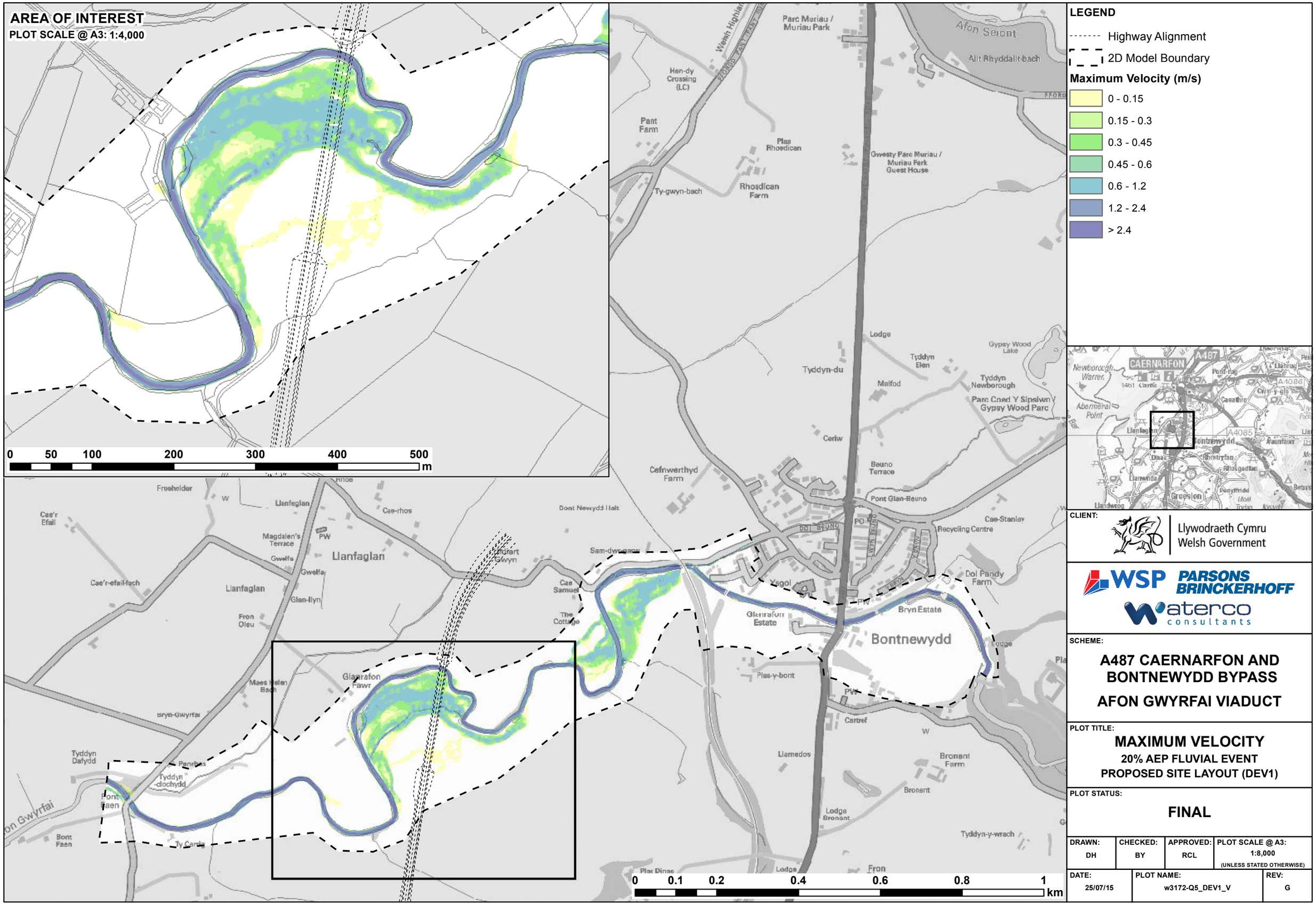
PLOT TITLE:
MAXIMUM VELOCITY
50% AEP FLUVIAL EVENT
PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q2_DEV1_V	G

AREA OF INTEREST
PLOT SCALE @ A3: 1:4,000



LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

CLIENT: Llywodraeth Cymru / Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM VELOCITY
20% AEP FLUVIAL EVENT
PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q5_DEV1_V	G

AREA OF INTEREST
PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

CLIENT:
Llywodraeth Cymru
Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

PLOT TITLE:
MAXIMUM VELOCITY
10% AEP FLUVIAL EVENT
PROPOSED SITE LAYOUT (DEV1)

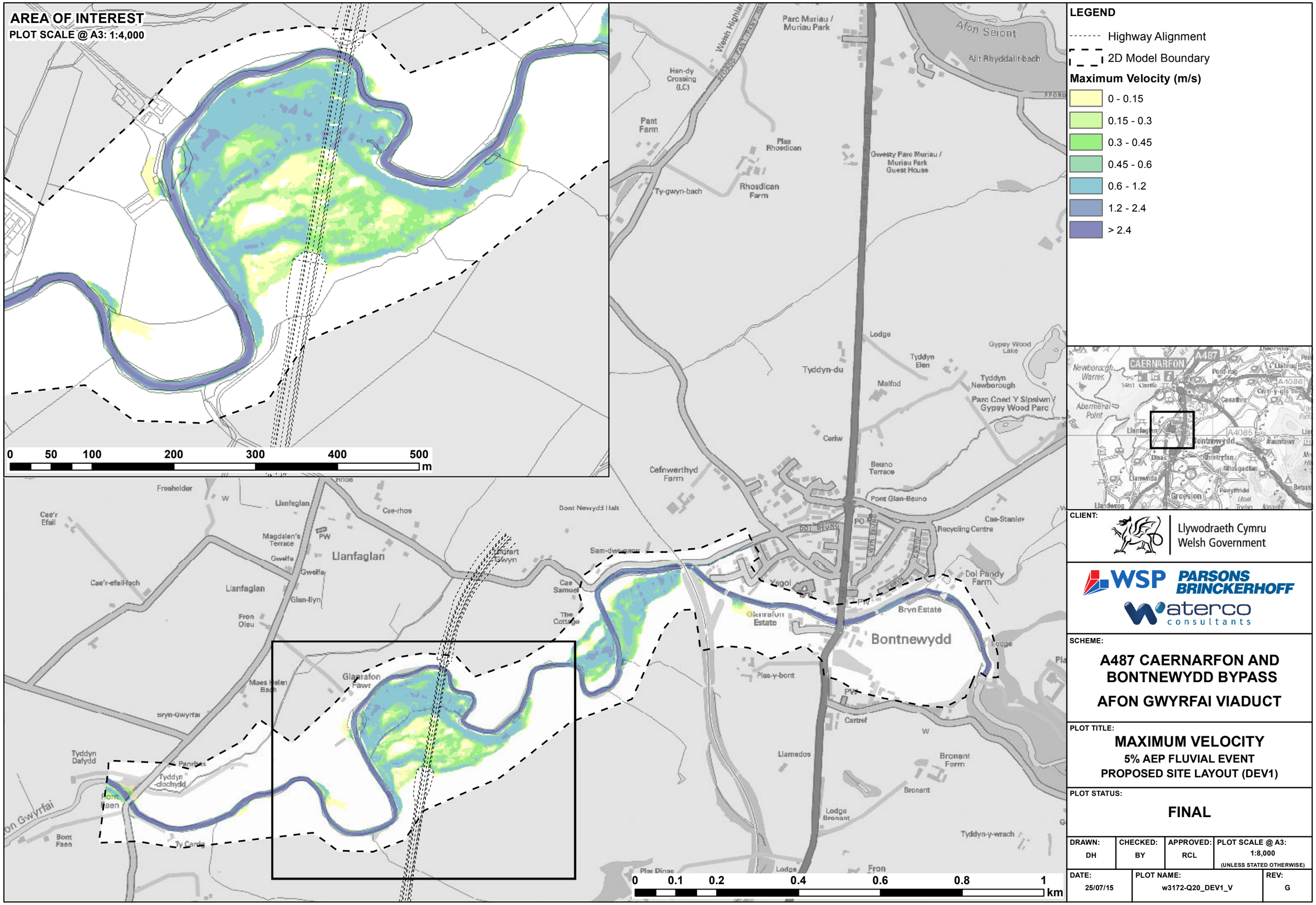
PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q10_DEV1_V	G

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000



LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM VELOCITY

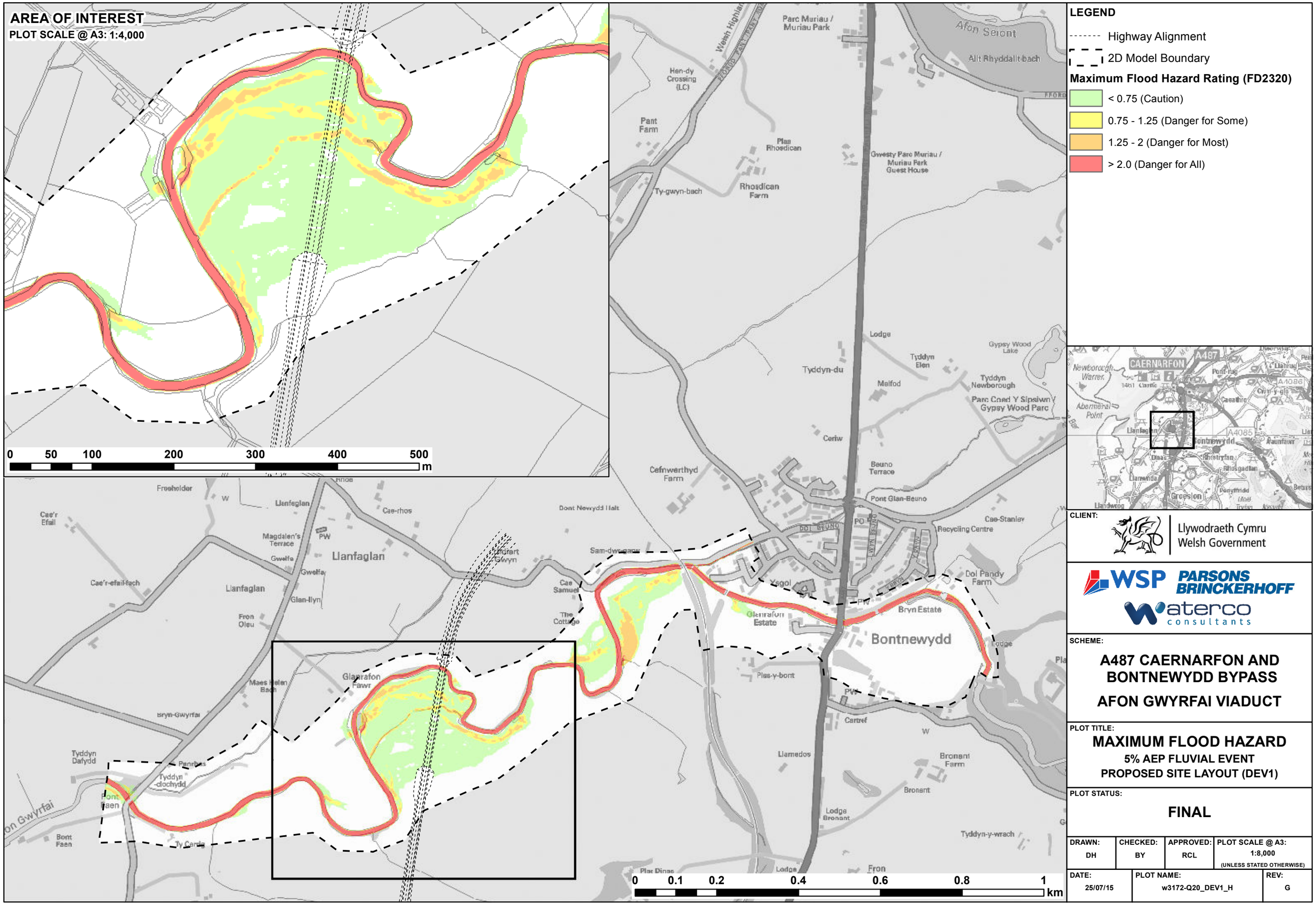
5% AEP FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q20_DEV1_V	G


AREA OF INTEREST
PLOT SCALE @ A3: 1:4,000
0 50 100 200 300 400 500 m
0 0.1 0.2 0.4 0.6 0.8 1 km
LEGEND
Highway Alignment
2D Model Boundary
Maximum Flood Hazard Rating (FD2320)
< 0.75 (Caution)
0.75 - 1.25 (Danger for Some)
1.25 - 2 (Danger for Most)
> 2.0 (Danger for All)
Parc Muriau / Muriau Park
Afon Seiont
Allt Rhyddalit bach
Hen-dy Crossing (LC)
Pant Farm
Plas Rhosdican
Gwesty Parc Muriau / Muriau Park Guest House
Ty-gwyn-bach
Rhosdican Farm
Lodge
Gypsy Wood Lake
Tyddyn Elen
Tyddyn-du
Melfod
Tyddyn Newborough
Parc Coed Y Sipsiwn / Gypsy Wood Parc
Ceriw
Cefnwerthyd Farm
Beuno Terrace
Pont Glan-Beuno
Cae-Stanley
Recycling Centre
Dol Pandy Farm
Ysgol
Bryn Estate
Glanrafon Estate
Bontnewydd
Lodge
Plas-y-bont
Cantref
Llamedos
Bronant Farm
Bronant
Lodge Bronant
Tyddyn-y-wrach
Fron
Plas Dinas
Freeholder
Llanfaglan
Cae-rhos
Bont Newydd Halt
Cae'r Efail
Magdalen's Terrace
Gwelfa
Cae'r-efail-fach
Glan-llyn
Fron Oleu
Cae Samuel
The Cottage
Maes Helen Bach
Glanrafon Fawr
Bryn-Gwyrfai
Tyddyn Dafydd
Pandy
Tyddyn-clochydd
Pont Faen
Bont Faen
Ty Canol
Afon Gwyrfai
CAERNARFON
A487
A4085
A4086
Newborough Warren
Abermenai Point
Llanfaglan
Bontnewydd
Caeathro
Groeslon
Llandwrog
Penygroes
Llanwnda
Dinas
Rhostryfan
Rhosgadfan
Pont-rug
Cwm-y-glo
Llanrug
Waunfawr
CLIENT:
Llywodraeth Cymru
Welsh Government
WSP PARSONS BRINCKERHOFF
waterco consultants
SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT
PLOT TITLE:
MAXIMUM FLOOD HAZARD
5% AEP FLUVIAL EVENT
PROPOSED SITE LAYOUT (DEV1)
PLOT STATUS:
FINAL
DRAWN: DH
CHECKED: BY
APPROVED: RCL
PLOT SCALE @ A3: 1:8,000 (UNLESS STATED OTHERWISE)
DATE: 25/07/15
PLOT NAME: w3172-Q20_DEV1_H
REV: G

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF

waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM VELOCITY

1% AEP FLUVIAL EVENT

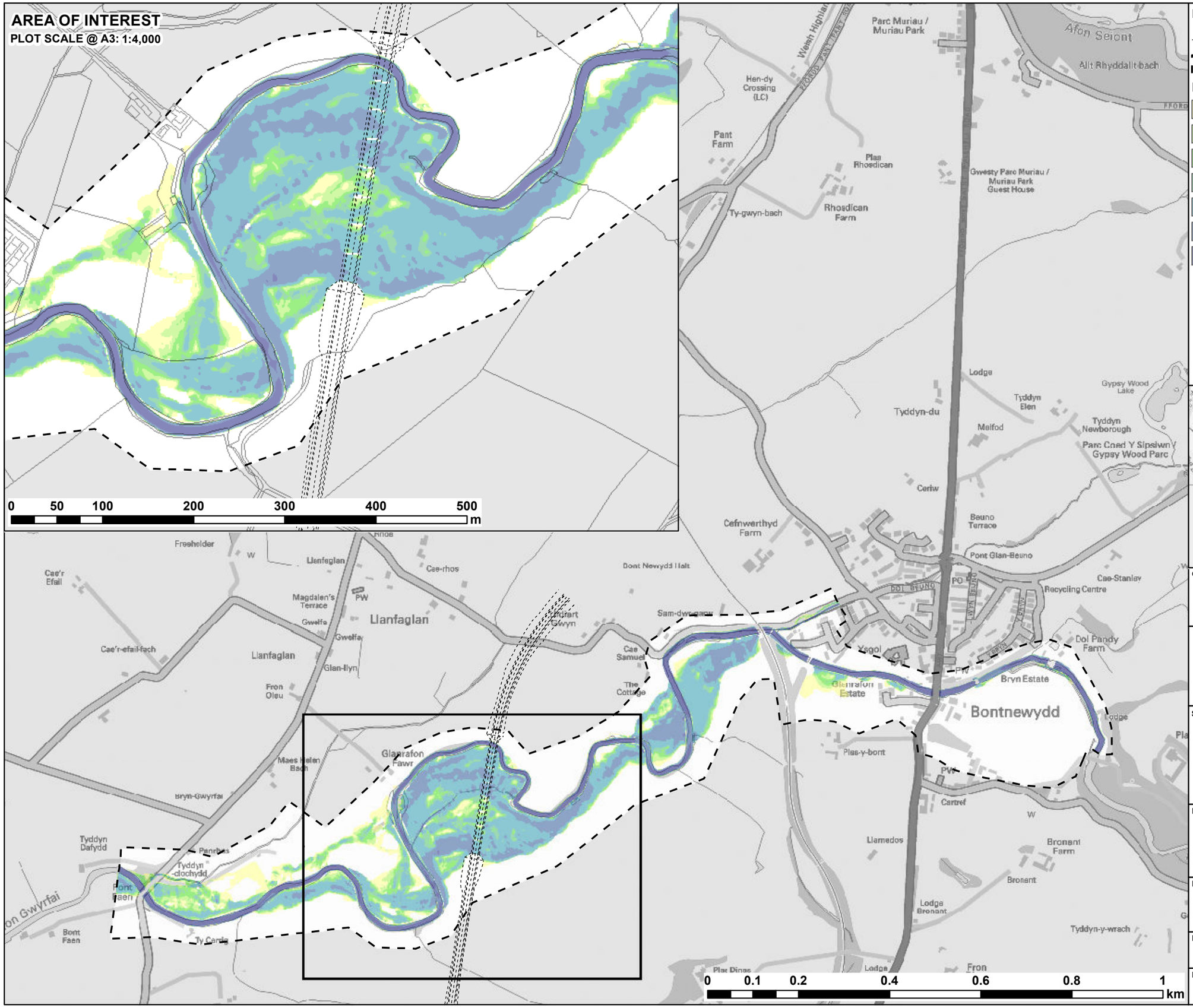
PROPOSED SITE LAYOUT (DEV1)

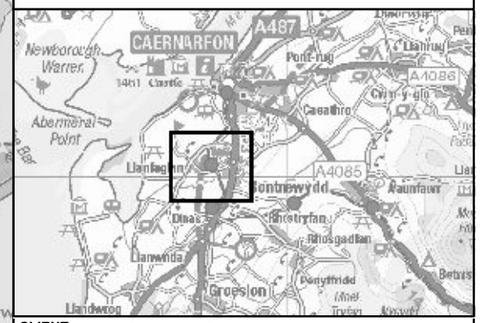
PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q100_DEV1_V	G





LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

CLIENT:

Llywodraeth Cymru
Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM VELOCITY

1% AEP + CCA FLUVIAL EVENT

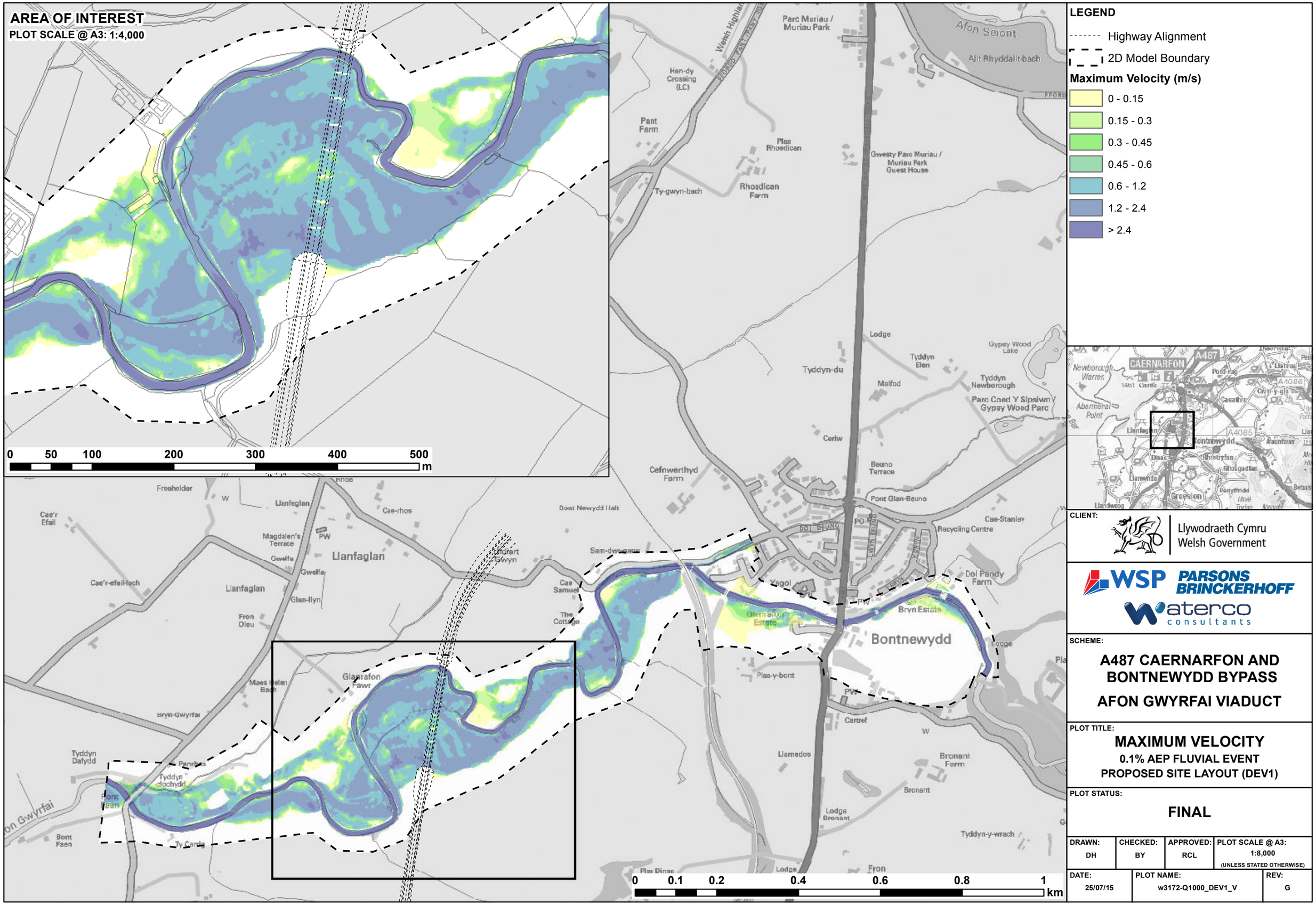
PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q100CC_DEV1_V	G



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM VELOCITY

0.1% AEP FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q1000_DEV1_V	G

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF

Waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD HAZARD

50% AEP FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q2_DEV1_H	G

AREA OF INTEREST
PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

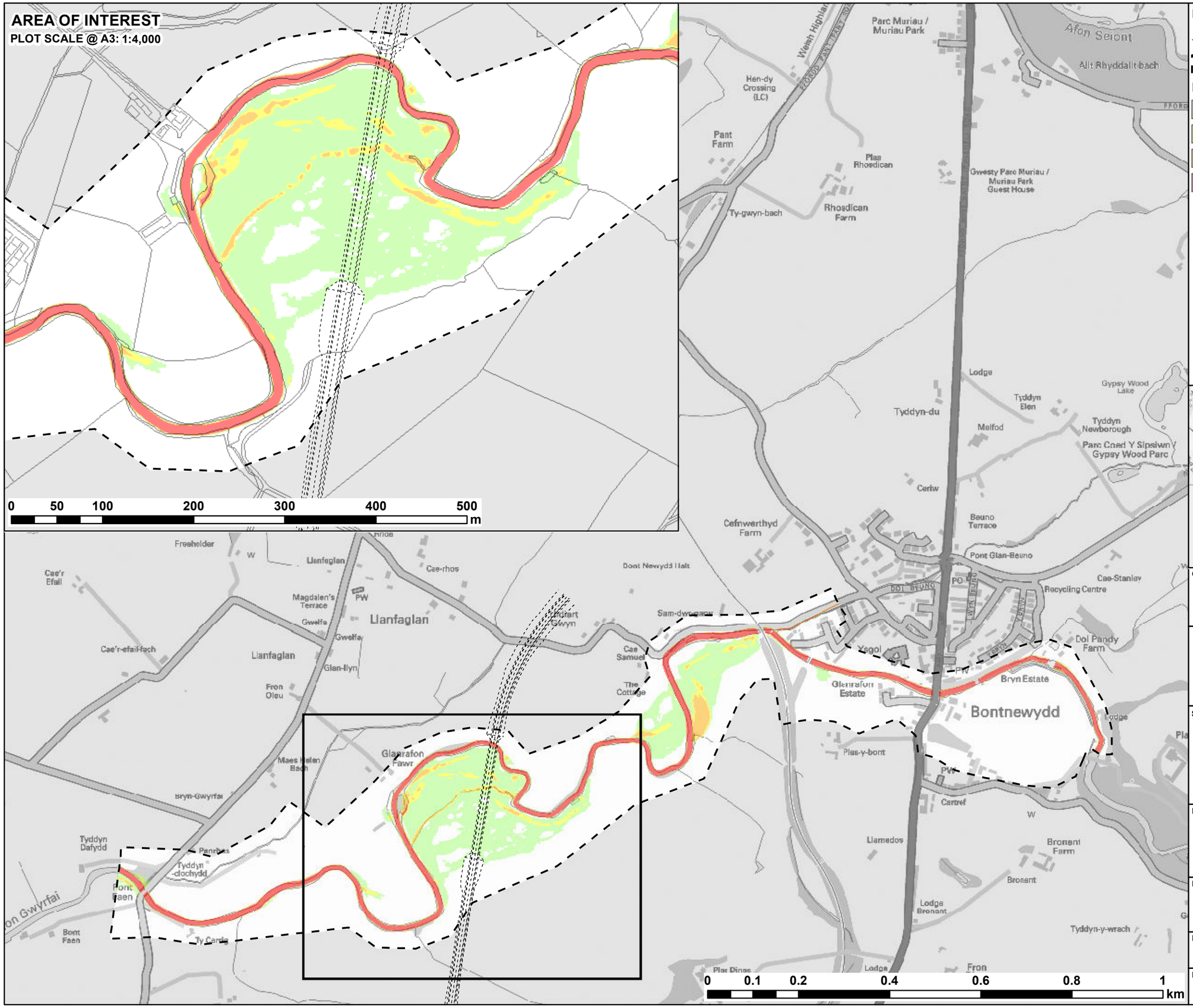
SCHEME:
A487 CAERNARFON AND BONTNEWYDD BYPASS
AFON GWYRFAI VIADUCT

PLOT TITLE:
MAXIMUM FLOOD HAZARD
20% AEP FLUVIAL EVENT
PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:
FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q5_DEV1_H	G



LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

CLIENT:

Llywodraeth Cymru
Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD HAZARD

10% AEP FLUVIAL EVENT

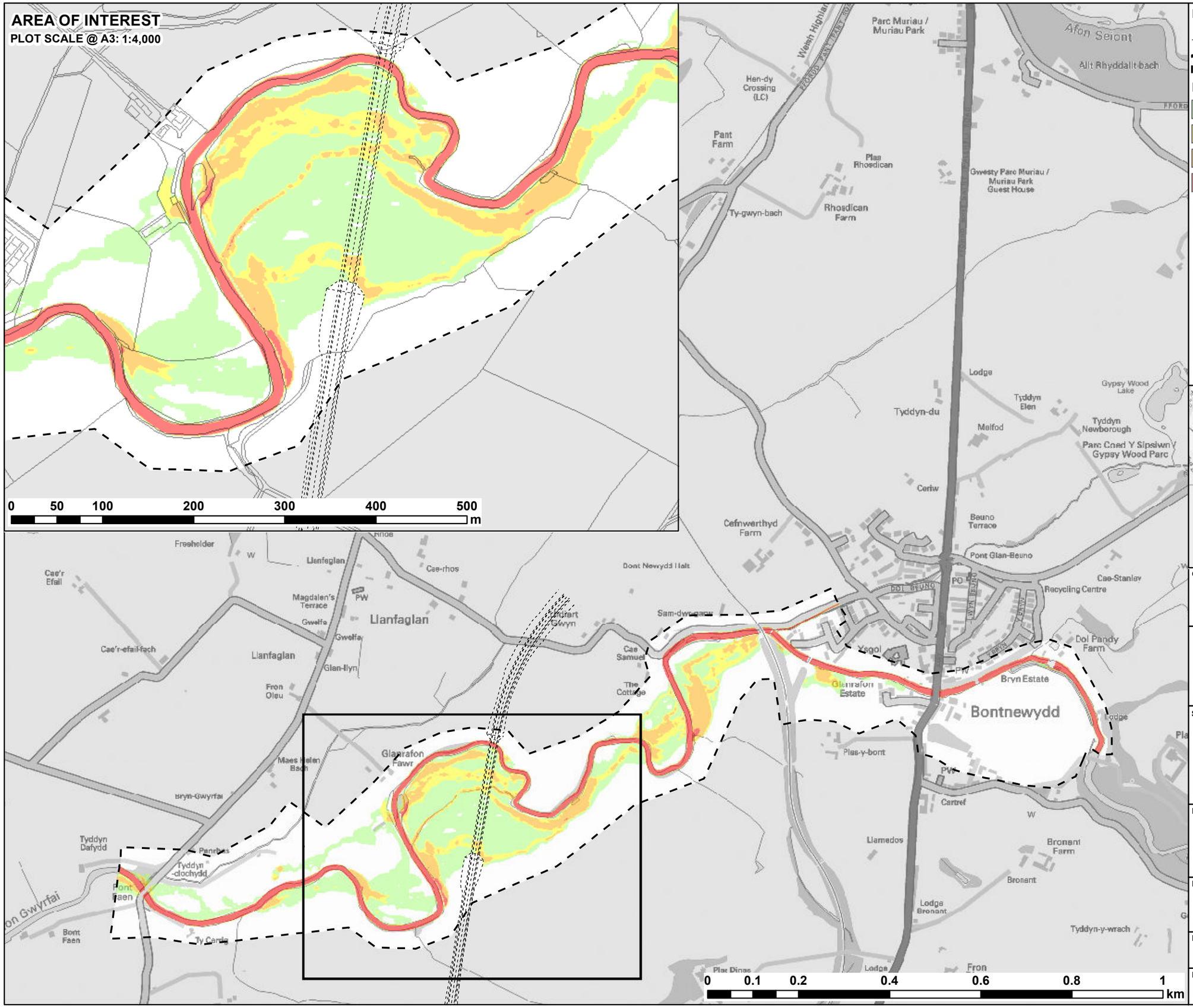
PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q10_DEV1_H	G



LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

CLIENT:

Llywodraeth Cymru
Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD HAZARD

1% AEP FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q100_DEV1_H	G

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF

Waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD HAZARD

1% AEP + CCA FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q100CC_DEV1_H	G

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- Highway Alignment
- 2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF

Waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD HAZARD

0.1% AEP FLUVIAL EVENT

PROPOSED SITE LAYOUT (DEV1)

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
DH	BY	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q1000_DEV1_H	G

Appendix E – Tabulated 1D Maximum Water Levels

Proposed A487 Caernarfon and Bontnewydd - Afon Gwyrfai Crossing

Hydraulic Model Results - Afon Gwyrfai / Afon Beuno
1D ISIS Model Results - Maximum Water Levels (mAOD) and Depths (m)

Primary Simulations

Job Name: A487 Caernarfon and Bontnewydd
Job Number: w3172
Date: 26/11/15
Model Type: ISIS-TUFLOW
ISIS Build: 3.7.1 64-bit DP
TUFLOW Build: 2013-12-AD 64-bit iDP

Notes:

Waterco model build 011
Nodes highlighted in yellow are situated close to the proposed road location
Nodes highlighted in grey indicate cross-sections generated from LiDAR dat

				50% AEP (Q2)			20% AEP (Q5)			10% AEP (Q10)			5% AEP (Q20)			1% AEP (Q100)			1% AEP + CCA (Q100CC)			0.1% AEP (Q1000)		
	Node Label	Bed Elevation (mAOD)	Notable Features / Structures	EXG Max WL (mAOD)	DEV1 Max WL (mAOD)	Flood Depth Variation EXG vs DEV1 (mm)	EXG Max WL (mAOD)	DEV1 Max WL (mAOD)	Flood Depth Variation EXG vs DEV1 (mm)	EXG Max WL (mAOD)	DEV1 Max WL (mAOD)	Flood Depth Variation EXG vs DEV1 (mm)	EXG Max WL (mAOD)	DEV1 Max WL (mAOD)	Flood Depth Variation EXG vs DEV1 (mm)	EXG Max WL (mAOD)	DEV1 Max WL (mAOD)	Flood Depth Variation EXG vs DEV1 (mm)	EXG Max WL (mAOD)	DEV1 Max WL (mAOD)	Flood Depth Variation EXG vs DEV1 (mm)	EXG Max WL (mAOD)	DEV1 Max WL (mAOD)	Flood Depth Variation EXG vs DEV1 (mm)
GWYRFAI	GWY_3522	38.92		39.70	39.70	0	39.79	39.79	0	39.85	39.85	0	39.92	39.92	0	40.08	40.08	0	40.19	40.19	0	40.33	40.33	0
	GWY_3490	37.84		38.79	38.79	0	38.91	38.91	0	39.00	39.00	0	39.08	39.08	0	39.28	39.28	0	39.42	39.42	0	39.53	39.53	0
	GWY_3440	36.48		37.57	37.57	0	37.70	37.70	0	37.79	37.79	0	37.88	37.88	0	38.09	38.09	0	38.24	38.24	0	38.39	38.39	0
	GWY_3390	35.87		36.88	36.88	0	37.01	37.01	0	37.09	37.09	0	37.17	37.17	0	37.37	37.37	0	37.51	37.51	0	37.62	37.62	0
	GWY_3340	34.99		35.99	35.99	0	36.10	36.10	0	36.18	36.18	0	36.25	36.25	0	36.44	36.44	0	36.56	36.56	0	36.64	36.64	0
	GWY_3290	34.10	Weir (U/S)	35.26	35.26	0	35.39	35.39	0	35.47	35.47	0	35.56	35.56	0	35.77	35.77	0	35.92	35.92	0	36.03	36.03	0
	GWY_3275	32.68	Weir (D/S)	33.61	33.61	0	33.75	33.75	0	33.83	33.83	0	33.91	33.91	0	34.14	34.14	0	34.30	34.30	0	34.42	34.42	0
	GWY_3225	31.76		32.93	32.93	0	33.07	33.07	0	33.17	33.17	0	33.28	33.28	0	33.54	33.54	0	33.72	33.72	0	34.18	34.18	0
	GWY_3190	31.49		32.49	32.49	0	32.65	32.65	0	32.76	32.76	0	32.88	32.88	0	33.20	33.20	0	33.41	33.41	0	33.83	33.83	0
	GWY_3132	30.62		32.40	32.40	0	32.62	32.62	0	32.76	32.76	0	32.90	32.90	0	33.28	33.28	0	33.50	33.50	0	33.90	33.90	0
	GWY_3110	30.68	Concrete weir (U/S)	32.37	32.37	0	32.57	32.57	0	32.70	32.70	0	32.84	32.84	0	33.19	33.19	0	33.41	33.41	0	33.92	33.92	0
	GWY_3103	30.28	Concrete weir (D/S)	31.37	31.37	0	31.49	31.49	0	31.56	31.56	0	31.64	31.64	0	31.85	31.85	0	32.04	32.04	0	32.78	32.78	0
	GWY_3096	30.27		31.27	31.27	0	31.40	31.40	0	31.48	31.48	0	31.57	31.57	0	31.78	31.78	0	31.94	31.94	0	32.42	32.42	0
	GWY_3017	29.67	A487 Road Bridge, Bontnewydd (U/S)	30.50	30.50	0	30.62	30.62	0	30.70	30.70	0	30.79	30.79	0	31.02	31.02	-1	31.19	31.19	0	31.72	31.72	0
	GWY_3005	29.67	A487 Road Bridge, Bontnewydd (D/S)	30.50	30.50	0	30.61	30.61	0	30.68	30.68	0	30.75	30.75	0	30.92	30.92	0	31.05	31.05	0	31.39	31.39	-1
	GWY_2870	27.73		28.90	28.90	0	29.04	29.04	0	29.14	29.14	0	29.23	29.23	0	29.45	29.45	0	29.57	29.57	0	29.91	29.91	0
	GWY_2723	27.00	Disused railway line (U/S)	27.89	27.89	0	28.03	28.03	0	28.12	28.12	0	28.20	28.20	0	28.41	28.41	0	28.56	28.56	0	28.98	28.98	0
	GWY_2715	27.00	Disused railway line (D/S)	27.89	27.89	0	28.03	28.03	0	28.12	28.12	0	28.20	28.20	0	28.41	28.41	0	28.54	28.54	0	28.88	28.88	0
	GWY_2613u	25.83	Confluence with Afon Beuno	27.31	27.31	0	27.42	27.42	0	27.48	27.48	1	27.51	27.51	0	27.61	27.61	0	27.69	27.69	0	27.95	27.95	0
	GWY_2596	26.10	Railway bridge (U/S)	27.23	27.23	0	27.32	27.32	0	27.35	27.35	0	27.37	27.37	0	27.41	27.41	0	27.43	27.43	0	27.49	27.49	0
	GWY_2581	26.10	Railway bridge (D/S)	27.00	27.00	0	27.04	27.04	0	27.07	27.07	0	27.09	27.09	0	27.12	27.12	-1	27.15	27.15	0	27.20	27.20	0
	GWY_2536	25.53		26.61	26.61	0	26.70	26.70	0	26.76	26.76	0	26.80	26.80	0	26.92	26.92	0	26.98	26.98	0	27.10	27.10	0
	GWY_2375	24.45		25.55	25.55	0	25.65	25.65	0	25.71	25.71	0	25.77	25.77	0	25.91	25.91	0	26.00	26.00	0	26.17	26.17	0
	GWY_2233	23.80		24.81	24.81	0	24.86	24.86	0	24.90	24.90	0	24.94	24.94	0	25.00	25.00	0	25.03	25.03	0	25.12	25.12	0
	GWY_2074	22.57		23.63	23.63	0	23.73	23.73	0	23.78	23.78	0	23.82	23.82	0	23.92	23.92	0	23.97	23.97	0	24.10	24.10	-1
	GWY_1930	20.88		22.34	22.34	0	22.52	22.52	0	22.64	22.64	0	22.75	22.75	0	22.96	22.96	0	22.99	23.00	1	23.20	23.20	0
	GWY_1787	20.15		21.71	21.71	0	21.88	21.88	0	21.97	21.97	0	22.03	22.03	0	22.17	22.18	2	22.31	22.31	-2	22.40	22.40	0
	GWY_1650	19.60		21.09	21.09	0	21.23	21.23	0	21.30	21.30	0	21.35	21.35	0	21.45	21.45	1	21.50	21.51	1	21.58	21.58	0
	GWY_1492	18.95		20.21	20.21	0	20.34	20.34	0	20.38	20.38	0	20.43	20.43	0	20.51	20.51	0	20.55	20.55	0	20.70	20.70	0
	GWY_1442	18.53	Proposed road crossing (U/S)	19.88	19.88	0	20.00	20.00	0	20.03	20.03	0	20.06	20.06	0	20.09	20.09	2	20.10	20.10	2	20.15	20.16	5
	GWY_1397	18.24	Proposed road crossing (DS)	19.50	19.50	0	19.59	19.59	0	19.63	19.63	0	19.67	19.56	-2	19.74	19.73	3	19.77	19.78	1	19.85	19.86	5
	GWY_1352	17.78		19.17	19.17	0	19.26	19.26	0	19.30	19.30	-5	19.36	19.34	-16	19.45	19.42	-23	19.50	19.47	-27	19.65	19.61	-43
	GWY_1193	17.02		18.08	18.08	0	18.16	18.16	-1	18.21	18.21	-2	18.26	18.25	-4	18.33	18.32	-3	18.37	18.36	-3	18.51	18.50	-6
	GWY_1032	15.36		16.77	16.77	0	16.95	16.95	0	17.06	17.06	2	17.14	17.14	5	17.29	17.31	15	17.37	17.43	53	17.63	17.68	52
	GWY_931	15.14		16.11	16.11	0	16.26	16.26	0	16.37	16.37	-2	16.47	16.46	-8	16.76	16.74	-23	16.90	16.87	-29	17.08	17.02	60
	GWY_795	13.28		15.07	15.07	0	15.25	15.25	0	15.37	15.37	0	15.49	15.49	-1	15.77	15.77	1	15.83	15.83	1	15.87	15.87	-1
	GWY_570	12.49		13.63	13.63	0	13.79	13.79	0	13.89	13.89	0	13.99	13.99	0	14.23	14.23	0	14.32	14.32	0	14.46	14.46	-1
	GWY_398	11.12		12.26	12.26	0	12.40	12.40	1	12.49	12.49	0	12.59	12.59	0	12.87	12.87	0	13.05	13.05	0	13.44	13.44	0
	GWY_227	9.82		10.90	10.90	0	11.05	11.05	0	11.15	11.15	0	11.24	11.24	1	11.49	11.49	0	11.62	11.62	0	11.79	11.79	-1
	GWY_79	8.46	Pont Faen Bridge (U/S)	9.67	9.67	0	9.84	9.84	0	9.92	9.92	0	10.02	10.02	0	10.28	10.28	0	10.40	10.40	0	10.76	10.76	1
	GWY_74	8.46	Pont Faen Bridge (D/S)	9.61	9.61	0	9.74	9.74	0	9.78	9.78	0	9.82	9.82	0	9.92	9.92	0	9.98	9.98	0	10.16	10.16	0
	GWY_0	7.84		9.04	9.04	0	9.17	9.17	0	9.25	9.25	0	9.32	9.32	0	9.49	9.49	-1	9.61	9.61	0	9.93	9.93	0
BEUNO	BEU_151	29.80		30.33	30.33	0	30.45	30.45	0	30.52	30.52	0	30.58	30.58	0	30.73	30.73	0	30.79	30.79	0	30.85	30.85	0
	BEU_50	27.39		27.96	27.96	0	28.07	28.07	0	28.14	28.14	0	28.21	28.21	0	28.39	28.39	0	28.49	28.49	0	28.75	28.75	0
	BEU_0	26.55		27.34	27.34	0	27.47	27.47	0	27.53	27.53	0	27.58	27.58	0	27.76	27.76	0	27.87	27.87	0	28.16	28.16	0

Proposed A487 Caernarfon and Bontnewydd - Afon Gwyrfai Crossing

Hydraulic Model Results - Afon Gwyrfai / Afon Beuno
1D ISIS Model Results - Maximum Water Levels (mAOD) and Depths (m)

Sensitivity Test Simulations

Job Name: A487 Caernarfon and Bontnewydd
Job Number: w3172
Date: 26/11/15
Model Type: ISIS-TUFLOW
ISIS Build: 3.7.1 64-bit DP
TUFLOW Build: 2013-12-AD 64-bit iDP

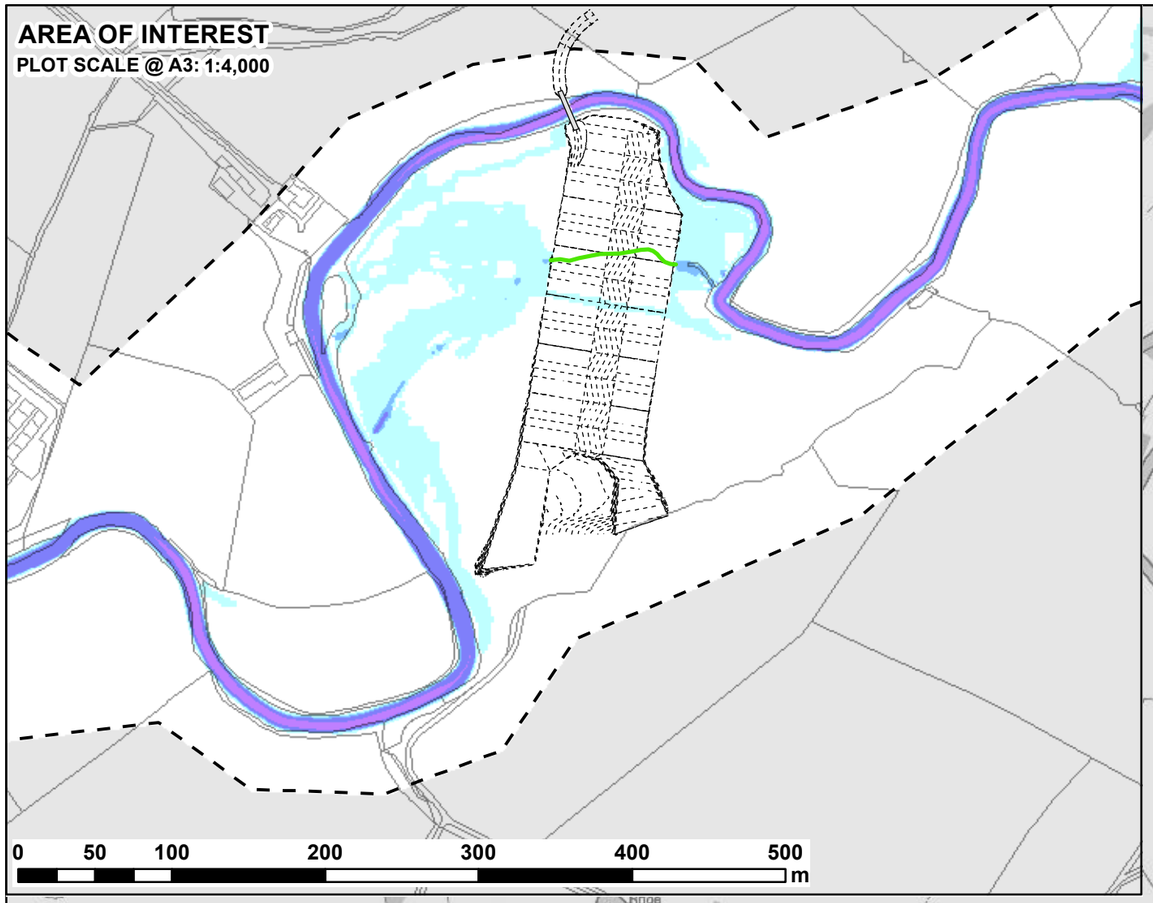
Notes:

Waterco model build 011
Nodes highlighted in yellow are situated close to the proposed road location
Nodes highlighted in grey indicate cross-sections generated from LiDAR dat

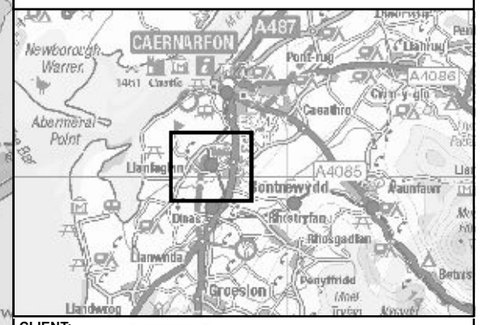
				ST1 (Mannings n +20%)			ST2 (Mannings n -20%)			ST3 (DSBC Slope +20%)			ST4 (DSBC Slope -20%)		
	Node Label	Bed Elevation (mAOD)	Notable Features / Structures	EXG Max WL (mAOD)	DEV1 Max WL (mAOD)	Flood Depth Variation EXG vs DEV1 (mm)	EXG Max WL (mAOD)	DEV1 Max WL (mAOD)	Flood Depth Variation EXG vs DEV1 (mm)	EXG Max WL (mAOD)	DEV1 Max WL (mAOD)	Flood Depth Variation EXG vs DEV1 (mm)	EXG Max WL (mAOD)	DEV1 Max WL (mAOD)	Flood Depth Variation EXG vs DEV1 (mm)
GWYRFAI	GWY_3522	38.92		40.19	40.32	128	40.19	40.05	-140	40.19	40.19	0	40.19	40.19	0
	GWY_3490	37.84		39.42	39.58	152	39.42	39.25	-172	39.42	39.42	0	39.42	39.42	0
	GWY_3440	36.48		38.24	38.39	150	38.24	38.06	-177	38.24	38.24	0	38.24	38.24	0
	GWY_3390	35.87		37.51	37.65	138	37.51	37.34	-168	37.51	37.51	0	37.51	37.51	0
	GWY_3340	34.99		36.56	36.70	141	36.56	36.43	-129	36.56	36.56	0	36.56	36.56	0
	GWY_3290	34.10	Weir (U/S)	35.92	35.92	3	35.92	35.92	-1	35.92	35.92	0	35.92	35.92	0
	GWY_3275	32.68	Weir (D/S)	34.30	34.47	167	34.30	34.15	-151	34.30	34.30	0	34.30	34.30	0
	GWY_3225	31.76		33.72	33.84	117	33.72	33.59	-131	33.72	33.72	0	33.72	33.72	0
	GWY_3190	31.49		33.41	33.53	124	33.41	33.32	-85	33.41	33.41	0	33.41	33.41	0
	GWY_3132	30.62		33.50	33.52	22	33.50	33.48	-19	33.50	33.50	0	33.50	33.50	0
	GWY_3110	30.68	Concrete weir (U/S)	33.41	33.41	2	33.41	33.41	-3	33.41	33.41	0	33.41	33.41	0
	GWY_3103	30.28	Concrete weir (D/S)	32.04	32.20	158	32.04	31.87	-171	32.04	32.04	0	32.04	32.04	0
	GWY_3096	30.27		31.94	32.06	122	31.94	31.76	-182	31.94	31.94	0	31.94	31.94	0
	GWY_3017	29.67	A487 Road Bridge, Bontnewydd (U/S)	31.19	31.33	134	31.19	30.99	-207	31.19	31.19	0	31.19	31.19	0
	GWY_3005	29.67	A487 Road Bridge, Bontnewydd (D/S)	31.05	31.18	139	31.05	30.90	-149	31.05	31.05	0	31.05	31.05	0
	GWY_2870	27.73		29.57	29.72	147	29.57	29.42	-156	29.57	29.57	0	29.57	29.57	0
	GWY_2723	27.00	Disused railway line (U/S)	28.56	28.71	152	28.56	28.39	-174	28.56	28.56	0	28.56	28.56	0
	GWY_2715	27.00	Disused railway line (D/S)	28.54	28.69	145	28.54	28.38	-163	28.54	28.54	0	28.54	28.54	0
	GWY_2613u	25.83	Confluence with Afon Beuno	27.69	27.81	117	27.69	27.58	-107	27.69	27.69	0	27.69	27.69	0
	GWY_2596	26.10	Railway bridge (U/S)	27.43	27.52	95	27.43	27.38	-50	27.43	27.43	0	27.43	27.43	0
	GWY_2581	26.10	Railway bridge (D/S)	27.15	27.22	77	27.15	27.10	-48	27.15	27.15	0	27.15	27.15	0
	GWY_2536	25.53		26.98	27.05	72	26.98	26.90	-79	26.98	26.98	0	26.98	26.98	0
	GWY_2375	24.45		26.00	26.07	73	26.00	25.87	-130	26.00	26.00	0	26.00	26.00	0
	GWY_2233	23.80		25.03	25.07	35	25.03	25.00	-29	25.03	25.03	0	25.03	25.03	0
	GWY_2074	22.57		23.97	24.00	29	23.97	23.96	-12	23.97	23.97	0	23.97	23.97	0
	GWY_1930	20.88		22.99	23.05	57	22.99	22.91	-81	22.99	22.99	0	22.99	22.99	0
	GWY_1787	20.15		22.31	22.40	90	22.31	22.11	-195	22.31	22.31	0	22.31	22.31	0
	GWY_1650	19.60		21.50	21.56	57	21.50	21.47	-31	21.50	21.50	0	21.50	21.50	0
	GWY_1492	18.95		20.55	20.59	34	20.55	20.55	-3	20.55	20.55	0	20.55	20.55	0
	GWY_1442	18.53	Proposed road crossing (U/S)	20.10	20.13	31	20.10	20.10	-3	20.10	20.10	0	20.10	20.10	0
	GWY_1397	18.24	Proposed road crossing (DS)	19.77	19.76	-12	19.77	19.79	19	19.77	19.77	0	19.77	19.77	0
	GWY_1352	17.78		19.50	19.49	-4	19.50	19.46	-37	19.50	19.50	0	19.50	19.50	0
	GWY_1193	17.02		18.37	18.37	-2	18.37	18.36	-8	18.37	18.37	0	18.37	18.37	0
	GWY_1032	15.36		17.37	17.46	92	17.37	17.28	-88	17.37	17.37	0	17.37	17.37	0
	GWY_931	15.14		16.90	16.97	69	16.90	16.73	-171	16.90	16.90	0	16.90	16.90	0
	GWY_795	13.28		15.83	15.87	44	15.83	15.70	-127	15.83	15.83	0	15.83	15.83	0
	GWY_570	12.49		14.32	14.37	42	14.32	14.22	-108	14.32	14.32	0	14.32	14.32	0
	GWY_398	11.12		13.05	13.17	120	13.05	12.82	-233	13.05	13.05	-2	13.05	13.05	-2
	GWY_227	9.82		11.62	11.67	44	11.62	11.46	-161	11.62	11.62	-1	11.62	11.62	-1
	GWY_79	8.46	Pont Faen Bridge (U/S)	10.40	10.60	194	10.40	10.19	-214	10.40	10.40	-4	10.40	10.40	3
	GWY_74	8.46	Pont Faen Bridge (D/S)	9.98	10.08	101	9.98	9.87	-115	9.98	9.98	-2	9.98	9.98	1
	GWY_0	7.84		9.61	9.69	82	9.61	9.48	-127	9.61	9.55	-61	9.61	9.68	72
BEUNO	BEU_151	29.80		30.79	30.83	39	30.79	30.72	-74	30.79	30.79	0	30.79	30.79	0
	BEU_50	27.39		28.49	28.58	91	28.49	28.38	-101	28.49	28.49	0	28.49	28.49	0
	BEU_0	26.55		27.87	27.91	40	27.87	27.87	1	27.87	27.87	0	27.87	27.87	0

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000







LEGEND

- TEMP1 Culvert (900mm dia)
- TEMP1 Bailey Bridge
- TEMP1 Work Platform
- 2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD DEPTH

50% AEP FLUVIAL EVENT
TEMPORARY WORKS LAYOUT (TEMP1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
SB	DH	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q2_TEMP1_D	-

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- TEMP1 Culvert (900mm dia)
- TEMP1 Bailey Bridge
- TEMP1 Work Platform
- 2D Model Boundary

Maximum Flood Depth Difference

- > 600mm
- 300mm to 600mm
- 100mm to 300mm
- 5mm to 100mm
- No Change (< +/-5mm)
- -5mm to -100mm
- -100mm to -300mm
- -300mm to -600mm
- > -600mm

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF

waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM DEPTH DIFFERENCE

50% AEP FLUVIAL EVENT

TEMP1 vs EXG

PLOT STATUS:

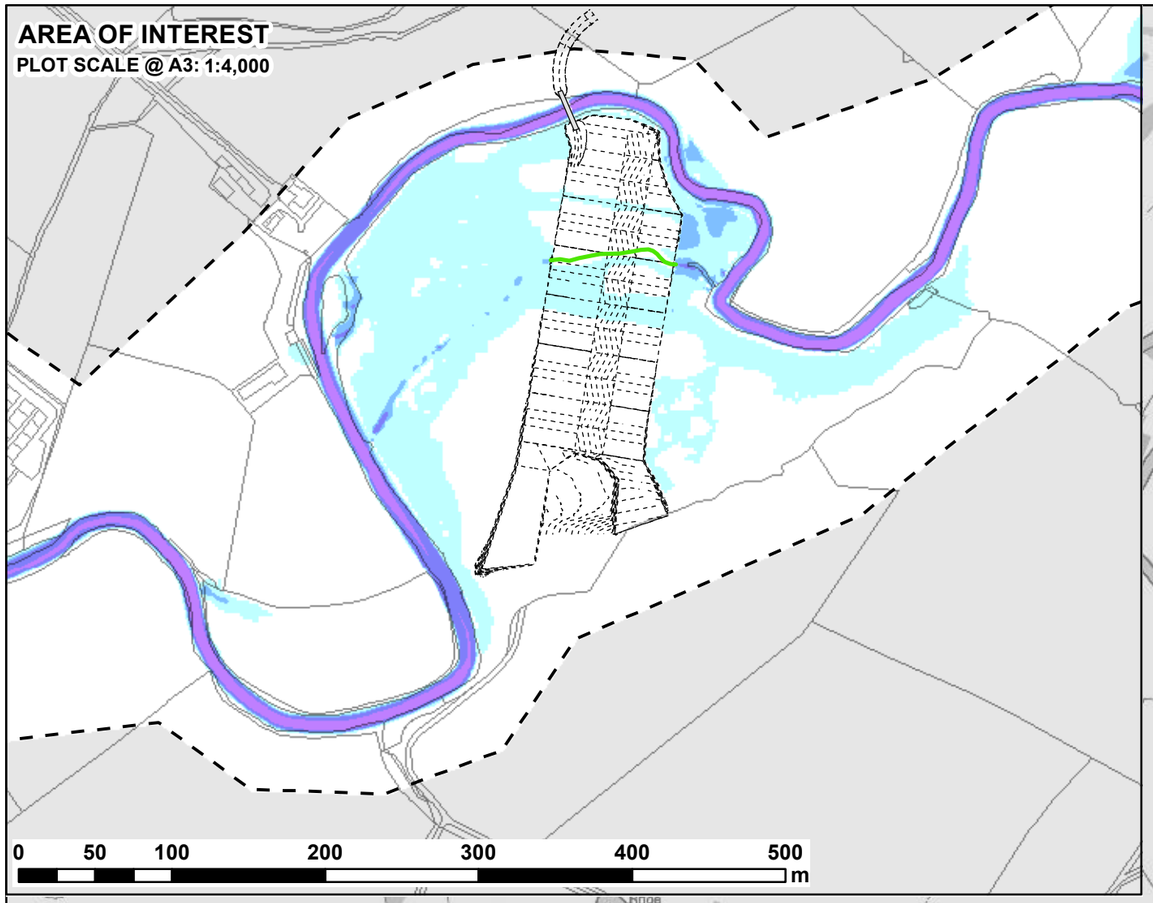
FINAL

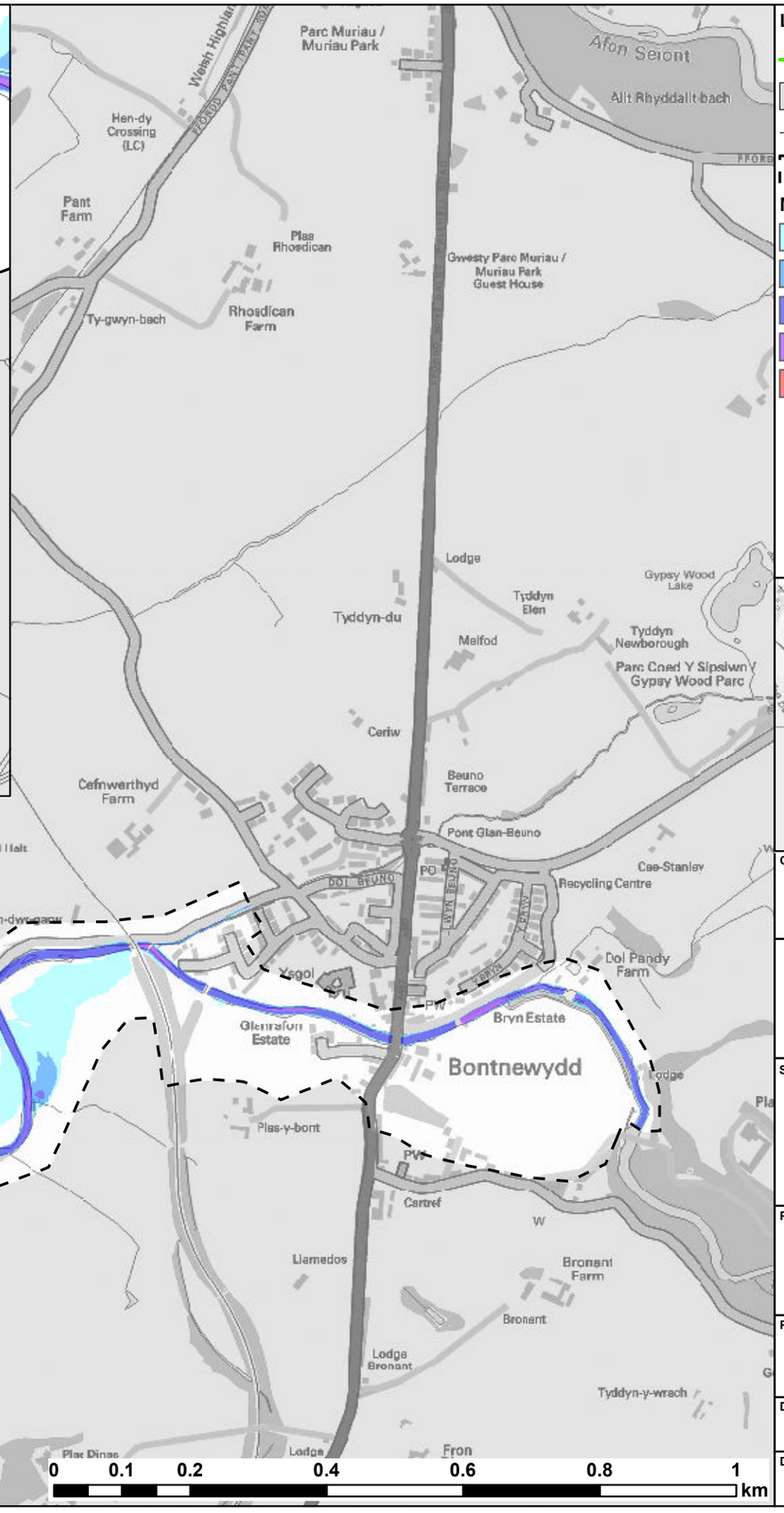
DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
SB	DH	RCL	1:8,000 (UNLESS STATED OTHERWISE)

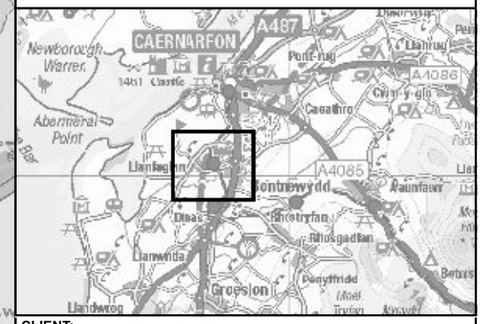
DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q2_TEMP1_DIFF	-

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000







LEGEND

- TEMP1 Culvert (900mm dia)
- TEMP1 Bailey Bridge
- TEMP1 Work Platform
- 2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

CLIENT:

Llywodraeth Cymru
Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD DEPTH
20% AEP FLUVIAL EVENT
TEMPORARY WORKS LAYOUT (TEMP1)

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
SB	DH	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q5_TEMP1_D	-

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- TEMP1 Culvert (900mm dia)
- TEMP1 Bailey Bridge
- TEMP1 Work Platform
- 2D Model Boundary

Maximum Flood Depth Difference

- > 600mm
- 300mm to 600mm
- 100mm to 300mm
- 5mm to 100mm
- No Change (< +/-5mm)
- -5mm to -100mm
- -100mm to -300mm
- -300mm to -600mm
- > -600mm

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF

waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM DEPTH DIFFERENCE

20% AEP FLUVIAL EVENT

TEMP1 vs EXG

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
SB	DH	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q5_TEMP1_DIFF	-

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

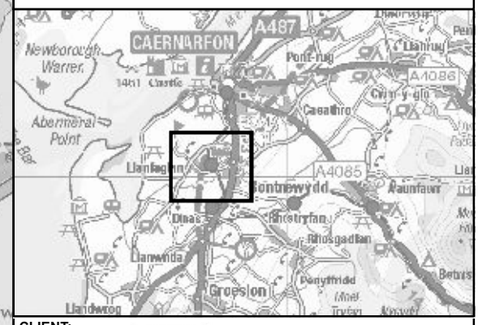
0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- TEMP1 Culvert (900mm dia)
- TEMP1 Bailey Bridge
- TEMP1 Work Platform
- 2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4



CLIENT: Llywodraeth Cymru / Welsh Government

WSP PARSONS BRINCKERHOFF

waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD DEPTH

10% AEP FLUVIAL EVENT

TEMPORARY WORKS LAYOUT (TEMP1)

PLOT STATUS: FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
SB	DH	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q10_TEMP1_D	-

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- TEMP1 Culvert (900mm dia)
- TEMP1 Bailey Bridge
- TEMP1 Work Platform
- 2D Model Boundary

Maximum Flood Depth Difference

- > 600mm
- 300mm to 600mm
- 100mm to 300mm
- 5mm to 100mm
- No Change (< +/-5mm)
- -5mm to -100mm
- -100mm to -300mm
- -300mm to -600mm
- > -600mm

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF

waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM DEPTH DIFFERENCE

10% AEP FLUVIAL EVENT

TEMP1 vs EXG

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
SB	DH	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q10_TEMP1_DIFF	-

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

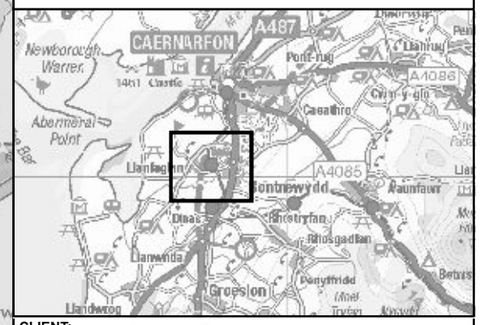
0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- TEMP1 Culvert (900mm dia)
- TEMP1 Bailey Bridge
- TEMP1 Work Platform
- 2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF

waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD DEPTH

5% AEP FLUVIAL EVENT

TEMPORARY WORKS LAYOUT (TEMP1)

PLOT STATUS:

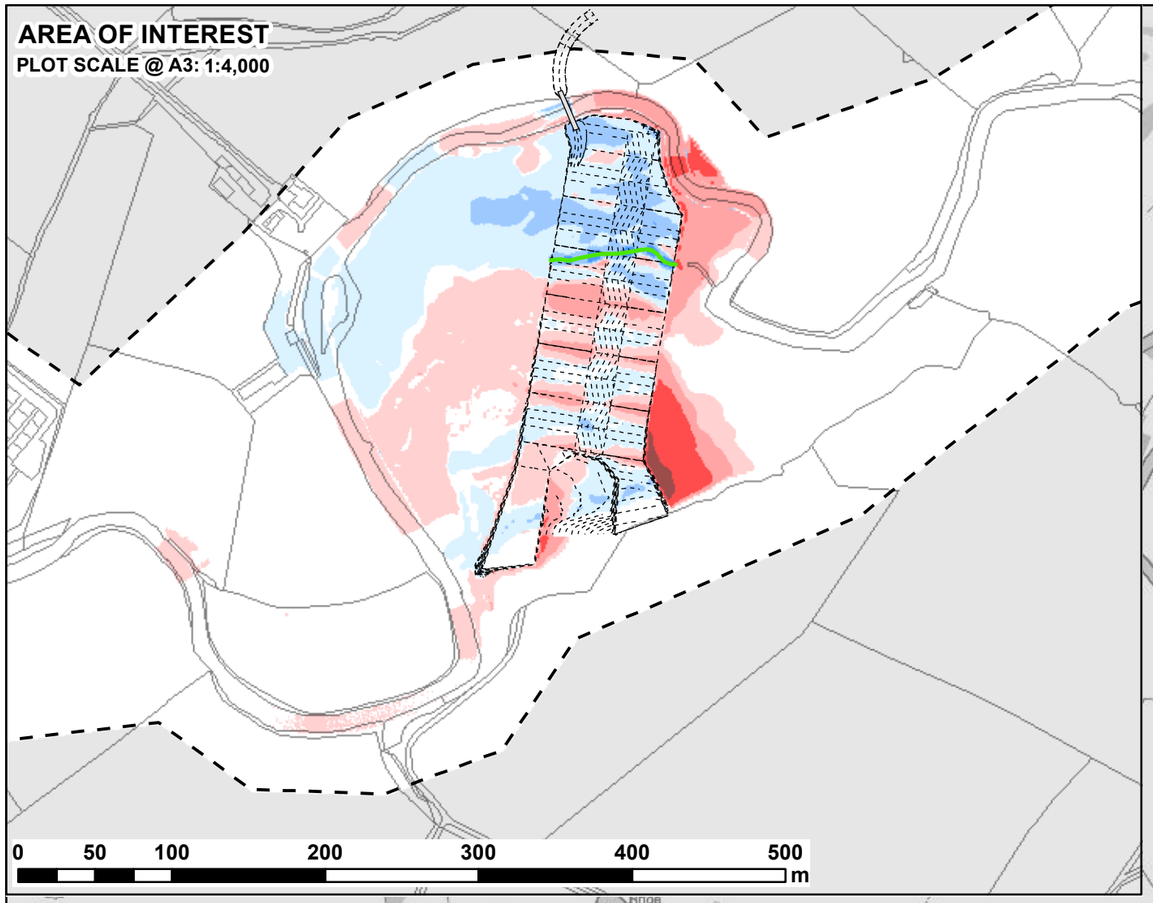
FINAL

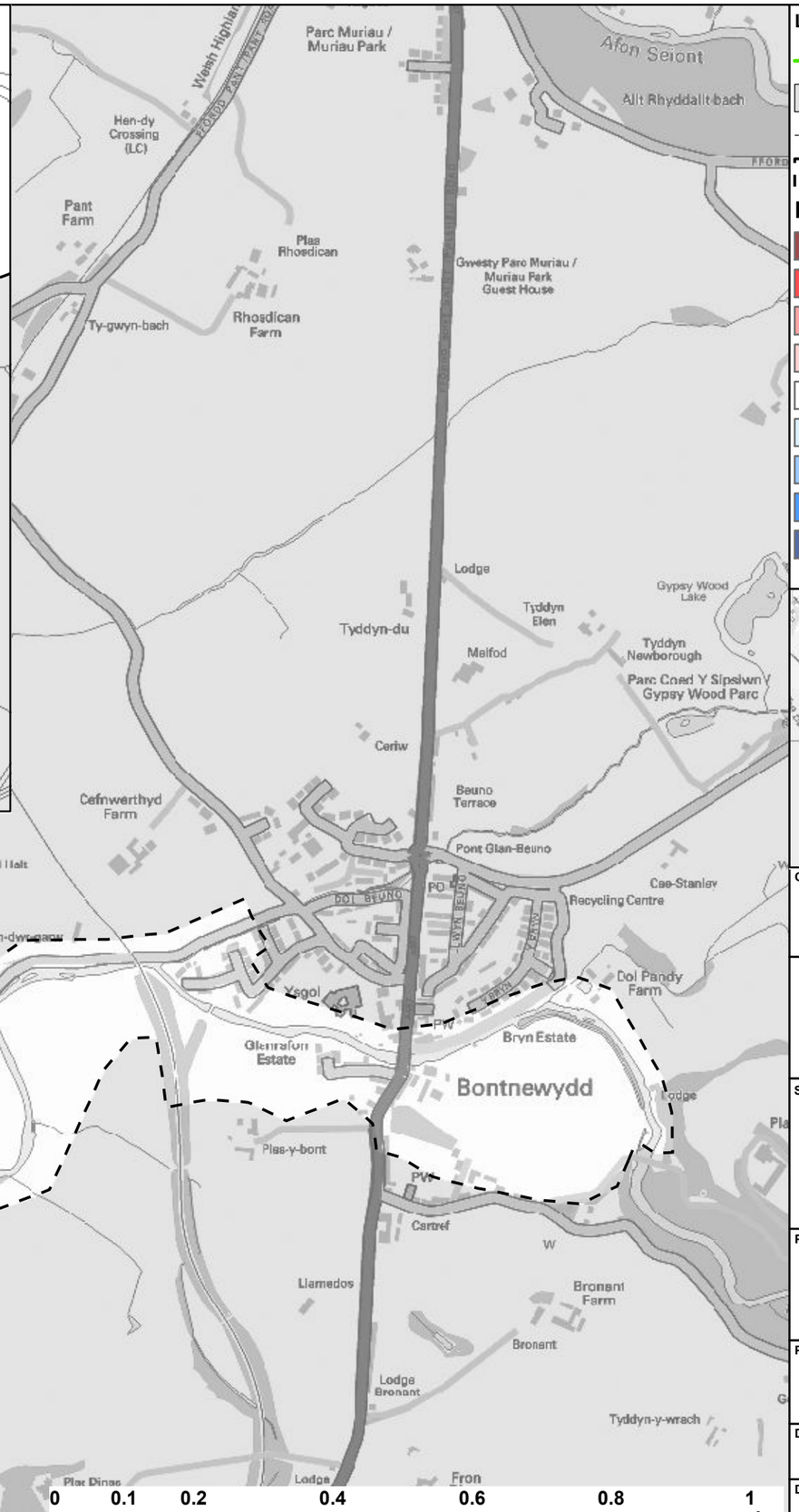
DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
SB	DH	RCL	1:8,000 (UNLESS STATED OTHERWISE)

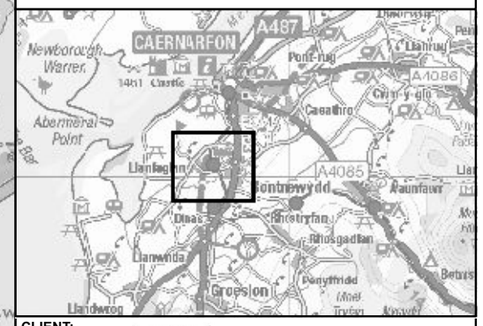
DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q20_TEMP1_D	-

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000







LEGEND

- TEMP1 Culvert (900mm dia)
- TEMP1 Bailey Bridge
- TEMP1 Work Platform
- 2D Model Boundary

Maximum Flood Depth Difference

- > 600mm
- 300mm to 600mm
- 100mm to 300mm
- 5mm to 100mm
- No Change (< +/-5mm)
- -5mm to -100mm
- -100mm to -300mm
- -300mm to -600mm
- > -600mm

CLIENT: Llywodraeth Cymru / Welsh Government

WSP PARSONS BRINCKERHOFF

waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM DEPTH DIFFERENCE

5% AEP FLUVIAL EVENT

TEMP1 vs EXG

PLOT STATUS: FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
SB	DH	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q20_TEMP1_DIFF	-

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

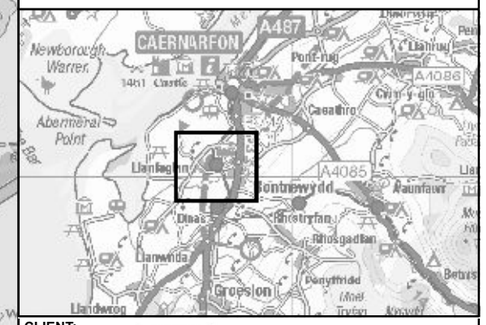
0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- TEMP1 Culvert (900mm dia)
- TEMP1 Bailey Bridge
- TEMP1 Work Platform
- 2D Model Boundary

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4



CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF

waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD DEPTH

1% AEP FLUVIAL EVENT

TEMPORARY WORKS LAYOUT (TEMP1)

PLOT STATUS:

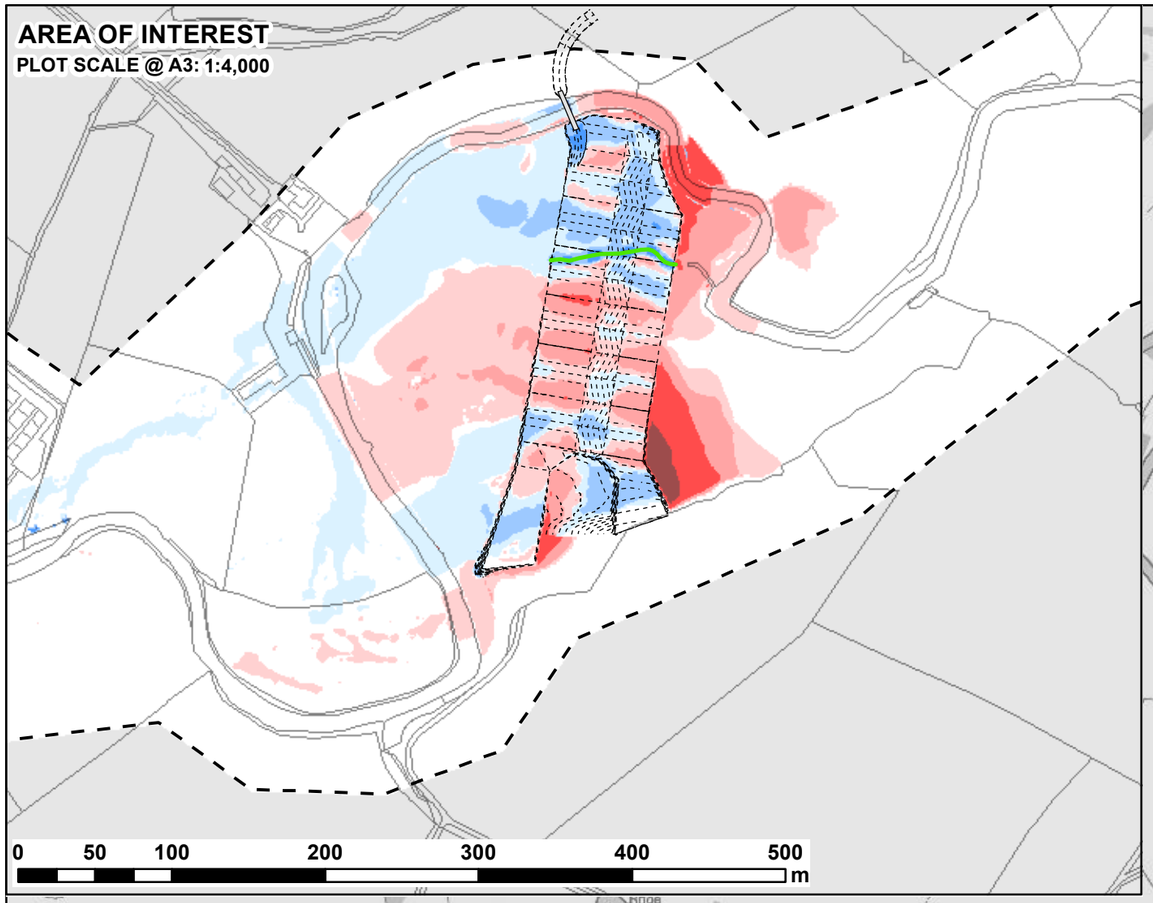
FINAL

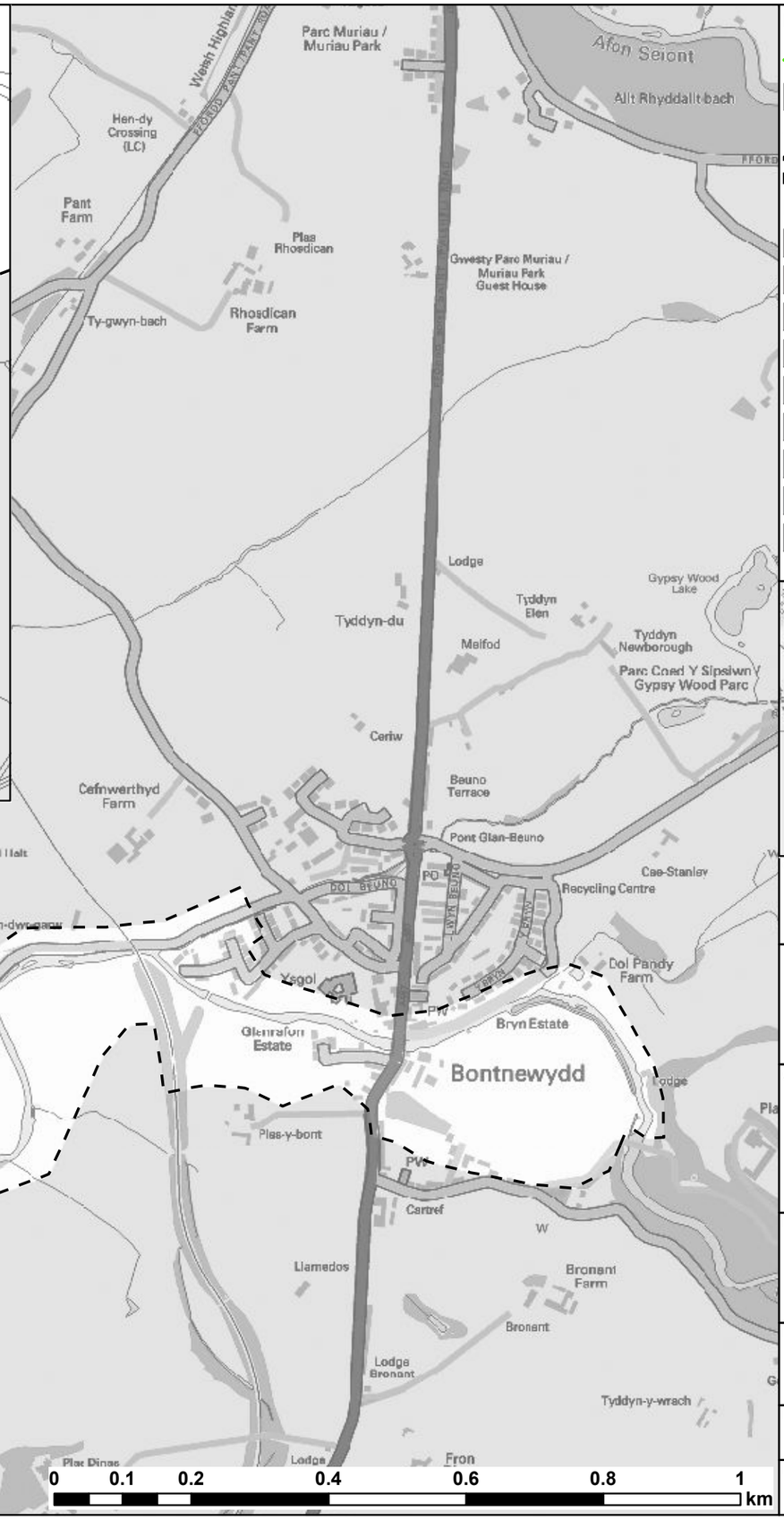
DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
SB	DH	RCL	1:8,000 (UNLESS STATED OTHERWISE)

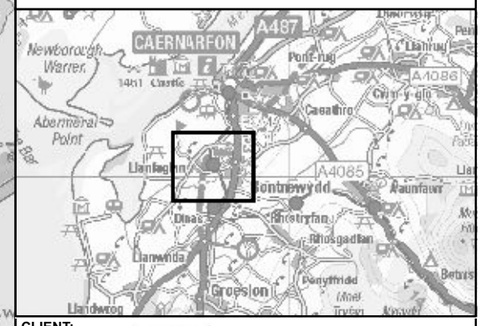
DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q100_TEMP1_D	-

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000







LEGEND

- TEMP1 Culvert (900mm dia)
- TEMP1 Bailey Bridge
- TEMP1 Work Platform
- 2D Model Boundary

Maximum Flood Depth Difference

- > 600mm
- 300mm to 600mm
- 100mm to 300mm
- 5mm to 100mm
- No Change (< +/-5mm)
- -5mm to -100mm
- -100mm to -300mm
- -300mm to -600mm
- > -600mm

CLIENT:

Llywodraeth Cymru
Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM DEPTH DIFFERENCE

1% AEP FLUVIAL EVENT

TEMP1 vs EXG

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
SB	DH	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q100_TEMP1_DIFF	-

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- TEMP1 Culvert (900mm dia)
- TEMP1 Bailey Bridge
- TEMP1 Work Platform
- 2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF

waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM VELOCITY

50% AEP FLUVIAL EVENT

TEMPORARY WORKS LAYOUT (TEMP1)

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
SB	DH	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q2_TEMP1_V	-

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- TEMP1 Culvert (900mm dia)
- TEMP1 Bailey Bridge
- TEMP1 Work Platform
- 2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF

waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM VELOCITY

20% AEP FLUVIAL EVENT

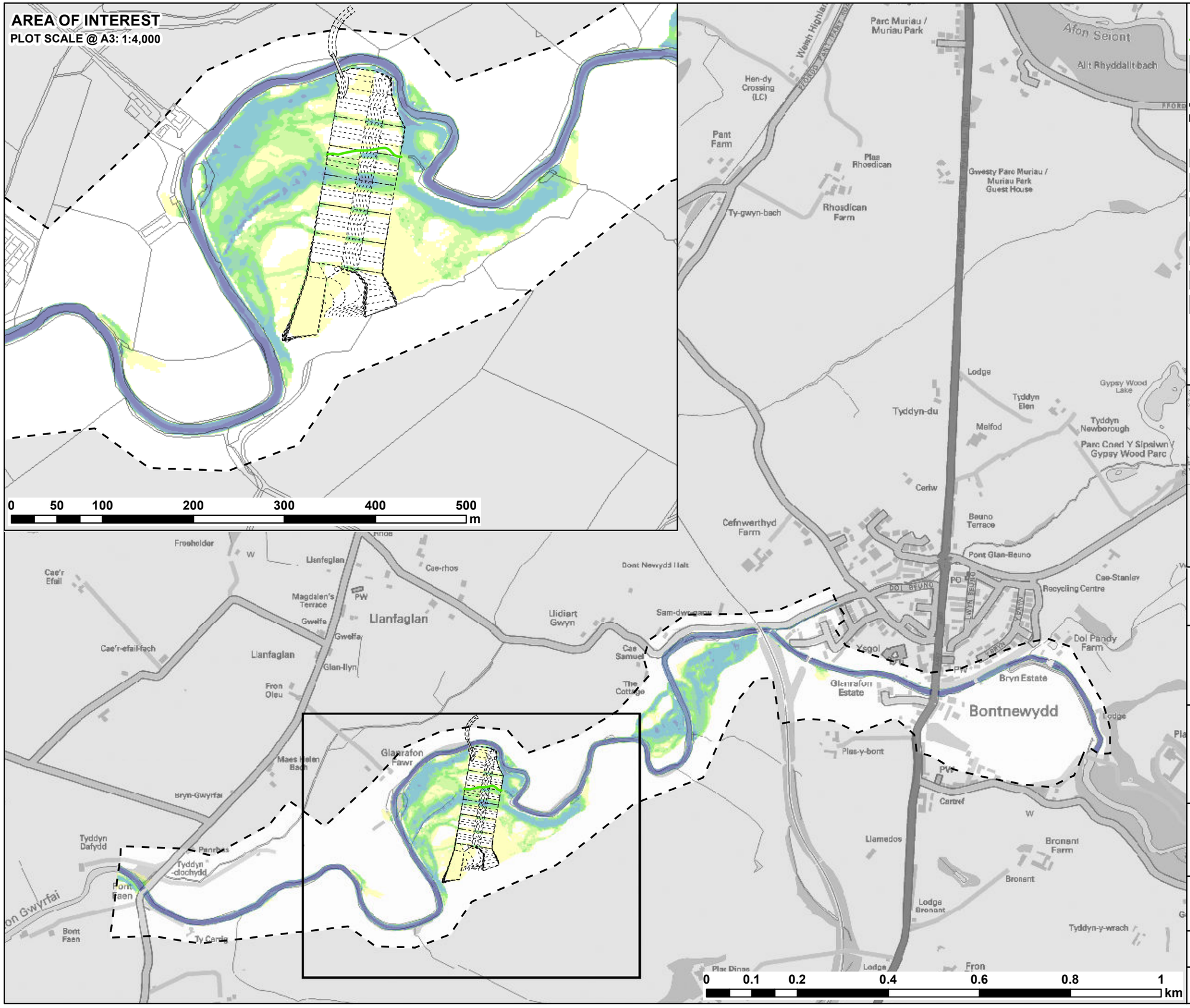
TEMPORARY WORKS LAYOUT (TEMP1)

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
SB	DH	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q5_TEMP1_V	-


AREA OF INTEREST
PLOT SCALE @ A3: 1:4,000
0 50 100 200 300 400 500 m
0 0.1 0.2 0.4 0.6 0.8 1 km
Parc Muriau / Muriau Park
Afon Seiont
Allt Rhyddalit bach
Hen-dy Crossing (LC)
Pant Farm
Plas Rhosdican
Gwesty Parc Muriau / Muriau Park Guest House
Ty-gwyn-bach
Rhosdican Farm
Lodge
Gypsy Wood Lake
Tyddyn Elen
Tyddyn-du
Melfod
Tyddyn Newborough
Parc Coed Y Sipsiwn / Gypsy Wood Parc
Ceriw
Cefnwerthyd Farm
Beuno Terrace
Pont Glan-Beuno
Cae-Stanley
Recycling Centre
Dol Pandy Farm
Ysgol
Bryn Estate
Glanrafon Estate
Bontnewydd
Plas-y-bont
Cartref
Llamedos
Bronant Farm
Bronant
Lodge Bronant
Tyddyn-y-wrach
Fron
Plas Dinas
Freeholder
Llanfaglan
Cae-rhos
Dont Newydd Halt
Cae'r Efail
Magdalen's Terrace
Gwelfa
Llidiart Gwyn
Sam-dwrgam
Cae'r-efail-fach
Glan-llyn
Fron Oleu
Cae Samuel
The Cottage
Maes Helen Bach
Glanrafon Fawr
Bryn-Gwyrfai
Tyddyn Dafydd
Penrhos
Tyddyn-clochydd
Pont Faen
Bont Faen
Ty Canol
Afon Gwyrfai
Llanfaglan
Llanfaglan
Llanfaglan

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- TEMP1 Culvert (900mm dia)
- TEMP1 Bailey Bridge
- TEMP1 Work Platform
- 2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF

waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM VELOCITY

5% AEP FLUVIAL EVENT

TEMPORARY WORKS LAYOUT (TEMP1)

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
SB	DH	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
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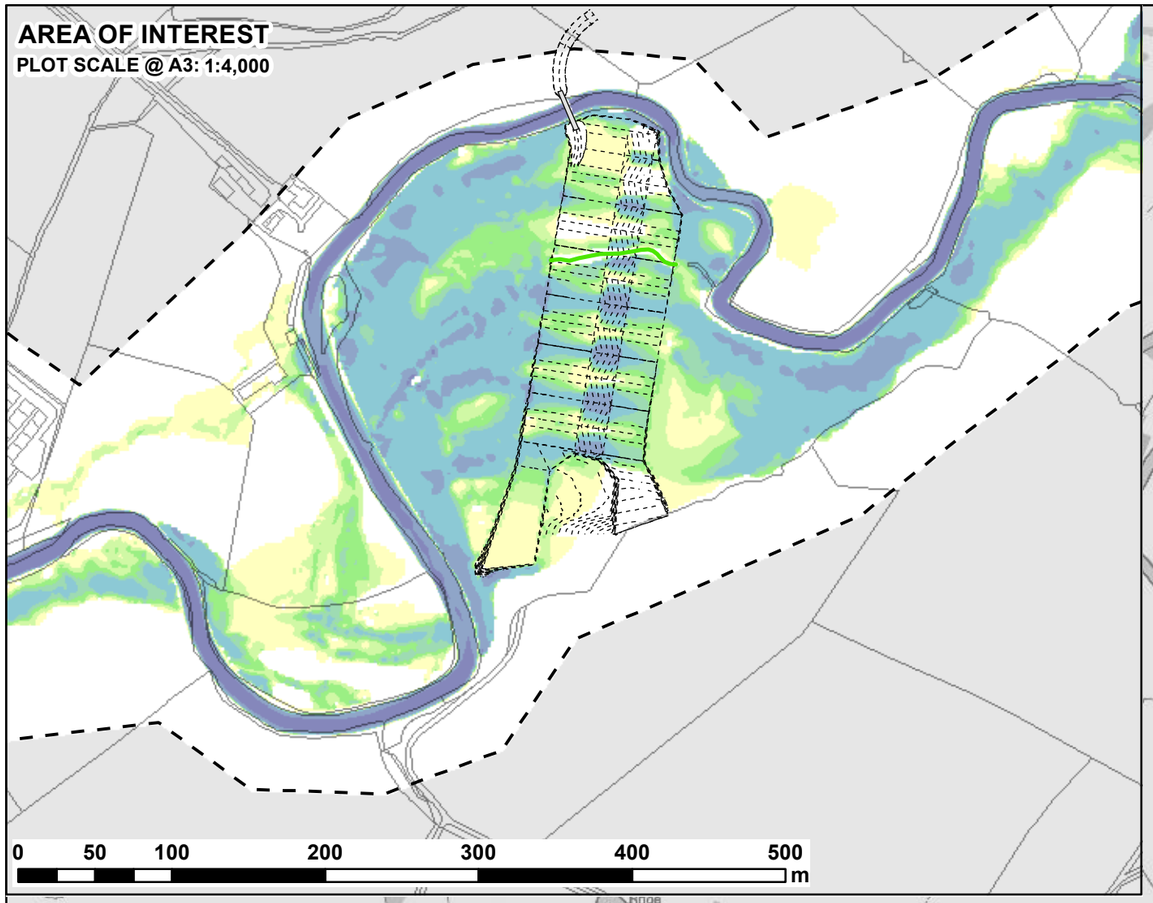
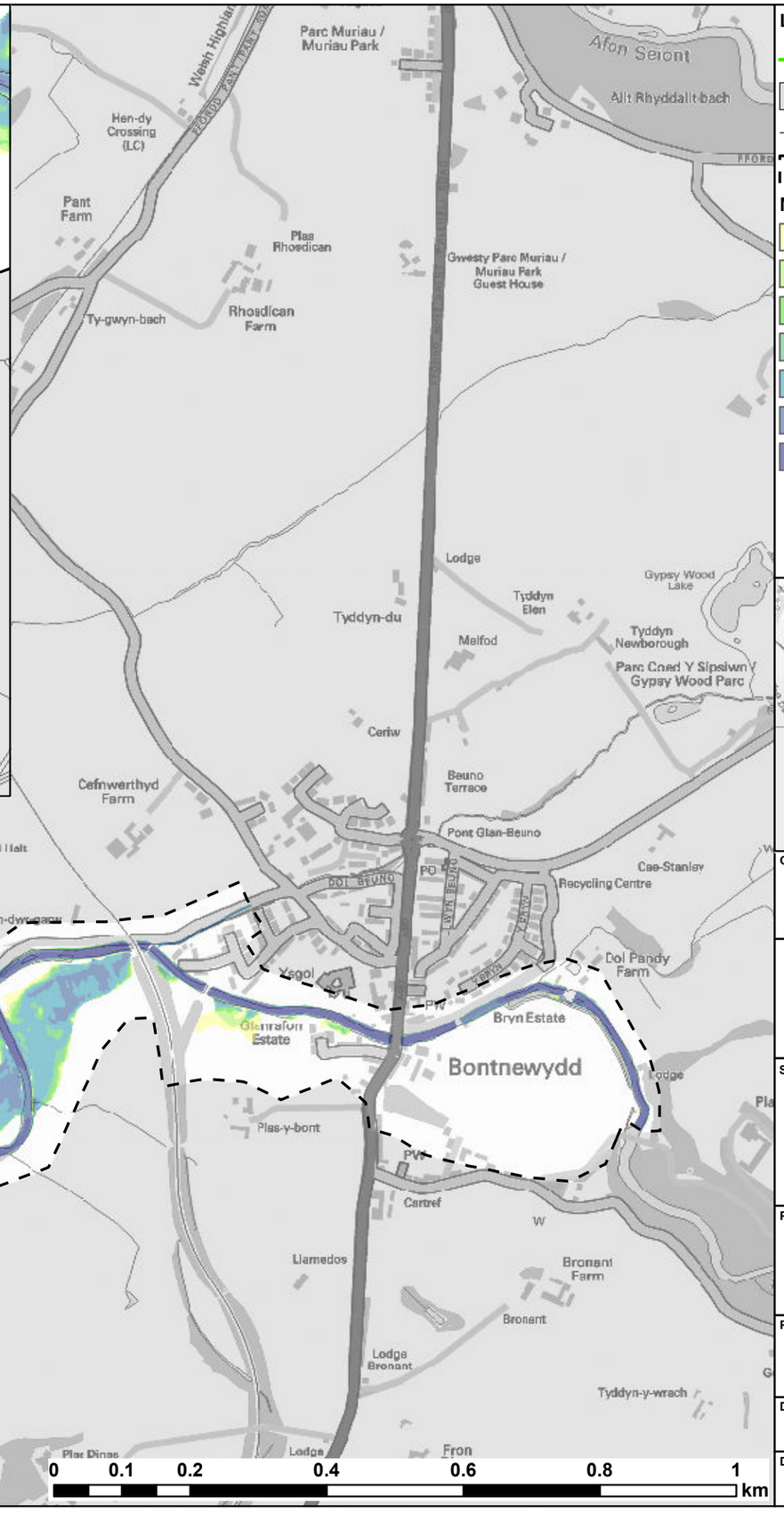
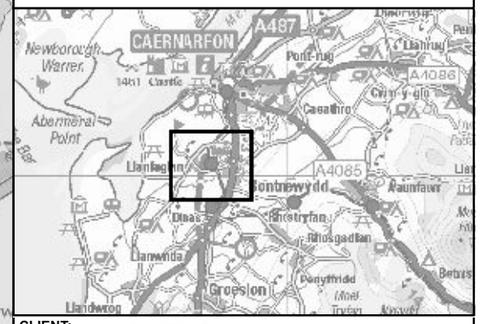
AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000





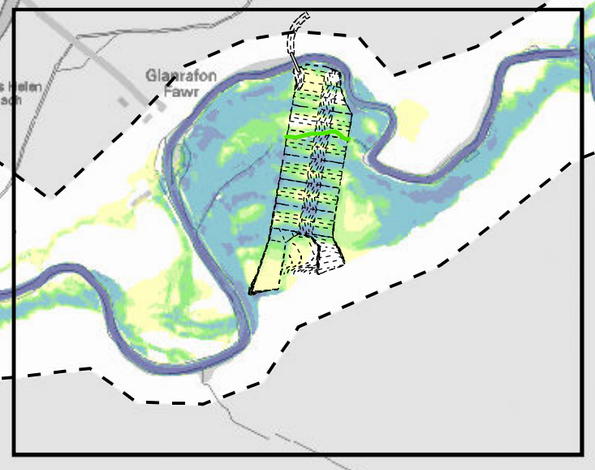


LEGEND

- TEMP1 Culvert (900mm dia)
- TEMP1 Bailey Bridge
- TEMP1 Work Platform
- 2D Model Boundary

Maximum Velocity (m/s)

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4



CLIENT: Llywodraeth Cymru / Welsh Government

WSP PARSONS BRINCKERHOFF

waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM VELOCITY

1% AEP FLUVIAL EVENT

TEMPORARY WORKS LAYOUT (TEMP1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
SB	DH	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
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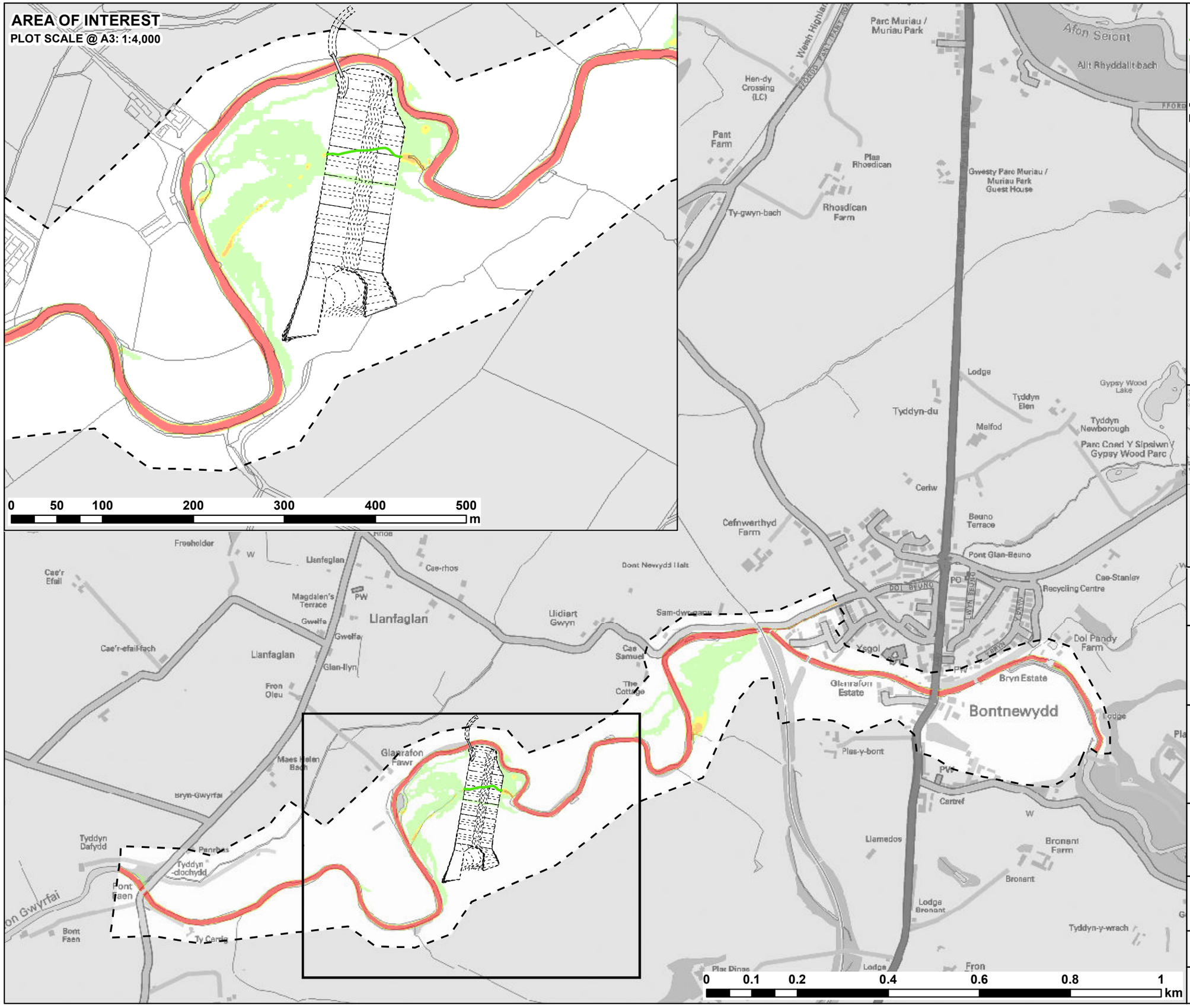
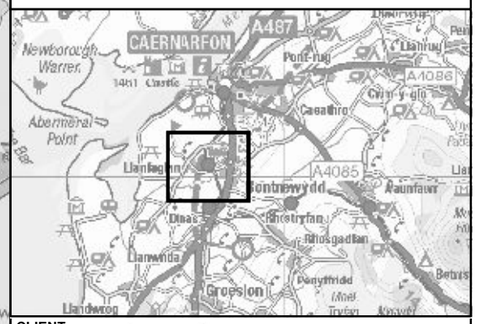




LEGEND

- TEMP1 Culvert (900mm dia)
- TEMP1 Bailey Bridge
- TEMP1 Work Platform
- 2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

CLIENT:

Llywodraeth Cymru
Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD HAZARD

50% AEP FLUVIAL EVENT

TEMPORARY WORKS LAYOUT (TEMP1)

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
SB	DH	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q2_TEMP1_H	-

AREA OF INTEREST

PLOT SCALE @ A3: 1:4,000

0 50 100 200 300 400 500 m

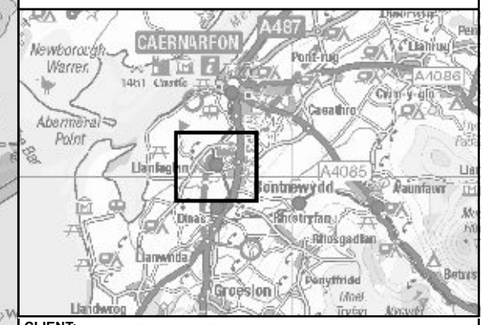
0 0.1 0.2 0.4 0.6 0.8 1 km

LEGEND

- TEMP1 Culvert (900mm dia)
- TEMP1 Bailey Bridge
- TEMP1 Work Platform
- 2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)



CLIENT: Llywodraeth Cymru / Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD HAZARD

20% AEP FLUVIAL EVENT

TEMPORARY WORKS LAYOUT (TEMP1)

PLOT STATUS:

FINAL

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
SB	DH	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
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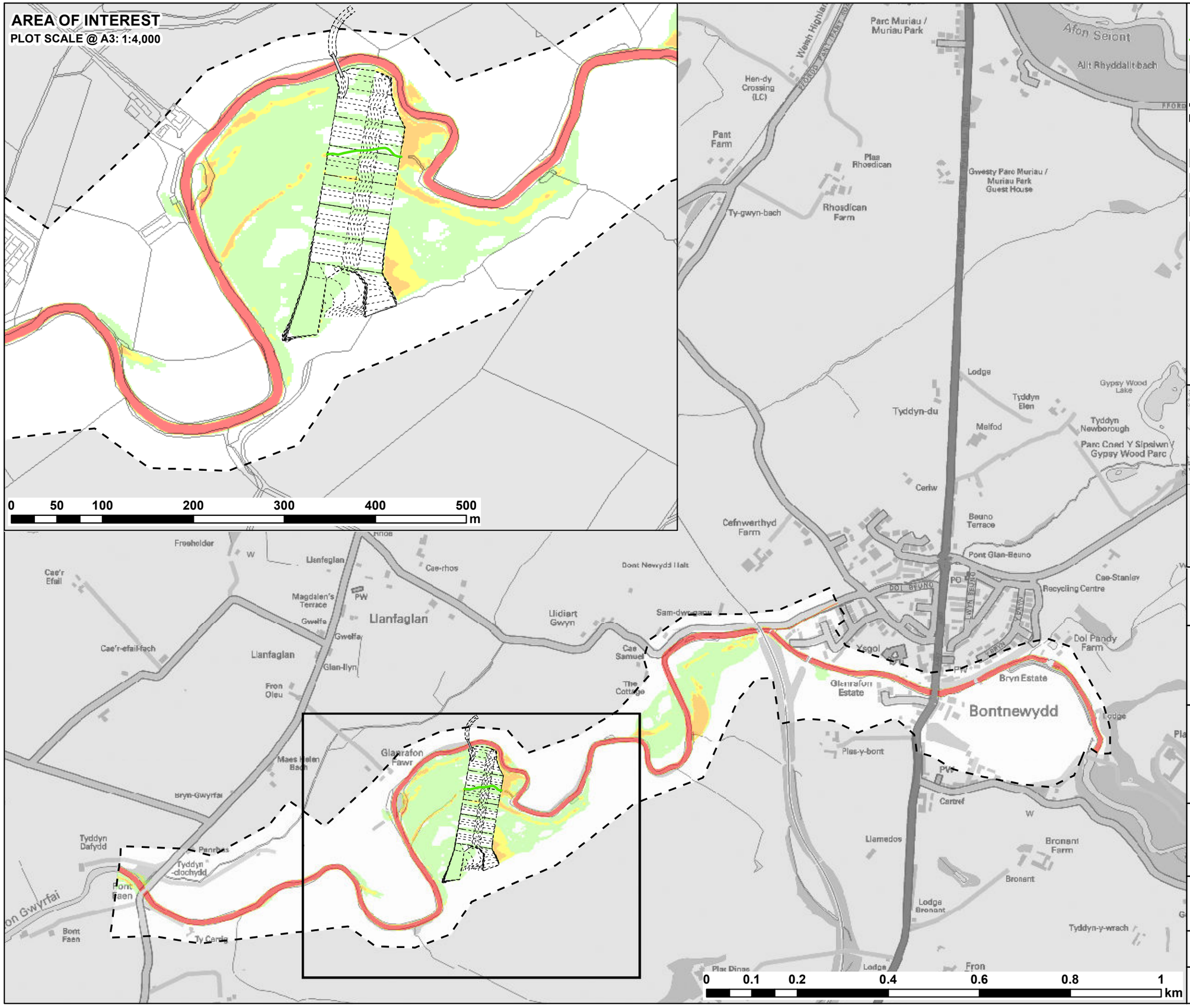

LEGEND

- TEMP1 Culvert (900mm dia)
- TEMP1 Bailey Bridge
- TEMP1 Work Platform
- 2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD HAZARD

10% AEP FLUVIAL EVENT
TEMPORARY WORKS LAYOUT (TEMP1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
SB	DH	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
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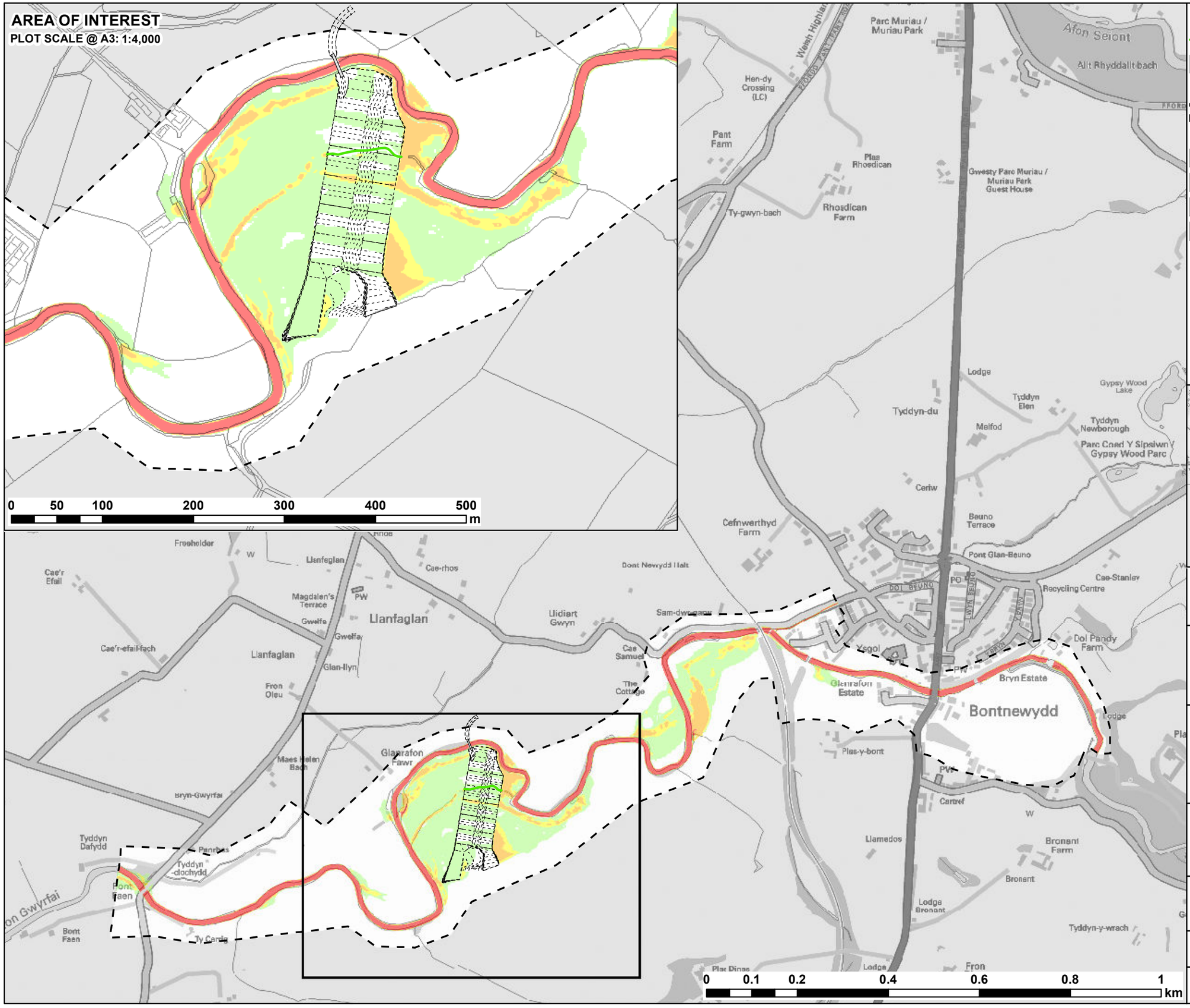
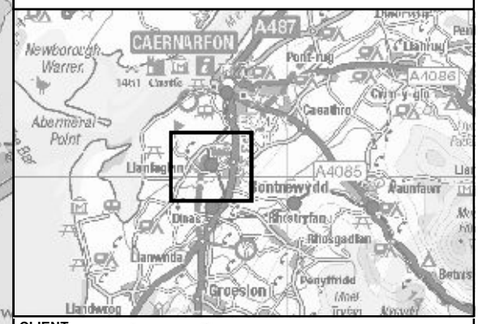




LEGEND

- TEMP1 Culvert (900mm dia)
- TEMP1 Bailey Bridge
- TEMP1 Work Platform
- 2D Model Boundary

Maximum Flood Hazard Rating (FD2320)

- < 0.75 (Caution)
- 0.75 - 1.25 (Danger for Some)
- 1.25 - 2 (Danger for Most)
- > 2.0 (Danger for All)

CLIENT:

Llywodraeth Cymru
Welsh Government

WSP PARSONS BRINCKERHOFF
waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD HAZARD

5% AEP FLUVIAL EVENT

TEMPORARY WORKS LAYOUT (TEMP1)

PLOT STATUS:

FINAL

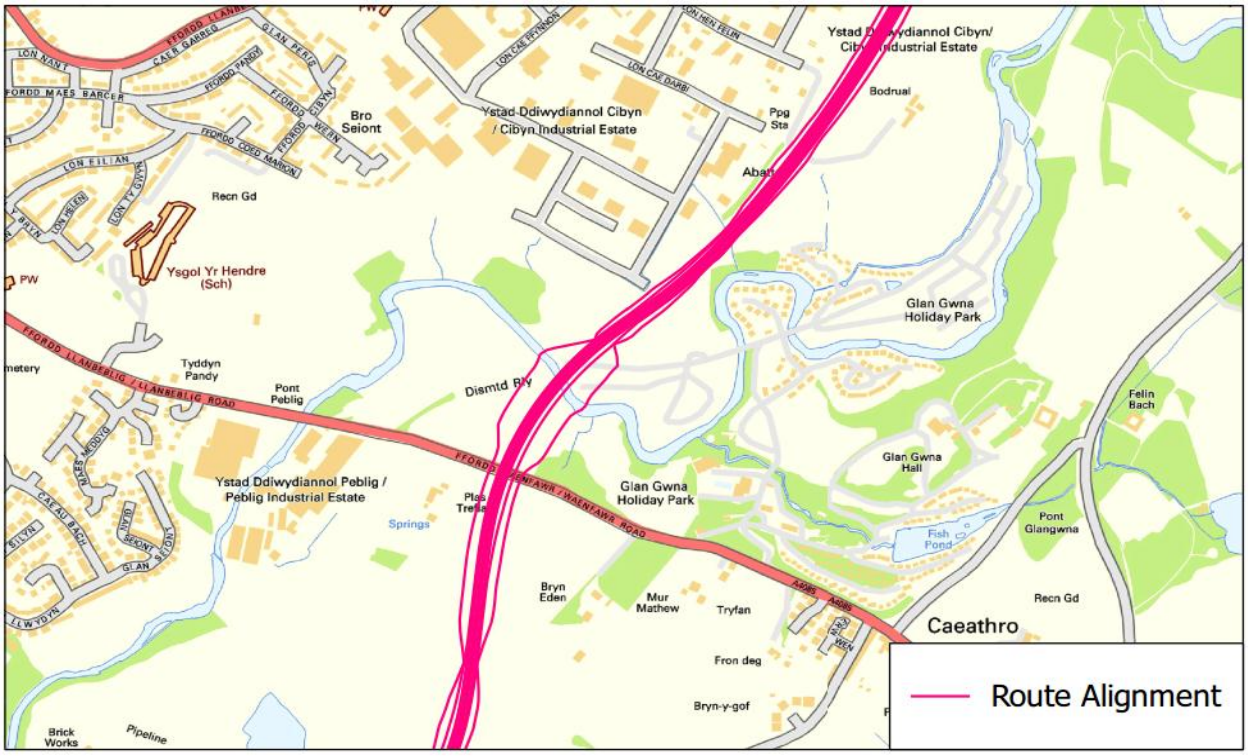
DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
SB	DH	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q20_TEMP1_H	-

Appendix K.6 – Afon Seiont Assessment

Project	A487 Caernarfon & Bontnewydd Bypass Flood Modelling
Job Number	3513874A-HHC
Location	Caernarfon, Gwynedd (SH 49533 62377)
Watercourse(s)	Afon Seiont and Glangwna

Objectives/Areas of interest



Contains Ordnance Survey data © Crown copyright and database right 2015

Parsons Brinckerhoff (PB) was commissioned to undertake a Flood Consequence Assessment to identify the consequences of development of a new highway bypassing Caernarfon centre from the existing A499/A487 Goat roundabout to the existing A487 Plas Menai roundabout. Hydraulic modelling of the Afon Seiont is required to support this assessment.

The objective of this study is to model the Afon Seiont and adjacent flooding around Glan Arrow Holiday Park in order to assess the impact of the proposed highway on flood levels, depths and extents. The highway will cross the Afon Seiont on a clear span structure with piers in the flood plain as necessary.

Existing Model Data

The Existing NRW flood data for the site is JFLOW. Therefore there is no existing model data suitable for use in this study.

Survey Data

Title	Type	Notes
Afon Seiont & Glan Gwna Channel Survey (March 2015)	Channel and structure sections	16 channel sections along the Afon Seiont from approx 1.1km downstream of the confluence of the Afon Seiont and Glan Gwna (just south of the A4085) to 0.6km upstream of the confluence of the Afon Seiont and Glan Gwna extent (near the eastern border of Glan Gwna holiday park) . 4 bridge structures and 1 formal weir structure surveyed within this reach. 4 channel sections along Glan Gwna from the confluence of the Afon Seiont and Glan Gwna to a point 200m upstream of this confluence. 1 bridge structure and 1 formal weir structure within this reach.

GIS Data

OS Tiles	Streetview:	SH45ne, SH45nw, SH46ne, SH46se, SH55ne, SH55nw, SH56nw, SH56se, SH56sw
	Vectormap:	SH45, SH46, SH55, SH56, SH65, SH66
OS Shapefiles	Mastermap:	Date unknown
LIDAR	Resolution:	1m
	Date :	LIDAR composite obtained February 2015. Flight date unknown
Satellite	Google:	Google Earth Pro 6.0.2.2074

Modelling Approach

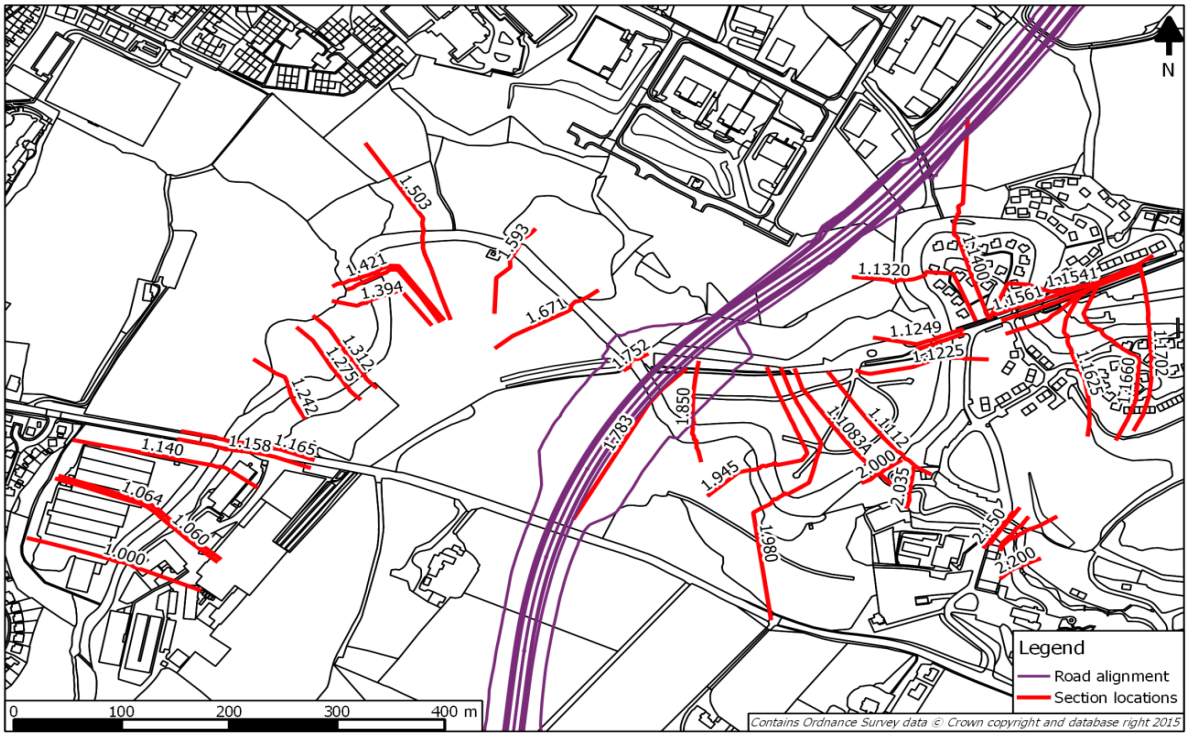
A 1D unsteady state ISIS hydraulic model of the Afon Seiont and Glan Gwna was developed to assess the baseline flood mechanisms and review the impact of the proposed highway across the Afon Seiont. The model was created using channel survey and LIDAR data obtained for this assessment and extends approximately 1.9km in total. The model extends along the Afon Seiont from approximately 1.1km downstream of the confluence of the Afon Seiont and Glan Gwna to approximately 0.6km upstream of the confluence. The model extends approximately 0.2km along Glan Gwna upstream of the confluence.

There is no flood plain on the right bank through Glan Gwna Holiday Park due to steep valley sides. Elsewhere, a flood plain is present however the LIDAR data and NRW Flood Map indicates the floodplain is reasonably confined and linear, with floodplain flows following the alignment of the river, hence a 1D model representation is appropriate. Extended cross-sections have been used to represent flooding out of the channel as a review of the topography indicated that the floodplain levels are generally at or above the channel bank levels. No significant low lying areas of floodplain, where floodwaters would pond, or raised channel banks were identified that would require an alternative schematisation. At some sections the channel banks are slightly higher than the adjacent floodplain but are overtopped, with active flow across the width of the floodplain, during the key events under consideration. Additional sections have also been included at several locations to improve model stability and better represent the flood plain by interpolating between sections using surveyed data and LiDAR.

An additional section (1.783) has been included at the location of the upstream face of the proposed bridge crossing. Topographic survey data exists for this area and this has been used to estimate this section in the absence of channel survey. A comparison with channel survey upstream and LiDAR for the area indicates the two sets of survey data are compatible. The bed levels in the topographic survey at this section were reduced to match a level interpolated from channel survey upstream and downstream of the proposed bridge location because the channel survey represents the most reliable source of bed level data.

Modelling Approach (cont.)

A model overview is provided below.



See Seiont section locations plan for full section layout

Model Extents

Watercourse	Approx. Length (km)	Upstream	Downstream
Afon Seiont	1.9	250059, 362192	249104, 361949
Glan Gwna	0.2	249939, 361946	249801, 362048

Model Schematisation

Model Method	1D
Software	ISIS (Version 3.7, Build 0.7.233 Mode 2)
Channel	1D surveyed sections
Floodplain	1D surveyed sections. Where surveyed sections do not extend far enough, ground levels have been represented using LIDAR data, with the ground surface roughness characteristics determined using sattelite immagery from Google Earth Pro.
Run Settings	Unsteady simulation (adaptive timestepping). -5h warm up time and 30 hour end time for run.Other settings as default.

Model inflows and Boundary Conditions

Peak flood flow estimates and hydrographs for the River Seiont were obtained using a hybrid FEH Statistical / Revitalised Flood Hydrograph (ReFH) method of flood estimation (ReFH hydrographs scaled to Statistical peak flow estimates). Details of the assessment are provided in Annex A. The flows have been applied to the hydraulic model using two flow nodes located at the upstream extent of the Seiont and Glan Gwna model reaches (nodes SNT_US and SNT_TRIB). Inflows downstream of the confluence have not been included as they are insignificant due to the small catchment area. Modelled peak flows have been compared with the estimated peak flows at the downstream extent of the model to verify this assumption. A summary of the peak flows is provided below.

The downstream extent of the model has been defined using a normal flow depth boundary based on the surveyed channel gradient. The downstream boundary is located approximately 0.8km downstream of the proposed road crossing over the Afon Seiont and is therefore unlikely to have a significant impact on the model results in the area of interest. The downstream boundary is approximately 1.6km upstream of the extents of tidal Flood Zone 2 along the Afon Seiont and approximately 10m above the maximum tidal water level in a 1000 year return period event provided by NRW. Flow through the subject site will not therefore be tidally influenced.

There is a weir approximately 110m downstream of the model boundary. This is considered a reasonable distance such that any backwater effects from the weir will not be too significant at the downstream boundary. Sensitivity testing has shown that the DS boundary assumption is unlikely to affect results in the area of interest.

Flow Node (Inflow Location)	Return							
	2	5	10	20	50	100	100 cc	1000
SNT_US (250050, 361250)	44.0	55.9	64.2	73.0	85.9	96.8	116.2	182.0
SNT_TRIB (249800, 362000)	1.8	2.5	3.0	3.6	4.6	5.4	6.5	9.7

Mannings 'n' Roughness Coefficients

Manning's co-efficients have been used to represent the roughness of the channel and floodplain. An established reference (Chow, 1984) and the judgement of experienced hydraulic modellers has been used to select appropriate values. Estimates of the channel roughness co-efficients were made following a site visit during February 2015 and from photographs taken during a channel survey undertaken as part of the commission. Typical values of Manning's n selected for the 1D domain are defined in the table below and a full schedule of the values used at each model node are specified in the '2.Cross-Sections' tab.

Model Domain	Description	Chow (1988). Table 5-6.	Manning's 'n'
1D	Natural streams > Minor Streams > Streams on plain > Clean, straight, full stage, no rifts or deep pools with stones and weeds.	D-1.a.2	0.035
1D	Flood plains > Brush > Light brush and trees in summer	D-2.c.3	0.060
1D	Flood plains > Trees > Dense willows, summer straight	D-2.d.1	0.150
1D	Flood plains > Pasture, no brush > Short grass	D-2.a.1	0.025
1D	Concrete/Asphalt road surface	N/A	0.020
1D	Built up area - buildings and roads , caravans etc.	N/A	0.150
1D	Solid building with doors and windows (not sealed)	N/A	0.500

Model File Naming Convention

File name: SNT_SSS_****_YYYY_@@@

e.g. SNT_BSC_0100_2015_012 or SNT_PA_0100_2015_012

SNT	Afon Seiont hydraulic model.
SSS	The topography scenario of the model.
****	The return period that is being modelled.
YYYY	2015 indicates current day / 2115 future (i.e. including allowance for climate change)
@@@	This represents the run number of the model and is increased for every model run

Model Scenarios

BSC	Baseline (existing scenario) and sensitivity (existing scenario)
PA	Proposed scenario A - post highway construction
PB	Proposed scenario B - post highway construction
P	Proposed scenario - post highway construction

Model Runs

Model Scenario	Return Periods / Events
Baseline (BSC)	2, 5, 10, 20, 50, 100, 100CC, 1000
Proposed (PA)	2, 5, 10, 20, 50, 100, 100CC, 1000

Sensitivity Analysis

Sensitivity analaysis has been performed on the following variables for the 1000yr and 100CCyr events.

- Flow
- Manning's values
- Downstream boundary (defined gradient for normal depth calculation)
- Afflux through structures (through altering the calibration coefficient)

A summary of the results of this analysis is outlined in the table below. The impact of the sensitivity of the model at the proposed crossing location is of key interest. Further details of the results of the sensitivity analysis are provided at the end of this document.

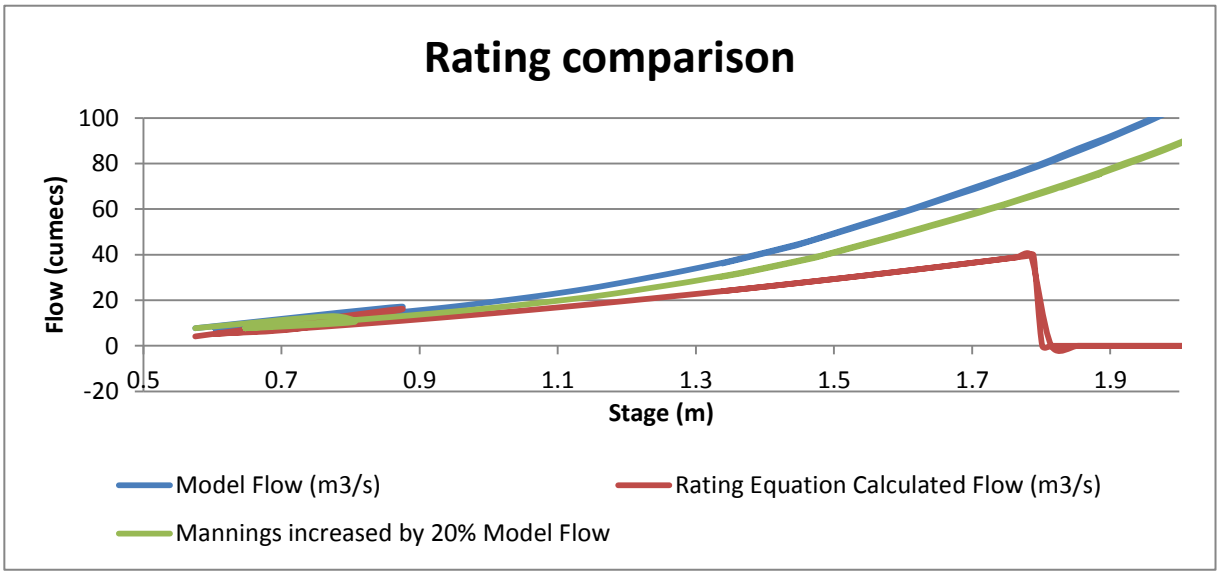
Sensitivity testing alteration	Impact on modelled stage
Scale 100CC ReFH boundaries by 1.2	Uniform increased stage everywhere (c.200mm in 100CCyr event).
Manning's increased by 20%	Limited impact upstream of bridges 1.1249BRUP and 1.165BRUP where flow is attenuated by the structures. Where there is less attenuation the Manning's value change results in an increase in peak stage of around 200 - 300mm. The increase in stage at the proposed road crossing is 254mm in the 1000yr event and 196mm in the 100CC year event.
Manning's decreased by 20%	There is a minimal change to stage along the entire longsection. There is a marginal decrease in stage at the proposed road crossings (35mm in the 1000yr event and 30mm in the 100CC event).
Slacken downstream boundary gradient by 50%	There is an increased stage upstream of the downstream boundary as far as 1.165BRUP. Throttling of flows upstream of 1.165BRUP removes effects of downstream boundary level changes upstream of this structure. There is no change in stage at the proposed road crossing.

Steepen downstream boundary gradient by 50%	There is a decreased stage upstream as far as 1.165BRUP. Throttling of flows upstream of 1.165BRUP removes effects of downstream boundary level changes upstream of this structure. There is no change at the proposed road crossing.
Increase calibration coefficient at structures by 20%	Increased stage upstream as far as channel section 1.776. There is a negligible increase at the proposed road crossing (14mm in 1000yr event).
Decrease calibration coefficient at structures by 20%	Decreased stage upstream as far as channel section 1.752. There is a negligible decrease at node the proposed bridge crossing (3mm in 1000yr event).

Model Verification

There is limited gauged data in the study reach to verify the model results. The Peblig Mill gauge (NRFA ref: 65006), is within the modelled reach of the Afon Seiont however the quality of the data at high flows is questionable. No level gauges were identified in the model reach and there is limited information on historic flood events. Therefore insufficient data is available to undertake calibration of the model. Instead the model results have been verified against the rating curve for the Peblig Mill gauge, comparison with the NRW Flood Map and a sensibility check based on site observations and LiDAR. The rating for the Peblig Mill gauge has been verified with check flow gaugings up to a depth of approximately 1.8m and has therefore been used to provide some model verification for flows at lower stages.

The graph below illustrates the rating curve for the Peblig Mill gauge (taken from the CEH dataset) and the rating curve calculated from the hydraulic model at a representative section (1.593). A second rating curve from the model is also shown from the sensitivity analysis (Manning's values increased by 20% throughout the model).



The rating curve calculated using the equations for the gauge (Peblig Mill 65006), taken from the CEH data set, estimates flows at the gauge that are approximately 45% less than the modelled flows for stage between 0.6 and 1.0m. A review of the model data and topography in this area does not indicate a specific reason for this discrepancy. For stages above 1.0m the model section nearest the gauge (1.593) shows flow occurring on the flood plain before flow would overtop the bank. This has been accepted in the model because the primary concern of the study is high flows when the bank at this location would be overtopped and flood plain flow would occur. The topography also suggests the channel could be bypassed from upstream. This additional flow on the flood plain potentially explains the higher modelled flows above 1.0m stage on the rating curve. For stages above 1.8m the difference between the rating curves increases rapidly. However, the equations given for the gauge do not apply beyond 1.8m and so meaningful comparison between the curves cannot be made.

Model Verification (cont.)

The difference between the two rating curves at the lower stages suggests that a global increase in Manning's roughness values could perhaps benefit the model accuracy. Increasing Manning's values globally by 20% was assessed as part of the sensitivity analysis. It is considered that increasing Manning's values beyond this range is unreasonable and exceeds the recommended limits as described by Chow (1984). The results of this analysis indicate that increasing Manning's values reduces the difference between the modelled rating curve and gauged rating curve to approximately 25%. Given that there is no particular basis for altering the Manning's values, and given that this exercise does not completely align the modelled and gauged ratings, it was considered that no global change to Manning's values should be made. The potential uncertainty in the model results will be considered when considering the impacts of the proposed development.

In addition to this, modelled peak flows have been compared to the flow estimates from the hydrological assessment, in particular to confirm the assertion that inflows through the model reach do not need to be included in the model. The difference in flows is very small, generally less than 1%, therefore no amendments were deemed necessary to the model or hydrology.

The modelled flood extents are a reasonable match to the NRW Flood Map although generally less extensive, particularly for the 100 year event. Less flooding is shown upstream of the proposed crossing. The survey / LiDAR in this area shows the left bank floodplain is raised therefore the model results are deemed more accurate. On the right bank the modelled 100 year flows are just retained in bank, hence a slight increase in flood level in the JFLOW modelling would explain the more extensive flooding shown. The model also suggests only limited flooding on the Glan Gwna. However as the channel is very steep in this area, it is unlikely to be well represented by the JFLOW modelling and the LiDAR is also likely to be less accurate. The JFLOW model underlying the NRW Flood Map is national generalised modelling that includes significant simplifications and assumptions. The detailed modelling undertaken for this study is therefore considered more accurate and appropriate for the FCA. Overall the modelled flood extents are considered sensible.

Baseline Results

Summary model results for the baseline scenario are provided below for the model node (1.783) where the proposed structure will be located.

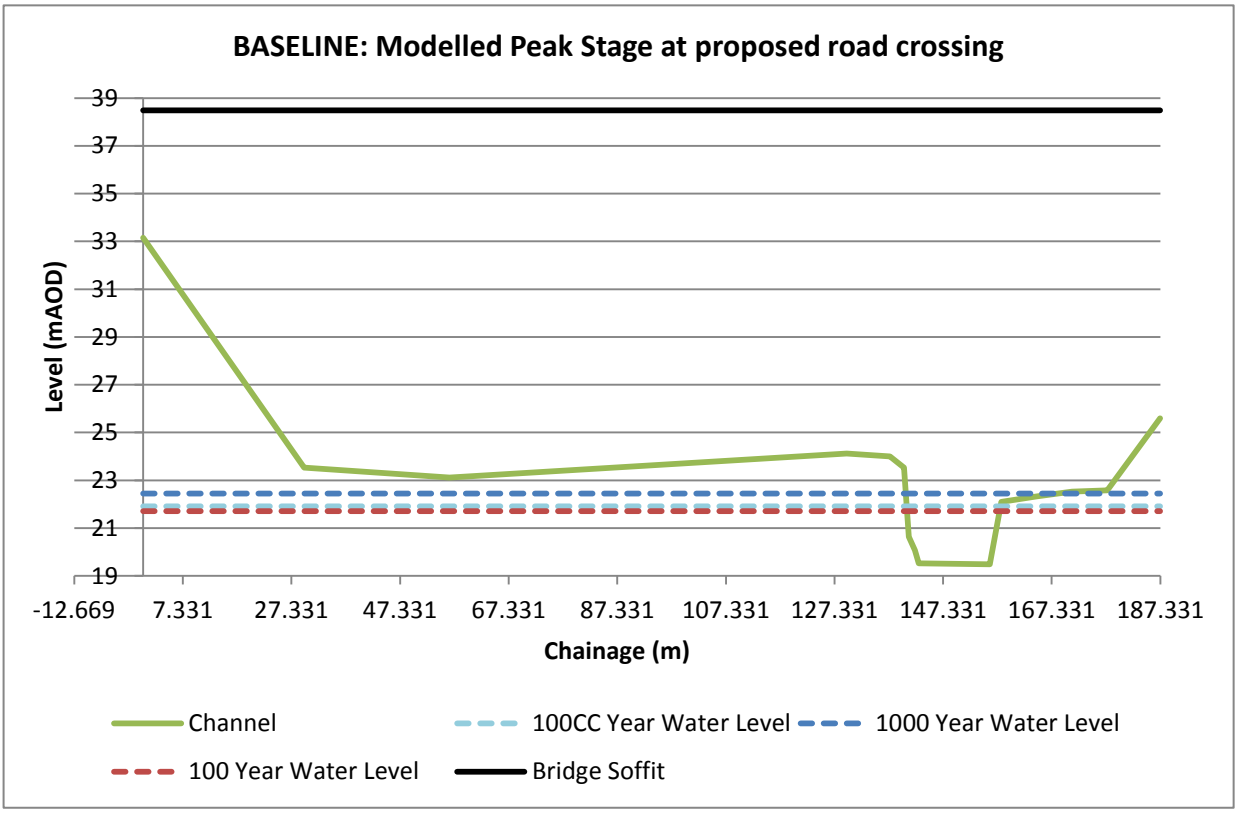
Peak flows (m3/s):

RP	1000	100CC	100	50	20	10	5	2
1.783	190.4	121.9	101.6	90.1	76.2	66.9	58.2	45.6

Peak stage (mAOD):

RP	1000	100CC	100	50	20	10	5	2
1.783	22.44	21.91	21.71	21.60	21.42	21.30	21.18	21.01

Baseline Results (cont.)



A review of the time series data through the modelled reach shows a small anomaly throughout the model at times ~8hrs and ~14hrs. This relates to the times of submergence of bridge 1.1568 (ISIS tolerance graphed output shows some red lining at these times also).

The soffit of structure 1.1568BRUP is at 29.63m AOD and has upper and lower transition distances of 0.5m so that the calculation mode at the structure switches in the range 29.13–30.13m AOD. This is the level at which model convergence is poor at the node and the stage time series data is anomalous at the upstream node 1.1568. The 1000yr peak stage at this node is 31.3m, well above the stage at which the mode changes at this structure. The 100CCyr peak stage is 28.8m AOD at this node, below the level at which the mode switches at this structure. Therefore, the slight anomaly resulting from mode switching at this structure is not affecting any of the key results.

Flood Mapping

Flood mapping has been completed using the 1D results in ISIS Mapper. A triangulated irregular network (TIN) surface has been created between points on adjacent sections in ISIS Mapper. The modelled water level at each section has then been displayed on the TIN surface. ISIS Mapper interpolates these results between adjacent sections across the TIN surface. Finally, the ground level within each grid square in the DTM has been compared with the results for water level at that point as displayed on the TIN surface. The difference between the values for ground level and water level represents the depths of water across the DTM. When plotted, these results form the flood map.

An area of very different and clearly incorrect level information exists in the LiDAR around Glan Gwna, especially toward the upper reaches. The result of this is that whilst flood depths as modelled in ISIS appear sensible, these flood depths do not display correctly when mapped against the LiDAR using ISIS Mapper.

Glan Gwna is a steep watercourse, increasing from approximately 23m AOD at the outfall of the watercourse to 31m AOD approximately 170m upstream. The watercourse is steep sided and due to this and the steepness of the watercourse, any impacts of the development will have no/negligible impacts on flooding along Glan Gwna.

For these reasons, flood extents along Glan Gwna have been removed completely from the mapping produced as part of this study.

Proposed structure (PA)

Refer to Parsons Brinckerhoff drawing 3513874-PB-SBR-SD-SK-S-00024_P01.2 for structure information (Annex B).

The proposed road crosses the Afon Seiont approximately 780m upstream of the downstream model boundary. The opening beneath the structure is approximately 168m wide and the soffit of the structure is approximately 20m above the bed level at this location. The structure has a clear span over the watercoruse with 3 rows of piers, each 1.8m in diameter. The toe of the embankment of the structure on the left bank is set back approximately 10m from the left bank. The toe of the embankment on the right side is set back approximately 60m from the right bank.

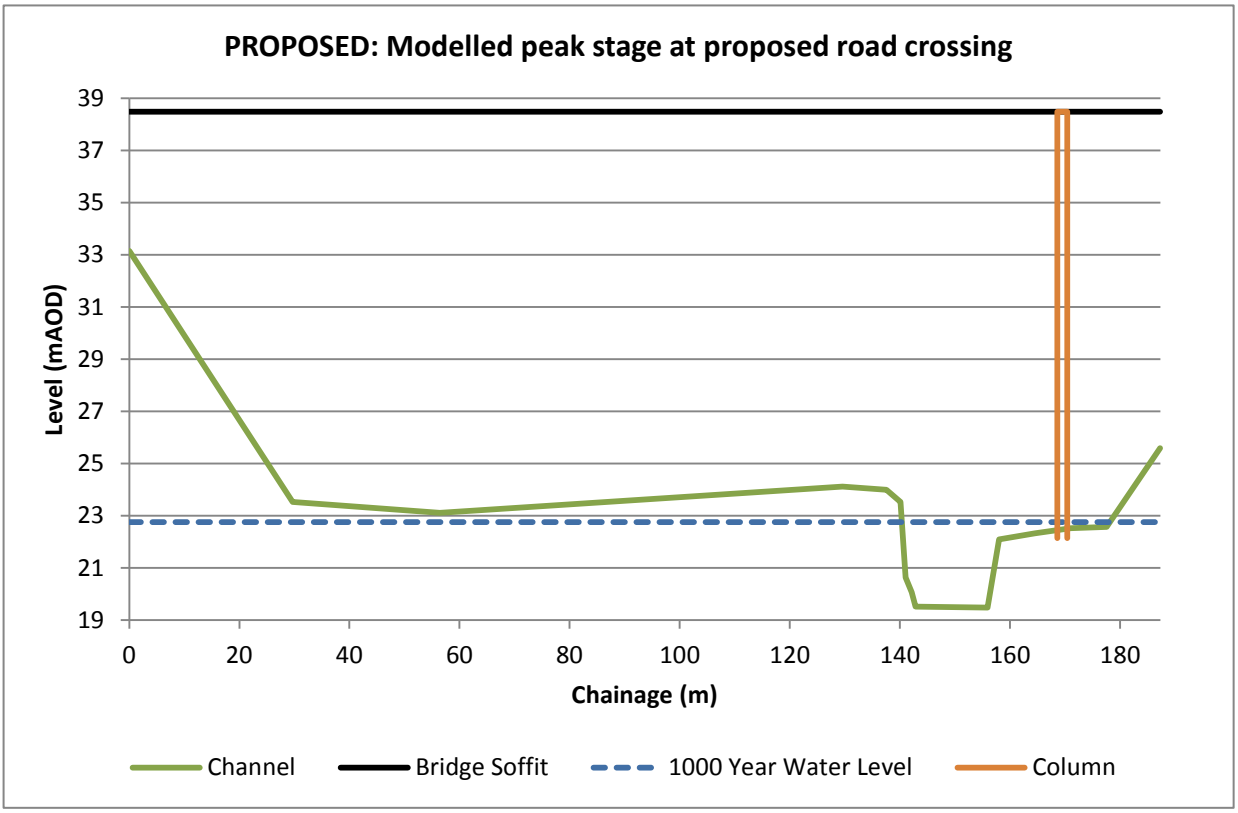
Because the soffit and embankments of the struture are set above the extreme flood level, the only effective impact the structure will have on flooding will result from the presence of piers in the flood plain. No piers are present in the river channel itself.

To model the impacts of the piers, the head (energy) loss associated with the piers has been calculated using the methodology outlined in Hydraulics of Bridge Waterways, HDS 1 (Bradley,1978). This has been applied to the model using a General Head Loss unit.

This methodology estimates a loss coefficient of 0.00 within the channel and 0.02 for flow above the right bank, where one row of bridge piers is located. The baseline results indicate during the 100 year return period flood event, including an allowance for climate change, the peak stage at section 1.783 is 21.906m AOD, 243mm below the base of the pier (22.149m AOD). In the 1000 year return period event, the baseline scenario indicates that the peak stage is 22.440m, 291mm above the pier base.

Proposed structure (PA) Results

The impact of the proposed structure has been modelled for the 1000 year return period event (the only modelled event affected by the pier). In the proposed scenario (PA) at node 1.783, where the proposed structure will be located, the 1000 year return period event modelled peak flow was 190.4m^3/s and the peak stage was 22.46m AOD.



The results indicate that the peak water level does not increase in any flood event up to and including the 100 year event, including an allowance for climate change. In the 1000 year event the peak flood level increases by 15mm (from 22.440 to to 22.455m AOD) as a result of the presence of the pier in the flood flow on the right bank at section 1.783.

The peak flow is unchanged from the baseline scenario in all return periods.

Proposed structure (PA) Impacts

In the 1000 year return period event the modelled peak stage increases by a maximum of 15mm at the proposed structure (1.783). This will have a negligible impact on the flood extents due to the topography. Approximately 130m upstream of the proposed crossing (1.915) the peak stage increases by only 3mm and approximately 300m upstream of the proposed crossing (1.1083) the baseline and proposed models show the same peak stage to the nearest millimetre.

The model indicates that there may be an increase to the 1000 year return period flood depth to land on the right bank up to 80m upstream of the proposed crossing. The increased depth of flooding is estimated to be between approximately 8mm and 15mm.

The slight increase in flood depth may affect the caravan park located on the right bank immediately upstream of the crossing, however the increase is negligible, up to 15mm compared with existing depths of up to approximately 750mm. The increase in flood depth will only occur for extreme events (~1000 year).

The model indicates that there will be no changes to the flood depths or extents downstream of the proposed crossing as a result of the development.

Cross Sections

Label	Type	Data Source	Additional Comments	X	Y	Left Bank Mannings	Channel Mannings	Right Bank Mannings	Channel Length	Invert	Left Bank Elevation	Right Bank Elevation
1.000	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Extended left and right bank using LiDAR	249100	361950	0.02 - 0.15	0.035	0.10 - 0.15	101	14.32	17.25	18.75
1.060	River Section	Copy of section 1.064	Provides downstream face of bridge 1.064BRUP	249145	361993	0.045 - 0.15	0.035	0.02 - 0.50	22	15.04	19.28	19.07
1.064SPUP	Spill Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Spill structure scaled from survey drawing of section 1.064.	249148	361996	N/A	N/A	N/A	N/A	19.22	N/A	N/A
1.064BRUP	Bridge (USBPR	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Bridge structure scaled from survey drawing of section 1.064.	249148	361996	0.45 - 0.15	0.035	0.02 - 0.5	N/A	15.04	19.28	19.07
1.064	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Extended left and right bank using LiDAR	249148	361996	0.45 - 0.15	0.035	0.02 - 0.5	124	15.04	19.28	19.07
1.140	River Section	Channel section copied from 1.165 and extended using LiDAR.	Provides flood plain representation using LiDAR to extend left and right banks.	249188	362051	0.15	0.035	0.02 - 0.5	178	15.17	17.10	19.53
1.158	River Section	Channel section copied from 1.165 and extended using LiDAR.	Provides downstream face of bridge 1.165BRUP as downstream face differs outside of channel.	249196	362069	0.15	0.035	0.15	126	15.20	17.04	16.95
1.165SPUP	Spill Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Spill structure scaled from survey drawing of section 1.165.	249205	362078	N/A	N/A	N/A	61	22.21	N/A	N/A
1.165BRUP	Existing NRW flood	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Bridge structure scaled from survey drawiong of section	249205	362078	0.15	0.035	0.025	61	15.20	20.92	22.42
1.165	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Extended left and right bank using LiDAR	249205	362078	0.15	0.035	0.025	61	15.20	20.92	22.42
1.242	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Extended right bank using LiDAR	249260	362131	0.15	0.035	0.06	55	15.70	17.05	16.85
1.259	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	17	N/A	N/A	N/A
1.275	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Extended left and right bank using LiDAR	249294	362135	0.15	0.035	0.07	103	17.09	17.75	18.12
1.284	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	9	N/A	N/A	N/A
1.293	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	9	N/A	N/A	N/A
1.303	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	10	N/A	N/A	N/A

Cross Sections

Label	Type	Data Source	Additional Comments	X	Y	Left Bank Mannings	Channel Mannings	Right Bank Mannings	Channel Length	Invert	Left Bank Elevation	Right Bank Elevation
1.312	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Extended right bank using LiDAR	249325	362150	0.150	0.035	0.150	41	16.65	18.05	17.71
1.353	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	65	N/A	N/A	N/A
1.394	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Extended left bank using LiDAR	249345	362228	0.150	0.035	0.150	4	18	19.07	18.88
1.413	River Section	Section copied from 1.415 and channel lowered by	Drop across weir assumed from photographic records.	249327	362241	0.06	0.035	0.15	4	17	19.76	24.31
1.415SPUP	Spill Section	Face of complex weir scaled from drawing of section	Spill unit used to represent complex weir shape. The spill	249335	362246	N/A	N/A	N/A	8	18	19.76	24.31
1.415	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Extended left and right bank using LiDAR. Bed levels	249327	362241	0.06	0.035	0.15	9	17.88	19.76	24.31
1.421	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Extended left and right bank using LiDAR. Bed levels	249327	362247	0.06	0.035	0.15	9	17.74	19.17	19.99
1.503	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Extended left bank using LiDAR	249383	362290	0.06	0.035	0.15	10	17.58	20.27	20.46
1.593	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Extended left bank using LiDAR	249471	362277	0.06	0.035	0.15	9	18.45	20.44	19.86
1.671	River Section	Channel section copied from 1.752 and extended using	Extended left and right bank using LiDAR	249521	362216	-	0.035	0.15	9	18.89	20.75	19.91
1.752	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Extended right bank using LiDAR	149579	362160	-	0.035	0.15	9	19.34	23.17	21.00
1.765	River Section	Based on topographic survey data at proposed bridge crossing from drawing 3513874-PB-SBR-112-DR-S-00001	LiDAR and channel survey data compared with topographic survey data at this location and acceptable differences between the data therefore topogrphic survey data used. Bed level adjusted to match interpolated level from channel survey data. Minor adjstments to right bank level to remove instability.	249600	362125	0.035	0.035	0.15	187	20.02	23.57	22.09

Label	Type	Data Source	Additional Comments	X	Y	Left Bank Mannings	Channel Mannings	Right Bank Mannings	Channel Length	Invert	Left Bank Elevation	Right Bank Elevation
Cross Sections												
1.783	River Section	Based on topographic survey data at proposed bridge crossing from drawing 3513874-PB-SBR-112-DR-S-00001	LiDAR and channel survey data compared with topographic survey data at this location and acceptable differences between the data therefore topogrphic survey data used. Bed level adjusted to match interpolated level from channel survey data. Minor adjstments to right bank level to remove instability.	249600	362125	0.035	0.035	0.15	187	20.02	23.57	22.09
1.850	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Extended right bank using LiDAR	249635	362086	0.035 - 1.0	0.035	0.15	8	20.21	21.71	22.70
1.915	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	7	N/A	N/A	N/A
1.945	River Section	Channel section copied from 1.980 and extended using LiDAR to represent flood plain	Extended left and right bank using LiDAR	249700	362051	0.15	0.035	0.15	7	21.08	22.31	22.99
1.980	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Extended left and right bank using LiDAR	249715	362017	0.035	0.035	0.15	7	21.40	22.63	23.62
1.1083A	River Section	Copy of section 1.1083A	Provides second node for junction connection at confluence of Glan Gwna and Afon Seiont.	249801	362048	0.15	0.035	0.02 - 0.15	10	22.20	25.00	24.70
1.1083	River Section	Manually interpolated to provide node at junction	Extended right bank using LiDAR	249801	362048	0.15	0.035	0.02 - 0.15	-	22.20	25.00	24.70
1.1112	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Extended right bank using LiDAR	249826	362065	0.15	0.035	0.02 - 0.15		22.38	25.25	24.95
1.1225	River Section	Channel section copied from 1.1249 and extended to represent flood plain with LiDAR	Extended left and right bank using LiDAR	249870	362163	0.15 - 0.035	0.035	0.6	3	22.97	24.53	24.60

Cross Sections

Label	Type	Data Source	Additional Comments	X	Y	Left Bank Mannings	Channel Mannings	Right Bank Mannings	Channel Length	Invert	Left Bank Elevation	Right Bank Elevation
1.1244	River Section	Channel section copied from section 1.1249 and amended using LidAR to provide downstream section at structure	Section 1.1249 does not provide adequate channel section downstream of bridge 1.1249BRUP therefore new channel provided using channel shape and LidAR.	249870	362183	0.15	0.035	0.15	3	23.07	25.24	24.70
1.1249SPUP	Spill Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Spill structure scaled from survey drawing of section 1.1249.	249869	362187	N/A	N/A	N/A	-	29.99	37.38	31.14
1.1249BRUP	Bridge (USBPR 1978)	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Bridge structure scaled from survey drawiong of section 1.1249.	249869	362187	0.15	0.035	0.15	13	23.07	25.24	25.89
1.1249	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont		249869	362187	0.15	0.035	0.15	13	23.07	25.24	25.89
1.1285	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	36	N/A	N/A	N/A
1.1320	River Section	Manually interpolated between sections in channel.	Extended left and right bank using LiDAR	249850	362249	0.15	0.035	0.15	63	24.02	25.87	27.37
1.1360	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	40	N/A	N/A	N/A
1.1400	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont		249878	362302	0.15	0.035	0.15	38	25.10	26.95	28.45
1.1447	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1.1494	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1.1541	River Section	Manually interpolated between sections in channel.	Extended left and right bank using LiDAR.	249950	362238	0.15	0.035	0.15	65	26.64	27.51	27.91
1.1561	River Section	Channel section copied from section 1.1568 and amended	Extended left and right bank using LiDAR.	249947	362219	0.15	0.035	0.15	52	26.87	28.30	28.21
1.1568SP2UP	Spill Section	Derived from LiDAR to represent spill between sections 1.1568 and 1.1244	Derived from LiDAR.	249933	362197	N/A	N/A	N/A	N/A	31.06	31.68	31.09
1.1568SPUP	Spill Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Spill structure scaled from survey drawing of section	249946	362211	N/A	N/A	N/A	N/A	31.77	32.48	32.75

Cross Sections

Label	Type	Data Source	Additional Comments	X	Y	Left Bank Mannings	Channel Mannings	Right Bank Mannings	Channel Length	Invert	Left Bank Elevation	Right Bank Elevation
1.1568BRUP	Bridge (USBPR	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Bridge structure scaled from survey drawiong of section	249946	362211	0.15	0.035	0.15	N/A	26.87	28.30	28.21
1.1568	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont		249946	362211	0.15	0.035	0.15	32	26.87	28.30	28.21
1.1583	River Section	Channel section copied from section 1.1568 and amended using LiDAR to provide section upstream of bridge	Extended right bank using LiDAR	249950	362197	0.15	0.035	0.15	140	27.01	28.44	28.35
1.1625	River Section	Channel section copied from section 1.1660 and amended using LiDAR to represent flood plain.	Extended left and right bank using LiDAR	249982	362178	0.15	0.035	0.15	213	27.40	28.99	27.51
1.1660	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Extended left and right bank using LiDAR	250017	362187	0.15	0.035	0.02 - 0.15	67	27.75	29.34	29.65
1.1702	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Extended left and right bank using LiDAR	250058	362192	0.15	0.035	0.02 - 0.15	75	27.51	29.41	30.60
2.000	River Section	Manually copy of section 2.035 geolocated at		249804	362042	0.15	0.035	0.15	27	22.20	23.10	23.27
2.008	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A
2.017	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	9	N/A	N/A	N/A
2.026	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	9	N/A	N/A	N/A
2.035	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont		249835	362025	0.15	0.035	0.15	10	24.25	25.15	25.32
2.045		Automatic interpolate		N/A	N/A	N/A	N/A	N/A	9	N/A	N/A	N/A
2.054	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	9	N/A	N/A	N/A

Label	Type	Data Source	Additional Comments	X	Y	Left Bank Mannings	Channel Mannings	Right Bank Mannings	Channel Length	Invert	Left Bank Elevation	Right Bank Elevation
Cross Sections												
2.063	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	9	N/A	N/A	N/A
2.072	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	10	N/A	N/A	N/A
2.082	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	10	N/A	N/A	N/A
2.092	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A
2.100	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	7	N/A	N/A	N/A
2.107	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	7	N/A	N/A	N/A
2.114	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	7	N/A	N/A	N/A
2.121	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	10	N/A	N/A	N/A
2.131	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	10	N/A	N/A	N/A
2.143	River Section	Copied from section 2.143 to represent dowsntream face	Photographs show a steep fall through this structure but no	249924	361989	0.02	0.035	0.02	12	29.46	31.95	29.31
2.150SPUP	Spill Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Spill structure scaled from survey drawing of section 2.250.	249920	61987	N/A	N/A	N/A	3	32.06	32.72	32.80
2.150BRUP	Bridge (USBPR	Merrett Survey Ltd (March 2014) - Glangna and Seiont	Bridge structure scaled from survey drawiong of section	249920	61987	0.02	0.02	0.035	3	29.46	31.95	29.31
2.150	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont		249920	61987	0.02	0.035	0.02	0	29.46	31.95	29.31
2.153	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	13	N/A	N/A	N/A
2.156	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	13	N/A	N/A	N/A
2.159	River Section	Section copied from section 2.161 and lowered scaling		249931	361980	0.15	0.035	0.02 - 0.15	26	29.64	30.15	31.70
2.161SPUP	Spill Section	Side slopes copied from section 2.161 and spill	Spill unit used to represent weir shape. The spill unit will nto	249929	361980	N/A	N/A	N/A	26	30.94	31.39	32.94
2.161	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont		249936	361978	0.15	0.035	0.02 - 0.15	26.00	30.88	31.39	32.94

Label	Type	Data Source	Additional Comments	X	Y	Left Bank Mannings	Channel Mannings	Right Bank Mannings	Channel Length	Invert	Left Bank Elevation	Right Bank Elevation
Cross Sections												
2.174	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	13	N/A	N/A	N/A
2.187	Interpolate	Automatic interpolate		N/A	N/A	N/A	N/A	N/A	13	N/A	N/A	N/A
2.200	River Section	Merrett Survey Ltd (March 2014) - Glangna and Seiont		249939	361946	0.15	0.035	0.06	19.000	30.82	31.46	32.00

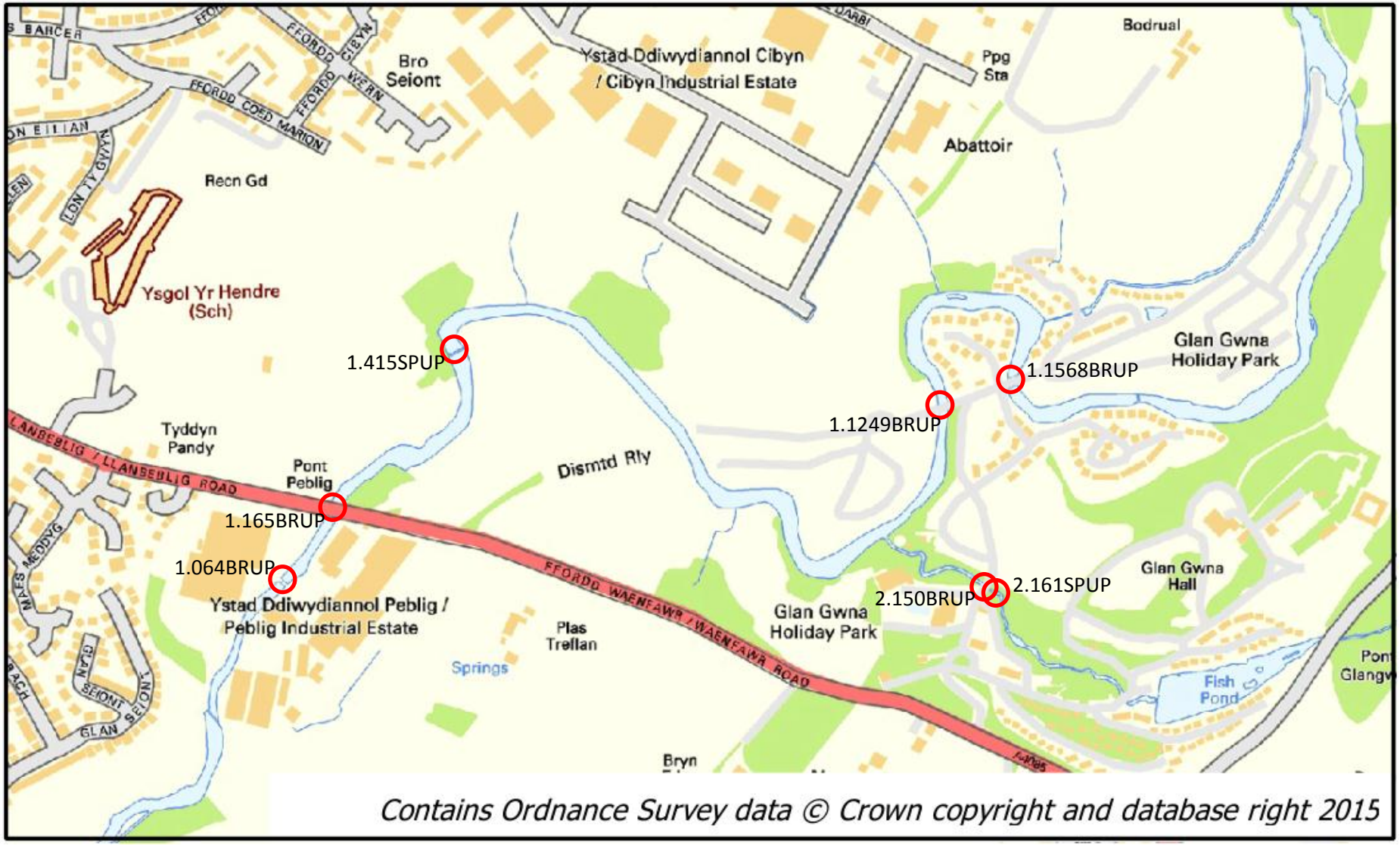
Structures

Model Ref.	Description	Photo Ref.	Data source	Modelling Approach	Dimensions	Blockage Risk
1.064BRUP	Private road bridge	Photo 1	Merrett Survey Ltd (March 2014) - Glangna and Seiont - Upstream Bridge Section (Northern Elevation)	Modelled using USBPR1978 bridge unit - dimensions not explicitly provided on survey therefore they have been scaled from survey drawing. Soffit level provided on survey. Section used from survey and extended using LIDAR.	16.0m x 2.5m	Low
1.165BRUP	Road bridge over A4085 (Waenfawr Road)	Photo 2	Merrett Survey Ltd (March 2014) - Glangna and Seiont - Upstream Bridge Section (Northern Elevation)	Modelled using arch bridge unit - Soffit level provided on survey. Section used from survey and extended using LIDAR.	13.78m wide x 6.4m hieght to soffit	Low
1.415SPUP	Weir	Photo 3	Merrett Survey Ltd (March 2014) - Glangna and Seiont - Upstream weir section (Northern Elevation)	Modelled using spill unit to provide complex shape of weir. Dimensions scaled from surveyed section drawing where not explicitaly provided on cross section drawing.	17.6m wide x 0.01 - 0.81m above upstream bed level	N/A
1.1249BRUP	Private road bridge in Glan Gwna Holiday Park	Photo 4	Merrett Survey Ltd (March 2014) - Glangna and Seiont - Upstream Bridge Section (Northern Elevation)	Modelled using USBPR1978 bridge unit - dimensions not explicitly provided on survey therefore they have been scaled from survey drawing. Soffit level provided on survey. Section used from survey and extended using LIDAR.	13.2m x 3.1m	Low

1.1568BRUP	Private road bridge in Glan Gwna Holiday Park	Photo 5	Merrett Survey Ltd (March 2014) - Glangna and Seiont - Upstream Bridge Section (Southern Elevation)	Modelled using USBPR1978 bridge unit - dimensions not explicitly provided on survey therefore they have been scaled from survey drawing. Soffit level provided on survey. Section used from survey and extended using LIDAR. Two spill units used to represent those flows over the bridge and those that bypass the bridge between sections 1.1568 and 1.1244.	15.7m x 1.0m	Low
2.150BRUP	Private road bridge in Glan Gwna Holiday Park	Photo 6 - 7	Merrett Survey Ltd (March 2014) - Glangna and Seiont - Upstream Bridge Section (Southern Elevation)	Modelled using arch bridge unit as USBPR units generally do not represent small bridges as well as acrh bridge units - dimensions provided on survey. Existing pipe below soffit of bridge modelled by lowering soffit (dimension scaled from surveyed section drawing). Bridge soffit level provded on survey. Section used from survey. Survey did not pick up fall through bridge (likely due to inaccessibility) and photo7 shows significant fall through bridge. This has not been modelled as no information is available. This is not expected to have any impacts on flow in the area of interest.	3.5m x 0.2m	Moderate
2.161SPUP	Weir	Photo 8	Merrett Survey Ltd (March 2014) - Glangna and Seiont - Upstream weir section (Northern Elevation) and surveyed river longsection	Modelled using spill unit to provide shape of weir. Dimensions scaled from surveyed section drawing where not explicitaly provided on cross section drawing.	3.9m wide x 0.06 - 0.16m above upstream bed level	N/A

1.783BRUP	Proposed bridge structure	None (proposed structure)	Parsons Brinckerhoff proposed bridge structrue drawing 3513874-PB-SBR-SD-SK-S-00024_P01.2	Modelled using a General Head Loss unit. Dimensions of the struicture have been scaled from the drawing. An upstream section has been inctroduced at the bridge using the topographic survey (data incldued in drawing).	168m wide x 20m high	N/A
	The soffit level and bridge abutments are >10m above the baseline maximum water level. Therefore, a small excavation in the north embankment near the soffit has not been included in the model and the same upstream section has been maintained throughout the baseline and proposed scenarios. Because the soffit and embankments of the struture are set above the extreme flood level, the only effective impact the structure will have on flooding will result from the presence of piers in the flood plain. No piers are present in the river channel itself. To model the impacts of the piers in the flood plain, a head loss associated with the piers has been calculated using the methodology outlined in Hydraulics of Bridge Waterways, HDS 1 (Bradley,1978). This head loss has been represented in the model using a General Head Loss unit at the structure. This methodology estimates a loss coefficient of 0 within the channel and 0.02 for flow above the right bank, where a bridge pier is located.					

Plan of Structure / Defence Locations



Photos

Photo 1 - Private road bridge 1.064BRUP - Upstream face of bridge



Photo 2 - Road bridge A4085 1.165BRUP - Upstream face of bridge



Photo 3 - Weir 1.415SPUP - From right bank



Photo 4 - Private road bridge 1.1249BRUP - Upstream face of bridge



Photo 5 - Private road bridge 1.1568BRUP - Upstream face of bridge



Photo 6 - Private road bridge 2.150BRUP - Upstream face of bridge



Photo 7 - Private road bridge 2.150BRUP - From right bank looking at downstream face of bridge



Photo 8 - Weir 2.161SPUP - From right bank looking at downstream face of weir



Model Files

File Naming Convention -
SSS - indicates run scenario e.g. BSC for Baseline, PA for Proposed
**** - indicates run event AEP, e.g. 0100F for 1% AEP flood event
YYYY - 2015 indicates current day / 2115 future (i.e. including allowance for climate change)

File name	Type	Format	Comments
SNT_SSS_****_YYYY_@@@.ief	ISIS 1D simulation file	Text file	The ISIS 1D simulation file contains the run parameters for a model simulation. The IEF file defines the 1D event data to be used in the simulation (.ied files).
SNT_SSS_@@@.dat	ISIS model data	Text file	The ISIS model data is stored in the .dat file. This contains information channel, floodplain and structure geometry data that forms the 1D model.
SNT_****.ied	ISIS event data	Text file	The ISIS event data files contain the the event hydrology to be used in conjunction with the .dat to simulate a particular storm event.
SNT__****_YYYY_nnn.icc	ISIS initial conditions	Text file	ISIS initial conditions file. Generated from low flow unsteady simulation.
SNT_SSS_****_YYYY_@@@.zzl	Results files	Text file	ISIS steady results files. Generated from simulation
SNT_SSS_****_YYYY_@@@.zzu	Results files	Text file	ISIS unsteady results files. Generated from simulation

Run List

Filepaths

Datafile: N:\Water Engineering\3513874A-HHC_A487_Caernarfon_WORKING\E Technical Design\6 Hydraulic Modelling\Afon Seiont\Model Files\
Results: N:\Water Engineering\3513874A-HHC_A487_Caernarfon_WORKING\E Technical Design\6 Hydraulic Modelling\Afon Seiont\Results Files\
Initial Conditons: N:\Water Engineering\3513874A-HHC_A487_Caernarfon_WORKING\E Technical Design\6 Hydraulic Modelling\Afon Seiont\Results Files\
Event Data: N:\Water Engineering\3513874A-HHC_A487_Caernarfon_WORKING\E Technical Design\6 Hydraulic Modelling\Afon Seiont\Boundary Files\IEDs\

Model Ref.	Scenario	Flood Event (~E)		Run No.	End Time	ISIS Event file (.IEF)	ISIS file (.DAT)	Result files	Initial Conditions (.ZZS)	ISIS Event Data (.IED)	Comments
		Return Period	Year								
Baseline Scenario											
SNT	BSC	1000	2115	089	30	SNT_BSC_1000_2115_089	SNT_BSC_089	SNT_BSC_1000_2115_089	SNT_BSC_1000_2115_089	SNT_1000CC_yr_v3	1000CCyr run using v089.dat and initial conditions. Min flow in .ied set to match initial conditions from SNT_BSC_1000_2115_089.zzd.
SNT	BSC	1000	2015	090	30	SNT_BSC_1000_2015_090	SNT_BSC_089	SNT_BSC_1000_2015_090	SNT_BSC_1000_2115_089	SNT_1000_yr	1000yr run using v089.dat and initial conditions. Min flow in .ied set to match initial conditions from SNT_BSC_1000_2115_089.zzd.
SNT	BSC	100	2115	091	30	SNT_BSC_100_2115_091	SNT_BSC_089	SNT_BSC_100_2115_091	SNT_BSC_1000_2115_089	SNT_100CC_yr	100CCyr run using v089.dat and initial conditions. Min flow in .ied set to match initial conditions from SNT_BSC_1000_2115_089.zzd.
SNT	BSC	100	2015	092	30	SNT_BSC_100_2015_092	SNT_BSC_089	SNT_BSC_100_2015_092	SNT_BSC_1000_2115_089	SNT_100_yr	100yr run using v089.dat and initial conditions. Min flow in .ied set to match initial conditions from SNT_BSC_1000_2115_089.zzd.
SNT	BSC	50	2015	093	30	SNT_BSC_50_2015_093	SNT_BSC_089	SNT_BSC_50_2015_093	SNT_BSC_1000_2115_089	SNT_50_yr	50yr run using v089.dat and initial conditions. Min flow in .ied set to match initial conditions from SNT_BSC_1000_2115_089.zzd.
SNT	BSC	20	2015	094	30	SNT_BSC_20_2015_094	SNT_BSC_089	SNT_BSC_20_2015_094	SNT_BSC_1000_2115_089	SNT_20_yr	20yr run using v089.dat and initial conditions. Min flow in .ied set to match initial conditions from SNT_BSC_1000_2115_089.zzd.
SNT	BSC	10	2015	095	30	SNT_BSC_10_2015_095	SNT_BSC_089	SNT_BSC_10_2015_095	SNT_BSC_1000_2115_089	SNT_10_yr	10yr run using v089.dat and initial conditions. Min flow in .ied set to match initial conditions from SNT_BSC_1000_2115_089.zzd.
SNT	BSC	5	2015	096	30	SNT_BSC_5_2015_096	SNT_BSC_089	SNT_BSC_5_2015_096	SNT_BSC_1000_2115_089	SNT_5_yr	5yr run using v089.dat and initial conditions. Min flow in .ied set to match initial conditions from SNT_BSC_1000_2115_089.zzd.
SNT	BSC	2	2015	097	30	SNT_BSC_2_2015_097	SNT_BSC_089	SNT_BSC_2_2015_097	SNT_BSC_1000_2115_089	SNT_2_yr	2yr run using v089.dat and initial conditions. Min flow in .ied set to match initial conditions from SNT_BSC_1000_2115_089.zzd.

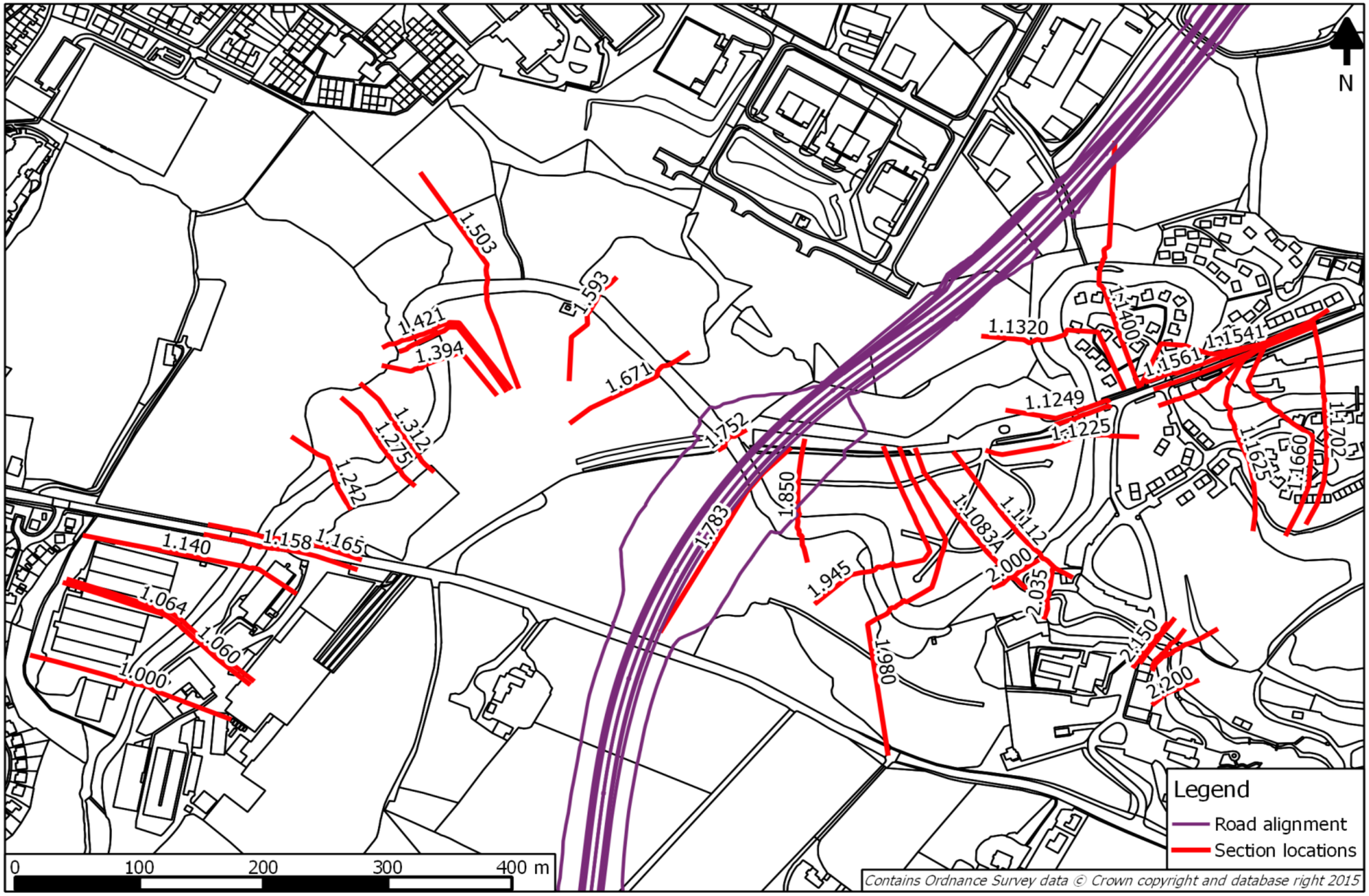
Run List

Model Ref.	Scenario	Flood Event (~E)		Run No.	End Time	ISIS Event file (.IEF)	ISIS file (.DAT)	Result files	Initial Conditions (.ZZS)	ISIS Event Data (.IED)	Comments
		Return Period	Year								
Sensitivity Analysis											
SNT	BSC	100	2115	061	30	SNT_BSC_100_2115_061	SNT_BSC_052	SNT_BSC_100_2115_061	SNT_BSC_1000_2115_052	SNT_100_yr_+20PC	Increase peak flows for 100 yr + CC by 20%.
SNT	BSC	1000	2015	062	30	SNT_BSC_1000_2015_062	SNT_BSC_062	SNT_BSC_1000_2015_062	SNT_BSC_1000_2115_052	SNT_1000CC_yr_v4	Increase global mannings values by 20% (n=0.15 becomes 0.18, n=0.035 becomes 0.042, n=0.02 becomes 0.025)
SNT	BSC	100	2115	063	30	SNT_BSC_100_2115_063	SNT_BSC_062	SNT_BSC_100_2115_063	SNT_BSC_1000_2115_052	SNT_100CC_yr	Increase global mannings values by 20% (n=0.15 becomes 0.18, n=0.035 becomes 0.042, n=0.02 becomes 0.025)
SNT	BSC	1000	2015	064	30	SNT_BSC_1000_2015_064	SNT_BSC_064	SNT_BSC_1000_2015_064	SNT_BSC_1000_2115_052	SNT_1000CC_yr_v4	Decrease global mannings values by 20% (n=0.15 becomes 0.12, n=0.028 becomes 0.042, n=0.02 becomes 0.016)
SNT	BSC	100	2115	065	30	SNT_BSC_100_2115_065	SNT_BSC_064	SNT_BSC_100_2115_065	SNT_BSC_1000_2115_052	SNT_100CC_yr	Decrease global mannings values by 20% (n=0.15 becomes 0.12, n=0.028 becomes 0.042, n=0.02 becomes 0.016)
SNT	BSC	1000	2015	066	30	SNT_BSC_1000_2015_066	SNT_BSC_066	SNT_BSC_1000_2015_066	SNT_BSC_1000_2115_052	SNT_1000CC_yr_v4	Slacken downstream slope by 20% (Gradient 107.53 becomes 129.036)
SNT	BSC	100	2115	067	30	SNT_BSC_100_2115_067	SNT_BSC_066	SNT_BSC_100_2115_067	SNT_BSC_1000_2115_052	SNT_100CC_yr	Slacken downstream slope by 20% (Gradient 107.53 becomes 129.036)
SNT	BSC	1000	2015	068	30	SNT_BSC_1000_2015_068	SNT_BSC_068	SNT_BSC_1000_2015_068	SNT_BSC_1000_2115_052	SNT_1000CC_yr_v4	Steepen downstream slope by 20% (Gradient 107.53 becomes 86.024)
SNT	BSC	100	2115	069	30	SNT_BSC_100_2115_069	SNT_BSC_068	SNT_BSC_100_2115_069	SNT_BSC_1000_2115_052	SNT_100CC_yr	Steepen downstream slope by 20% (Gradient 107.53 becomes 86.024)
SNT	BSC	1000	2015	070	30	SNT_BSC_1000_2015_070	SNT_BSC_070	SNT_BSC_1000_2015_070	SNT_BSC_1000_2115_052	SNT_1000CC_yr_v4	Increase calibration coefficient of bridges 1.1568BRUP, 1.1249BRUP and 1.165BRUP by 20% to increase afflux through structures.
SNT	BSC	100	2115	071	30	SNT_BSC_100_2115_071	SNT_BSC_070	SNT_BSC_100_2115_071	SNT_BSC_1000_2115_052	SNT_100CC_yr	Increase calibration coefficient of bridges 1.1568BRUP, 1.1249BRUP and 1.165BRUP by 20% to increase afflux through structures.
SNT	BSC	1000	2015	072	30	SNT_BSC_1000_2015_072	SNT_BSC_072	SNT_BSC_1000_2015_072	SNT_BSC_1000_2115_052	SNT_1000CC_yr_v4	Decrease calibration coefficient of bridges 1.1568BRUP, 1.1249BRUP and 1.165BRUP by 10% to decrease jafflux through structures.
SNT	BSC	100	2115	073	30	SNT_BSC_100_2115_073	SNT_BSC_072	SNT_BSC_100_2115_073	SNT_BSC_1000_2115_052	SNT_100CC_yr	Decrease calibration coefficient of bridges 1.1568BRUP, 1.1249BRUP and 1.165BRUP by 10% to decrease jafflux through structures.

Run List

Model Ref.	Scenario	Flood Event (~E)		Run No.	End Time	ISIS Event file (.IEF)	ISIS file (.DAT)	Result files	Initial Conditions (.ZZS)	ISIS Event Data (.IED)	Comments
		Return Period	Year								
Proposed Scenario A											
SNT	PA	1000	2115	107	30	SNT_PA_1000_2115_107	SNT_PA_107	SNT_PA_1000_2115_107	SNT_PA_1000_2115_107	SNT_1000CC_yr_v4	1000CCyr run using v107.dat. Initial conditions used from SNT_PA_1000_2115_089 to generate steady stae results, which were then used to run the model unsteady with an initial timestep of 5s.
SNT	PA	1000	2015	107	30	SNT_PA_1000_2015_107	SNT_PA_107	SNT_PA_1000_2015_107	SNT_PA_1000_2115_107	SNT_1000_yr	1000yr run using v107.dat. Initial conditions used from SNT_PA_1000_2115_107.
SNT	PA	100	2115	107	30	SNT_PA_100_2115_107	SNT_PA_107	SNT_PA_100_2115_107	SNT_PA_1000_2115_107	SNT_100CC_yr	100CCyr run using v107.dat. Initial conditions used from SNT_PA_1000_2115_107.
SNT	PA	100	2015	107	30	SNT_PA_100_2015_107	SNT_PA_107	SNT_PA_100_2015_107	SNT_PA_1000_2115_107	SNT_100_yr	100yr run using v107.dat. Initial conditions used from SNT_PA_1000_2115_107.
SNT	PA	50	2015	107	30	SNT_PA_50_2015_107	SNT_PA_107	SNT_PA_50_2015_107	SNT_PA_1000_2115_107	SNT_50_yr	50yr run using v107.dat. Initial conditions used from SNT_PA_1000_2115_107.
SNT	PA	20	2015	107	30	SNT_PA_20_2015_107	SNT_PA_107	SNT_PA_20_2015_107	SNT_PA_1000_2115_107	SNT_20_yr	20yr run using v107.dat. Initial conditions used from SNT_PA_1000_2115_107.
SNT	PA	10	2015	107	30	SNT_PA_10_2015_107	SNT_PA_107	SNT_PA_10_2015_107	SNT_PA_1000_2115_107	SNT_10_yr	10yr run using v107.dat. Initial conditions used from SNT_PA_1000_2115_107.
SNT	PA	5	2015	107	30	SNT_PA_5_2015_107	SNT_PA_107	SNT_PA_5_2015_107	SNT_PA_1000_2115_107	SNT_5_yr	5yr run using v107.dat. Initial conditions used from SNT_PA_1000_2115_107.
SNT	PA	2	2015	107	30	SNT_PA_2_2015_107	SNT_PA_107	SNT_PA_2_2015_107	SNT_PA_1000_2115_107	SNT_2_yr	2yr run using v107.dat. Initial conditions used from SNT_PA_1000_2115_107.

SEIONT SECTION LOCATIONS



Sensitivity Analysis

Sensitivity analaysis has been performed on the following variables:

- Flow
- Mannings values
- Mannings values
- Afflux through structures

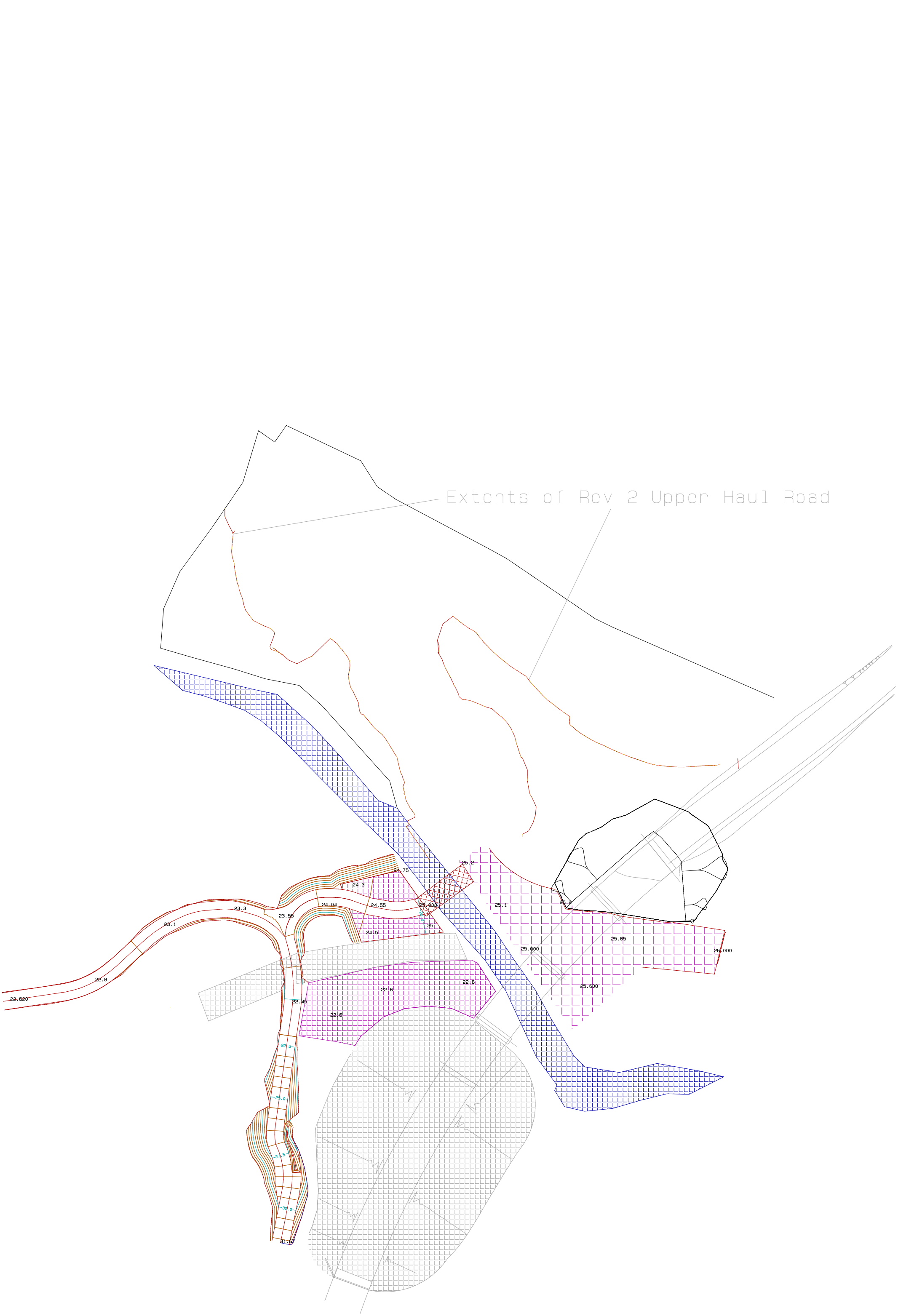
The table below gives a summary of the peak flows and levels at the proposed road section for the 1000yr and 100CCyr events. Minor changes to the model sections at the proposed crossing were made to the final model. The sensitivity scenarios have not been re-run as the changes will not affect the outcome.

Node 1.776	1000yr event		100yrCC event		Comments
	Peak Flow	Peak Stage	Peak Flow	Peak Stage	
Baseline scenario	190.5	22.39	121.9	21.87	
Scale 100CC ReFH boundaries by 1.2	N/A	N/A	145.9	22.07	Uniform increased stage everywhere (c.200mm in 100CCyr event)
Mannings increased by 20%	190.4	22.65	121.8	22.07	Significant increase in stage at node (254mm in 1000yr event)
Mannings decreased by 20%	190.5	22.36	121.9	21.84	Marginal decrease in stage at node (35mm in 1000yr event)
Slacken downstream boundary by 50%	190.5	22.39	121.9	21.87	No change at node
Steepen downstream boundary by 50%	190.5	22.39	121.9	21.87	No change at node
Increase calibration coefficient at structures by 20%	190.5	22.41	121.9	21.87	Negligible change (14mm in 1000yr event)
Decrease calibration coefficient at structures by 20%	190.4	22.39	121.9	21.87	Negligible change (3mm in 1000yr event)

A complete list of the analysis undertaken by return period and the results of the analysis is listed below:

Model Ref.	Scenario	Flood Event (~E)		Run No.	End Time	Sensitive variable alteration	General impacts of variable alteration	Changes required to model
		Return Period	Year					
SNT	BSC	100	2115	061	30	Increase peak flows for 100 yr + CC by 20% (to fit peaks of SNT=139.44 and TRIB = 7.80)	Stage increased along entire longsection comapred to the 100CCyr event. Peak stage still significantly less than 1000CC event along entire long section.	None required.
SNT	BSC	1000	2015	062	30	Increase global mannings values by 20% (n=0.15 becomes 0.18, n=0.035 becomes 0.042, n=0.02 becomes 0.025 - within maximum/minimum ranges quoted in Chow)	Where flow is attenuated upstream by bridges 1.1249BRUP and 1.165BRUP the stage generally remains unaltered by the increase in Manning's values. However, elsewhere the increase in Manning's values results in an increase in peak stage in a relatively uniform fashion along the watercourse by approximately 200-300mm.	None required.
SNT	BSC	100	2115	063	30	Increase global mannings values by 20% (n=0.15 becomes 0.18, n=0.035 becomes 0.042, n=0.02 becomes 0.025 - within maximum/minimum ranges quoted in Chow)	Where flow is attenuated upstream by bridges 1.1249BRUP and 1.165BRUP the stage generally remains unaltered by the increase in Manning's values. However, elsewhere the increase in Manning's values results in an increase in peak stage in a relatively uniform fashion along the watercourse by approximately 150-300mm.	None required.
SNT	BSC	1000	2015	064	30	Decrease global mannings values by 20% (n=0.15 becomes 0.12, n=0.035 becomes 0.028, n=0.02 becomes 0.016 - within maximum/minimum ranges quoted in Chow)	There is a minimal decrease in stage along the entire longsection. The decrease is generally uniform along the longsection with the the greatest decrease in stage at section 1.980 of approximately <50mm.	None required.
SNT	BSC	100	2115	065	30	Decrease global mannings values by 20% (n=0.15 becomes 0.12, n=0.035 becomes 0.028, n=0.02 becomes 0.016 - within maximum/minimum ranges quoted in Chow)	There is a minimal decrease in stage along the entire longsection. The decrease is generally uniform along the longsection with the the greatest decrease in stage at section 1.980 and 1.415 of approximately <50mm.	None required.
SNT	BSC	1000	2015	066	30	Slacken downstream slope by 50% (Gradient 107.53 becomes 161.295)	Increased stage upstream as far as 1.165BRUP. Throttling upstream of 1.165BRUP removes effects of downstream boundary changes upstream of this structure.	None required.
SNT	BSC	100	2115	067	30	Slacken downstream slope by 50% (Gradient 107.53 becomes 161.295)	Increased stage upstream as far as 1.165BRUP. Throttling upstream of 1.165BRUP removes effects of downstream boundary changes upstream of this structure.	None required.

Model Ref.	Scenario	Flood Event (~E)		Run No.	End Time	Sensitive variable alteration	General impacts of variable alteration	Changes required to model
		Return Period	Year					
SNT	BSC	1000	2015	068	30	Steepen downstream slope by 50% (Gradient 107.53 becomes 53.765)	Decreased stage upstream as far as 1.165BRUP. Throttling upstream of 1.165BRUP removes effects of downstream boundary changes upstream of this structure.	None required.
SNT	BSC	100	2115	069	30	Steepen downstream slope by 50% (Gradient 107.53 becomes 53.765)	Decreased stage upstream as far as 1.165BRUP. Throttling upstream of 1.165BRUP removes effects of downstream boundary changes upstream of this structure.	None required.
SNT	BSC	1000	2015	070	30	Increase calibration coefficient of bridges 1.1568BRUP, 1.1249BRUP and 1.165BRUP by 20% to increase impact of structures on flow.	Change to structures downstream of proposed crossing increases stage upstream as far as channel section 1.776. Change to upstream structure does not influence results downstream.	None required.
SNT	BSC	100	2115	071	30	Increase calibration coefficient of bridges 1.1568BRUP, 1.1249BRUP and 1.165BRUP by 20% to increase impact of structures on flow.	Change to structures downstream of proposed crossing increases stage upstream of bridge as far as weir 1.415SPUP. Change to upstream structure does not influence results downstream.	None required.
SNT	BSC	1000	2015	072	30	Decrease calibration coefficient of bridges 1.1568BRUP, 1.1249BRUP and 1.165BRUP by 20% to decrease impact of structures on flow.	Change to structures downstream of proposed crossing decreases stage upstream as far as channel section 1.752. Change to upstream structure does not influence results downstream.	None required.
SNT	BSC	100	2115	073	30	Decrease calibration coefficient of bridges 1.1568BRUP, 1.1249BRUP and 1.165BRUP by 20% to decrease impact of structures on flow.	Change to structures downstream of proposed crossing decreases stage upstream of bridge as far as weir 1.415SPUP. Change to upstream structure does not influence results downstream.	None required.


Extents of Rev 2 Upper Haul Road
22.620
22.8
23.1
23.3
23.55
24.04
24.3
24.75
24.55
25.000
25
24.5
25.2
25.1
25.2
25.65
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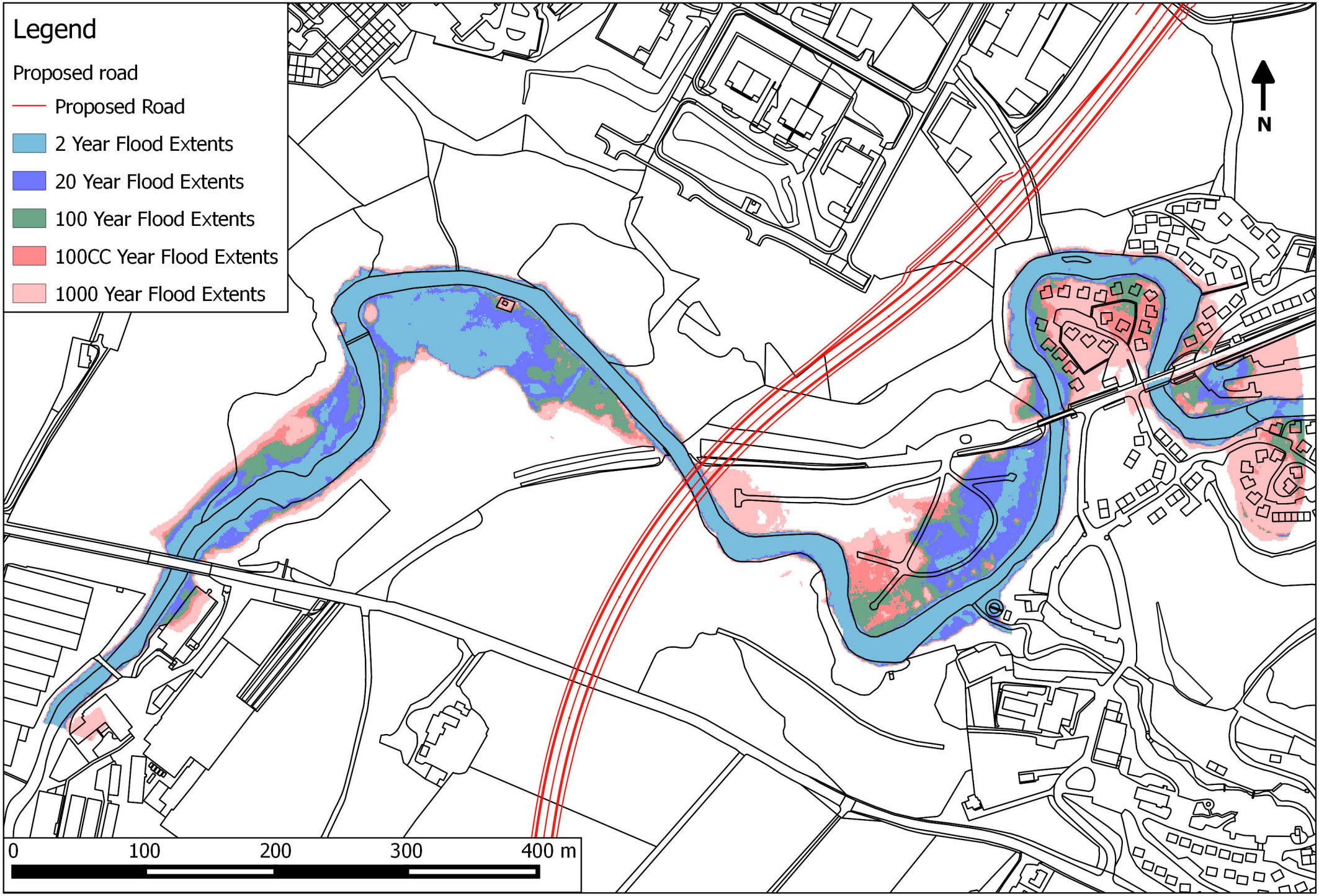
25.0
27.5
30.0
31.57


Legend
Proposed road
Proposed Road
2 Year Flood Extents
20 Year Flood Extents
100 Year Flood Extents
100CC Year Flood Extents
1000 Year Flood Extents
N
0
100
200
300
400 m

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
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3	STATISTICAL METHOD	8
4	REVITALISED FLOOD HYDROGRAPH (REFH) METHOD	13
5	DISCUSSION AND SUMMARY OF RESULTS	14
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Approval

	Name and qualifications	For Environment Agency staff: Competence level (see below)
Calculations prepared by:	Nathan Sherwood, MEng	
Calculations checked by:	Claire Storer, MEng CEng MICE	
Calculations approved by:	Claire Storer, MEng CEng MICE	

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 study aims to produce hydrographs for a range of return period events on the Afon Seiont to enable hydraulic modelling of the watercourse south-east of Caernarfon. Hydrographs are required for the 1, 2, 5, 10, 20, 50, 100, 100+cc, 200, 500, 1000 and 1000+cc year return period events. Approximately 15 hours is available for the calculation and reporting of the flood estimation.

1.2 Overview of catchment

Item	Comments
Brief description of catchment, or reference to section in accompanying report	The catchment assessment is based on information from the FEH CD ROM and OS mapping. The Seiont catchment is reasonably large, covering an area of approximately 82 km^2 and can be roughly split into upper and lower catchments upstream and downstream of the Llyn Padarn. The upper catchment to the outfall of Llyn Padarn, is the northern side of Mount Snowdon and the southern sides of Glyder Fawr and Elidir Fawr, steep mountainous areas draining to the Nant Peris, Llyn Peris and Llyn Padarn (glacial lakes) in the base of the valley. The upper catchment is sparsely developed although there have been some significant works in the past due to mining and hydropower operations. The underlying geology comprises mudstones, siltstones and sandstones, with outcrops of igneous rocks, generally overlain by freely draining, loamy soils. The Llyn Peris forms part of the Dinorwig hydropower scheme. Water is stored in the upper Marchlyn Marw lake and discharges to the Llyn Peris during peak electricity demand periods. The water is then pumped from the Llyn Peris to the upper lake during off-peak periods. During normal flows the Nant Peris is diverted around the Llyn Peris although there is capacity for the stream to overflow into the lake during periods of high flows. The upper catchment is exceptionally wet with impermeable geology and much bare rock exposure. The catchment characteristics suggest a rapid response with little attenuation of runoff. The lower catchment downstream of Llyn Peris is much less steep and is predominantly greenfield land as far as Glan Gwna holiday park on the outskirts of Caernarfon. Downstream of Glan Gwna holiday park the catchment to the Afon Seiont and its tributaries becomes more urbanised but still largely undeveloped. As for the upper catchment the bedrock geology comprises a combination of igneous and sedimentary rocks (sandstones and conglomerates) overlain by till, sands and gravels. The catchment soils become more impermeable in the lower lying areas. Overall it is expected the lower catchment will have a moderate response to rainfall The catchment of the small tributary of the Seiont near Glan Gwna holiday park is relatively flat and small (approximately 4 km^2) with a managed fishing lake in the upper reaches. Its overall impact on flows in the Afon Seiont are likely to be minor. The Afon Seiont discharges to the Menai Straits at Caernarfon, however the study area is upstream of the tidal limit.

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	Yes – Version 3.3.4, February 2013

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 / ultrasonic / level…)	Start and end of flow record
Afon Seiont	Seiont at Peblig Mill	NRW	65006	SH 49450 62273	79.9*	Velocity-area	1976-2013
Afon Nant Peris	Peris at Nant Peris	NRW	65008	SH 60834 57965	12.0	Velocity-area	1971-2013

*There is a discrepancy between the catchment areas quoted for this gauge by the NRFA dataset and the FEH CD-ROM. The value provided by the FEH CD-ROM has been used in this assessment.

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.
Seiont at Peblig Mill	1975 – ongoing	No – data received after hydrology completed (however checked against updated AMAX series)	Yes - Gauged to within 12% of QMED. QMED remains in bank and is well gauged.	No - Few high flow gaugings. Rating does not consider out of bank flow.	No	Well gauged across the in-bank range with a good fit of ratings to gauging. Extrapolated beyond QMED. 352 days missing data during 1989-1990. Rating curve extrapolated beyond 2m bankfull level not considered accurate.
Peris at Nant Peris	None.	No – donor not used		Substantial problems with maintaining an accurate rating due to non-standard concrete control d/s and extensive gravel accumulation problems u/s and d/s.	No	
Give link/reference to any further data quality checks carried out		N/A				

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.
Seiont at Peblig Mill	Empirical. Extrapolated beyond QMED.	No	Available information suggests the current rating is accurate for QMED estimation. The rating has not been verified above bankfull, and there is some potential for bypassing, however the AMAX values are not too much higher than bankfull therefore the rating may be reasonable in this range. A pooled growth curve is preferred due to the record length at the gauge. It was not necessary to complete a rating review considering the influence on the growth curve.
Peris at Nant Peris	CEH notes substantial problems with maintaining an accurate rating	No	Site not used in the assessment
Give link/reference to any rating reviews carried out		N/A	

1.7 Other data available and how it has been obtained – N/A

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)					
Historic flood data – give link to historic review if carried out.					
Flow data for events					
Rainfall data for events					
Potential evaporation data					
Results from previous studies					
Other data or information (e.g. groundwater, tides)					

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.	Yes, large predominantly greenfield catchments with catchment descriptor values within the bounds of FEH methodologies.
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 a 1.7km length of the Afon Seiont through Glan Gwna Holiday Park and downstream as far as Peblig Industrial Estate. A secondary site is a 200m length of tributary of the Afon Seiont from its outfall upstream through the holiday park. Flooding at this location on the Seiont is likely to be caused by peak flows beyond channel capacity. Upstream, Llyn Peris is used for temporary storage as part of a power generation scheme bypassed by the Nant Peris during normal operation although during high flows it can overtop into the lake. It is possible that in high flows Llyn Peris may attenuate runoff from upstream in the catchment. The Afon Seiont site is wide enough that temporary debris dams are unlikely to form along the watercourse to significantly influence flows.
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	FARL is reasonably low (0.85) due to the presence of Llyn Padarn (c.100ha footprint) and Llyn Peris (c.45ha footprint at low level). The Dinorwig power project on Llyn Peris diverts flows around Llyn Peris during normal operation but in high flows it is possible that Llyn Peris provides attenuation storage as described above. On occasion, excess water has to be released from Llyn Peris into Llyn Padarn but NRW have confirmed that these occurrences should not exacerbate flooding that occurs naturally within the catchment. NRW confirmed that sensitivity testing was performed within a recent Flood Risk Assessment by others whereby the Llyn Peris catchment was removed from the catchment descriptors (i.e. changes to Area and FARL) to see what effect this had on the QMED-CD estimate at the Peblig Mill gauging station. The effect was negligible and is not something NRW require of future assessments.

Initial choice of method(s) and reasons Will the catchment be split into subcatchments? If so, how?	Flows will be provided for three nodes at the upstream end of the Seiont hydraulic model, at the downstream end of the Seiont hydraulic model and at the downstream end of the tributary of the Seiont, which will be included in the hydraulic model. Provisionally, the statistical FEH methodology will be used to estimate QMED and a growth curve at each of the nodes. A comparison against the growth curve generated by ReFH is proposed, with particular attention being paid to the highest return period growth factors. Consideration will be given to the low FARL values in selection of sites for in pooling group analysis.
Software to be used (with version numbers)	FEH CD-ROM v3.0[1] WINFAP-FEH v3.0.003[2] ISIS v3.7.0.233 Mode 2[3]

[1] FEH CD-ROM v3.0 © NERC (CEH). © Crown copyright. © AA. 2009. All rights reserved.

[2] WINFAP-FEH v3 © Wallingford HydroSolutions Limited and NERC (CEH) 2009.

[3] ISIS FREE v3.7.0.233 Mode 2 © CH2M HILL and other 2013.

2 Locations where flood estimates required

The table below lists the locations of subject sites. The site codes correspond to the nodes for which flow estimates are required. These are 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
SNT_DS	Afon Seiont	DS extent of model	249050	361900	80.49	-
SNT_US	Afon Seiont	US model extent	250050	362150	75.46	-
SNT_TRIB	Tributary of Afon Seiont	Tributary of the Afon Seiont around Glan Gwna holiday park	249800	362000	3.9	-
Reasons for choosing above locations		Upstream and downstream extents of hydraulic model on the Afon Seiont. The tributary node is at the downstream end of the tributary and will account for all flow into the Afon Seiont from the tributary source.				

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	FPEXT
SNT_DS	0.850	0.49	0.500	14.68	260.7	2249	39.31	0.0058	0.0625
SNT_US	0.840	0.49	0.493	13.60	273.2	2310	39.68	0.0054	0.0611
SNT_TRIB	0.926	0.45	0.594	3.23	80.3	1413	34.49	0.0017	0.0685

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (refer to maps if needed)	Catchment boundary compared visually against contours on OS mapping. No changes required.
Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary.	FARL values seem appropriate for the catchment based on a visual inspection of OS mapping. DPLBAR and DPSBAR seem appropriate for the catchment based on a visual inspection of OS mapping. SPRHOST and BFIHOST checked indicatively against BGS geology mapping and Soilscapes mapping. In the upper catchment of the Seiont, no superficial deposits are recorded and aerial imagery and site observations indicate exposed rock. In the lower catchment of the Seiont superficial deposits are glacial sands, gravels and till. On average across the whole catchment, the SPRHOST and BFIHOST values are considered appropriate. On the same basis, SPRHOST and BFIHOST for the tributary are considered appropriate. URBEXT values seem appropriate for the catchment based on review of aerial imagery and OS mapping. The values listed in Section 2.2 have been updated using the relevant urban expansion factors and these values will be used in the assessment. FPEXT values seem appropriate for the catchment based on the limited extent of the flood plain as illustrated on EA flood maps.
Source of URBEXT	FEH CD-ROM
Method for updating of URBEXT	Updated Statistical method technical report (URBEXT 2000) / FEH Volume 5 (URBEXT 1990)

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.	Potential donor sites were identified using WINFAP-FEH. Gauged sites as far as c.20km from the subject site were reviewed on the basis that close sites will be most likely to have similar hydrology. A comparison the catchment descriptors was made as well as reviewing the record length and suitability of each gauged site for estimating QMED. Consideration was given to 5 potential donor sites for the main Afon Seiont nodes. The distance between the centroids of the main Afon Seiont catchment nodes and the donor sites ranged between 0.06 and 22.00km. The nearest potential donor site (65006) lies within the reach of the Afon Seiont that is to be modelled. This donor site therefore has almost identical catchment descriptors to the Seiont subject sites. According to Hi-Flows the gauge is suitable for QMED estimation, as this flow remains in bank and is well gauged. The rating is extrapolated and ungauged above bank full therefore the site is not recommended for pooling. A suitable donor site for the tributary was not identified. The catchment size, SAAR and FARL values for the local gauged sites were not considered to reflect the tributary catchment.

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 (Seiont @ Peblig Mill)	Same catchment as SNT_DS & SNT_US. Not appropriate for SNT_TRIB due to size, FARL & SAAR.	AM	No	46.22	40.48	1.142
65004 (gwyrfai @ Bontnewydd)	Rejected for SNT_TRIB due to size					
65001 (Glaslyn @ Beddgelert)	Rejected for SNT_TRIB due to size					
65007 (Dwyfawr @ Glarndolben maen)	Rejected for SNT_TRIB due to size					
66011 (Conwy @ Cwm Llanerch)	Rejected for SNT_TRIB due to size					
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).				Kjeldsen (2010)		

3.3 Overview of estimation of QMED at each subject site

Site code	Method	Initial estimate of QMED (m^3/s)	Data transfer						Final estimate of QMED (m^3/s)
			NRFA numbers for donor sites used (see 3.3)	Distance between centroids d_{ij} (km)	Power term, a	Moderated QMED adjustment factor, $(A/B)^a$	If more than one donor		
							Weight	Weighted average adjustment factor	
SNT_DS	DT	40.47	65006	0.06	0.98	1.139	-	-	46.12
SNT_US	DT	39.01	65006	0.35	0.91	1.128	-	-	44.03
SNT_ TRIB	CD	1.84	-	-	-	-	-	-	1.84

Are the values of QMED consistent, for example at successive points along the watercourse and at confluences?	Yes, along the Afon Seiont. Only one node on the tributary of the Afon Seiont.
Which version of the urban adjustment was used for QMED, and why?	Kjeldsen (2010)

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**Error! Bookmark not defined.** 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.

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, (after urban adjustment)	
				L-CV	L-Skew
Seiont unadjusted FEH statistical pooling	65006 (Seiont @ Peblig Mill)	No	All sites with short records, discordant records or noted to be unsuitable for pooling were removed from the pooling group. Sites with large differences in CDs were removed from the pooling group.	0.173	0.167
Seiont trib unadjusted FEH statistical pooling	SNT_TRIB	No	All sites with short records, discordant records or noted to be unsuitable for pooling were removed from the pooling group. Sites with large differences in CDs were removed from the pooling group.	0.232	0.249
Seiont single site FEH statistical pooling	65006 (Seiont @ Peblig Mill)	Yes – single site analysis	N/A	-	-

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, (after urban adjustment)	
				L-CV	L-Skew
Seiont enhanced FEH statistical pooling	65006 (Seiont @ Peblig Mill)	Yes – enhanced pooling	All sites with short records, discordant records or noted to be unsuitable for pooling were removed from the pooling group. Sites with large differences in CDs were removed from the pooling group.	0.146	0.147
Seiont high FARL FEH statistical pooling	65006 (Seiont @ Peblig Mill)	No	The catchment descriptors for the actual gauged site were used to generate a pooling group for the catchment but FARL was increased manually to consider effects of the diversion of the Nant Peris around Llyn Peris. The CD FARL value may be over representing the effects of the lake on attenuation and storage in the Seiont catchment. All sites with short records, discordant records or noted to be unsuitable for pooling were removed from the pooling group. Sites 73011,78004, 76014, 84020 and 47020 were removed from the pooling group as the SAAR values were deemed to be very low compared to the subject site.	0.166	0.154

Notes

Pooling groups were derived using the revised procedures from Science Report SC050050 (2008).

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)[1]	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
					Location	Scale	Shape	Bound	
SNT_DS	SS	Seiont unadjusted FEH statistical pooling	Generalised Logistic distribution used[2]	UEF and UAF applied in growth curve derivation.	1.000	0.173	-0.169	-0.020	2.199
SNT_US	SS	Seiont unadjusted FEH statistical pooling	Generalised Logistic distribution used[2]	UEF and UAF applied in growth curve derivation.	1.000	0.173	-0.169	-0.020	2.199
SNT_ TRIB	SS	Seiont trib unadjusted FEH statistical pooling	Generalised Logistic distribution used – best fit	UEF and UAF applied in growth curve derivation.	1.000	0.229	-0.251	0.088	2.975

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.

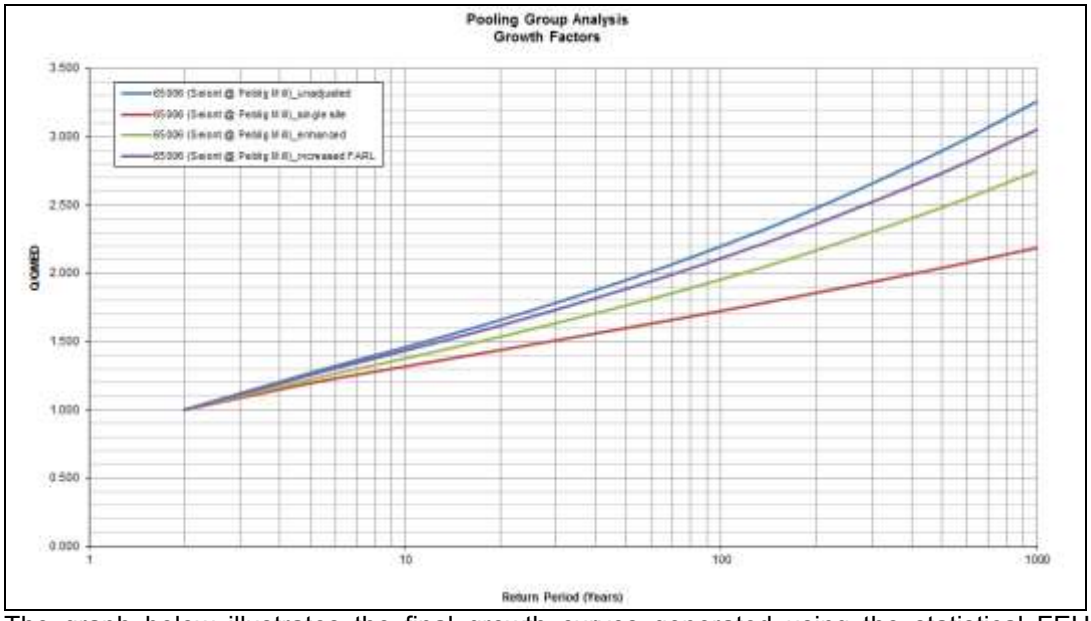
Urban adjustments to growth curves should use the version 3 option in WINFAP-FEH: Kjeldsen (2010).

Growth curves were derived using the revised procedures from Science Report SC050050 (2008).

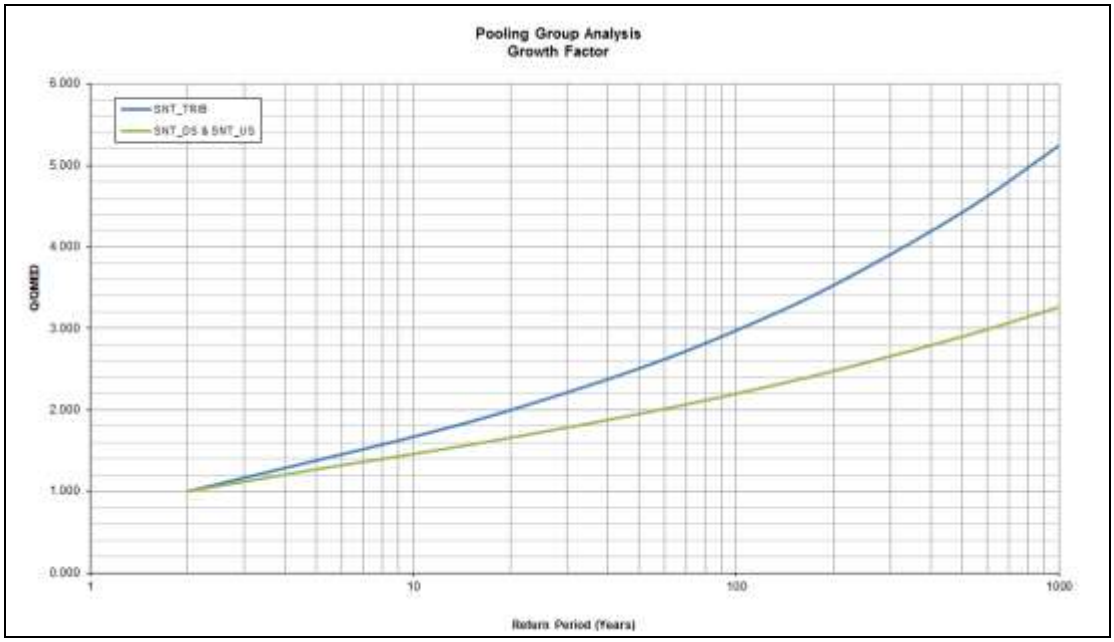
[1]For an explanation of the unadjusted FEH pooling group selection see Table 5.2.

[2]For the Seiont nodes, a GEV distribution provides the best fit to the pooled data but a GL distribution has been selected. This is because a GL distribution is generally recommended for UK sites and because the GEV growth curve is less similar to the single site analysis for lower return periods (where confidence in lower return periods is high due to the nature of the gauged single site data). The GEV distribution also gives but lower growth factors at higher return periods and a conservative result is sought for the extreme events.

The graph below illustrates the growth curves generated for the Afon Seiont using the pooling groups above that were derived for site 65006.



The graph below illustrates the final growth curves generated using the statistical FEH method for the different sites.



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	20	50	100	200	500	1000
SNT_DS	46.12	58.57	67.28	76.46	89.93	101.41	114.23	133.60	150.34
SNT_US	44.03	55.92	64.24	73.00	85.86	96.82	109.06	127.55	143.54
SNT_ TRIB	1.84	2.53	3.07	3.67	4.61	5.47	6.48	8.12	9.63

4 Revitalised flood hydrograph (ReFH) method

4.1 Parameters for ReFH 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
SNT_DS	CD	3.515	366.548	46.419	1.372
SNT_US	CD	3.318	361.671	45.437	1.351
SNT_TRIB	CD	2.192	440.638	38.788	1.603
Brief description of any flood event analysis carried out (further details should be given below or in a project report)	None carried out. Observed parameters obtained for a potential donor (66011) but due to the significant differences in CDs it was not considered appropriate to use. The observed Cmax and Tp for the donor were close to CD values, suggesting the CD values for the subject are reasonable. O quite a bit lower than CD value (~ 0.4), a quick test suggested use of this value may increase peak flows by 15 – 20%. As this is not a standard application it has not been used but considered in the choice of flow estimates.				

4.2 Design events for ReFH method

Site code	**Urban or rural**	**Season of design event (summer or winter)**	**Storm duration (hours)**	**Storm area for ARF** (if not catchment area)
SNT_DS	Rural	Winter	11.5	80.49 ha
SNT_US	Rural	Winter	11.5	80.49 ha
SNT_TRIB	Rural	Winter	11.5	80.49 ha
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?	No			

4.3 Flood estimates from the ReFH method

Site code	**Flood peak (m^3/s) for the following return periods (in years)**								
	2	**5**	**10**	**20**	**50**	**100**	**200**	**500**	**1000**
SNT_DS	64.07	83.33	98.63	115.02	141.14	165.51	197.25	252.70	308.43
SNT_US	64.26	83.66	99.08	115.57	141.88	166.79	199.28	256.20	313.56
SNT_ TRIB	1.96	2.53	2.98	3.44	4.17	4.83	5.69	7.16	8.61

5 Discussion and summary of results

5.1 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.

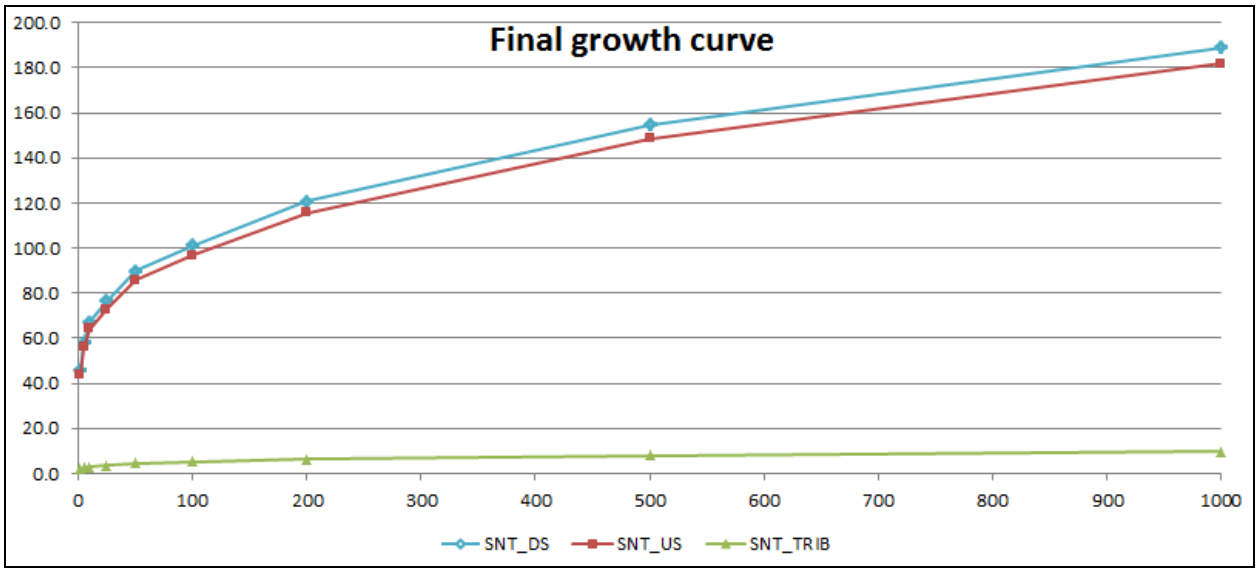
Site code	Return period 2 years		Return period 100 years	
	FEH Stats	ReFH	FEH Stats	ReFH
SNT_DS	46.12	64.07	101.41	165.51
SNT_US	44.03	64.26	96.82	166.79
SNT_TRIB	1.84	1.96	5.47	4.83

5.2 Final choice of method

Choice of method and reasons – include reference to type of study, nature of catchment and type of data available.	**Statistical FEH method** The gauge within the subject catchment (65006) is considered reliable for QMED estimation (which is in bank) but once flows are above the bank top the rating curve is extrapolated and there is potential for bypassing which isn't reflect in the rating. Of the 37 AMAX values, AMAX 1 to 19 are from the extrapolated portion of the rating curve. Measurement of high flows is not therefore considered accurate. The subject site has 37 years of data. This relatively short record length and the low confidence in the accuracy of high flows measurement means that a single site statistical FEH analysis is not appropriate for development of a growth curve for the catchment. FEH pooling analysis has been undertaken to derive growth curves for the statistical method. The inclusion of the gauged subject site within the pooling group has little impact on the growth curve up to the 20 year event (the reduction in Q/QMED ratio in the 20 year return period event by applying the enhanced method is less than 10%). Given the low confidence in high flow measurements at the gauge (65006) and the small impact of enhanced statistical FEH analysis on the lower return period flows, the enhanced method cannot with confidence be considered to provide a better estimate of the growth curve than an ungauged pooled growth curve. The low value of FARL for the catchment has been investigated as the Nant Peris actually bypasses Llyn Peris, used for hydroelectric power generation storage. It is expected that in high flows this lake could provide some attenuation storage in the upper catchment, as the stream can overtop into the lake, but the exact operation of the lake is currently unknown. To consider the impacts of Llyn Peris being taken offline in the catchment, the value of FARL at the subject site was manual increased by 0.1 prior to the selection of a pooling group. The donor adjustment accounts for any inaccuracies in QMED estimation. This resulted in selection of pooling sites that generally had lower SAAR values and DSPBAR values than before the increase in FARL. Given the subject site has high very SAAR and DSPBAR values this is not desirable. By increasing FARL, pooling sites have been selected which are less similar to the mountainous subject site, which are more likely to have lower FARL values. The growth curve obtained was also flatter than the one obtained using the lower FARL value. This use of a higher FARL value in the development of the growth curve has therefore been dismissed. **ReFH method** Consideration was given to use of a donor site to provide a better estimate of flows using the ReFH methodology. Observed parameters obtained for a potential donor (66011) but due to the significant differences in CDs it was not considered appropriate to use. The observed Cmax and Tp for the donor were close to CD values, suggesting the CD derived values for the subject are reasonable. Observed BFI for the subject from the CEH website is lower than CD value (~ 0.4), a quick test suggested use of this value may increase peak flows by 15 – 20%. As this is not a standard application it has not been used but considered in the choice of flow estimates. It was decided not to use the donor catchment adjustments for the subject site and use a ReFH methodology based on catchment descriptors alone. **Selection of a final flow estimates** The statistical estimate of QMED for the SNT_US and SNT_DS nodes has been adjusted using gauged data from the subject site catchment (65006). There is confidence in the gauged data for QMED. The ReFH method is based solely on catchment descriptors and gives higher flow estimates, even at low return periods, which reduces the confidence in this method. On this basis the statistical method flow estimates are considered most appropriate. However, at return period events greater than the 100 year event, the ReFH method begins to generate disproportionately larger flows at the SNT_US and SNT_DS nodes, due to a steeper growth curve. In these extreme events, the method used for the pooled analysis begins to become less applicable as the pooling group will contain fewer higher return period events. There is usually greater confidence in rainfall

	estimates at higher return periods due to the much larger dataset and it is also considered that the catchment will likely be saturated in these extreme return period events where rainfall runoff models may perform better. For this reason, the hybrid method has been adopted, whereby the 200, 500 and 1000 year flows have been estimated using the ratio between the 200, 500, 1000 year and 100 year ReFH flows respectively to scale the 100 year statistical flows and generate revised 200, 500 and 1000 year flows. To maintain uniformity of methodologies across the catchment, this method has been applied to the SNT_TRIB node even though the ReFH growth curve at the upper end is flatter than the Statistical growth curve. Due to the lack of similar sites in the FEH dataset there is less confidence in the statistical growth curve obtained for this site The tributary contributes only a small proportion of the total flow in the Seiont therefore inaccuracies in the flow estimates are less critical.

The graph below illustrates the final flood frequency curve selected for the three nodes.



5.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	Using the FEH CD ROM FARL value provides a good representation of the catchment regardless of the detailed operation of the Dinorwig power station and effects of the Llyn Peris.
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed	None identified
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).	WINFAP analysis suggests approximate 15 – 25% variation in flow estimates for the 95% confidence interval.
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	The growth curves estimated may be suitable for use along the Afon Seiont within a few km of the study site. Consideration should be given to deriving new growth curves further upstream as the catchment becomes increasingly mountainous upstream. Consideration should be given to tidal influence downstream of the study site toward the Menai Straits.
Give any other comments on the study, for example suggestions for additional work.	None identified

5.4 Checks

Are the results consistent, for example at confluences?	At all return periods flow is greater at the downstream node (SNT_DS) than the upstream node (SNT_US) and the difference is similar orders of magnitude to the flows generated at the tributary node (SNT_TRIB).
What do the results imply regarding the return periods of floods during the period of record?	The record of AMAX data at station 65006 suggests that flow comes out of channel at the gauging station in approximately a 5 year return period event. This is based on a review of AMAX records compared with the final flood frequency curve The maximum flow recorded in the 37 years of AMAX data at station 65006 corresponds to the 20 year event flow estimate but because the rating curve at the station is extrapolated once flows are above the channel top it is expected that the actual flow may have been higher, corresponding to a larger return period event.
What is the 100-year growth factor? Is this realistic? (The guidance suggests a typical range of 2.1 to 4.0)	100 year growth factors: SNT_DS = 2.2 SNT_US = 2.2 SNT_TRIB = 3.0 Whilst the SNT_DS & SNT_US growth factors are reasonably low they lie within the suggested typical range suggesting they are reasonable estimates.
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	Ratio 1000:100 year flow: SNT_DS = 1.9 SNT_US = 1.9 SNT_TRIB = 1.8
What range of specific runoffs (l/s/ha) do the results equate to? Are there any inconsistencies?	Specific runoffs (l/s/ha) [2yr, 100yr]: SNT_DS = 5.7, 12.6 SNT_US = 5.8, 12.8 SNT_TRIB = 4.7, 13.9
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	No other studies are available on this watercourse with which a meaningful comparison can be made.
Are the results compatible with the longer-term flood history?	No information available
Describe any other checks on the results	N/A

5.5 Final results

Site code	Flood peak (m^3/s) for the following return periods (in years)										
	2	5	10	20	50	100	100+20%	200	500	1000	1000+20%
SNT_DS	46.1	58.6	67.3	76.5	89.9	101.4	121.7	120.9	154.8	189.0	226.8
SNT_US	44.0	55.9	64.2	73.0	85.9	96.8	116.2	115.7	148.7	182.0	218.4
SNT_TRIB	1.8	2.5	3.0	3.6	4.6	5.4	6.5	6.4	8.0	9.6	11.5

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)	N:\Water Engineering\3513874A-HHC_A487_Caernarfon_WORKING\E Technical Design\6 Hydraulic Modelling\Afon Seiont\Boundary Files\IEDs

6 Annex - supporting information

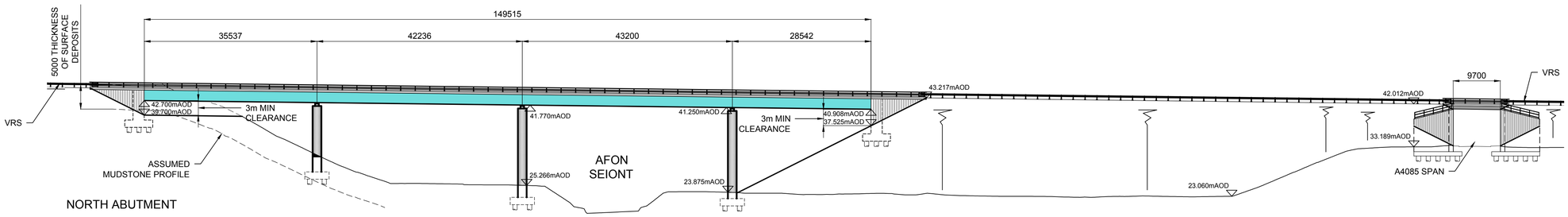
6.1 Pooling group composition

Station	Distance Value	Years of data	QMED AM	AREA	SAAR	FPEXT	FARL	URBEXT 2000	SPR	BFIHOST	DPSBAR	QMED Suitability	Pooling Suitability
4006 (Bran @ Dosmucheran)	0.6	17	85.372	117.54	2203	0.048	0.81	0.000	52.93	0.33	164.6	YES	YES
75004 (Cocker @ Southwaite Bridge)	0.604	46	51.271	116.17	1976	0.049	0.83	0.000	40.13	0.48	289.7	YES	YES
84017 (Black Cart Water @ Milliken Park)	0.694	38	34.646	103.14	1790	0.055	0.79	0.017	42.41	0.45	89.3	YES	YES
73017 (Kent @ Bowston)	0.714	13	67.089	70.61	1919	0.060	0.95	0.002	43.29	0.45	177.6	YES	YES
96004 (Strathmore @ Allnabad)	0.732	19	198.528	105.31	2456	0.041	0.94	0.000	55.28	0.35	192.4	YES	YES
73002 (Crake @ Low Nibthwaite)	0.786	48	19.559	72.90	2147	0.052	0.73	0.001	50.37	0.36	197.6	YES	YES
4005 (Meig @ Glenmeanie)	0.796	21	111.347	123.45	2147	0.037	0.92	0.000	52.87	0.39	289.0	YES	YES
93001 (Carron @ New Kelso)	0.835	27	181.095	139.13	2616	0.048	0.86	0.000	49.12	0.41	291.6	YES	YES
86002 (Eachaig @ Eckford)	0.853	19	80.978	138.63	2470	0.033	0.84	0.000	48.90	0.38	302.9	YES	YES
74001 (Duddon @ Duddon Hall)	0.877	45	119.58	86.01	2261	0.047	0.99	0.000	53.61	0.34	210.3	YES	YES
58006 (Mellte @ Pontneddfechan)	0.95	41	89.48	65.35	1981	0.030	0.98	0.000	51.30	0.32	131.7	YES	YES
75009 (Greta @ Low Briery)	0.952	41	113.755	146.97	2025	0.052	0.91	0.000	47.22	0.40	227.2	YES	YES
85003 (Falloch @ Glen Falloch)	1.056	35	183.936	79.62	2848	0.028	0.99	0.000	49.31	0.38	256.1	YES	YES
76004 (Lowther @ Eamont Bridge)	1.061	50	110.229	156.20	1828	0.055	0.90	0.002	45.62	0.41	153.0	YES	YES
16003 (Ruchill Water @ Cultybraggan)	1.091	45	148.085	98.48	1900	0.033	1.00	0.000	44.46	0.43	216.4	YES	YES
TOTAL years of data		**505**											

Final pooling group for the tributary of the Afon Seiont tributary:

Station	Distance Value	Years of data	QMED AM	AREA	SAAR	FPEXT	FARL	URBEXT2000	SPRHOST	BFIHOST	DPSBAR	QMED Suitability	Pooling Suitability
45816 (Haddeo @ Upton)	1.149	19	3.456	6.81	1210	0.011	1.00	0.005	31.27	0.59	81.0	YES	YES
28033 (Dove @ Hollinsclough)	1.295	33	4.666	7.93	1346	0.007	1.00	0.000	42.49	0.40	166.9	YES	YES
76011 (Coal Burn @ Coalburn)	1.394	35	1.84	1.63	1096	0.074	1.00	0.000	58.93	0.20	47.2	YES	YES
91802 (Allt Leachdach @ Intake)	1.583	34	6.35	6.52	2555	0.003	0.99	0.000	53.32	0.40	407.5	YES	YES
27051 (Crimple @ Burn Bridge)	1.607	40	4.539	8.15	855	0.013	1.00	0.006	40.77	0.31	62.9	YES	YES
25003 (Trout Beck @ Moor House)	1.705	39	15.164	11.46	1904	0.041	1.00	0.000	59.85	0.23	91.9	YES	YES
54022 (Severn @ Plynlimon Flume)	1.751	37	15.031	8.69	2483	0.010	1.00	0.000	52.70	0.32	180.2	YES	YES
47022 (Tory Brook @ Newnham Park)	1.805	19	7.331	13.45	1403	0.023	0.94	0.014	44.18	0.43	106.0	YES	YES
25011 (Langdon Beck @ Langdon)	1.836	26	15.878	12.79	1463	0.013	1.00	0.001	58.21	0.24	123.4	YES	YES
206006 (Annalong @ Recorder)	1.892	48	15.33	13.66	1720	0.024	0.98	0.000	51.75	0.34	275.8	YES	YES
25019 (Leven @ Easby)	2.263	34	5.538	15.07	830	0.019	1.00	0.004	38.58	0.53	128.0	YES	YES
26802 (Gypsey Race @ Kirby Grindalythe)	2.38	13	0.109	15.85	757	0.030	1.00	0.000	5.67	0.96	57.2	YES	YES
57017 (Rhondda Fawr @ Tynewydd)	2.418	11	24.059	16.64	2458	0.012	1.00	0.016	52.88	0.32	217.4	YES	YES
27010 (Hodge Beck @ Bransdale Weir)	2.444	41	9.42	18.84	987	0.009	1.00	0.001	50.56	0.34	149.8	YES	YES
51002 (Horner Water @ West Luccombe)	2.449	31	8.354	20.38	1485	0.003	0.98	0.000	29.75	0.54	213.9	YES	YES
49003 (de Lank @ de Lank)	2.451	46	13.559	21.61	1628	0.064	1.00	0.000	47.75	0.38	76.0	YES	YES

Total years: 506



WEST ELEVATION B-B

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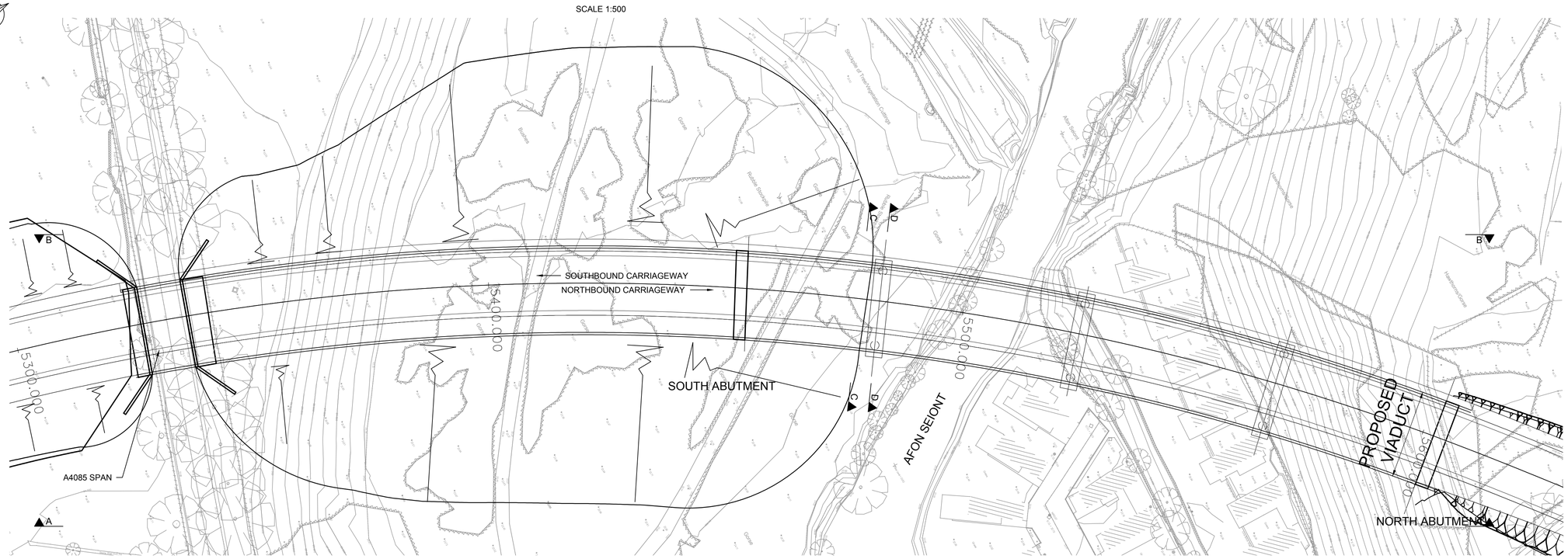
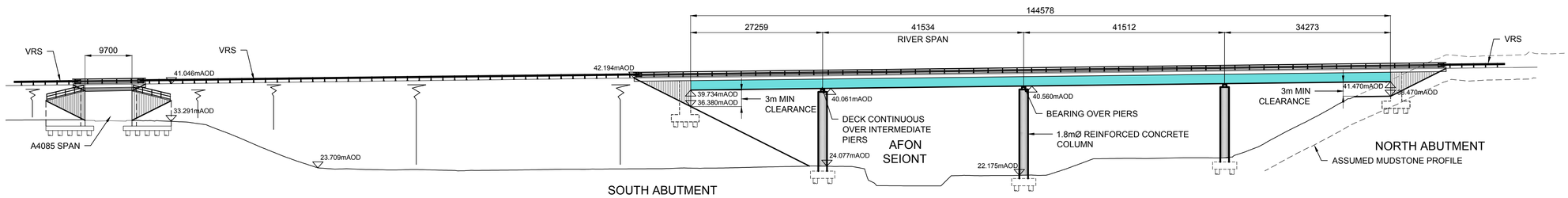


PLAN

SCALE 1:500



EAST ELEVATION A-A

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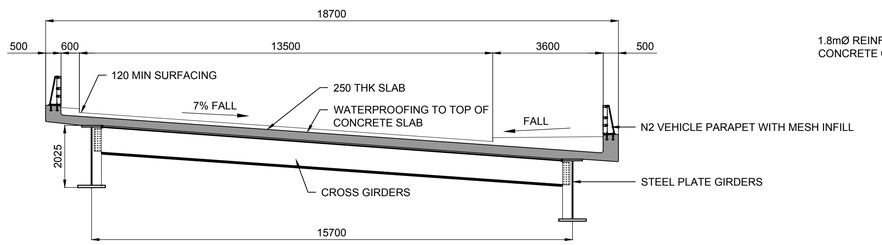

SECTION C-C

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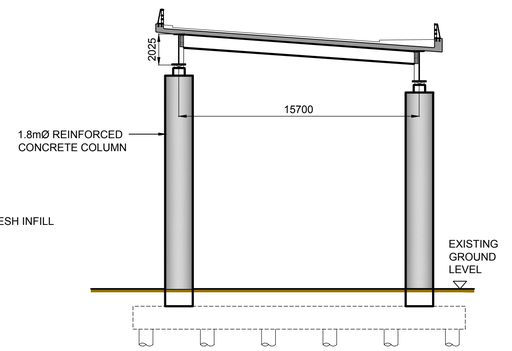

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NOTES

A1

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2. ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED.
3. THE LEVEL AND HIGHWAY ALIGNMENT INFORMATION ON THIS DRAWING USE THE FOLLOWING MODELS.
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   (Topographical survey Ch.5200 to Ch.6150)
   HIGHWAY:3513874-PB-XX-XX-M3-J-00006 VER P01.1
   (Mainline Proposed strings Design Freeze 14.05.15)

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SIGNIFICANT OR EXCEPTIONAL RISKS ARE IDENTIFIED BELOW

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2. IN PREPARATION OF CONSTRUCTION METHOD STATEMENTS CONSIDERATION SHOULD BE GIVEN TO THE CLOSE PROXIMITY OF ANY STRUCTURES THAT MAY BE AFFECTED BY CONSTRUCTION.
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4. THE CONTRACTOR SHALL REFER TO STATUTORY UNDERTAKERS LAYOUT DRAWINGS AND IDENTIFY LOCATIONS OF EXISTING UNDERGROUND SERVICES PRIOR TO CARRYING OUT EXCAVATION WORKS.

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Rev	Date	Description	By	Chk	App

Initial Status or WIP

EC HARRIS BUILT ASSET CONSULTANCY
Llywodraeth Cymru Welsh Government
RAMBOLL
Balfour Beatty
JONES BROS CIVIL ENGINEERING UK
PARSONS BRINCKERHOFF
TACP
Ty Glyn, Caerol Y Dre, Ruthin Denbighshire Tel: 01824 703661

Site/Project:

A487 CAERNARFON TO BONTNEWYDD BYPASS

Title:

S112 OPTION 6

Drawn: ---		Checked: ---	
Designed: ---		Approved: ---	
Date: 18/05/15	Scale: AS SHOWN A1	Sheet:	

Container Number: 3513874-PB-SBR-SD-SK-S-00024 Revision: P01.2

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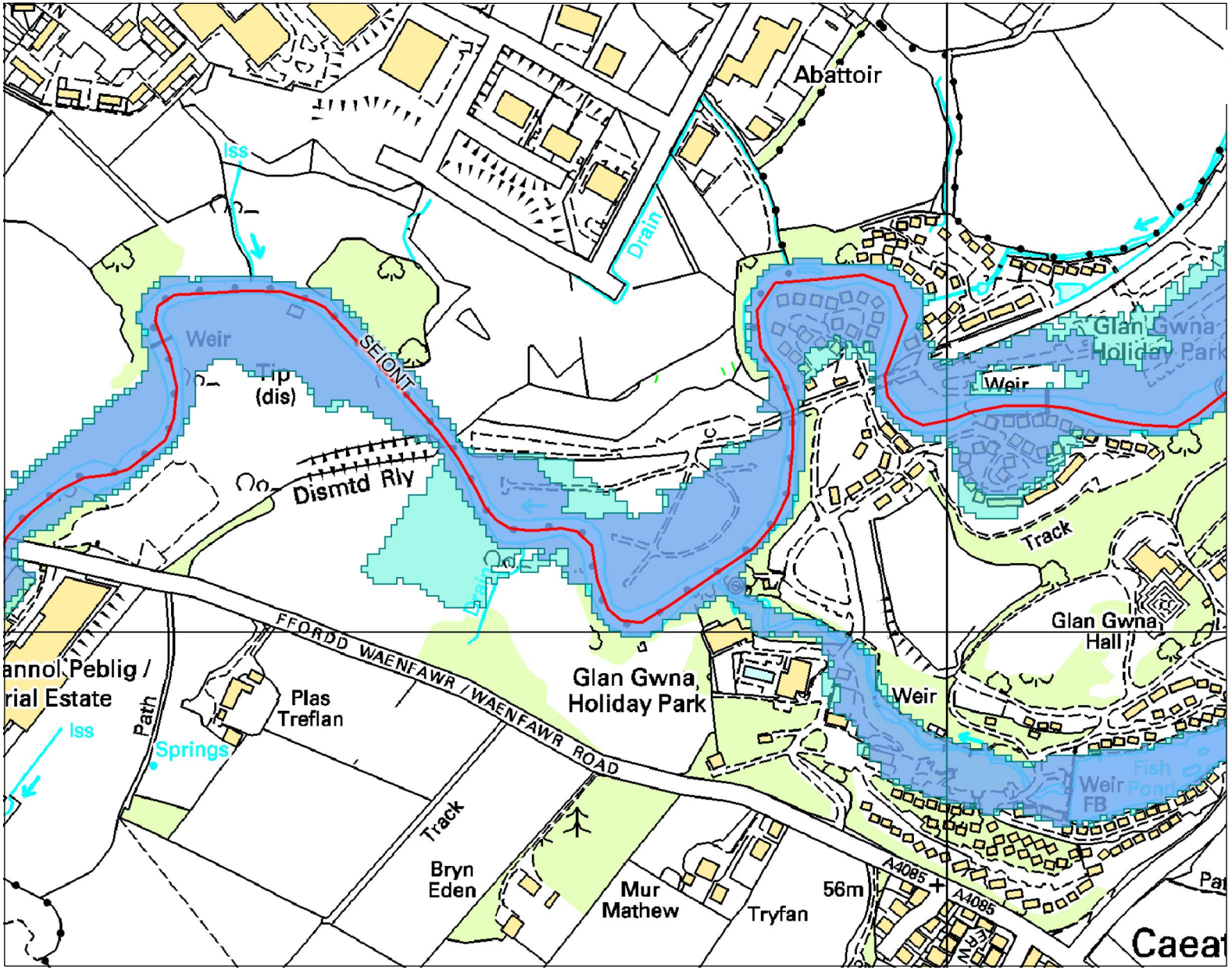
Flood Zone Maps/Main River Maps



Cyfoeth Naturiol Cymru
Natural Resources Wales

Scale 1:5,000

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Flood Map for Planning (Rivers and Sea)

- Sealed Main Rivers
- Flood Map - Defences
- Areas Benefiting from Flood Defences
- Flood Map - Flood Storage Areas
- Flood Map - Flood Zone 3
- Flood Map - Flood Zone 2

Flood Map for Planning (Rivers and Sea) (assuming no defences)

Flood Zone 3 shows the area that could be affected by flooding:
- from the sea with a 1 in 200 or greater chance of happening each year
- or from a river with a 1 in 100 or greater chance of happening each year.

Flood Zone 2 shows the extent of an extreme flood from rivers or the sea with up to a 1 in 1000 chance of occurring each year.

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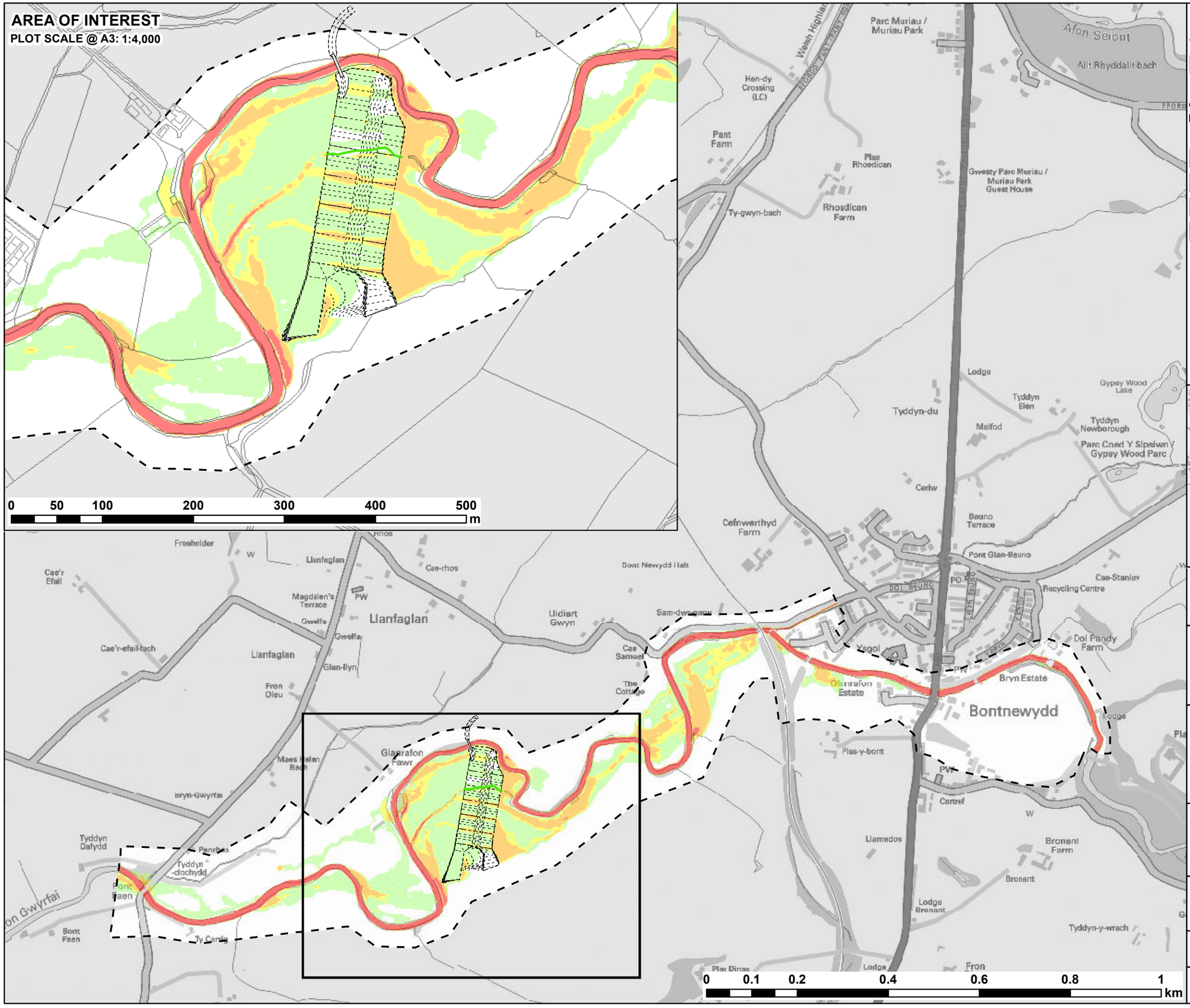

CLIENT: Llywodraeth Cymru Welsh Government

WSP PARSONS BRINCKERHOFF
Waterco consultants

SCHEME:

A487 CAERNARFON AND BONTNEWYDD BYPASS

AFON GWYRFAI VIADUCT

PLOT TITLE:

MAXIMUM FLOOD HAZARD

1% AEP FLUVIAL EVENT
TEMPORARY WORKS LAYOUT (TEMP1)

PLOT STATUS: **FINAL**

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
SB	DH	RCL	1:8,000 (UNLESS STATED OTHERWISE)

DATE:	PLOT NAME:	REV:
25/07/15	w3172-Q100_TEMP1_H	-

Appendix K.7 – Afon Cadnant Assessment

AFON CADNANT MODELLING, A487 CAERNARFON AND BONTNEWYDD BYPASS

HYDRAULIC MODELLING REPORT

WSP | PARSONS BRINCKERHOFF

AFON CADNANT MODELLING, A487 CAERNARFON AND BONTNEWYDD BYPASS

HYDRAULIC MODELLING REPORT

Report (v01)
Public

Project no: 62103423-FM01-01
Date: May 2016

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QUALITY MANAGEMENT

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Date	13/05/2016	13/06/2016		
Prepared by	Pete Harrison	Pete Harrison		
Checked by	Claire Storer	Claire Storer		
Authorised by		Andy Smith		
Project number	62103423	62103423		
Report number	FM01-01	FM01-02		
File reference	62103423-FM01-01	62103423-FM01-02		

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2 KEY INPUT DATA 2

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APPENDICES

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APPENDIX D BLOCKAGE AND SENSITIVITY ANALYSIS

1 PROJECT BACKGROUND

1.1 PROJECT SUMMARY, AIMS AND LIMITATIONS

Project summary

Project name:	**Afon Cadnant Modelling, A487 Caernarfon to Bontnewydd Bypass**
Project type:	Supporting Flood Consequences Assessment for site including new roads crossing watercourse
What is being modelled?	Afon Cadnant and bifurcation watercourse named here as "Northern Ditch"
What existing modelling exists?	No detailed hydraulic model
What modelling has been undertaken and why was that approach chosen?	ESTRY-TUFLOW as a detailed 1D-2D modelling package
What existing hydrological analysis exists?	None
What hydrological analysis has been undertaken?	FEH Statistical Method has been chosen, other methods undertaken for comparison. ReFH method used to provide flood hydrographs
What outputs have been produced?	Flood maps and levels for a range of return periods

Project aims

1.1.1 This report aims to:

- Support the evidence base in the Flood Consequences Assessment (FCA).
- Provide evidence to statutory consultees (i.e. Natural Resources Wales and/or Local Authorities) of the suitability of the hydraulic model for predicting flood risk.
- Enable efficient future use of the hydraulic model.

Project limitations

1.1.2 WSP | Parsons Brinckerhoff hydraulic modelling is based on best practice and guidance current at the time of undertaking the project.

1.1.3 The baseline modelling undertaken assesses flood risk to an existing site/area in its current state. Any increase in flood risk caused by any alterations or future works to the area which are not modelled in the post-development scenarios are not included in this assessment.

1.1.4 The modelling undertaken is based on the interpretation and assessment of data provided by third parties. WSP | Parsons Brinckerhoff cannot be held responsible for the accuracy of the third party data and the conclusions and findings of this report may change if the data is amended or updated after the date of consultation.

1.1.5 The conclusions of the modelling report are based on the data gathered for the purpose of the project and therefore are limited in their accuracy in proportion to the validity of the dataset. The data gathered in turn has been based on an agreed scope of works. WSP | Parsons Brinckerhoff cannot guarantee that the data used is the best available at the time of the modelling, but it is the best available data that could be gathered within the scope of the agreed instruction.

1.2 SITE/AREA DESCRIPTION

1.2.1 A site/area location plan can be found in Appendix A.

Site National Grid Reference:	Approximately NGR 251000 364800
Current use:	The modelled area includes farmland and the existing highway network
Wider setting:	1.2km to the south-east of Menai Straight, 1.7km to the west of the village of Bethel, 3km to the north-east of Caernarfon.
Proposed use:	The modelled area will include part of the new A487 Caernarfon and Bontnewydd Bypass. This includes the construction of a new highway and a realignment of the existing, minor road network. A number of new structures are planned for the Afon Cadnant and a bifurcation channel, named here as "Northern Ditch".
Existing waterbodies:	Both watercourses (Afon Cadnant and Northern Ditch) are relatively informal channels at this location with slack banks and a channel width of between 3m to 5m. The channels are heavily vegetated in the main although at structures and towards the downstream ends of the modelled area the channels become clearer and more pronounced.
Existing flood defences:	None
Any other important comments:	The present day situation is that a wooden board has been placed at the Afon Cadnant / Northern Ditch bifurcation. The effect of this board is to promote flow down the Afon Cadnant and away from the Northern Ditch. The modelling presented here has not included for the board as it is a temporary measure/structure. However, with its removal the model predicts most low flows going down the Northern Ditch and not the Afon Cadnant. At higher flows these effects are quickly lost.

2 KEY INPUT DATA

2.1.1 Multiple sources of information have been used for this project; some of the key datasets used are set out below:

DATASET	SOURCE	DATE	USE	QUALITY[1]
Channel survey	NRG Engineering Services Ltd	Surveyed and processed in November 2015	Provides cross section and structure details for the hydraulic model	1
Design drawings, surfaces and details for proposed scheme	WSP|Parsons Brinckerhoff	2015 to 2016	Provides cross section and structure details for the hydraulic model	1

[1] Data quality scoring taken from Multi-Coloured Manual (Flood Hazard Research Centre, 2005) – 1 = best possible, 2 = data with known deficiencies, 3 = gross assumptions, 4 = heroic assumptions

DATASET	SOURCE	DATE	USE	QUALITY[1]
LiDAR	Environment Agency	Flown in 2010	Forms basis of ground DTM for hydraulic model (where coverage allowed)	1
NextMAP ground surface	Intermap	Obtained in 2002	Provides floodplain surface detail for the model DTM where LiDAR and topographical survey data not available	3
Ordnance Survey Mastermap	Ordnance Survey	Unknown	Used for detailed model roughness calculations and ensuring correct LiDAR filtering	1
Topographical survey	Received from Balfour Beatty	Received from Balfour Beatty in 2015	Provides more detail for the model DTM where LiDAR data not available	1

3 METHODOLOGY AND IMPLEMENTATION

3.1 HYDROLOGICAL ANALYSIS

Overview

3.1.1 Details of the hydrological analysis can be found in Appendix B.

Peak flows, hydrographs or hyetographs?	**Hydrographs**
Return periods:	1 in 2, 5, 10, 25, 50, 75, 100, 200 and 1000 year return period events.
Climate change estimation?	1 in 100 year multiplied by 20%
Choice of approach?	Flow estimates obtained with the FEH Statistical method were selected
Reason for approach:	More appropriate than ReFH – see Appendix B for discussion
Comparison against other approaches undertaken?	Yes – ReFH peak flows
How incorporated into the hydraulic model?	ReFH ISIS boundary units scaled to fit Statistical Method peak flow and incorporated with IED files. Three separate inflows used: → Catchment 2 in the Afon Cadnant (based on flow estimation point at OS 251034, 364501) → Catchment 3 in the Afon Cadnant tributary (based on flow estimation point at OS 251067, 364324) → Catchment 5 at the unnamed watercourse confluence with the Northern Ditch (remaining flow estimation for Northern Ditch catchment)

Final peak flow estimates (m^3/s)

LOCATION	1 IN 2	1 IN 5	1IN 10	1 IN 25	1 IN 50	1 IN 75	1 IN 100	1 IN 200	1 IN 1000
Catchment 2 (Afon Cadnant)	1.08	1.57	1.94	2.52	3.04	3.39	3.66	4.40	6.73
Catchment 3 (Afon Cadnant tributary)	0.49	0.71	0.89	1.15	1.39	1.54	1.67	2.00	3.06
Catchment 5 (unnamed watercourse confluence with the Northern Ditch)	0.21	0.3	0.38	0.49	0.59	0.66	0.71	0.85	1.3

3.2 BASELINE HYDRAULIC MODELLING

What existing modelling exists?	JFLOW – no detailed hydraulic model
What modelling has been undertaken and why was that approach chosen?	ESTRY-TUFLOW combines an accurate, very stable 1D channel solver able to model channels and culverted networks with a 2D floodplain model based on a finite grid approach. The two solvers are dynamically linked, such that water can flow from the channel to the floodplain, and vice-versa.
What software version(s) have been used?	2016-03-AA-iSP-w64
How have watercourse channels been represented?	Watercourses were constructed using ESTRY and based on the surveyed cross sections. Where appropriate sections were trimmed to ensure no double counting of the floodplain. Cross section information was kept in CSV files with these being referenced using a 1d_tab format layer.
How have watercourse channel structures been represented?	In ESTRY the relevant channel type was selected depending on the structure being modelled. They were parameterised in line with the TUFLOW manual recommendations.
How have sewer networks been represented?	There are no sewer networks in the baseline hydraulic model.
How has the floodplain/ground surface been represented?	The 2D domain was constructed using TUFLOW and based upon Environment Agency filtered LiDAR data flown in 2010. A grid size of 2m was chosen to allow for detailed modelling of fluvial flowpaths.
How have different models been linked?	The open channel boundary between the 1D and 2D models was chosen as appropriate for each individual cross section. This was usually close to the top of bank but current best practice suggests going slightly past top of bank can help the 1D-2D link stability. Cross sections in ESTRY were trimmed to make them suitable for linking to TUFLOW. A HX boundary (Head-eXchange or Head from eXternal source) was used for the link in TUFLOW which takes the water level from ESTRY and applies it along the boundary to allow flow into the 2D domain. The area between the 1D-2D boundary (HX lines) was set to 'inactive' in the 2D model to ensure that flow was not double-counted. Care was also taken to ensure that the width of the 1D element was reflected in the width of the inactive cells.
Have any adjustments to the raw DTM been made?	To ensure a better and more accurate link between the two models a thick Z line (a 3D polyline) was snapped along the boundary based on surveyed levels (and where needed LiDAR) to ensure the 2D domain levels match the ESTRY model. Changes (or re-enforcements) to the base LiDAR include: ■ Updating the model DTM with NextMap data (where no

<table>
<tr><td></td><td>topographical survey or LiDAR).
■ Updating the model DTM with topographical survey (where no LiDAR).
■ Filling in structures which had been removed in the LiDAR as they are now represented in the hydraulic model.</td></tr>
<tr><td>How have flood defences been represented?</td><td>No flood defences are present</td></tr>
<tr><td>What boundary conditions have been used?</td><td>See hydrological analysis for inflows – these were applied at the relevant nodes.

In ESTRY the downstream boundary condition consists of a head versus time boundary unit applied to the most downstream nodes in the1D Afon Cadnant and Northern Ditch model network. The boundary condition was based on a normal depth flow-level relationship calculated using ISIS for a short section of the watercourse. The resulting relationship was used to set a water level based on the flows predicted in the hydrological analysis in the relevant watercourse. The downstream boundary is based on the level from the predicted 1 in 1000 year flow.

A HQ (head verses flow) boundary based on floodplain slope in TUFLOW was created to allow floodplain flow to exit the model. TUFLOW creates this automatically based on a normal depth relationship.</td></tr>
<tr><td>What roughness values have been used?</td><td>Channel and floodplain roughness was represented within the model by using Manning’s n values for roughness. Values were chosen with reference to standard values and using site visit photographs and judgement.

<table>
<tr><th>ESTRY</th><th>Manning’s n</th></tr>
<tr><td>In-channel – normal bed</td><td>0.04</td></tr>
<tr><td>In channel – overgrown bed</td><td>0.05</td></tr>
<tr><td>Concrete culverts</td><td>0.02</td></tr>
<tr><td>Brick culverts</td><td>0.025</td></tr>
<tr><th>TUFLOW</th><th>Manning’s n</th></tr>
<tr><td>Roads</td><td>0.02</td></tr>
<tr><td>Buildings</td><td>0.3</td></tr>
<tr><td>General rural surface / grass</td><td>0.05</td></tr>
<tr><td>Inland water</td><td>0.035</td></tr>
<tr><td>Dense trees</td><td>0.08</td></tr>
<tr><td>Gravel road</td><td>0.035</td></tr>
<tr><td>Hard surface, standing areas, work yards</td><td>0.025</td></tr>
</table></td></tr>
<tr><td>What structure coefficients have been used?</td><td>Default coefficients have been used for structures.</td></tr>
<tr><td>Are there any changes to default model or run parameters? Why?</td><td>No changes to default parameters.</td></tr>
<tr><td>What timestep has been used?</td><td>A 0.25 second ESTRY time step was used for all model runs.
A 0.5 second TUFLOW time step was used for the model runs. This is in accordance with the recommendations that the time step should be at least a quarter of the 2D grid cell size.</td></tr>
</table>

3.3 POST-DEVELOPMENT MODELLING

3.3.1 Changes to the model for the post-development are relatively extensive due to the nature of the proposed works. The changes included:

- Inclusion of the new diverted channels for both the Afon Cadnant and Northern Ditch.
- Removal of the old channels from the model.
- Inclusion of a number of crossings and structures under the proposed highway network. In particular, four new culverts on the Afon Cadnant, one new culvert on its tributary, one new culvert on the Northern Ditch and an associated otter pass.
- Modelling of the proposed ground surface following the completion of the proposed highway works. This included ensuring that Crug Lane had a minimum level of 54mAOD.
- Modelling of a proposed bund between Crug Lane and the A487 to prevent flows in exceptional events (greater than the 1 in 200 year) flooding the bypass.
- Updates to the river bank elevation polyline based on the post-development cross sections.

3.3.2 No changes were made to the model's floodplain roughness coefficients as the existing and proposed floodplains are both rural grass environments and the proposed highways do not flood (except for Crug Lane in the 1 in 1000 year event – model results are found in Appendix C).

3.3.3 At the otter pass the model linked flow between the 1D pipe and 2D floodplain through a SX link that takes floodplain flow and transfers it to the 1D pipe network. Due to the complexity of the structure, it is in effect an inverted syphon; a manhole layer was added to correctly calculate the energy losses. They were calculated at every timestep using the Engelhund loss approach which takes into account velocities at the entrance and the exit of the manhole. .

3.3.4 The parameterization of the culvert energy losses were set to default ESTRY values for the proposed circular and rectangular culverts.

3.3.5 No changes to the floodplain cell size or time steps were undertaken.

3.4 POST-PROCESSING AND MAPPING

3.4.1 TUFLOW water level lines were used to map the output from ESTRY.

3.4.2 However, TUFLOW automatically created water level lines at culverts – even after this option was turned off in the command file. Therefore, the mapping shows flooding of roads and structures that in reality are not inundated. To avoid confusion, these locations were clearly marked on the maps produced.

4 MODEL PROVING

4.1 CALIBRATION AND OTHER MODELS

4.1.1 No calibration data was available.

4.1.2 Comparing against the National Resource Wales Flood Maps for the Afon Cadnant is not particularly useful given that their upstream boundary is approximately in the same location as this model's downstream boundary. No Flood Map exists for the Northern Ditch.

4.2 RUN PERFORMANCE

Is the model stable?	Overall yes. There is a little fluctuation in the ESTRY model results for the post-development scenario but this does not impact the model's results or conclusions.
Is the mass balance error sensible?	The mass balance errors for the model are within the +/-1% recommended within the TUFLOW manual as appropriate values for the baseline scenario (1 in 100 year plus climate change event). During the post-development scenario (1 in 100 year plus climate change event) the cumulative mass error exceeds these tolerances for 1.5 hours – this is not believed to undermine the results or conclusions as flows remain consistent and results appear sensible.
Are there any negative water depths?	No
What warnings and checks does the model give? Are any systematic of problems?	All warnings and checks associated with non-critical checks by TUFLOW.
Any other comments?	None

4.3 SENSITIVITY ANALYSIS

4.3.1 Flood extents for the sensitivity analysis scenarios can be found in Appendix D. A map is not provided for the downstream boundary test on the Northern Ditch as the increase in water level did not produce out-of-bank flooding.

What sensitivity tests have been undertaken?	+/-20% roughness +/-20% inflows +0.5m at downstream boundary
Are there any significant differences between the baseline and sensitivity tests?	Roughness – fairly minor differences. Mean differences are +50mm for +20% and -53mm for -20%. Inflows – smaller differences than might be expected, likely due to the large floodplain and throttling of flows at structures. Mean differences are +77mm for +20% and -82mm for -20%. Downstream boundary – No differences are observed in the model upstream of 75m on the Afon Cadnant, and 25m on the Northern Ditch.
Is the model sensitive to key parameters tested?	The model demonstrates relatively little sensitivity in peak water levels to roughness, inflows or downstream boundary.

5 MODEL RESULTS

5.1 OVERVIEW

5.1.1 Mapped and tabulated model results are shown in Appendix C.

5.1.2 Models were run with the 1 in 2, 5, 10, 25, 50, 75, 100, 200 and 1000 year return period inflows for both the baseline and post-development scenarios.

5.1.3 The baseline and post-development scenario was also run with the 1 in 100 year return period inflows plus 20% as an approximation for climate change.

5.2 BASELINE RESULTS

5.2.1 The baseline (pre-development) results show a large area around the bifurcation, to both the north and south, flooding in all but the 1 in 2 year event. The largest increase in flood extents in this area is between the 1 in 10 year and 1 in 25 year return periods.

5.2.2 On the Afon Cadnant, downstream of Bethel Road very little out of bank flooding is predicted. This is due to large amounts of water ponding around the bifurcation and the channel slope steepening downstream of Crug Lane.

5.2.3 On the Northern Ditch, water backs up behind Crug Lane for even the 1 in 2 year event. The 1 in 1000 year event is large enough to overtop Crug Lane and re-join the watercourse further downstream.

5.2.4 The predicted peak flow and level in the model approximately 75 to 100m before the downstream boundaries are shown in Table 5.1 (the downstream nodes themselves have fixed water levels as part of the model's schematisation – see Section 3.2).

Table 5.1: Baseline maximum water levels and flows approximately 100m from downstream boundaries

Model Node / Channel	Watercourse	Maximum Water Level (mAOD)				Maximum 1D/2D Flow (m^3/s)			
		1 in 25	1 in 100	1 in 100+CC	1 in 1000	1 in 25	1 in 100	1 in 100+CC	1 in 1000
CAND0075.1	Afon Cadnant	48.07	48.24	48.32	48.48				
CADN0075	Afon Cadnant					3.07	4.94	6.11	9.70
Ditch0100.1	Northern Ditch	49.97	49.97	49.97	49.97				
Ditch0100	Northern Ditch					0.57	0.60	0.61	0.67

5.2.5 The results clearly demonstrate the throttling effect of Crug Lane on the Northern Ditch as the flows only increase by a small amount with larger return periods. On the Afon Cadnant, due to the relatively steep channel, large increases in flow only lead to relatively small increases in water level.

5.3 POST-DEVELOPMENT RESULTS

5.3.1 Differences in flood extent between the baseline and proposed scenarios for the 1 in 100 year, 1 in 100 year plus climate change and 1 in 1000 year events can be found in Appendix C.

5.3.2 The post-development results demonstrate that the A487 is not flooded for any of the events tested, including the 1 in 1000 year event. The proposed realignment of Crug Lane is not affected by flooding in the 1 in 200 year event but is overtopped to a depth of approximately 170mm for the 1 in 1000 year event at the Northern Ditch culvert.

5.3.3 Table 5.2 compares the baseline and post-development results at the nodes reported in Table 5.1, close to the downstream boundaries of the model.

Table 5.2: Post-development maximum water levels and flows approximately 100m from downstream boundaries

Model Node / Channel	Watercourse	Maximum Water Level (mAOD)				Maximum 1D/2D Flow (m^3/s)			
		1 in 25	1 in 100	1 in 100+CC	1 in 1000	1 in 25	1 in 100	1 in 100+CC	1 in 1000
CADN0075.1	Afon Cadnant	48.00	48.14	48.23	48.37				

Model Node /	Watercourse	Maximum Water Level (mAOD)				Maximum 1D/2D Flow (m^3/s)			
Difference from baseline		*-0.07*	*-0.1*	*-0.09*	*-0.11*				
CADN0075	Afon Cadnant					2.51	3.74	4.73	7.10
Difference from baseline						*-0.56*	*-1.2*	*-1.38*	*-2.6*
Ditch0100.1	Northern Ditch	50.11	50.12	50.12	50.13				
Difference from baseline		*+0.14*	*+0.15*	*+0.15*	*+0.16*				
Ditch0100	Northern Ditch					1.51	1.69	1.73	1.84
Difference from baseline						*+1.16*	*+1.09*	*+1.12*	*+1.17*

5.3.4 The results show a decrease in the post-development flows and levels on the Afon Cadnant. On the Northern Ditch, compared to the baseline, the post-development flows increase leading to an approximate 150mm rise in water levels. The flows down the Northern Ditch are still throttled due to the surcharging of culvert S116/S118.

5.3.5 On the Afon Cadnant and its tributary the post-development 1 in 100 year plus climate change peak water levels are at least 690mm below the soffit level of the proposed new structures. The structures therefore are predicted to comfortably exceed the desired 600mm freeboard for this event, as shown in Table 5.3. However, the S116/S118 structure is surcharged by 1710mm.

Table 5.3: Post-development maximum 1 in 100 year plus climate change water levels compared to soffit levels for structures

Structure	Watercourse	Model Node	Soffit Level (mAOD)	Max 1 in 100 year plus climate change flood level (mAOD)	Freeboard (nearest 10mm)
S114	Afon Cadnant	350.2	52.29	50.52	1770
S114A	Tributary	S114A.1	51.9	51.21	690
S115A	Afon Cadnant	1.285.2	54	53.21	790
S115B	Afon Cadnant	675.2	54.53	53.75	780
S115C	Afon Cadnant	124.281	53.6	52.88	720
S116/S118	Northern Ditch	NDU0028.2	51.8	53.51	-1710

5.3.6 The cattle creep (structure S114) is predicted to flood to a shallow depth in the model at around 250l/s. The creep floods to a depth of 550mm in the 1 in 25 year event, 690mm for the 1 in 100 year and 950mm for the 1 in 100 year plus climate change event.

5.3.7 The otter pass (structure S116A/S118A) is flooded in the events including and above the 1 in 25 year return period, but not in the 1 in 10 year return period or below.

5.4 BLOCKAGE ANALYSIS

Differences in flood extents from the blockage analysis can be found in Appendix D.

Was blockage analysis undertaken?	Yes
What scenarios were tested?	A 50% blockage of the proposed culvert S116/S118 using 1 in 100 year inflows
What were the key outcomes?	The blockage tested led to up to a 120mm increase in water levels upstream of the structure. The backing-up of waters leads to more flow going down the Afon Cadnant than under non-blockage conditions, but the flow remains below the baseline rates. There is a maximum rise in levels of 199mm at the upstream face of the S115B culvert.

6 CONCLUSIONS

6.1.1 The following conclusions for the hydraulic modelling exercise are made:

- An ESTRY-TUFLOW model for the Afon Cadnant and Northern Ditch near Caernarfon has been built to better assess flood risk to the catchment and proposed A487 bypass.
- The post-development results demonstrate that the A487 is not flooded for any of the events tested, including the 1 in 1000 year event. The proposed realignment of Crug Lane is not affected by flooding in the 1 in 200 year event but is overtopped to a depth of approximately 170mm for the 1 in 1000 year event at the Northern Ditch culvert.
- The results show that in the post-development scenario the flows and levels on the Afon Cadnant decrease for the same relevant event with the baseline scenario. On the Northern Ditch, compared to the baseline, the post-development flows increase leading to an approximate 150mm rise in water levels. The flows down the Northern Ditch are still throttled due to the surcharging of culvert S116/S118.
- On the Afon Cadnant and its tributary the post-development 1 in 100 year plus climate change peak water levels are below the soffit level of the proposed new structures by at least 690mm. The structures therefore are predicted to comfortably exceed the desired 600mm freeboard for this event. However, the S116/S118 structure is surcharged by 1710mm.
- The model demonstrates relatively little sensitivity in peak water levels to roughness, inflows or downstream boundary.
- A 50% blockage of the proposed culvert S116/S118 using 1 in 100 year inflows was tested. The blockage led to up to a 120mm increase in water levels upstream of the structure. The backing-up of waters leads to more flow going down the Afon Cadnant than under non-blockage conditions and a maximum rise in levels of 199mm at the upstream face of the S115B culvert. However the flow in the Afon Cadnant remains below the baseline rate.

The main limitation to the hydraulic modelling is uncertainty in the flow estimates. No hydrometric data exists for the Afon Cadnant and Northern Ditch therefore flow estimation has relied on statistical analysis based on catchment descriptors.

Appendix A

LOCATION PLAN



File: Created using iGIS, WSP's Online Mapping System
Drawn By: UKPJH004
Date Modified: 27/05/2016 09:33

WSP | PARSONS BRINCKERHOFF

TITLE:
AFON CADNANT MODELLING
A487 CAERNARFON AND
BONTNEWYDD BYPASS

FIGURE No:
LOCATION PLAN

Appendix B

HYDROLOGICAL ANALYSIS

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.

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2	LOCATIONS WHERE FLOOD ESTIMATES REQUIRED	8
3	STATISTICAL METHOD	10
4	REVITALISED FLOOD HYDROGRAPH (REFH) METHOD	13
5	FEH RAINFALL-RUNOFF METHOD - N/A	14
6	DISCUSSION AND SUMMARY OF RESULTS	15
7	ANNEX 1- SUPPORTING INFORMATION	19

Approval

	Signature	Name and qualifications	For Environment Agency staff: Competence level (see below)
Calculations prepared by:		Alexandra Consoli	
Calculations checked by:		Nathan Sherwood	
Calculations approved by:		Claire Storer	

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 original purpose of this study was to calculate peak flow estimates in the Afon Cadnant to support a hydraulic assessment of new culverts proposed as part of the A487 Caernarfon to Bontnewydd bypass works. Following the initial assessment it was determined that hydraulic modelling would be required. Therefore the hydrological assessment was revisited to provide appropriate inflow hydrographs for the model. The additional work built on the original assessment and is described in Annex 2. The description that follows relates to the original assessment. It is proposed that the Afon Cadnant and its tributary will be crossed at four locations. Estimates of peak flow are therefore required at the four locations listed below: Crossing 1 (S115B): OS 250993, 364679 Crossing 2 (S115A): OS 251034, 364501 Crossing 3 (S114A): OS 251067, 364324 Crossing 4 (S114): OS 251017, 364284 Peak flow estimates have been calculated for the 2, 5, 10, 25, 50, 75, 100, 200 and 1000 year return period events. Approximately 1 week of time is available to complete this work. Please see section 7.3 for Flow Node locations.

1.2 Overview of catchment

Item	Comments
Brief description of catchment, or reference to section in accompanying report	The catchment has been assessed from a review of the FEH CD-ROM, OS mapping, the Cranfield Soil and Agrifood Institute Soilscapes website and the CEH NFRA. The study area is located in the upper reaches of the Afon Cadnant approximately 5 km north east of Caernarfon, Gwynedd. The catchment area is reasonably small at this location (~ 4 km^2 to crossing 4), located around the village of Bethel. The land is predominantly rural; fields & grassland used for pasture except for the village of Bethel which is situated almost centrally within the catchment. The watercourses follow reasonably well defined valleys upstream of the site. The catchment topography becomes flatter, and the valleys less defined, further downstream. According to the Cranfield Soil and Agrifood Institute Soilscapes website, the soils in this area are mainly freely draining. From the initial review it is expected the catchment will have a moderate response to rainfall. Infiltration to the underlying permeable soils may reduce direct runoff from the catchment, however as the study location is in the upper reaches the overall catchment response from direct runoff and baseflows are expected to be similar.

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	Yes – Version 3.3.4 August 2014

1.4 Gauging stations (flow or level)

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

No flow gauges were identified on the Afon Cadnant. Potential nearby donor sites were identified from the Hi-Flows dataset (using WINFAP).

The following four donor stations were assessed as potential donor sites as these were deemed to be the most similar to the subject catchment of the ten closest sites initially identified.

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
Glaslyn	Glaslyn @ Beddgelert		65001	259200, 347800	66.95	Velocity - Area	1961 - 2014
Elwy	Elwy @ Pant yr Onen		66002	302100, 370350	218.53	Velocity - Area	1961 - 1974
Elwy	Elwy @ Pont-y-Gwyddel		66006	295250, 371850	191.38	Velocity - Area	1973 - 2014
Conwy	Conwy @ Cwmlanerch		66011	280300, 358200	341.76	Velocity - Area	1964 - 2014

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.
Glaslyn @ Beddgelert	1961 - 2012	No	Yes	No		BFI/SPRHOST quite different, SAAR much higher Catchment descriptors indicate different hydrological response to the subject catchment (much steeper, wetter, more impermeable, attenuation). No high flow gaugings to check rating

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.
Elwy @ Pant yr Onen	1961 - 1974	No	Yes	No		Relatively short record length Site closed in 1974. BFI/SPRHOST quite different, but similar SAAR Catchment descriptors indicate different hydrological response to the subject catchment (steeper, less permeable, larger).
Elwy @ Pont-y-Gwyddel	1973 - 2012	No	Yes	Yes		BFI/SPRHOST quite different, but similar SAAR Catchment descriptors indicate different hydrological response to the subject catchment (steeper, less permeable, larger).
Conwy @ Cwmlanerch	1964 - 2012	No	Yes	No		BFI/SPRHOSTs quite different, SAAR higher Catchment descriptors indicate different hydrological response to the subject catchment (steeper, wetter, less permeable, larger).
			From the assessment of catchment characteristics none of the four gauging stations were considered suitable as donor sites for the Afon Cadnant catchment.			

1.6 Rating equations

Ratings have not been assessed as no donor sites were considered to be acceptable.

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.

1.7 Other data available and how it has been obtained- None available

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)					
Historic flood data – give					

link to historic review if carried out.					
Flow data for events					
Rainfall data for events					
Potential evaporation data					
Results from previous studies					
Other data or information (e.g. groundwater, tides)					

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.	FEH methods are appropriate however it is noted the BFIHOST values obtained from the FEH CD-ROM are at or slightly higher than the recommended limit for ReFH.
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 sites of interest are the locations of the four proposed culverts. Exceedence of channel capacity at each of these locations or the effects of downstream structures restricting flow are likely to be the main causes of flooding at these locations. It is possible that temporary debris dams could be formed however it is anticipated that the available storage will be exceeded relatively quickly, hence the flow capacity of the culverts will be the key consideration. Design criteria set by NRW is based on peak flows. Peak flows rather than flood volume is the key consideration.
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 only notable catchment features are the reasonably high BFIHOST values for the catchments: Crossing 1: BFIHOST = 0.646 Crossing 2: BFIHOST = 0.651 Crossing 3: BFIHOST = 0.701 Crossing 4: BFIHOST = 0.667 Other than this, there are no unusual catchment features although it is noted that the catchments are small.
Initial choice of method(s) and reasons Will the catchment be split into subcatchments? If so, how?	The four proposed crossing locations are all within the same catchment. Due to the high BFIHOST values and small sub-catchment areas, the FEH statistical approach is considered likely to be more appropriate than the ReFH method however both methods have been assessed for comparison.

Software to be used (with version numbers)	FEH CD-ROM v3.0[1] WINFAP-FEH v3.0.002[2] / ReFH (ISIS v3.7)

[1] FEH CD-ROM v3.0 © NERC (CEH). © Crown copyright. © AA. 2009. All rights reserved.

[2] WINFAP-FEH v3 © Wallingford HydroSolutions Limited and NERC (CEH) 2009.

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
Crossing 1	Afon Cadnant	A487 Caernarfon to Bontnewydd bypass	251000	364650	2.78	2.42
Crossing 2	Afon Cadnant	A487 Caernarfon to Bontnewydd bypass	251050	364500	2.87	2.53
Crossing 3	Afon Cadnant	A487 Caernarfon to Bontnewydd bypass	251100	364350	1.40	-
Crossing 4	Afon Cadnant	A487 Caernarfon to Bontnewydd bypass	251000	364250	4.34	3.98
Reasons for choosing above locations		Four crossing locations. Revisions to catchment areas represent the removal of the catchment area of a smaller watercourse which is included in the FEH CD-ROM catchment however OS mapping indicates drains elsewhere. This only affects Crossings 1, 2 & 4.				

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	FPEXT
Crossing 1	1.00	0.45	0.65	2.38	37.80	1177.0	30.55	0.045	0.050
Crossing 2	1.00	0.45	0.65	2.47	37.70	1175.0	30.39	0.043	0.048
Crossing 3	1.00	0.45	0.70	1.33	43.10	1174.0	28.67	0.000	0.050
Crossing 4	1.00	0.45	0.67	2.30	39.70	1175.0	29.84	0.029	0.047

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (refer to maps if needed)	Catchment boundary was checked against contour lines on OS Terrain 50 mapping, LIDAR data where available, and OS mapping. The catchment areas for Crossings 1, 2 and 4 were reduced by 0.356 km^2 for each location, recorded in Table 2.2, to remove an area which would drain to another watercourse as shown on OS Mastermap data.
Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary.	The soils types within each catchment were also checked via the Cranfield Soil and Agrifood Institute Soilscapes website. http://www.landis.org.uk/soilscapes/ The Soilscapes mapping showed both freely draining and slowly permeable soils covering the catchment. The accuracy of soil mapping means there may be some uncertainty in the BFI / SPR values obtained from the FEH CD-ROM. Site observations indicated waterlogged soils and the BFI value obtained from the FEH CD-ROM seems relatively high. However there is not considered sufficient justification to amend the values obtained from the CD. FARL (reservoirs and lakes) and URBEXT (urban extent) values were checked against OS mapping and considered appropriate. The reduction in catchment area is not sufficient to make a significant difference to other catchment descriptors therefore these have been left unchanged.
Source of URBEXT	FEH CD-ROM
Method for updating of URBEXT	Relevant CPRE formula from FEH (URBEXT1990) / Defra/EA report 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.	Of the ten closest donor sites none were considered suitable due to significant differences in catchment descriptors indicating they are not hydrologically similar to the subject site.

3.2 Donor sites chosen and QMED adjustment factors - N/A

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)
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).						

3.3 Overview of estimation of QMED at each subject site

Site code	Method	Initial estimate of QMED (m^3/s)	Data transfer						Final estimate of QMED (m^3/s)
			NRFA numbers for donor sites used (see 3.3)	Distance between centroids d_{ij} (km)	Power term, a	Moderated QMED adjustment factor, (A/B)[a]	If more than one donor		
							Weight	Weighted average adjustment factor	
Crossing 1	CD	1.07							1.07
Crossing 2	CD	1.08							1.08
Crossing 3	CD	0.49							0.49
Crossing 4	CD	1.46							1.46

3.4 Derivation of pooling groups

The composition of the pooling groups is given in Annex 1. 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)
CAD_Cross 4 Pooling Group 2	Crossing 4	No	Stations were retained or removed based on the similarity of their catchment descriptors (CDs) to those of the study catchment, Crossing 4 and the quality as indicated in Hi-Flows UK. . A high number of stations were noted in the Hi-Flows dataset to be unsuitable for pooling. However, to minimise the use of a high number of stations with high catchment descriptor distance values (a measure of hydrological similarity) in the pooling group, stations with the smallest distance values were reviewed using the information available from the NFRA CEH website (http://nrfa.ceh.ac.uk/data/search) and those stations which were deemed to be suitable for pooling were retained in the pooling group. Stations with short records and those that were considered unsuitable for pooling were removed from the pooling group. CDs were compared with the values for the crossing 4 catchment in this exercise. Particular attention was paid to SPRHOST and BFIHOST which are not used in the distance measure. In some instances sites were rejected where the SPR / BFI values were very different to the subject site.	L-CV = 0.271 L-Skewness = 0.257
Notes Pooling groups were derived using the revised procedures from Science Report SC050050 (2008). 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
Crossing 1	P	CAD_Cross 4 Pooling Group 2	Generalised Logistic distribution chosen, as recommended in the FEH handbook for sites in the UK. This distribution also provides the best fit to the pooled data.	UAF applied to the pooling group.	Location = 1.000 Scale = 0.267 Shape = -0.262 Bound = -0.018	3.377
Crossing 2	P	CAD_Cross 4 Pooling Group 2	As above	As above	As above	3.377
Crossing 3	P	CAD_Cross 4 Pooling Group 2	As above	As above	As above	3.377
Crossing 4	P	CAD_Cross 4 Pooling Group 2	As above	As above	As above	3.377

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).

Please see Section 7.1, Growth Curve Plot

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	75	100	200	1000
Crossing 1	1.07	1.55	1.92	2.49	3.00	3.35	3.61	4.34	6.64
Crossing 2	1.08	1.57	1.94	2.52	3.04	3.39	3.66	4.40	6.73
Crossing 3	0.49	0.71	0.89	1.15	1.39	1.54	1.67	2.00	3.06
Crossing 4	1.46	2.11	2.62	3.39	4.09	4.57	4.93	5.92	9.05

4 Revitalised flood hydrograph (ReFH) method

4.1 Parameters for ReFH model

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
Crossing 1	CD	2.11	477.21	35.55	1.75
Crossing 2	CD	2.16	480.71	36.04	1.77
Crossing 3	CD	1.54	515.72	34.98	1.92
Crossing 4	CD	2.09	491.93	36.71	1.82
Brief description of any flood event analysis carried out (further details should be given below or in a project report)		N/A			

4.2 Design events for ReFH method

Site code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)	Storm area for ARF (if not catchment area)
Crossing 1	Rural	Winter	4.50	-
Crossing 2	Rural	Winter	4.75	-
Crossing 3	Rural	Winter	3.25	-
Crossing 4	Rural	Winter	4.50	-
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?			No. The next stage of the study will be hand calculations at proposed culverts.	

4.3 Flood estimates from the ReFH method

Site code	Flood peak (m^3/s) for the following return periods (in years)								
	2	5	10	25	50	75	100	200	1000
Crossing 1	0.89	1.17	1.39	1.71	2.01	2.20	2.36	2.81	4.40
Crossing 2	0.91	1.20	1.43	1.75	2.06	2.26	2.41	2.88	4.50
Crossing 3	0.47	0.62	0.75	0.93	1.11	1.22	1.31	1.58	2.55
Crossing 4	1.36	1.79	2.14	2.62	3.08e	3.38	3.62	4.32	6.79

5 FEH rainfall-runoff method - N/A

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		
	ReFH	-	-	ReFH	-	-
Crossing 1	0.83			0.65		
Crossing 2	0.84			0.66		
Crossing 3	0.95			0.79		
Crossing 4	0.93			0.73		

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.	The flow estimates obtained with the FEH Statistical method were selected for numerous reasons; • The Hi-Flows dataset used as the basis for the FEH statistical method contains a greater number of small catchments than the dataset used in the development of the ReFH method. Therefore the statistical method may provide more reasonable flow estimates than the ReFH method. • The BFIHOST values for the catchments indicate reasonably high permeability and are either at or slightly higher the recommended limit for application of the ReFH method. Rainfall runoff methods are generally not suited to permeable catchments. • The FEH statistical method produced higher flow estimates. Although the choice of flows should not be made solely on this basis in this instance a precautionary approach is considered appropriate as the flow estimates will inform the design of new watercourse crossings. As detailed above, the Statistical method is likely to be preferred over the ReFH method and the flow estimates, whilst proportionately slightly higher than observed for many UK rivers, are considered reasonable for an upland catchment in this location and lie within typical ranges.

6.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	Usual FEH assumptions. Use of Catchment Descriptor equations to obtain QMED estimates & ReFH model parameters as no available gauged data. One pooling group has been used for all of the flow node catchments, however this is considered appropriate given their hydrological similarity. Crossing 4 was used to select the pooling group as it is the largest catchment area, encompassing Crossings 1, 2 and 3 within its boundaries.
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed	Small catchments - limited number of similar catchments in the FEH dataset. No donor sites identified to refine the flow estimates / model parameters based on catchment descriptors.

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).	Factorial Standard Error (fse) taken as 1.431, based on using the HiFlows-UK Data Set used to generate the QMED Model. **QMED (m^3/s)** | **68%** Lower / Upper | **95%** Lower / Upper **Crossing 1**: 1.07 | 0.75 | 1.53 | 0.52 | 2.19 **Crossing 2**: 1.08 | 0.76 | 1.55 | 0.53 | 2.22 **Crossing 3**: 0.49 | 0.35 | 0.71 | 0.24 | 1.01 **Crossing 4**: 1.46 | 1.02 | 2.09 | 0.71 | 2.99 Comparison of ReFH and Statistical flow estimates shows a 10-20% difference at QMED, increasing to a 30 - 40% difference for the 100 year return period.
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	Not required for this study
Give any other comments on the study, for example suggestions for additional work.	Installation of flow gauges would improve the certainty in the flow estimates however project timescales may not allow sufficient data to be obtained to inform the design. The adoption of standard FEH methods is appropriate for the FCA.

6.4 Checks

Are the results consistent, for example at confluences?	The flow estimates obtained are consistent with the changes in catchment area and other characteristics at each of the four flow nodes. The specific runoffs, whilst slightly higher than may be typical across the UK, are reasonable for a small upland catchment at this location.
What do the results imply regarding the return periods of floods during the period of record?	No data is available for historic flooding in the catchment.
What is the 100-year growth factor? Is this realistic? (The guidance suggests a typical range of 2.1 to 4.0)	The 100 year growth factor for Crossings 1, 2, 3 and 4 for the selected FEH statistical method, is well within the acceptable range of 2.1 to 4.0 at 3.38.
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	Site Code | Flow Estimates (m^3/s) 1000 Year / 100 Year | 1000 /100 Year Ratio Crossing 1: 6.64 | 3.61 | 1.84 Crossing 2: 6.73 | 3.66 | 1.84 Crossing 3: 3.06 | 1.67 | 1.84 Crossing 4: 9.05 | 4.93 | 1.84

What range of specific runoffs (l/s/ha) do the results equate to? Are there any inconsistencies?	

	Specific Runoffs (l/s/ha)								
	2	**5**	**10**	**25**	**50**	**75**	**100**	**200**	**1000**
Crossing 1	4.41	6.38	7.92	10.26	12.38	13.81	14.91	17.92	27.39
Crossing 2	4.28	6.19	7.67	9.94	12.00	13.38	14.45	17.37	26.54
Crossing 3	3.53	5.10	6.33	8.20	9.90	11.03	11.91	14.32	21.89
Crossing 4	3.66	5.30	6.57	8.51	10.28	11.46	12.37	14.87	22.73

How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	No other studies are available on this watercourse with which a meaningful comparison can be made.
Are the results compatible with the longer-term flood history?	No information available
Describe any other checks on the results	N/A

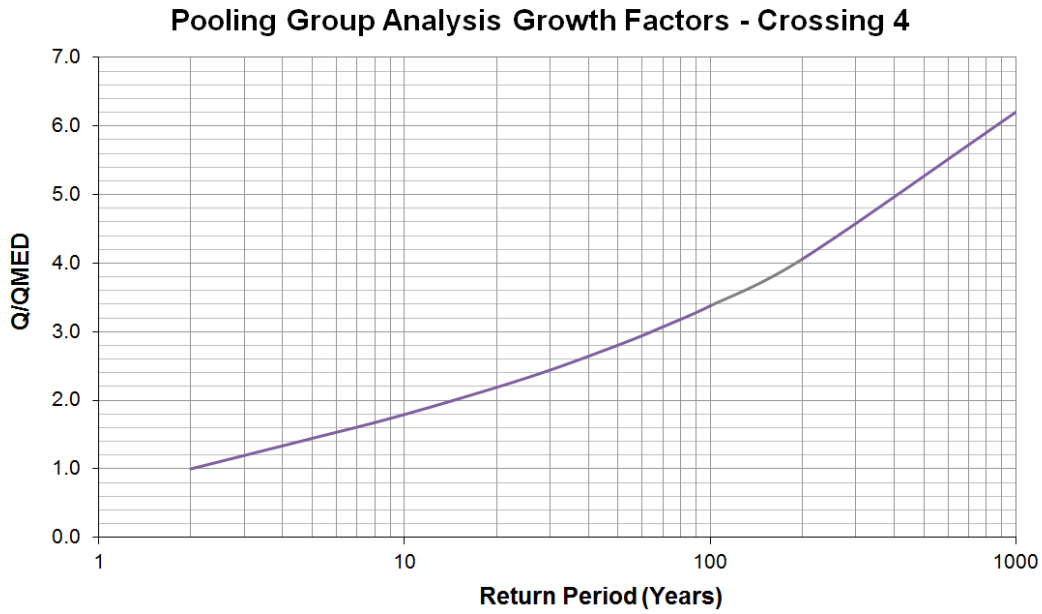
6.5 Final results

Site code	Flood peak (m^3/s) for the following return periods (in years)								
	2	**5**	**10**	**25**	**50**	**75**	**100**	**200**	**1000**
Crossing 1	1.07	1.55	1.92	2.49	3.00	3.35	3.61	4.34	6.64
Crossing 2	1.08	1.57	1.94	2.52	3.04	3.39	3.66	4.40	6.73
Crossing 3	0.49	0.71	0.89	1.15	1.39	1.54	1.67	2.00	3.06
Crossing 4	1.46	2.11	2.62	3.39	4.09	4.57	4.93	5.92	9.05

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)	None required

7 Annex 1- supporting information

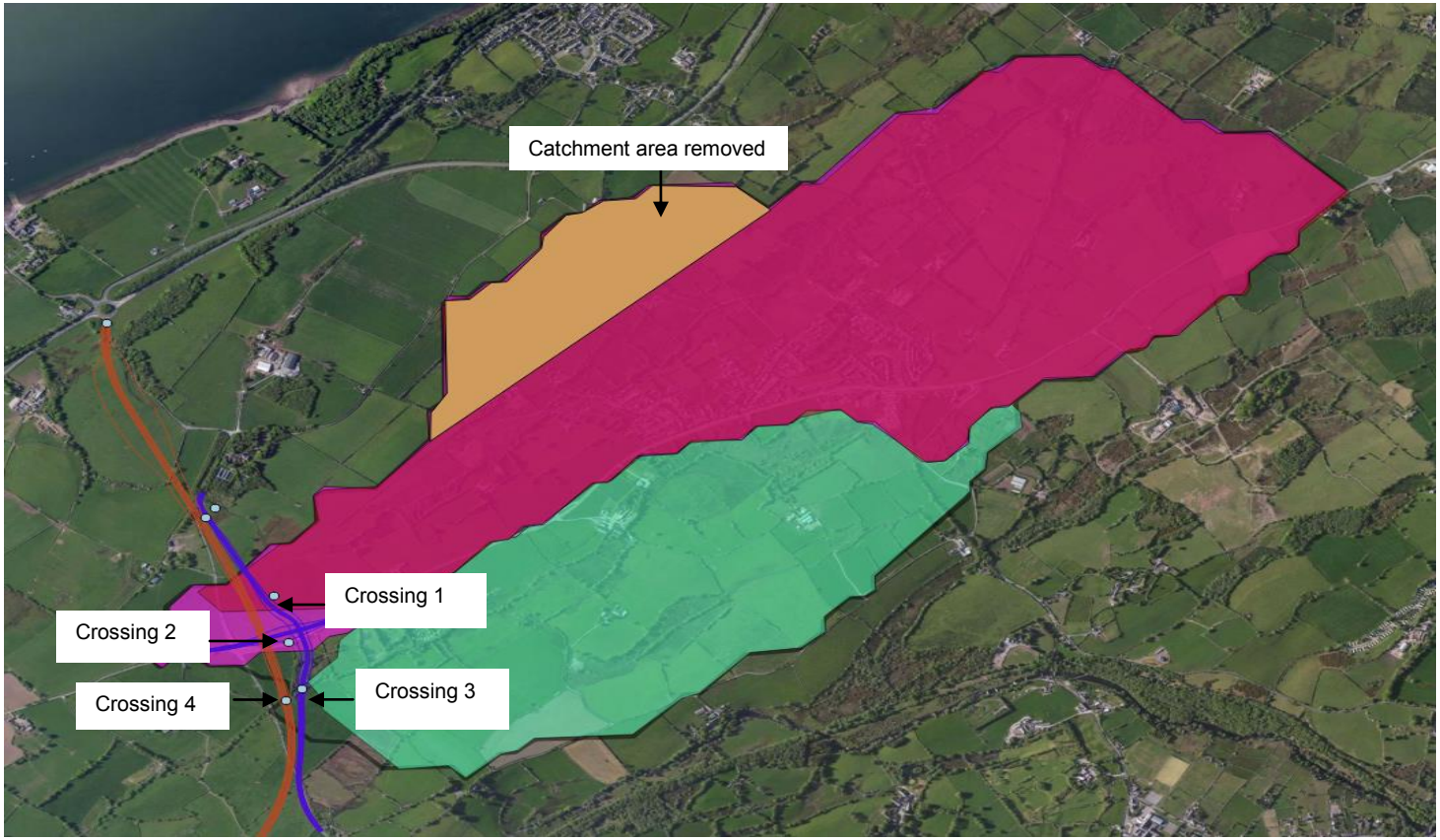
7.1 Growth Curve Plot



7.2 Pooling group composition

STATION REF.	STATION NUMBER	DISTANCE VALUE	YEARS OF DATA
45816 (Haddeo @ Upton)	**45816**	1.54	42
28033 (Dove @ Hollinsclough)	**28033**	1.53	20
28070 (Burbage Brook @ Burbage)	**28070**	1.32	19
27051 (Crimple @ Burn Bridge)	**27051**	1.14	40
45817 (Unnamed Stream @ Upton)	**45817**	0.99	56
44801 (Hooke @ Hooke)	**44801**	0.99	33
27038 (Costa Beck @ Gatehouses)	**27038**	0.75	19
54091 (Severn @ Hafren Flume)	**54091**	1.54	34
31026 (Egleton Brook @ Egleton)	**31026**	1.54	34
55033 (Wye @ Gwy flume)	**55033**	1.55	33
54092 (Hore @ Hore Flume)	**54092**	1.61	34
206006 (Annalong @ Recorder)	**206006**	1.78	48
25019 (Leven @ Easby)	**25019**	1.89	34
44008 (South Winterbourne @ Winterbourne Steepleton)	**44008**	2.2	33
51002 (Horner Water @ West Luccombe)	**51002**	2.27	31

7.3 Additional supporting information – Map showing location of Flow Nodes



8 Annex 2- Supplementary Assessment

8.1 Overview

Following completion of the hydrological assessment for the reach of Afon Cadnant outlined above, the need to model the Afon Cadnant arose. The purpose of the modelling is to quantify the impacts of proposed structures and channel re-alignment works on flood risk along the Afon Cadnant. Flow hydrographs were therefore required to use as inflows to the model.

8.2 Flow hydrograph locations and catchments

For modelling purposes, inflow hydrographs are required at the following locations:

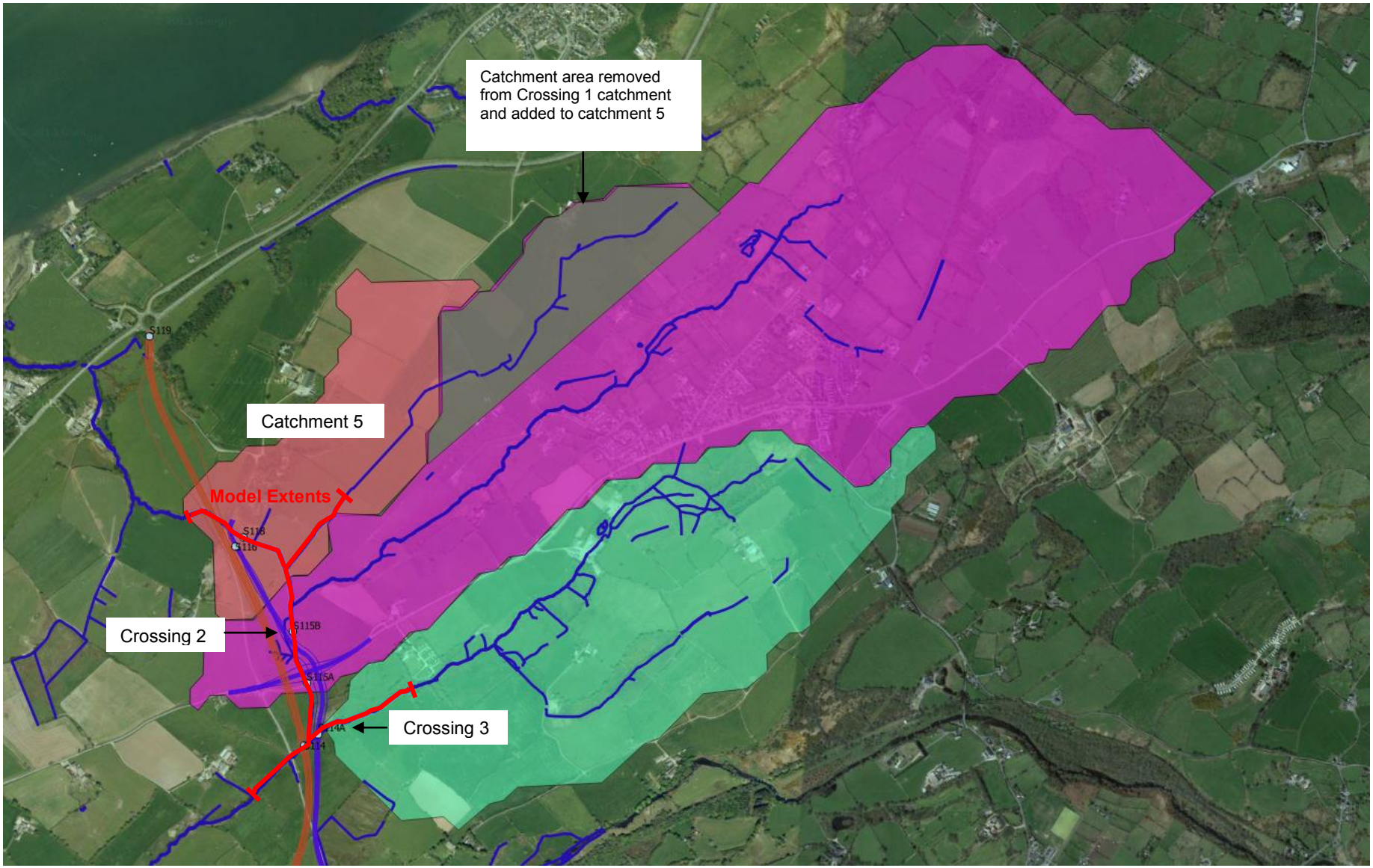
- Location of crossing 2, representing the catchment draining to the Cadnant
- Location of crossing 3, representing the catchment draining to the Cadnant tributary
- Catchment 5 (new location), representing the catchment which drains directly to the watercourse that bifurcates from the Afon Cadnant north of the Scheme

Additional hydrographs representing the lateral / incremental catchments within the model extent were not deemed necessary as the catchment areas and flows are insignificant compared with the runoff from the upper catchment.

As described in Section 2.3, the catchment boundaries on the FEH CD Rom were checked against OS mapping and topographic data. An alteration was made in the original assessment to remove an area shown on the FEH CD-Rom to drain to the Afon Cadnant which in fact drains to the north. This area was instead attributed to the catchment of the watercourse that bifurcates from the Afon Cadnant (catchment 5). The value of DPLBAR for catchment 5 was also increased as a result of this alteration to the catchment boundaries. No other changes were made to the other catchment descriptors for catchment 5 as the FEH CD-Rom values were deemed appropriate. The impact of increasing DPLBAR on the ReFH estimation of flows was to increase the values of Tp by 10% and BL by 3%.

These catchments / inflows used for the modelling are illustrated in the figure below. The FEH catchment descriptors used in the assessment are shown in the table below.

Site code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPRHOST	URBEXT	FPEXT
Crossing 2	1.00	0.45	0.65	2.47	37.70	1175.0	30.39	0.043	0.048
Crossing 3	1.00	0.45	0.70	1.33	43.10	1174.0	28.67	0.000	0.050
Catchment 5	1.00	0.45	0.79	1.0	23.60	1128.0	25.20	0.000	?


Catchment area removed from Crossing 1 catchment and added to catchment 5
Catchment 5
Model Extents
Crossing 2
Crossing 3
S119
S118
S116
S115B
S115A
S114A
S114

8.3 Peak flow estimates

The FEH Statistical method was selected to derive peak flow estimates in the original study and this approach has been retained. No suitable donor sites exist for this catchment as for the other nodes. Using the catchment descriptor equation, QMED was estimated for catchment 5 to be **0.21m^3/s**.

The growth factors derived in the original study were considered to be suitable for catchment 5. Catchment 5 is similar to catchment 4 for which the pooling group was derived. The growth factors and peak flow estimates are shown in the following table.

Return Period (Years)									
	2	**5**	**10**	**25**	**50**	**75**	**100**	**200**	**1000**
Growth Factors	1.000	1.446	1.793	2.324	2.805	3.128	3.377	4.059	6.204
Crossing 2 peak flow (m^3/s)	1.08	1.57	1.94	2.52	3.04	3.39	3.66	4.40	6.73
Crossing peak flow (m^3/s)3	0.49	0.71	0.89	1.15	1.39	1.54	1.67	2.00	3.06
Catchment 5 peak flow (m^3/s)	0.21	0.30	0.38	0.49	0.59	0.66	0.71	0.85	1.30

8.4 Hydrograph production

The ReFH method was used to derive the hydrographs required for the model. As detailed in the original study, the statistical estimates of peak flow are considered likely to be more accurate than the ReFH estimates. Therefore the ReFH hydrographs have been scaled to the Statistical peak flow estimates. The 1000 / 100 year ratios are very similar for both methods therefore there is little benefit in applying the hybrid method for the larger events and this has not been adopted. The ReFH module in the Flood Modeller software (previously ISIS) was used to generate the scaled hydrographs.

The storm area was set to 4.81km^2, the total area of all the sub-catchments. The storm duration was set to 4.75hours, representing the calculated critical storm duration for the catchment draining to crossing 2. This location represents the key study location– several proposed structures being located close to this crossing. It is also the longest of the critical durations calculated for all nodes and will therefore generate the highest runoff volume. The largest variation in the critical storm duration is for catchment 5 (critical storm duration 2.97 hours), i.e. a difference of 1.73 hours. With a duration of 2.97 hours, catchment 5 has a peak flow in the 100 year return period event, including an allowance for climate change, of 0.85m^3/s, which is the same as the storm with a 4.75 hour duration. It is assumed that the impacts of selecting a storm duration of 4.75 hours on the accuracy of results elsewhere, and in all return periods, will be very small therefore.

Appendix C

MODEL RESULTS

Legend

Model extent

Flood extents for each return period:

- 1 in 2 year
- 1 in 5 year
- 1 in 10 year
- 1 in 25 year
- 1 in 50 year
- 1 in 75 year
- 1 in 100 year
- 1 in 100 year plus climate change
- 1 in 200 year
- 1 in 1000 year

Flood mapping at these locations shows water underneath structures. The flood model does not predict flooding of the highways.

Nursery
Crug
Iss
Issues
Sinks
Sewage Works
Tycerrig
Track
B4366
74m
Caerlan Tibot
Water Works
Drain
Erw Fawr
71m
Rhyd-y-galen
Caravan Site
Hut Circle
Pont Rhyd-y-Galen
Afon Cadnant
Tyddyn Hen
59m
FFORDD BETHEL / BETHEL ROAD
Annedd Eryri
Pen-y-Gelli
Pengelli Isaf
Ford
FB

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AFON CADNANT MODELLING, A487 CAERNARFON TO BONTNEWYDD BYPASS

CADNANT
BASELINE MODELLED FLOOD EXTENTS

WSP | PARSONS BRINCKERHOFF

DRAWN BY	CHECKED BY	APPROVED BY	STATUS	DATE	SCALE	DRAWING NO.	REV.
SF	PH	PH	FI	10/05/16	NTS	62103423-BASE-EXT-v11	A

Legend

Model extent

Modelled flood depths (1 in 100 year event):

- 0 - 0.3 m
- 0.3 - 0.6 m
- 0.6 - 1.2 m
- 1.2 - 2.4 m
- >2.4 m

Flood mapping at these locations shows water underneath structures. The flood model does not predict flooding of the highways.

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AFON CADNANT MODELLING, A487 CAERNARFON TO BONTNEWYDD BYPASS

CADNANT BASELINE MODELLED FLOOD DEPTHS 1 IN 100 YEAR EVENT

WSP | PARSONS BRINCKERHOFF

DRAWN BY	CHECKED BY	APPROVED BY	STATUS	DATE	SCALE	DRAWING NO.	REV.
SF	PH	PH	FI	25/05/16	NTS	62103423-BASE-DEP-v11-Q0100	A

Legend

Model extent

Modelled flood depths (1 in 100 year plus climate change event):

- 0 - 0.3 m
- 0.3 - 0.6 m
- 0.6 - 1.2 m
- 1.2 - 2.4 m
- >2.4 m

Flood mapping at these locations shows water underneath structures. The flood model does not predict flooding of the highways.

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Pengelli Isaf
Ford
FB
Issues

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AFON CADNANT MODELLING, A487 CAERNARFON TO BONTNEWYDD BYPASS

CADNANT
BASELINE MODELLED FLOOD DEPTHS
1 IN 100 YEAR PLUS CLIMATE CHANGE EVENT

WSP | PARSONS BRINCKERHOFF

DRAWN BY	CHECKED BY	APPROVED BY	STATUS	DATE	SCALE	DRAWING NO.	REV.
SF	PH	PH	FI	25/05/16	NTS	62103423-BASE-DEP-v11-Q0100CC	A

Legend

Model extent

Modelled flood depths (1 in 1000 year event):

- 0 - 0.3 m
- 0.3 - 0.6 m
- 0.6 - 1.2 m
- 1.2 - 2.4 m
- >2.4 m

Flood mapping at these locations shows water underneath structures. The flood model does not predict flooding of the highways.

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AFON CADNANT MODELLING, A487 CAERNARFON TO BONTNEWYDD BYPASS

CADNANT
BASELINE MODELLED FLOOD DEPTHS
1 IN 1000 YEAR EVENT

WSP | PARSONS BRINCKERHOFF

DRAWN BY	CHECKED BY	APPROVED BY	STATUS	DATE	SCALE	DRAWING NO.	REV.
SF	PH	PH	FI	25/05/16	NTS	62103423-BASE-DEP-v11-Q1000	A

Legend

Model extent

Maximum velocities (m/s)
1 in 100 year event:

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

Flood mapping at these locations shows water underneath structures. The flood model does not predict flooding of the highways.

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AFON CADNANT MODELLING, A487 CAERNARFON TO BONTNEWYDD BYPASS

CADNANT BASELINE MAXIMUM VELOCITIES 1 IN 100 YEAR EVENT

WSP | PARSONS BRINCKERHOFF

DRAWN BY	CHECKED BY	APPROVED BY	STATUS	DATE	SCALE	DRAWING NO.	REV.
SF	PH	PH	FI	25/05/16	NTS	62103423-BASE-V-v11-Q0100	A

Legend

Model extent

Maximum velocities (m/s)
1 in 100 year plus climate change event

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

Flood mapping at these locations shows water underneath structures. The flood model does not predict flooding of the highways.

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AFON CADNANT MODELLING, A487 CAERNARFON TO BONTNEWYDD BYPASS

CADNANT
BASELINE MAXIMUM VELOCITIES
1 IN 100 YEAR PLUS CLIMATE CHANGE EVENT

WSP | PARSONS BRINCKERHOFF

DRAWN BY	CHECKED BY	APPROVED BY	STATUS	DATE	SCALE	DRAWING NO.	REV.
SF	PH	PH	FI	25/05/16	NTS	62103423-BASE-V-v11-Q0100CC	A

Legend

Model extent

Maximum velocities (m/s)
1 in 1000 year event

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

Flood mapping at these locations shows water underneath structures. The flood model does not predict flooding of the highways.

AFON CADNANT MODELLING, A487 CAERNARFON TO BONTNEWYDD BYPASS

CADNANT BASELINE MAXIMUM VELOCITIES 1 IN 1000 YEAR EVENT

DRAWN BY	CHECKED BY	APPROVED BY	STATUS	DATE	SCALE	DRAWING NO.	REV.
SF	PH	PH	FI	25/05/16	NTS	62103423-BASE-V-v11-Q1000	A

WSP | PARSONS BRINCKERHOFF

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Legend

- Model extent
- Proposed highways

Flood extents for each return period:

- 1 in 2 year
- 1 in 5 year
- 1 in 10 year
- 1 in 25 year
- 1 in 50 year
- 1 in 75 year
- 1 in 100 year
- 1 in 200 year
- 1 in 1000 year

Flood mapping at these locations shows water underneath structures. The flood model does not predict flooding of the highways.

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AFON CADNANT MODELLING, A487 CAERNARFON TO BONTNEWYDD BYPASS

CADNANT PROPOSED MODELLED FLOOD EXTENTS

WSP | PARSONS BRINCKERHOFF

DRAWN BY	CHECKED BY	APPROVED BY	STATUS	DATE	SCALE	DRAWING NO.	REV.
SF	PH	PH	FI	10/05/16	NTS	62103423-PROP-EXT-v11	A

Legend

- Model extent
- Proposed highways

Modelled flood depths (1 in 100 year event):

- 0 - 0.3 m
- 0.3 - 0.6 m
- 0.6 - 1.2 m
- 1.2 - 2.4 m
- >2.4 m

Flood mapping at these locations shows water underneath structures. The flood model does not predict flooding of the highways.

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AFON CADNANT MODELLING, A487 CAERNARFON TO BONTNEWYDD BYPASS

CADNANT PROPOSED MODELLED FLOOD DEPTHS 1 IN 100 YEAR EVENT

WSP | PARSONS BRINCKERHOFF

DRAWN BY	CHECKED BY	APPROVED BY	STATUS	DATE	SCALE	DRAWING NO.	REV.
SF	PH	PH	FI	25/05/16	NTS	62103423-PROP-DEP-v11-Q0100	A

Legend

- Model extent
- Proposed highways

Modelled flood depths (1 in 100 year plus climate change event):

- 0 - 0.3 m
- 0.3 - 0.6 m
- 0.6 - 1.2 m
- 1.2 - 2.4 m
- >2.4 m

Flood mapping at these locations shows water underneath structures. The flood model does not predict flooding of the highways.

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CADNANT
PROPOSED MODELLED FLOOD DEPTHS
1 IN 100 YEAR PLUS CLIMATE CHANGE EVENT

WSP | PARSONS BRINCKERHOFF

DRAWN BY	CHECKED BY	APPROVED BY	STATUS	DATE	SCALE	DRAWING NO.	REV.
SF	PH	PH	FI	25/05/16	NTS	62103423-PROP-DEP-v11-Q0100CC	A

Legend

- Model extent
- Proposed highways

Modelled flood depths (1 in 1000 year event):

- 0 - 0.3 m
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CADNANT PROPOSED MODELLED FLOOD DEPTHS 1 IN 1000 YEAR EVENT

WSP | PARSONS BRINCKERHOFF

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SF	PH	PH	FI	25/05/16	NTS	62103423-PROP-DEP-v11-Q1000	A

Legend

- Model extent
- Proposed highways

Maximum velocities (m/s)
1 in 100 year event:

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

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AFON CADNANT MODELLING, A487 CAERNARFON TO BONTNEWYDD BYPASS

CADNANT PROPOSED MAXIMUM VELOCITIES 1 IN 100 YEAR EVENT

WSP | PARSONS BRINCKERHOFF

DRAWN BY	CHECKED BY	APPROVED BY	STATUS	DATE	SCALE	DRAWING NO.	REV.
SF	PH	PH	FI	25/05/16	NTS	62103423-PROP-V-v11-Q0100	A

Legend

- Model extent
- Proposed highways

Maximum velocities (m/s)
1 in 1000 year event

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
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Flood mapping at these locations shows water underneath structures. The flood model does not predict flooding of the highways.

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AFON CADNANT MODELLING, A487 CAERNARFON TO BONTNEWYDD BYPASS

CADNANT
PROPOSED MAXIMUM VELOCITIES
1 IN 1000 YEAR EVENT

WSP | PARSONS BRINCKERHOFF

DRAWN BY	CHECKED BY	APPROVED BY	STATUS	DATE	SCALE	DRAWING NO.	REV.
SF	PH	PH	FI	25/05/16	NTS	62103423-PROP-V-v11-Q1000	A

Legend

- Model extent
- Proposed highways

Maximum velocities (m/s)
1 in 100 year plus climate change event

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4

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CADNANT
PROPOSED MAXIMUM VELOCITIES
1 IN 100 YEAR PLUS CLIMATE CHANGE EVENT

WSP | PARSONS BRINCKERHOFF

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SF	PH	PH	FI	25/05/16	NTS	62103423-PROP-V-v11-Q0100	A

Legend

- Model extent
- Proposed highways

Maximum flood depth difference

- <-600mm
- -600mm to -300mm
- -300mm to -100mm
- -100mm to - 5mm
- No change (<+/-5mm)
- 5mm to 100mm
- 100mm to 300mm
- 300mm to 600mm
- >600mm

Flood mapping at these locations shows water underneath structures. The flood model does not predict flooding of the highways.

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AFON CADNANT MODELLING, A487 CAERNARFON TO BONTNEWYDD BYPASS

CADNANT
MAXIMUM FLOOD DEPTH DIFFERENCE
1 IN 100 YEAR EVENT

WSP | PARSONS BRINCKERHOFF

DRAWN BY	CHECKED BY	APPROVED BY	STATUS	DATE	SCALE	DRAWING NO.	REV.
SF	PH	PH	FI	25/05/16	NTS	62103423-DIFF-v11-Q0100	A

Legend

- Model extent
- Proposed highways

Maximum flood depth difference

- <-600mm
- -600mm to -300mm
- -300mm to -100mm
- -100mm to - 5mm
- No change (<+/-5mm)
- 5mm to 100mm
- 100mm to 300mm
- 300mm to 600mm
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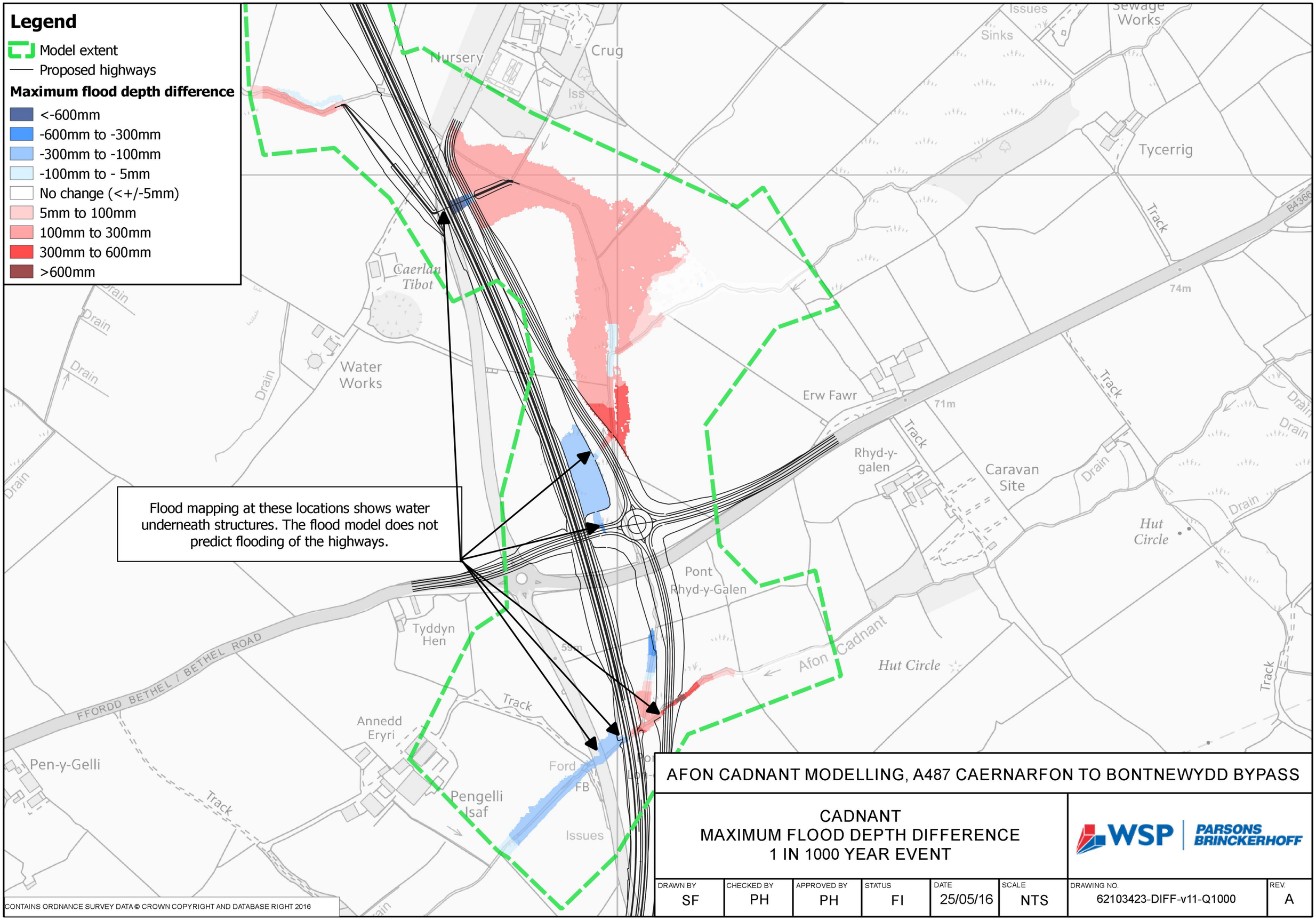
CADNANT
MAXIMUM FLOOD DEPTH DIFFERENCE
1 IN 100 YEAR PLUS CLIMATE CHANGE EVENT

WSP | PARSONS BRINCKERHOFF

DRAWN BY	CHECKED BY	APPROVED BY	STATUS	DATE	SCALE	DRAWING NO.	REV.
SF	PH	PH	FI	25/05/16	NTS	62103423-DIFF-v11-Q0100CC	A



AFON CADNANT MODELLING, A487 CAERNARFON TO BONTNEWYDD BYPASS

CADNANT
MAXIMUM FLOOD DEPTH DIFFERENCE
1 IN 1000 YEAR EVENT

WSP | PARSONS BRINCKERHOFF

DRAWN BY	CHECKED BY	APPROVED BY	STATUS	DATE	SCALE	DRAWING NO.	REV.
SF	PH	PH	FI	25/05/16	NTS	62103423-DIFF-v11-Q1000	A

Channel ID	Baseline																				Post-development																			
	1 in 2 year		1 in 5 year		1 in 10 year		1 in 25 year		1 in 50 year		1 in 75 year		1 in 100 year		1 in 100 year + CC (20%)		1 in 200 year		1 in 1000 year		1 in 2 year		1 in 5 year		1 in 10 year		1 in 25 year		1 in 50 year		1 in 75 year		1 in 100 year		1 in 100 year + CC (20%		1 in 200 year		1 in 1000 year	
	Qmax	Vmax	Qmax	Vmax	5.3467	5.3467	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax
1.285																					0.496	0.5893	0.761	0.6339	1.02	0.6878	1.413	0.7253	1.711	0.7454	2.023	0.754	2.272	0.7519	3.041	0.7541	3.046	0.7543	3.527	0.7577
124.281																					0.494	0.6148	0.758	0.6528	1.017	0.6537	1.417	0.6808	1.708	0.6861	2.019	0.7072	2.269	0.7088	3.035	0.7236	3.041	0.7238	4.594	0.7293
173.258																					0.492	0.8234	0.757	0.9378	1.015	1.0227	1.414	1.1259	1.706	1.1873	2.017	1.2448	2.267	1.2862	3.032	1.3941	3.039	1.3949	4.592	1.561
239.434																					0.491	0.8489	0.755	0.9709	1.014	1.061	1.411	1.1692	1.704	1.2336	2.015	1.2932	2.265	1.3357	3.03	1.4468	3.036	1.4476	4.589	1.616
276.611																					0.49	1.1545	0.754	1.327	1.013	1.4554	1.409	1.6101	1.703	1.7039	2.014	1.7904	2.264	1.8524	3.029	2.0175	3.035	2.0187	4.588	2.2721
350																					1.104	0.9951	1.105	0.9951	1.055	0.9961	1.426	1.0008	1.707	0.9847	2.018	0.9933	2.281	0.9775	3.567	1.0095	3.569	0.999	4.595	0.997
Cad_at_Ditch	1.381	1.1884	1.478	1.2157	6.3554	6.3554	1.407	1.1768	1.426	1.1856	1.435	1.1899	1.444	1.1941	1.448	1.195	1.474	1.2066	1.514	1.2252	1.578	1.2529	1.585	1.256	1.588	1.2572	1.613	1.2678	1.627	1.2736	1.635	1.2768	1.645	1.2807	1.649	1.2826	1.653	1.2841	1.684	1.297
CADN0025	1.152	0.3806	1.761	0.577	5.3446	5.3446	3.065	0.976	3.944	1.2267	4.471	1.3693	4.934	1.4903	6.12	1.7822	6.125	1.7833	9.545	2.5093	0.966	0.3199	1.446	0.4762	1.863	0.6092	2.508	0.8095	3.017	0.9619	3.391	1.071	3.74	1.1698	4.79	1.4528	4.79	1.4527	7.098	2.0055
CADN0050	1.151	0.766	1.76	1.0754	5.3385	5.3385	3.065	1.5617	3.944	1.7743	4.471	1.8734	4.934	1.9424	6.12	2.0832	6.125	2.0838	9.36	2.3263	0.965	0.6586	1.447	0.9239	1.862	1.1214	2.507	1.3789	3.018	1.548	3.391	1.6488	3.739	1.7306	4.786	1.9209	4.786	1.9208	7.09	2.174
CADN0075	1.151	1.3153	1.761	1.555	5.3271	5.327	3.066	1.8744	3.945	2.0119	4.472	2.0536	4.935	2.0723	6.114	2.0904	6.119	2.0905	9.441	2.1767	0.965	1.2185	1.447	1.4444	1.862	1.5866	2.507	1.757	3.018	1.8659	3.392	1.9288	3.74	1.9822	4.798	2.0821	4.799	2.0822	7.07	2.1064
CADN0109	1.151	1.343	1.761	1.5259	5.1508	5.1502	3.066	1.795	3.946	1.9103	4.473	1.9184	4.936	1.9189	6.109	1.928	6.114	1.928	9.425	1.9697	0.965	1.273	1.448	1.4406	1.863	1.5514	2.508	1.6936	3.019	1.7879	3.392	1.8392	3.741	1.8846	4.821	1.931	4.822	1.931	7.049	1.9404
CADN0125	1.152	1.1099	1.762	1.2732	5.1492	5.149	3.067	1.4927	3.947	1.5923	4.474	1.5997	4.938	1.6118	6.11	1.6323	6.116	1.6325	9.557	1.7515	0.965	1.0411	1.448	1.1995	1.863	1.2946	2.508	1.4121	3.02	1.4879	3.393	1.5311	3.742	1.572	4.853	1.6326	4.852	1.6327	7.05	1.6583
CADN0150	1.152	0.9589	1.762	1.0759	5.2855	5.2855	3.068	1.2374	3.948	1.3154	4.476	1.3552	4.939	1.3892	6.114	1.4539	6.12	1.4542	9.49	1.6105	0.966	0.9127	1.449	1.0218	1.864	1.0916	2.509	1.177	3.021	1.2331	3.394	1.2673	3.743	1.2968	4.906	1.4099	4.904	1.4099	7.056	1.4994
CADN0172	1.153	0.9715	1.763	1.0808	5.2428	4.5939	3.069	1.2355	3.949	1.3007	4.477	1.3281	4.94	1.3541	6.116	1.424	6.122	1.4243	9.435	1.6072	0.966	0.9282	1.45	1.0295	1.865	1.0953	2.51	1.1796	3.022	1.2299	3.395	1.2618	3.744	1.2834	5.035	1.3845	5.031	1.3846	7.057	1.4826
CADN0179C	1.153	1.4211	1.764	1.6533	5.1552	4.594	3.07	2.0242	3.95	2.2094	4.477	2.304	5.027	2.3892	6.117	2.5556	6.122	2.5564	9.55	2.9467	0.967	1.3402	1.45	1.5404	1.865	1.6868	2.511	1.8914	3.023	2.0138	3.396	2.0984	3.744	2.1697	5.322	2.515	5.323	2.5151	7.058	2.6797
CADN0210	1.154	0.9131	1.764	1.0166	5.2231	5.2231	3.071	1.0942	3.929	1.1088	4.337	1.1136	4.661	1.1119	5.262	1.1107	5.264	1.1108	6.601	1.2142	0.968	0.8422	1.451	0.9553	1.867	1.0036	2.521	1.0523	3.024	1.0722	3.398	1.0903	3.741	1.0949	5.135	1.2327	5.126	1.2269	5.778	1.1974
CADN0227	1.155	1.271	1.765	1.455	5.1975	5.1975	3.072	1.6358	3.949	1.638	4.437	1.6439	4.832	1.6421	5.642	1.646	5.644	1.646	6.312	1.7021																						
CADN0250	1.155	1.0184	1.766	1.1631	5.8892	6.1348	3.073	1.2811	3.951	1.2822	4.475	1.2905	4.94	1.3052	6.003	1.3158	6.008	1.316	7.974	1.328																						
CADN0275	0.683	0.7573	1.145	0.9076	5.889	5.9184	2.165	1.0738	2.791	1.1303	3.194	1.1652	3.535	1.1919	4.401	1.2435	4.411	1.2449	6.648	1.3019	0.49	0.9939	0.756	1.0273	1.017	1.2285	1.413	1.2374	1.704	1.3765	2.016	1.4309	2.265	1.4624	2.94	1.4168	2.999	1.4197	4.22	1.4651
CADN0310	0.683	0.9987	1.144	1.1912	5.9007	5.4933	2.164	1.435	2.789	1.5456	3.193	1.6078	3.533	1.6501	4.4	1.7153	4.41	1.7163	6.95	1.9792	0.49	0.8947	0.754	1.0243	1.014	1.1508	1.408	1.2625	1.704	1.3601	2.015	1.4337	2.265	1.4762	3.03	1.432	3.037	1.4326	4.567	1.6308
CADN0350	0.683	1.2484	1.145	1.4837	5.903	5.903	2.164	1.8511	2.79	2.0273	3.193	2.129	3.534	2.2071	4.401	2.4013	4.411	2.4035	6.951	2.9101																						
CADN0375	0.683	1.316	1.145	1.5536	5.8961	5.8961	2.165	1.9035	2.791	2.061	3.194	2.1495	3.535	2.2188	4.401	2.3759	4.411	2.3775	6.952	2.6632																						
CADN0409	0.683	1.2971	1.145	1.5434	5.8877	5.8877	2.165	1.9027	2.791	2.0701	3.194	2.1641	3.535	2.2366	4.402	2.3988	4.412	2.4004	6.953	2.7292																						
CADN0425	0.684	1.4202	1.146	1.6864	5.8779	5.8779	2.166	2.068	2.792	2.2274	3.195	2.3125	3.536	2.3752	4.402	2.5149	4.412	2.5163	6.953	2.8367																						
CADN0450	0.684	1.1931	1.146	1.4122	5.5274	5.8527	2.166	1.7394	2.793	1.8872	3.196	1.9682	3.537	2.0275	4.404	2.1542	4.413	2.1555	6.955	2.4035																						
CADN0463C	0.685	1.2243	1.147	1.5746	5.8526	5.8526	2.167	1.8982	2.793	2.0495	3.196	2.133	3.537	2.1972	4.404	2.3421	4.414	2.3436	6.956	2.6734																						
CADN0489	0.685	0.5291	1.147	0.6675	5.8315	5.8315	2.168	0.7489	2.794	0.7559	3.197	0.7572	3.538	0.758	4.389	0.7593	4.398	0.7593	6.214	0.7615																						
CADN0509	0.686	0.526	1.148	0.6753	5.5261	5.5087	2.169	0.8339	2.796	0.8448	3.199	0.8476	3.541	0.8493	4.39	0.8523	4.399	0.8523	6.154	0.8573																						
CADN0525	0.687	0.561	1.149	0.7331	5.5138	5.5137	2.154	0.8271	2.743	0.83	3.053	0.8314	3.241	0.8326	3.593	0.8352	3.597	0.8353	4.41	0.8402																						
CADN0550	0.687	0.4626	1.15	0.5898	5.5233	5.5067	2.02	0.6467	2.349	0.6549	2.433	0.6583	2.515	0.6599	2.741	0.6636	2.744	0.6637	3.32	0.6688																						
CADN0575	0.688	0.3866	1.151	0.4836	5.5047	5.5044	1.87	0.5543	2.059	0.5627	2.109	0.5659	2.155	0.5675	2.23	0.5708	2.231	0.571	2.32	0.5776																						
CADN0598	0.689	0.3364	1.152	0.426	5.5057	5.5055	1.858	0.5175	2.039	0.5291	2.143	0.5332	2.221	0.5354	2.39	0.5401	2.392	0.5402	2.506	0.5475																						
CADN0610	0.689	0.3814	1.152	0.4608	5.5012	5.501	1.86	0.5547	2.04	0.5678	2.144	0.5725	2.222	0.5751	2.392	0.5804	2.394	0.5806	2.52	0.5888																						
CADN0625	0.69	0.5949	1.153	0.6491	5.4981	5.4939	1.861	0.7235	2.04	0.7353	2.145	0.7398	2.223	0.7422	2.394	0.747	2.395	0.7473	2.527	0.7553																						
CADN0638	0.69	0.7506	1.153	0.8525	5.5028	5.4956	1.863	0.9488	2.041	0.9617	2.145	0.9662	2.224	0.9691	2.394	0.974	2.396	0.9743	2.533	0.9827																						
CADN0675	0.69	0.6415	1.154	0.7603	5.5634	5.5634	1.865	0.8742	2.041	0.8897	2.146	0.8952	2.225	0.8985	2.402	0.904	2.404	0.9041	2.655	0.9132	0.497	0.6989	0.763	0.8022	1.022	0.8639	1.416	0.9248	1.713	0.9538	1.921	0.9608	2.048	0.9626	2.351	0.9648	2.353	0.9649	2.509	0.968
CADN0710	0.691	0.4985	1.155	0.5933	5.4793	5.2617	1.866	0.6925	2.024	0.7061	2.113	0.7105	2.172	0.7129	2.329	0.7178	2.331	0.718	3.001	0.7841	0.511	0.452	0.764	0.507	1.023	0.5729	1.417	0.6434	1.715	0.6862	1.911	0.7048	1.973	0.7071	2.006	0.7098	2.006	0.7099	2.025	0.7151
CADN0722	0.715	0.5043	1.156	0.5121	5.4533	5.2611	2.019	0.5891	2.354	0.6297	2.533	0.6543	2.633	0.6693	2.9	0.6935	2.903	0.6941	3.688	0.7778	0.723	0.4765	0.764	0.4796	1.024	0.4804	1.418	0.5057	1.745	0.5541	1.858	0.5722	1.965	0.5788	2.19	0.5899	2.191	0.5903	2.366	0.6036
CADN0734	0.692	0.2871	1.156	0.3336	4.756	4.1393	2.189	0.4854	2.758	0.5766	3.092	0.6299	3.269	0.6581	3.751	0.7198	3.756	0.7204	4.901	0.844	0.661	0.2899	0.765	0.2929	1.024	0.3154	1.418	0.3695	1.759	0.4143	2.023	0.4477	2.255	0.4814	2.814	0.5624	2.816	0.5627	3.241	0.6199
CADN0775	1.073	0.8618	1.563	0.8903	4.7735	4.5408	2.51	0.9652	3.016	1.0161	3.297	1.056	3.451	1.0794	3.709	1.1173	3.714	1.1204	3.948	1.1745	1.101	0.9382	1.562	0.9811	1.931	1.0278	2.51	1.0738	3.028	1.1219	3.342	1.1585	3.53	1.1737	3.832	1.1965	3.838	1.1977	4.084	1.2273
CADN0800	1.074	0.6106	1.563	0.7124	4.7733	4.7547	2.511	0.8373	3.031	0.8984	3.362	0.9385	3.588	0.966	4.032	1.0199	4.037	1.0209	4.711	1.0895	1.074	0.5981	1.563	0.7139	1.933	0.7826	2.511	0.8649	3.031	0.9261	3.372	0.9637	3.607	0.9879	4.057	1.0359	4.064	1.037	4.651	1.091
CADN0835	1.075	0.5948	1.564	0.6907	4.7725	4.754	2.513	0.8013	3.033	0.8464	3.383	0.8783	3.651	0.9043	4.282	0.9738	4.29	0.975	5.913	1.1697	1.075	0.589	1.564	0.6914	1.934	0.7493	2.513	0.816	3.033	0.861	3.383	0.8893	3.652	0.9124	4.283	0.9776	4.29	0.9786	5.888	1.1627
CADN0850	1.076	0.6792	1.565	0.7745	4.7721	4.7638	2.514	0.8782	3.034	0.9168	3.384	0.9425	3.653	0.9633	4.306	1.0217	4.315	1.0224	6.088	1.1955	1.076	0.6757	1.565	0.775	1.935	0.8284	2.514	0.8877	3.034	0.9261	3.384	0.9495	3.653	0.9684	4.306	1.0234	4.316	1.0244	6.08	1.193
CADN0875	1.076	0.8548	1.566	0.9586	4.7752	4.767	2.515	1.0893	3.034	1.1403	3.384	1.1711	3.64	1.1938	4.24	1.2386	4.247	1.2392	5.721	1.3516	1.077	0.8525	1.566	0.9589	1.936	1.0221	2.514	1.0957	3.034	1.1469	3.384	1.176	3.642	1.1975	4.24	1.2398	4.248	1.2406	5.714	1.3499
CADN0900	1.077	0.9858	1.567	1.106	4.8463	4.8461	2.515	1.2713	3.035	1.3398	3.385	1.3803	3.655	1.4122	4.385	1.5029	4.394	1.5041	6.364	1.7276	1.077	0.9854	1.567	1.1061	1.936	1.1807	2.515	1.2737	3.035	1.3424	3.385	1.3823	3.655	1.4136	4.385	1.5035	4.395	1.5046	6.363	1.7278
CADN0933	1.078	1.0612	1.567	1.1989	4.8538	4.8538	2.516	1.3964	3.036	1.4857	3.386	1.5398	3.656	1.5797	4.386	1.6815	4.395	1.6828	6.723	1.9301	1.078	1.0613	1.567	1.1989	1.937	1.2841	2.516	1.3969	3.036	1.4863	3.386	1.5403	3.656	1.5801	4.386	1.6816	4.396	1.6829	6.723	1.9303
CADN0950	1.078	1.1809	1.568	1.3242	4.8372	4.8372	2.517	1.5167	3.037	1.6061	3.386	1.6633	3.656	1.7056	4.386	1.8118	4.396	1.8132	6.724	2.0176	1.078	1.1809	1.568	1.3243	1.938	1.4089	2.516	1.5167	3.036	1.6062	3.386	1.6634	3.657	1.7057	4.387	1.8119	4.396	1.8132	6.725	2.0176
CADN0975	1.079	1.2826	1.568	1.4353	4.751	4.7508	2.517	1.5963	3.037	1.66	3.387	1.7058	3.657	1.7399	4.387	1.8266	4.397	1.8278	6.725	2.0379	1.079	1.2826	1.568	1.4353	1.938	1.5159	2.517	1.5963	3.037	1.66	3.387	1.7058	3.657	1.74	4.387	1.8267	4.397	1.8278	6.726	2.0379
CADN1000	1.079	1.3133	1.569	1.4761	4.7501	4.7497	2.518	1.5948	3.038	1.6436	3.388	1.6829	3.658	1.713	4.388	1.7914	4.398	1.7924	6.727	2.0028	1.079	1.3133	1.569	1.4761	1.938	1.543	2.518	1.5948	3.038	1.6436	3.388	1.6829	3.658	1.713	4.388	1.7914	4.398	1.7924	6.727	2.0028
CADN1037	1.08	1.351	1.57	1.5024	2.9708	2.9706	2.519	1.5564	3.039	1.5945	3.389	1.6269	3.659	1.6541	4.389	1.7262	4.399	1.7272	6.729	1.9309	1.08	1.3509	1.569	1.5024	1.939	1.5369	2.519	1.5564	3.039	1.5945	3.389	1.6269	3.659	1.6541	4.389	1.7262	4.399	1.7272	6.729	1.9309
Ditch0025	0.457	1.6362	0.513	1.6947	6.6887	6.6887	0.568	1.7465	0.581	1.758	0.587	1.7636	0.592	1.768	0.602	1.7767	0.602	1.7767	0.661	1.8254	0.767	1.9058	1.049	2.0839	1.156	2.1427	1.489	2.3089	1.626	2.3691	1.671	2.3881	1.688	2.3951	1.727	2.4113	1.728	2.4114	1.84	2.4561
Ditch0050	0.315	1.3669	0.327	1.3843	7.5068	7.5068	0.336	1.397	0.339	1.3999	0.34	1.4014	0.34	1.4025	0.342	1.4048	0.342	1.4048	0.349	1.4146	0.767	1.8171	1.05	1.9991	1.157	2.0577	1.49	2.2211	1.605	2.2741	1.634	2.287	1.648	2.2929	1.68	2.3072	1.681	2.3072	1.772	2.3461
Ditch0075	0.315	1.2838	0.321	1.2917	7.2189	7.2189	0.324	1.2961	0.325	1.297	0.325	1.2974	0.325	1.2978	0.326	1.2983	0.326	1.2983	0.328	1.3013	0.768	1.7308	1.051	1.914	1.157	1.9732	1.49	2.1347	1.606	2.184	1.635	2.196	1.648	2.2015	1.681	2.2149	1.681	2.215	1.773	2.2547
Ditch0100	0.316	1.2137	0.321	1.2214	6.7447	6.7447	0.325	1.2257	0.325	1.2266	0.326	1.227	0.326	1.2274	0.326	1.2279	0.326	1.2279	0.328	1.2308	0.768	1.6531	1.051	1.8355	1.158	1.8946	1.491	2.0566	1.606	2.1062	1.635	2.1182	1.649	2.1238	1.682	2.1371	1.682	2.1372	1.773	2.1734
Ditch0125	0.316	0.8781	0.322	0.8837	6.3199	6.3199	0.325	0.8867	0.326	0.8874	0.326	0.8877	0.326	0.8879	0.327	0.8883	0.327	0.8883	0.329	0.8904																						
Ditch0150	0.411	0.9436	0.429	0.9606	5.5439	5.5439	0.439	0.9704	0.442	0.9724	0.443	0.9733	0.443	0.974	0.445	0.9752	0.445	0.9753	0.452	0.9816																						
Ditch0175	0.463	1.0175	0.52	1.0671	6.1606	6.1606	0.567	1.1064	0.577	1.1138	0.58	1.117	0.583	1.1193	0.589	1.1237	0.589	1.1237	0.618	1.1467																						
Ditch0200	0.464	1.0208	0.52	1.0592	6.1056	6.1056	0.577	1.0971	0.59	1.1062	0.596	1.1104	0.601	1.1138	0.611	1.121	0.611	1.121	0.663	1.1567																						
Ditch0210	0.464	1.1134	0.521	1.162	5.6262	5.6262	0.577	1.2037	0.59	1.2124	0.596	1.2163	0.601	1.2189	0.61	1.2245	0.611	1.2245	0.663	1.2548																						
Ditch0230	0.465	0.8926	0.521	0.9294	5.9863	5.9862	0.578	0.9648	0.591	0.973	0.597	0.9767	0.601	0.9794	0.611	0.9855	0.611	0.9856	0.653	1.0081																						
Ditch0250	0.465	0.7892	0.522	0.8254	5.8877	5.8877	0.578	0.8588	0.591	0.8663	0.597	0.8697	0.601	0.8721	0.611	0.8775	0.611	0.8776	0.646	0.8941																						
Ditch0272	0.465	0.8463	0.522	0.8839	5.6631	5.6631	0.578	0.9189	0.592	0.9268	0.598	0.9304	0.602	0.933	0.612	0.9387	0.612	0.9388	0.639	0.9511																						
Ditch0305	0.466	1.4646	0.522	1.6427	4.0389	2.5395	0.579	1.8201	0.592	1.8615	0.598	1.8806	0.602	1.894	0.612	1.9246	0.612	1.9249	0.636	2.001																						
Ditch0328	0.466	0.2848	0.506	0.2854	4.0428	2.5609	0.523	0.2857	0.527	0.2858	0.531	0.2859	0.533	0.286	0.536	0.2858	0.536	0.2863	0.543	0.2866																						
Ditch0350	0.479	0.2191	0.504	0.2205	3.2674	2.5481	0.528	0.2211	0.534	0.2215	0.537	0.2214	0.541	0.2216	0.542	0.2209	0.546	0.2215	0.558	0.2228																						
Ditch0369	0.493	0.1592	0.523	0.1611	3.7869	2.6331	0.554	0.162	0.572	0.1621	0.583	0.1623	0.592	0.1624	0.604	0.1618	0.609	0.1625	0.644	0.164																						
Ditch0387	0.532	0.1116	0.581	0.1133	4.0471	2.631	0.674	0.1148	0.705	0.1148	0.729	0.1152	0.742	0.1152	0.769	0.1147	0.777	0.1157	0.849	0.1214	0.845	1.2496	1.067	1.259	1.259	1.2634	1.385	1.2716	1.458	1.2716	1.496	1.2734	1.519	1.2788	1.56	1.2783	1.565	1.2754	1.661	1.2839
Ditch0400	0.538	0.1263	0.688	0.1291	3.7219	2.6128	0.844	0.131	0.899	0.1332	0.935	0.1363	0.956	0.1385	0.995	0.1412	1.005	0.1431	1.126	0.1524	0.788	1.5027	1.072	1.5323	1.264	1.5398	1.464	1.5458	1.624	1.5504	1.687	1.5525	1.728	1.5537	1.793	1.5548	1.797	1.5564	1.928	1.5638
Ditch0425	0.582	0.1935	0.797	0.1988	4.2068	2.6154	0.994	0.202	1.091	0.2022	1.145	0.2045	1.186	0.2072	1.252	0.2113	1.262	0.2138	1.429	0.2276	0.789	1.1241	1.076	1.2126	1.268	1.2238	1.541	1.2356	1.799	1.2424	1.895	1.2459	1.955	1.2486	2.094	1.2525	2.098	1.254	2.352	1.2635
Ditch0450	0.581	0.2575	0.799	0.2653	4.2059	2.5776	1.038	0.2705	1.164	0.2709	1.221	0.2765	1.266	0.2806	1.347	0.2861	1.357	0.2896	1.538	0.3086	0.793	0.9165	1.081	0.9936	1.272	1.0092	1.547	1.0226	1.821	1.031	1.932	1.0348	2.022	1.037	2.202	1.0423	2.207	1.0435	2.582	1.0555
Ditch0475	0.582	0.3508	0.803	0.3599	4.2208	2.3967	1.059	0.3659	1.188	0.3673	1.247	0.368	1.291	0.3686	1.378	0.3662	1.387	0.3703	1.573	0.3935	0.796	0.9013	1.082	0.9704	1.275	0.9869	1.552	1.0012	1.829	1.0095	1.944	1.0139	2.038	1.0162	2.223	1.0221	2.228	1.0235	2.63	1.0353
Ditch0500	0.583	0.5126	0.806	0.5185	4.07	2.5979	1.077	0.5234	1.209	0.5245	1.274	0.5254	1.319	0.5272	1.407	0.5246	1.418	0.5291	1.61	0.5557	0.802	0.8952	1.083	0.9611

Channel ID	Baseline																				Post-development																	
	1 in 2 year		1 in 5 year		1 in 10 year		1 in 25 year		1 in 50 year		1 in 75 year		1 in 100 year		1 in 100 year + CC (20%)		1 in 200 year		1 in 1000 year		1 in 2 year		1 in 5 year		1 in 10 year		1 in 25 year		1 in 50 year		1 in 75 year		1 in 100 year		1 in 100 year + CC (20%		1 in 200 year		1 in 1000 year	
	Qmax	Vmax	Qmax	Vmax	5.3467	5.3467	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax	Qmax	Vmax
NDD0183																					0.769	1.1488	1.052	1.2925	1.158	1.3399	1.492	1.4717	1.607	1.5127	1.636	1.5226	1.65	1.5272	1.682	1.5383	1.683	1.5383	1.774	1.5686
NDU0028																					1.465	1.049	1.471	1.058	1.483	1.0614	1.517	1.0638	1.499	1.0659	1.501	1.0666	1.531	1.0678	1.53	1.0675	1.507	1.0682	1.542	1.0708
S114																					0.968	2.0693	1.564	2.2267	1.866	2.297	2.668	2.4615	3.025	2.527	3.4	2.5916	3.747	2.6483	5.727	5.5068	5.729	5.5069	7.104	5.5514
S114A																					0.488	1.4849	0.706	1.6795	0.889	1.9234	1.262	2.0405	1.387	2.0504	1.538	2.1211	1.713	2.2319	2.002	2.2977	2.002	2.2977	3.616	2.8812
S115A																					0.494	1.4417	0.759	1.5494	1.018	1.8016	1.418	1.9887	1.709	2.1119	2.02	2.1567	2.27	2.0465	3.036	2.0465	3.042	1.9634	4.596	2.1391
S115B																					0.53	1.4735	0.765	1.6502	1.021	1.8033	1.415	1.9933	1.712	2.1133	2.024	2.2246	2.274	2.3056	3.265	2.5918	3.274	2.5954	4.671	2.8258
S115C																					0.493	1.4406	0.758	1.539	1.016	1.5864	1.415	1.8083	1.707	1.88	2.019	1.985	2.268	2.0609	3.034	2.2639	3.04	2.2654	4.594	2.5968
S116A-1																					0	0	0	0	0	0.2385	0.334	1.1836	0.443	1.5691	0.457	1.6163	0.461	1.6303	0.476	1.6833	0.476	1.6838	0.517	1.8297
S116A-2																					0	0	0	0	0	0	0.334	1.333	0.443	1.7064	0.457	1.7514	0.461	1.7634	0.476	1.7636	0.476	1.7634	0.517	1.841
S116-S118																					0.773	1.8078	1.056	2.1189	1.163	2.3336	1.18	2.3669	1.2	2.408	1.222	2.4515	1.234	2.476	1.259	2.526	1.259	2.5265	1.331	2.6702
S118A																					0	0	0	0	0	0.2053	0.335	1.2274	0.443	1.5692	0.457	1.6164	0.461	1.6304	0.476	1.6834	0.476	1.6839	0.517	1.8298

Node ID	Baseline										Post-development									
	1 in 2 year	1 in 5 year	1 in 10 year	1 in 25 year	1 in 50 year	1 in 75 year	1 in 100 year	1 in 100 year +CC (20%)	1 in 200 year	1 in 1000 year	1 in 2 year	1 in 5 year	1 in 10 year	1 in 25 year	1 in 50 year	1 in 75 year	1 in 100 year	1 in 100 year +CC (20%)	1 in 200 year	1 in 1000 year
	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax
350.1											49.8518	49.9916	50.075	50.1301	50.1798	50.2304	50.2751	50.526	50.5266	50.8171
350.2											49.8447	49.9835	50.0664	50.1167	50.1664	50.217	50.2624	50.5198	50.5203	50.8129
1.285.1											52.8132	52.8804	52.9385	53.0162	53.0685	53.125	53.1713	53.3092	53.3103	53.6028
1.285.2											52.5178	52.6285	52.6963	52.8159	52.882	52.9634	53.0259	53.2105	53.212	53.5836
124.281.1											52.2333	52.3451	52.4297	52.5417	52.6194	52.6957	52.7541	52.9222	52.9235	53.2321
124.281.2											52.1173	52.2707	52.3618	52.4796	52.562	52.6421	52.7033	52.8787	52.8801	53.2003
173.258.1											51.8664	51.9257	51.9743	52.0382	52.0789	52.1184	52.1477	52.2275	52.2281	52.3599
173.258.2											51.0798	51.1395	51.1876	51.2498	51.2897	51.328	51.3564	51.4338	51.4344	51.5624
239.434.2											50.6332	50.6886	50.7343	50.7946	50.8339	50.872	50.9004	50.9777	50.9783	51.1075
276.611.2											50.2583	50.348	50.4219	50.5143	50.5732	50.6312	50.6738	50.7816	50.7821	50.9261
Cad_at_Dit.2	53.5058	53.6434	53.7286	53.8066	53.8484	53.8685	53.8825	53.9148	53.9152	53.996	53.4825	53.5209	53.5965	53.6925	53.7563	53.7995	53.8267	53.8929	53.8937	54.1659
CADN0025.1	47.3278	47.331	47.3436	47.3689	47.4014	47.4226	47.4421	47.494	47.4942	47.6472	47.3278	47.3278	47.3334	47.3509	47.3672	47.3805	47.3935	47.4366	47.4366	47.538
CADN0025.2	47.31	47.31	47.31	47.31	47.31	47.31	47.31	47.31	47.31	47.31	47.31	47.31	47.31	47.31	47.31	47.31	47.31	47.31	47.31	47.31
CADN0050.1	47.3921	47.464	47.5227	47.6111	47.6981	47.7414	47.7792	47.8646	47.8649	48.0466	47.3717	47.4264	47.4762	47.5509	47.6058	47.6458	47.6796	47.7671	47.7671	47.9254
CADN0075.1	47.7946	47.9023	47.9717	48.0663	48.1547	48.2058	48.2408	48.3164	48.3167	48.4818	47.7537	47.8508	47.9175	48.0029	48.061	48.1025	48.1365	48.2309	48.2309	48.37
CADN0109.1	48.4415	48.5365	48.6029	48.6962	48.7807	48.8315	48.8622	48.9307	48.931	49.0782	48.4094	48.489	48.5508	48.6331	48.6904	48.7315	48.7637	48.8552	48.8552	48.9781
CADN0125.1	48.6428	48.7426	48.81	48.902	48.9885	49.0345	49.0678	49.1401	49.1404	49.2981	48.6066	48.6942	48.7572	48.8401	48.8969	48.9358	48.9703	49.0597	49.0597	49.1898
CADN0150.1	48.8729	48.9623	49.0242	49.1101	49.1907	49.2349	49.2695	49.3466	49.347	49.5179	48.8415	48.9186	48.9757	49.0524	49.1054	49.1413	49.1729	49.2642	49.2642	49.4002
CADN0172.1	49.0939	49.1663	49.2142	49.2856	49.3554	49.3962	49.4333	49.5068	49.5071	49.6765	49.0688	49.1304	49.1773	49.238	49.2826	49.3125	49.342	49.4416	49.4416	49.5594
CADN0179C.1	49.2958	49.403	49.4874	49.6076	49.7325	49.8049	49.8644	50.0201	50.0208	50.4237	49.2599	49.35	49.4204	49.5263	49.6016	49.6561	49.7046	49.8555	49.8556	50.1365
CADN0210.1	49.4882	49.5815	49.6526	49.7546	49.8575	49.9118	49.9549	50.0802	50.0808	50.4452	49.4708	49.5453	49.6132	49.7067	49.7647	49.81	49.8483	49.9565	49.9565	50.189
CADN0227.1	49.6974	49.7907	49.8577	49.9526	50.0298	50.0706	50.1017	50.1858	50.1862	50.4719										
CADN0250.1	49.8929	49.9895	50.0564	50.1451	50.2134	50.2509	50.2802	50.3444	50.3447	50.5328										
CADN0275.1	49.9806	50.0859	50.1543	50.249	50.32	50.3593	50.3906	50.4578	50.4583	50.6044	50.0033	50.0989	50.1692	50.2497	50.3016	50.3536	50.3961	50.5625	50.5629	50.8248
CADN0310.1	50.2794	50.3907	50.4615	50.5651	50.6455	50.6909	50.728	50.8048	50.8056	50.9483										
CADN0350.1	50.8329	50.9478	51.0214	51.1385	51.234	51.2897	51.3336	51.436	51.4371	51.6908										
CADN0375.1	51.2293	51.3382	51.4093	51.5222	51.6139	51.6676	51.7104	51.8109	51.812	52.061										
CADN0409.1	51.7358	51.8492	51.9226	52.0386	52.1304	52.184	52.2267	52.3275	52.3286	52.5786										
CADN0425.1	52.0562	52.1329	52.1824	52.2605	52.3237	52.3605	52.3899	52.4563	52.457	52.6092										
CADN0450.1	52.6542	52.7117	52.7482	52.805	52.8509	52.8776	52.899	52.9484	52.949	53.0673										
CADN0463C.1	52.7902	52.9165	52.9809	53.0978	53.192	53.2499	53.2975	53.4137	53.415	53.7259										
CADN0489.1	52.9306	53.0145	53.0724	53.1761	53.2607	53.3121	53.3544	53.4563	53.4574	53.7411										
CADN0509.1	52.9838	53.0844	53.1496	53.2568	53.3387	53.3858	53.4242	53.5162	53.5172	53.7571										
CADN0525.1	53.0253	53.1395	53.2121	53.3207	53.4003	53.4432	53.4755	53.5462	53.547	53.765										
CADN0550.1	53.0643	53.1903	53.2683	53.3741	53.4468	53.4827	53.5083	53.5689	53.5696	53.7727										
CADN0575.1	53.0889	53.2219	53.3033	53.4053	53.4731	53.5044	53.5273	53.5825	53.5831	53.7767										
CADN0598.1	53.1046	53.2422	53.3262	53.4268	53.4921	53.5224	53.5446	53.5977	53.5984	53.7789										
CADN0610.1	53.118	53.2566	53.3414	53.4405	53.5043	53.5342	53.556	53.608	53.6086	53.7804										
CADN0625.1	53.1805	53.3098	53.3913	53.4815	53.5392	53.5672	53.5877	53.636	53.6365	53.7846										
CADN0638.1	53.2566	53.382	53.4612	53.5421	53.592	53.6172	53.6357	53.6788	53.6793	53.793										
CADN0675.1	53.4107	53.5415	53.6233	53.6968	53.737	53.7573	53.772	53.8046	53.8049	53.8687	53.3639	53.4428	53.5063	53.5933	53.6529	53.6978	53.7299	53.84	53.8412	54.1576
CADN0675.2											53.0621	53.1464	53.2272	53.3375	53.4129	53.4867	53.5428	53.7461	53.7478	54.1476
CADN0710.1	53.4928	53.625	53.7077	53.7804	53.818	53.8367	53.8494	53.8779	53.8782	53.9448	53.4341	53.5212	53.5906	53.6816	53.7427	53.7851	53.8103	53.8751	53.8759	54.1605
CADN0722.1	53.5051	53.6392	53.7231	53.7979	53.8365	53.8551	53.868	53.8969	53.8973	53.9656	53.4468	53.5334	53.6044	53.697	53.759	53.7995	53.824	53.8851	53.8858	54.162
CADN0734.1	53.5093	53.6446	53.7292	53.8067	53.8484	53.8685	53.8824	53.9139	53.9143	53.9876	53.4493	53.5378	53.6095	53.703	53.7658	53.807	53.8323	53.8944	53.8951	54.1641
CADN0775.1	53.7182	53.7984	53.8589	53.9358	53.9882	54.0141	54.0292	54.0563	54.0566	54.099	53.7316	53.7951	53.8413	53.9109	53.9661	53.9981	54.0174	54.0506	54.051	54.1783
CADN0800.1	53.7995	53.8877	53.9486	54.0291	54.0874	54.1186	54.138	54.173	54.1734	54.2247	53.8047	53.8862	53.9398	54.0156	54.0752	54.1104	54.1324	54.171	54.1714	54.2403
CADN0835.1	53.8923	53.9894	54.0531	54.1381	54.2013	54.2372	54.2613	54.31	54.3106	54.4027	53.8948	53.9888	54.0488	54.1313	54.195	54.233	54.2585	54.309	54.3096	54.4036
CADN0850.1	53.952	54.0516	54.1158	54.2017	54.2661	54.3033	54.3287	54.382	54.3826	54.4848	53.9536	54.0512	54.113	54.1971	54.2617	54.3004	54.3267	54.3813	54.382	54.4852
CADN0875.1	54.1128	54.208	54.27	54.3537	54.4179	54.4563	54.4823	54.5382	54.5388	54.6497	54.1131	54.2079	54.2691	54.352	54.4162	54.4551	54.4816	54.5379	54.5386	54.6495
CADN0900.1	54.3211	54.4122	54.472	54.5537	54.6167	54.6553	54.6827	54.7481	54.7489	54.8902	54.3211	54.4122	54.4719	54.5534	54.6163	54.6549	54.6825	54.748	54.7488	54.8901
CADN0933.1	54.5875	54.6822	54.7434	54.8264	54.8902	54.9294	54.9579	55.0293	55.0302	55.2071	54.5876	54.6822	54.7434	54.8263	54.8901	54.9293	54.958	55.0293	55.0302	55.2072
CADN0950.1	54.7748	54.8694	54.9305	55.0125	55.0756	55.1141	55.1424	55.2138	55.2147	55.3994	54.7749	54.8694	54.9306	55.0124	55.0756	55.1141	55.1424	55.2138	55.2147	55.3995
CADN0975.1	55.0805	55.1721	55.2323	55.3092	55.3679	55.4032	55.4291	55.495	55.4958	55.6747	55.0806	55.1721	55.2323	55.3092	55.3679	55.4032	55.4291	55.495	55.4958	55.6748
CADN1000.1	55.3892	55.4847	55.544	55.6164	55.6709	55.7037	55.7278	55.7885	55.7893	55.9568	55.3892	55.4847	55.5441	55.6164	55.6709	55.7038	55.7278	55.7885	55.7893	55.9568
CADN1037.1	55.8447	55.9446	55.9999	56.0655	56.1149	56.1452	56.1669	56.2219	56.2226	56.3747	55.8447	55.9446	55.9999	56.0655	56.1149	56.1452	56.1669	56.2219	56.2226	56.3747
Ditch0025.1	46.1064	46.1172	46.1226	46.1272	46.1294	46.1305	46.1314	46.1331	46.1331	46.1429	46.1596	46.1992	46.2128	46.2512	46.2654	46.27	46.2716	46.2755	46.2755	46.2862
Ditch0025.2	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51
Ditch0050.1	47.4005	47.4031	47.4041	47.405	47.4054	47.4056	47.4058	47.4062	47.4062	47.4076	47.4772	47.514	47.5266	47.5625	47.574	47.5768	47.5781	47.5812	47.5812	47.5898
Ditch0075.1	48.6644	48.6655	48.6658	48.6661	48.6662	48.6663	48.6663	48.6664	48.6664	48.6668	48.735	48.7692	48.7809	48.8144	48.8251	48.8278	48.829	48.8319	48.8319	48.84
Ditch0100.1	49.9649	49.9659	49.9662	49.9665	49.9666	49.9666	49.9667	49.9668	49.9668	49.9671	50.0304	50.0623	50.0732	50.1047	50.1147	50.1172	50.1184	50.1211	50.1211	50.1287
Ditch0125.1	50.4772	50.4788	50.4792	50.4796	50.4798	50.4799	50.4799	50.48	50.48	50.4806										
Ditch0150.1	50.9541	50.9594	50.961	50.9625	50.9632	50.9634	50.9637	50.9641	50.9641	50.9661										
Ditch0175.1	51.4646	51.4803	51.4877	51.4928	51.4952	51.4962	51.497	51.4984	51.4984	51.5056										

Node ID	Baseline										Post-development									
	1 in 2 year	1 in 5 year	1 in 10 year	1 in 25 year	1 in 50 year	1 in 75 year	1 in 100 year	1 in 100 year +CC (20%)	1 in 200 year	1 in 1000 year	1 in 2 year	1 in 5 year	1 in 10 year	1 in 25 year	1 in 50 year	1 in 75 year	1 in 100 year	1 in 100 year +CC (20%)	1 in 200 year	1 in 1000 year
	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax	Hmax
Ditch0200.1	51.9375	51.947	51.9524	51.9575	51.9602	51.9615	51.9625	51.9647	51.9647	51.9759										
Ditch0210.1	52.2298	52.2424	52.2486	52.2534	52.2558	52.2569	52.2576	52.2592	52.2592	52.268										
Ditch0230.1	52.4355	52.4503	52.4581	52.4645	52.4678	52.4692	52.4703	52.4726	52.4727	52.4824										
Ditch0250.1	52.5763	52.5943	52.6036	52.6112	52.6151	52.6168	52.618	52.6208	52.6208	52.6306										
Ditch0272.1	52.7418	52.762	52.7724	52.781	52.7853	52.7872	52.7886	52.7917	52.7918	52.8006										
Ditch0305.1	53.467	53.6253	53.7184	53.801	53.8447	53.8652	53.8796	53.913	53.9133	53.9984										
Ditch0328.1	53.4694	53.6266	53.7192	53.8016	53.8451	53.8656	53.88	53.9133	53.9136	53.9986										
Ditch0350.1	53.4706	53.627	53.7194	53.8017	53.8451	53.8656	53.88	53.9133	53.9137	53.9987										
Ditch0369.1	53.4709	53.6272	53.7195	53.8017	53.8452	53.8656	53.8801	53.9133	53.9137	53.9987										
Ditch0387.1	53.4711	53.6272	53.7195	53.8017	53.8452	53.8657	53.8801	53.9133	53.9137	53.9987	52.405	52.9947	53.3779	53.5099	53.627	53.7131	53.7615	53.863	53.864	54.1645
Ditch0387.2											52.1405	52.9917	53.3771	53.5093	53.6267	53.7129	53.7614	53.8629	53.8639	54.1644
Ditch0400.1	53.4712	53.6272	53.7195	53.8018	53.8452	53.8657	53.8801	53.9133	53.9137	53.9987	52.613	53.0015	53.3792	53.5107	53.6274	53.7133	53.7617	53.8631	53.8641	54.1645
Ditch0425.1	53.4719	53.6274	53.7196	53.8018	53.8453	53.8657	53.8801	53.9134	53.9137	53.9987	52.8544	53.0452	53.3865	53.5156	53.6296	53.7146	53.7626	53.8636	53.8646	54.1646
Ditch0450.1	53.4732	53.628	53.72	53.802	53.8454	53.8659	53.8803	53.9135	53.9139	53.9988	52.9927	53.115	53.3996	53.5261	53.6353	53.7177	53.7649	53.8649	53.8658	54.1648
Ditch0475.1	53.4753	53.629	53.7206	53.8024	53.8456	53.8661	53.8805	53.9137	53.914	53.9989	53.1025	53.1947	53.4189	53.5411	53.6448	53.7232	53.7688	53.8668	53.8678	54.1651
Ditch0500.1	53.4829	53.6326	53.7228	53.8037	53.8466	53.8669	53.8812	53.9142	53.9146	53.9993	53.2779	53.3495	53.4752	53.587	53.6746	53.7424	53.7835	53.8738	53.8747	54.1658
Ditch0525.1	53.4911	53.6364	53.7247	53.8047	53.8474	53.8675	53.8817	53.9146	53.915	53.9995	53.3554	53.428	53.5223	53.6263	53.6986	53.7563	53.7934	53.8785	53.8793	54.1661
Ditch0550.1	53.4974	53.6397	53.7269	53.8062	53.8485	53.8685	53.8826	53.9152	53.9156	53.9997	53.3928	53.4683	53.5529	53.6528	53.7206	53.7724	53.8065	53.8855	53.8863	54.1664
Ditch0575.1	53.4993	53.6405	53.7272	53.8063	53.8484	53.8685	53.8826	53.9151	53.9155	53.9993	53.409	53.4821	53.5637	53.6623	53.7288	53.7784	53.811	53.8871	53.8879	54.1664
Ditch0600.1	53.5009	53.6412	53.7275	53.8063	53.8484	53.8685	53.8826	53.9151	53.9155	53.9991	53.4204	53.4921	53.5722	53.6701	53.7357	53.7834	53.8145	53.8886	53.8894	54.1664
Ditch0630.1	53.503	53.6422	53.728	53.8064	53.8484	53.8685	53.8826	53.9151	53.9155	53.999	53.4453	53.5053	53.5834	53.6807	53.7452	53.7905	53.8198	53.8909	53.8916	54.1664
Ditch0645.1	53.5044	53.6428	53.7283	53.8065	53.8484	53.8685	53.8825	53.915	53.9154	53.9982	53.4622	53.5131	53.59	53.6866	53.7509	53.795	53.8233	53.892	53.8928	54.1662
MH116A-1to-2											50.906	50.906	50.9279	52.5557	52.909	52.9564	52.993	53.0454	53.0459	53.199
MH118A116A-1											50.998	50.998	51.0142	52.8023	53.3423	53.4161	53.4607	53.544	53.5448	53.7882
NDD0000.1											51.2872	51.3914	51.4269	51.5316	51.5686	51.578	51.5823	51.5929	51.593	51.6221
NDD0000.2											51.2523	51.3541	51.3887	51.491	51.5272	51.5364	51.5407	51.551	51.5511	51.5796
NDD0010.2											50.939	51.0137	51.0387	51.1113	51.1363	51.1427	51.1456	51.1527	51.1528	51.1723
NDD0080.2											50.8952	50.9668	50.9907	51.06	51.0839	51.0899	51.0927	51.0995	51.0995	51.1181
NDD0100.2											50.7942	50.8615	50.884	50.9492	50.9716	50.9772	50.9799	50.9862	50.9862	51.0037
NDD0126.2											50.668	50.729	50.7493	50.8078	50.8277	50.8327	50.835	50.8405	50.8406	50.8559
NDD0160.2											50.5283	50.5809	50.5987	50.6488	50.6647	50.6685	50.6703	50.6746	50.6747	50.6865
NDU0028.2											52.1233	52.9909	53.3769	53.5091	53.6265	53.7128	53.7613	53.8628	53.8638	54.1644
S114A.1											50.7372	50.8236	50.957	51.0253	51.0428	51.0854	51.1345	51.2073	51.2072	51.5841
S114A.2											50.1346	50.1754	50.2133	50.2664	50.3097	50.3378	50.3662	50.5549	50.555	50.8318
S118A.1											51.975	51.975	51.9848	52.9587	53.6171	53.7078	53.7574	53.8603	53.8613	54.1619
Trib0025.1	50.122	50.1718	50.2112	50.2666	50.3102	50.3428	50.3661	50.425	50.4249	50.5904										
Trib0046.1	50.3828	50.4454	50.4886	50.5402	50.58	50.6019	50.6192	50.6595	50.6595	50.7676										
Trib0064.1	50.5451	50.6045	50.647	50.7002	50.7425	50.7661	50.7847	50.8271	50.8271	50.9288										
Trib0077.1	50.6801	50.7365	50.7772	50.8294	50.8726	50.8969	50.9167	50.9621	50.962	51.0726	50.7683	50.8545	50.9766	51.0432	51.0676	51.1077	51.1504	51.2233	51.2233	51.5884
Trib0102.1	51.0281	51.0843	51.1248	51.1774	51.2214	51.2472	51.2687	51.3203	51.3203	51.4508	50.9994	51.0607	51.1194	51.1812	51.2056	51.244	51.2707	51.3212	51.3212	51.6244
Trib0127.1	51.3975	51.4504	51.489	51.5393	51.5816	51.6064	51.6271	51.677	51.6769	51.8075	51.4119	51.4601	51.4913	51.5383	51.5842	51.6072	51.6268	51.6769	51.6769	51.8238
Trib0152.1	51.7446	51.7968	51.8348	51.8843	51.9259	51.9503	51.9706	52.0194	52.0194	52.1506	51.7381	51.7933	51.8346	51.8845	51.9257	51.9504	51.9707	52.0194	52.0194	52.1502
Trib0177.1	52.1239	52.1738	52.2105	52.2585	52.299	52.3228	52.3427	52.3904	52.3904	52.5205	52.1272	52.1753	52.2107	52.2584	52.2991	52.3228	52.3427	52.3904	52.3904	52.5205
Trib0202.1	52.7186	52.775	52.8068	52.8485	52.8836	52.9041	52.9213	52.9626	52.9626	53.078	52.7229	52.775	52.8068	52.8485	52.8836	52.9041	52.9213	52.9626	52.9626	53.078
Trib0227.1	53.3747	53.4128	53.4468	53.4911	53.5282	53.5499	53.5681	53.6113	53.6114	53.7305	53.3717	53.4128	53.4468	53.4911	53.5282	53.5499	53.5681	53.6113	53.6114	53.7305
Trib0252.1	53.9945	54.0507	54.0869	54.1338	54.1732	54.1962	54.2154	54.2612	54.2612	54.3848	53.9966	54.0507	54.0869	54.1338	54.1732	54.1962	54.2154	54.2612	54.2612	54.3848
Trib0277.1	54.6529	54.7017	54.7398	54.7892	54.8305	54.8547	54.8748	54.9227	54.9227	55.0482	54.6515	54.7017	54.7398	54.7892	54.8305	54.8547	54.8748	54.9227	54.9227	55.0482

Appendix D

BLOCKAGE AND SENSITIVITY ANALYSIS

Legend

- Model extent
- Proposed highways

Sensitivity analysis:

- 1 in 100 year proposed
- Roughness minus 20%
- Roughness plus 20%

Flood mapping at these locations shows water underneath structures. The flood model does not predict flooding of the highways.

AFON CADNANT MODELLING, A487 CAERNARFON TO BONTNEWYDD BYPASS

CADNANT ROUGHNESS SENSITIVITY ANALYSIS 1 IN 100 YEAR EVENT

WSP | PARSONS BRINCKERHOFF

DRAWN BY	CHECKED BY	APPROVED BY	STATUS	DATE	SCALE	DRAWING NO.	REV.
SF	PH	PH	FI	11/05/16	NTS	62103423-SENS-N20-v11	A

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Legend

- Model extent
- Proposed highways

Sensitivity analysis:

- 1 in 100 year proposed
- 1 in 100 year minus 20%
- 1 in 100 year plus 20%

Flood mapping at these locations shows water underneath structures. The flood model does not predict flooding of the highways.

Nursery
Crug
Issues
Sinks
Sewage Works
Tycerrig
Caerlan Tibot
Drain
Water Works
Track
B4366
74m
Erw Fawr
71m
Rhyd-y-galen
Caravan Site
Hut Circle
Pont Rhyd-y-Galen
Afon Cadnant
Tyddyn Hen
FFORDD BETHEL / BETHEL ROAD
Annedd Eryri
Pen-y-Gelli
Pengelli Isaf
Ford
FB

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AFON CADNANT MODELLING, A487 CAERNARFON TO BONTNEWYDD BYPASS

CADNANT FLOWS SENSITIVITY ANALYSIS 1 IN 100 YEAR EVENT

WSP | PARSONS BRINCKERHOFF

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SF	PH	PH	FI	11/05/16	NTS	62103423-SENS-Q0100-20-v11	A

Legend

- Model extent
- Proposed highways

Sensitivity analysis:

- 1 in 100 year proposed
- 1 in 100 year proposed with doownstream boundary plus 500mm

Flood mapping at these locations shows water underneath structures. The flood model does not predict flooding of the highways.

AFON CADNANT MODELLING, A487 CAERNARFON TO BONTNEWYDD BYPASS

CADNANT DOWNSTREAM BOUNDARY SENSITIVITY TEST 1 IN 100 YEAR EVENT

WSP | PARSONS BRINCKERHOFF

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Legend

- Model extent
- Proposed highways

Sensitivity analysis

- 1 in 100 year proposed
- 1 in 100 year proposed with 50% blockage at the northern structure

50% blockage here

Flood mapping at these locations shows water underneath structures. The flood model does not predict flooding of the highways.

Nursery
Crug
Issues
Sinks
Sewage Works
Tycerrig
Caerlan Tibot
Water Works
Drain
Track
B4366
74m
71m
Erw Fawr
Rhyd-y-galen
Caravan Site
Hut Circle
Pont Rhyd-y-Galen
Afon Cadnant
Tyddyn Hen
FFORDD BETHEL / BETHEL ROAD
Annedd Eryri
Pen-y-Gelli
Pengelli Isaf
Ford
FB
Issues

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AFON CADNANT MODELLING, A487 CAERNARFON TO BONTNEWYDD BYPASS

CADNANT BLOCKAGE SENSITIVITY ANALYSIS 1 IN 100 YEAR EVENT

WSP | PARSONS BRINCKERHOFF

DRAWN BY	CHECKED BY	APPROVED BY	STATUS	DATE	SCALE	DRAWING NO.	REV.
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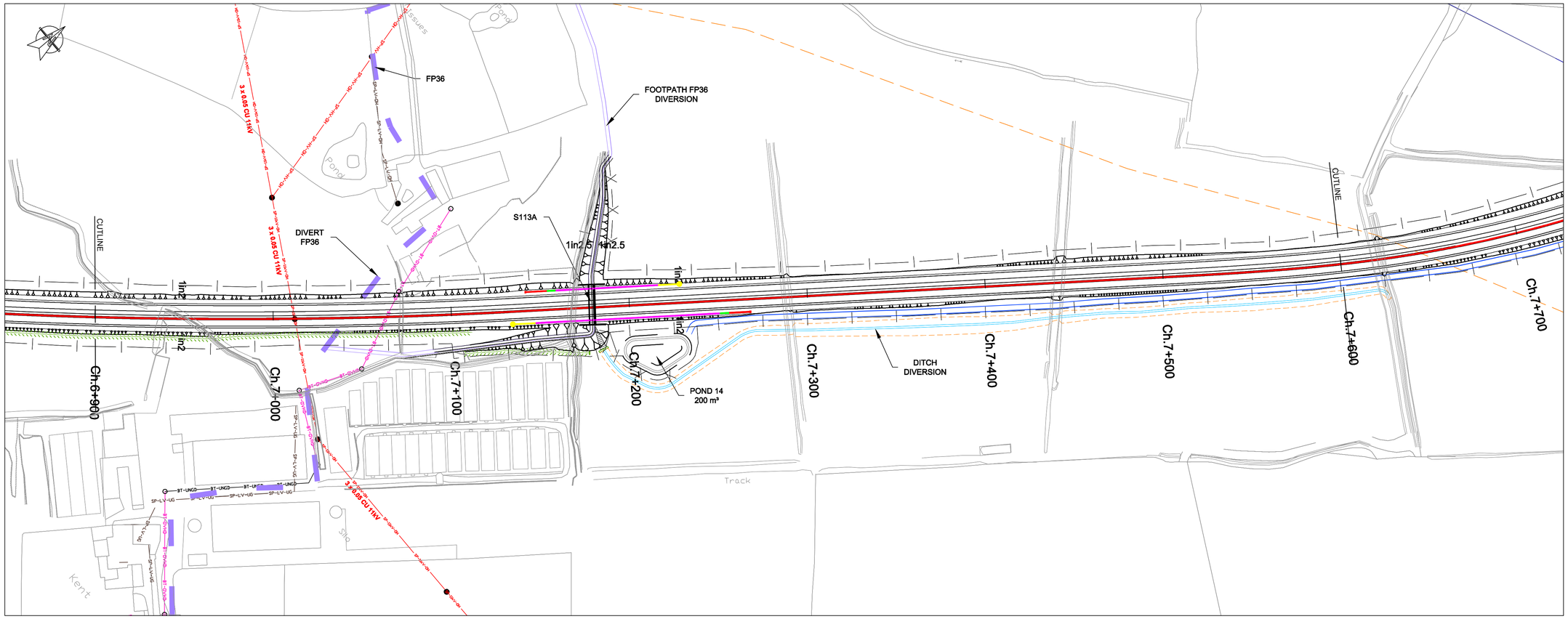

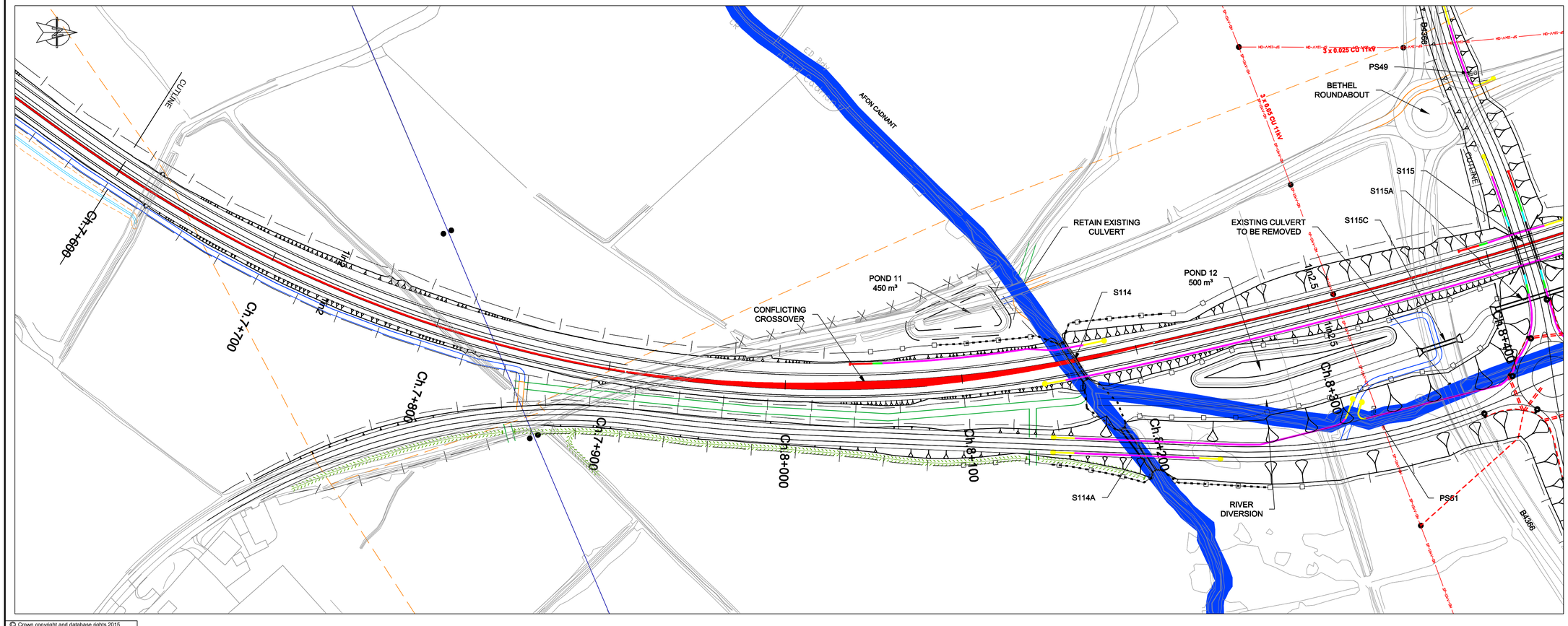

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NOTES

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KEY

- 2+1 CARRIAGEWAY
- EARTHWORKS
- ATTENUATION POND
- BAT FENCE
- OTTER FENCE
- HIGHWAY BOUNDARY
- STOCK PROOF FENCE
- VEHICLE RESTRAINT SYSTEM (TRANSITION, P1, VRS, P4)
- TRAFFIC SIGN (ADS)
- TRAFFIC SIGN (REGULATION)
- STREET LIGHTING COLUMN
- SHARED USED PMA (CONTRETE)
- PMA (GRANULAR)
- POND ACCESS (GRANULAR)
- EXISTING FOOTPATH
- FOOTPATH DIVERSION (GRANULAR)
- EXISTING RECREATIONAL ROUTE
- RECREATIONAL ROUTE DIVERSION (ASPHALT)
- MAIN RIVER OR TRIBUTARY
- RIVER TRAINING/DITCH WORKS
- CUT-OFF DITCH

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Llywodraeth Cymru Welsh Government
RAMBOLL
Balfour Beatty
JONES BROS CIVIL ENGINEERING UK
PARSONS BRINCKERHOFF
Ty Glyn, Canol Y Dre, Ruthin Denbighshire Tel: 01824 703661
TACP

Site/Project:

A487 CAERNARFON TO BONTNEWYDD BYPASS

Title:

LAYOUT APPROVAL PLAN

Drawn: R.Boyle		Checked: M.Godfrey	
Designed: M.Godfrey		Approved: S.Carr	
Date: 24/02/15	Scale: 1:1250	A1	Sheet: 7 of 9

Container Number: 3513874-PB-06-XX-DR-J-00007

Revision: P10

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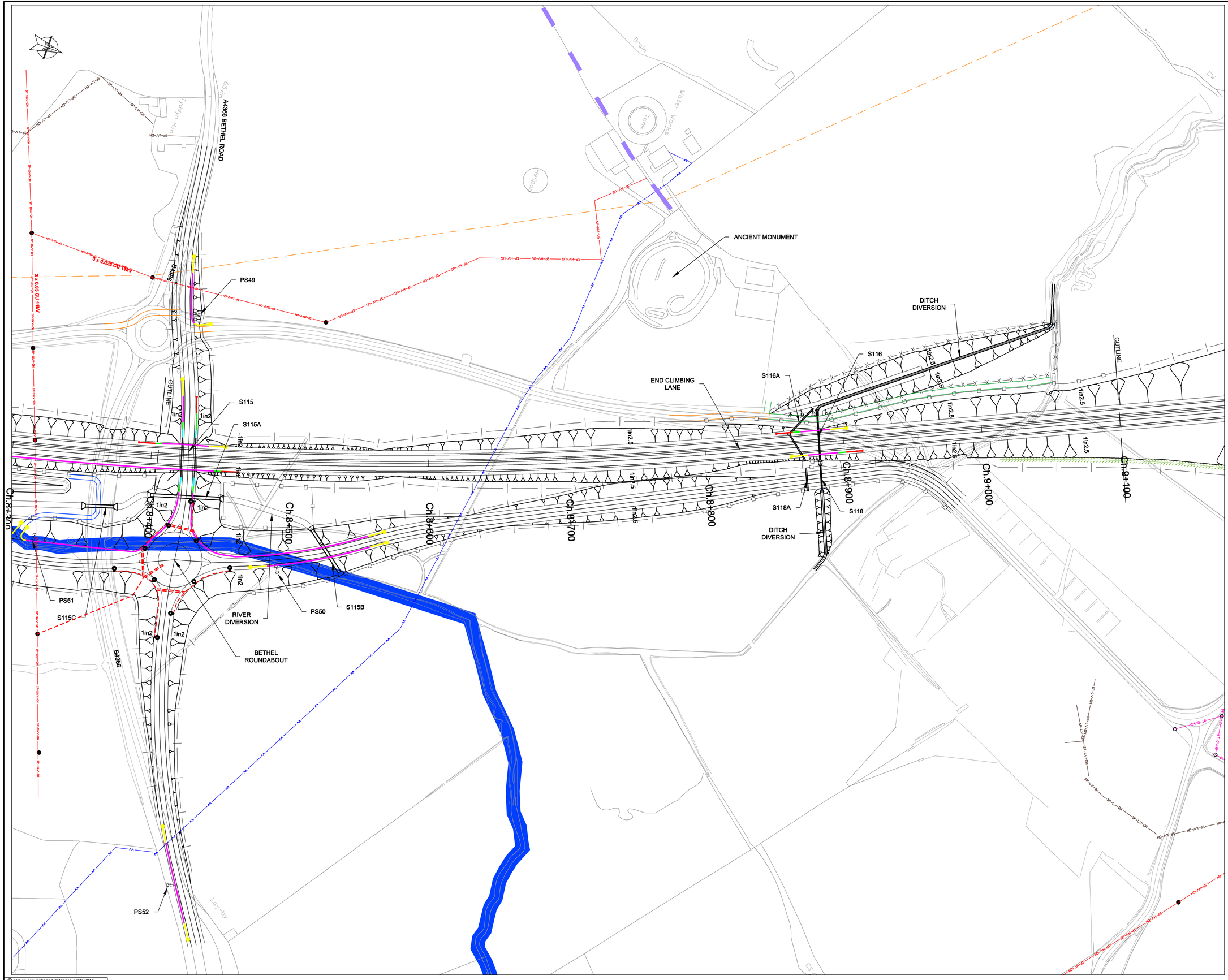

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Drawn: R.Boyle		Checked: M.Godfrey	
Designed: M.Godfrey		Approved: S.Carr	
Date: 07/05/15	Scale: 1:1250	A1	Sheet: 8 of 9
Container Number:			Revision:
3513874-PB-06-XX-DR-J-00008			P12

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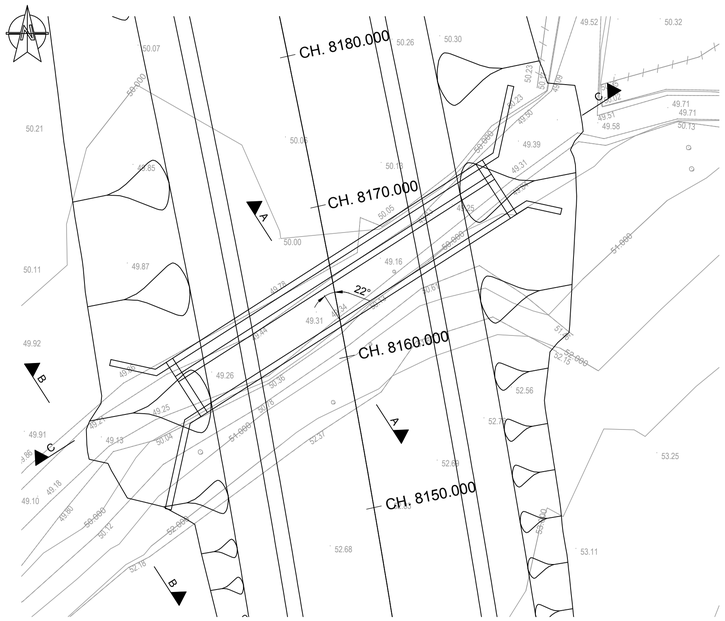

PLAN

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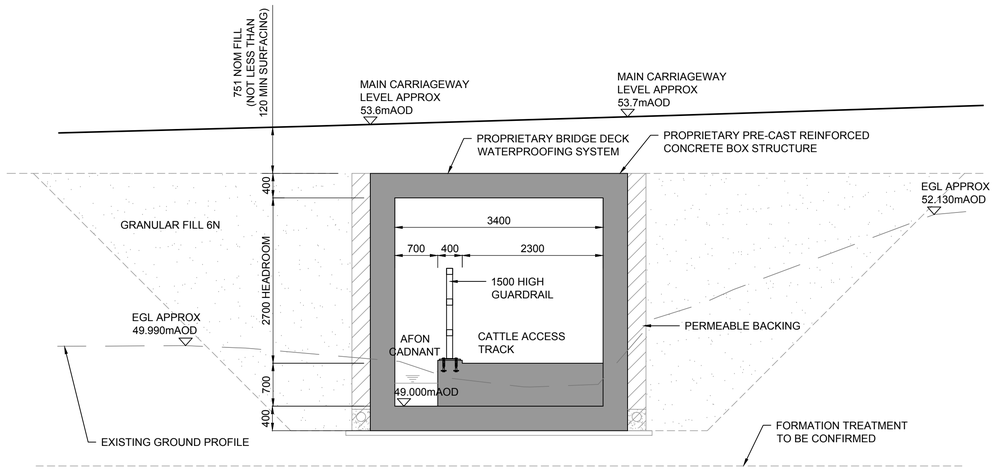

SECTION A-A

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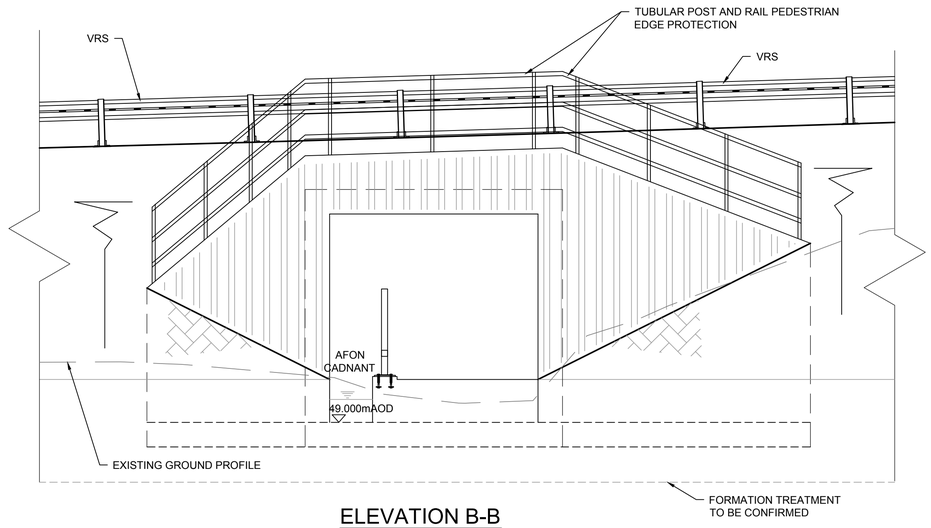
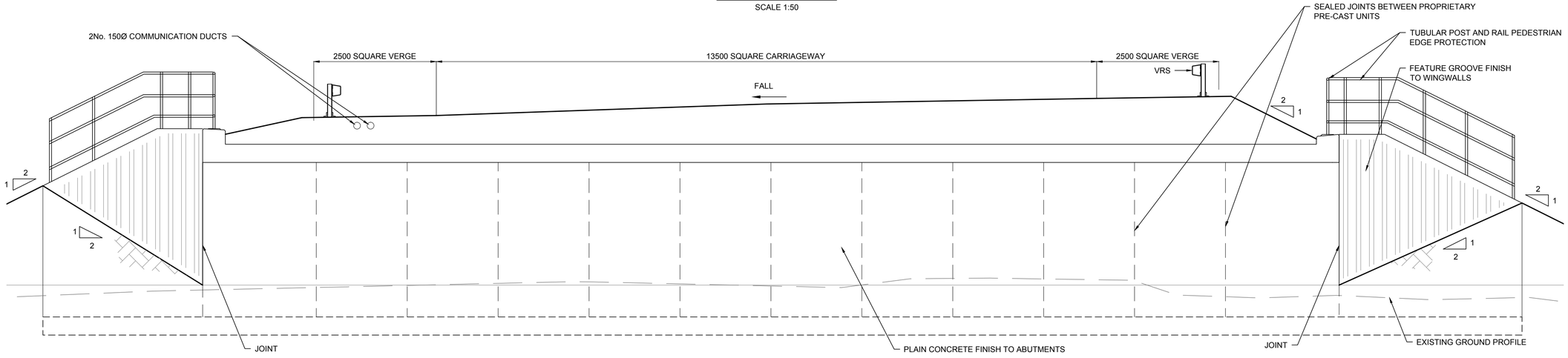


ELEVATION B-B

SCALE 1:50



ELEVATION C-C

SCALE 1:50

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NOTES

A1

1. THIS IS A C.A.D. DRAWING AND SHOULD NOT BE AMENDED BY HAND.
2. ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED.

HEALTH AND SAFETY INFORMATION

SIGNIFICANT OR EXCEPTIONAL RISKS ARE IDENTIFIED BELOW

CONSTRUCTION PHASE

1. PLEASE REFER TO THE HAZARD RISK REGISTER AND THE WORKS INFORMATION FOR DETAILS OF THE RISKS ASSOCIATED WITH THIS WORK.
2. IN PREPARATION OF CONSTRUCTION METHOD STATEMENTS CONSIDERATION SHOULD BE GIVEN TO THE CLOSE PROXIMITY OF ANY STRUCTURES THAT MAY BE AFFECTED BY CONSTRUCTION.
3. RESIDUAL HAZARDS ARE LISTED HERE AND REFERENCED ON THE DRAWING.
   i. NOTHING SIGNIFICANT OR UNUSUAL.
4. THE CONTRACTOR SHALL REFER TO STATUTORY UNDERTAKERS LAYOUT DRAWINGS AND IDENTIFY LOCATIONS OF EXISTING UNDERGROUND SERVICES PRIOR TO CARRYING OUT EXCAVATION WORKS.

MAINTENANCE / OPERATION / DECOMMISSIONING / DEMOLITION PHASES

1. PLEASE REFER TO THE HAZARD RISK REGISTER AND THE MAINTENANCE AND REPAIR STRATEGY FOR DETAILS OF THE RISKS ASSOCIATED WITH THE MAINTENANCE, OPERATION, DECOMMISSIONING AND DEMOLITION PHASES.
2. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE HEALTH AND SAFETY FILE(S) PRODUCED AND HANDED OVER ON COMPLETION OF THIS PROJECT.
3. RESIDUAL HAZARDS ARE LISTED HERE AND REFERENCED ON THE AS-BUILT DRAWING.
   i. NOTHING SIGNIFICANT OR UNUSUAL

Rev	Date	Description	By	Chk	App
P01	12/06/2015	FOR INFORMATION	MB	AMJ	AKG

FIT FOR INFORMATION

EC HARRIS BUILT ASSET CONSULTANCY
Llywodraeth Cymru
Welsh Government
Balfour Beatty
JONES BROS CIVIL ENGINEERING UK
PARSONS BRINCKERHOFF
TACP
Ty Glyn, Canol Y Dre, Ruthin Denbighshire Tel: 01824 703661

Site/Project:

A487 CAERNARFON TO BONTNEWYDD BYPASS

Title:

S114 AFON CADNANT CATTLE CREEP / CULVERT GENERAL ARRANGEMENT (WG A487 631)

Drawn: M.Barka		Checked: A.Jarman	
Designed: A. GROVES		Approved: A.Groves	
Date: 26/05/15	Scale: AS SHOWN	A1	Sheet:

Container Number: 3513874-PB-SBR-114-DR-S-00001

Revision: P01

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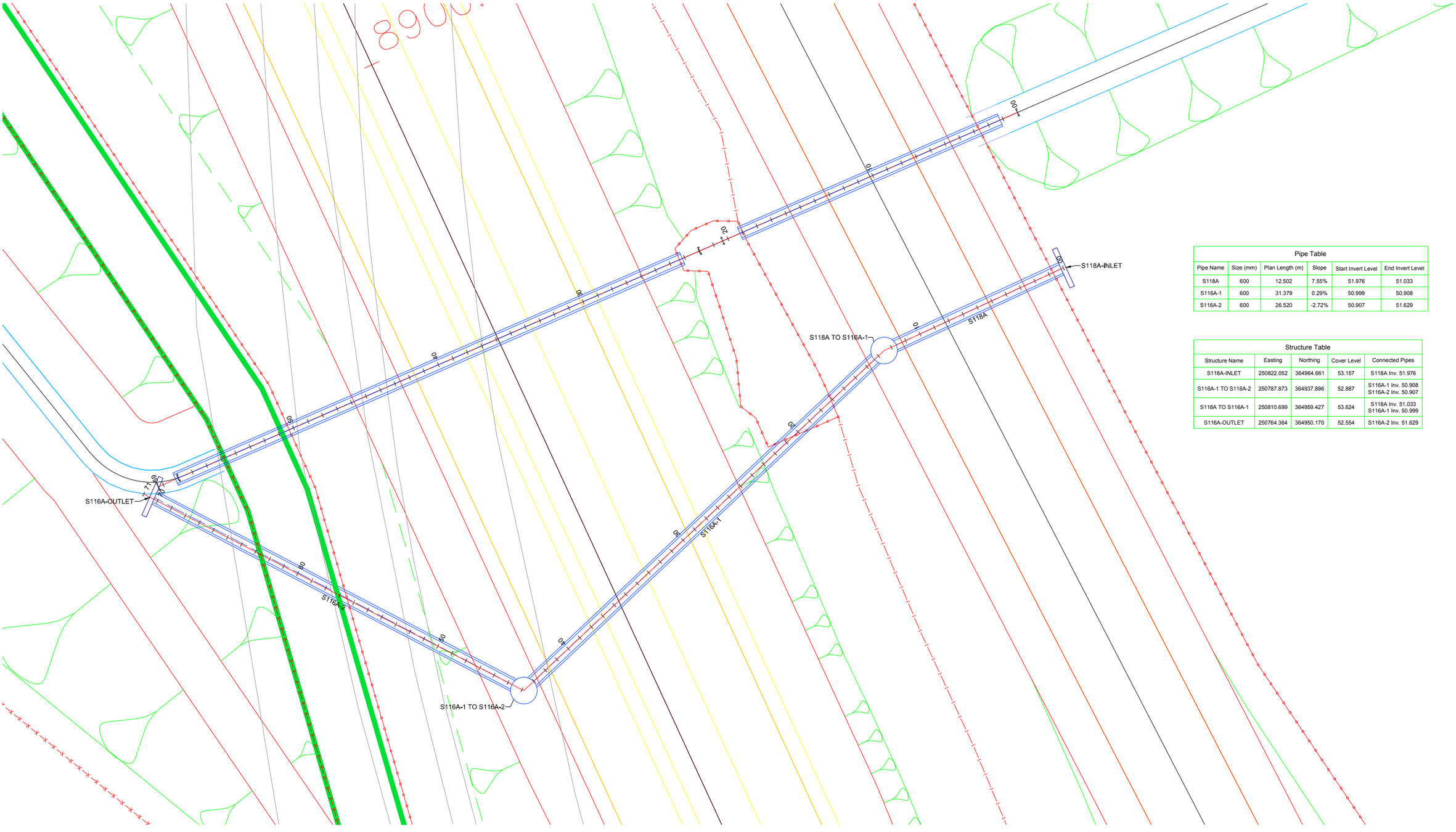

Pipe Table					
Pipe Name	Size (mm)	Plan Length (m)	Slope	Start Invert Level	End Invert Level
S118A	600	12.502	7.55%	51.976	51.033
S116A-1	600	31.379	0.29%	50.999	50.908
S116A-2	600	26.520	-2.72%	50.907	51.629

Structure Table				
Structure Name	Easting	Northing	Cover Level	Connected Pipes
S118A-INLET	250822.052	364964.661	53.157	S118A Inv. 51.976
S116A-1 TO S116A-2	250787.873	364937.896	52.887	S116A-1 Inv. 50.908 S116A-2 Inv. 50.907
S118A TO S116A-1	250810.699	364959.427	53.624	S118A Inv. 51.033 S116A-1 Inv. 50.999
S116A-OUTLET	250764.364	364950.170	52.554	S116A-2 Inv. 51.629