HORIZON NUCLEAR POWER

WYLFA NEWYDD

ENERGY WORKING FOR BRITAIN

Wylfa Newydd Project

6.5.16 ES Volume E - Off-Site Power Station Facilities: AECC, ESL and MEEG App E8-1 - MEEG/AECC/ESL - Flood Consequence Assessment

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1 Introduction

1.1 Overview

1.1.1 This Flood Consequence Assessment (FCA) describes the assessment of potential flood risk from all local sources resulting from the operation and decommissioning of the proposed Wylfa Newydd Off-Site Power Station Facilities; the Mobile Emergency Equipment Garage (MEEG), Alternative Emergency Control Centre (AECC) and the Environmental Survey Laboratory (ESL) .

1.1.2 The FCA has assessed the flood risk posed to the proposed Off-Site Power Station Facilities as well as any changes to flood risk arising from them.

1.1.3 The hydrological baseline is outlined in chapter E8 (surface water and groundwater) (Application Reference Number: 6.5.8), information from which is used in this FCA. This FCA is an appendix to chapter E8 (Application Reference Number: 6.5.8) and should be read in conjunction with it.

1.1.4 Consultation with relevant statutory bodies has taken place during the production of this FCA. A record of consultation can be found in section 8.3 of chapter B8 (surface water and groundwater) (Application Reference Number: 6.2.8).

1.2 Site location and study area

1.2.1 The proposed site for the Off-Site Power Station Facilities is at Llanfaethlu, on a former bus depot that is currently being used as a garage and for vehicle parking. This site consists of approximately 2ha of land (measuring 140m by 91m) located to the east of the existing A5025, approximately 6.1km south of the Wylfa Newydd Development Area. The site boundary is shown in figure E8-1-1.

1.2.2 The proposed Off-Site Power Station Facilities site is predominantly hardstanding and houses two existing commercial garages and a motor vehicle repair building, which have been present since 1979. It is therefore a brownfield site. There is an existing single-storey house to the south-west of the site. Vegetation and scattered planting is present on the northern boundary, bunding mounds around the eastern and southern sides of the boundary, and an evergreen shelterbelt to the north.

1.2.3 The proposed Off-Site Power Station Facilities site is bounded by the A5025 to the west, residential and storage buildings to the north, and farmland to the south and east. There are residential properties located to the north and south of the existing entrance, as well as some scattered properties to the north-east. The site is located within an area of undulating landform gently rising to the north-west, and sits at a lower elevation than the surrounding area.

1.2.4 The surface water study area is 500m in all directions around the proposed site for the Off-Site Power Station Facilities as shown in figure E8-1-1. Within this study area an assessment is completed to determine if there are any surface watercourses or features that could be relevant for flooding, and an assessment is completed to identify any areas currently at risk of flooding. If watercourses are identified where there is potential for flood risk to be increased downstream then the study area is extended along that watercourse. The whole downstream watercourse is then assessed as far as a point where it enters the sea. The surface water study area with respect to flood risk is therefore based on the stream catchments in and around the proposed Off-Site Power Station Facilities, which in some cases extend beyond 500m.

1.3 Technical Advice Note (TAN) 15 Development Advice Map

1.3.1 There are two initial reference maps for assessing the level of fluvial and tidal flood risk associated with land: the TAN 15 Development Advice Map [RD1] and the Natural Resources Wales (NRW) flood map of fluvial flood risk [RD2]. These are broadly similar, although the NRW flood map provides additional detail in relation to flood probability. The TAN 15 Development Advice Map, which shows the fluvial and coastal flood zones as issued by the Welsh Government, is primarily used in this assessment, as the TAN 15 Development Advice Maps form the basis of assessment of flood risk in accordance with planning policy.

1.3.2 The TAN 15 flood zones are defined as follows:

- Zone A: Considered to be at little or no risk of fluvial or coastal/tidal flooding;
- Zone B: An area known to have been flooded in the past evidenced by sedimentary deposits;
- Zone C1: An area with an annual probability of flooding from river, tidal or coastal sources equal to or greater than 0.1%, but which are developed and served by significant infrastructure including flood defences; and
- Zone C2: An area with an annual probability of flooding from river, tidal or coastal sources equal to or greater than 0.1% and without significant flood defence infrastructure.

1.4 Planning guidance for a FCA

1.4.1 In Wales, *Planning Policy Wales* (PPW) [RD3] and TAN 15: Development and Flood Risk [RD4] provide the national policy framework for the assessment and management of flood risk for new developments. Taken together, they establish a presumption against development in areas at the highest risk of flooding, setting a framework for the sequential assessment of the suitability of sites for development. They also set out the FCA assessment methodology for the evaluation of flood risk and the need to integrate mitigation and flood resilience in the design of new development.

1.4.2 This FCA has been written to address the planning policy requirements for the proposed Off-Site Power Station Facilities, in association with TAN 15 and PPW.

1.5 Report objectives

1.5.1 The objectives of this FCA are to:

- identify possible mechanisms by which the Off-Site Power Station Facilities site could flood;
- identify any aspects of the design that could exacerbate flooding elsewhere;
- undertake a formal assessment of the risks posed to the proposed Off-Site Power Station Facilities from all identified flood risk sources and mechanisms;
- confirm that the proposed Off-Site Power Station Facilities would not exacerbate flooding elsewhere;
- consider the level and acceptability of any residual flood risk; and
- produce an FCA compliant with TAN 15 and PPW.

2 Policy and planning

2.1 Planning context

2.1.1 The context for planning policy in Wales is set out within PPW [RD3]. This provides the national policy framework for the assessment and management of flood risk for new developments and references a range of European and national legislation that relates to the flood risk. This is supplemented by TAN 15 [RD4] and local planning policy. Although there is other legislation and guidance relevant to flood risk (including National Policy Statement for Energy (EN-1) (NPS EN-1) and Policy Statement for Nuclear Power Generation (EN-6) (NPS EN-6)), this is discussed in section 8.2 of chapter B8 (Application Reference Number: 6.5.8) and is not repeated in this FCA.

2.2 PPW

2.2.1 The objective of PPW is to avoid the construction of new development within areas defined as being at flood risk, with planning authorities adopting a precautionary approach when formulating development plan policies, including the principle that climate change will likely increase the risk of coastal and river flooding. A strategic approach to flood risk that considers the catchment as a whole is encouraged.

2.2.2 PPW states that new development should not be at risk of flooding itself and should not increase the risk of flooding elsewhere. Additionally, hard-engineered flood defences should be considered likely to be unsustainable in the long term, and new development should avoid development in flood hazard zones.

2.2.3 Only essential transport and utilities infrastructure is considered acceptable within unobstructed floodplains, and then only when such infrastructure is designed to remain operational during times of flooding and with no net loss of floodplain storage or increase in flood risk elsewhere.

2.3 TAN 15

2.3.1 TAN 15 provides technical guidance that supplements the policy set out in PPW in relation to development and flooding. It advises on development and flood risk relating to sustainability principles and provides a framework within which risks arising from both river and coastal flooding, and from additional runoff from development in any location, can be assessed. This incorporates climate change scenarios.

2.3.2 TAN 15 provides guidance on flood consequences that may not be acceptable for particular types of development. The location of the development needs to be justified in line with TAN 15 and flood risk areas, and the consequence needs to be acceptable given the vulnerability and use of the receptor.

2.3.3 TAN 15 states that development should be directed towards Flood Zones A and B and will only be acceptable in Flood Zones C1 and C2 if it is necessary as part of a local regeneration scheme or to sustain an existing settlement or if key to support employment objectives.

2.3.4 The guidance defines a threshold for the frequency of flooding below which development should not be allowed. This threshold for General Infrastructure is equivalent to the 1% Annual Exceedance Probability (AEP) event, or an event with a 1 in 100 chance of occurring in any given year, for fluvial flooding and it is equivalent to the 0.5% AEP event, or an event with a 1 in 200 chance of occurring in any given year, for tidal flooding. Additionally, the depth of flooding, regardless of development type, should not be greater than 1m for any storm event. These thresholds automatically apply to all developments in Flood Zone A and B and to those in Flood Zone C once the justification test has been passed. A justification test is a set of criteria only applicable to developments located in Flood Zone C, which must be considered for the development to take place.

2.3.5 It is also a requirement of TAN 15 that future users and occupiers of all types of development are adequately aware of the flood risk and consequences, that effective flood warning is provided, that emergency flood plans are available and that safe access and egress is available. There is also a requirement that the site is designed to facilitate movement of goods/possessions away from flooding, to minimise structural damage and to facilitate recovery.

2.3.6 TAN 15 also states that new development should not increase flooding elsewhere; however, it acknowledges that there may be practical difficulties in achieving this aim.

2.3.7 TAN 15 states that consideration must be given to the impacts climate change may have on the risk of flooding over the lifetime of a development; to ensure that development does not take place where flooding would be unacceptable either now or in the future. The Welsh Government has provided guidance (CL-03-16) [RD5] on how the UK climate change projections (UKCP09) [RD6] should be used to determine the future flood consequences for developments in Wales and must be incorporated in all FCAs produced after December 2016.

2.4 Local planning policy

2.4.1 The Anglesey and Gwynedd Joint Local Development Plan forms the basis for land use planning in the Anglesey and Gwynedd areas. The Written Statement was published in 2017 [RD7] and is the main source of local planning policy. Within the Plan, the strategic objectives in relation to flood risk are the following.

- Strategic Objective 6 (SO6): "*Minimise, adapt and mitigate the impacts of climate change. This will be achieved by: ensuring that highly vulnerable development is directed away from areas of flood risk wherever possible*".
- Strategic Objective 8 (SO8): "*Ensure that settlements are sustainable*, accessible and meet the range of needs of their communities". This will

be achieved by, amongst others, ensuring that: “*new developments that are vulnerable to harm will not be located in areas at risk from flooding*”.

2.4.2 In order to adapt to the effects of climate change Policy PS 6 (Alleviating and adapting to the effects of climate change) requires proposals to take account and respond to a number of concerns, including: “*Locating* (developments) *away from flood risk areas, and aim to reduce the overall risk of flooding within the Plan area and areas outside it, taking account of a 100 years and 75 years of flood risk in terms of the lifetime of residential and non-residential development, respectively, unless it can be clearly demonstrated that there is no risk or that the risk can be managed” and to: “Aim for the highest possible standard in terms of water efficiency and implement other measures to withstand drought, maintain the flow of water and maintain or improve the quality of water, including using sustainable drainage systems*”.

2.4.3 The Anglesey and Gwynedd Joint Local Development Plan Stage 1 Strategic Flood Consequence Assessment [RD8] forms a key part of the evidence base for planning with respect to review of FCAs. The document helps to determine appropriate development policies and land allocations that avoid or minimise flood risk from all sources, and helps to assess any future development proposals in line with the precautionary framework in PPW and TAN 15. This document and the IACC’s *Preliminary Flood Risk Assessment* [RD9] include information on surface water, groundwater, ordinary watercourses and small reservoir flooding. Information on the IACC flood strategy and the Council’s objectives in managing flood risk is provided in the *Anglesey Local Flood Risk Management Strategy* [RD10].

2.5 River Basin Management Plan

2.5.1 The proposed Off-Site Power Station Facilities are wholly located within the Western Wales River Basin District, an area encompassing river basins from Anglesey in the north of Wales to the Bristol Channel in the south. The Western Wales River Basin Management Plan for 2015 – 2021 [RD11] provides an overview of NRW’s approach to managing flood risk within the Western Wales River Basin and details measures designed to reduce the potential flooding, such as use of sustainable drainage systems and improvements and maintenance of flood defence schemes. In addition, the plan proposes improving the understanding of flood risk through the application of mapping and modelling.

3 Baseline site context

3.1 Climate

3.1.1 The UK Meteorological Office rainfall data available online for the period 1981 to 2010 show an average annual rainfall at Valley (11km to the south of the proposed Off-Site Power Station Facilities site) of 841mm/year, which is below the UK average of 1,154mm/year. Long-term data indicate rainfall is typically higher in the late autumn/early winter and lowest in late spring/early summer.

3.2 Landscape

3.2.1 The key feature of the landscape is a drumlin field: a series of low rolling hillocks formed by glaciation. The hillocks run south-west to north-east and the majority are covered by improved grassland. There are also areas of marsh, scrub and rocky outcrops in the surrounding area.

3.2.2 The vegetation pattern in the vicinity of the proposed site for the Off-Site Power Station Facilities includes hedgerows with dense linear belts of planting. Areas of low-level vegetation fill small pockets around local farmsteads.

3.3 Topography

3.3.1 The proposed Off-Site Power Station Facilities site is located within an area of undulating landform gently rising to the north-west. There are also noticeable drumlin features to the west and east. The site topography gently falls from 55 metres Above Ordnance Datum (mAOD) at the western edge along the A5025 to 48mAOD on the eastern edge. A bund 1.5m to 2.0m high is present along the southern and eastern boundaries. This bund contains the site and separates it from the East Drain. The topographic survey is provided in appendix E8-1-2.

3.4 Off-site receptors

3.4.1 The proposed Off-Site Power Station Facilities are located on the immediate eastern side of the A5025. This road is a critical transport route from Holyhead and Valley to the north of Anglesey, and onwards to the A5 and A55 and main off- island UK road network.

3.4.2 There are isolated properties in the vicinity of the proposed Off-Site Power Station Facilities: Bod Helen adjacent to the site to the north, Bryn Maethlu to the north-west and Berth to the east.

3.4.3 The proposed Off-Site Power Station Facilities would be located to the north of Llanfaethlu. The majority of the village is on the opposite side of the A5025. The village has a church and post office, and a school. These are not considered receptors as they are at a higher level than the proposed Off-Site Power Station Facilities.

3.4.4 Downstream of the proposed Off-Site Power Station Facilities is the Beddmanarch-Cymyran Site of Special Scientific Interest. The shallow waters between Holy Island and the Anglesey mainland include the tidal estuary of the Afon Alaw at Llanfachraeth. The wide range of coastal habitats supports a range of ornithological and botanical species. The current water level regime is important to conserve the habitats of the Site of Special Scientific Interest. This is an important receptor to consider.

3.4.5 Settlements and individual properties are located downstream from the proposed Off-Site Power Station Facilities. These include Tyddyn-y-Waen, Sisial y Nant, Penhesgyn, Pen-yr-argae, Tan-yr-allt, Pont Dronwy and Llwyn Y Ffynnon. Alteration of the river regime may increase flood risk to these receptors, and so they are included within this assessment.

3.4.6 The receiving watercourse passes under the A5025 at Tan-yr-allt, north of Llanfachraeth. Increases in water in the river may increase the flood risk to this receptor, and so it is included within this assessment.

3.5 Surface water features

3.5.1 Figure E8-1-1 shows the surface water features around the proposed Off-Site Power Station Facilities site. The Afon Llanrhyddlad runs southwards close to the east of the site. A small tributary of this watercourse, the East Drain, runs from the proposed Off-Site Power Station Facilities site eastwards to the Afon Llanrhyddlad at Tyddyn-y-waen. There is a well indicated within the site boundary on the Ordnance Survey 1:50,000 maps. Ponds are evident on the neighbouring land to the north and on the other side of the A5025.

3.5.2 A small drain flows from north to south along the eastern field boundary of the proposed Off-Site Power Station Facilities site. This drain, referred to here as the Hen-shop Drain, runs perpendicular to the East Drain and eventually discharges into the East Drain.

3.5.3 The Afon Llanrhyddlad flows in a north to south direction parallel to the A5025 and joins the Tan R'Allt, approximately 2.7km downstream. The Tan R'Allt crosses the A5025 and ultimately discharges into the sea, 8km downstream via the Alaw Estuary.

3.6 Geology and hydrogeology

3.6.1 There are no records of artificial or made ground on-site, although as the Off-Site Power Station Facilities would be located on a brownfield site there is likely to be some made ground present. Superficial deposits are absent from the site based on British Geological Survey maps [RD12], although given the scale of the maps there is slight potential for some drift to be present beneath the eastern side of the proposed Off-Site Power Station Facilities site. The area surrounding the site is mantled by glacial till. The bedrock recorded consists of quartzite and schist.

3.6.2 The superficial deposits surrounding the site are classified by NRW as Secondary (Undifferentiated) aquifer, whilst the bedrock beneath the site is classified as a Secondary B aquifer. Ground investigations along the adjacent A5025 indicate that groundwater in the area is 3m to 4m below ground level at a borehole that is 170m to the south-west of the proposed Off-Site Power Station Facilities.

3.6.3 The slowly permeable soils that characterise the proposed Off-Site Power Station Facilities site contribute to the limited infiltration potential. Areas underlain by these soils are typically prone to surface water ponding and high rates of runoff generation. The site is currently covered in hardstanding, and therefore runoff rates to the existing drainage are already high.

3.7 Water services

3.7.1 A foul-water drainage pipe runs along the A5025 to the west of the proposed Off-Site Power Station Facilities site; it then branches off and enters the site in the middle of the western boundary. There are a total of three main foul-water drainage pipes, running from west to east in the centre of the site.

3.7.2 There is an existing mains water pipe that runs along the A5025 road to the west outside the proposed Off-Site Power Station Facilities site boundary. It is currently unclear where the existing building's water supply enters the site and how it is distributed.

3.8 Reservoirs

3.8.1 Llyn Alaw is a man-made water supply reservoir located 6km to the east of the proposed Off-Site Power Station Facilities site. It has a surface area of 3.6km^2. There is a substantial risk area downstream of the reservoir should the reservoir fail. This shows that the flood waters would follow the Afon Alaw valley in a south-easterly direction and would not affect the Off-Site Power Station Facilities.

4 Off-Site Power Station Facilities

4.1.1 The Off-Site Power Station Facilities would consist of two main buildings. To the east would be a building that would house both the MEEG and the AECC. Adjacent to the road, to the west of the site, would be the ESL.

4.2 Timescale

4.2.1 The Off-Site Power Station Facilities are to be designed for a life of 60 years, the operational life of the Power Station. The design of the Off-Site Power Station Facilities has been developed in consultation with a number of stakeholders, including the IACC, Design Commission for Wales, NRW, Scottish Power Energy Networks, Dŵr Cymru Welsh Water, North Wales Police and North Wales Fire Service. This consultation is ongoing. Construction is expected to take approximately 42 months.

4.3 Site layout

4.3.1 Details of the design for the Off-Site Power Station Facilities are provided in chapter E1 (proposed development) (Application Reference Number: 6.5.1) along with detailed descriptions of the development phases and activities. The approach adopted for the design of the Off-Site Power Station Facilities has been to utilise a parameter approach to the development. Parameters have been set for the two main buildings, the MEEG / AECC, which would be located in Parameter Zone 5-1, and the ESL which would be located in Parameter Zone 5-2. The location and extent of these zones and the relevant maximum parameters are detailed in chapter E1 (Application Reference Number: 6.5.1) of the Environmental Statement.

4.3.2 The parameters listed in chapter E1 (Application Reference Number: 6.5.1) only allow the size of the buildings to be changed and so have no substantial effect on the FCA. Although making a building smaller would reduce the amount of rainfall runoff from that building, as the surrounding area would remain as hardstanding the total rainfall moving to drain and the rainfall / runoff relationship would remain the same. The FCA has therefore been completed on the basis that building sizes within Parameter Zones 5-1 and 5-2 could change. Within these parameters, and based on the assumptions in this FCA, the assessment therefore provides a worst case scenario.

4.3.3 Figure E8-1-2 shows the draft outline layout of the proposed Off-Site Power Station Facilities, with more detail provided in chapter E1 (Application Reference Number: 6.5.1) and chapter E2 (alternatives and design evolution) (Application Reference Number: 6.5.2). Much of the site is hard standing, allowing the movement of vehicles on the site.

4.3.4 The following facilities have been included in the layout and design of the Off-Site Power Station Facilities:

- the MEEG and AECC building;
- the ESL building;

- a staff car park with grassed overflow car park to the south of the site;
- access/delivery areas;
- underground surface water runoff/storage;
- an underground fuel tank;
- ancillary/plant buildings including a pump house and generator; and
- a temporary mobile telecommunications mast.

4.3.5 Due to the nature and function (emergency/contingency planning support) of the Off-Site Power Station Facilities, there are certain locational criteria that must be met in selecting an appropriate site for this facility. These include requirements for the facility to be at least 1.5km away from the Power Station, positioned in a low seismic zone, on land that is at low risk of flooding and that offers access to strategic road infrastructure.

4.4 Drainage strategy

4.4.1 All piped surface and foul water systems would be designed in accordance with Sewers for Adoption [RD13], which contains guidance on the design and construction of sewers. The design would be as if it were to be adopted by sewerage undertakers in accordance with Section 104 of the *Water Industry Act 1991.*

4.4.2 The key drainage principles that have been employed are described below.

- Pipes would be designed for flow from a 1 in 5 year (20% AEP) storm event plus a 20% allowance for climate change with no surcharging above soffit.
- There would be no flooding from manholes or above ground (allowing for a 300mm freeboard below ground level) for a flow from a 1 in 30 year (3.33% AEP) storm plus a 20% allowance for climate change.
- There would be no significant ponding caused from flow from a 1 in 100 year storm event plus 20% climate change.
- The drainage system would be designed so that the peak discharge runoff rates for a 1 in 100 year (1% AEP) storm event would be constrained to current runoff rates for the mean annual maximum flow rate, such that there is no change to the risk of off-site flooding.

4.4.3 Surface water runoff from the developed areas within the proposed Off-Site Power Station Facilities site would be captured by traditional gully, channel and kerb drain systems and stored on-site using geo-cellular storage systems and discharged to the local watercourse subject to an agreed Ordinary Watercourse Consent from IACC. Surface water runoff would be stored within a below ground storage system.

4.5 Water services

4.5.1 Due to the close proximity to residential properties and the small number of employees associated with the Off-Site Power Station Facilities, it is assumed that foul flow connections would be possible on-site using the existing sewers.

4.5.2 A potable mains water supply runs along the A5025 supplying water to the local properties. It is assumed that this water supply would be available for use at the Off-Site Power Station Facilities.

5 Flood modelling

5.1 Sources of modelling data

5.1.1 The sources of flood modelling data and flood mapping described below have been considered within the preparation of this FCA.

- **NRW river and tidal flood mapping [RD2]:** This mapping, delivered as part of a national programme, delineates indicative areas of elevated flood risk into four flood zones and includes both major fluvial (catchment area greater than $3km^2$), surface water and tidal sources.
- **TAN 15 Development Advice Map [RD1]:** This mapping, which is primarily based on the NRW flood map, defines indicative areas where the annual probability of inundation from fluvial and tidal sources is greater than 0.1% (Zone C). It also identifies areas where there are geological indicators of elevated flood risk (Zone B) with low risk areas classified as Flood Zone A.
- **Pluvial Flood Risk Hydraulic Modelling (Amec Foster Wheeler, 2018):** Hydraulic modelling was undertaken to better understand the baseline pluvial flood risk for a range of events and to inform the development of measures to mitigate and manage the pluvial risk, as well as to inform an understanding of the need for adaptation for more extreme events. A Hydraulic Modelling Report is presented in appendix E8-1-3.

5.2 NRW and TAN 15 flood maps

5.2.1 While the NRW flood map [RD2] does provide some additional detail in relation to flood probabilities over and above the TAN 15 Development Advice Map, the two are broadly comparable. The TAN 15 Development Advice Map, which shows the fluvial and coastal flood zones, as issued by the Welsh Government, is primarily used in this FCA as the classifications from this better relate to planning policy.

5.2.2 The TAN 15 Development Advice Map [RD1] categorises locations from A to C based on their perceived flood risk as detailed in section 1.3. The maps are based on the best currently available data. They use the Environment Agency's extreme flood outlines to inform Zone C and the British Geological Society's drift data to inform Zone B.

5.2.3 The TAN 15 map indicates that land within the proposed Off-Site Power Station Facilities site is predominantly at low risk of fluvial and tidal flooding (Zone A). However, due to their small catchment size, (< $3km^2$), the watercourses are unlikely to have been included in broad scale modelling used in the production of the maps. The risk of flooding from the Afon Llanrhyddlad, East Drain and Hen-shop Drain may therefore be underestimated in TAN 15 maps but will still be considered in this assessment.

5.2.4 NRW's surface water flood maps indicate a flood risk within the proposed Off-Site Power Station Facilities site associated with shallow ponding on the western side of the A5025. Water from the area of ponding would flow along the northern boundary of the site towards the eastern boundary from where it would ultimately flow eastwards to the Afon Llanrhyddlad. NRW's surface water flood map suggests a low risk to the west of the A5025 but a medium to high risk along the northern boundary of the proposed Off-Site Power Station Facilities site and east of the site associated with East Drain.

5.3 Pluvial flood modelling

5.3.1 Whilst NRW's surface water flood maps indicate a risk along the northern boundary of the proposed Off-Site Power Station Facilities site, there is insufficient information on which to assess the impact of the site's development on flood risk within the site or elsewhere. Furthermore, the detailed topographical information available suggests that flow across the proposed Off-Site Power Station Facilities site would occur more centrally than those indicated in NRW's surface water flood maps.

5.3.2 To address these issues and to provide greater understanding of the existing flood risks, an Infoworks ICM model v7.5.5 [RD14] was developed to assess the pluvial flood risk at the site. The modelling uses more detailed topography and provides a more accurate representation of flood risk than the NRW surface water map. Further details of the modelling are provided in appendix E8-1-3 and the results are discussed in section 6.

5.3.3 The flood model was run for the 3.33% AEP, 1% AEP and 0.1% AEP storm event. The pluvial flood model was run for the 60-minute storm duration with a summer rainfall profile. The 1% AEP event was run for periods in the 2020s and 2050s and incorporated climate change allowances of 20% and 40% for the 2050s, representing the central and upper end estimates for the West Wales river basin [RD15].

5.3.4 A number of output points and lines have been used to retrieve model results as shown in appendix E8-1-3 from which flood depths and flows have been obtained.

Comparison to the NRW flood maps

5.3.5 The more detailed pluvial modelling outputs are generally similar to the NRW flood maps in that they indicate a flow path across the site from west to east (figure E8-1-3). The modelling shows a more extensive footprint for the more frequent storm events with a constant route identified across the site rather than areas of ponding identified by the NRW surface water maps for the 3.33% AEP event.

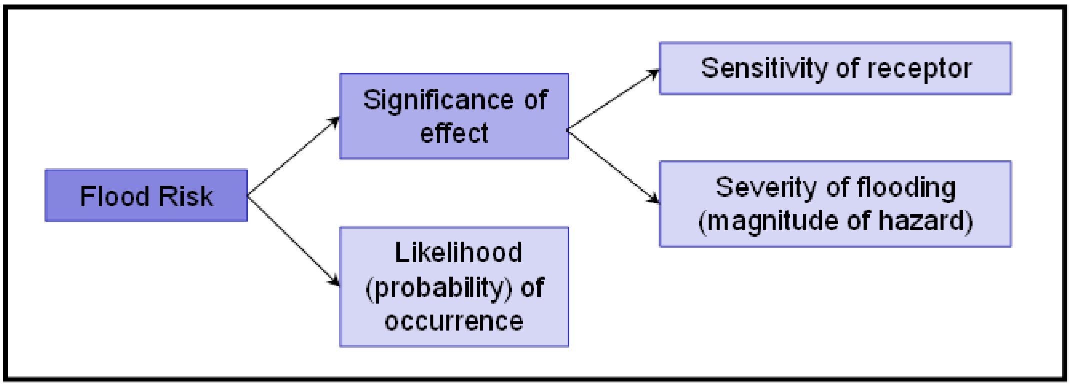
5.3.6 There is also a greater extent of flooding to the west of the A5025 shown by the modelling, which is outside of the study area. A detailed description of the level of risk of pluvial flooding is provided in section 6.

6 Flood risk assessment

6.1 FCA methodology

6.1.1 The risk assessment methodology used within this FCA is set out in appendix E8-1-4, and is based on PPW [RD3] and associated guidance [RD4]. The guidance recommends that flood risk be assessed through consideration of both the significance of potential effects and the likelihood of occurrence. The significance of effect is dependent on two factors: the sensitivity of potential receptors and the severity of the flooding. Thus, the three criteria on which flood risk is assessed are:

- sensitivity of the receptors;
- severity of flooding (i.e. the magnitude of the hazard); and
- likelihood (i.e. probability) of occurrence.



6.1.2 The assessment of flood risk has been completed on the basis that the embedded and good practice mitigation detailed in section 8.4 of chapter E8 (Application Reference Number: 6.5.8) is implemented.

Sensitivity of receptors

6.1.3 The sensitivity of receptors is defined according to the method outlined in appendix E8-1-4 with a range of sensitivities from very high through high, medium and low, to very low being defined. TAN15 guidance outlines the vulnerability of different types of on-site development and also classes all off-site receptors as highly sensitive to flooding. The sensitivity of the receptors at and around the Off-Site Power Station Facilities are defined in section 6.3.

Severity of flooding

6.1.4 Appendix 1 of TAN 15 identifies acceptable thresholds of flooding for different types of development and also presents indicative consequences of flooding that may be acceptable subject to adequate warnings and preparation. This guidance has been used to define the magnitude of flooding that falls within the categories negligible, very low, low, medium and high hazard. Further information on the typical criteria against which the category is defined is presented in appendix E8-1-4.

Likelihood of occurrence

6.1.5 The likelihood of occurrence is used to give an understanding of how regularly a given event or outcome will occur. This is fully defined within appendix E8-1-4, and the classification of this criteria is discussed for the different flood sources in the sections below.

Consideration of seasonality

6.1.6 Flooding can occur at any time of year, although it can exhibit quite different seasonal characteristics. Summer flooding is generally associated with localised, high intensity, convective rainfall events, resulting in rapid runoff response in which the peak flow is the main driver of flood risk. This can be a particular issue in urban catchments where significant areas of impermeable surfaces result in rapid runoff. Winter events are generally associated with slower moving frontal systems, they are often prolonged and less intensive and they occur on typically wetter catchments, resulting in longer hydrographs with lower peaks but substantially more volume.

6.1.7 The catchments of concern in this study are essentially rural, they are generally small in size and have shallow low permeability soils meaning that they are likely to be more susceptible to high intensity summer storms than to winter frontal events; a conclusion that is supported by predicted flood flows and levels from modelling of both winter and summer rainfall profiles. Presentation of the results for a summer event only is therefore based on the source of key flood risks on the proposed Off-Site Power Station Facilities during a relatively dry period. Furthermore, the mitigation measures proposed (see chapter E8, Application Reference Number: 6.5.8) are effective and appropriate for the hazards identified, and these are equally appropriate and no-less valid whether the hazard is derived from intense periods of runoff during summer events or longer volume-based events in the winter months.

6.2 FCA screening

6.2.1 Industry guidance [RD16] recommends that an FCA should consider all possible sources of flooding for a given site. This is also reflected in the TAN 15 guidance on flood risk. A number of specific mechanisms exist to identify possible sources of flooding, but many of these can be easily discounted. Table E8-1-1 summarises a range of potential risks and whether these are relevant to the proposed Off-Site Power Station Facilities site.

Table E8-1-1 Screening of potential flood sources and receptors

Flood type	Source	Pathway	Receptor	Consider further?
Tidal	Irish Sea flooding of the proposed Off-Site Power Station Facilities	The site is situated away from the Irish Sea and is not within the flood zone.	Off-Site Power Station Facilities	No
Fluvial and pluvial	Fluvial flooding	Site is in Flood Zone A, and it is considered that there is little or no risk of fluvial flooding.	Off-Site Power Station Facilities	No
	Pluvial flooding from surface water	Flood route identified flowing across site from west to east	Off-Site Power Station Facilities	Yes
	Surface runoff from the proposed Off-Site Power Station Facilities	Changes in runoff due to changes to site layout and extent of impermeable surfaces	Off-site receptors	Yes
Groundwater	Groundwater	Flooding from groundwater emergence	Off-Site Power Station Facilities	Yes
	Groundwater	Risk of groundwater inflow to excavations associated with underground attenuation storage and underground fuel storage	Off-Site Power Station Facilities	Yes
Services	Sewerage network	Overland flows from sewerage system	Off-Site Power Station Facilities	Yes
	Drainage system	Overland flows from drainage systems	Off-Site Power Station Facilities	Yes
Reservoir flooding	Failure of reservoir walls	There are no reservoirs in the catchment that would cause a flood risk to the site.	Off-Site Power Station Facilities	No

6.3 Sensitivity of receptors

6.3.1 Receptors have been divided into two groups; on-site receptors in the form of the Off-Site Power Station Facilities, and all built developments off-site. Under TAN 15 guidance an assessment of the built development off-site receptors considers them all to have a very high sensitivity to flooding. Undeveloped land, such as that west of the A5025, is considered to have a medium sensitivity to flooding.

6.3.2 Following TAN 15 guidance, the Off-Site Power Station Facilities can be classified as an emergency services development, as it is required to be operational and accessible at all times. Following appendix E8-1-4, the proposed Off-Site Power Station Facilities are assessed as having very high sensitivity within this assessment.

6.4 Pluvial flooding

Risk to the Off-Site Power Station Facilities

6.4.2 Baseline pluvial modelling has been undertaken for the proposed Off-Site Power Station Facilities. The results show that at the 3.33% AEP event water runs off from higher ground to the west of the A5025 and ponds in an area next to the western edge of the highway. Runoff also flows from the village of Llanfaethlu in a north-eastern direction across agricultural fields towards this location. For this event, depths of water to the west of the road reach a maximum depth of 0.75m to 1.5m.

6.4.3 Surface water runoff from Llanfaethlu also runs north-eastwards along the A5025. At the proposed Off-Site Power Station Facilities site, surface water from west of the road and from the south would enter the Off-Site Power Station Facilities site.

6.4.4 There is a well-defined flow path across the site from the western corner to the east. The flow has a maximum depth of 0.10m in the centre of the site. The maximum velocity of flow at this point during the 3.33% AEP is 0.20m/s, which is considered a medium magnitude of hazard. Figures showing the depth of flooding from pluvial events are shown in appendix E8-1-3. The locations with the maximum depth and velocities are identified in the figures in appendix E8-1-3 and these are shown in table E8-1-2.

6.4.5 At the 1% AEP event, the flood extents look similar, but the maximum depth of the flow route across the site increases to 0.15m. The maximum predicted velocity is higher at 0.66m/s. Adding a 40% allowance (to accommodate climate change) to the 1% AEP event increases the maximum depth to 0.22m and maximum velocity to 1.15m/s. These are further increased at the 0.1% AEP event to a maximum depth of 0.27m and maximum velocity of 1.46m/s. Simulations of the 0.1% AEP event indicate that the peak flow through the site is 2.71m^3/s.

6.4.6 The potential magnitude of hazard at the site at the 1% AEP event is classified as high as water flow velocities exceed 0.45m/s. At velocities above 0.45m/s, it can become difficult to stand. Given the very high sensitivity of the Off-Site Power Station Facilities, high magnitude of hazard and a high likelihood of occurrence, the overall flood risk is determined as high (see table E8-1-4 for details of the assessment).

Table E8-1-2 Maximum baseline depths and velocities reached during pluvial events within the Off-Site Power Station Facilities

AEP event (%)	Maximum depth		Maximum velocity	
	Location	Depth (m)	Location	Maximum velocity (m/s)
3.33	NRP_Site_104	0.10	NRP_Site_103	0.20
1	NRP_Site_104	0.15	NRP_Site_103	0.66
1+40%	NRP_Site_104	0.22	NRP_Site_103	1.15
0.1	NRP_Site_104	0.27	NRP_Site_103	1.46

6.4.7 Based on the above baseline assessment, there is an existing risk to the land and garage at the site proposed for the Off-Site Power Station Facilities. This risk must be managed, in order to reduce the risk to acceptable levels for the proposed Off-Site Power Station Facilities. In order to achieve this risk reduction, mitigation has been included in the design of the Off-Site Power Station Facilities in the form of a swale. This swale would be constructed to the south of the proposed Off-Site Power Station Facilities site to capture and divert the surface flood flows originating from west of the A5025 and from the A5025 itself safely around the proposed facility. The location of the swale would be between the main Off-Site Power Station Facilities and the area of additional car parking as shown on figure E1-4 (Application Reference Number: 6.5.27). The swale would be trapezoidal in section with a base width of approximately 2m, depth of 1m and a top width of at least 8m. Calculations (using Manning's equation) of its capacity indicate that it would pass a flow of up to $9.5m^3/s$ assuming a roughness of no greater than 0.04, which is reasonable for a grassed swale at that depth of flow.

6.4.8 Drainage features, which form part of the design, would be constructed at the entrance of the site and swale to capture and channel overland flows from the road into the swale. The swale and drainage features have been simulated in a 'with-development' hydraulic model developed from the baseline hydraulic model and in practice would resemble a cattle grid that would allow water to drop into the drainage channel whilst at the same time maintaining vehicular access.

6.4.9 Vehicular access would also be required to the overflow carpark that is located to the south of the swale. Therefore, a culvert or clear span structure would be included in the detailed design to allow water in the swale to pass downstream whilst allowing Horizon access to the car park. This structure would need regular maintenance by Horizon to ensure that it does not get blocked and cause flooding to the Off-Site Power Station Facilities. In addition, the grass in the swale would require cutting by Horizon to prevent excessive growth, reducing capacity. Fencing and signage would be installed by Horizon to keep employees and visitors away from the swale.

6.4.10 The incorporation of the swale into the design of the Off-Site Power Station Facilities would manage the mechanism of flooding noted from pluvial modelling of the site and, as a result, would remove the risk of surface water flooding to the proposed Off-Site Power Station Facilities. 'With-development' modelling demonstrates that the flow path through the centre of the Off-Site Power Station Facilities site is successfully mitigated by the incorporation of the swale up to the 0.1% AEP event. The swale is simulated to pass approximately 2.55m^3/s of flow in this scenario. The remaining 0.15m^3/s, believed to be direct runoff from the site itself, flows directly into Hen-shop Drain. Localised, shallow ponding is shown in the centre of the site in this scenario, however, as with the direct runoff to Hen-shop Drain, this would be attenuated by the site's drainage system.

6.4.11 Sensitivity testing of a more extreme, 0.01% AEP event has indicated that the swale and drainage features proposed are effective at preventing significant ingress of water into the site, leaving little more than shallow ponding in hard standing areas away from buildings. Consequently, it is considered that the site would remain operational under such extreme conditions.

6.4.12 Table E8-1-3 outlines the maximum depths and velocities after the implementation of the mitigation measures and demonstrates the minimal depths that are present as a result of the implementation of the swale and the drainage scheme with maximum depths of up to 0.022m in the 0.01% AEP event.

6.4.13 The rate at which the maximum peak flow and velocity is reached increases slightly post-development taking approximately 34 minutes compared to 38 minutes derived from the baseline model. The maximum depth and velocity is reached quicker which is expected given the decrease in depths of flooding simulated.

6.4.14 In accordance with TAN 15, the modelled results show that the rate of rise of the floodwater does not exceed the 0.1m/hour depth threshold and the velocity does not exceed the 0.3m/hour for flows across the development for emergency service developments and therefore meets the criteria.

6.4.15 There remains a risk of surface water flooding from blockage or structural failure of the drainage structures. Regular maintenance of the structures by Horizon should ensure that this risk is reduced and the post development flood risk to the Off-Site Power Station Facilities is therefore low (table E8-1-4).

Table E8-1-3 Maximum 'with-development' depths and velocities reached during pluvial events with scheme

AEP event (%)	Maximum depth		Maximum velocity	
	Location	Depth (m)	Location	Maximum velocity (m/s)
3.33	NRP_Site_103	0.004	NRP_Site_103	0.06
1	NRP_Site_103	0.005	NRP_Site_103	0.08
1+40%	NRP_Site_103	0.006	NRP_Site_103	0.1
0.1	NRP_Site_103	0.007	NRP_Site_103	0.12
0.01	NRP Site 103	0.022	NRP Site 103	0.43

Risk to off-site receptors

6.4.16 The proposed Off-Site Power Station Facilities site is a brownfield site, and much of the site is currently covered in hardstanding. The development of the Off-Site Power Station Facilities is therefore not going to increase the runoff from the current site. Impermeable surfaces are included in the design for the main part of the site with some landscaping and natural woodland to the south of the site. With the south of the site given over to landscaping and grass surfaced car parking, interception of the runoff rates from the proposed Off-Site Power Station facilities means that runoff would be less than current rates.

6.4.17 The existing drainage would be removed and new drainage installed. The design for the proposed new drainage system includes an underground geo-cellular storage system that would provide attenuation of flows off-site. The 1% AEP flow would be restricted to the mean annual average greenfield runoff rate.

6.4.18 Agricultural land off-site is deemed to have a medium sensitivity (this is defined as undeveloped land in TAN 15), whilst the A5025 and built developments have a very high sensitivity to flood risk. The baseline model indicates that the agricultural land and A5025 / built developments already have moderate and high pluvial flood risks (respectively).

6.4.19 Comparison of the baseline hydraulic modelling simulations to those of the 'with-development' simulations indicates no increase in risk to the A5025, no increase in risk to the land to the west of the A5025 and no increase in risk to built developments to the western corner or to the east of the proposed Off-Site Power Station Facilities. Eastwards, there is simulated to be a reduction in flood extent to agricultural land between the Off-site Power Station Facilities and the Afon Llanrhyddlad. The current and post development flood risk is detailed in table E8-1-4.

6.4.20 With a betterment in the runoff rates from the proposed Off-Site Power Station Facilities compared to the current land use, there would be no increase to the flood risk to other receptors further downstream (see table E8-01.4 for details of the assessment). These receptors include the villages and individual properties identified in section 3.4 and the Beddmanarch-Cymyran Site of Special Scientific Interest.

6.5 Groundwater

Groundwater emergence at surface

6.5.2 The bedrock at the proposed Off-Site Power Station Facilities site is classed as a Secondary B aquifer, with the superficial deposits that surround the site classed as a Secondary (Undifferentiated) aquifer by NRW. The bedrock has some, albeit limited, groundwater in the near-surface weathered zone and fractures.

6.5.3 As much of the area around the proposed Off-Site Power Station Facilities site, including the elevated land to the east, is mantled by glacial till, which generally has a clay matrix and therefore a low permeability, there will be limited recharge to bedrock groundwater (typically across clayey drift only 10% of effective rainfall recharges groundwater). Therefore, during periods of heavy rain, surface water runoff will dominate over groundwater recharge. In addition, the proposed Off-Site Power Station Facilities site is already largely covered in hardstanding, so there will be limited recharge directly to the bedrock underlying the site.

6.5.4 The groundwater in the area adjacent to the A5025 around the proposed Off-Site Power Station Facilities was measured in March 2016 at 3m below ground level, dropping to 4m in April 2016 [RD17]. Water levels are likely to drop further during the summer months, with annual fluctuations in the bedrock in this area typically being of the order of 2m.

6.5.5 Based on the combination of low recharge rates, groundwater levels that are not shallow and limited groundwater fluctuation, the likelihood of groundwater flooding is considered to be low over the 60 year design life. With the low hazard and consequences of flooding, the overall groundwater flood risk is considered low (see table E8-1-4 for details of the assessment).

6.6 Services

Site sewerage

6.6.2 Existing sewer systems serve the existing garage on the proposed site for the Off-Site Power Station Facilities and surrounding properties. The foul sewer runs along the A5025. The sewerage from the Off-Site Power Station Facilities would be connected to the existing services, although there is potential for use of an on-site package wastewater treatment plant if connections are not possible.

6.6.3 Foul sewers for the Off-Site Power Station Facilities have been designed to be able to cope adequately well with the volumes of foul sewerage produced at the site. The discharge from the Off-Site Power Station Facilities is not expected to increase considerably from the current discharge. Any failure of the sewer along the A5025 would be directed into the swale rather than across the site as surface water. The low likelihood of flooding of the proposed Off-Site Power Station Facilities from this source, with low magnitude of hazard, suggests a low flood risk (see table E8-1-4 for details of the assessment).

6.7 Decommissioning

6.7.1 At present, it is assumed that the MEEG, AECC and ESL buildings would be decommissioned and removed from the site around the same time as decommissioning of the Power Station commences at the end of its operational life. Any alternative proposals for use of the buildings or the site beyond this period would need to be considered and determined as part of a future planning application at that time. There would therefore be very limited changes in runoff as there would be little change to the extent of impermeable areas. The flood risk is therefore not likely to change from the operational scenario. All activities will be undertaken in accordance with the relevant legislation and guidance in place at the time.

6.7.2 The drainage system would not be removed during decommissioning and this system will continue to provide mitigation against surface water flooding within the runoff. Maintenance will be required to ensure the continued efficiency of this drainage system.

6.8 Flood risks

6.8.1 The flood risk from the sources outlined above, to the receptors identified in section 3, are provided in table E8-1-2. This is based on the methodology detailed in appendix E8-1-4. For the off-site receptors there are currently moderate and high fluvial flood risks and these would not change following the development (as shown in the last two columns of the table).

Table E8-1-4 Flood risk

Flood type	Source	Pathway	Receptor	Sensitivity	Magnitude of hazard	Significance of effect	Likelihood of occurrence	Current Flood risk	Post development flood risk
Fluvial and pluvial	Pluvial	Surface water runoff	Off-Site Power Station Facilities	Very high	High	High	High	High	Low
	Pluvial	Surface water runoff	Off-site receptor – A5025	Very high	Medium	High	High	High	High
			Off-site receptor – built developments	Very high	Low	Moderate	Medium	Moderate	Moderate
			Off-site receptor – agricultural land west of A5025	Medium	High	Moderate	High	High	High
			Off-site receptor – agricultural land to east	Medium	Medium	Moderate	High	High	Moderate
	Site development	Runoff from the site due to introduction of impermeable surfaces	Off-site receptors	Medium	Low	Low	Low	Low	Low
Groundwater	Groundwater	Emergence of groundwater at the surface	Off-Site Power Station Facilities	Very high	Low	Moderate	Low	Low	Low
	Groundwater	Risk of groundwater inflow to excavations	Off-Site Power Station Facilities development	Very high	Low	Moderate	Low	Low	Low

Flood type	Source	Pathway	Receptor	Sensitivity	Magnitude of hazard	Significance of effect	Likelihood of occurrence	Current Flood risk	Post development flood risk
		associated with underground attenuation storage and underground fuel storage							
Services	Sewerage network	Surface water runoff from failure of sewerage network	Off-Site Power Station Facilities	Very high	Medium	High	Very low	Low	Low

7 Conclusions

7.1.1 The Off-Site Power Station Facilities are classed as very high sensitivity receptors as they will provide emergency services to the Power Station.

7.1.2 Based upon this FCA, despite its location in Flood Zone A, there is currently a high baseline risk of pluvial flooding to the proposed Off-Site Power Station Facilities site. The design for the Off-Site Power Station Facilities therefore includes a swale and drainage features designed to capture and manage surface water flows through the site. Incorporating these features into the design ensures that there would be no risk of flooding to the Off-Site Power Station Facilities from any source and that there would be minor benefits downstream. Assessment of more extreme events has shown that the residual risks are low and that the site would remain operational even under more severe scenarios.

7.1.3 The introduction of vegetated areas to the currently brownfield site would produce a slight reduction in runoff from the site. The proposed drainage strategy includes attenuation via a below ground facility to reduce the runoff from the site to the current runoff rate and therefore not increase flood risk to downstream receptors.

7.1.4 It is concluded that pluvial flood risks can be managed and betterment provided through the site layout and design described in this report and the Environmental Statement.

8 References

Table E8-1-4 Schedule of references

ID	Reference
RD1	Welsh Government. 2017. *Technical Advice Note* (TAN) *15 Development Advice Map*. [Online] [Accessed: May 2017]. Available from https://maps.cyfoethnaturiolcymru.gov.uk/Html5Viewer/Index.html?configBase=https://maps.cyfoethnaturiolcymru.gov.uk/Geocortex/Essentials/REST/sites/Flood_Risk/viewers/Flood_Risk/virtualdirectory/Resources/Config/Default
RD2	Natural Resources Wales. 2016. *Flood Risk Map*. [Online] [Accessed: April 2017] Available from: https://naturalresources.wales/our-evidence-and-reports/maps/flood-risk-map/?lang=en
RD3	Welsh Government. 2016. *Planning Policy Wales* (PPW). Edition 9 [Online] [Accessed: April 2017] Available from: http://gov.wales/topics/planning/policy/ppw/?lang=en
RD4	Welsh Government. 2004. *Technical Advice Note* (TAN) *15: Development and Flood Risk*. [Online] [Accessed: October 2016]. Available from: http://wales.gov.uk/docs/desh/publications/040701tan15en.pdf.
RD5	Welsh Government. 2016. *CL-03-16 Climate Change Allowances for Planning Purposes*. [Online] [Accessed: April 2017] Available from http://gov.wales/topics/planning/policy/policyclarificationletters/2016/cl-03-16-climate-change-allowances-for-planning-purposes/?lang=en
RD6	Meteorological Office. 2009. *UK Climate Projections*. [Online] [Accessed: April 2017] Available from http://ukclimateprojections.metoffice.gov.uk/22530
RD7	Isle of Anglesey County Council (IACC) and Gwynedd Council. 2017. *Anglesey and Gwynedd Joint Local Development Plan 2011-2026, Written Statement.* [Online] [Accessed: September 2017] Available from: http://www.anglesey.gov.uk/planning-and-waste/planning-policy/joint-local-development-plan-anglesey-and-gwynedd/
RD8	Isle of Anglesey County Council and Gwynedd Council. 2013. *Anglesey and Gwynedd Joint Local Development Plan, Topic Paper 8: Strategic Flood Consequence Assessment (Level 1)*. [Online] [Accessed: October 2016] Available from: http://www.anglesey.gov.uk/download/31094.
RD9	Isle of Anglesey County Council. undated. *Preliminary Flood Risk Assessment*. [Online] [Accessed: October 2016] Available from: http://webarchive.nationalarchives.gov.uk/20140328084622/http://cdn.environment-agency.gov.uk/flho1111bvfk-e-e.pdf
RD10	Isle of Anglesey County Council. 2013. *Anglesey Local Flood Risk Management Strategy*. [Online] [Accessed: October 2016] Available from: http://www.anglesey.gov.uk/download/32358.
RD11	Natural Resources Wales. 2015. *Western Wales River Basin Management Plan 2015-2021.* [Online] [Accessed: April 2017] Available from: https://naturalresources.wales/media/676165/wwrbdsummary.pdf.
RD12	British Geological Society. 2017. *Geology of Britain Viewer*. [Online] [Accessed: April 2017] http://mapapps.bgs.ac.uk/geologyofbritain/home.html
RD13	WRc plc. 2012. Sewers for Adoption: A Design & Construction Guide for Developers. 7th Edition. Swindon: WRc plc.
RD14	Innovyze. 2017. Infoworks ICM (Integrated Catchment Modelling) v 5.7.7.
RD15	Welsh Government. 2016. *Flood Consequence Assessments: Climate Change Allowances*. [Online] [Accessed: April 2017]. Available from: http://gov.wales/docs/desh/publications/160831guidance-for-flood-consequence-assessments-climate-change-allowances-en.pdf

ID	Reference
RD16	Lancaster, J.W., Preene, M. and Marshall, C.T. 2004. *Development and Flood Risk – Guidance for the Construction Industry* (C624). London: CIRIA.
RD17	Structural Soils Ltd. 2016. Site 3 – Llanfaethlu Improvements, Task Order 4, A5025 Off-line Highways Improvements Ground Investigation, Project No: 730168.

Appendix E8-1-1 Figures

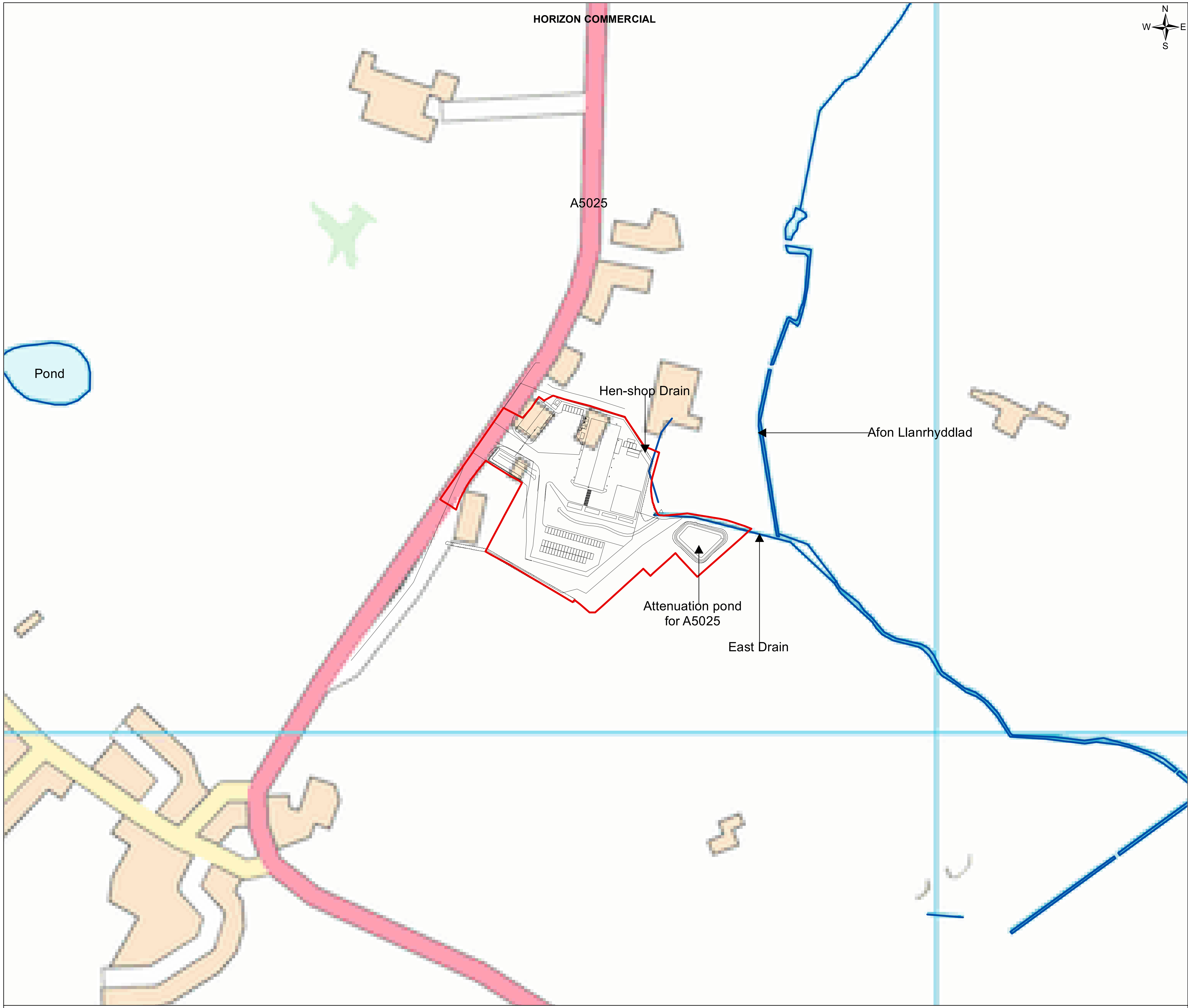


FIGURE E8-1-1

Legend

- Off-site Power Station Facilities
- Off-site Power Station Facilities masterplan
- Surface water features

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
0	JUL 17	Initial Issue	HT	AJ	SH	RB

Client

HORIZON NUCLEAR POWER

Project

WYLFA NEWYDD PROJECT
FLOOD CONSEQUENCE ASSESSMENT

Drawing Title

SURFACE WATER FEATURES

Scale @ A3	1:3,000	DO NOT SCALE
Jacobs No.	60PO8077	
Client No.		

Drawing No.

60PO8077_DCO_VOL_E_08_01_01_01

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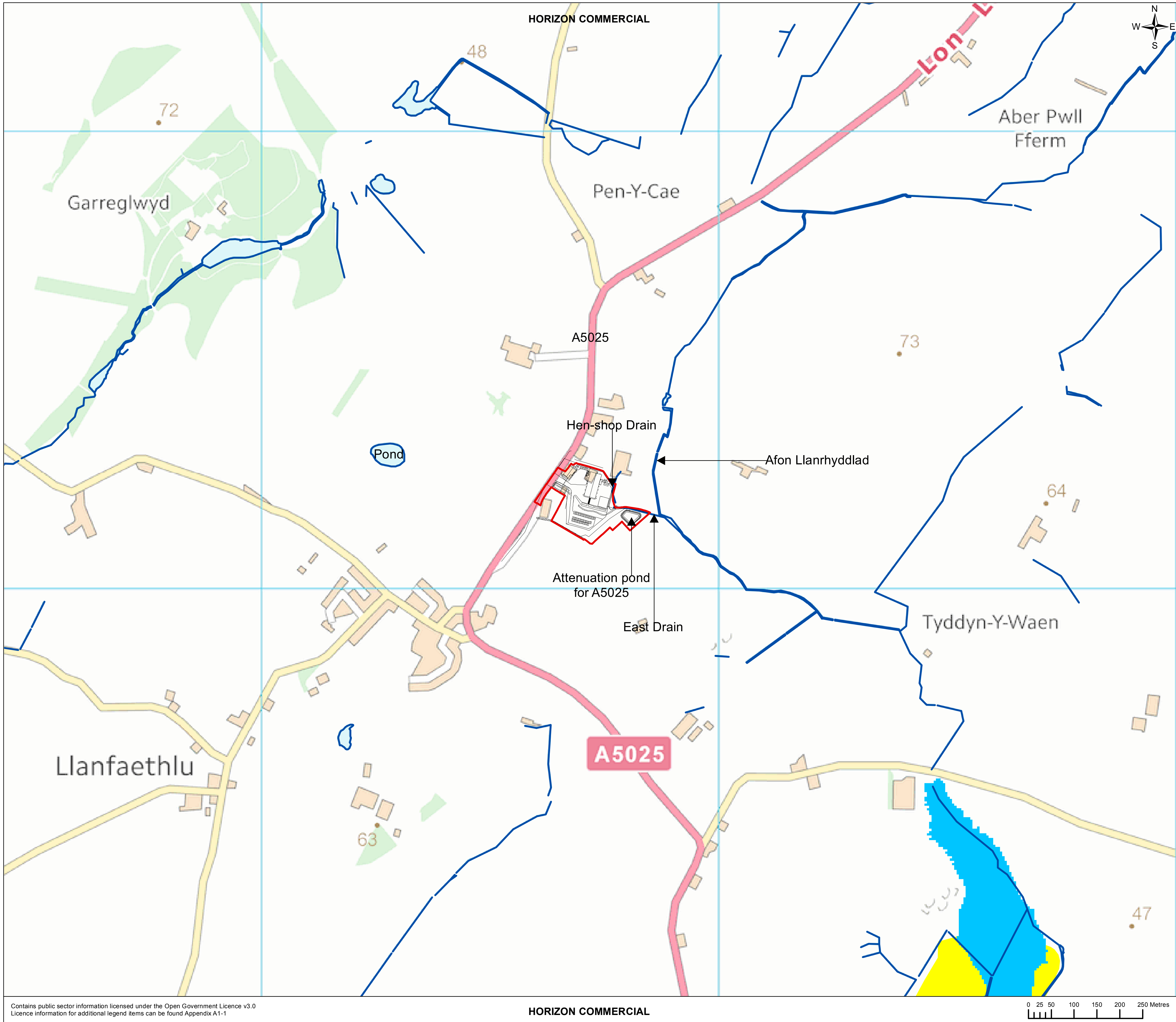
FIGURE E8-1-2



Legend

- Off-site Power Station
- Off-site Power Station Facilities
- Surface water features
- Zone B
- Flood Zone C2

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
0	JUL 17	Initial Issue	HT	AJ	SH	RB

Client

HORIZON NUCLEAR POWER

Project

WYLFA NEWYDD PROJECT
FLOOD CONSEQUENCE ASSESSMENT

Drawing Title

RISK OF FLOODING
FROM RIVERS AND SEA

Scale @ A3	1:8,000	DO NOT SCALE
Jacobs No.	60PO8077	
Client No.		

Drawing No.

60PO8077_DCO_VOL_E_08_01_01_02

FIGURE E8-1-3

Legend

- Off-site Power Station Facilities
- Off-site Power Station Facilities masterplan
- Surface water features
- High surface water flood risk - extent
- Medium surface water flood risk - extent
- Low surface water flood risk - extent

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
0	JUL 17	Initial Issue	HT	AJ	SH	RB

Client

HORIZON NUCLEAR POWER

Project

WYLFA NEWYDD PROJECT
FLOOD CONSEQUENCE ASSESSMENT

Drawing Title

RISK OF FLOODING
FROM SURFACE WATER

Scale @ A3	1:3,000	DO NOT SCALE
Jacobs No.	60PO8077	
Client No.		

Drawing No.

60PO8077_DCO_VOL_E_08_01_01_03

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Appendix E8-1-2 Topographical Survey

HORIZON COMMERCIAL

ANNOTATIONS:

AV	Air Valve	RE	Rodding Eye
BH	Borehole	RNP	Road Name Plate
BL	Bed Level	RP	Reflector Post
Bol	Bollard	RS	Road sign
OSBM	Bench Mark	SAP	Sapling
BS	Bus Stop	SF	Soffit Level
BT	Telcom IC	Slt	Salt Box
Br	Stay Wire	ST	Stop Tap
Cbx	Control Box	SV	Sluice Valve
Culv	Culvert	Tap	Water Tap
CL	Cover Level	TCB	Telephone Call Box
CTV	Cable TV	TS	Traffic Signal
DP	Down Pipe	TL	Traffic Light
Dr	Drain cover	Thl	Threshold Level
Ebx	Electric Box	TM	Traffic Master
EC	Electric Cover	TP	Telegraph Pole
EP	Electric Pole	CCTV	CCTV Camera
PY	Electric Pylon	Gvp	Vent Pipe
ER	Earthing Rod	W	Water Cover
FH	Fire Hydrant	WE	Well
FL	Flood Light	WL	Water Level
FS	Flag Staff	WM	Water Meter
Gas	Gas Manhole	WO	Wash Out
Scam	Speed Camera		
Gt	Gate Post		
G	Gully		
GV	Gas Valve		
IC	Inspection Cover		
IL	Invert Level		
Jbx	Junction Box		
KO	Kerb Outlet		
KI	Kerb Inlet		
LB	Litter Bin		
LC	Light Column		
LP	Lamp Post		
MH	Manhole		
Mkr	Marker Post		
MP	Mile Post		
MS	Mile Stone		
NB	Notice Board		
Pi	Pipe		
PM	Parking Meter		
P	Post		
PU	Pump		
PZ	Piezometer		

FENCE TYPES:

CBF	Close Boarded Fence
IRF	Iron Railings Fence
PWF	Post & Wire Fence
PRF	Post & Rail Fence
BWF	Barbed Wire Fence
PCLF	Post & Chain Link Fence

WALL TYPES:

AB	Abutment Wall
BW	Brick Wall
SW	Stone wall
DSW	Dry Stone Wall
RTW	Retaining Wall
CW	Concrete Wall

SYMBOLS:

Building
Open Building
Gate
Bottom of Bank
Ditch
Fence
Foliage Line
Hedge (width varies)
Kerb
Overhead Line
Road Edge (no kerb)
Rock Outcrop
Top of Bank
Track Edge
Verge
Wall
Tree (spread varies)
Bush (spread varies)
+ (value) (Spot Level)
name value (Survey Station)

Notes:

Survey Control Grid:

Survey Control Point P101 was used as a base point for the survey (due to the higher precision of the two satellite observations recorded), with Survey Control Point P100 used to calculate the correct bearing between the two points. The coordinates of P101 and the bearing and distance to P100 was then used to recalculate the coordinates of P100. The topographical survey data is therefore centered around OS National Grid with the correct orientation but maintaining a scale factor of 1. The surveyed data will therefore correctly overlay on to OS mapping but users must note that there may be minor discrepancies between the two sets of data due to the inherent errors within OS mapping.

All additional survey control stations were established from P100 & P101.

Survey Stations

Name	Easting (m)	Northing (m)	Level (m)
P100	231543.984	387113.367	61.333
P101	231675.471	387284.722	54.872
P102	231702.332	387234.162	52.327
P103	231644.110	387235.645	54.151
102A	231739.206	387215.031	50.538
102B	231741.269	387261.583	52.282

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
1.0	23.03.16	Final Revision	SP	NJH	NMB	LM

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HORIZON NUCLEAR POWER

Project
Wylfa - Llanfaethlu

Drawing title
2d Topographical Survey

Drawing status
FINAL

Scale	1:200 @ A0	DO NOT SCALE
Jacobs No.	60PO8049	
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Drawing number: 60PO8049/JAC/TOPO/DRG/00001 — Rev 1.0

Appendix E8-1-3 Pluvial Modelling Results and Report

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Horizon Nuclear Power

Wylfa Newydd DCO Project – MEEG/ESL/AECC, Llanfaethlu Anglesey, NW Wales

Hydrology and Hydraulic Modelling Factual Report

January 2018

Amec Foster Wheeler

Report for

Horizon Nuclear Power
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Contents

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Appendix A Supporting Mapping

1. Introduction

1.1 Purpose of this report

This factual report has been produced for the purpose of describing the hydrology assessment and the hydraulic modelling of the pluvial flood hazard modelling undertaken to support the Wylfa Newydd DCO Project, specifically for the proposed development at Llanfaethlu. The Site at Llanfaethlu (hereon referred to as 'Site') has been selected for the Mobile Emergency Equipment Garage (MEEG), Environmental Survey Laboratory (ESL) and the Alternative Emergency Control Centre (AECC) developments. This factual report does not present an assessment of the significance of the results. This factual report provides a detailed statement of the hydrological and hydraulic modelling methods applied, assumptions made and the limitations within the approaches.

1.2 Purpose of modelling

2D hydraulic modelling has been undertaken to determine the pluvial flood hazard to the Site, including climate change impacts. There are no main rivers in the immediate vicinity of the Site, therefore pluvial flood risk was the only source of flooding modelled. A range of flood event return periods have been modelled to establish the extent of the hazard. A summary of the model scenarios required for hydrology assessment and hydraulic modelling is shown in Table 1.1. The 10,000 year AEP and beyond design basis return period will be determined and simulated to support the Nuclear Safety Case in due course.

Table 1.1 Summary of model scenarios

Source	Hydrology method	Event	Season	Storm duration	Epoch	Climate change
Pluvial	ReFH2.2 with FEH13 rainfall data	1:30, 1:100, 1:1000 year AEP	Summer	1 hour	2017	N/a
		1:100 year AEP	Summer	1 hour	2080s	20% central 40% upper

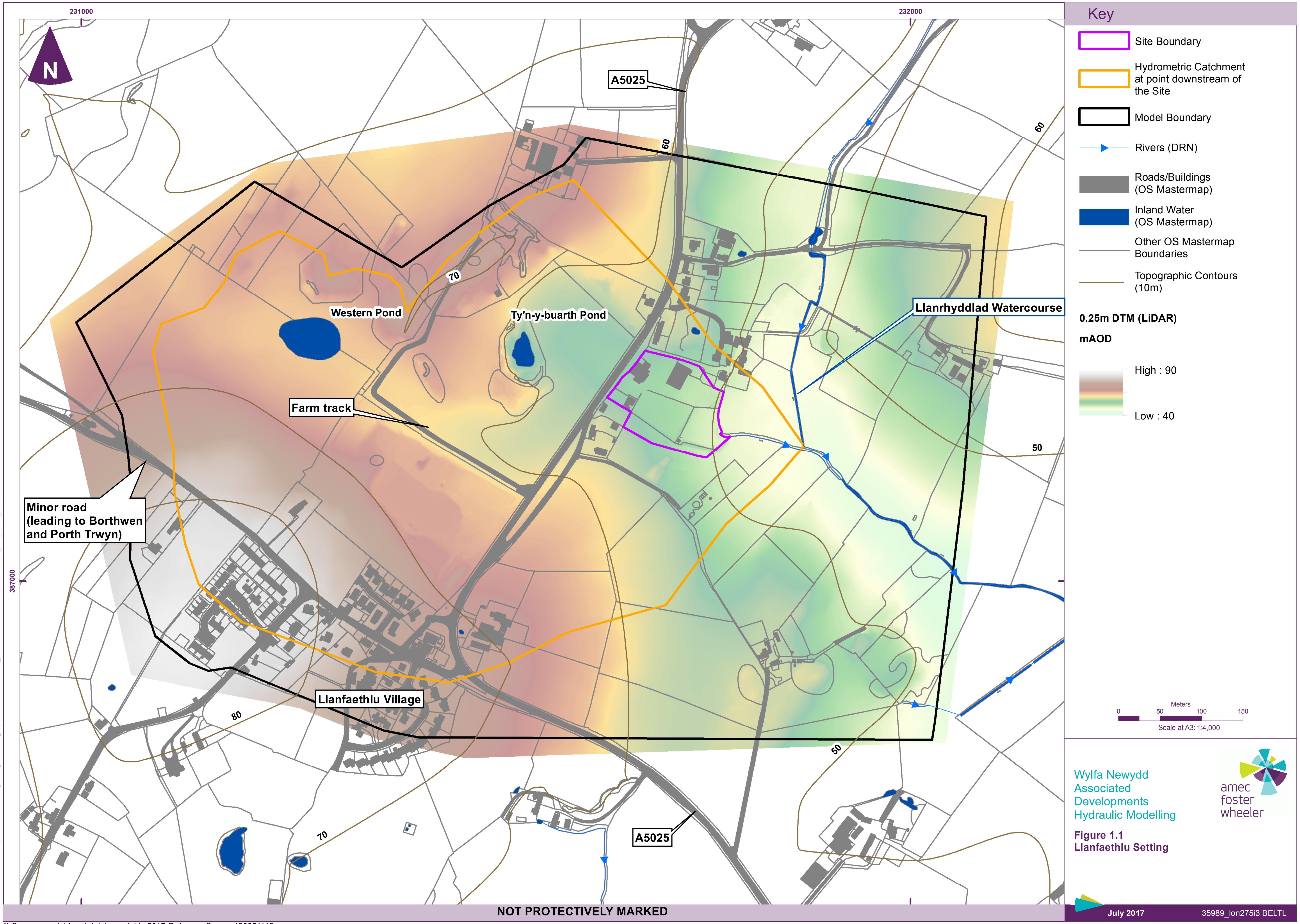
AEP = Annual exceedance probability

Section 3.2 and Table 3.2 provide an overview of the selection of the 1 hour critical storm duration used in the production model runs.

1.3 Site overview

The Site is located on the eastern side of the A5025, north of the village of Llanfaethlu (Figure 1.1). The Site at present is predominantly hard-standing with various buildings located within it. There are no known open channel water-features within the Site, however there is a small unnamed watercourse originating at the eastern end of the Site, which flows south-east into the Afon Llanrhyddlad. The Afon Llanrhyddlad flows from the north-east of the Site, and then continues to flow south/south-east. It is understood (from a meeting in Bangor on 12 April attended by NRW and IACC) that there is a culvert underneath the Site which connects the highway drain along the A5025 to this unnamed tributary of the Afon Llanrhyddlad. This unserved drain has been excluded from the modelling, providing a conservative estimate of water flowing across the surface of the Site.

A hydrometric catchment has been delineated for the unnamed tributary of the Afon Llanrhyddlad, which originates from the eastern end of the Site. The catchment was delineated using 5m OS Terrain 5 digital terrain model (DTM). The catchment extends to the west and includes two ponds, labelled Western Pond and Ty'n-y-buarth Pond on Figure 1.1. This catchment was used to inform the pluvial hydrology assessment (Section 3) and to inform the spatial extent of the 2D model domain, described in Section 4. The scope of the modelling in this report is limited to pluvial modelling only. A small fluvial waterbody is situated ~5m down slope (e.g. elevational change) from the MEEG Site. The accompanying FCA concludes that this watercourse does not present a risk to the Site and as such no hydraulic modelling is undertaken. The 2D model domain, therefore, has been scaled back to fully capture the catchment to the Site and not the Afon Llanrhyddlad catchment.



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This report is a factual account of the hydraulic modelling undertaken using InfoWorks ICM (Integrated Catchment Model) and the associated hydrology assessment. The modelling and hydrology assessment have been undertaken for the purpose of providing quantified descriptions of the pluvial flood risk environment at the Site in Llanfaethlu.

1.4 Overview of modelling approach

To fulfil the requirements of the Wylfa Newydd DCO Project it was necessary to construct a detailed 2D model of the Llanfaethlu area to determine the pluvial flood hazard in the vicinity of the Site.

A 2-Dimensional flood modelling approach using InfoWorks ICM has been adopted to provide estimates of the pluvial flood hazard to the Site. The Site at Llanfaethlu and the surrounding catchment is being modelled using InfoWorks ICM v7.5, which is an industry standard software package widely used for flood modelling to inform FCAs and nuclear safety related assessments. The small tributary channel which drains directly from the eastern boundary of the Site, and the Afon Llanrhyddlad watercourse into which it flows, are represented in the 2D model using the DTM elevations, breaklines and roughness zones (these aspects of the model build are described further in Table 4.1). At the outset, it was envisaged that the development proposal might require the modification of existing pluvial flow routes through the Site. InfoWorks ICM has been selected for this application as it is better equipped to represent such flow modifications.

1.5 Key assumptions

Detailed (0.25m) LiDAR data was captured in March 2017, and was used to represent the topography. The following key assumptions have been made:

- Model extents have been determined by topography to prevent any artificial model boundary influences on the flood hazard estimate at the Site;
- 0.25m LiDAR data has been flown for this model (BlueSky, 2017) and is assumed to be representative of the catchment, and critical elements within the catchment, such as roads, watercourses, ponds and land depressions (see Section 4.1); and
- It has been assumed that the DTM provides a sufficiently accurate representation of the channel capacity of minor watercourses within the model domain so as not to underestimate the hazard description on Site.

1.6 Document structure

The remainder of this report is structured as follows:

- Section 2 - Available data: Identifies data collated or commissioned to aid model build and catchment representation;
- Section 3 - Hydrology: Details the pluvial hydrology assessment;
- Section 4 - Model overview: Details the representation of the 2D model domain including any assumptions made;
- Section 5 - Model runs: Lists the model scenarios run;
- Section 6 – Baseline model results: Provides a summary of model results, including flood extents and depths;
- Section 7 – 'With development' model results: Provides a summary of model results, including flood extents and depths; and

- Section 8 - Sensitivity testing: Lists sensitivity runs carried out on the 2D model and discusses outputs.

2. Available data

The 2D model was built following collation of data (topography, structures and rainfall) of the Site and the surrounding catchment area data. Table 2.1 below lists the data sets used and provides a description of the contents of each data set.

Table 2.1 Available Data

Item	Comments
Topographic Data	0.25m LiDAR was flown in March 2017 for this model (0.25m ASCII grid, supplied April 2017) 5m OS Terrain DTM (5m ASCII grid, downloaded from UK Map Centre July 2016)
Topographic Contour Data	OS Open Data Terrain 50 (10Km x 10Km grid, 10m contour intervals)
OS Map Data	OS Mastermap (URS, October 2014)
Rainfall data	FEH 2013 DDF rainfall data - Pluvial inflow for hydraulic modelling, and to derive hydrographs FEH Web Service https://fehweb.ceh.ac.uk
Climate change	To determine the climate change allowance factors applied to the 1:100 year AEP event Adapting to Climate Change: guidance for flood risk and coastal erosion risk management authorities in Wales (Llywodraeth Cymru/Welsh Government, 2011) Flood Consequence Assessments: climate change allowances (Llywodraeth Cymru/Welsh Government, 2016)
Flood Studies Report	Flood Studies Report (NERC, 1975) method for sub-hourly rainfall to estimate the 0.5 hour storm.
Catchment descriptors	SPRHOST used to estimate runoff from pluvial inflows, utilised in the 2D model domain as a runoff coefficient (see Section 4.2) FEH Web Service https://fehweb.ceh.ac.uk
Calibration/verification events identified	No calibration events identified due to no gauged data available
Flood history	Risk of flooding from surface water (Natural Resources Wales, July 2016); ► Yellow is low risk ► Light orange is medium risk ► Dark orange is high risk ► Aproximate location of MEEG/ESL Site in red outline. 

3. Hydrology assessment

This section describes the process to derive the hydrology inputs for the hydraulic modelling. The hydrology inputs were in the form of hyetograph (rain/time) data for a range of storm durations and annual exceedance probabilities. The hydrology inputs have been calculated for the baseline description of the Site. The same baseline hyetographs have been applied in the 'with development' simulations.

3.1 Input data

The data sourced for the pluvial input to the model is detailed in Table 2.1. The FEH 13 depth duration frequency (DDF) rainfall data was downloaded for a point close to the Site at NGR 231700 387210. The point data is taken to be representative of the 1km grid square which it is located in.

3.2 Method of hyetograph calculation

Deriving hyetographs

Rainfall depths were obtained from FEH 13 DDF tables for the Site coordinates. The FEH 13 data provides total depths for storm durations from 1 hour up to 96 hours, and for annual exceedance probabilities for the 1:30 year AEP to 1:1,000 year AEP events. The FEH13 dataset does not contain rainfall depths for the 0.5 hour storm duration, instead flood estimation guidance from the Environment Agency (EA, 2015) was applied to yield estimates for the 0.5 hour storm duration. Rainfall depths for the 0.5 hour and 1.0 hour storm were calculated from the Flood Studies Report (FSR) method; the factor 'FSR rain 0.5 hour/FSR rain 1.0 hour' was applied to the FEH13 1.0 hour rainfall depth to produce 0.5 hour rainfall values which are consistent with the FEH13 data for longer storm durations.

Rainfall depths were profiled using the design summer storm profile in ReFH2.2, as justified by the results of Sensitivity Test 4 in Section 8 of this report.

Rainfall hyetographs have been calculated using total rainfall depths without infiltration values or areal reduction factors applied, and these total rainfall depths calculated are presented in Table 3.1. The total rainfall hyetographs were generated for use as a direct input for the InfoWorks ICM model. In InfoWorks ICM the total rainfall depths are reduced by applying a factor 0.40; this is the SPRHOST (Standard Percentage Runoff (%) associated with the distribution of soil types) for the catchment, taken from the FEH descriptors (see Section 4.2). Section 8 presents the findings of a sensitivity test into alternative reduction factors to account for infiltration loses, to evaluate the sensitivity of the onsite pluvial flood hazard to the SPRHOST reduction factor. It is possible that in higher return periods the standard SPRHOST value could lead to an underestimation from permeable surfaces due to more saturated ground conditions.

Table 3.1 Total rainfall depths (mm)

Storm duration (hour)	1:30 year AEP	1:100 year AEP	1:1,000 year AEP
0.5	23.31	35.53	61.80
1.0	30.49	46.84	82.87
3.0	42.35	60.37	97.77
6.0	50.67	69.27	107.53
24.0	71.32	91.29	131.06

Critical storm duration

The 1:100 year AEP event was used to determine the critical storm duration, by running five storm durations (0.5, 1, 3, 6 and 24 hour storms). The critical storm was determined based on peak depths achieved on the Site. The detail of the selection of the critical storm is discussed in Section 5.1. The critical duration was identified as the 1.0 hour storm. Table 3.2 presents the pluvial scenarios that were run through the InfoWorks Hydraulic model.

Table 3.2 Pluvial scenarios run in InfoWorks

	1:30 year AEP	1:100 year AEP	1:100 year AEP plus climate change	1:1000 year AEP
Storm duration (hour)	Critical duration	0.5, 1, 3, 6, 24hrs (to determine critical duration)	Critical duration	Critical duration
Seasonal storm profile	Summer storm profile	Summer storm profile	Summer storm profile	Summer storm profile

AEP: Annual Exceedance Probability.

Climate change allowance

Climate change was applied to the 1:100 year AEP event only. Climate change to the 2080s was accounted for in two scenarios, by applying a central change 20% uplift factor and also an upper end estimate 40% uplift factor to rainfall depth. This increase is informed by guidance (2011/2016) from Llwodraeth Cymru Welsh Government, Adapting to Climate Change (for pluvial rainfall intensity, for the 2080's epoch). The central change factor would normally be applied to the 1:100 year AEP event for design standards.

3.3 Hydrology for baseline runs

This section presents the rainfall hyetographs which are used in the InfoWorks ICM hydraulic modelling, based on the approach presented in Section 3.2. Figure 3.1 displays the storm profiles of the five different durations for the 1:100 year AEP. The graph presents the profiles in a 36 second time step. The 0.5 hour storm has the highest peak rainfall at approximately 2.9 mm (in 36 seconds), with the 24 hour storm peaking at approximately 0.1 mm.

The critical 1 hour baseline design hyetographs for the different annual exceedance probabilities and climate change factors are displayed in Figure 3.2. The 1 hour design runs were run using a 3 minute timestep; with the peak rainfall greatest for the 1:1,000 year AEP, peaking at a depth of 15.7mm (in 3 minutes).

Figure 3.1 Pluvial 1:100 year AEP hyetographs for all storm durations

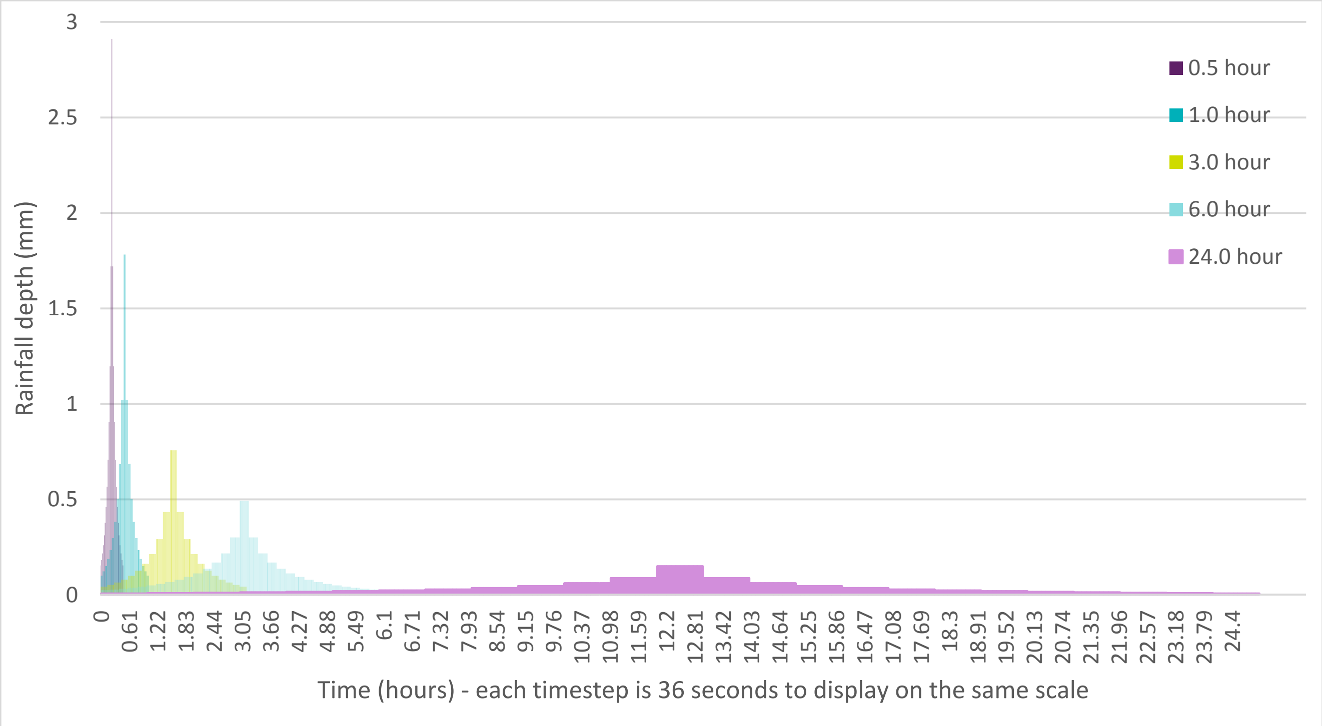
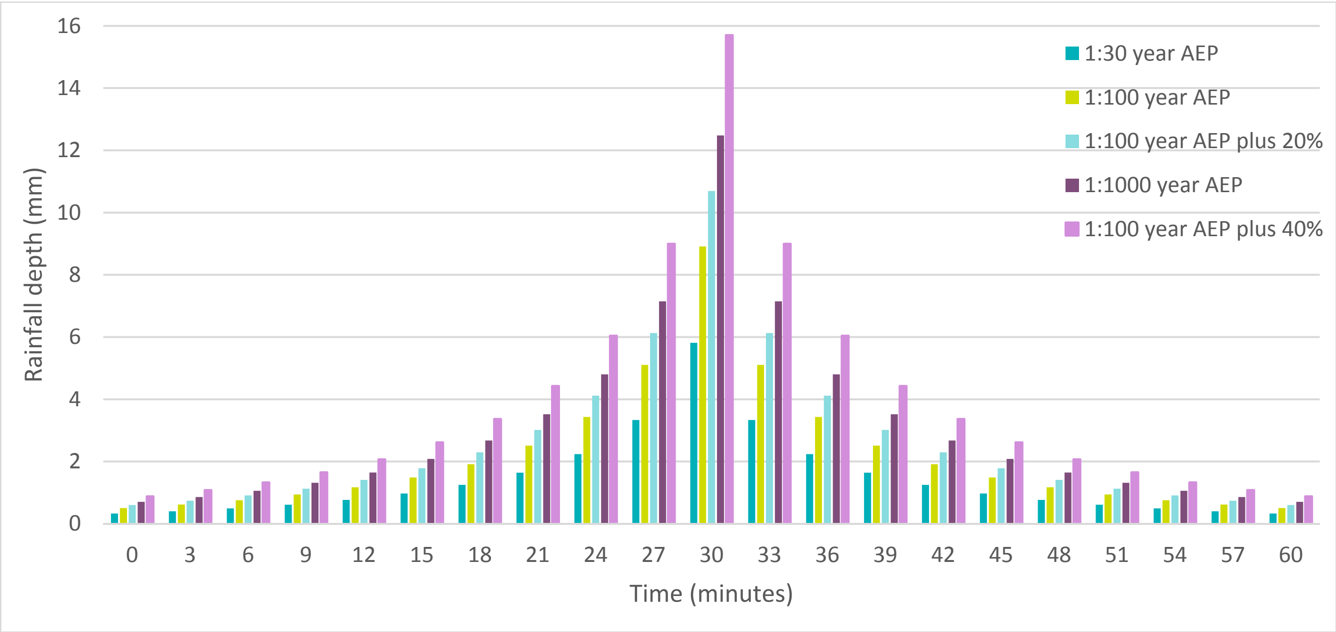


Figure 3.2 Pluvial 1 hour 'critical' storm hyetographs for baseline runs



4. Hydraulic modelling

This section provides an overview of the baseline 2D model built to represent the MEEG, ESL and AECC Site at Llanfaethlu. The Llanfaethlu 2D model was originally built in InfoWorks ICM v7.0 and then upgraded to v7.5.5 in April 2017.

Section 4.1 provides an overview of the 2D baseline model set up, with the details documented in Table 4.1. Figure 4.1 displays the spatial extent of the model roughness, and also details the result lines and points that define where model output data are available.

Section 4.2 provides an overview of the changes made to the baseline model to represent the proposed MEEG, ESL and AECC development and associated Site drainage infrastructure.

4.1 Baseline model

Table 4.1 2D model overview

Item	Description
2D model area	64 ha
Maximum triangle size	5 m^2 - Elements within the mesh used for the hydraulic calculations will be no larger than this.
Minimum element area	1 m^2 - Elements within the mesh used for the hydraulic calculations will be no smaller than this.
Terrain sensitive meshing	Maximum height variation within a triangle is 0.05m Therefore, if any given triangle has a difference in sampled ground levels within its area of more than 0.05m, the meshing algorithm will spilt the triangle into smaller triangles until the difference is less than 0.05m.
Number of triangles in mesh	358256
Number of elements in mesh	354077
Breaklines (see Figure 4.1)	Breaklines are used to define the mesh along specified lines, forcing the mesh to generate triangles along its edge. Breaklines were added to define field boundaries (using OS MasterMap polyline). In addition, the boundaries of the roughness zones digitised to define areas of different surface roughness (described below) are also being used as breaklines.
Representation of buildings	Buildings are represented as roughness zones, with an increased Manning's n of 0.3 (Syme, 2008). OS MasterMap was used to define the building areas.
Representation of river banks	0.25m LiDAR (there are no main watercourses in the proximity of the Site)
2D boundary conditions	Normal Condition – allowing water to flow out of the 2D zone where the zone does not exactly match the catchment boundary
Delineation of roughness Zones (see Figure 4.1)	Roughness zones were delineated using OS Mastermap and also freely available aerial photography. Aerial photography picked up cement/man-made ground in the area of the MEEG Site which was described by OS Mastermap as 'general surface'. Edits were made to the Site and is now represented with a similar roughness value to path/roadside. Roughness zones also act as breaklines; for example, the elements representing the roughness of a building will generate triangles which fit exactly within the building, each with the representative roughness. The Manning's n values selected for each land cover type were chosen based on published information (Chow, 1959; Syme, 2008) modeller experience and judgement. They are also consistent with the ongoing A5025 associated development modelling project. The Manning's n value assumptions were subjected to sensitivity testing (Section 8) which confirms the appropriateness of the values applied.

Item	Description	
Hydraulic roughness values	**2D Surface**	**Roughness Value**
	Grass/General surface	0.04
	Building/Glasshouse	0.3
	Road	0.015
	Path/Roadside	0.025
	Inland water (watercourses and ponds)	0.035
	Rough grassland/Scrub/Trees	0.080
Delineation of infiltration zones	There are no infiltration zones in the 2D domain. A single infiltration surface has been applied to the entire 2D Zone.	
Infiltration/runoff values	**Infiltration surface**	**Fixed runoff coefficient**
	'SPRHOST' for entire 2D zone to determine the net runoff using the pluvial total rainfall inflows. SPRHOST runoff coefficient compared to values derived from NCB (1982) for confirmation.	0.40
Model output (See Figure 4.1)	A series of results lines and points were included in the 2D domain to allow for results to be output at the specific locations (available as depth, flow and velocity).	

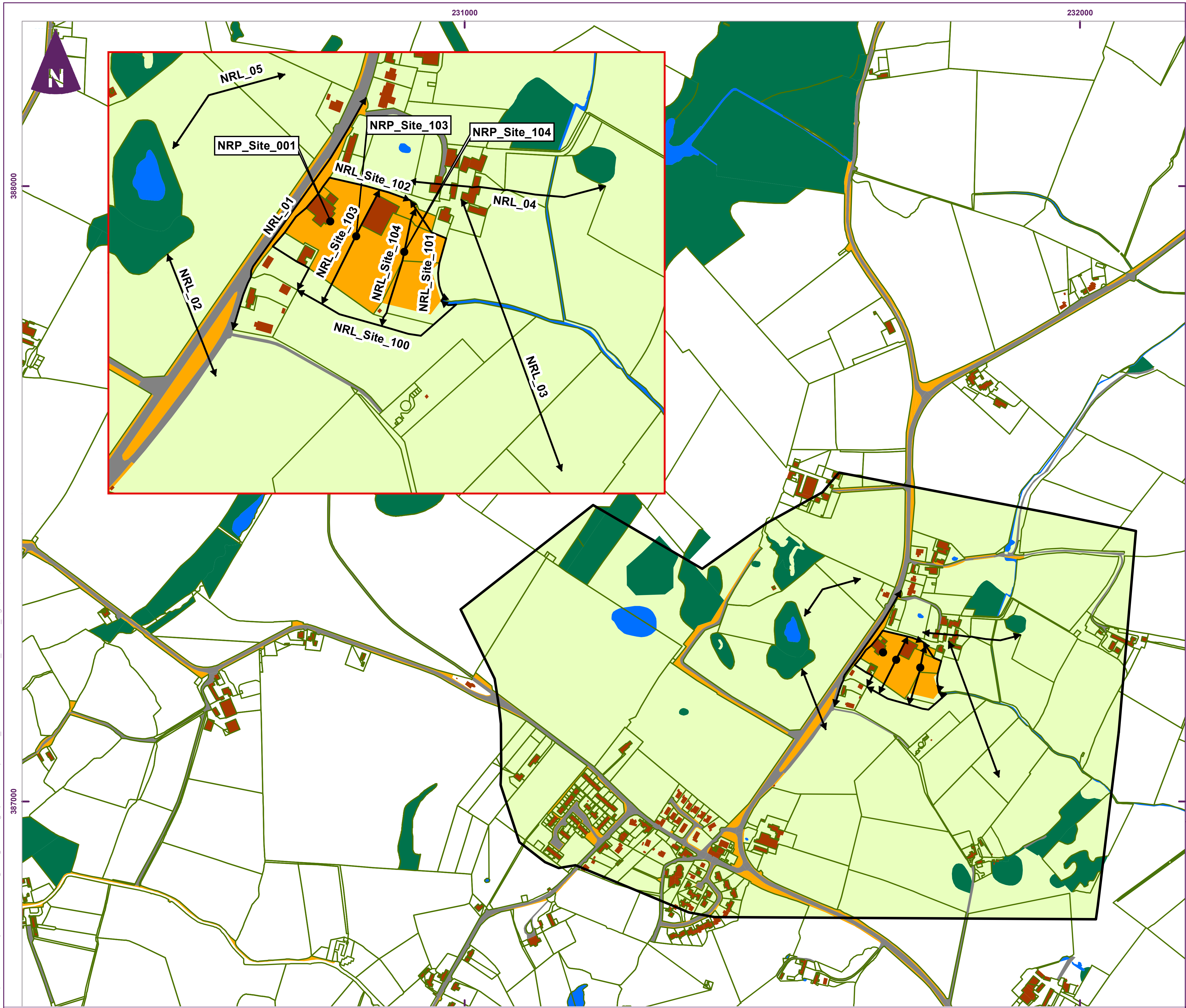
Topography

The 2D model derives elevation values from the 0.25m LiDAR which was flown in March 2017 for the purpose of this model. Figure 1.1 displays the 0.25m LiDAR which is used in the model. Earlier versions of the model, which are now superseded, used 5m DTM (OS Terrain 5) data. As would be expected, the 0.25m LiDAR data captures the terrain and land features, including drains, in greater detail compared to the 5m OS Terrain 5 data. The LiDAR was flown and commissioned for this model and is the most accurate and up to date DTM data available.

Runoff coefficient

Pluvial hydrological calculations have applied total rainfall depths to the hyetograph storm profiles. Due to the relative homogeneous land use and soil type across the 2D model (in particular across NRW defined surface water flow pathways), runoff coefficient is applied as a fixed factor across the 2D model. The SPRHOST value has been used as the runoff coefficient, as this represents the standard percentage runoff associated with soil types categorised for their specific hydrological characteristics. This value has been obtained from FEH for catchment areas surrounding and including the 2D model area; analysis of the FEH catchments in the surrounding had shown that the SPRHOST value did not change in the vicinity of the model.

The SPRHOST value has been confirmed against values calculated in National Coal Board (1982), using catchment slope, soil type and vegetation type. The slope values were calculated as 0.01 for critical surface water pathways. The soil type was identified as being loam across the majority of the model domain (Cranfield University Soilscapes website). The vegetation type was identified as part grassland, part scrubland,) for the Llanfaethlu model area. The identification of these three parameters confirm that the 0.40 SPRHOST value is within the range of runoff coefficients in National Coal Board (1982). The runoff coefficient described here is the subject to two sensitivity model tests discussed in Section 8.



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Key

Roughness Zones (Mannings n coefficient)

- 0.015 - Road
- 0.025 - Path, Roadside
- 0.035 - Inland Water
- 0.08 - Rough Grassland, Scrub, Trees
- 0.3 - Buildings, Glasshouse
- 0.04 - Grass, General surface
- Model boundary
- 1D Model Domain
- Site Boundary
- Results Point
- Results Line
- OS Mapping

0 100 200 300 m

Scale at A3

Wylfa Newydd Associated Developments Hydraulic Modelling

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Figure 4.1
Llanfaethlu 1D-2D Hydraulic Model

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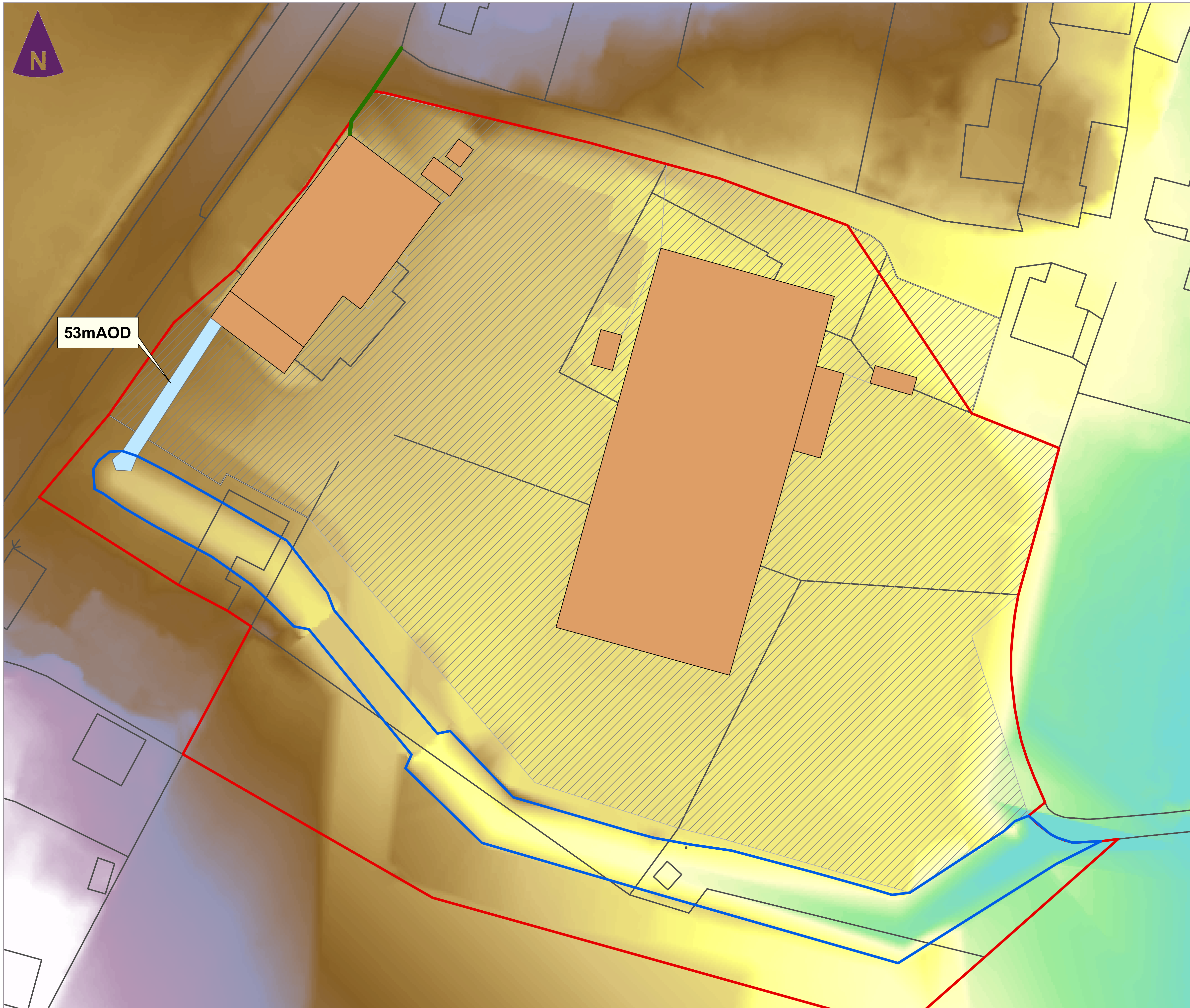
4.2 With development' model runs

As part of the proposed MEEG/AECC/ESL development, drainage infrastructure is proposed to manage the flow of surface run-off through the Site. The measures include a swale feature, a gateway drain running across the entrance to the Site, impermeable tanked buildings and feature in the northern corner to collect water flowing from the A5025. The representation of the proposed drainage infrastructure is based on a concept level of design detail only. The location of the Site drainage features represented in the model are illustrated on Figure 4.2. The representation of these mitigation measures in the hydraulic model was as follows:

- **Buildings** – eight buildings were extracted from the MEEG/AECC/ESL proposed general arrangement plan (drawing 60PO8077-JAC-LSC-DRG-01002), these were assumed to be 'tanked' to make them impermeable to water ingress. To represent the buildings in this way in the InfoWorks ICM model they have been represented as 'void polygons'. As these buildings are 'voids' no 'rain' will fall on the model in these areas. It has been assumed that the volume of rainfall that would fall on these buildings would be managed by the Site drainage strategy.
- **Swale** – the swale feature proposed to convey flows from the north west to south east across the southern edge of the Site. It has been developed to capture and safely convey water flowing from the A5025. It has been represented in the 2D domain of the model by amending the underlying topography. The 0.25m DTM was manipulated by incorporating the contour level information describing the geometry of the swale and adjoining ground. The source of this information is drawing 60PO8081-JAC-CIV-MOD-00020.dwg. An additional roughness zone was added to the model to represent the swale feature. The swale was given the Manning's n roughness value of 0.035 (equivalent to that used for 2D watercourses in other parts of the model). The roughness zone also acted like a breakline in the model to define this area in the mesh.
- **Gateway drain** – across the Site entrance a feature will exist to capture water flowing from the A5025 and connect in to the swale feature. This will prevent the uncontrolled flow of water through the Site. The trench is represented as a 25m x 2m mesh zone polygon extending between the northern Site building and swale. The mesh zone is set to a level of 53mAOD (~1m deep) which corresponds to the invert of the swale feature.
- A raised feature – within the northern corner of the complex will be a feature that will act to prevent water flowing onto Site from the A5025 to the northern corner of the Site. The feature will redirect the flow south west along the front of the Site into the gateway drain and then into the Swale. For the purposes of modelling this wall has been represented as a low wall feature. Within InfoWorks walls are described as porous walls, to achieve the desired redirection of flow the porosity of this wall was set to zero.

The 'with development' modelling also encompassed the following additional change:

- The roughness zones in the vicinity of the Site representing the baseline condition have been removed or edited to represent the proposed development. The roughness zones removed represented the four buildings currently onsite which are to be replaced with the proposed building plan. The remaining 'site_concrete' roughness zone which represents the impermeable surface of the Site was altered to provide for the swale roughness zone described above.



Key

- Site Boundary
- Grated trench site entrance
- Area of assumed hardstanding
- Impermeable buildings
- Swale
- Proposed flood defence wall
- OS Mapping

Proposed development topography

High : 59.4mAOD

Low : 47.7mAOD

0 10 20 30 m

Scale at A3

Wylfa Newydd
Associated
Developments
Hydraulic Modelling

amec foster wheeler

Figure 4.2
Llanfaethlu proposed development layout

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5. Model runs

The 2D Llanfaethlu model described in Sections 3 and 4 was run for a range of pluvial return period events. This section details the runs which have been completed and the process of selecting the 'critical' storm duration.

5.1 Selection of the critical storm duration

It is usual practice to test a realistic range of storm durations to find the critical duration storm at the site of interest. The critical duration storm is the one that produces the largest flow, highest water level or greatest storage (volume) at the subject site (EA, 2016). The Llanfaethlu model was run using the 1:100 year AEP for the 0.5 hour, 1 hour, 3 hour, 6 hour and 24 hour storm durations. The peak flood depths across results lines and at results points in the 2D zone are displayed in Table 5.1. The maximum peak depths along the two results lines, 'NRL_05' and 'NRL_Site_100', were achieved in the 0.5 hour and the 3 hour storm respectively. The remaining observation points and lines achieved maximum peak depths in the 1 hour storm. As the maximum peak flood depths occurred during the 1 hour storm event for the majority of observation points and lines (with the exception of only two results lines), it is reasonable to select the critical storm duration as the 1 hour storm for all the scenario modelling.

Table 5.1 1:100 year AEP summary results – Peak flood depth (m) across a line or at a point

Network Results Line (NRL) or Point (NRP) in 2D Zone	0.5 hour	1 hour	3 hour	6 hour	24 hour
NRL_01	0.200	0.228	0.227	0.220	0.186
NRL_02	0.096	0.110	0.096	0.082	0.052
NRL_03	0.048	0.066	0.066	0.061	0.040
NRL_04	0.065	0.088	0.085	0.076	0.051
NRL_05	0.024	0.022	0.015	0.012	0.006
NRL_Site_100	0.029	0.037	0.037	0.034	0.020
NRL_Site_101	0.055	0.0805*	0.0798*	0.073	0.045
NRL_Site_102	0.200	0.228	0.227	0.220	0.186
NRL_Site_103	0.044	0.061	0.060	0.055	0.036
NRL_Site_104	0.058	0.0814*	0.0805*	0.074	0.047
NRP_Site_001	0.037	0.055	0.054	0.048	0.028
NRP_Site_103	0.044	0.061	0.060	0.055	0.036
NRP_Site_104	0.058	0.0814*	0.08053*	0.074	0.047

Note: three (* and four) decimal places has been reported so the reader can view the difference between the depths.

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5.2 Baseline runs

The details of the baseline runs are in Table 5.2. Five baseline runs with different annual exceedance probabilities and climate change factors were run using the critical 1 hour storm duration.

Table 5.2 Baseline runs

Item	Comments
Baseline events	For the critical duration pluvial storm (1 hour): ► R30: 1:30 year AEP event, present day. ► R100: 1:100 year AEP event, present day. ► R100CC: 1:100 year AEP event with climate change (20%). ► R100CC: 1:100 year AEP event with climate change (40%). ► R1000: 1:1000 year AEP event, present day.
Model run parameters and settings	► Timestep: 10 s. ► Duration: 12 hours. Default parameters in InfoWorks ICM v7.5.5 were used for all settings, no changes were made to these during the modelling.
Model network and version	MEEG_Llanfaethlu_v1.0 #18
Model run names	► MEEG_ReFH2.2_R30_PD_2020s_1hr. ► MEEG_ReFH2.2_R100_PD_2020s_1hr. ► MEEG_ReFH2.2_R100_PD_2020s_1hr_1.2CC. ► MEEG_ReFH2.2_R100_PD_2020s_1hr_1.4CC. ► MEEG_ReFH2.2_R1000_PD_2020s_1hr.
2D model stability	Total mass error reported as 0.00 m^3
Model warnings	No reported warnings

5.3 ‘With development’ runs

The details of the ‘with development’ runs are in Table 5.3. The ‘with development’ runs have been run for the same pluvial annual exceedance probabilities as were run using baseline model.

Table 5.3 'With development' pluvial runs

Item	Comments
Pluvial events	For the critical duration pluvial storm (1 hour): ▶ R30: 1:30 year AEP event, present day. ▶ R100: 1:100 year AEP event, present day. ▶ R100CC: 1:100 year AEP event with climate change (20%). ▶ R100CC: 1:100 year AEP event with climate change (40%). ▶ R1000: 1:1000 year AEP event, present day.
Model run parameters and settings	▶ Timestep: 10 s. ▶ Duration: 12 hours. ▶ Default parameters in InfoWorks ICM v7.5.5 were used for all settings, no changes were made to these during the modelling.
Model network and version	MEEG_Llanfaethlu_v1.0 #26
Model run names	▶ Development MEEG_ReFH2.2_R30_PD_2020s_1hr. ▶ Development MEEG_ReFH2.2_R100_PD_2020s_1hr. ▶ Development MEEG_ReFH2.2_R100_PD_2020s_1hr_1.2CC. ▶ Development MEEG_ReFH2.2_R100_PD_2020s_1hr_1.4CC. ▶ Development MEEG_ReFH2.2_R1000_PD_2020s_1hr.
2D model stability	Total mass error reported as 0.00 m^3

6. Baseline model results

This section summarises the results of the baseline model runs. Results are presented as peak flood depths in Table 6.2, (either as the peak maximum depth value of the elements intersected by the results line or the peak maximum depth value of the element containing a point in the 2D zone). Peak flood depth maps are also provided in Appendix A which also illustrate the spatial extent of the pluvial flooding. Appendix A contains the following flood depth and extent and flood velocities maps which describe the baseline flood hazard:

Figure 6.1 Llanfaethlu baseline peak pluvial flood extents

Figure 6.2 Llanfaethlu baseline peak pluvial flood depth 1:30 year AEP present day (1 hour storm event)

Figure 6.3 Llanfaethlu baseline peak pluvial flood depth 1:100 year AEP present day (1 hour storm event)

Figure 6.4 Llanfaethlu baseline peak pluvial flood depth 1:1000 year AEP present day (1 hour storm event)

Figure 6.5 Llanfaethlu baseline peak pluvial flood depth 1:100 year AEP (1 hour storm event) plus climate change (20%)

Figure 6.6 Llanfaethlu baseline peak pluvial flood depth 1:100 year AEP (1 hour storm event) plus climate change (40%)

6.1 Model results lines and points

The results data (issued as an excel spreadsheet for each annual exceedance event) contain the results of flow, depth and velocity time-series for a range of observation lines and points across the 2D model. The labelled location of these lines and points are in Figure 4.1.

The observation points are in the model as 2D network results points. They have been positioned in the Site and provide the time series of Unit Flow (m^3/s), Depth (m), Elevation (mAOD) and velocity (m/s) at each individual location.

The observation lines are in the model as 2D network results lines. They have been positioned at strategic locations to provide the time series of total flow across the line (m^3/s), maximum of the depth values at a given timestep of the elements intersected by the line (m) and the maximum of the velocity values at a given timestep of the elements intersected by the line (m/s) experienced in the 2D mesh at each individual location.

Flow values for each line are calculated as follows: for each 2D mesh element that the results line intersects the unit flow normal to the line is determined. This mesh element unit flow value is multiplied by the length of the line which falls within the individual element. The total flow result is then calculated by summing the flows from each element that crosses the line. Flows can be positive or negative depending on the direction of flow across the line, and the direction the line has been digitised. Table 6.1 describes how the various results lines were digitised in the model and what a positive flow means in terms of flow direction.

Table 6.1 Network results line flow description

Network results line	How digitised	Positive flow description
NRL_01	From north to south	Water flowing south-east across the road onto the roadside (towards the MEEG Site)
NRL_02	From north to south	Water flowing north-east
NRL_03	From north to south	Water flowing east, away from the MEEG Site
NRL_04	From east to west	Water flowing south
NRL_05	From east to west	Water flowing south-east
NRL_Site_100	From east to west	Water flowing south out of MEEG Site
NRL_Site_101	From north to south	Water flowing east out of MEEG Site
NRL_Site_102	From north-east to south-west	Water flowing onto MEEG Site from north and west
NRL_Site_103	From north to south	Water flowing east through the MEEG Site
NRL_Site_104	From north to south	Water flowing east through the MEEG Site

6.2 Results

The peak flood depths in Table 6.2 have been extracted from the 2D zone as lines and points, the locations of which are shown in Figure 4.1. For all baseline runs, the three highest peak flood depths recorded are across lines ‘NRL_04’, ‘NRL_03’ and ‘NRL_Site_100’, although the order varies between different annual exceedance events.

‘NRL_04’, located north-east of the Site, measures the flow from the north along the Afon Llanrhyddlad and records the highest peak flood depths for all 1:100 year AEP events (including the two climate change scenarios). The highest peak flood depth for the 1:1,000 year AEP event occurs at ‘NRL_Site_100’, located along the south-eastern boundary of the Site and records the flow off the Site in the south-eastern corner. The highest peak flood depth recorded for the 1:30 year AEP event is at ‘NRL_03’, which is located downstream (to the east) of the Site and measures the flow from the west (including flow off the Site) before it reaches the Afon Llanrhyddlad. As would be expected, the highest peak depth occurs during the 1:1,000 year AEP event, with three results lines recording depths of 0.65m or higher.

Table 6.2 Baseline runs summary results – peak flood depth (m) across a line or at point

Network results line (NRL) or point (NRP) in 2D zone	1:30 year AEP	1:100 year AEP	1:100 year AEP plus 20%	1:100 year AEP plus 40%	1:1000 year AEP
NRL_01	0.04	0.05	0.06	0.08	0.09
NRL_02	0.08	0.12	0.13	0.15	0.17
NRL_03	0.47	0.51	0.54	0.58	0.65
NRL_04	0.46	0.54	0.58	0.61	0.66
NRL_05	0.03	0.04	0.05	0.05	0.06
NRL_Site_100	0.38	0.48	0.55	0.60	0.67
NRL_Site_101	0.29	0.36	0.43	0.48	0.55
NRL_Site_102	0.05	0.06	0.07	0.08	0.09
NRL_Site_103	0.06	0.11	0.14	0.17	0.21
NRL_Site_104	0.13	0.18	0.21	0.23	0.27
NRP_Site_001	0.00	0.01	0.03	0.04	0.06
NRP_Site_103	0.01	0.04	0.05	0.07	0.09
NRP_Site_104	0.10	0.15	0.19	0.22	0.27

The peak flood depth maps (Figures 6.2 – 6.6 in Appendix A) show a preferential flow route onto the Site from the western boundary. Multiple flow routes combine and pond on the western boundary of the A5025 before crossing the road onto the Site. A significant portion of the flow reaching the Site originates in the west, upstream of the Western Pond (as shown on Figure 1.1). This western flow route is joined by various branches of flow from the southwest, with some originating from the village of Llanfaethlu. The water, flowing from the west, ponds on the western side of the A5025 before it reaches a threshold level (~53.9 mAOD) and then flows across the A5025 onto the Site. In addition to this western flow path there are flow routes along the A5025. Water flows north east towards the Site along the A5025 from the village of Llanfaethlu. Water also flows down the A5025 to the north of the Site.

During the 1:30 year AEP event (Figure 6.2) there are areas of localised ponding within the Site. In the larger storm events these isolated areas of ponding become increasingly connected and form a flow route through the Site. The flow route through the Site is almost central within the boundary, flowing west to east across the Site towards the drain which originates at the eastern end of the Site boundary.

7. 'With development' model results

Analysis of the impact of the MEEG/AECC/ESL Site on the flood risk and the change to the flood mechanism is discussed in this Section. Background to the inclusion of the infrastructure representation in the model is detailed in Section 4.2. The summary of the results obtained from the hydraulic modelling are discussed in the following sections. Results are presented as peak flood depths extracted from 2D network results lines and points in the vicinity of the Site.

Appendix A contains the following flood depths and extent maps which describe the bypass flood hazard:

Figure 7.1 Llanfaethlu 'with development' peak pluvial flood depth 1:30 year AEP present day (1 hour storm event)
Figure 7.2 Llanfaethlu 'with development' peak pluvial flood depth 1:100 year AEP present day (1 hour storm event)
Figure 7.3 Llanfaethlu 'with development' peak pluvial flood depth 1:1000 year AEP present day (1 hour storm event)
Figure 7.4 Llanfaethlu 'with development' peak pluvial flood depth 1:100 year AEP (1 hour storm event) plus climate change (20%)
Figure 7.5 Llanfaethlu 'with development' peak pluvial flood depth 1:100 year AEP (1 hour storm event) plus climate change (40%)
Figure 7.6 Llanfaethlu peak pluvial flood extent difference 1:30 year AEP present day (1 hour storm event)
Figure 7.7 Llanfaethlu peak pluvial flood extent difference 1:100 year AEP present day (1 hour storm event)
Figure 7.8 Llanfaethlu peak pluvial flood extent difference 1:1000 year AEP present day (1 hour storm event)
Figure 7.9 Llanfaethlu peak pluvial flood extent difference 1:100 year AEP (1 hour storm event) plus climate change (20%)
Figure 7.10 Llanfaethlu peak pluvial flood extent difference 1:100 year AEP (1 hour storm event) plus climate change (40%)

7.1 Flood depths

The impact of the MEEG/AECC/ESL development on water levels and therefore flood depths is described in two ways:

1. By means of change in depth of flooding at the 2D results lines and points across the Site (see Table 7.1), the location of which are detailed in Figure 4.1; and
2. By mapping the difference in flood extent across the 2D domain for each scenario assessed (see Figure 7.6 to Figure 7.10 in Appendix A).

The impact of the development on water depths across the floodplain is shown in Table 7.1. The degree of change to peak flood depths on Site varies with location, owing to how ground levels are proposed to be manipulated within the scheme design.

'NRL_04' (located north-east of the Site, measuring the flow from the north along the Afon Llanrhyddlad), 'NRL_02' (located west of the Site measuring the flow along the A5025) and 'NRL_05' (located north-west of the Site, measuring the flows across the field to the north-west) are not affected by the changes to the Site. There is no change in peak flood depth observed in these locations.

'NRL_01' is located along the A5025 parallel to the Site entrance. Here depths are observed to increase up to 0.2m in all events modelled, as a result of the inclusion of the Site drainage features described in Section 4.2.

‘NRL_03’, to the south east of Site shows a reduction in flood depth in the 1:30 and 1:100 year AEP events, as a consequence of the increased storage provided by the trench and Swale feature. In the 1:100 year future climate and 1:1000 year AEP events increase in peak flood depth up to 0.1m are observed. In the baseline model, the surface water flow is distributed across the Site with some water finding its way across land and directly into the Afon Llanrhyddlad, and some flowing towards the unnamed watercourse (and then subsequently into the Afon Llanrhyddlad). The increase in flood depth observed in the with development runs is a consequence of the Swale collecting and conveying water through the Site, with less water flowing across land to the Afon Llanrhyddlad (see Figure 7.8 to Figure 7.10). To the east of the Site, where the overland flow has returned to the central Afon Llanrhyddlad flow path downstream of the Site, the levels between the ‘with development’ and baseline models are consistent.

Three of the onsite results lines (‘NRL_Site_100’, ‘NRL_Site_103’ and NRL_Site_104’) all show increases in maximum flood depth observed along the line. This is due to the fact that all three of these lines intersect the new proposed Swale feature.

The onsite results line ‘NRL_Site_102’ shows the largest increase in peak flood depth along the line of up to 1.1m in the 1:1000 year AEP event. This is a consequence of the results line being collinear with the proposed impermeable building where water will pond before being diverted to the south west into the gateway drain and swale features.

The three results points (‘NRP_Site_001’, ‘NRP Site 103’ and ‘NRP Site 104’) within the Site boundary all show a reduction in flood depth for all flood events. This is consistent with Site design to prevent surface water to flow onto Site. The only water on Site is that which falls directly, which will be managed by the onsite drainage strategy.

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Table 7.1 'With development' runs summary results – peak flood depth (m) across a line or at point

Network results line (NRL) or point (NRP) in 2D zone	1:30 year AEP	Difference (m)	1:100 year AEP	Difference (m)	1:100 year AEP plus 20%	Difference (m)	1:100 year AEP plus 40%	Difference (m)	1:1000 year AEP	Difference (m)
NRL_01	0.04	0.00	0.16	0.11	0.21	0.15	0.25	0.18	0.32	0.22
NRL_02	0.08	0.00	0.11	0.00	0.13	0.00	0.15	0.00	0.17	0.00
NRL_03	0.43	-0.04	0.50	-0.01	0.61	0.07	0.68	0.10	0.78	0.14
NRL_04	0.45	0.00	0.54	0.00	0.57	0.00	0.61	0.00	0.66	0.00
NRL_05	0.03	0.00	0.04	0.00	0.04	0.00	0.05	0.00	0.06	0.00
NRL_Site_100	0.54	0.16	0.67	0.19	0.78	0.23	0.86	0.26	0.97	0.30
NRL_Site_101	0.27	-0.02	0.40	0.04	0.51	0.08	0.59	0.11	0.71	0.16
NRL_Site_102	0.76	0.71	1.01	0.96	1.06	0.99	1.10	1.02	1.17	1.07
NRL_Site_103	0.12	0.06	0.19	0.08	0.27	0.13	0.34	0.17	0.45	0.23
NRL_Site_104	0.19	0.05	0.33	0.16	0.45	0.24	0.52	0.29	0.68	0.41
NRP_Site_001	0.00	0.00	0.00	-0.01	0.00	-0.03	0.00	-0.04	0.00	-0.05
NRP_Site_103	0.00	-0.01	0.00	-0.03	0.01	-0.05	0.01	-0.06	0.01	-0.08
NRP_Site_104	0.00	-0.10	0.00	-0.15	0.00	-0.19	0.00	-0.22	0.00	-0.27
Swale	0.12	n/a*	0.23	n/a*	0.32	n/a*	0.40	n/a*	0.52	n/a*

Notes: n/a denotes the fact that the 'Swale' results line was not included in the baseline model therefore it is not possible to calculate the difference from the baseline. The 'Swale' network results line was included to provide the Site designers with information to inform the sizing of the culvert required for the bridge to the proposed car park area which crosses the Swale.

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7.2 Summary of MEEG/AECC/ESL Site impact

- **Onsite**: the inclusion of the MEEG/AECC/ESL Site with swale, trench and flood defence features reduces water levels and extents on Site for all flood events. This is a result of creating an impermeable barrier along the north western Site boundary and directing surface water into the proposed trench and swale drainage features. In the location of these two drainage features increases in flood depths are observed as expected.
- **Offsite** - A5025: In the vicinity of the Site along the A5025 the impermeable boundary proposed along the north western Site boundary results in localised increases in flood depths. The largest increases in flood depths (up to 1m) are observed on the layby area adjacent to the Site boundary. Depths along the main A5025 carriageway appear mostly unchanged, with the occasional increase of 0.1m in a few localised places.
- **Offsite** – wider catchment: there is no difference in peak flood depth observed along the result lines sited in the wider area. Figure 7.6 to Figure 7.10 show the difference in flood extents. It is observed that at the periphery of the flood extent there looks to be a slight difference between the baseline and with development flood extents. Please note that this is not an actual impact of the development, rather it is the consequence of the InfoWorls ICM model which has an irregular 2D mesh. The changes made to the model, to represent the proposed development, have resulted in a subtle difference in irregular mesh across the model domain. Resulting in the extremities of the flood extent not aligning exactly.

8. Sensitivity testing

The objective of sensitivity testing is to test the validity of the underlying assumptions in the model, and ensure the model is behaving as expected. Sensitivity testing provides a means of assessing how sensitive the predicted flood depths are to changes in the model parameters and assumptions. It is expected that if a parameter is changed then the resultant flood depth will change. The aim of the sensitivity testing is to highlight the potential degree of change associated with adjusted parameters so as to provide confidence in the value selected.

Section 8.1 details the sensitivity tests undertaken and their application in the 2D model domain. A discussion on the sensitivity testing results is in Section 8.2.

8.1 Sensitivity test method

Table 8.1 summarises the four sensitivity tests performed. Two tests pertain to the parameters in the 2D model domain and two relate to the pluvial hydrology inputs to the model.

The model is a 2D model only and as such industry standard sensitivity tests such as those on structure coefficients, downstream boundary and blockage are not applicable to this 2D model as there are no 1D channel elements being modelled in detail.

Table 8.1 Sensitivity test methods

Sensitivity test	Description			
1. Manning's n roughness *	Two scenarios were run to assess the degree of change resultant of the roughness in the 2D model: a. Roughness decreased to respective **minimum** value for each roughness category b. Roughness increased to respective **maximum** value for each roughness category			
2D model domain roughness zone application (Manning's n)	**Category**	**Baseline**	**a. Min**	**b. Max**
	Grass/General surface	0.04	0.03	0.05
	Building/Glasshouse	0.3	0.01	0.5
	Rough Grassland/Scrub/Trees	0.08	0.06	0.11
	Inland Water	0.035	0.025	0.045
	Path/Roadside	0.025	0.02	0.03
	Road	0.015	0.013	0.017
2. Infiltration-runoff factor *	Two scenarios were run to assess the maximum degree of change as a result of an increase in runoff due to higher runoff factors (applied to the entire 2D zone as an infiltration surface).			
Application to the infiltration surface	The factor applied to the 2D zone which determines the amount of rainfall which becomes runoff was increased from the SPRHOST value of 0.40 (in the baseline, described in section 4.2) for two scenarios: a. increased to **0.55** – Where 0.55 represents the maximum upper limit for the area when using the upper limits for the soil, slope and land-use parameters (NCB, 1982) of possible Llanfaethlu catchment characteristics (slope 0.02; soil type part loam, part clay-loam; vegetation type grassland only). b. Increased to **0.80 –** where 0.80 considers the possibility the modelled pluvial event follows a previous event and the 2D zone would be partly saturated.			
3. Storm duration	Four additional scenarios were run using the baseline model (see Section 5.2) with four different pluvial storm durations (2 hour, 4 hour, 5 hour, 7 hour), to assess the sensitivity of the model to storm duration. The hyetographs were derived using the same method described in Section 3.2: using ReFH2.2 with FEH 13 rainfall data, and applying the summer storm profile. All four scenarios were undertaken using the baseline model and the 1:100 year AEP event.			
4. Seasonal storm profile	The summer storm was selected for the baseline runs. The aim of this test was to assess the sensitivity of the model to the seasonal storm profile by running the winter 1:100 year AEP event with the base model, confirming the summer storm profile as critical. As with Test 3, the hyetograph was derived in the same manner as those for the baseline runs, described in Section 3.2: using ReFH2.2 with FEH 13 rainfall data, this time adjusting the seasonal profile to winter.			

Asterisk (*) denotes the sensitivity test applied to the 1 hr, 100 year AEP event.

8.2 Sensitivity test results

This section discusses the results of the sensitivity tests. All sensitivity test results are compared against the 1:100 year AEP for the critical 1 hour summer storm.

Test 1: Manning's n roughness

Modelled peak flood depths for Manning's roughness sensitivity tests have a relatively small difference in absolute terms (within 0.01m) when compared to the depths of the baseline 1:100 year AEP 1 hour pluvial event (Table 8.2). As the pluvial flood depths are typically in the order of 0.1m, a small change in absolute flood depth can translate into a notable percentage difference. Table 8.2 presents absolute and % difference values. The absolute change is therefore deemed the more sensible metric by which to judge the sensitivity of the model.

The model is behaving as would be expected; a decrease in the roughness of the 2D zone causes an increase in the peak flood depth, and the opposite occurs when the roughness is increased. The choice of value used remains appropriate as in the large majority of cases the percentage difference is less than 10%.

Table 8.2 Sensitivity test 1 summary results – Peak flood depth (m) and difference compared to baseline for the 1:100 year AEP 1 hour pluvial event

Network results line (NRL) or point (NRP) in 2D zone	Baseline (m)	Test 1a. Min (m)	Difference (1a Min minus Baseline)	1a. Min difference cf. Baseline (%)	Test 1b. Max (m)	Difference (1b Max minus Baseline)	1b. Max difference cf. Baseline (%)
NRL_01	0.05	0.05	0.00	-6	0.06	0.00	7
NRL_02	0.12	0.10	-0.01	-10	0.12	0.01	6
NRL_03	0.51	0.51	0.00	0	0.51	0.00	1
NRL_04	0.54	0.53	0.00	0	0.54	0.00	1
NRL_05	0.04	0.04	0.00	-9	0.04	0.00	7
NRL_Site_100	0.48	0.48	0.00	1	0.48	0.00	-1
NRL_Site_101	0.36	0.36	0.00	0	0.35	0.00	-1
NRL_Site_102	0.06	0.05	0.00	-8	0.06	0.00	7
NRL_Site_103	0.11	0.10	0.00	-5	0.11	0.01	6
NRL_Site_104	0.18	0.18	0.00	0	0.18	0.00	0
NRP_Site_001	0.01	0.01	-0.01	-40	0.02	0.00	17
NRP_Site_103	0.04	0.03	0.00	-8	0.04	0.00	8
NRP_Site_104	0.15	0.15	0.00	0	0.15	0.00	1

Test 2: Infiltration-runoff factor

Two tests were run with an increase in the runoff factor (Tests 2a and 2b). The runoff factor in Test 2a was increased to 0.55, and increased further to 0.80 in Test 2b. As would be expected the maximum flood depths for Test 2b are higher than the depths in Test 2a and the baseline run. The maximum depth increase, compared to baseline, in Test 2a and Test 2b is 0.11m and 0.23m respectively (Table 8.3). There is also an increase in flood extent (Figure 8.1). The resultant increase confirms the model is behaving as expected when increasing the infiltration-runoff factor. Whilst slightly deeper flood depths are achieved when a higher infiltration-run-off factor is adopted, it is not considered grounds to support the permanent adoption of this value as the assumed value of 0.4 for SPRHOST can be supported in the literature (see Section 4.2).

Table 8.3 Sensitivity test 2 summary results – Peak flood depth (m) and difference compared to baseline for the 1:100 year AEP 1 hour pluvial event

Network results line (NRL) or point (NRP) in 2D zone	Baseline (m)	Test 2a (m)	Test 2a Difference (Test 2a minus Baseline)	Test 2a difference cf. Baseline (%)	Test 2b (m)	Test 2b Difference (Test 2b minus Baseline)	Test 2b difference cf. Baseline (%)
NRL_01	0.05	0.07	0.02	40	0.10	0.05	100
NRL_02	0.12	0.14	0.03	25	0.19	0.07	63
NRL_03	0.51	0.57	0.06	12	0.68	0.17	33
NRL_04	0.54	0.60	0.06	11	0.68	0.14	26
NRL_05	0.04	0.05	0.01	22	0.06	0.02	50
NRL_Site_100	0.48	0.59	0.11	23	0.71	0.23	47
NRL_Site_101	0.36	0.47	0.11	31	0.59	0.23	64
NRL_Site_102	0.06	0.08	0.02	39	0.10	0.05	87
NRL_Site_103	0.11	0.16	0.05	49	0.24	0.13	122
NRL_Site_104	0.18	0.23	0.05	28	0.30	0.12	67
NRP_Site_001	0.01	0.04	0.03	181	0.06	0.05	356
NRP_Site_103	0.04	0.06	0.02	66	0.11	0.07	185
NRP_Site_104	0.15	0.21	0.06	43	0.29	0.14	97

Key

Pluvial
Peak flood extents (>0.01m depth)

- 1:100 year AEP
- 1:100 Year AEP - Runoff 0.50
- 1:100 year AEP - Runoff 0.80

AEP - Annual Exceedance Probability

- Model boundary
- Results Point
- Results Line
- OS Mastermap

0 50 100 150 m
Scale at A3

Wylfa Newydd Associated Developments Hydraulic Modelling

amec foster wheeler

Figure 8.1
Llanfaethlu runoff sensitivity pluvial flood extents (>0.01m depth)

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Test 3: Storm duration

The sensitivity of the model to the duration of the pluvial event is small, with most results lines and points resulting in only a few centimetres of change in peak flood depth compared to the baseline 1 hour duration 1:100 year AEP Present Day event (Table 8.4). The only exception is the results line NRL_04 in the 4 hour, 5 hour and 7 hour event where the peak depth falls by 6cm, 7cm and 9cm respectively, compared to the 1 hour baseline. It can be concluded that the 2D model, and the overall Site, are not sensitive to the duration of a pluvial event.

Table 8.4 Sensitivity test 3 summary results – Peak flood depth (m) and difference compared to baseline for the pluvial storm duration sensitivity test

Network results line (NRL) or point (NRP) in 2D zone	Baseline (m)	2 hour (m)	2 hour minus Baseline (m)	4 hour (m)	4 hour minus Baseline (m)	5 hour (m)	5 hour minus Baseline (m)	7 hour (m)	7 hour minus Baseline (m)
NRL_01	0.05	0.05	0.00	0.05	0.00	0.05	0.00	0.05	0.00
NRL_02	0.12	0.11	-0.01	0.09	-0.02	0.09	-0.02	0.08	-0.03
NRL_03	0.51	0.51	0.00	0.51	0.00	0.50	-0.01	0.50	-0.01
NRL_04	0.54	0.52	-0.02	0.48	-0.06	0.47	-0.07	0.45	-0.09
NRL_05	0.04	0.03	-0.01	0.02	-0.02	0.02	-0.02	0.02	-0.02
NRL_Site_100	0.48	0.51	0.03	0.51	0.02	0.50	0.02	0.49	0.01
NRL_Site_101	0.36	0.38	0.03	0.38	0.02	0.38	0.02	0.37	0.01
NRL_Site_102	0.06	0.06	0.00	0.06	0.00	0.06	0.00	0.06	0.00
NRL_Site_103	0.11	0.12	0.01	0.12	0.01	0.12	0.01	0.11	0.00
NRL_Site_104	0.18	0.19	0.01	0.19	0.01	0.19	0.01	0.18	0.00
NRP_Site_001	0.01	0.02	0.00	0.02	0.00	0.02	0.00	0.02	0.00
NRP_Site_103	0.04	0.04	0.01	0.04	0.00	0.04	0.00	0.04	0.00
NRP_Site_104	0.15	0.16	0.01	0.16	0.01	0.16	0.01	0.16	0.01

Test 4: Seasonal storm profile

The results of seasonal storm profile sensitivity test shows the summer profile creates higher peak depths, with all network results lines and points across the model resulting in a higher peak depth in the summer season compared to the winter season for the 1 hour, 1:100 year AEP, Present Day event (Table 8.5).

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Table 8.5 Sensitivity test 4 summary results – Peak flood depth (m) and difference compared to summer (baseline) for the 1:100 year AEP 1 hour pluvial event

Network results line (NRL) or point (NRP) in 2D zone	Winter	Summer	Difference (Summer minus Winter 'baseline')
NRL_01	0.04	0.05	0.01
NRL_02	0.08	0.12	0.03
NRL_03	0.46	0.51	0.05
NRL_04	0.45	0.54	0.08
NRL_05	0.03	0.04	0.01
NRL_Site_100	0.37	0.48	0.11
NRL_Site_101	0.29	0.36	0.07
NRL_Site_102	0.04	0.06	0.01
NRL_Site_103	0.06	0.11	0.05
NRL_Site_104	0.13	0.18	0.05
NRP_Site_001	0.00	0.01	0.01
NRP_Site_103	0.01	0.04	0.03
NRP_Site_104	0.09	0.15	0.06

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8.3 Sensitivity test conclusions

The sensitivity tests of the 2D model parameters (Tests 1 and 2) indicate possible increases in depth on the Site resulting from the selection of parameters describing less rough conditions and less infiltration potential. The detailed design of the Site drainage infrastructure will account for the possible increases in flow that are estimated by the sensitivity test, to ensure that the design has sufficient headroom built in.

The sensitivity tests on the pluvial hydrology assumptions (Tests 3 and 4) confirm the summer event is the critical season, and that the model is not sensitive to the duration of a pluvial storm.

9. References

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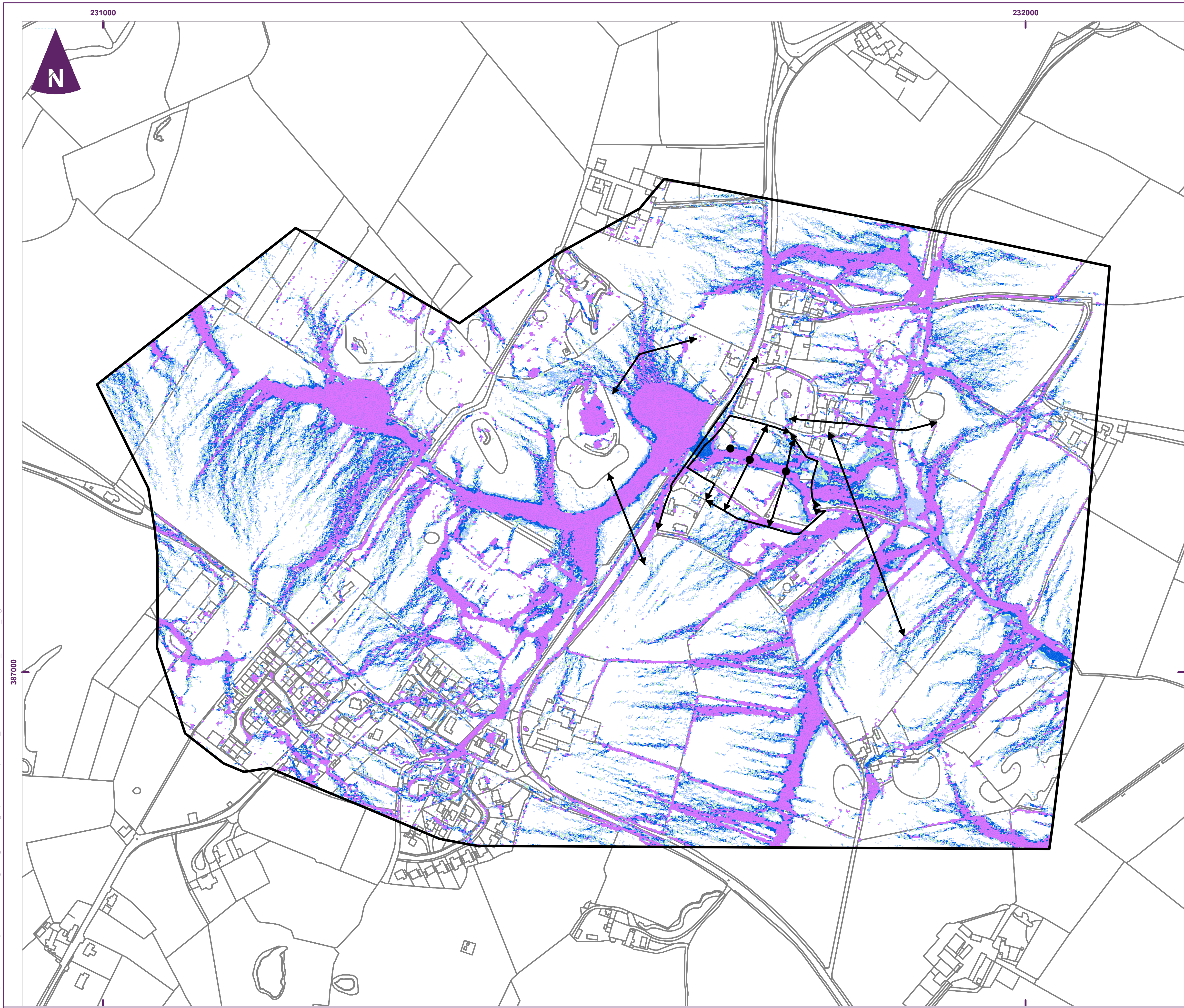
Appendix A
Supporting Mapping

Table of contents:



Key

Baseline pluvial
Peak flood extents (>0.01m depth)

- 1:30 year AEP
- 1:100 year AEP
- 1:100 year AEP - plus 20% climate change
- 1:100 year AEP - plus 40% climate change
- 1:1000 year AEP

AEP - Annual Exceedance Probability

- Model boundary
- Results Point
- Results Line
- OS Mastermap

0 50 100 150 m
Scale at A3

Wylfa Newydd
Associated
Developments
Hydraulic Modelling

amec foster wheeler

Figure 6.1
Llanfaethlu baseline peak pluvial flood extents

July 2017 35989_Lon277i4 beltl

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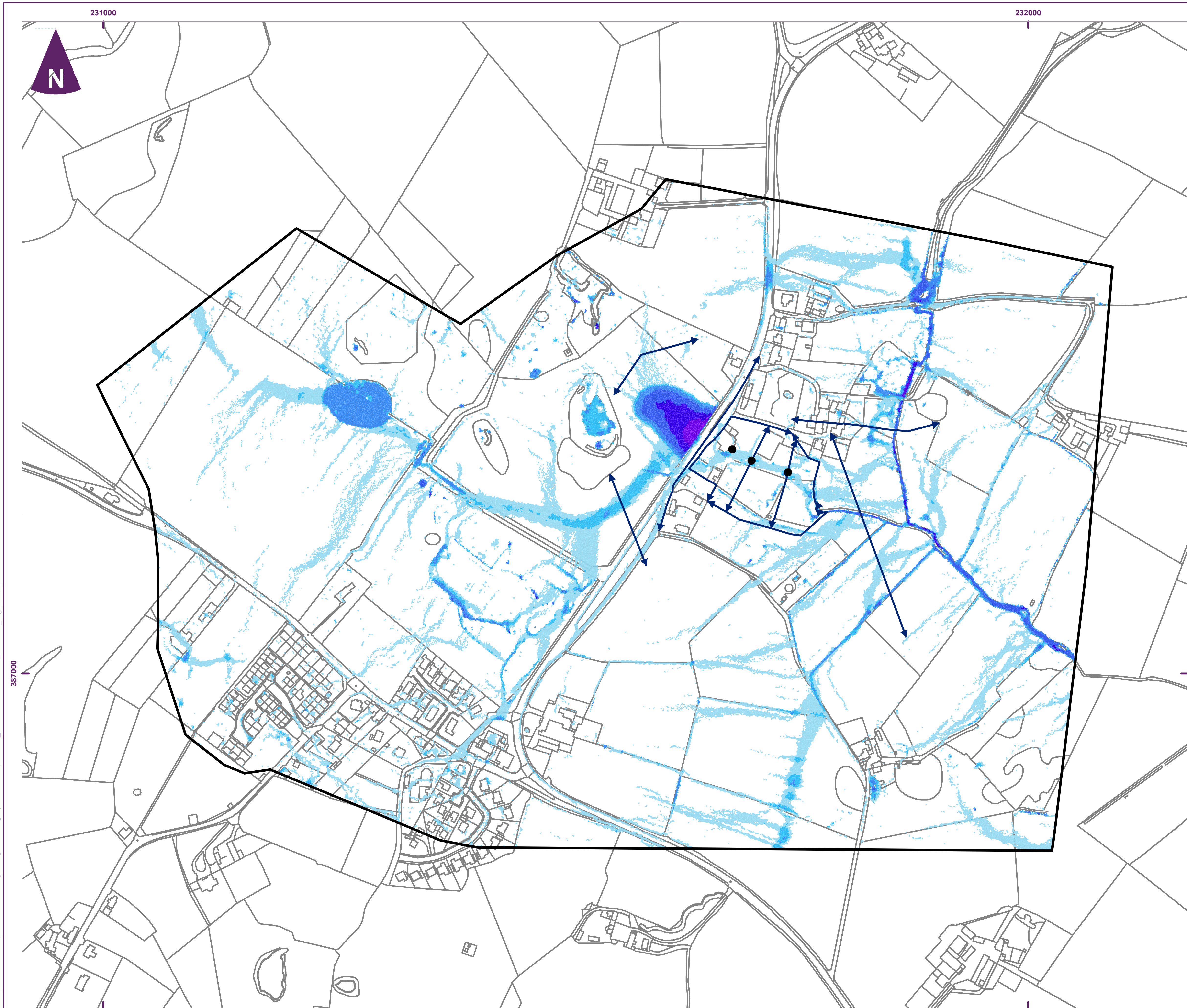

Key

Peak flood depth (m)
Baseline
1:30 year AEP pluvial
Present day

- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- >2.00
- Model boundary
- Results Point
- Results Line
- OS Mastermap

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.

Model run date: 10/04/2017
Corresponding data: 35989-C1331_Llanfaethlu_Base_R30_60m.xlsx

0 50 100 150 m
Scale at A3

Wylfa Newydd
Associated
Developments
Hydraulic Modelling

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Figure 6.2
Llanfaethlu baseline peak pluvial flood depth 1:30 year AEP present day (1 hour storm event)

July 2017 35989_Lon278i4 beltl

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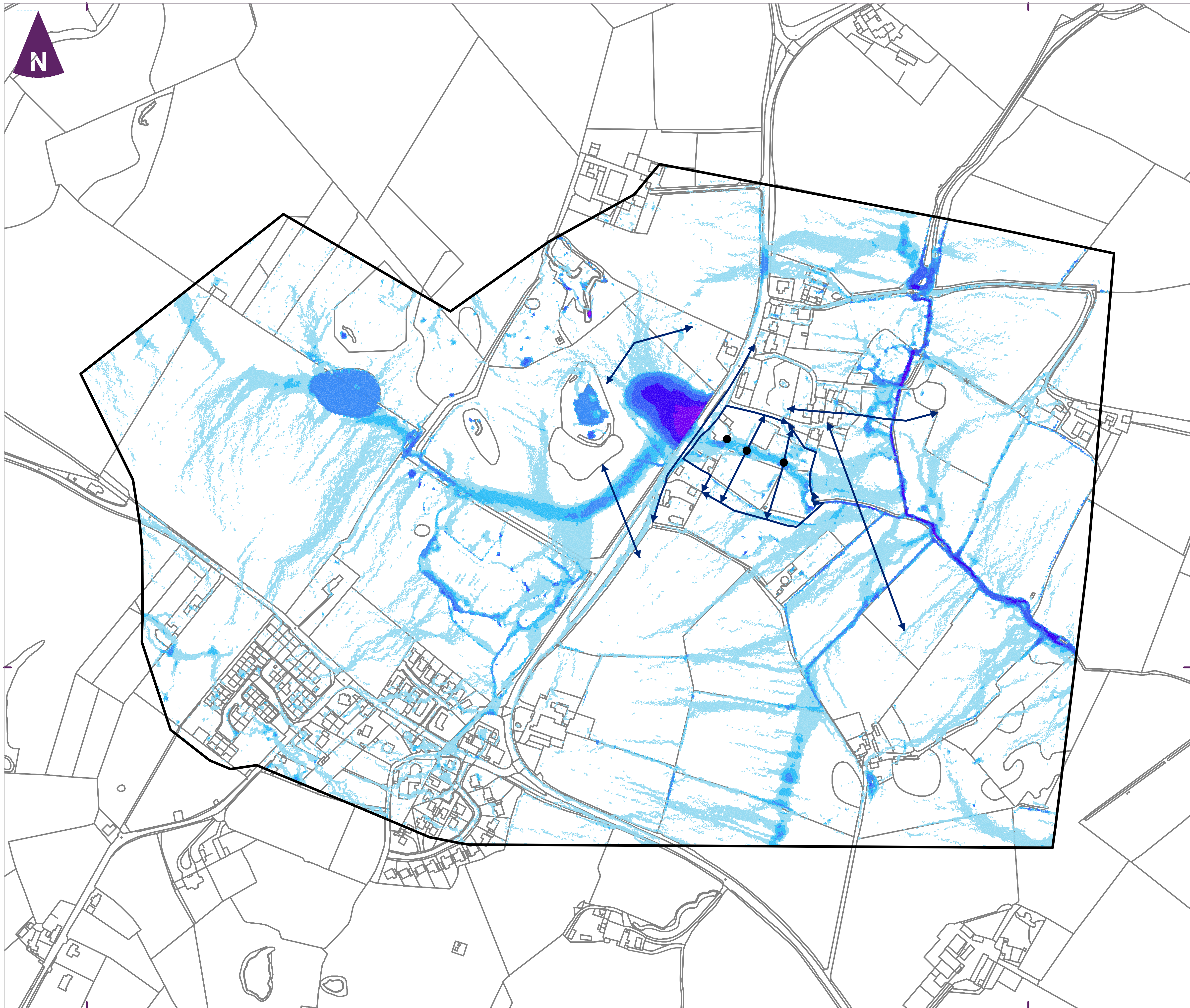

Key

Peak flood depth (m)
Baseline
1:100 year AEP pluvial
Present day

- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- >2.00
- Model boundary
- Results Point
- Results Line
- OS Mastermap

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.

Model run date: 10/04/2017
Corresponding data: 35989-C1332_Llanfaethlu_Base_R100_60m.xlsx

0 50 100 150 m
Scale at A3

Wylfa Newydd
Associated
Developments
Hydraulic Modelling

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Figure 6.3
Llanfaethlu baseline peak pluvial flood depth 1:100 year AEP present day (1 hour storm event)

July 2017 35989_Lon279i4 beltl

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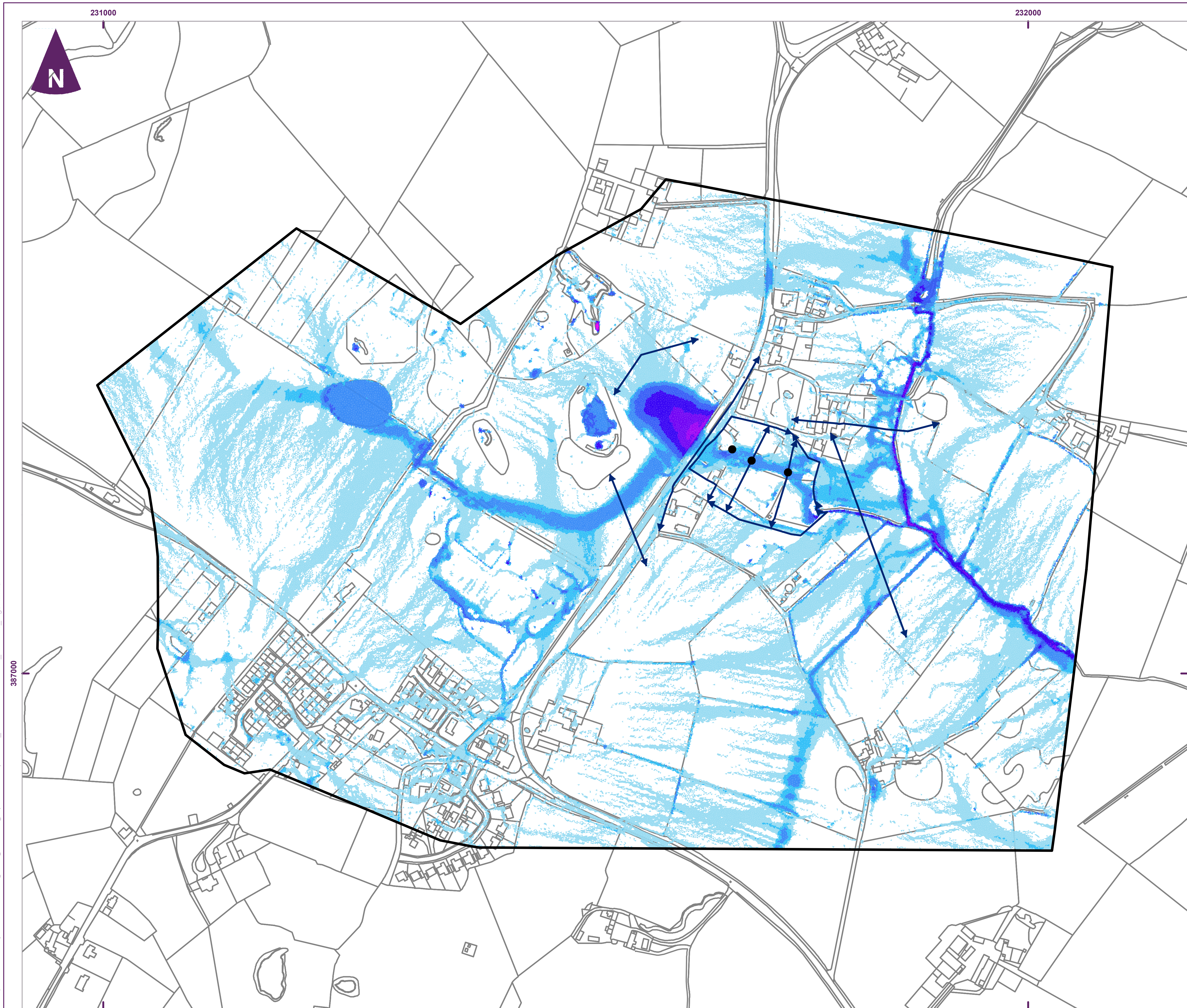

Key

Peak flood depth (m)
Baseline
1:1000 year AEP pluvial
Present day

- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- >2.00
- Model boundary
- Results Point
- Results Line
- OS Mastermap

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.

Model run date: 10/04/2017
Corresponding data: 35989-C1335_Llanfaethlu_Base_R1000_60m.xlsx

0 50 100 150 m
Scale at A3

Wylfa Newydd Associated Developments Hydraulic Modelling

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Figure 6.4
Llanfaethlu baseline peak pluvial flood depth 1:1000 year AEP present day (1 hour storm event)

July 2017 35989_Lon291i4 beltl

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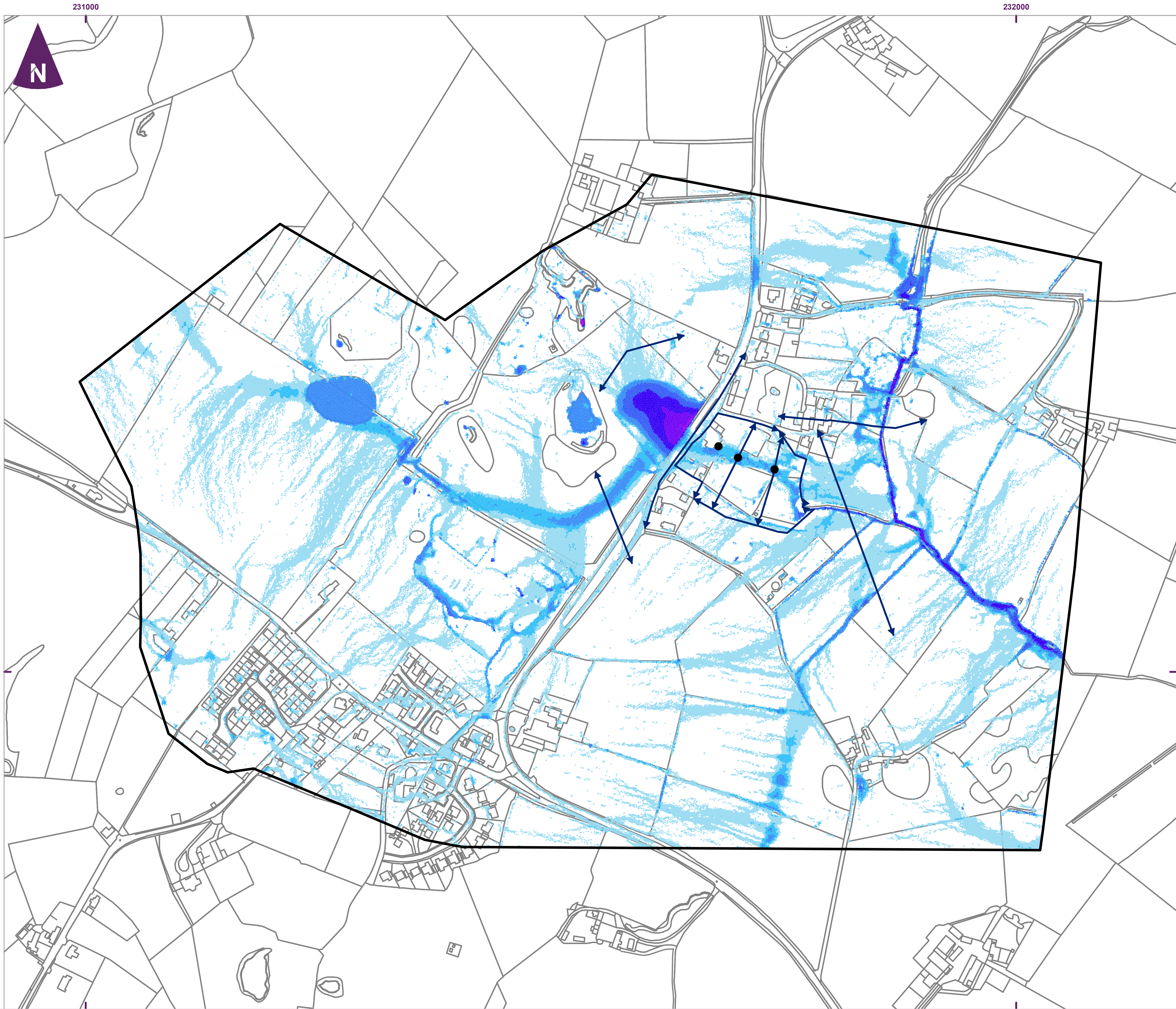

Key

Peak flood depth (m)
Baseline
1:100 year AEP pluvial
Climate change (20%)

- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- >2.00
- Model boundary
- Results Point
- Results Line
- OS Mastermap

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.

Model run date: 10/04/2017
Corresponding data: 35989-C1333_Llanfaethlu_Base_R100_60m_1.2CC.xlsx

0 50 100 150 m
Scale at A3

Wylfa Newydd
Associated
Developments
Hydraulic Modelling

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Figure 6.5
Llanfaethlu baseline peak pluvial flood depth 1:100 year AEP (1 hour storm event) plus climate change (20%)

July 2017 35989_Lon292i3 beltl

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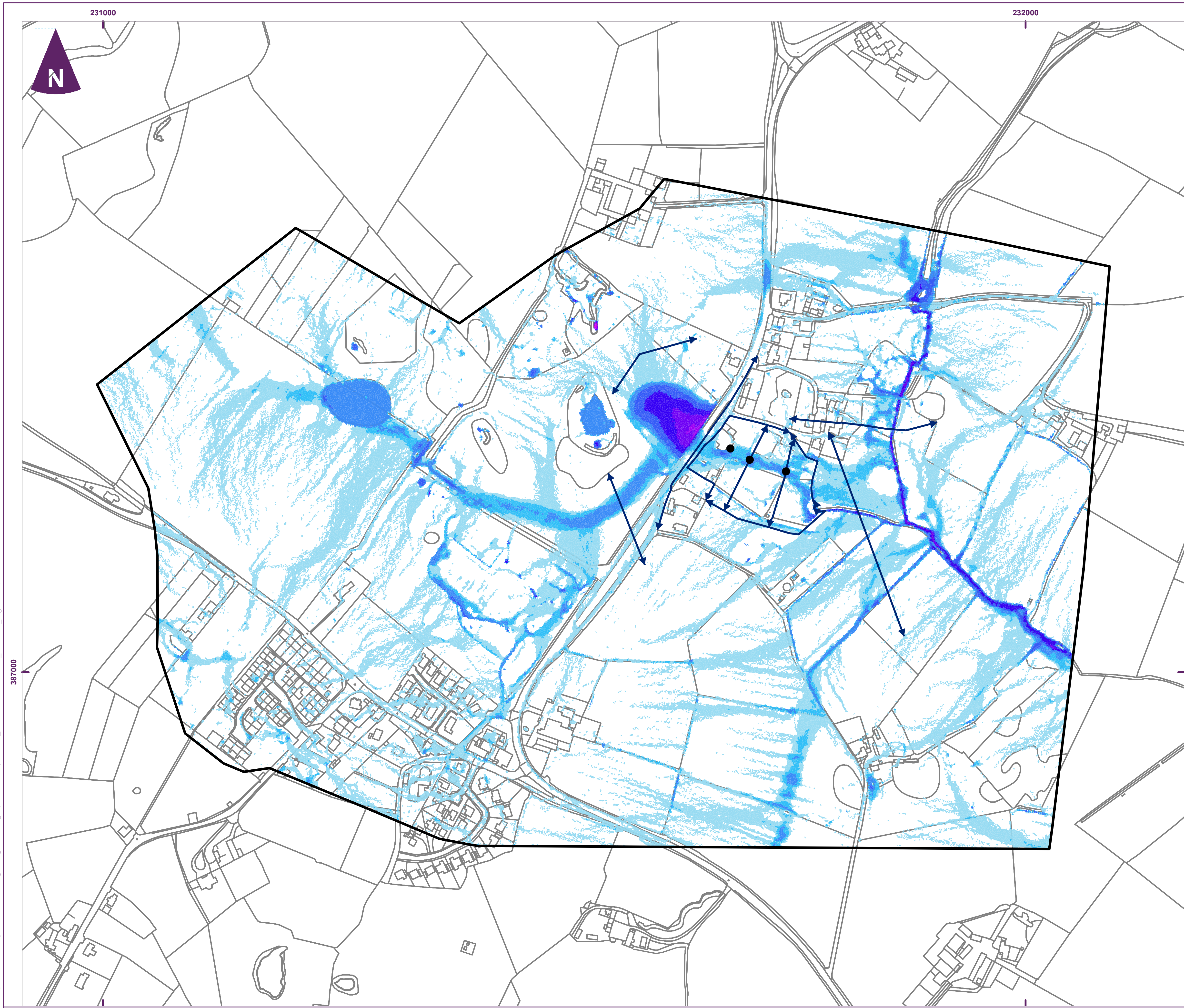

Key

Peak flood depth (m)
Baseline
1:100 year AEP pluvial
Climate change (40%)

- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- >2.00
- Model boundary
- Results Point
- Results Line
- OS Mastermap

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.

Model run date: 10/04/2017
Corresponding data: 35989-C1334_Llanfaethlu_Base_R100_60m_1.4CC.xlsx

0 50 100 150 m
Scale at A3

Wylfa Newydd Associated Developments Hydraulic Modelling

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Figure 6.6
Llanfaethlu baseline peak pluvial flood depth 1:100 year AEP (1 hour storm event) plus climate change (40%)

July 2017 35989_Lon292i3 beltl

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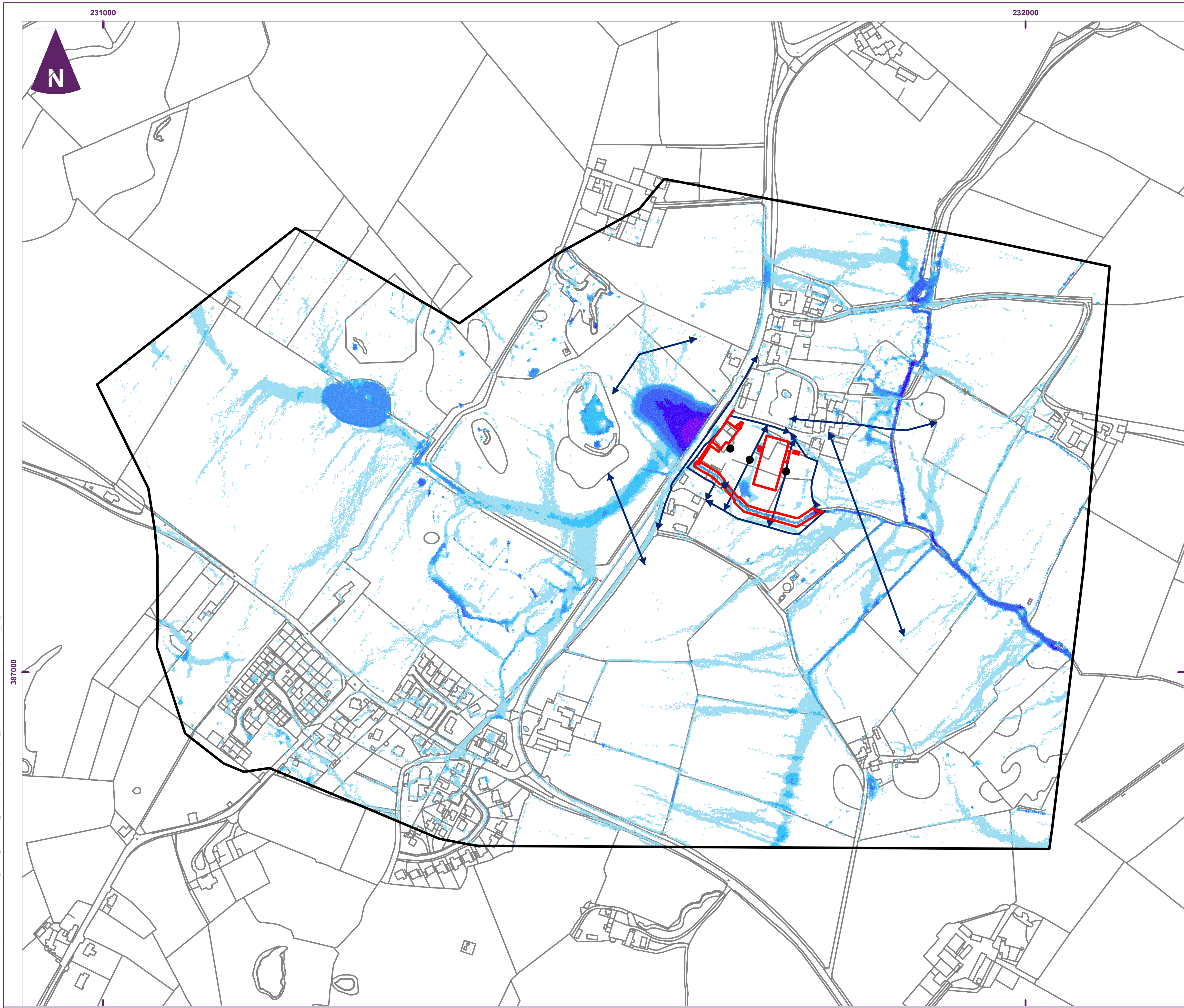

Key

Peak flood depth (m)
'With development'
1:30 year AEP pluvial
Present day

- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- >2.00

- Model boundary
- Results Point
- Results Line
- OS Mastermap
- MEEG/AECC/ESL Site Features

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.

Model run date: 05/07/2017
Corresponding data: 35989-C1343_Llanfaethlu_Dev_R30_60m.xlsx

MEEG/AECC/ESL development features include a swale, trench, impermeable wall and buildings.

0 50 100 150 m
Scale at A3

Wylfa Newydd Associated Developments Hydraulic Modelling

amec foster wheeler

Figure 7.1
Llanfaethlu 'with development' peak pluvial flood depth 1:30 year AEP present day (1 hour storm event)

July 2017 35989_Lon586i1 hurtf

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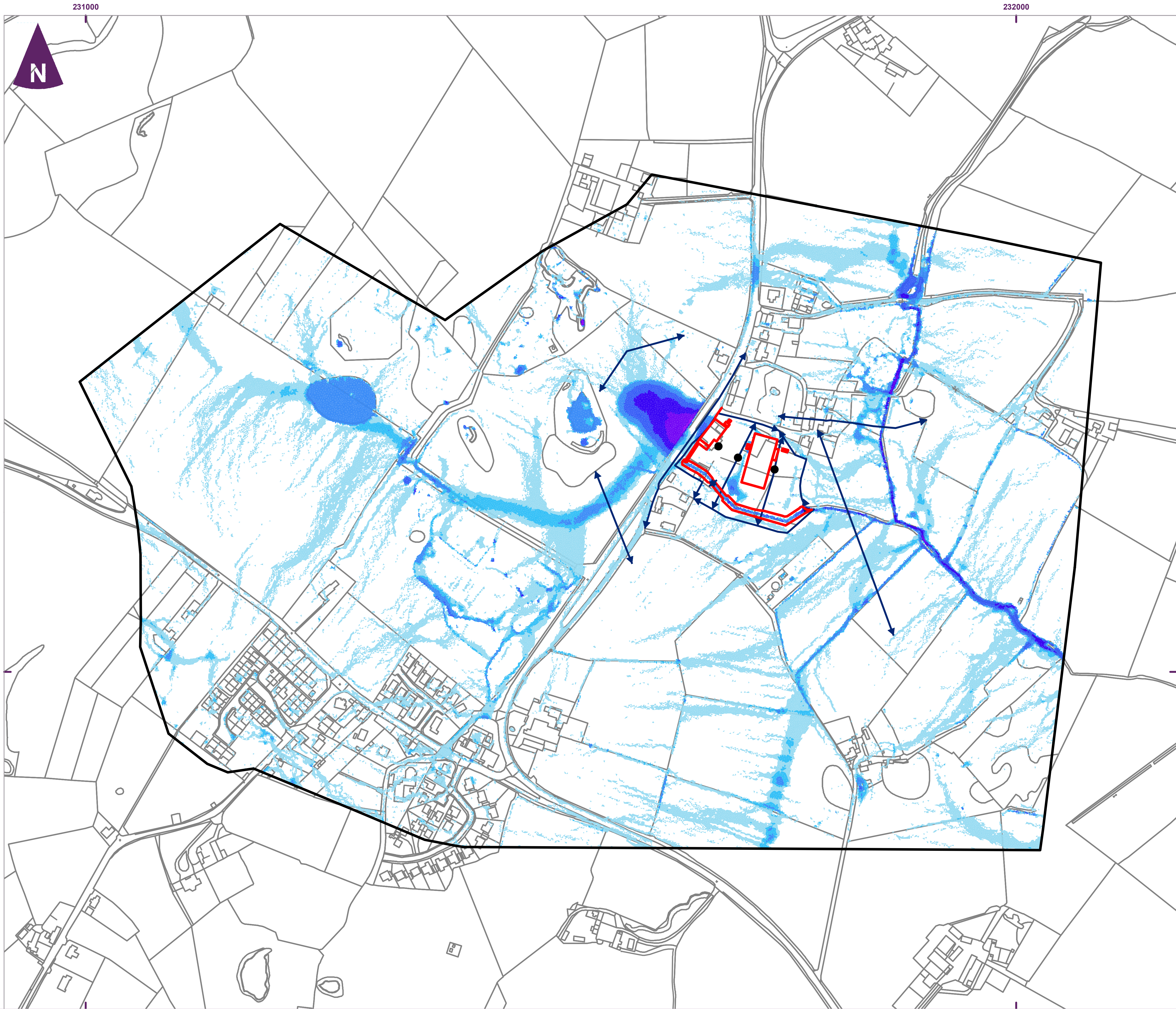

Key

Peak flood depth (m)
'With development'
1:100 year AEP pluvial
Present day

- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- >2.00
- Model boundary
- Results Point
- Results Line
- OS Mastermap
- MEEG/AECC/ESL Site Features

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.

Model run date: 05/07/2017
Corresponding data: 35989-C1344_Llanfaethlu_Dev_R100_60m.xlsx

MEEG/AECC/ESL development features include a swale, trench, impermeable wall and buildings.

0 50 100 150 m
Scale at A3

Wylfa Newydd
Associated
Developments
Hydraulic Modelling

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Figure 7.2
Llanfaethlu 'with development' peak pluvial flood depth 1:100 year AEP present day (1 hour storm event)

July 2017 35989_Lon587i1 hurtf

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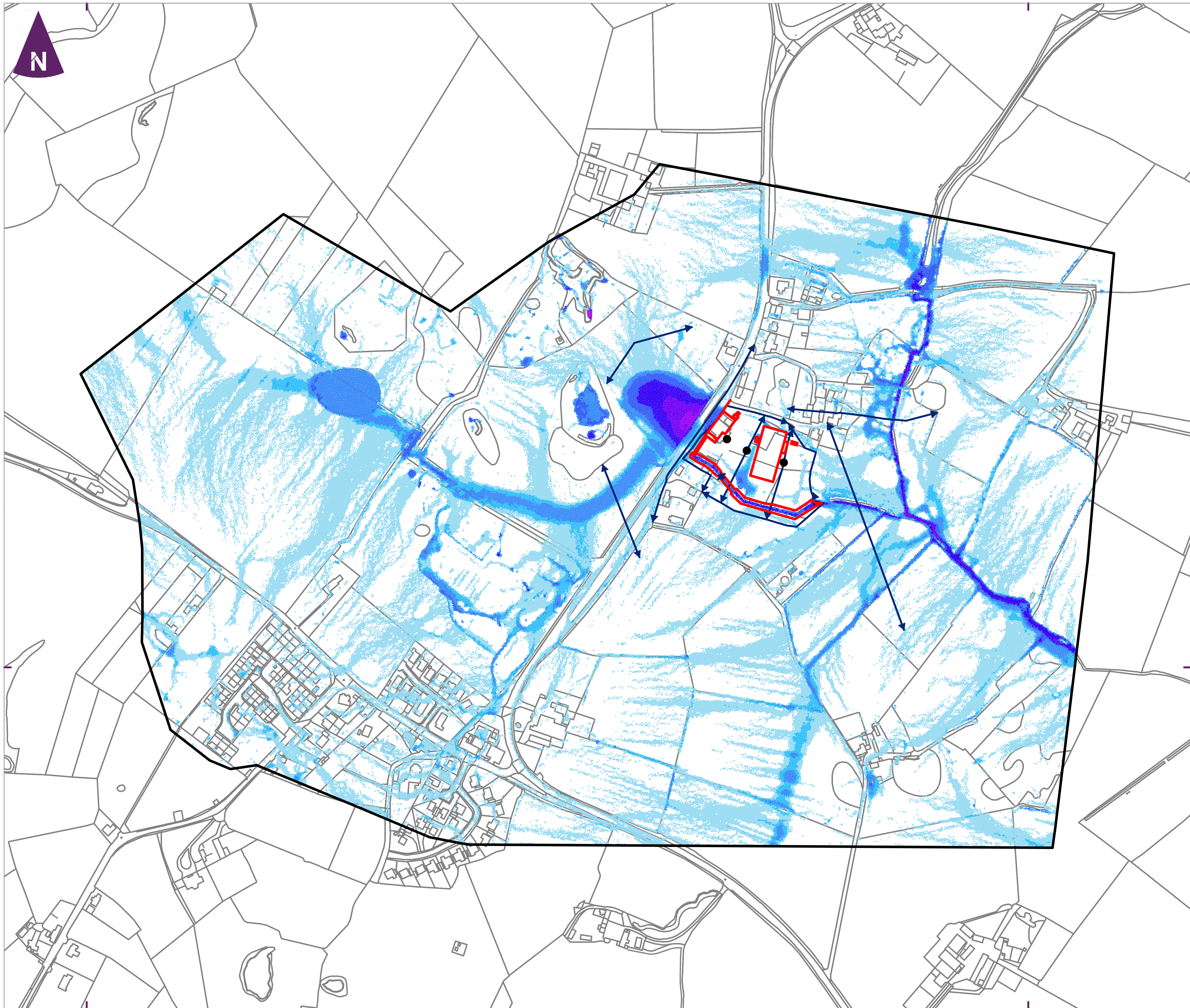

Key

Peak flood depth (m)
'With development'
1:1000 year AEP pluvial
Present day

- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- >2.00
- Model boundary
- Results Point
- Results Line
- OS Mastermap
- MEEG/AECC/ESL Site Features

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.

Model run date: 05/07/2017
Corresponding data: 35989-C1345_Llanfaethlu_Dev_R1000_60m.xlsx

MEEG/AECC/ESL development features include a swale, trench, impermeable wall and buildings.

0 50 100 150 m
Scale at A3

Wylfa Newydd Associated Developments Hydraulic Modelling

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Figure 7.3
Llanfaethlu 'with development' peak pluvial flood depth 1:1000 year AEP present day (1 hour storm event)

July 2017 35989_Lon588i1 hurtf

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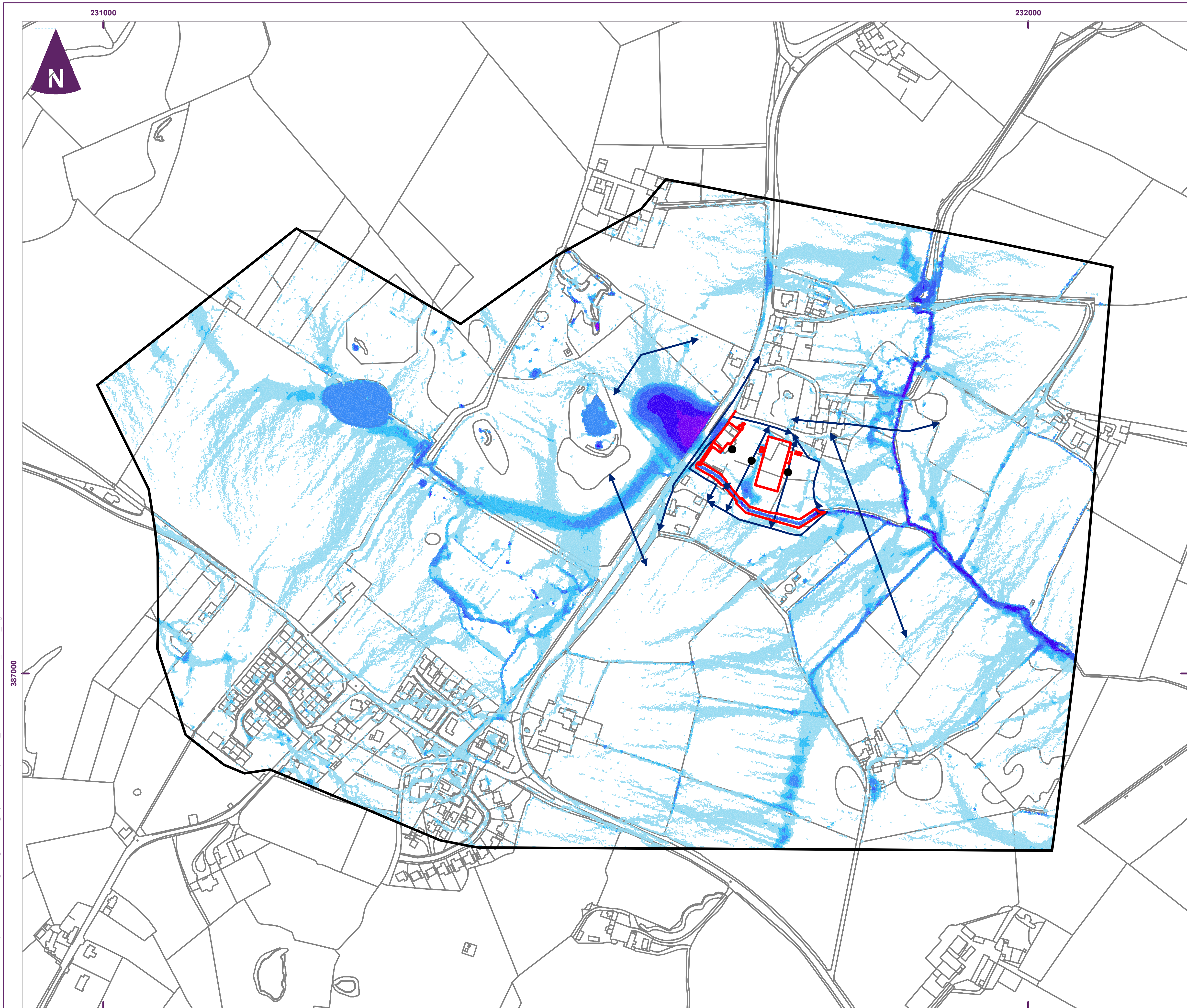

Key

Peak flood depth (m)
'With development'
1:100 year AEP pluvial
Climate change (20%)

- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- >2.00
- Model boundary
- Results Point
- Results Line
- OS Mastermap
- MEEG/AECC/ESL Site Features

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.

Model run date: 05/07/2017
Corresponding data: 35989-C1346_ Llanfaethlu_Dev_R100_60m_1.2CC.xlsx

MEEG/AECC/ESL development features include a swale, trench, impermeable wall and buildings.

0 50 100 150 m
Scale at A3

Wylfa Newydd Associated Developments Hydraulic Modelling

amec foster wheeler

Figure 7.4
Llanfaethlu 'with development' peak pluvial flood depth 1:1000 year AEP (1 hour storm event) plus climate change (20%)

July 2017 35989_Lon589i1 hurtf

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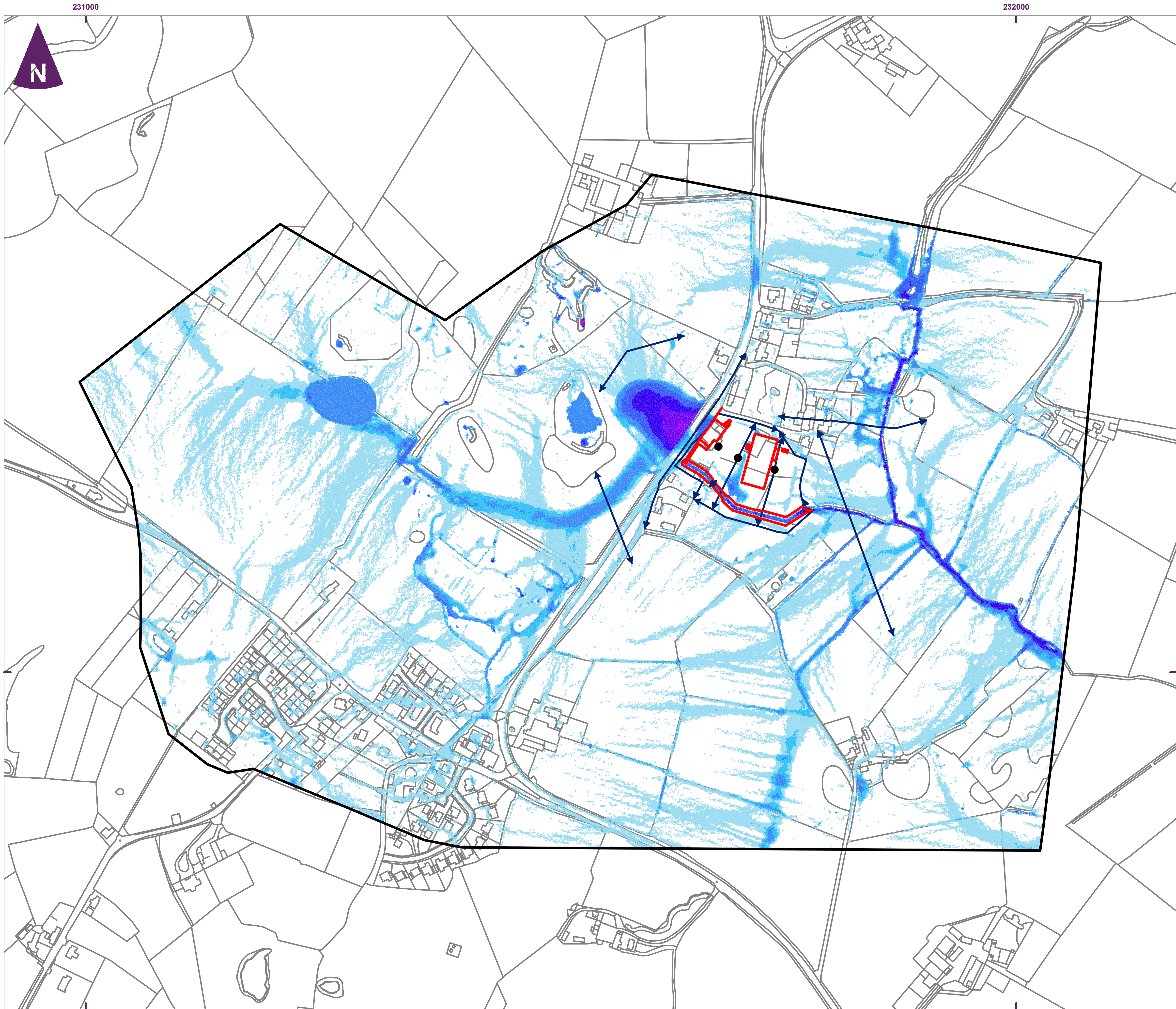

Key

Peak flood depth (m)
'With development'
1:100 year AEP pluvial
Climate change (40%)

- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- >2.00
- Model boundary
- Results Point
- Results Line
- OS Mastermap
- MEEG/AECC/ESL Site Features

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.

Model run date: 05/07/2017
Corresponding data: 5989-C1347_ Llanfaethlu_Dev_R100_60m_1.4CC.xlsx

MEEG/AECC/ESL development features include a swale, trench, impermeable wall and buildings.

0 50 100 150 m
Scale at A3

Wylfa Newydd Associated Developments Hydraulic Modelling

amec foster wheeler

Figure 7.5
Llanfaethlu 'with development' peak pluvial flood depth 1:100 year AEP (1 hour storm event) plus climate change (40%)

July 2017 35989_Lon590i1 hurtf

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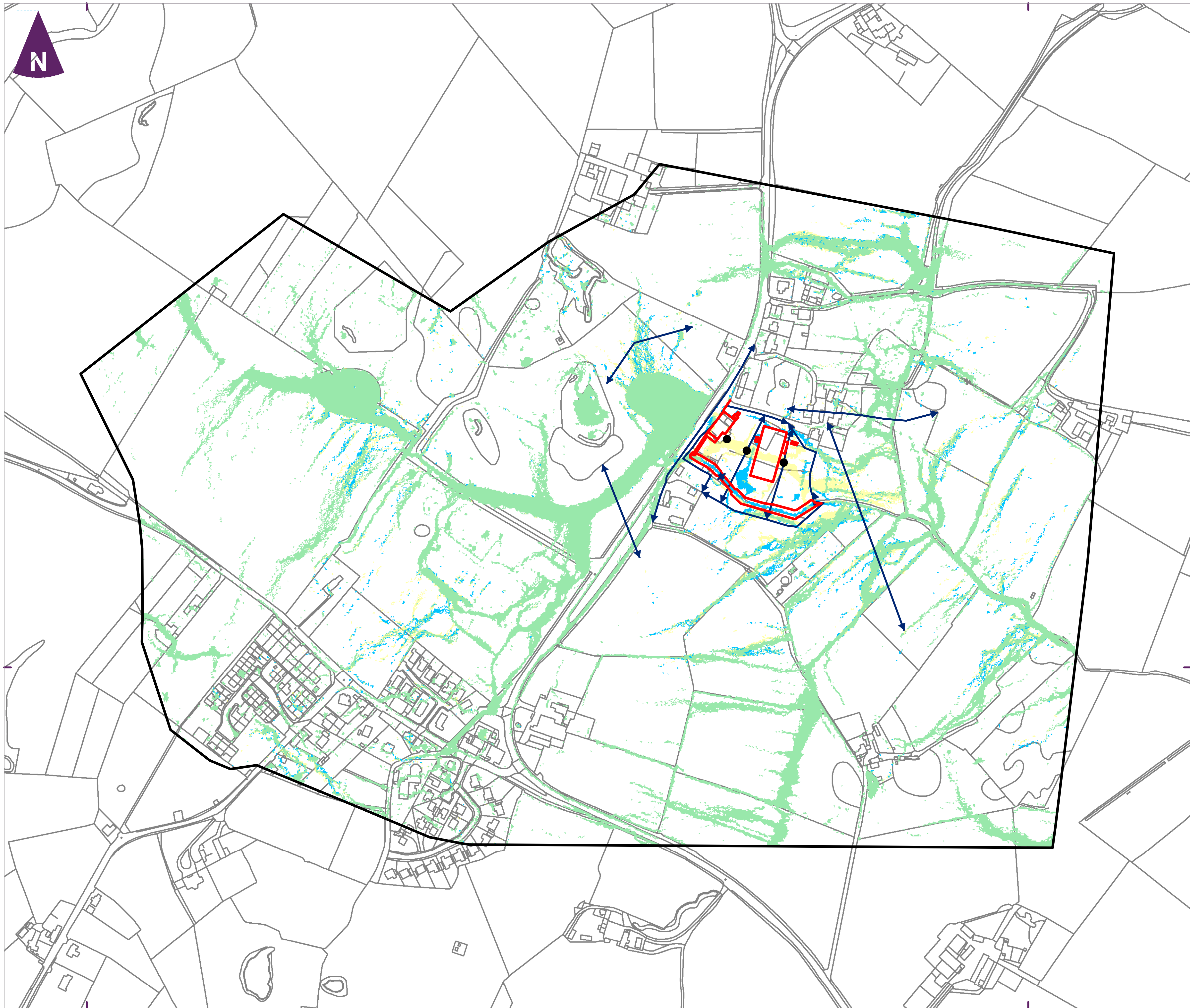

Key

Peak flood extent difference
1:30 year AEP pluvial
Present day

Baseline flood extent

'With development' flood extent

Notes:
Only depths >0.01m shown.

Yellow denotes where baseline extent is larger that the 'with development' extent.

Green denotes where baseline and 'with development' flood extents are the same.

Blue denotes where the 'with development'

Model boundary

Results Point

Results Line

OS Mastermap

MEEG/AECC/ESL Site Features

0 50 100 150 m
Scale at A3

Wylfa Newydd
Associated
Developments
Hydraulic Modelling

amec foster wheeler

Figure 7.6
Llanfaethlu peak pluvial flood extent difference 1:30 year AEP present day (1 hour storm event)

July 2017 35989_Lon593i1 hurtf

NOT PROTECTIVELY MARKED

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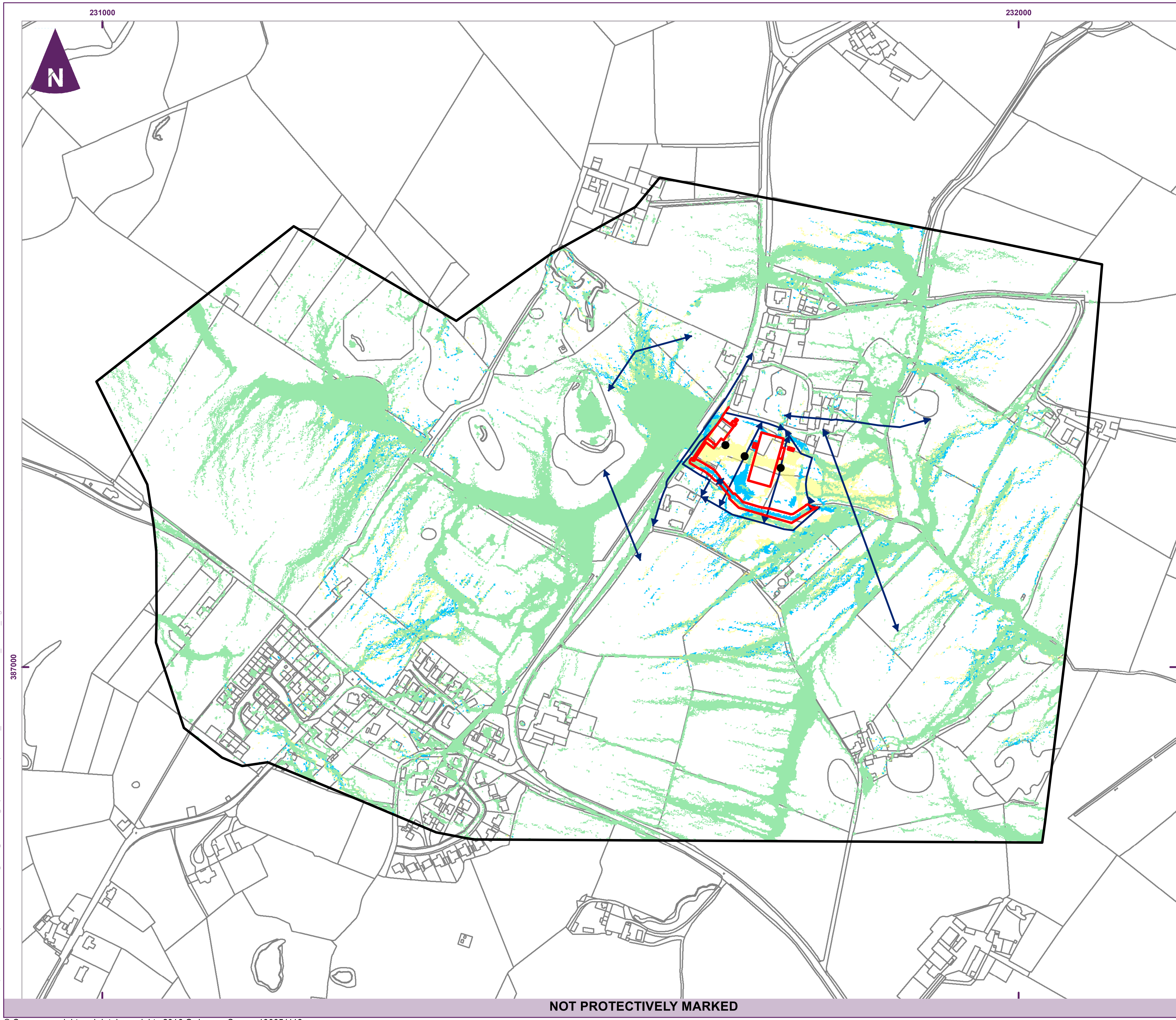

Key

Peak flood extent difference
1:100 year AEP pluvial
Present day

Baseline flood extent

'With development' flood extent

Notes:
Only depth >0.01m shown.

Yellow denotes where baseline extent is larger that the 'with development' extent.

Green denotes where baseline and 'with development' flood extents are the same.

Blue denotes where the 'with development'

Model boundary

Results Point

Results Line

OS Mastermap

MEEG/AECC/ESL Site Features

0 50 100 150 m
Scale at A3

Wylfa Newydd
Associated
Developments
Hydraulic Modelling

amec foster wheeler

Figure 7.7
Llanfaethlu peak pluvial flood extent difference 1:100 year AEP present day (1 hour storm event)

July 2017 35989_Lon594i1 hurtf

NOT PROTECTIVELY MARKED

Key

Peak flood extent difference
1:1000 year AEP pluvial
Present day

Baseline flood extent

'With development' flood extent

Notes:
Only depth >0.01m shown.

Yellow denotes where baseline extent is larger that the 'with development' extent.

Green denotes where baseline and 'with development' flood extents are the same.

Blue denotes where the 'with development'

Model boundary

Results Point

Results Line

OS Mastermap

MEEG/AECC/ESL Site Features

0 50 100 150 m

Scale at A3

Wylfa Newydd Associated Developments Hydraulic Modelling

amec foster wheeler

Figure 7.8
Llanfaethlu peak pluvial flood extent difference 1:1000 year AEP present day (1 hour storm event)

July 2017 35989_Lon595i1 hurtf

NOT PROTECTIVELY MARKED

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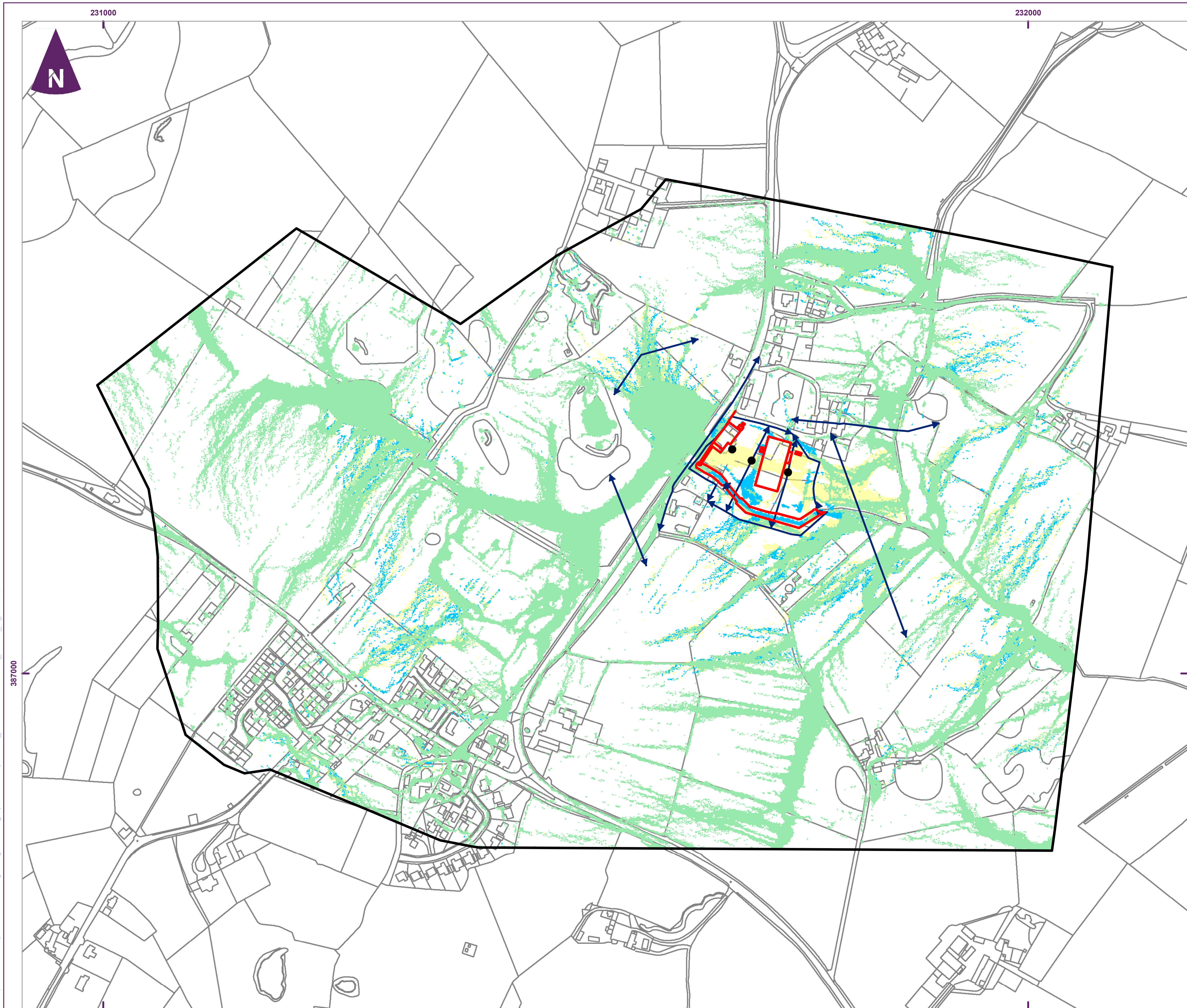

Key

Peak flood extent difference
1:100 year AEP pluvial
Climate change (20%)

Baseline flood extent

'With development' flood extent

Notes:
Only depth >0.01m shown.

Yellow denotes where baseline extent is larger that the 'with development' extent.

Green denotes where baseline and 'with development' flood extents are the same.

Blue denotes where the 'with development'

Model boundary

Results Point

Results Line

OS Mastermap

MEEG/AECC/ESL Site Features

0 50 100 150 m
Scale at A3

Wylfa Newydd
Associated
Developments
Hydraulic Modelling

amec foster wheeler

Figure 7.9
Llanfaethlu peak pluvial flood extent difference 1:100 year AEP (1 hour storm event) plus climate change (20%)

July 2017 35989_Lon596i1 hurtf

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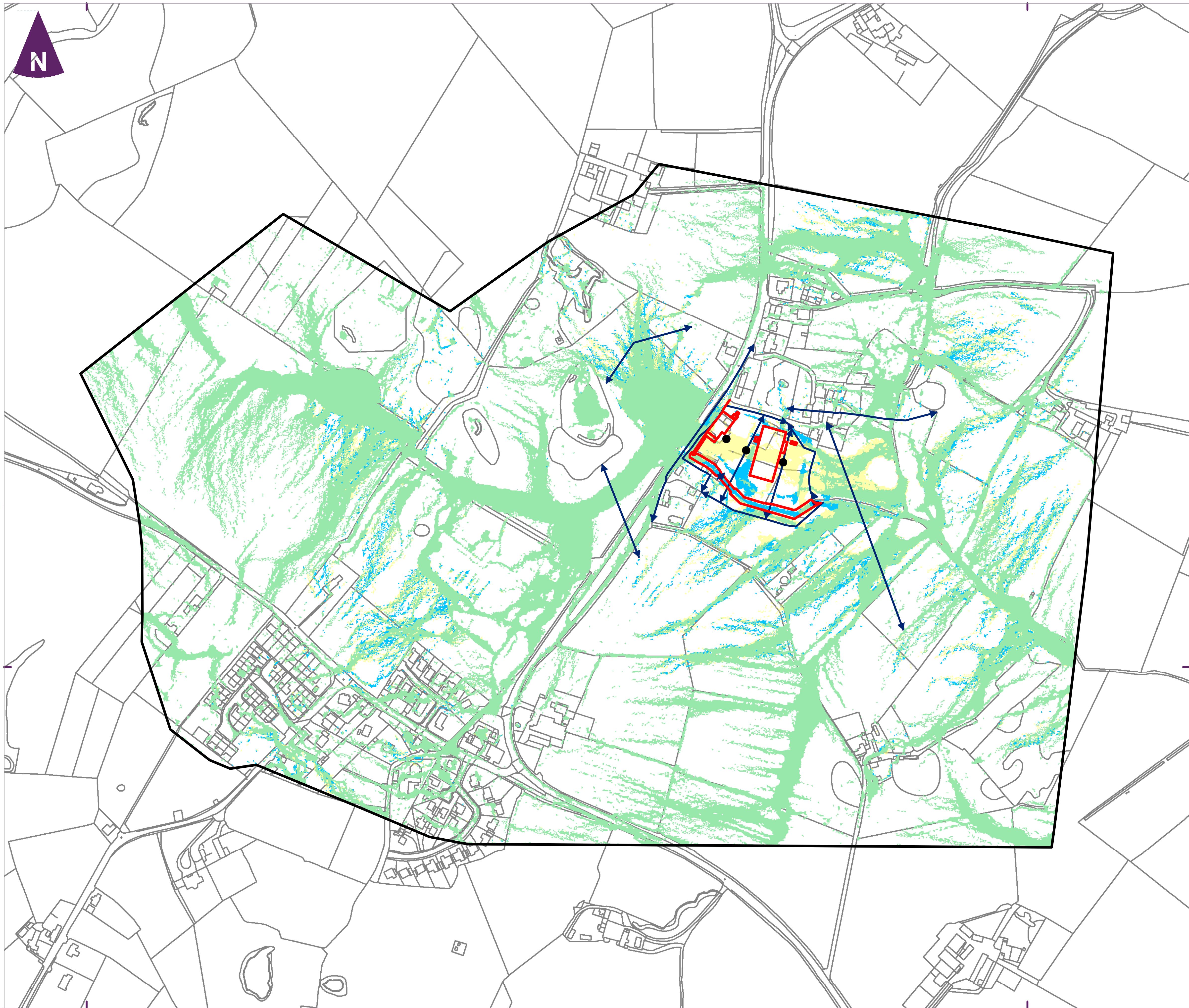

Key

Peak flood extent difference
1:100 year AEP pluvial
Climate change (40%)

- Baseline flood extent
- 'With development' flood extent

Notes:
Only depth >0.01m shown.

Yellow denotes where baseline extent is larger that the 'with development' extent.

Green denotes where baseline and 'with development' flood extents are the same.

Blue denotes where the 'with development'

- Model boundary
- Results Point
- Results Line
- OS Mastermap
- MEEG/AECC/ESL Site Features

0 50 100 150 m
Scale at A3

Wylfa Newydd Associated Developments Hydraulic Modelling

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Figure 7.10
Llanfaethlu peak pluvial flood extent difference 1:100 year AEP (1 hour storm event) plus climate change (40%)

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Appendix E8-1-4 Assessment methodology

Assessment methodology

8-1.1.1 In order to allow for the wider assessment of flood risk, a generalised assessment methodology has been developed in line with the risk-based approach detailed by the Welsh Government and recommended elsewhere in industry guidance [RD17]. The key to the classification is that the designation of risk is based upon the consideration of:

- the sensitivity of the receptor – takes into account the nature of the proposals or receptor and its likely response to increased risk;
- the severity of flooding (or magnitude of the hazard) – takes into account the potential nature of the flooding; and
- the probability of occurrence (i.e. likelihood) – takes into account the presence of the hazard and receptor, and the integrity of the pathway.

Classification of sensitivity of the receptor

8-1.1.2 When considering new developments, the classification of sensitivity is based (where possible) directly on the technical guidance set out within TAN 15 [RD4]. When considering off-site impacts, there is a general assumption that all developments are highly sensitive. This assumption can, however, typically be relaxed when considering a water compatible development or undeveloped land. Given this, the sensitivity of the receptor is ranked as shown in table E8-1-5.

Table E8-1-5 Classification of sensitivity of receptor

Sensitivity of receptor	New development	Off-site
Very high	Emergency services* developments	All built developments unless mitigating circumstances exist Key access routes
High	Highly vulnerable* developments	Other access routes
Medium	Less-vulnerable* developments	Undeveloped land
Low	Water-compatible[1] developments	-
Very low	Flood attenuation features	-

* For definitions of terms, please see figure 2 in TAN 15

[1] Category not outlined within TAN 15, but would include any types of development that clearly by their nature often need to be in a floodplain, such as buildings associated with water-sports or pumping stations for low-lying areas.

Classification of the magnitude of hazard

8-1.1.3 To classify the severity of flooding, it is necessary to look at the nature and scale of the individual impacts. These include, but are not confined to, the extent, depth and duration of flooding, and the velocity of flood waters. For new developments, the assessment is based on the likely post-development situation; for off-site receptors, it is based solely on the likely deterioration.

8-1.1.4 Given this, the severity of flooding is then ranked in terms of its magnitude as shown below in table E8-1-6.

Table E8-1-6 Classification of magnitude of hazard

Magnitude of hazard	New development	Off-site
High	Any one of the following criteria achieved: • flood depths greater than 1m; • flood flow velocities greater than 0.45m/s; or • likely flood duration in excess of 24 hours.	Any marked (>10%) increase in flood depth, flood flow velocity or flood duration Any change in flood extent that impacts additional properties, including access to those properties
Medium	Any one of the following criteria achieved: • flood depths between 0.3m and 1m; • flood flow velocity greater than 0.15m/s; • likely flood duration in excess of one hour; or • any restrictions to access and egress.	Any other measurable increase of flood depths, durations, flow velocities or extent
Low	All of the following criteria achieved: • flood depths below 0.3m; • likely flood duration below one hour; and • flood-proofing measures planned.	Likely, but unquantifiable, small increases of flood depths, durations, flow velocities or extent
Very low	Planned or permitted flooding that does not adversely impact the built development	-
Negligible	No potential for flooding, or no identifiable impact of flooding	No likely increase in flood severity at any off-site location

Significance of potential effect

8-1.1.5 The magnitude of the hazard and the sensitivity of the receptor are combined using a matrix (shown below in table E8-1-7) to determine the significance of the potential effect, if realised.

Table E8-1-7 Matrix for determining the significance of the potential effect

		Sensitivity of receptor				
		Very low	**Low**	**Medium**	**High**	**Very high**
Magnitude of potential hazard	**High**	Low	Moderate	Moderate	High	High
	Medium	Very low	Low	Moderate	Moderate	High
	Low	Very low	Very low	Low	Moderate	Moderate
	Very low	Negligible	Very low	Very low	Low	Low
	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible

Classification of likelihood of occurrence

8-1.1.6 To classify the likelihood or probability of occurrence for a potential effect, it is necessary to understand how regularly a given event or outcome will occur. This can be assessed in a number of ways, including assessments based on historical data, quantitative analysis or experience from other similar sites. Often, this assessment will be based on standard guidance. The likelihood of the potential effect is then ranked as shown below in table E8-1-8.

Table E8-1-8 Classification of likelihood of occurrence

Likelihood of occurrence	Potential effect
High	Any consequence would likely appear in the medium term and inevitably in the long term (i.e. the lifetime of the proposed development).
	Equivalent to an annual probability of flooding of greater than 1% (0.5% for tidal).
Medium	Circumstances are such that an event is possible in the medium term and likely over the long term, although not necessarily inevitable.
	Equivalent to an annual probability between 0.1% and 1% (0.1% and 0.5% for tidal).
Low	It is unlikely that any consequence would arise within the lifetime of the proposed development.
	Equivalent to an annual probability of less than 0.1%.
Very low	It is unlikely that any consequence will ever arise.

8-1.1.7 It should be noted that, in circumstances where sites are defended by flood defences, determining an accurate assessment of probability of flood occurrence is complex, and assumptions that defences will not fail are unlikely to be acceptable. In such cases, assessments cannot be prescriptive and site-specific assessments would be undertaken. Factors that would be considered include construction methods, age, condition, maintenance, exposure and other external pressures.

Risk assessment

8-1.1.8 Once the significance of the potential effect and likelihood of occurrence have been assessed, these are then combined using a risk matrix (table E8-1-9) to assess the flood risk of each potential effect.

Table E8-1-9 Risk matrix

		LIKELIHOOD OF OCCURRENCE			
		VERY LOW	LOW	MEDIUM	HIGH
SIGNIFICANCE OF POTENTIAL EFFECT	HIGH	Low	Moderate	High	High
	MODERATE	Low	Low	Moderate	High
	LOW	Very low	Low	Low	Moderate
	VERY LOW	Negligible	Very low	Low	Low
	NEGLIGIBLE	Negligible	Negligible	Negligible	Negligible

8-1.1.9 Typically, flood risks assessed as low or less are considered acceptable. If the assessment results in moderate or high risk, this is considered significant (i.e. equivalent to a significant effect under the Environmental Impact Assessment regulations), and additional mitigation measures would be required to facilitate development.

8-1.1.10 In some situations, the risk assessment procedure will result in an artificially low assessment of risk. This is particularly the case in situations where consequences of very rare flooding (i.e. breach scenarios) are so extreme that any residual risk, however low, would not be allowed. In such instances, the assessed risk would be elevated. Such decisions must always be accompanied by detailed justification.