HORIZON NUCLEAR POWER

WYLFA NEWYDD

ENERGY WORKING FOR BRITAIN

Wylfa Newydd Project

6.4.29 ES Volume D - WNDA Development App D8-4 - Flood Consequence Assessment (Part 1/8)

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1 Introduction

1.1 Overview

1.1.1 This Flood Consequence Assessment (FCA) describes the assessment of flood risk from all sources resulting from the construction, operation and decommissioning of the Power Station. It includes all development activities within the Wylfa Newydd Development Area as described in chapter D1 (proposed development) (Application Reference Number 6.4.1), including Marine Works and the Site Campus.

1.1.2 The FCA assesses the flood risk posed to the above areas as well as any changes to flood risk arising from the developments within the Wylfa Newydd Development Area.

1.1.3 The hydrological baseline for the Wylfa Newydd Development Area is outlined in chapter D8 (surface water and groundwater) (Application Reference Number: 6.4.8), information from which is used in this FCA. This FCA should be read in conjunction with chapter D8 (Application Reference Number: 6.4.8).

1.1.4 Consultation with relevant statutory bodies and stakeholders has taken place throughout 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 Wylfa Newydd Development Area is located on the north coast of Anglesey to the west of the village of Cemaes as shown in figure D8-4-1. The surface water study area is shown on figure D8-1 (Application Reference Number: 6.4.101). There are a number of watercourses within the Wylfa Newydd Development Area that have the potential to affect or be affected by the developments. These are discussed in more detail in section 3 of this FCA.

1.2.2 The study area is based on the surface water catchments in and around the Wylfa Newydd Development Area. The northern boundary of the study area is defined by the Irish Sea coastline. The eastern, southern and western boundaries are defined by the surface water catchment boundaries of relevant watercourses. Beyond this area, significant flood related impacts associated with the developments are highly unlikely to occur.

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. The maps only produce an outline for fluvial flood extent for catchments greater than $3km^2$.

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 as 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 an assessment methodology (the FCA methodology) for the systematic 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 Power Station, other on-site development (as described in chapter A1 of this Environmental Statement), Marine Works and the Site Campus within the Wylfa Newydd Development Area, in association with TAN 15 guidance.

1.5 Report objectives

1.5.1 The objectives of this FCA are to:

- identify possible mechanisms by which the Power Station, other on-site development (as described in chapter A1 of this Environmental Statement), Marine Works and the Site Campus within the Wylfa Newydd Development Area could flood;
- identify any aspects of the design that could exacerbate flooding elsewhere;
- undertake a formal assessment of the risks posed to the developments from all identified flood risk sources and mechanisms;

- confirm that the Power Station and associated developments within the Wylfa Newydd Development Area 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. These are the key documents, along with local planning policy, relevant to this assessment. 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 chapter B8 (Application Reference Number: 6.2.8) 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 high risk areas.

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 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 for industrial development, residential development and emergency services should not be greater than 1m, 0.6m and 0.45m (see section A1.15 of [RD4]), respectively, for any return period.

2.3.4 It is also a requirement of TAN 15 that future users and occupiers of all types of developments 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.

2.3.5 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.

2.3.6 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. This information has therefore been incorporated into this FCA.

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 Wylfa Newydd Development Area is 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 (RBMP) (see [RD11] for the summary document) 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 RBMP 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 average annual rainfall data available online [RD12] for the period 1981 to 2010 shows an average annual rainfall at Valley (18km to the south of the Wylfa Newydd Development Area) of 841mm/year, which is below the UK average of 1154mm/yr. Long-term data indicates rainfall is typically higher in the late autumn/early winter and lowest in late spring/early summer.

3.2 Landscape

3.2.1 The Wylfa Newydd Development Area is largely rural inland from coastal areas, with isolated farmsteads and villages. The vegetation pattern in the vicinity of the Wylfa Newydd Development Area includes hedgerows with dense linear belts of planting. Areas of low-level vegetation fill small pockets around local farmsteads.

3.2.2 Key features of the landscape within and around the Wylfa Newydd Development Area are drumlins (a series of low rolling hillocks formed by glaciation) and three Sites of Special Scientific Interest (SSSI). Tre'r Gof SSSI is a small basin mire within the Wylfa Newydd Development Area and which is adjacent to the Existing Power Station. Cae Gwyn SSSI a system of basin mires separated by dry heathland habitat to the south of the Wylfa Newydd Development Area. Cemlyn Bay SSSI, Special Protection Area (SPA) and Special Area of Conservation (SAC) is a tidal lagoon and shingle ridge to the south-west of the Wylfa Newydd Development Area.

3.3 Topography

3.3.1 The Wylfa Newydd Development Area is mostly above an elevation of approximately 12m Above Ordnance Datum (AOD) with lower areas in the vicinity of the Tre'r Gof SSSI (<6m AOD), inland of Porth-y-pistyll beach and south-west of the Existing Power Station (<10m AOD) and upstream of Cemlyn Bay (<10 m AOD). However, the drumlins to the south of the Wylfa Newydd Development Area are at levels of 20m to 25m AOD with crests at levels of 30m to 40m AOD. The topographical survey is provided in appendix D8-4-10.

3.4 Off-Site receptors

3.4.1 There are three SSSI's in and close to the Wylfa Newydd Development Area: Tre'r Gof, Cae Gwyn and Cemlyn Bay. These are all sites of high environmental importance and have national or international value. Changes to the flood risk at these sites could affect the important ecological features of the SSSIs.

3.4.2 Tre'r Gof SSSI is a lime-rich wetland, dependent on a steady water supply through springs, groundwater seepages, ditches and surface water runoff. It is sensitive to changes in water flow, water level and water quality. Groundwater input from the bedrock aquifer is only a small component of the overall water balance for the Tre’r Gof SSSI. However, it is recognised that the hydroecology is complex and there is some uncertainty regarding water movement to the SSSI. A comprehensive assessment of the SSSI is provided in appendix D8-5, WNDA Development - Tre'r Gof Hydroecological Assessment (Application Reference Number: 6.4.30).

3.4.3 The Cae Gwyn SSSI is located immediately south of the Wylfa Newydd Development Area. Cae Gwyn SSSI comprises four small acidic basin mires that are largely dependent on rainwater input and locally on groundwater inflow. It is locally groundwater-fed and high water levels in the peat and soil is essential for the survival of wetland plants and animals. It is important not to lower water levels at the Cae Gwyn SSSI and to maintain the water supply. A comprehensive assessment of the SSSI is provided in appendix D8-6, WNDA Development – Cae Gwyn Hydroecological Assessment (Application Reference Number: 6.4.31).

3.4.4 Cemlyn Bay saline coastal lagoon is designated as a SSSI, SPA and SAC (for brevity, in this appendix it is referred to as the Cemlyn Bay SSSI). The lagoon that forms part of the Cemlyn Bay SSSI is separated from the sea by a shingle bank with a narrow channel at the western end. Drainage from one of the landscape mounds would discharge into Nant Cemlyn leading to the Cemlyn Bay SSSI. There is potential for it to be affected by changes in runoff rates from the development of the Power Station. The locations of the SSSIs are shown on figure D8-4-3.

3.4.5 Cestyll Gardens are located on the Afon Cafnan close to its outfall at Porth-y-Pistyll. The early-20th-century garden is situated in a narrow, rocky stream valley leading to the sea. It is an ornamental garden informally planted with a considerable variety of shrubs and perennials.

3.4.6 There are residential properties in the villages of Cemaes and Tregele which border the Wylfa Newydd Development Area to the east and south-east. At Cemaes there are properties adjacent to the Nant Cemaes on the A5025 and also downstream towards Cemaes Bay where the watercourse is restricted by a culvert under Ffordd Y Traeth.

3.4.7 The A5025 is an important Class A Road in a rural area which runs along the eastern side of the Wylfa Newydd Development Area. The Nant Cemaes passes under the road at the west of the village. Further south the Nant Caerdegog Uchaf also crosses the road. Both of these road crossings are upstream of the Power Station.

3.4.8 There are a number of historical public wells in the area. However, it is believed that these have not been used for a potable water source for many years and are derelict. These are not considered further as Off-Site receptors of flood risk.

3.5 Surface water features

3.5.1 The Wylfa Newydd Development Area is located within the Ynys Môn Catchment Abstraction Management Strategy (CAMS), part of the Western Wales River Basin District, prepared under the Water Framework Directive . The surface water study area (figure D8-1 (Application Reference Number: 6.4.101)) consists of five small surface water catchments as summarised in table D8-4-1; in addition to these, there are a number of small ponds within the study area, apparently isolated from the small watercourses. The Existing Power Station is drained directly to the sea by three surface-water drainage systems. In addition, there are small coastal areas not drained by the five main catchments as shown on figure D8-4-3. These drain informally (i.e. there are no defined watercourses) to the sea.

3.5.2 The northern boundary of the Wylfa Newydd Development Area is the Irish Sea. There are a number of inlets along the northern site boundary. These include Porth-y-pistyll to the east of the Existing Power Station, Porth y Wylfa to the north of Tre'r Gof SSSI, and Porth yr Ogof to the east of Wylfa Head. The locations of these features are shown on figure D8-4-3.

3.6 Geology and soils

3.6.1 The soils and geology across the study area are defined in detail in chapter D7 (soils and geology) (Application Reference Number: 6.4.7). The soils across the study area are defined as "*freely draining, slightly acid loamy soils*" in the areas towards the coast, and "*slowly permeable, seasonally wet, acid loamy and clayey soil*" further inland.

3.6.2 This variation in soil characteristics affects the river catchments as follows.

- The Power Station Catchment and Tre'r Gof Catchment are wholly or almost wholly within the area of more permeable soils.
- The Afon Cafnan Catchment and the Cemlyn Catchment are approximately half within the area of the more permeable soils and half in the area of the less permeable soils.
- The Cemaes Catchment is almost wholly in the area of less permeable soils.

3.6.3 The change in soil characteristics is likely to have a bearing on the flow characteristics, with catchments dominated by the more impermeable soil type more likely to display rapid rates of runoff, and an associated sharp response to rainfall events. Conversely, catchments dominated by the more permeable soil types are more likely to have a more subdued response to rainfall and a high proportion of baseflow.

3.6.4 The study area is located in a geologically complex area. Despite the complexity, all of the bedrock units underlying the study area are designated by NRW as Secondary B aquifers, meaning that the bedrock has low permeability but some layers that may store some water due to local features such as fissures, thin permeable horizons and weathering. The glacial till is designated as a Secondary (Undifferentiated) aquifer. Further information on the geology and soils is included in chapter D7 (Application Reference Number: 6.4.8).

Table D8-4-1 Wylfa Newydd Development Area baseline context

Catchment	Description
Tre'r Gof Catchment	The Tre'r Gof Catchment has an area of approximately 1km^2 and comprises Tre'r Gof SSSI, an inland basin fed by four small watercourses (three of which are ephemeral), direct rainfall and shallow groundwater inflow. The Tre'r Gof basin drains north to the coast via a culvert and outfall at Porth Wylfa.
Afon Cafnan Catchment	The Afon Cafnan Catchment has an area of 10km^2. It is mostly located to the south of the Wylfa Newydd Development Area. The Afon Cafnan is a main river within this catchment and flows in a northerly direction through the Wylfa Newydd Development Area to discharge to the sea at Porth-y-pistyll. This catchment includes Cae Gwyn SSSI (0.3km^2 area) which drains via an incised channel named in this report as Nant Caerdegog Isaf.
Cemaes Catchment	The Cemaes Catchment has an area of approximately 3km^2 located immediately to the east of the Wylfa Newydd Development Area, draining north from Llanfechell, via Tregele and discharging into Cemaes Bay. Small parts of the eastern Wylfa Newydd Development Area extend into this catchment. The main channel has been named 'Nant Cemaes' within this report. The watercourse flows in a generally northern direction through the village of Tregele to the east of the development boundary. Nant Cemaes then flows in a north-easterly direction beneath the A5025 and through the village of Cemaes. Nant Cemaes discharges into Cemaes Bay via a culvert.
Power Station Catchment	The Power Station Catchment has an area of 0.3km^2 and drains a small catchment immediately south of the Existing Power Station. The small channel shown on OS mapping within this catchment is referred to as 'Nant Porth-y-pistyll' within this report. The upper reaches of this channel are culverted, and the remainder of the channel is a large flush (wetland) across a field which drains in a westward direction and discharges to the coast at Porth-y-pistyll.
Cemlyn Catchment	The Cemlyn Catchment has an area of approximately 2km^2 located to the west and south-west of the Wylfa Newydd Development Area. Small parts of the eastern Wylfa Newydd Development Area extend into this catchment. This channel drains north via a small south-western area of Wylfa Newydd Development Area to drain into the lagoon which forms part of Cemlyn Bay SSSI and Special Area of Conservation (for simplicity referred to in this FCA as Cemlyn Bay SSSI).

3.7 Groundwater

3.7.1 The groundwater baseline report (appendix D8-3, WNDA Development - Groundwater baseline report (Application Reference Number: 6.4.28)), and contains further details of groundwater within the Wylfa Newydd Development

Area. Groundwater is found in both the superficial deposits and in discontinuities such as fractures in the underlying bedrock. Over most of the Wylfa Newydd Development Area, groundwater appears to form a continuous body with water in the bedrock interacting with water in the superficial deposits to some degree, although this is spatially very variable. In some areas the groundwater in the two deposits are separate whilst in other areas the superficial deposits have no groundwater and can confine the groundwater in the underlying bedrock.

3.7.2 The groundwater contours for the superficial deposits, which are shown in appendix D8-3 (Application Reference Number: 6.4.28), generally follow topographic contours from the south towards the sea. The maximum-recorded groundwater level within the Wylfa Newydd Development Area is 31.5m AOD to the east of Tregele. The maximum-recorded groundwater level adjacent to the coast is at approximately 1m AOD.

3.7.3 There is ongoing monitoring of groundwater levels at a large number of monitoring boreholes, which have demonstrated that groundwater is generally shallow at a depth of between 0.1m and 3.2m below ground level across much of the Wylfa Newydd Development Area. The water level data shows groundwater flow in two directions, either towards Tre'r Gof or towards Porth-y-pistyll.

3.8 Water services

3.8.1 The utilities survey does not show any surface water sewers in the vicinity of the Wylfa Newydd Development Area. A Dŵr Cymru Welsh Water (DCWW) foul water sewer that originates in Tregele flows in a north-easterly direction following the general direction of Nant Cemaes. The sewer conveys flows from Tregele, properties along the A5025 and Cemaes. Near to Cemaes Bay, the sewer flows in a north-westerly direction, north of Tre'r Gof, to the sewage works at Wylfa Head to the north of the Existing Power Station. The residential properties to the west of the Wylfa Newydd Development Area, and the properties not adjacent to the A5025, are not served by DCWW foul water sewers.

3.8.2 The utilities survey shows that there are water mains running beneath many of the roads in the Wylfa Newydd Development Area, including beneath the A5025 from Cemaes to Tregele, and beneath the road from Tregele, west to Cemlyn Bay.

3.9 Reservoirs

3.9.1 There are no reservoirs in the vicinity of the Wylfa Newydd Development Area and the study area is not located within the maximum extent of a reservoir flood, therefore there is no risk to the Wylfa Newydd Development Area from reservoirs and this flood source will not be considered further within this report.

3.10 Water use and abstractions

3.10.1 Surface water from rivers and streams can be abstracted for a variety of uses including as a potable supply, for use in agriculture (for watering crops or for water for animals) or for industrial uses. However, there are no known surface water public or private water abstractions within the Wylfa Newydd Development Area, although there is the potential that there are some abstractions which are not recorded. It is likely that some watercourses will be used for riparian purposes. In particular, it is known that the channels are used to water livestock across the study area.

3.10.2 There are three known groundwater fed private water supplies within the study area, these are discussed further in appendix D8-3 (Application Reference Number: 6.4.28)Environmental Statement.

4 Power Station, other on-site development, Marine Works and Site Campus

4.1 Site Areas

4.1.1 The Wylfa Newydd Development Area can be split into four areas for the purpose of this FCA: the Power Station, landscaped areas (i.e. other on-site development), Marine Works and the Site Campus. Associated with these areas are a series of drainage and water treatment systems. For the purpose of the FCA all developments excluding the Site Campus have been assessed as the Wylfa Newydd Development Area, whilst the Site Campus has been assessed individually.

4.1.2 An outline of the onshore elements of the proposed works within the Wylfa Newydd Development Area is included below insofar as these are relevant to the FCA. Full details of the proposed works are included in chapter D1 (Application Reference Number: 6.4.1).

4.2 Parameters

4.2.1 As detailed in section 8.4 of chapter D8 (Application Reference Number 6.4.8) the approach adopted for the design of the Power Station, Site Campus and landscape mounds has been to utilise a parameter approach to the development. Parameter plans have been submitted with the application for development consent and show the extent of each parameter zone. These parameters are detailed in chapter D8 (Application Reference Number 6.4.8) and are not repeated here.

4.3 Power Station

4.3.1 The main onshore construction activities relevant to flood risk within the Wylfa Newydd Development Area would be:

- realignment of Nant Caerdegog Isaf within the Afon Cafnan Catchment;
- installation of a new drainage system and levelling to create the Power Station platform;
- deep excavations and tunnelling; and
- construction of temporary and permanent buildings.

4.3.2 In addition, there would be a number of marine works associated with the Power Station, including a Cooling Water System (intake and outfall) and breakwater, and a Marine Off-Loading Facility (MOLF). These works would be located in Porth-y-pistyll, just south of the existing jetty, constructed to serve the Existing Power Station. These structures are water compatible (as defined in [RD4], i.e. they will remain operational and safe for users in times of flood, and as such can be considered appropriate to be sited in an area at risk of flooding. Only the onshore elements of the Marine Works are included in this FCA.

Watercourse realignment

4.3.3 Nant Caerdegog Isaf, a tributary of Afon Cafnan that conveys flows discharging from the Cae Gwyn SSSI, is to be realigned at the south of the Wylfa Newydd Development Area due to the encroachment of the Power Station platform. This realignment would create a more natural channel profile with the channel width and depth reduced to encourage natural geomorphological processes. The diverted channel would be slightly shorter than the existing channel, which has been historically diverted along land ownership boundaries.

4.3.4 The new channel would be created in a dry environment by stripping topsoil, excavating and profiling the new realignment. A gravel bed would then be built up using locally won stone and the banks top soiled, planted and allowed to establish before flows are introduced.

Creation of the Power Station platforms

4.3.5 The Power Station platforms would be created by excavation of soils and superficial deposits and the removal of a significant volume of rock. This work would take place within the Power Station Catchment and would involve extensive changes to the drainage in this area. A new drainage system would be constructed that would take water from the platform areas, pass it through a treatment system with discharge to the sea.

4.3.6 The platforms range in elevation from 6m AOD at the cooling water intakes, to around 31m AOD for some of the material laydown areas to the east. The material excavated to create the platforms would be transferred to create the landscape mounds. The platforms would include perimeter drainage trenches as part of the construction drainage network that would divert any surface water or groundwater from the area; construction phase drainage would be installed during the site preparation and clearance stage and then re-established and maintained through later phases.

Retaining wall

4.3.7 To create and stabilise the Power Station platforms, a retaining wall would be constructed between the Power Station platforms and Nant Caerdegog Isaf. The retaining wall would be located in close vicinity to Nant Caerdegog Isaf near the watercourse realignment.

Deep excavations

4.3.8 The basements for the Power Station would be relatively deep, excavated to approximately 30m to 40m below the ground surface (i.e. at their deepest to -18m AOD). Dewatering of these excavations would be required during construction of the basements with abstracted water treated in sediment settlement ponds and discharged to the sea.

Temporary laydown areas and buildings

4.3.9 The construction of temporary laydown areas would occur in the early phases of the development, and would cover significant areas to the south-east and south-west of the Power Station. These areas would however be set back from the watercourses and outside of areas where significant flooding is predicted.

4.3.10 A concrete batching plant would be located on the coast to the south-west of the Existing Power Station.

4.3.11 Other buildings that would be required include those for construction site management and other contractors' facilities, security access points and on site office facilities for support staff. These buildings would be located to the south of the Power Station. A number of contractors compounds would also be required across the Wylfa Newydd Development Area.

Construction of permanent buildings

4.3.12 The permanent buildings comprise the turbine hall, control buildings and reactor buildings, with the service building and the radiological waste building on either side.

MOLF

4.3.13 The MOLF would be constructed to import construction materials, and it is likely that approximately 98% of construction materials would be delivered via the MOLF. The onshore component of the MOLF comprises the bulk quay and the roll-on and roll-off pier, and the proposed level of the MOLF is 8m AOD.

Onshore cooling water intake structure and pump house

4.3.14 An onshore intake structure would be constructed at Porth-y-pistyll to draw seawater to meet the cooling water requirements. There would be one intake structure for each power generating unit, each one a concrete structure, approximately 50m wide and 80m long, extending below ground level. The top slab is to be at a final ground level that is at approximately 6m AOD for the seaward part of the structure, and 14m AOD for the landward part, with the transition in the middle achieved by means of a retaining wall.

4.3.15 The intake structure would extend vertically across the tidal range, ensuring sufficient submergence at all stages of tide for water intake operations. Construction would therefore take place below sea level; in order to carry out the construction in the dry, a temporary cofferdam would be constructed first, positioned in front of the intake seaward face, to seal the area from seawater ingress during construction.

Onshore cooling water outfall

4.3.16 The cooling water would be discharged back to sea via outfall tunnels ending at the outfall structure, which is to be located in the rocky cove where the Existing Power Station outfall is. The outfall structure would include a common concrete apron that is used to control the hydraulic jump and avoid erosion of the bedrock at any stages of the tide. The structure would be some 50m in length and 40m in width.

4.3.17 The outfall would be constructed at the same time as the intake structure, and would require a cofferdam in front to enable construction in the dry. The cofferdam would likely be made of a double line of steel sheet piles, driven into the bedrock and reinforced with tie rods connecting the two lines of sheet piles. The cofferdam would be removed following construction.

4.4 Landscape mounds

4.4.1 The landscaping areas are the areas of land that would be used to create the landscaping mounds. The elements within these areas include:

- landscape mounds;
- temporary and permanent roads;
- temporary and permanent fences; and
- new services and infrastructure.

4.4.2 The drainage associated with the landscape mounds is discussed in section 4.5.

Landscape mounds

4.4.3 The excavated material from the platform construction would be used to form landscape mounds in the south and east of the Wylfa Newydd Development Area. Topsoil, superficial deposits and bedrock would be excavated through the early phases of construction. The excavated material would be used on-site in five landscape mounds. The mounds would incorporate drainage and would capture and control flows prior to discharge back to the environment. The locations and receiving watercourses of each mound are summarised in table D8-4.2.

Table D8-4-2 Location and discharge receptors of mounds

Mound	Mound Location	Drainage discharge point
A	South and east of Tre'r Gof SSSI	Cemaes Bay, Tre'r Gof Catchment and Cemaes Catchment
B	West of the A5025 in the vicinity of Tregele	Tre'r Gof Catchment
C	East of Cae Gwyn SSSI	Afon Cafnan Catchment via Nant Caerdegog Isaf
D	West of the Power Station	Afon Cafnan Catchment
E	South-east of Cemlyn Bay, south of Cemlyn Bay Road	Afon Cafnan Catchment and Cemlyn Catchment (discharges to the Nant Cemlyn will only take place once the western side of Mound E is vegetated and there is no sediment risk from Mound E to the stream)

4.4.4 These mounds are all to be set back a minimum of 15m from any watercourses. In addition, there would be temporary storage areas for stone and topsoil, which would be within areas of managed drainage.

Amendments to catchment areas

4.4.5 The landscaping and creation of mounds would have the effect of changing the natural catchment areas of the catchments identified in section 3.4 and described in table D8-4-3. This would increase or decrease the natural runoff into the receiving watercourses.

Table D8-4-3 Location and likely discharge receptors of mounds

Catchment	Natural catchment area (ha)	Change in area(ha)	Change in area (%)	Consequence
Tre'r Gof Catchment	100	-9	-9	A reduction in natural catchment runoff due to the smaller catchment area
Afon Cafnan Catchment	992	-60	-6	A reduction in natural catchment runoff due to the smaller catchment area
Cemaes Catchment	299	6	2	An increase in natural catchment runoff due to the larger catchment area
Cemlyn Catchment	226	2	1	A small increase in natural catchment runoff due to the larger catchment area
Power Station Catchment	This catchment would be lost during platform construction and the drainage from this area would be replaced by a new drainage system from the Power Station that would discharge to the sea.			

Security fences

4.4.6 A series of security fences would be installed around the Power Station and the Wylfa Newydd Development Area. The security fences would comprise twin outer and twin inner fences. Security fences for the Wylfa Newydd Development Area would be constructed during the early stages of construction. Some of these fences would be temporary and only in use during the construction phase, while some would be retained for permanent security during the operational phase. The permanent security fences would not cross any permanent watercourses, including Afon Cafnan, Nant Caerdegog Isaf and drains within the Tre’r Gof Catchment.

Construction of temporary haul roads

4.4.7 Main haul roads would be installed in the early phases of construction to provide links to the main Contractor’s compound in the centre of the Wylfa Newydd Development Area and to allow access onto the east to west route (Cemlyn Bay road). Main haul roads would be approximately 10m wide with a

2.5% fall across the road to a ditch for drainage/runoff. Soil would be stripped along the haul roads and then compacted rock would be used to construct the road surface so that track would be semi-permeable, permitting some infiltration of rainfall. Sediment control would be implemented during construction works to limit the potential for sediment accumulation to increase flood risk.

4.4.8 The drainage ditches for the haul roads would drain to the sedimentation ponds associated with the landscape mound drainage system prior to discharging to surface water receptors. Main haul roads would incorporate an oil/water separator prior to discharge to the sedimentation ponds.

Construction of road culverts and bridges

4.4.9 The haul roads and security roads would cross a number of minor watercourses and field drains. The following two types of minor watercourse crossing structures would be constructed in the early stages of construction:

- small bridges would be constructed over the streams; and
- oversized pipes would be installed on any ditches that are typically dry.

4.4.10 A large crossing across the Afon Cafnan would be required to provide additional capacity for transporting excavated material to Mound E. The bridge would likely be constructed of simple reinforced concrete abutments supporting steel beams with a timber deck. This would be approximately 16m in span (compared to a typical wetted channel width of 2m-4m) and it would likely be located to the south of the Cemlyn Bay Road.

4.4.11 These structures would be in place during the entire construction period (i.e. seven years) but would be removed following construction.

Permanent roads

4.4.12 The permanent roads across the Wylfa Newydd Development Area would be constructed at the end of the construction period and all would incorporate drainage. It is likely that these would incorporate some culverts and/or bridges.

Existing roads

4.4.13 Use of the existing Cemlyn Road that runs approximately east to west across the Wylfa Newydd Development Area would be significantly reduced, as the road is expected to be largely removed by the development of the Power Station. Access would still be available to existing properties at Cafnan, though it would be restricted to traffic from the west.

4.5 Site Campus

4.5.1 The Site Campus would provide accommodation for up to 4,000 workers and would be constructed in phases. It would occupy approximately 15 hectares of land, located in the north-east of the Wylfa Newydd Development Area. It would consist of:

- accommodation in 'campus' style modular form;
- amenity building including cafeteria, café, reception area, gym, bar and other social space;
- outdoor recreation including three multi-use games areas, outdoor seating and informal public spaces;
- Site Campus access road (from the site to the A5025);
- bus set down and parking area;
- disabled parking spaces and parking for light vans/minibuses;
- internal access ways for pedestrians, service vehicles and emergency vehicles;
- 2.4m high Paladin type fence around the perimeter; and
- soft landscaping works, retaining existing landscape features.

4.5.2 The layout of the Site Campus is shown on figure D8-4-2 with further detail provided in chapter D1 (Application Reference Number: 6.4.1).

4.5.3 The Site Campus would be used during the construction phase of the Power Station to accommodate workers on a temporary basis. The development would be designed to have a service life of a minimum of 10 years. This is less than the minimum service life recommended by Welsh Government for housing, but this is a reflection of the temporary nature of the accommodation.

4.5.4 Following construction of the Power Station, the Site Campus would be decommissioned and the land returned to its pre-developed condition. Public footpaths and access to Fisherman's car park would be reinstated after decommissioning.

4.6 Drainage strategy

Construction phase

4.6.2 During construction, the landscape mounds would be susceptible to erosion by surface water runoff resulting in sediment-laden runoff. A construction-phase drainage strategy would be implemented throughout the construction and operational phases. Management of sediment during the construction phase is outlined in the Wylfa Newydd Code of Construction Practice (Application Reference Number: 8.6). In relation to the landscape mounds:

- existing surface water features would have a minimum buffer of 15m from the foot of a mound;
- toe drains would extend around the entire perimeter of each mound, with steep channels requiring check dams/upstream silt sumps;

- the drainage channels would divert flows into sedimentation ponds, silt trap or reed bed as required to control suspended sediment discharge to watercourses; and
- water treatment would be used as required to control suspended sediment concentrations in the discharge.

4.6.3 The temporary drainage would include drain trenches along haul roads, security roads and around construction areas as required. These would also incorporate settlement ponds or other pollution control features before drainage water is discharged to surface water features. As far as is reasonably practicable, the temporary drainage during construction has been designed to mimic the existing surface water catchments, including catchment areas and discharge points.

4.6.4 The drainage principles that have been considered by Horizon when developing the mitigation concept for the construction phase are:

- prevention of unmitigated water flows into existing watercourses for all rainfall scenarios up to and including the 1% AEP event;
- discharges would be treated to reduce sediment content for the 100% AEP event;
- rainfall return periods greater than the 1% AEP event would overtop or bypass into the receiving watercourse with the exception of those discharging to Tre'r Gof, where a toe drain would direct excess runoff towards the sea (see details in appendix D8-8 (summary of preliminary design for construction surface water drainage) (Application Reference Number: 6.4.33));
- passive systems would be used in preference to active pumped systems where practicable;
- drainage design would take into account ecological and visual impact during construction and operation; and
- construction phase drainage would be designed to become passive "naturalised" drainage during operation.

4.6.5 Storm water falling on the landscape mounds would be drained through sedimentation ponds before discharging to surface water catchments, mimicking existing catchments where practicable. The only exception is the Nant Cemlyn Catchment. Due to the potential sensitivity of Cemlyn Lagoon, which is at the downstream end of the catchment, there would be no input of treated water from Mound E to the Nant Cemlyn. Instead, this water would be temporarily diverted to the Afon Cafnan whilst work is undertaken on the western side of Mound E. Once the western side of Mound E is vegetated the water would be diverted back into the Nant Cemlyn.

Operational phase

4.6.6 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. Design would be as if it were to be adopted by sewerage undertakers in accordance with Section 104 of the Water Industry Act 1991.

4.6.7 A summary of the surface water system requirements are:

- no surcharging above pipe soffit for the 20% AEP flood event;
- no flooding from manholes or above ground (allowing for 300mm freeboard) for the 3.33% AEP flood event;
- no significant ponding for the 1% AEP flood event; and
- attenuation of runoff to the greenfield mean annual rate.

Services

4.6.8 Water supply during construction and operation would be from DCWW existing licensed supplies delivered to site via a new purpose built supply main.

4.6.9 During site preparation and clearance waste/foul water would be stored in tanks on site and discharged off-site by tanker to a suitably licensed facility. As construction worker numbers increase on site a package plant would be used to treat sewage before discharging to the marine environment. Sewage from the Site Campus would likely be treated by DCWW at the existing treatment works on Wylfa Head, once the facility is upgraded. If there is insufficient capacity at the Wylfa Head facility, then a package treatment plant would be used.

4.6.10 During operation, foul drainage from the Power Station would generally be via gravity systems to a point from where it would be pumped to the DCWW treatment plant. The existing DCWW waste water treatment plant is to be scaled up and upgraded to treat foul sewage from the Power Station and Cemaes village. The waste water outfall maybe relocated, but would remain on Wylfa Head. The foul sewer that currently links Cemaes village to the sewage treatment plant would likely be diverted to follow the fisherman's car park road. It is unlikely that this would include a significant rise in flows. The sewerage design has only been developed in concept for the Wylfa Newydd Development Area and there is no indication of connection route.

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 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 >3km^2) and tidal sources. Surface water flood maps are also available.
- **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.
- **Nuclear Safety, Meteorological and Hydrological Hazards Assessment (NSMHHA) [RD14]**:This was carried out by Amec (now Wood) to model extreme flood risk events in line with EN-1 [RD15] and EN-6 [RD16] guidance. This report includes marine modelling, taking into account tidal and wave action, and a combined pluvial and fluvial flood modelling.
- **Coastal and tidal flood modelling** has been undertaken for the coastline of the Wylfa Newydd Development Area (see appendix D8-4-3).
- **Pluvial and fluvial flood modelling** has been undertaken by Wood in support of the Environmental Impact Assessment and expands the combined pluvial and fluvial flood modelling within NSMHHA to include Nant Cemlyn and to consider scenarios through the construction and operation of the developments (see appendices D8-4-4 to D8-4-9 for details of the modelling and assumptions).

5.1.2 These sources of information are detailed below.

5.2 NRW and TAN 15 flood maps

5.2.1 Whilst the NRW flood map does provide some additional detail in relation to flood probabilities over and above the TAN 15 Development Advice Map, the two are broadly comparable. Only the TAN 15 Development Advice Map (figure D8-4-5), which shows the fluvial and coastal flood zones, as issued by the Welsh Government, is primarily discussed here as the classifications from this better relate to planning policy. However, the maps only show current day flood and do not show the impact of climate change and nor are they applicable to catchments less than 3km^2 in area.

5.2.2 The TAN 15 Development Advice Map indicates that the Wylfa Newydd Development Area is predominantly at low risk of fluvial and coastal flooding (Zone A, which is not separately illustrated in the mapping) except for the areas outlined below.

- Low lying areas inland of Porth-y-pistyll in Zone C where extreme sea levels result in inland flooding.
- Along the main Afon Cafnan channel southwards to Ty-croes, and along the downstream end of the Nant Caerdegog Isaf, where areas within fluvial Flood Zone C2 are shown.
- Five low lying marshy areas in the study area, including one inland of Porth Wylfa associated with Tre'r Gof SSSI, that are shown to be within Zone B.

5.3 Coastal and tidal flood modelling

5.3.1 Wave modelling has been undertaken for the Wylfa Newydd Development Area (see details in appendix D8-4-3). A SWAN (Simulating Waves Nearshore) model [RD17] has been used to demonstrate the wave propagation. Baseline, partially built, and fully built situations were modelled, with the MOLF, coffer dams and breakwaters included. Two future scenarios were considered to model climate change, representing reasonably foreseeable and credible maximum values for the years 2087 (end of power generation) and 2187 (end of decommissioning).

5.3.2 Wave disturbance modelling was undertaken for the area in the lee of the breakwaters, including the MOLF and the cooling water intake. An ARTEMIS wave model [RD18] was constructed for the fully-built layout, including the two breakwaters and the lowering of the bed level within the harbour relative to present day levels (see details in appendix D8-4-3). The model was run for a range of events with a reasonable foreseeable climate change scenario for 2087 and 2187 and the credible maximum scenario for the 0.5% and 0.1% AEP events.

5.4 Fluvial and pluvial flood modelling

5.4.1 Hydraulic modelling has been undertaken and is reported in appendix D8-7 (Application Reference Number: 6.4.32). Pluvial and fluvial models have been used to determine the degree of flood risk from both sources during different phases of the development, including allowances for climate change. The fluvial model incorporates tidal influences. A linked 1-Dimensional 2-Dimensional (1D-2D) hydraulic model has been built utilising the modelling software package Infoworks ICM (Integrated Catchment Model) version 7.0.4 [RD19].

- The baseline model represents the environment in and around the Wylfa Newydd Development Area as it is today, before any development activities. The purpose of this scenario is to provide a baseline against which the other two development scenarios can be compared. The baseline model excludes underground assets. A full list of input data is provided in appendix D8-7 (Application Reference Number: 6.4.32).

- The reference point 4 model represents the environment in and around the Wylfa Newydd Development Area at a point during construction (2020s). It includes, soil mounding, laydown areas, temporary structures and channel diversion. The purpose of this scenario is to quantify the theoretical impacts during the construction phase.
- The reference point 5 model represents the environment in and around the Power Station during the operational phase (2080s). It includes, final landforms, roads and buildings. The purpose of this scenario is to quantify the theoretical impacts during the operational phase.

5.4.2 There are four watercourses in the model, Nant Cemlyn in the West, Nant Cemaes in the east and the Afon Cafnan and its tributary the Nant Caerdegog Isaf in the centre. The locations of these watercourses are shown on figure D8-4-5.

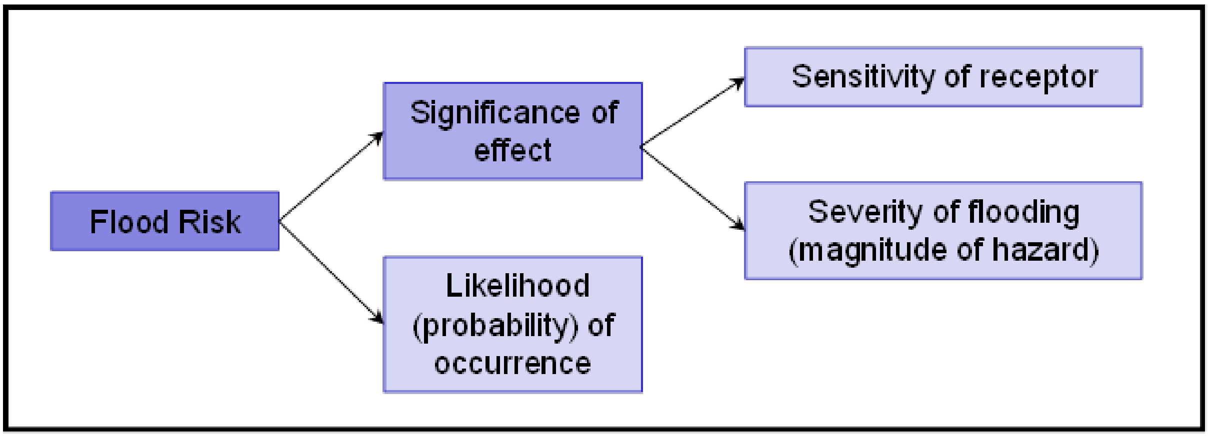
6 Flood risk assessment methodology

6.1 FCA methodology

6.1.1 Industry guidance [RD20] 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.

6.1.2 The risk assessment methodology used within this FCA is set out in appendix D8-4-2 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 then dependant 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 receptor;
- severity of flooding (i.e. the magnitude of hazard); and
- likelihood (i.e. probability) of occurrence.



Sensitivity of receptors

6.1.3 The sensitivity of receptors is defined according to the method outlined in appendix D8-1-4 with a range of sensitivities from very high through high, medium and low, to very low being defined. TAN 15 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 Wylfa Newydd Development Area are defined in section 7.1.

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 severity (magnitude) of flooding that fall 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 D8-4-2.

Likelihood of occurrence

6.1.5 The likelihood of flooding is used to give an understanding of how regularly a given event or outcome will occur. This is defined within appendix D8-4-2 and the classification of these criteria is discussed in sections 8 (construction), 9 (operation) and 10 (decommissioning).

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 to the Wylfa Newydd Development Area. Furthermore, the mitigation measures proposed 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.

7 Sensitive receptors and screening of potential flood sources

7.1 Sensitive receptors

7.1.1 During construction the majority of the land within the Wylfa Newydd Development Area would be classified as an employment site which is defined in TAN 15 as "*less vulnerable development*" [RD4]. Following appendix D8-4-2, construction activities within the Wylfa Newydd Development Area therefore have a medium sensitivity. The onshore development of marine facilities, including the MOLF, are classed as low sensitivity receptors as they are water compatible structures (appendix D8-4-2).

7.1.2 In addition to construction works, the Tre'r Gof SSSI is located within the Wylfa Newydd Development Area. There would not be any construction works within this site and it is not currently developed so it would not be classed as an employment site, nor would it meet the definition of a "highly vulnerable development" in TAN 15. However, given its ecological status it is classed here as having high sensitivity rather than medium or low.

7.1.3 Following TAN 15 guidance, once operational, the Power Station is classified as a "*highly vulnerable development*" [RD4]. Following appendix D8-4-2, the Power Station therefore has a high sensitivity.

7.1.4 The Site Campus is classified as residential accommodation, which is classified within TAN 15 as a "*highly vulnerable development"* [RD4]. Following Appendix D8-4-2, this is classified as having high sensitivity within this assessment.

7.1.5 Off-site receptors include buildings, roads, services, undeveloped/agricultural land and environmental designated sites including Cae Gwyn SSSI and Cemlyn Bay SSSI, Special Area of Conservation and Special Protection Area. All off-site buildings/infrastructure and environmental designated sites are categorised as having a very high or high sensitivity with regard to flood risk. The exception to this is Cemlyn Bay SSSI, which is considered to have a medium sensitivity as a tidal lagoon that is frequently inundated. Undeveloped / agricultural land has a medium sensitivity. Properties that would remain within the Wylfa Newydd Development Area, for example those at Cafnan, are categorised as having a very high sensitivity with regard to flood risk. Where there is a flood risk to a road, including those within the Wylfa Newydd Development Area, if it is a key access route it has a very high sensitivity. In this assessment, if a route only has one access direction (i.e. the other is a dead end) it is considered a key access route.

7.1.6 Undeveloped land within the Wylfa Newydd Development Area is classified as having a medium sensitivity. The landscape mounds are not assessed as being a receptor to flooding as they are considered to be a flood risk source area.

7.2 Power Station screening

7.2.1 Table D8-4-4 summarises a range of potential risks and whether these are relevant to the proposed Power Station.

Table D8-4-4 Power Station site screening of potential flood sources

Flood type	Source	Pathway	Consider further?
Tidal	Irish Sea flooding of the Power Station	Tidal flooding to the Power Station. Situated on the coast	Yes
Fluvial and pluvial	Fluvial flooding of the Power Station	Out of bank flows from the watercourses	Yes
	Pluvial flooding of the Power Station	Surface water flooding from extreme rainfall	Yes
	Site development, and in particular creation of landscape mounds and drainage.	Off-site runoff due to introduction of impermeable surfaces and changes to landform and drainage	Yes
Groundwater	Groundwater	Groundwater emergence	Yes
Services	Sewerage network	Runoff to the Power Station from failure of sewerage network	Yes
	Water mains	Runoff to Power Station from failure of water mains	Yes
Reservoir flooding	Failure of reservoir walls	Not located downstream of a reservoir	No

7.3 Site Campus screening

7.3.1 Table D8-4-5 summarises a range of potential risks and whether these are relevant to the proposed Site Campus.

Table D8-4-5 Site Campus screening of potential flood sources

Flood type	Source	Pathway	Consider further?
Tidal	Irish Sea flooding	Tidal flooding to the Site Campus. Situated on the coast	Yes
Fluvial and pluvial	Fluvial flooding	No watercourses adjacent to the Site Campus. Entirely within Flood Zone A	No
	Pluvial flooding	Surface water flooding from extreme rainfall	Yes
	Site development and in particular creation of landscape mounds and drainage.	Off-site runoff due to introduction of impermeable surfaces and changes to drainage	Yes
Groundwater	Groundwater	Groundwater emergence	Yes
Services	Sewerage network	Runoff to Site Campus from failure of sewerage network	Yes
	Water mains	Runoff to Site Campus from failure of water mains	Yes
Reservoir flooding	Failure of reservoir walls	Not located downstream of a reservoir	No

8 Wylfa Newydd Development Area construction phase flood risk assessment

8.1 Tidal flooding

8.1.1 The risk of flooding from the sea is included on the TAN 15 Development Advice map provided on figure D8-4-5. The information is based on broad scale modelling and does not differentiate between the risks from the rivers or the sea at river mouths. This assessment is based on the more detailed wave modelling described in section 5.3.

8.1.2 Table 3.2 of the wave modelling report (appendix D8-4-3) presents baseline (2008), present day (2023) and both reasonably foreseeable and maximum sea levels (2087 and 2187). These levels are presented in table D8-4-6.

Table D8-4-6Peak still-water sea levels for the Wylfa Newydd Development Area for a range of scenarios and AEP events

Scenario	Sea Level (m AOD) for a given scenario and AEP (%)						
	Mean High Water Spring	100	2	1	0.5	0.1	0.01
“EA3” (2008)	N/A	3.81	4.23	4.30	4.36	4.50	4.67
“Present Day” (2023)	3.05	3.86	4.28	4.35	4.41	4.55	4.72
2087 – reasonably foreseeable	3.67	4.48	4.90	4.97	5.03	5.17	5.34
2187 – reasonably foreseeable	5.12	5.93	6.35	6.42	6.48	6.62	6.79
2087 – maximum credible	4.50	5.84	6.53	6.60	6.66	6.80	6.97
2187 – maximum credible	6.80	8.27	9.03	9.10	9.16	9.30	9.47

8.1.3 Only small coastline areas bordering the Wylfa Newydd Development Area lie at levels below the highest maximum credible sea water level presented in table D8-4-6. The lowest area within the Wylfa Newydd Development Area is Tre’r Gof, which lies at between 5m AOD and 10m AOD. The elevation at which sea levels would breach the high ground to the north of Tre’r Gof is approximately 11m AOD, therefore, still-water tidal inundation of Tre’r Gof or anywhere else outside of the coastal margins of the Wylfa Newydd Development Area is not expected during the construction phase. Figure 4.6 of the wave modelling report indicates that simulated wave heights for the 2023 present day scenario at the low-point access to Tre’r Gof do not exceed 0.4m, therefore, wave assisted overtopping of Tre’r Gof is also not expected.

8.1.4 During construction the proposed crest level for both the MOLF and the cofferdam is 5m AOD. The high and extreme sea conditions tested indicate that present day still water levels would not exceed the proposed crest level for all scenarios up to and including the 0.01% AEP event. The cofferdam is a feature of construction only, therefore, still water levels in isolation are not expected to be an issue.

8.1.5 Table D8-4-7 gives the predicted overtopping rates for the MOLF for a range of joint wave and sea level probabilities for the present day scenario. Note that the probability of extreme wave heights coinciding with extreme sea levels is very low, hence, sea levels presented in table D8-4-7 all relate to present day events lower than the mean annual sea level. Note also that overtopping rates can only be calculated where still water levels are below the crest level of the structure being assessed.

8.1.6 The joint probability results suggest that overtopping would occur in a 20% AEP event. Overtopping rates are simulated to be approximately three times higher in a 0.1% AEP event. As indicated, these overtopping rates are driven by mean wave heights between 3.3m and 4m high acting on sea levels of just less than the present day mean annual sea level. Because the source of this flood risk is tide related, overtopping could only occur in any one period for a period of approximately 3 hours.

8.1.7 Despite the small window for overtopping in any one period, the mean overtopping rates are significant and higher than those that could result in physical damage of the structures. Further, the conditions in the vicinity of the MOLF are likely to render it unusable under these conditions. Use of the MOLF would be restricted to appropriate operating conditions to avoid exposure of people, assets or materials to unnecessary risk. Regular inspection and maintenance of the MOLF and associated structures would be undertaken to maintain the integrity of the structures over the lifetime of their use.

8.1.8 Comparison of the baseline to construction wave environment scenarios in the wave modelling report indicates that during construction, with the cofferdams and breakwaters constructed and the harbour dredged, the wave heights in the harbour decrease considerably during summer (figure 4.6 of the wave modelling report provided in appendix D8-4-3). For the fully-built scenario with the subsequent removal of the cofferdams, the residual changes compared to the baseline modelling are localised around structures. Under present day (2023) conditions the wave heights in the harbour are lower than the baseline.

Table D8-4-7Construction phase - peak values of mean overtopping rate for waves and sea levels with joint probabilities of 20%, 4%, 1.33%, 0.5% and 0.1% AEP for the MOLF for the 2023 present day scenario

AEP (%)	Worst case sea condition ARTEMIS point			Mean overtopping rate (l/s/m)
	H_s(s)	T_{m-10} (s)	Sea level (mAOD)	
20.00	3.27	8.2	3.05	168
4.00	3.53	8.7	3.30	249
1.33	3.79	9.1	3.54	300
0.50	3.77	9.0	3.54	348
0.10	4.03	9.4	3.78	410

8.1.9 In conclusion, the land and construction activities at risk within the Wylfa Newydd Development Area during the construction period from coastal flooding is considered to be of medium sensitivity to flooding. The magnitude of potential hazard in these areas is considered to be very low, giving a very low significance of effect. Since the likelihood of occurrence is classed as medium, due to the 0.1% AEP probability of occurrence, the overall flood risk is determined as being low.

8.1.10 The sensitivity of the MOLF is classed as low, as these structures are water compatible. Given the above information on overtopping, the magnitude of the potential hazard is determined to be medium, on the basis of overtopping that could occur over a 3-hour period (i.e. over peak of tide, as identified in appendix D8-4-3), giving a low significance of the potential effect. Since the likelihood of occurrence is classed as high, due to the 20% AEP joint probability of occurrence, the overall flood risk is determined as being moderate.

8.1.11 The low sensitivity of the MOLF notwithstanding, as detailed in the Wylfa Newydd Code of Construction Practice (Application Reference Number: 8.6) a flood mitigation action plan would be developed to ensure that in the event of flooding appropriate plans are in place to manage the risks.

8.2 Fluvial and pluvial flooding

Fluvial flood risk

8.2.2 The risk of fluvial flooding may be altered due to the construction activities within the Wylfa Newydd Development Area. Although most of the Wylfa Newydd Development Area is classed as being in Flood Zone A, being at little or no risk of fluvial flooding, there are at least four named watercourses that cross the site, with numerous other smaller watercourses, all of which could come out of bank during extreme events. The named watercourses that cross the Wylfa Newydd Development Area are Nant Caerdegog Isaf, the Afon Cafnan, Nant Porth-y-Pistyll and the Tre'r Gof drains. Hydraulic modelling has been undertaken and is reported on in appendix D8-7 (Application Reference

Number: 8.4.32). The effects of flooding to sensitive receptors during the construction phase are detailed below.

8.2.3 Only three of the five catchments have been modelled for fluvial flood risk, which are the Afon Cafnan Catchment, the Cemlyn Catchment and Cemaes Catchment. Both the Tre’r Gof Catchment and the Power Station Catchment are pluvial catchments. The baseline fluvial modelling of the Wylfa Newydd Development Area identified sites where flooding was likely at different probabilities.

8.2.4 Areas of noticeable risk of fluvial flooding are as follows:

- **Land adjacent to the Nant Caerdegog Isaf.** The new channel created by the watercourse realignment would be immediately south of the existing Nant Caerdegog Isaf within the fluvial floodplain and would involve some work being carried out within the existing channel. The downstream end of the diversion, has the highest modelled risk of flooding, while the centre and upstream end of the diversion have a lower risk of fluvial flooding.
- **Cemlyn Bay SSSI.** Cemlyn Bay SSSI is within the Cemlyn Catchment and it includes Cemlyn Lagoon, a brackish area of water that receives flows from Nant Cemlyn and a pluvial driven small road drain. The risk from Nant Cemlyn is limited to the eastern end of Cemlyn Lagoon and would be limited, as the majority of the SSSI lies within the extent of tidal flood risk identified on the TAN 15 Development Advice Maps.
- **Cemaes.** Cemaes is a village within the Cemaes Catchment and is located to the north-east of the Wylfa Newydd Development Area. Nant Cemaes flows past the west of the town prior to discharging to Cemaes Bay via a culvert. Areas that are potentially at risk are limited to those properties that border the watercourse on Ffordd Caergybi, Maes Capel and Ffordd Y Traeth.
- **Cemlyn Road.** Cemlyn Road runs from the A5025 west towards Cemlyn Bay; the road crosses both the Afon Cafnan at Pont Cafnan (grid reference 234242, 393106) and Nant Cemlyn west of Plas Cemlyn (grid reference 233395, 392806).

Baseline conditions (current fluvial flood risk)

8.2.5 The modelled baseline fluvial flood outputs at the observation lines (appendix D8-4-4) corresponding to these locations is summarised in table D8-4-8. The results show that there is already a significant risk of flooding at a number of locations.

Table D8-4-8Modelled baseline fluvial flood risk (summer) at observation lines

Receptor	Description of flooding	Maximum flood depth (m)			
		50% AEP	3.3% AEP	1% AEP	0.1% AEP
Land adjacent to the watercourse realignment	Upstream end of watercourse realignment (CAER4)	0.00	0.00	0.04	0.08
	Eastern portion of watercourse realignment (CAER9)	0.00	0.29	0.51	0.89
Eastern end of Cemlyn Lagoon	Flood depth at Nant Cemlyn where it flows into Cemlyn Lagoon (CEML7)	0.22	0.25	0.30	0.40
Cemaes Village	Nant Cemaes flood levels upstream of Cemaes village (CEMA5)	0.00	0.58	0.68	0.84
	Nant Cemaes flood level within Cemaes village (CEMA9)	0.00	0.40	0.55	0.74
Cemlyn Road	Nant Cemlyn at Cemlyn Road (CEML6)	0.41	0.70	0.79	0.93
	Afon Cafnan at Cemlyn Road (CAFN9)	0.24	0.67	0.94	1.33

Note: the designations in brackets (e.g. CAFN9) refer to nodes included in the AMEC model and have been used to assess effects at specific locations / sensitive features.

Watercourse realignment

8.2.6 There is currently minimal flood risk where the proposed watercourse realignment is proposed. In the baseline scenario at the upstream end of the proposed watercourse realignment, depths reach 0.04m and 0.08m in the 1% AEP and 0.1% AEP events respectively. Where the eastern portion of the watercourse realignment is proposed, flood depths reach 0.29m during the 3.3% AEP event, rising to 0.51m during the 1% AEP event. Fluvial flood risk is purely confined to agricultural land of medium sensitivity.

Cemlyn Lagoon

8.2.7 The flows from Nant Cemlyn outfall into Cemlyn Lagoon which is part of a SSSI with flood depths recorded at 0.22m during the 50% AEP event, rising to 0.3m during the 1% AEP event. No properties are at risk with narrow out of bank flooding confined to agricultural land.

Cemaes village

8.2.8 One of the key current fluvial flood risk areas during the 1% AEP event is in Cemaes village with fluvial flood depths reaching 0.68m upstream of Cemaes village and 0.55m within Cemaes village itself.

8.2.9 Flooding also currently occurs approximately 750m upstream of Cemaes village around the confluence of Nant Cemaes and an associated tributary during the 50% AEP onwards. The extents impact agricultural land with no other receptors considered at fluvial risk.

8.2.10 The onset of flooding immediately upstream of Cemaes village currently occurs during the 3.33% AEP event whereby north-easterly flows along Nant Cemaes back up at the culvert under Brookside Garages impacting the garages and a residential property at a depth of up to 0.58m. During the 1% event and 0.1% AEP event the flood depths increase to 0.68m and 0.84m respectively, with the extents largely confined by the A5025 to the north and Ffordd-Y-Felin to the east.

8.2.11 The flows largely remain in bank downstream of the A5025 and west of Cemaes village before discharging into Cemaes Bay, however at the outfall location there is minor overtopping of Nant Cemaes during the 3.33% AEP event or greater with flood depths reaching 0.40m. The flood depths increase to 0.55m and 0.74m in the 1% AEP and 0.1% AEP events, however the extents are narrowly confined to the surrounding rural landscape with no properties considered at fluvial risk.

Cemlyn Road

8.2.12 Afon Cafnan largely flows in a northerly direction joining with Nant Caerdegog Isaf which flows in a westerly direction upstream of Cemlyn Road. The flows pass largely through agricultural land with out of bank flooding on both banks until its outfall into Porth-y-pistyll. The key receptor is Cemlyn Road which currently shows flooding upstream of Cemlyn Road reaching depths up to 0.24m during the 50% AEP event, rising to 0.94m and 1.33m during the 1% AEP and 0.1% AEP flood events.

8.2.13 The hydraulic modelling show Cemlyn Road to be impacted during the 1% AEP. As the road lies approximately 0.75m above Afon Cafnan, the depth on the road is less than 0.3m which allows safe passage of vehicles. Downstream flows extend out of bank, however there are no receptors at risk other than agricultural land.

8.2.14 Nant Cemlyn flows in a northerly direction and joins with Nant Plas Cemlyn flowing in an easterly direction immediately upstream of Cemlyn Road, located approximately 1000m to the west of the minor impacts associated with Afon Cafnan. The local topography is flat with the watercourses situated just below road level. The combined flows therefore overtop as early as the 50% AEP event impacting Cemlyn Road at a flood depth up to 0.41m, rising to 0.79m during the 1% AEP event. No properties are at risk with any out of bank flooding confined to agricultural land.

8.2.15 These baseline results can be compared to the results of the modelling of the Wylfa Newydd Development Area during reference point 4, the construction phase. The results are mapped in appendix D8-4-5 and the resultant flood depths for key locations are provided in table D8-4-9.

Wylfa Newydd Development Area

8.2.16 All construction works within the Wylfa Newydd Development Area are considered to have a medium sensitivity to fluvial flood risk. Where the construction works lie in areas shown to be at risk in the modelled 0.1% AEP event, the magnitude of the hazard is assessed as high, by virtue of the duration and potential depth of flooding, and the significance of effect is therefore considered to be moderate. The likelihood of flooding in these areas is medium, therefore, the overall risk from this source is considered moderate.

Flood conditions predicted during construction

8.2.17 It can be seen by the modelling results presented in table D8-4-9, that there is either a small increase or no increase in flood depths simulated at every location selected during the construction phase, when compared to the baseline. At the 1% AEP event all increases in flood depth are below 0.14m. For this level of flood risk the magnitude of the potential effect is classed as medium, as it is a measureable increase in flood depth (appendix D8-4-2, table D8-4-20). Despite these increases, there is little difference to the flood extents on the Nant Cemaes at Cemaes village shown on the figures in appendix D8-4-5. Similarly the flood extents at Cemlyn Road from both the Nant Cemlyn and Afon Cafnan have not changed significantly, as shown on the figures in appendix D8-4-5.

Table D8-4-9 Modelled phase 4 fluvial flood risk (summer) at observation lines

Receptor	Description of flooding	Maximum flood depth (m)			
		50% AEP	3.3% AEP	1% AEP	0.1% AEP
Land adjacent to the watercourse realignment	Upstream end of watercourse realignment (CAER4)	0.00 (0.00)	0.08 (+0.08)	0.10 (+0.06)	0.15 (+0.07)
	Eastern portion of watercourse realignment (CAER9)	0.00 (0.00)	0.33 (+0.04)	0.54 (+0.03)	0.95 (+0.06)
Eastern end of Cemlyn Lagoon	Flood depth at Nant Cemlyn where it flows into Cemlyn Lagoon (CEML7)	0.24 (+0.02)	0.28 (+0.03)	0.32 (+0.02)	0.40 (0.00)
Cemaes Village	Nant Cemaes flood levels upstream of Cemaes village (CEMA5)	0.00 (0.00)	0.62 (+0.04)	0.72 (+0.04)	0.87 (+0.03)
	Nant Cemaes flood level within Cemaes village (CEMA9)	0.00 (0.00)	0.41 (+0.01)	0.55 (0.00)	0.74 (0.00)
Cemlyn Road	Nant Cemlyn at Cemlyn Road (CEML6)	0.54 (+0.13)	0.74 (+0.04)	0.81 (+0.02)	0.94 (+0.01)
	Afon Cafnan at Cemlyn Road (CAFN9)	0.34 (+0.10)	0.84 (+0.17)	1.08 (+0.14)	1.39 (+0.06)

* The values in brackets are the change in flood depth relative to the baseline case for the scenario considered. Otherwise maximum flood depths.

Watercourse realignment

8.2.18 The difference between the baseline and the construction phase at the watercourse realignment along Nant Caerdegog Isaf is a minor reduction in the flood extents upstream on the right bank of the watercourse, approximately 100m north-east of Cae Gwyn SSSI. The increase in flood depth due to the construction of the Power Station is small at between 0.03m and 0.06m, which is considered to have a medium magnitude of hazard. The sensitivity of the land adjacent to the watercourse diversion is classed as medium at the construction stage, as the land is considered an employment area due to the activities taking place. This medium sensitivity and medium magnitude of hazard results in a moderate magnitude of effect, which combined with a medium likelihood of occurrence indicates a moderate flood risk. However, the moderate flood risk only applies where there is construction activity in this area, as this is limited and of short duration no additional mitigation is required.

Cemlyn Lagoon

8.2.19 The eastern end of Cemlyn Lagoon has a medium sensitivity as it is part of a SSSI. At the discharge point of the Nant Cemlyn into the lagoon the flood depth is predicted to be 0.32m, which based on the approach described in appendix D8-4-2 is a medium magnitude of hazard and would result in a moderate significance of effect. The likelihood of occurrence is medium which indicates a moderate flood risk. As the increase in flood level due to construction of the Power Station is small (0.02m for the 1%) on Nant Cemlyn and because Cemlyn Lagoon is large in comparison to the flood depth, the potential magnitude of change and risk to the lagoon can be considered low which indicates a low significance of effect. With a likelihood of occurrence of medium this yields a low impact on flood risk.

Cemaes village

8.2.1 There is a 0.04m increase in flood depth upstream of Cemaes village during the 1% AEP events where Brookside Garages and a residential property are located. This change in flood depth is considered to have a medium magnitude of potential hazard. Given the very high sensitivity of the receptor to flood risk the significance of effect is considered to be high. The high likelihood of effect results in a high overall impact on flood risk and additional mitigation would be needed.

8.2.2 There is no change in flood depth downstream within Cemaes village in this event where a depth of flooding of 0.55m is predicted (as per the baseline scenario), though a 0.01m increase is noted in a 3.33% AEP event. The flood risk in this area is not considered significant as the extents are restricted to the edge of Cemaes Bay and do not impact any properties. Whilst properties have a very high sensitivity of the receptor to flood risk the sensitivity of gardens and undeveloped land is arguably lower and no greater than medium. Following the approach described in appendix D8-4-2, no change in flood severity in the 1% AEP event is considered to have a negligible magnitude of hazard, which with a medium sensitivity receptor results in a negligible significance of potential effect. The 0.01m increase in the 3.33% AEP event is, however, considered to have a medium magnitude of hazard, which with a medium sensitivity receptor results in a moderate significance of potential effect. The likelihood of flooding is assessed as medium, the impact on flood risk would therefore be moderate in the worst-case. Additional mitigation measures to address the increased risk upstream of Cemaes Village would also benefit this area.

Cemlyn Road

8.2.3 The potential increase in flood depth where Cemlyn Road crosses the Nant Cemlyn (and which is due to construction of the Power Station) is predicted to be 0.02m (absolute flood depth of 0.81m) during the 1% AEP event, although the maximum flood depth is located upstream of Cemlyn Road rather than at the road itself. The change in flood depth along Cemlyn Road is considered to have a medium magnitude of potential flood hazard, as the depth is a measureable increase to an offsite receptor. With Cemlyn Road considered very high sensitivity, as it is an access route, the significance of the effect is considered high. The medium likelihood of effect results in a high overall impact on flood risk and additional mitigation would be needed.

8.2.4 The increase in flood depth of 0.14m during the 1% AEP event (0.17m in the 3.33% AEP event) upstream of Cemlyn Road on the Afon Cafnan is caused by Mounds D and E reducing the amount of land available for flood storage and from backing up of the flows behind the culvert under Cemlyn Road, spilling over the road and into Porth-y-pistyll. The road at this crossing location is at a higher elevation than the watercourse, however, shallow flooding of the road of up to 0.10m is indicated to the east and west of the crossing itself. Increases of up to 0.17m in the depth of flooding on the road would remain below 0.3m hence passage would continue to be possible.

8.2.5 Cemlyn Road has a very high sensitivity, which combined with a medium magnitude of hazard indicates a high significance of effect. With a likelihood of occurrence of medium this yields a high impact on flood risk. Despite the classification of the impact on flood risk as high, after the granting of DCO the property at Cafnan, that is accessed by Cemlyn Road at this point, would become owned by Horizon and it would also be unoccupied during the construction period. Use of the road and therefore exposure to this increased risk is therefore expected to be significantly reduced. No additional mitigation measures are therefore proposed.

Cemlyn Road (temporary diversion of Mound E runoff)

8.2.6 The results detailed above exclude the effect of temporarily diverting flows from the western side of Mound E to the Afon Cafnan (see appendix D8-8 (Application Reference Number: 6.4.33) for details of the temporary diversion). Currently the location for the temporary discharge along the Afon Cafnan has not been selected. It may be at point E2 where the discharge from the eastern side of Mound E would be discharged, or it may be further downstream.

8.2.7 Although the assessments above exclude the effects of the temporary diversion, Amec Foster Wheeler did complete a sensitivity run as part of the hydraulic modelling for the Wylfa Newydd Development Area (section 7.5 and figure 7.2 in appendix D8-7 (Application Reference Number: 6.4.32)). This indicated that if the discharge was diverted from the Nant Cemlyn to the Afon Cafnan at outfall E2 (upstream of the Cemlyn Road) it would result in an increase in stream level at Cemlyn Road (model point CAFN9) of between 0.03m and 0.07m, depending whether the 1:100 or 1:30 year AEP is assessed. Downstream of Cemlyn Road (at model point CAFN11) the modelled effect is predicted as 0.01m and 0.03m for the 1:100 and 1:30 year AEP respectively. On the Nant Cemlyn at CEML6, the stream level would reduce by 0.03m for both the 1:30 year AEP and 1:100 year AEP.

8.2.8 The sizing of the attenuation pond would be reviewed at detailed design and may be increased to provide a higher level of attenuation of flows to the Afon Cafnan. In addition, currently the discharge location to the Afon Cafnan has not been identified, but it may be downstream of the Cemlyn Road in order to avoid the above effect which would be caused by backing up behind the culvert under the road, although any flood risk below the culvert would also need to be assessed, and could necessitate an increase in attenuation pond size.

8.2.9 Once working on the western side of Mound E is complete and the land vegetated such that there would be no further risk of sediment runoff, the water would be routed back to the Nant Cemlyn. This would take place at some point during the construction programme.

Wylfa Newydd Development Area

8.2.10 Construction works within the Wylfa Newydd Development Area are considered to have a medium sensitivity to fluvial flood risk. Where the construction works lie in areas shown to be at risk in the modelled 0.1% AEP event, the magnitude of the hazard is assessed as high, by virtue of the duration and potential depth of flooding, and the significance of effect is therefore considered to be moderate. The likelihood of flooding in these areas is medium, therefore, the overall impact on flood risk from this source is considered moderate.

Pluvial flood risk due to landscape mound construction

8.2.11 The drainage design for the landscape mounds is detailed in the drainage strategy (appendix D8-8 (Application Reference Number: 6.4.33)) and summarised here. The drainage design has been developed to ensure the surface water flow from landscaped areas outside the Power Station platform would not impact on the Power Station platform itself. The drainage strategy would manage surface water runoff and provide natural treatment of water flow through the use of Sustainable Drainage Systems (SuDS). SuDS work by mimicking the natural drainage system and provide a method of surface water drainage which can decrease the peak rate of surface water runoff, and hence reduce the risk of flooding. It is proposed that the surface water runoff would be collected using open ditches and swales where possible. The drainage design would be updated throughout the initial phases of the project, in order to mitigate any of the effects that have been identified in the Environmental Statement Chapter D8 (Application Reference Number: 6.4.8).

8.2.12 Using open ditch gravity systems would provide flexible and low maintenance solutions for the site surface water drainage management. Where swales can be used they would be constructed with a French drain below to improve silt capture efficiency and capacity.

8.2.13 There are known wells, springs and seeps below or to the west of Mound A, flow from which could be altered by construction of the mound. To try to minimise the potential effect on these, a drainage blanket would be placed across the base of Mound A. This would be used to capture any overflow from areas of restricted surface water drainage that occur around the southern perimeter of Mound A and to encourage seepage of water into the ground to the west of the mound in order to try to replicate baseline conditions.

8.2.14 Mound B surface water drainage would be provided by means of ditches and a piped section is proposed under the Simulator building area. The majority of surface water runoff from Mound B would drain to the north and swales and a settlement pond are proposed for removal of the increased suspended solids.

Runoff from Mound B would be discharged into the western end of Tre'r Gof SSSI via an existing drain.

8.2.15 Surface water from Mounds D and E would be drained by means of ditches. which would largely be permanent and would also provide the drainage for the mound. However, there are areas where the drainage ditch would need to be relocated. The treatment pond would be positioned and sized to support construction and operation of the Power Station. Surface water runoff from Mound D would be discharged to the Afon Cafnan to the west. A minimum 15 metres easement would be maintained from the river edge to allow for maintenance access.

8.2.16 Surface water runoff from the western side of Mound E would discharge into the Nant Cemlyn and the eastern and northern side into the Afon Cafnan. To maintain water quality a settlement pond and treatment facility would be constructed prior to water discharge to the adjacent watercourses. Reeds and natural habitat would be planted within the settlement pond and swales to improve visual amenity and improve water quality.

Baseline conditions (current pluvial flood risk)

8.2.17 The pluvial modelled depths of surface water for the baseline are mapped in appendix D8-4-6 and results at key locations are provided in table D8-4-10. The results show that there is already a significant risk of flooding at a number of locations.

Table D8-4-10 Modelled baseline pluvial flood risk (summer)

Receptor	Description of flooding	Maximum flood depth (m)			
		50% AEP	3.3% AEP	1% AEP	0.1% AEP
Land adjacent to the watercourse realignment	Upstream end of watercourse realignment (CAER4)	0.03	0.04	0.06	0.10
	Eastern portion of watercourse realignment (CAER9)	0.18	0.23	0.26	0.50
Eastern end of Cemlyn Lagoon	Flood depth at Nant Cemlyn where it flows into Cemlyn Lagoon (CEML7)	0.22	0.26	0.32	0.45
Cemaes Village	Nant Cemaes flood levels upstream of Cemaes village (CEMA5)	0.12	0.21	0.48	0.66
	Nant Cemaes flood level within Cemaes village (CEMA9)	0.08	0.52	0.64	0.83
Cemlyn Road	Nant Cemlyn at Cemlyn Road (CEML6)	0.25	0.68	0.79	0.98
	Afon Cafnan at Cemlyn Road (CAFN9)	0.09	0.20	0.41	0.78

Watercourse realignment

8.2.1 There is minimal flood risk at the upstream end of the proposed watercourse realignment with depths reaching 0.06m during the 1% AEP event. The location where the eastern portion of the watercourse realignment is proposed shows flood depths of up to 0.26m during the 1% AEP event. In the baseline scenario (without the watercourse realignment in place) there is only risk to agricultural land with no risk to other receptors.

Cemlyn Lagoon

8.2.2 The flows from Nant Cemlyn outfall into Cemlyn Lagoon which is part of a SSSI with flood depths recorded at 0.22m during the 50% AEP event, rising to 0.48m during the 1% AEP event. No properties are at risk with narrow out of bank flooding confined to agricultural land.

Cemaes village

8.2.3 One of the key risk areas during the 1% AEP event is Cemaes village with surface water flood depths reaching 0.48m upstream of Cemaes village, and 0.64m within Cemaes village.

8.2.4 Upstream of Cemaes village there are three surface water flowpaths, two of which are attributable to Nant Cemaes and its associated tributary. However, one minor surface water flowpath exists during the 50% AEP event, water in which flows in a north westerly direction, starting 350m south-east of the crossing between Nant Cemaes and the A5025. The flowpath follows topographic low points, typically field boundaries where there are existing drainage ditches and ponds near the culvert inlet under the A5025, impacting Brookside Garages and a nearby residential property which are situated in a topographic depression. At the crossing where the surface water flows converge, flood depths reach 0.12m during the 50% AEP event, rising to 0.48m during the 1% AEP event. Surface water flowpaths north of A5025 do not impact this location as the topography directs surface water flows away from the road.

8.2.5 With the land to the west of Cemaes sloping in an easterly direction downstream of the A5025, three surface water flowpaths feed into Nant Cemaes however the flood depths associated with these flows are largely <0.05m up to the 0.1% AEP event and are therefore unlikely to have a significant influence on the flows and existing risk in Cemaes village. The maximum flood depth during the 1% AEP is 0.64m located at the culvert inlet under Ffordd-Y-Traeth, however this is highly localised and with no properties at risk.

Cemlyn Road

8.2.6 The modelled surface water flows along Cemlyn Road are largely attributable to Afon Cafnan, Nant Cemlyn and associated tributaries with pockets of surface water ponding in excess of 0.25m matching the fluvial flood extents. This suggests these areas are natural floodplains and locations where surface water flows accumulate in the topographical low points. The maximum flood depths reach 0.09m during the 50% AEP event, rising to 0.41m during the 1% AEP attributable to the Afon Cafnan. The maximum flood depths reach 0.25m during the 50% AEP event, rising to 0.79m during the 1% AEP attributable to the Nant Cemlyn.

8.2.7 Numerous minor flowpaths (<0.05m in depth) feed into both watercourses from both banks during the 50% AEP event or greater, however these are unlikely to have a significant influence on the watercourse or on any nearby receptors.

8.2.8 Surface water flows downstream of Cemlyn Road are typically <0.05m in depth and flow into Cemlyn Lagoon. The maximum flood depth is 0.32m during the 1% AEP event which is highly localised and outside the SSSI.

Flood conditions predicted during construction

8.2.9 The baseline results can be compared to the results of the modelling of the Wylfa Newydd Development Area during Phase 4, the construction phase. The results are mapped in appendix D8-4-7 and the resultant flood depths for key locations are provided in table D8-4-11.

8.2.10 During the construction phase the pluvial modelling results show a decrease in the depth of flooding at four of the key locations selected during the 1% AEP event, at the eastern point of the watercourse realignment, the outfall of Nant Cemlyn to Cemlyn Bay, Nant Cemlyn at Cemlyn Road and Nant Cemaes flood level within Cemaes village all show at least a 0.01m decrease in water depth at the 1% AEP event. The biggest reduction at this event is 0.07m at Cemaes Village.

8.2.11 There is an increase in flood levels predicted for the upstream end of the watercourse realignment, Nant Cemaes upstream of Cemaes village and the Afon Cafnan at Cemlyn Road. These all show an increase of approximately 0.04-0.05m in the 1% AEP event, excluding the Afon Cafnan which records the highest increase at 0.12m. Upstream of Cemaes village, on the south side of Ffordd Caergybi, there are properties that are shown to be at risk from flooding during the 50% AEP event and which are simulated to experience a slight increase in flood risk. These changes are all discussed further below.

Table D8-4-11 Modelled phase 4 pluvial flood risk at observation lines

Receptor	Description of flooding	Maximum flood depth (m)			
		50% AEP	3.3% AEP	1% AEP	0.1% AEP
Land at the watercourse realignment	Upstream end of watercourse realignment (CAER4)	0.04 (+0.01)	0.07 (+0.03)	0.10 (+0.04)	0.21 (+0.11)
	Eastern portion of watercourse realignment (CAER9)	0.18 (0.00)	0.22 (-0.01)	0.25 (-0.01)	0.52 (+0.02)
Eastern end of Cemlyn Lagoon	Flood depth at Nant Cemlyn where it flows into Cemlyn Lagoon (CEML7)	0.24 (+0.02)	0.27 (+0.01)	0.30 (-0.02)	0.43 (-0.02)
Cemaes Village	Nant Cemaes flood levels upstream of Cemaes village (CEMA5)	0.13 (+0.01)	0.28 (+0.07)	0.53 (+0.05)	0.70 (+0.04)
	Nant Cemaes flood level within Cemaes village (CEMA9)	0.06 (-0.02)	0.43 (-0.09)	0.57 (-0.07)	0.85 (-0.02)
Cemlyn Road	Nant Cemlyn at Cemlyn Road (CEML6)	0.37 (+0.12)	0.65 (-0.03)	0.76 (-0.03)	0.97 (-0.01)
	Afon Cafnan at Cemlyn Road (CAFN9)	0.11 (+0.02)	0.32 (+0.12)	0.53 (+0.12)	0.92 (+0.14)

Watercourse realignment

8.2.12 The upstream end of the watercourse realignment shows an increase in flood depth of 0.04m, although this reduces to -0.01m at the downstream end of the section. The sensitivity of the land adjacent to the watercourse diversion is classed as medium at the construction stage, as the land is considered an employment area due to the activities taking place. This medium sensitivity and medium magnitude of hazard results in a moderate magnitude of effect, which combined with a medium likelihood of occurrence indicates a moderate flood risk. However, the moderate flood risk only applies where there is construction activity in this area, as this is limited and of short duration no additional mitigation is required.

Cemlyn Lagoon

8.2.13 The eastern end of Cemlyn Lagoon has a medium sensitivity, and the flood depth at 1% AEP is 0.30m. However, there is a 0.02m reduction in flood risk due to the construction of the Power Station which is a negligible magnitude beneficial change and indicates a negligible significance of effect. With a likelihood of occurrence of high (despite the embedded mitigation that includes an attenuation pond in the Mound E drainage system) this yields a negligible impact on flood risk.

Cemaes village

8.2.14 There would be an increase in the size of the Cemaes Catchment with the construction of Mounds A and B of 15.23ha (5%). This would produce additional runoff towards Cemaes village, however these flows would be captured by the proposed drainage system during the construction phase and directed to three attenuation ponds controlling discharge into Port Wylfa, Cemaes Bay and Foel Fawr.

8.2.15 During construction the flood depths are predicted to increase by 0.05m upstream of Cemaes village during the 1% AEP event, however there is a reduction of 0.07m downstream at Cemaes village. The flood extents remain largely the same in the construction phase compared to the baseline case. The design of the mound directs a large percentage of the surface water towards the toe drainage downstream of CEMA5, that would otherwise flow into Nant Cemaes thereby reducing the flood depths downstream. The small south-eastern section of the mound that extend out towards the A5025 does not contain any toe drainage which could account for the minor increase in flood depth.

8.2.16 The area upstream of Cemaes village, on the south side of Ffordd Caergybi, is considered to have a very high sensitivity to flood risk as it contains off-site built developments. The magnitude of the hazard is assessed as medium, due to the potential increase in flood depth of 0.05m, and the significance of effect is therefore considered to be high. The likelihood of flooding in these areas is high, therefore, the overall impact on flood risk from this source is considered high and additional mitigation would be needed.

8.2.17 Cemaes village downstream has a reduction in flood depth of 0.07m during the 1% AEP event. Properties in Cemaes village is considered to have a very high sensitivity, however, gardens and undeveloped land are considered to have a medium sensitivity. With a negligible magnitude of change based on the depth reduction, this indicates a negligible significance of effect of the construction of the Power Station. With a medium likelihood of occurrence, due to the potential interaction with Cemaes upstream, this yields a negligible impact on flood risk.

Cemlyn Road

8.2.18 There would be a reduction in the size of the contributing catchment for Afon Cafnan of 85.79ha (8.6% of the existing catchment area), with surface water directed into Afon Cafnan during construction. However, Mounds D and E reduce the land available for floodplain storage upstream of the Cemlyn Road. Furthermore, during construction the exposed steeper surfaces of Mounds D and E would produce increased runoff. Consequently, the flood depths increase by up to 0.12m during the 1% AEP event increasing the surface water flood risk.

8.2.19 Cemlyn Road here has a very high sensitivity, which combined with a medium magnitude of hazard indicates a high significance of effect. With a likelihood of occurrence of medium this yields a high impact on flood risk. Despite the classification of the impact on flood risk as high, after the granting of DCO the property at Cafnan that is accessed by Cemlyn Road at this point would become owned by Horizon and it would also be unoccupied during the construction period. Use of the road and therefore exposure to this increased risk is therefore expected to be significantly reduced. No additional mitigation measures are therefore proposed.

8.2.20 There would be a minor increase in the Nant Cemlyn Catchment with the surface water runoff coming from Mound E. Flood depths are expected to reduce by 0.03m and 0.01m along Cemlyn Road during the 1% AEP and 0.1% AEP events respectively due to the drainage associated with Mound E during construction. Flood depths also reduce by 0.02m downstream at Nant Cemaes outfall.

8.2.21 Based on the approach described in appendix D8-4-2, the flood depth along Cemlyn Road at Nant Cemlyn is considered to have a negligible magnitude of potential flood hazard as there is a 0.03m reduction in flood depth. The significance of the effect is considered negligible as a result and with a medium likelihood of effect the overall impact on flood risk is considered to be negligible flood risk.

Cemlyn Road (temporary diversion of Mound E runoff)

8.2.22 The sensitivity assessment shows that the pluvial results are similar to the fluvial results, and predict a 0.07m and 0.06m increase at CAFN9 for the 1:30 year AEP and 1:100 year AEP respectively. Downstream on the Afon Cafnan at CAFN11 the increase is 0.02m and 0.03m respectively. On the Nant Cemlyn at CEML6, the stream level would reduce by 0.04m and 0.03m for the 1:30 year AEP and 1:100 year AEP respectively.

Wylfa Newydd Development Area

8.2.23 Construction activities within the Wylfa Newydd Development Area are considered to have a medium sensitivity to pluvial flood risk during construction. The magnitude of the hazard is assessed as low, by virtue of the short duration and shallow depth of surface water flooding, and the significance of effect is therefore considered to be low. The likelihood of flooding is medium, therefore, the overall impact on flood risk from this source is considered low.

Fluvial and pluvial flood risk due to decreased permeable area

8.2.24 An aspect of the Power Station construction of concern to flood risk is the increase in impermeable area associated with site establishment, haul roads, tracks and laydown areas. The potential impact of each is described below.

- Main Site Compound – the majority of the compound would be permeable, therefore not increasing the fluvial flood risk within each watercourse. In the event of the drainage being exceeded above 3.33% AEP storm event (medium probability) any water would discharge via the surface water flow pathway and swale to Porth-y-pistyll with no increases in fluvial or pluvial flooding to off-site receptors.

- Satellite compounds – the satellite compounds would be permeable or constructed on existing hardstanding, therefore there would be no increase in impermeable area and no potential impact on fluvial or pluvial flood risk.
- Haul roads – these would be semi-permeable with active drainage, which would drain to watercourses and the sea via the drainage network. The drainage network would be designed to prevent increases in flow up to the 3.33% AEP event. In the event of a larger event occurring, the potential hazard, magnitude and overall risk would be low. Given that the haul roads would be partially permeable, resulting in a negligible impact on pluvial flow in relation to the soil compaction, the impact off-site is assessed as negligible.
- Tracks – these would be constructed from permeable material and therefore there would be no increase in impermeable area and no potential impact on pluvial or fluvial flood risk.
- Laydown areas – these would be located on existing hardstanding or would be underlain by permeable hardcore, with no potential to increase impermeable area. Where the areas for Mounds B and D are firstly used as laydown areas, drainage ditches would be installed to capture surface water runoff and discharge it to a designated outfall.

8.2.25 Overall the potential increases in impermeable area would have negligible impact on pluvial and fluvial flooding to construction activities in the Wylfa Newydd Development Area or to all off-site receptors. The magnitude of hazard is therefore assessed as negligible, as is the significance of effect and overall impact on flood risk.

Fluvial flood risk due to water vole fencing

8.2.26 Water vole fencing is to be in place for approximately 3 months across the reach of the Nant Caerdegog Isaf to be diverted. The installation of this fencing would likely be subject to an environmental permit; therefore, any impacts are likely to be identified and managed through this process. The water vole fencing would be checked regularly as part of the works and any debris would be cleared. In the unlikely event of a flood event with debris causing flooding, the effects would be localised to the floodplain upstream, without any impact on the built environment.

8.2.27 The potential receptors include land adjacent to the watercourse diversion and off-site receptors. In light of the anticipated negligible magnitude of hazard, the significance of effect and overall impact on flood risk is also considered negligible.

Changes in pluvial and fluvial flood water conveyance due to fencing

8.2.28 The boundary fences have not been modelled as part of the Infoworks flood model as the detailed design of these fences has not been completed. The boundary fence does not cross any watercourses, however it is located within the floodplain of the Afon Cafnan and potentially other watercourses. In the event of a flood it is unlikely that that fencing would result in any constriction of flood water, given the porous nature of the fencing. However, boundary fences could block and divert overland flow routes should debris build up in front of the fences. The specification of the fences should be considered at detailed design and take into account the potential for blockages. For all security fences maintenance would form part of operational procedures as this would be critical to operational requirements.

8.2.29 Potential receptors to flooding associated with the fences include construction activities within the Wylfa Newydd Development Area and off-site receptors. With a regular inspection regime, and with appropriate design of fences and plinths to ensure that free water movement is allowed during periods of heavy rainfall, there would be a negligible magnitude of hazard. The significance of effect and overall impact on flood risk is also considered negligible.

8.3 Groundwater

Groundwater emergence at surface

8.3.2 The rapid groundwater level response to rainfall and slow recession are likely to reflect the low effective storage and low transmissivity in the aquifer system(s) beneath the study area. Based on these hydrogeological conditions, any shallow groundwater beneath the study area is unlikely to occur in great enough quantities to cause significant groundwater flooding. When groundwater levels (in response to high rainfall) are significantly above average, it is likely these would be contemporaneous with high surface water flows and saturated ground conditions. There is therefore the potential for some localised groundwater flow through springs appearing in low-lying areas across the Wylfa Newydd Development Area.

8.3.3 The Wylfa Newydd Development Area site would incorporate a construction drainage network that would intercept shallow groundwater flows and prevent any significant flows or ponding on site. These drainage systems would be designed to manage very high volumes of runoff associated with pluvial events, and any additional influx from groundwater would not be significant in terms of flood risk. Therefore, the magnitude of effect associated with groundwater flood risk is very low.

8.3.4 There are a number of springs across the landscaped areas, however they are all small and many of them cease to flow during the drier summer months. The majority of these occur along existing drains and watercourses within the 15m buffer zone and as such would not come into contact with construction activities. If groundwater were expressed in other low areas, flows would be intercepted by the drainage network or would run directly to a water feature and is unlikely to result in significant harm. Given this, the magnitude of effect associated with groundwater emergence in the landscaped areas has been assessed as very low.

8.3.5 There is the potential for perched groundwater to be intercepted in the platform levelling and cause groundwater flow onto the Power Station platform. This would be intercepted by the construction drainage network, which would include an interception trench around the boundary of the Power Station platform that would cause any groundwater flows to be discharged to sea. Given this, the magnitude of effect associated with groundwater impact upon the Power Station platform due to levelling has been assessed as very low.

8.3.6 Given the medium sensitivity of the construction works as a receptor within the Wylfa Newydd Development Area, the overall significance of effect is considered to be very low and therefore the risk from this source is considered very low based on a low likelihood of occurrence during construction.

Groundwater risks due to dewatering

8.3.7 The construction of the Power Station would involve deep excavations for two reactor units, to depths of 30m to 40m below ground level and groundwater would be encountered during the construction. A pumped dewatering regime would dewater the excavations (detailed in chapter D8 (Application Reference Number: 6.4.8)) and the excavation walls would be shotcreted (i.e. sprayed with liquid concrete) to reduce groundwater inflow further reducing the risk of groundwater flooding. The sensitivity of the receptor (area of work) would be medium, whilst the magnitude of the potential hazard would be very low as any flooding would not affect the built development. This results in a very low significance of effect, which combined with a low likelihood of occurrence would result in a very low flood risk.

8.3.8 The groundwater pumped from the excavations would be pumped to a sedimentation pond to be treated prior to being discharged to the sea at Porth-y-pistyll. This would not increase the flood risk off-site, therefore, the risk of the pumped groundwater to all off-site receptors is negligible with the resulting significance of effect and flood risk from this source also considered negligible.

8.4 Services

Sewerage

8.4.2 There are no surface water sewers across the entire Wylfa Newydd Development Area, although there are sewers beneath the Existing Power Station. In the event of the surface water sewers surcharging south of the Existing Power Station, water would be shallow and discharge west to Porth-y-pistyll. With a worst-case medium likelihood and low magnitude of hazard, the significance of effect and overall flood risk to construction receptors within the Wylfa Newydd Development Area from surface water sewers is assessed as low.

8.4.3 Foul water sewers are located adjacent to Cemaes Stream and to the north of the Tre'r Gof SSSI. In the event of the sewers becoming either blocked or surcharging, there is likely to be a limited volume of water reaching the surface. This water is likely to discharge directly into either Nant Cemaes, the Tre'r Gof SSSI basin or direct to the sea. With a worst-case medium likelihood and low magnitude of hazard, the significance of effect and overall flood risk is assessed as low.

8.4.4 There is no potential for either of these sources of flooding to impact upon the construction works within the Wylfa Newydd Development Area. Any flows near the landscape mounds would be intercepted by the construction drainage channels without any impact upon construction areas. With a medium sensitivity of receptor and low magnitude of hazard, the significance of effect is assessed as low. Combined with a medium likelihood of occurrence this would result in an overall flood risk of low.

8.4.5 The IACC preliminary flood risk assessment [RD9] does not include any records of sewer flooding in the vicinity of the Wylfa Newydd Development Area.

Water supply systems

8.4.6 It is considered that the design of the water supply network for construction would be sufficient to transport the flows of water required without surcharging. If there is any failure it would likely be of short duration whilst the failure is addressed. This new infrastructure would be designed to be serviceable for the duration of construction and then the lifetime of the Power Station. In the event of failure this could affect construction activities within the Wylfa Newydd Development Area, a medium sensitivity receptor. The magnitude of the hazard is assessed as low and therefore the significance of effect would be low. The likelihood of occurrence is also assessed as low resulting in an overall low risk from this source.

8.5 Construction phase flood risks

8.5.1 The probability and severity of each type of flooding has been assessed in line with the methodology and guidance set out in appendix D8-4-2. This is then combined with the assessment of receptor sensitivity to define the level of flood risk on a scale ranging from negligible to high. The risk assessment for each receptor is contained in table D8-4-12.

8.5.2 Typically, risks assessed to be low or less are acceptable whereas risks assessed to be moderate or high require additional mitigation or management to enable development to proceed.

Table D8-4-12 Construction phase flood risk

Flood type	Source	Pathway	Receptor	Sensitivity	Magnitude of potential hazard	Significance of potential effect	Likelihood of occurrence	Flood risk
Tidal	Irish Sea	Storm surge, spring tide and wave overtopping causing overland flooding	Construction activities within Wylfa Newydd Development Area	Medium	Very low	Very low	Medium	Low
			MOLF (onshore)	Low	Medium	Low	High	Moderate
Fluvial and pluvial	Fluvial	Increased risk of fluvial flooding due to the construction activities altering infiltration capacity, evapotranspiration, in-channel changes and changes to drainage paths and catchment areas.	Land adjacent to watercourse realignment	Medium	Medium	Moderate	Medium	Moderate
			Eastern end of Cemlyn Lagoon	Medium	Medium	Low	Medium	Low
			Property upstream Cemaes village	Very high	High	High	Medium	High
			Property in Cemaes Village	Very high	Medium	High	Medium	High
			Cemlyn Road at Afon Cafnan	Very high	High	High	Medium	High
				Based on professional judgement high risk is reduced to:				Low*
			Cemlyn Road at Nant Cemlyn	Very high	Medium	High	Medium	High
			Construction activities within Wylfa Newydd Development Area	Medium	High	Moderate	Medium	Moderate

Flood type	Source	Pathway	Receptor	Sensitivity	Magnitude of potential hazard	Significance of potential effect	Likelihood of occurrence	Flood risk
Fluvial and pluvial	Pluvial	Increases in surface water runoff due to compaction of surfaces and changes to catchments	Land adjacent to watercourse realignment	Medium	Low	Low	Medium	Low
			Eastern end of Cemlyn Lagoon	Medium	Negligible	Negligible	High	Negligible
			Property upstream of Cemaes village	Very high	Medium	High	High	High
			Property in Cemaes Village	Very high	Negligible	Negligible	Medium	Negligible
			Cemlyn Road at Afon Cafnan	Very high	Medium	High	Medium	High
				Flood risk reduced from high to low based on professional judgement				Low*
			Cemlyn Road at Nant Cemlyn	Very high	Negligible	Negligible	Medium	Negligible
			Construction activities within Wylfa Newydd Development Area	Medium	Low	Low	Medium	Low

Flood type	Source	Pathway	Receptor	Sensitivity	Magnitude of potential hazard	Significance of potential effect	Likelihood of occurrence	Flood risk
Fluvial and pluvial	Pluvial	Potential increases in flooding due to decreased permeable area from site development, haul roads, security tracks, laydown areas.	All off-site receptors	Very high	Negligible	Negligible	Low	Negligible
			Construction activities within Wylfa Newydd Development Area	Medium	Negligible	Negligible	Low	Negligible
		Changes in drainage paths and flood conveyance due to fencing	All off-site receptors	Very high	Negligible	Negligible	Low	Negligible
			Construction activities within Wylfa Newydd Development Area	Medium	Negligible	Negligible	Low	Negligible
		In-channel water vole fencing across Nant Caerdegog Isaf causing fluvial flooding	All off-site receptors	Very high	Negligible	Negligible	Low	Negligible
			Land adjacent to watercourse realignment	Medium	Negligible	Negligible	Low	Negligible

Flood type	Source	Pathway	Receptor	Sensitivity	Magnitude of potential hazard	Significance of potential effect	Likelihood of occurrence	Flood risk
Groundwater	Groundwater	Groundwater flooding expressed at surface	Construction activities within Wylfa Newydd Development Area	Medium	Very low	Very low	Low	Very low
		Groundwater flooding due to dewatering discharge	Excavation (construction site)	Medium	Very low	Very low	Low	Very low
			Off-site receptors (Sea)	Low	Negligible	Negligible	Low	Negligible
Services	Sewerage network	Surcharge, blockage or failure of existing sewers	Construction activities within Wylfa Newydd Development Area	Medium	Low	Low	Medium	Low
	Mains water supply	Surcharge or failure of mains supply	Construction activities within Wylfa Newydd Development Area	Medium	Low	Low	Low	Low

*Areas where the approach in appendix D8-4-2 suggests a higher overall flood risk than that stated. Evidence has been provided that shows that the flood risk is low and that further mitigation is not required.

9 Wylfa Newydd Development Area operational phase flood risk assessment

9.1 Tidal flooding

9.1.1 Given that the risk posed to the operational site needs to be considered through until the eventual end of decommissioning, the tidal flooding levels given for 2187 should be taken as the maximum sea levels to affect the operational site. These maximum sea levels are combined astronomical tide and surge levels for 0.1% AEP and 0.01% AEP flood events. These estimated extreme sea levels (excluding wave action) are:

- 9.30m AOD for a maximum climate change scenario (0.1% AEP event); and
- 9.47m AOD for a maximum climate change scenario (0.01% AEP event).

9.1.2 Table D8-4-13 gives the predicted overtopping rates for the northern MOLF quay (as these are the largest) for a range of joint wave and sea level probabilities for this future scenario. Note that the probability of extreme wave heights coinciding with extreme sea levels is very low, hence, sea levels presented in table D8-4-7 all relate to present day events lower than the mean annual sea level. Note also that overtopping rates can only be calculated where still water levels are below the crest level of the structure being assessed, i.e. lower than 5.0m AOD.

9.1.3 The joint probability results suggest that overtopping would occur in a 20% AEP event. Overtopping rates are simulated to be approximately 50% larger in a 0.1% AEP event, however, in all cases the flows overtopping the MOLF are substantial, at more than 1 m^3/s per meter of quay. These overtopping rates are driven by mean wave heights between 3.3m and 4.4m high acting on still water sea levels equal to the crest height of the MOLF quay.

9.1.4 Despite the small window for overtopping in any one period, the mean overtopping rates are significant and could result in physical damage of the structures. Further, the conditions in the vicinity of the MOLF are likely to render it unusable under these conditions. Use of the MOLF would be restricted to appropriate operating conditions to avoid exposure of people, assets or materials to unnecessary risk. Regular inspection and maintenance of the MOLF and associated structures would be undertaken to maintain the integrity of the structures over the lifetime of their use.

9.1.5 Given that still water levels could be significantly higher than this when the effects of climate change are considered, it is possible that worst-case combined still water and wave heights could approach 10.95m AOD (3.30m wave heights with 9.30m AOD credible maximum sea level, allowing for still water sea level to lie equally between trough and peak) if not reach 11.65m AOD (4.36m wave heights with 9.47m AOD credible maximum sea level).

9.1.6 The majority of the Power Station and all supporting buildings would be sited at above 18m AOD, the only exception being the cooling water intake structures which are water compatible. This level is 6m above the maximum credible tidal and wave level; as such, there is no reasonably foreseeable flood risk to the Power Station Site from coastal flooding for up to the 0.01% AEP flood event.

Table D8-4-13 Operational phase - peak values of mean overtopping rate for waves and sea levels with joint probabilities of 20%, 4%, 1.33%, 0.5% and 0.1% AEP for the MOLF for the 2187 present day scenario

AEP (%)	Worst case sea condition ARTEMIS point			Mean overtopping rate (l/s/m)
	H_s(s)	T_{m-10} (s)	Sea level (mAOD)	
20.00	3.30	8.7	5.00	1,077
4.00	3.82	9.5	5.00	1,341
1.33	4.09	9.8	5.00	1,487
0.50	4.22	10.0	5.00	1,558
0.10	4.36	10.1	5.00	1,634

9.1.7 The marine elements adjacent to Porth-y-pistyll, such as the MOLF, intake and outfall are water compatible and so the sensitivity of these structures to flooding is classed as low. Although the above information indicates overtopping, the magnitude of the potential hazard is determined to be low as this would not affect the cooling water structures, although it could limit access to the land based elements of the structures and the MOLF would not be used. However, this would not adversely affect the structures and this inundation is considered in the design. This would result in a very low significance of potential effect. The likelihood of occurrence is classed as high, due to the 20% AEP joint probability of occurrence, but the overall flood risk is determined as being low due to the very low significance of effect.

9.1.8 Land along the coastal edges of the Wylfa Newydd Development Area is considered to be of medium sensitivity to flooding. The magnitude of potential hazard in these areas is also considered to be high, given that a larger area of land is at risk of inundation and the land that is already at risk would be inundated to a greater depth. Notably, land to the north of Tre'r Gof, which is approximately 11m AOD, could be inundated with run-up and overtopping volumes flowing over this low point and into the SSSI. Given the sensitivity to flood risk, the significance of this effect is considered to be moderate. Despite the effects of climate change, the likelihood of occurrence is classed as medium, due to the 0.1% AEP probability of occurrence, and the overall flood risk in this location is determined as being moderate. However, these flood risks are not caused by the development of the Power Station, they are due to climate change. Therefore, although the flood risk is recognised, it is not a material consideration as it is not caused by the Power Station development and does not affect the Power Station operation.

9.2 Fluvial and pluvial flooding

Fluvial flood risk

9.2.2 The fluvial flood risk assessment for the Power Station Site during operation incorporates an allowance for climate change for the 2080s. An increase of 20% has been added to the river flows to model the reasonably foreseeable climate change scenario [RD5]. The depths of flooding at key locations around the Power Station are shown in table D8-4-14 and presented in appendix D8-4-9. Information is also provided for the credible maximum (CM) climate change scenario for the 1% AEP event of 75% increase in rainfall intensity.

Table D8-4-14 Modelled phase 5 fluvial flood risk (summer) at observation lines

Receptor	Description of flooding	Maximum flood depth (m)				
		50% AEP RF	3.3% AEP RF	1% AEP RF	0.1% AEP RF	1% AEP CM
Land adjacent to the watercourse realignment	Upstream end of watercourse realignment (CAER4)	0.00 (0.00)	0.02 (+0.01)	0.06 (+0.01)	0.15 (+0.06)	0.11
	Eastern portion of watercourse realignment(CAER9)	0.00 (0.00)	0.35 (0.00)	0.60 (+0.01)	1.02 (+0.04)	0.83
Eastern end of Cemlyn Lagoon	Flood depth at Nant Cemlyn where it flows into Cemlyn Lagoon (CEML7)	0.65 (+0.02)	0.65 (+0.02)	0.66 (+0.02)	0.68 (+0.01)	1.70
Cemaes Village	Nant Cemaes flood levels upstream of Cemaes village (CEMA5)	0.16 (+0.03)	0.66 (+0.04)	0.75 (+0.03)	0.92 (+0.04)	0.40
	Nant Cemaes flood level within Cemaes village (CEMA9)	0.00 (0.00)	0.32 (0.01)	0.54 (-0.01)	0.77 (0.00)	0.74
Cemlyn Road	Nant Cemlyn at Cemlyn Road (CEML6)	0.50 (+0.01)	0.72 (-0.01)	0.80 (-0.01)	0.95 (-0.01)	0.90
	Afon Cafnan at Cemlyn Road (CAFN9)	0.33 (+0.03)	0.79 (+0.05)	1.09 (+0.6)	1.44 (+0.03)	1.29

*The values in brackets are the change in flood depth relative to the baseline case for the scenario considered. Otherwise maximum flood depths.

9.2.3 The figures in appendix D8-4-9 show marginal difference in the extent of flooding at the Power Station Site between the baseline case and the operational phase.

Watercourse realignment

9.2.4 There is a 0.06m increase in flood depth along the upstream end of the watercourse realignment during the 0.1% AEP event with no risk to receptors aside from agricultural land. As this is within the floodplain for the watercourse it has a low value (in comparison to the medium value during construction). The change in flood depth along the watercourse realignment is considered to have a medium magnitude of potential flood hazard as there is a measurable increase in flood depth. With the watercourse realignment considered to be of low sensitivity, the significance of the effect is considered low. The high likelihood of effect results in a moderate overall impact on flood risk, however, no additional mitigation measures are required as the effect occurs within the existing floodplain.

Cemlyn Lagoon

9.2.5 Fluvial flood depths at the outlet to Cemlyn Lagoon are predicted to increase by up to 0.02m compared to the baseline case. The effect is driven by an increase in catchment area of Nant Cemlyn where Mound E is located and potentially the result of the proposed drainage system which includes a treatment pond and swales. Additional assessment as part of detailed drainage design is required to mitigate this risk.

9.2.6 The eastern end of Cemlyn Lagoon has a medium sensitivity. As the increase in flood level is small in Nant Cemlyn and Cemlyn Lagoon is large in comparison, the potential magnitude of change and risk to the lagoon can be considered negligible which produces a negligible significance of effect. With a likelihood of occurrence of medium this yields a negligible impact on flood risk.

Cemaes village

9.2.7 There is a 0.04m increase in flood depth upstream of Cemaes village during the 1% AEP events where Brookside Garages and a residential property are located. This increase in flood depth is considered to have a medium magnitude of potential hazard. Given the very high sensitivity of the receptor to flood risk the significance of effect is considered to be high. The high likelihood of effect, which occurs across all events simulated, results in a high overall impact on flood risk and additional mitigation would be needed.

9.2.8 There is a 0.01m reduction in flood depth downstream of the A5025 within Cemaes village in the 1% AEP event. The change in extents in close proximity to Cemaes Bay are potentially due the hydraulic modelling limitations detailed in appendix D8-7 (Application Reference Number: 6.4.32), however, for the purposes of this assessment it is taken that this impact is as a result of the development. There is considered to be a negligible magnitude of potential hazard to Cemaes village as a result. Properties have a very high sensitivity to flood risk and as such, the significance of effect is considered to be negligible based on the consequences simulated. The likelihood of effect is classed as medium and the overall impact on flood risk considered negligible. The additional mitigation required to address increases in flood risk upstream in Cemaes is expected to benefit this area also, potentially providing further reductions in flood level.

Cemlyn Road

9.2.9 Upstream of the point where Nant Cemlyn flows into Cemlyn Lagoon, Cemlyn Road crosses the Nant Cemlyn. Cemlyn Road has a very high sensitivity (as it is the only access route to some properties), which combined with a medium magnitude of hazard from the 0.01m increase in flood depth indicates a high significance of effect. With a likelihood of occurrence of medium this yields a high impact on flood risk. Given the very small difference in flood levels no additional mitigation is required.

9.2.10 The increase in flood depth of up to 0.6m from Afon Cafnan during the 1% AEP event along Cemlyn Road is caused by Mounds D and E reducing floodplain storage. In addition, the flows back up behind Cemaes Road, eventually spilling over the road and into Porth-y-pistyll. Cemlyn Road's very high sensitivity combined with a medium magnitude of hazard indicates a high significance of effect. With a likelihood of occurrence of medium this yields a high impact on flood risk. Despite the classification of the impact on flood risk as high, after the granting of DCO the property at Cafnan affected by this increased risk would become owned by Horizon and only leased if appropriate. Use of the road and therefore exposure to this increased risk is therefore expected to be reduced and no additional mitigation measures are currently proposed.

9.2.11 The increases noted above do not affect the existing property at Cafnan, however, when the effect of climate change to the 2180s is considered the increase in flood levels observed (+0.02m) would potentially results in an increase in flood risk to the property. As owners of the property, future adaptation is the preferred approach to managing this increased risk, once the effects of climate change on flood risk in this area become clearer.

Pluvial flood risk

9.2.12 The risk of pluvial flooding to the Power Station Site has been assessed using the hydraulic model for the operational phase. This includes a 30% increase for climate change for the reasonably foreseeable (RF) situation for the 2080s. The flood depths for key locations are provided in table D8-4-15. Information is also provided for the credible maximum (CM) climate change scenario for the 1% AEP event of 75% increase in rainfall intensity.

Table D8-4-15 Modelled phase 5 pluvial flood risk at observation lines

Receptor	Description of flooding	Maximum flood depth (m)				
		50% AEP RF	3.3% AEP RF	1% AEP RF	0.1% AEP RF	1% AEP CM
Land adjacent to the watercourse realignment	Upstream end of watercourse realignment (CAER4)	0.04 (+0.01)	0.10 (+0.06)	0.15 (+0.08)	0.24 (+0.10)	0.18 (+0.10)
	Eastern portion of watercourse realignment (CAER9)	0.18 (-0.01)	0.23 (-0.01)	0.26 (-0.13)	0.62 (-0.18)	0.53 (+0.03)
Eastern end of Cemlyn Lagoon	Flood depth at Nant Cemlyn where it flows into Cemlyn Lagoon (CEML7)	0.65 (+0.02)	0.67 (+0.01)	0.70 (+0.01)	0.75 (-0.01)	1.69 (-0.04)
Cemaes Village	Nant Cemaes flood levels upstream of Cemaes village (CEMA5)	0.13 (0.00)	0.37 (-0.05)	0.57 (0.00)	0.74 (+0.01)	0.65 (+0.03)
	Nant Cemaes flood level within Cemaes village (CEMA9)	0.06 (-0.03)	0.49 (-0.04)	0.67 (+0.01)	0.91 (+0.02)	0.81 (+0.03)
Cemlyn Road	Nant Cemlyn at Cemlyn Road (CEML6)	0.36 (-0.14)	0.70 (-0.05)	0.82 (-0.04)	1.03 (-0.11)	0.93 (0.00)
	Afon Cafnan at Cemlyn Road (CAFN9)	0.18 (+0.08)	0.39 (-0.02)	0.54 (-0.13)	1.02 (-0.11)	0.91 (+0.12)

*The values in brackets are the change in flood depth relative to the baseline case. Otherwise maximum flood depths.

9.2.13 The differences in the flood outlines can be seen on the figures in appendix D8-4-9. There is a small increase in the extent of flooding in the study area, and some differences in the areas affected by flooding due to the landscaping changes, compared to the baseline case.

9.2.14 During the operation phase there is an increase in water depths at the majority of the reference points selected.

Watercourse realignment

9.2.15 At the eastern portion of the watercourse realignment there is only a decrease in water depth simulated and an increase of up to 0.10m in flood depth at the upstream end. This increase in flood depth along the watercourse realignment is considered to have a medium magnitude of flood hazard as there is a measurable increase in flood depth. With the land adjacent to the watercourse realignment considered to be of low sensitivity (as it is in the floodplain), the significance of the effect is considered low. The high likelihood of effect results in a moderate overall impact on flood risk, however, no mitigation is required.

Cemlyn Lagoon

9.2.16 Pluvial flood depth increases are less than 0.02m at the Nant Cemlyn outfall to Cemlyn Bay. Cemlyn Lagoon has a medium sensitivity as it is part of a SSSI. As the increase in flood level is relatively small in Nant Cemlyn and Cemlyn Lagoon is large in comparison, the potential magnitude of change and risk to the lagoon can be considered negligible which indicates a negligible significance of effect. Despite a high likelihood of occurrence this yields a negligible impact on flood risk.

Cemaes village

9.2.17 At Cemaes village the onset of flooding remains the same as the baseline case and the increase in the extent of flooding is very small. The increase in flood depths are 0.01m upstream of Cemaes village, restricted to the 0.1% AEP event with no change or a reduction in more frequent events. Downstream small increases of up to 0.02m in the 0.1% AEP event are seen, however for more frequent events there is a reduction in flood level.

9.2.18 Mound A directs a large percentage of the surface water towards the toe drainage with overflow pipes from the drainage discharging water away from the Nant Cemaes, thereby reducing flood depths in the village downstream compared to the baseline case for events up to and including the 3.33% AEP event. The small south-eastern section of the mound that extends out towards the A5025 does not contain any toe drainage which could account for the minor increase in flood depth upstream of Cemaes village in the 0.1% AEP event.

9.2.19 Upstream of Cemaes village, Brookside Garages and residential property have a very high sensitivity, which combined with a medium magnitude of hazard indicates a high significance of effect. With a medium likelihood of occurrence this yields a high impact on flood risk and further mitigation is needed.

9.2.20 Cemaes village downstream of Cemlyn Road has a very high sensitivity, however, no properties are affected. Gardens and undeveloped land are considered to have a medium sensitivity. Combined with a medium magnitude of hazard this indicates a high significance of effect. With a likelihood of occurrence of medium this yields a moderate impact on flood risk. Cemlyn village downstream of Cemlyn Road would also benefit from additional mitigation measures to manage the impact on flood risk upstream of the road.

Cemlyn Road

9.2.21 A decrease in flood depth at Cemlyn Road from Nant Cemlyn of up to 0.14m is predicted. This decrease in flood depth along Cemlyn Road is considered to have a negligible magnitude of flood hazard. With Cemlyn Road considered to have a very high sensitivity, as it is an access route, the significance of the effect is considered negligible. The medium likelihood of effect results in a negligible overall impact on flood risk and additional mitigation would be needed.

9.2.22 An increase in flood depth of up to 0.08m is simulated during the 50% AEP event along Cemlyn Road from the Afon Cafnan, which is caused by Mounds D and E reducing the amount of land available for flood storage and from backing up of the flows behind the culvert under Cemlyn Road, spilling over the road and towards Porth-y-pistyll. Under more extreme events there is a small reduction in flood depths of up to 0.13m. Cemlyn Road's very high sensitivity combined with a medium magnitude of hazard indicates a high significance of effect. With a likelihood of occurrence of medium this yields a high impact on flood risk. Despite the classification of the impact on flood risk as high for frequent events, after the granting of DCO the property at Cafnan, affected by this increased risk, would become owned by Horizon, and would only leased if appropriate. Use of the road and therefore exposure to this increased risk is therefore expected to be reduced and no additional mitigation measures are currently proposed.

9.2.23 The increases noted above do not affect the existing property at Cafnan even when the effect of climate change to the 2180's is considered.

Power Station

9.2.24 When the Power Station is operational there would be an increase in hard standing areas due to the incorporation of buildings and car park areas. These buildings, hardstanding and drains would alter the natural recharge to groundwater and runoff to surface waters. The drainage systems of building and hardstanding areas would comprise drainage ditches/swales and piped systems with surface water being discharged directly to the sea. Due to the design of the drainage system to meet nuclear safety requirements the magnitude of hazard as a result of the increase in hard standing within the Power Station would be negligible, resulting in overall impact on flood risk from this source of negligible.

9.3 Groundwater

Groundwater emergence at surface

9.3.2 Any emergence of groundwater at the surface is unlikely to be significant in terms of volume given that the underlying bedrock is of low permeability and recharge to the aquifer is limited where the glacial till has a clay matrix and is of low permeability, and the presence of the Power Station buildings, hardstanding and drainage system. In addition, the extent of concrete across the surface of the Power Station would limit groundwater emergence to areas of soft standing which would predominantly be at the periphery of the site. Any groundwater flows expressed at the surface be intercepted by surface drainage features to be constructed around the perimeter of the Power

Station. These flows would be directed away from the Power Station and would not therefore cause flooding or contribute to flooding from another source elsewhere.

9.3.3 Groundwater levels at the Power Station would be maintained at an artificially low level by the passive drainage system installed around the deep basements. With a regular maintenance schedule to ensure the drainage system is working at full capacity this would prevent any groundwater flooding at the surface in this area.

9.3.4 The sensitivity of the Power Station is considered very high, however, the magnitude of the hazard is considered to be negligible for the reasons identified. The resulting significance is therefore negligible, as is the overall risk from this source.

9.4 Services

Upgraded sewer network

9.4.2 The development of the Power Station Site includes upgrading of the DCWW sewage treatment plant at Wylfa Head, realignment of the sewer from Cemaes and the creation of a foul water sewer network to serve the Power Station.

9.4.3 The volume of sewage within the section of the sewer from Cemaes village is unlikely to increase, therefore the risks from this sewer do not change from baseline conditions.

9.4.4 The new sewer network from the Power Station to Wylfa Head introduces a risk to the Power Station; however, given that the sewer would be new and designed to a high standard as part of this development, the likelihood of failure is very low, although this could decrease towards the end of the operational life of the Power Station due to age. Given that any sewage volumes would be relatively small and any leak short lived, in the event of a failure within the operational lifetime of the Power Station, flows would be intercepted by the surface-water drainage network. Although this may present a risk to public health, it is unlikely to cause flooding across the Power Station. The sensitivity of the Power Station is very high, but the magnitude of the hazard would be very low resulting in a low significance of effect. As the likelihood of a major sewer failure is low the flood risk has been assessed as low.

Site drainage network

9.4.5 In the event of the Power Station Site drainage network becoming blocked there is the potential for excess flows to surcharge from the storm drains at the Power Station. However, the drainage system would be designed, constructed and maintained to ensure that the annual probability of surcharge is less than 3.3% and that there is no significant ponding on site for up to a 1% AEP storm event. The landform would also be designed to ensure that for events larger than this (up to at least the 0.01% AEP event) water is always directed away from buildings and areas critical for nuclear safety.

9.4.6 The sensitivity of the Power Station is very high, but the magnitude of the hazard is low resulting in a moderate significance of effect. As the likelihood of flooding from the drainage network is low the flood risk posed due to the drainage network is assessed as low.

Water supply systems

9.4.7 It is considered that the design of the water supply network would be sufficient to transport the flows of water required without surcharging. This new infrastructure would be designed to be serviceable for the lifetime of the development. The sensitivity of the Power Station is very high, but the magnitude of the hazard is expected to be no greater than low resulting in a moderate significance. As the likelihood of flooding from mains failure is low the flood risk is assessed as low.

9.5 Operational phase flood risks

9.5.1 The probability and severity of each type of flooding has been assessed in line with the methodology and guidance set out in appendix D8-4-2. This is then combined with the assessment of receptor sensitivity to define the level of flood risk on a scale ranging from negligible to high. The risks to identified receptors, including those where additional mitigation, is required are contained in table D8-4-16.

9.5.2 Typically, risks assessed to be low or less are acceptable whereas risks assessed to be moderate or high require additional mitigation or management to enable development to proceed.

Table D8-4-16 Operational phase flood risk

Flood type	Source	Pathway	Receptor	Sensitivity	Magnitude of hazard	Significance of effect	Likelihood of occurrence	Flood risk
Tidal	Irish Sea	Storm surge, spring tide and wave overtopping causing overland flooding	Power Station	Very high	Very Low	Low	Low	Low
			MOLF (onshore)	Low	Very low	Very low	High	Low
			Coastal areas of Wylfa Newydd Development Area, including Tre'r Gof	Medium to High	High	Moderate	Medium	Moderate
				The increased risk of flooding is caused by climate change rather than the development and so mitigation of this risk is not required				
Fluvial and pluvial	Fluvial	Increased fluvial flooding off-site due to the operational activities altering infiltration capacity, evapotranspiration, in-channel changes and changes to drainage paths and catchment areas.	Land at watercourse realignment	Low	Medium	Low	High	Moderate
			Cemlyn Lagoon	Medium	Negligible	Negligible	Medium	Negligible
			Property upstream of Cemaes village	Very high	Medium	High	Medium	High
			Cemaes Village	Very high	Negligible	Negligible	Medium	Negligible
			Cemlyn Road at Afon Cafnan	Very high	Medium	High	Medium	High
				Based on professional judgement the high risk is reduced to:				Low*
			Cemlyn Road at Nant Cemlyn	Very high	Medium	High	Medium	Negligible
				Based on professional judgement the high risk is reduced to:				Low*
			Power Station	Medium	Very Low	Very Low	High	Low
	Pluvial	Surface water runoff flooding residential	Land at watercourse realignment	Low	Medium	Low	High	Moderate

Flood type	Source	Pathway	Receptor	Sensitivity	Magnitude of hazard	Significance of effect	Likelihood of occurrence	Flood risk
		properties at Cemaes village	Cemlyn Lagoon	Medium	Negligible	Negligible	High	Negligible
			Property upstream of Cemaes village	Very high	Medium	High	High	High
			Cemaes Village	Very high	Medium	High	Medium	High
				Based on professional judgement the high risk is reduced to:				Moderate*
			Cemlyn Road at Afon Cafnan	Very high	Medium	High	Medium	High
				Based on professional judgement the high risk is reduced to:				Low*
			Cemlyn Road at Nant Cemlyn	Very high	Negligible	Negligible	Medium	Negligible
			Power Station	Medium	Negligible	Negligible	High	Negligible
Ground-water	Groundwater	Groundwater flooding expressed at surface	Power Station	Very high	Negligible	Negligible	Negligible	Negligible
Services	Sewerage network	Surcharge, blockage or failure of existing sewers	Power Station	Very high	Very low	Low	Low	Low
	Site drainage network	Blockage or failure of drainage network	Power Station	Very high	Low	Moderate	Low	Low
	Mains water supply	Surcharge or failure of mains supply	Power Station	Very high	Low	Moderate	Low	Low

*Areas where the approach in appendix D8-4-2 suggests a higher overall flood risk than that stated. Evidence has been provided that shows that the flood risk is low and that further mitigation is not required.

10 Wylfa Newydd Development Area decommissioning flood risk assessment

10.1 Tidal flooding

10.1.1 For decommissioning the tidal flooding levels given for 2187 have been taken as the maximum sea levels likely to affect the site. These levels are the same as those presented in section 9 for the operational site.

10.1.2 The majority of the land at the decommissioned Power Station Site would be above 18m AOD and as such, there is no reasonably foreseeable flood risk to the land from coastal flooding for up to the 0.01% AEP flood event. However, lower lying areas such as the platform around the cooling water intake tunnels and the onshore elements of the MOLF would be at risk of tidal flooding, but this would be to a limited area and as these areas would no longer be in use, it is only the flooding of the land that is of concern.

10.1.3 The sensitivity of the Power Station Site at decommissioning would be considered medium. The magnitude of the hazard would be low across the majority of the site resulting in a low significance. As the likelihood of tidal flooding is low for the majority of the decommissioned platform areas the risk of tidal flooding to the surface is assessed as low.

10.1.4 Land along the coastal edges of the Wylfa Newydd Development Area is considered to be of medium sensitivity to flooding during decommissioning. The magnitude of potential hazard in these areas is considered to be high, given that a larger area of land is at risk of inundation and the land that is already at risk would be inundated to significantly greater depths. Notably, land to the north of the Tre’r Gof SSSI, which is approximately 11m AOD, could be inundated with run-up and overtopping volumes flowing over this low point and into the SSSI. Given the sensitivity to flood risk, the significance of effect is considered to be moderate. Taking climate change into account in the wave modelling, the likelihood of occurrence is classed as medium, due to the 0.1% AEP probability of occurrence, and the overall flood risk in this location is deemed moderate. However, these flood risks are not caused by the development or decommissioning of the Power Station, they are due to climate change. Therefore, although the flood risk is recognised, it is not a material consideration as it is not caused by the Power Station development and does not affect the Power Station decommissioning.

10.2 Fluvial and pluvial flooding

Fluvial flood risk

10.2.2 The landscape mounds and hence the river catchments would not be altered with decommissioning. After the 60-year life of the Power Station the vegetation of the mounds would be well established. The runoff from these areas would therefore be less than when they were first constructed.

10.2.3 The removal of buildings and hardstanding areas across the Power Station Site would reduce runoff into the watercourses. It is assessed that the fluvial flood risk after the Power Station is decommissioned would be less than during the operational stage. The sensitivity of the site at decommissioning would be medium. The magnitude of the hazard would be low resulting in a low significance. As the likelihood of fluvial flooding is low the risk of fluvial flooding to the surface is assessed as low.

10.2.4 During the decommissioning period the risk to properties upstream of Cemaes remain broadly the same as during operation, i.e. there would remain a high flood risk unless further mitigation is implemented. The risks to Cemaes village, Cemlyn Lagoon and Cemlyn Road all remain unchanged from those identified during the operation period (i.e. low or negligible when professional judgement is taken into account).

Pluvial flood risk

10.2.5 Pluvial flood risk would be reduced following decommissioning. The reversion to a more natural landscape with the removal of much of the hardstanding and built areas would allow an increase in infiltration and therefore a reduction in the amount of runoff generated. The sensitivity of the site at decommissioning would be medium. The magnitude of the hazard would be low resulting in a low significance. As the likelihood of fluvial flooding is low the risk of fluvial flooding to the surface is assessed as low.

10.2.6 During the decommissioning period the risk to properties upstream of Cemaes and to Cemlyn Road remain broadly the same as during operation, i.e. there would remain a high flood risk unless further mitigation is implemented. The risks to Cemaes village, Cemlyn Lagoon and Cemlyn Road all remain unchanged from those identified during the operation period (i.e. low or negligible when professional judgement is taken into account).

10.3 Groundwater

10.3.1 Following decommissioning of the Power Station's drainage system, including the passive drainage system used to control the groundwater levels around the reactor and generator buildings, groundwater levels would rise to 'natural' levels (likely to be similar to the groundwater levels identified in the baseline conditions). However, as ground levels would have been lowered in parts of the Power Station Site during the construction works to create the construction platform, there is the potential that groundwater levels could rise above the created platforms if the drainage channels on the platform could not drain water away quickly enough. Mitigation, which could include installation of land drains or modification to the passive drainage system, would be used to prevent this from happening.

10.3.2 At decommissioning the sensitivity of the site would be medium, with the magnitude of the hazard being low resulting in a low significance. As the likelihood of groundwater flooding (post mitigation) is very low the risk of groundwater to the surface is assessed as very low.

10.4 Services

10.4.1 The removal of water service infrastructure to the Power Station would mean that there would no longer be a source to cause a flood risk.

10.5 Decommissioning phase flood risks

10.5.1 The probability and severity of each type of flooding has been assessed in line with the methodology and guidance set out in appendix D8-4-2. This is then combined with the assessment of receptor sensitivity to define the level of flood risk on a scale ranging from negligible to high. The risk assessment is contained in table D8-4-17.

10.5.2 Typically, risks assessed to be low or less are acceptable whereas risks assessed to be moderate or high require additional mitigation or management to enable development to proceed.

Table D8-4-17 Decommissioning phase flood risks

Flood type	Source	Pathway	Receptor	Sensitivity	Magnitude of hazard	Significance of effect	Likelihood of occurrence	Flood risk
Tidal	Irish Sea flooding	Storm surge, spring tide and wave overtopping causing overland flooding	Land at the former Power Station site (excluding cooling water intake area)	Medium	Low	Low	Low	Low
			Coastal areas of Wylfa Newydd Development Area, including Tre'r Gof SSSI	Medium to High	High	Moderate	Medium	Moderate
				The increased risk of flooding is caused by climate change rather than the development and so mitigation of this risk is not required				
Fluvial and pluvial	Fluvial	Changes to infiltration	Land at the former Power Station site	Medium	Low	Low	Low	Low
		Increased fluvial flooding off-site due to changes in infiltration capacity, evapotranspiration, in-channel changes and changes to drainage paths and catchment areas.	Property upstream of Cemaes village	Very high	High	High	Medium	High
			Land adjacent to the watercourse realignment, Cemlyn Lagoon, Cemlyn Road, Cemaes village	As per operation				Low to negligible*
	Pluvial	Surface water runoff	Land at the former Power Station site	Medium	Low	Low	Low	Low
		Increases in surface water runoff due to changes in catchments	Property upstream of Cemaes village	Very high	Medium	High	High	High
			Land adjacent to the watercourse realignment, Cemlyn	As per operation				Low to negligible*

Flood type	Source	Pathway	Receptor	Sensitivity	Magnitude of hazard	Significance of effect	Likelihood of occurrence	Flood risk
			Lagoon, Cemlyn Road, Cemaes village					
Groundwater	Groundwater	Groundwater flooding expressed at surface	Land at the former Power Station site	Medium	Low	Low	Very low	Very low
Services	Sewerage network	Removal of services – no risk	Land at the former Power Station site	Risk removed				
	Water mains	Removal of services – no risk	Land at the former Power Station site	Risk removed				

*Areas where the approach in appendix D8-4-2 suggests a higher overall flood risk than that stated. Evidence has been provided that shows that the flood risk is low and that further mitigation is not required.

11 Site Campus flood risk assessment

11.1 Tidal flooding

11.1.1 The Site Campus would be sited at above 14m AOD which is above the maximum extreme sea levels (including freeboard); as such, there is no reasonably foreseeable flood risk to the Site Campus from coastal flooding for up to the 0.01% AEP flood event. With a high sensitivity and a low potential magnitude of effect the significance of the potential hazard is moderate. As the likelihood is assessed as low, the risk of flooding is assessed as low.

11.2 Pluvial flooding

11.2.1 A study of the NRW maps of surface water flood risk [RD2] has identified that there are no areas at risk of surface water flooding within the Site Campus and therefore the risk of flooding from this source has been classed as negligible. This notwithstanding, the Site Campus is proposed to be constructed in an elevated part of the Wylfa Newydd Development Area minimising surface water flooding.

11.2.2 Pluvial modelling of the Site Campus has shown that there is some surface water flooding at the site from the 50% AEP event upwards. The flooding extents are not extensive and suggest shallow flow routes to the east of the Site Campus, north of Tre'r Gof. At the 50% AEP event depths are estimated to be 0.01-0.05m with a very small area of low lying land where ponding to depths of 0.25-0.50m may be expected (figures of surface water flood risk are provided in appendix D8-4-6 for the baseline case, D8-4-7 for the construction phase and D8-4-8 for the operational phase). The extent and depth of surface water flooding does not increase greatly with likelihood of event.

11.2.3 The operational phase shows the layout of the accommodation blocks on the figures in appendix D8-4-7. This shows that there is some overlap between the areas of surface water flood risk and the buildings. At the 50% AEP event, the identified low spot corresponds to one of the accommodation blocks, however, slab levels and thresholds are expected to be such that this low spot would no longer exist and as such the area would not pose a risk to the Site Campus buildings. The sensitivity of the Site Campus is high and with an anticipated magnitude of the hazard assessed as very low and the significance of effect is determined as low. Given the above the likelihood of pluvial flooding is low and therefore the risk of flooding of the Site Campus is assessed as low and further mitigation would not be required.

11.2.4 The introduction of impermeable surfaces would lead to an increase in runoff from the Site Campus. A new surface water network is proposed to serve the site's drainage requirements, including drainage of the building roof areas, the car park, bus transfer area, and all permeable and impermeable hardstanding areas.

11.2.5 The site is naturally split into two catchment areas. The proposed surface water on the northern catchment from the accommodation building roof areas would be served by a piped system by linear/gully drainage receptors. Storm water attenuation would be provided in line with The SUDS Manual [RD21] in the form of a permeable paving systems and swales. Surface water flows would be discharged to the sea via the Existing Power Station site outfall, which is located north-west of the proposed Site Campus. Discharge flows would be limited to greenfield run-off rates for the mean annual maximum event via a flow control chamber.

11.2.6 The southern catchment is divided into two components. The western part would drain the car park, building roofs, bus transfer area, and all permeable and impermeable hardstanding areas into a piped system by linear/gully drainage receptors. Storm water attenuation would be provided in line with The SUDS Manual [RD21] in the form of a permeable paving system in the car parking areas and a below ground storage system elsewhere. Surface water flows would be discharged to an existing local watercourse, which flows into Tre'r Gof SSSI, and then through the SSSI to the sea. Discharge flows would be limited to greenfield mean annual maximum run-off rates via a flow control chamber.

11.2.7 The drainage from the eastern end of the Site Campus, which would only be developed if required (i.e. it is not certain that it would be needed), would be discharged to ground via a series of soakaways in order to encourage diffuse water movement into Tre'r Gof SSSI.

11.2.8 The drainage has been designed such that all events up to and including the 1% AEP event with a 20% allowance for climate change [RD6] would be restricted to the greenfield runoff for the mean annual maximum event.

11.2.9 The sensitivity of the Site Campus is high, but the magnitude of the hazard resulting from failure of the drainage system would be low resulting in a moderate significance. As the likelihood of pluvial flooding is low the risk of flooding of the Site Campus is assessed as low.

11.2.10 Given the location and topography of the site, the off-site receptors are limited to the sea at Cemaes Bay and the Tre'r Gof SSSI. There is no potential flood risk to the sea as the volume of water discharged from the Site Campus is very small in comparison to the open sea in Cemaes Bay. The Tre'r Gof SSSI has a high sensitivity, but the magnitude of the hazard would be low to medium resulting in a low to moderate significance. As the likelihood of flooding is low (due to the embedded mitigation that includes an attenuation tank) the risk of flooding is assessed as low.

11.3 Groundwater

Groundwater emergence at surface

11.3.2 Given that the Site Campus is located on a headland; it is unlikely that there would be any significant upward groundwater head in the superficial deposits or underlying bedrock. In addition, any flows are likely to flow down gradient to the Tre'r Gof SSSI or to the coast.

11.3.3 The sensitivity of the Site Campus would be high, with the magnitude of the hazard being low resulting in a moderate significance. As the likelihood of groundwater flooding is very low the risk of groundwater flooding to the Site Campus has been assessed as low.

11.4 Services

Sewerage systems

11.4.2 There is an existing foul sewer that runs beneath the location proposed for the Site Campus. It is not known whether this would require diverting as part of construction, or whether it would remain. In the event that it remains, any flooding caused by a blockage or surcharge would be localised due to the relatively small volume and limited timescale involved and any sewage would flow downslope or to the site drainage system without flooding the Site Campus.

11.4.3 The sensitivity of the Site Campus is high, but the magnitude of the hazard would be low resulting in a moderate significance. As the likelihood of sewer failure is low (and if it were to fail the volume of sewage involved would be small and the duration of discharge short lived as it would be quickly repaired) the risk of flooding is assessed as low.

Water supply systems

11.4.4 The Site Campus would be connected to a mains supply by DCWW. As the pipeline would be new the potential for failure during the relatively short lifetime of the buildings would be low. In addition, any failure would be of limited duration and given the elevated location of the Site Campus any water would flow downslope away from the facility.

11.4.5 The sensitivity of the Site Campus is high, but the magnitude of the hazard would be low resulting in a moderate significance. As the likelihood of water mains failure is low the risk of flooding is assessed as low.

11.5 Decommissioning of the Site Campus

11.5.1 The Site Campus would be decommissioned and all buildings and infrastructure would be removed. The land would be returned to its current state such that there would be no change to the current flood risk.

11.6 Site Campus flood risks

11.6.1 The probability and severity of each type of flooding during construction and operation of the Site Campus has been assessed in line with the methodology and guidance set out in appendix D8-4-2. This is then combined with the assessment of receptor sensitivity to define the level of flood risk on a scale ranging from negligible to high. The risk assessment is contained in table D8-4-18. As the land would be returned to its current state at decommissioning there would be no change in flood risk at that time. During the decommissioning process the flood risks would be similar to those present during construction.

11.6.2 Typically, risks assessed to be low or less are acceptable whereas risks assessed to be moderate or high require additional mitigation or management to enable development to proceed.

Table D8-4-18 Site Campus flood risk during construction and operation

Flood type	Source	Pathway	Receptor	Sensitivity	Magnitude of potential effect	Significance of potential hazard	Likelihood of occurrence	Flood risk
Tidal	Irish Sea flooding	Flooding from tides	Site Campus	High	Low	Moderate	Low	Low
Surface water	Pluvial	Surface water flooding to the Site Campus	Site Campus	High	Very low	Low	Low	Low
	Site development	Increase in runoff from impermeable surfaces	Off-site receptors including Tre'r Gof SSSI	High	Low to medium	Moderate	Low	Low
		Site drainage failure	Site Campus	High	Low	Moderate	Low	Low
Groundwater	Groundwater	Groundwater emergence	Site Campus	High	Low	Moderate	Very low	Low
Services	Sewerage network	Flooding from sewer network failure	Site Campus	High	Low	Moderate	Low	Low
	Mains water supply	Pipe failure	Site Campus	High	Low	Moderate	Low	Low

12 Mitigation

12.1.1 This section discusses mitigation measures from a flood risk perspective during the construction, operation and decommissioning phases. The assessment of flood risk has been completed on the basis on embedded mitigation and good practice mitigation being in place. The additional mitigation is that which is required to address high residual flood risks.

12.1.2 The preliminary design for surface water drainage is contained in appendix D8-8 (Application Reference Number: 6.4.33) with key features of the drainage system and associated landscape mounding shown in figure D8-4 (Application Reference Number: 6.4.101) and outlined below. Good practice mitigation is detailed in section 8.4 of chapter D8 (Application Reference Number: 6.4.8).

12.2 Embedded mitigation during construction

12.2.1 A buffer zone around the Tre'r Gof SSSI would be put in place. This zone would be a minimum of an approximate 20m on the northern side of the SSSI, 50m to the south and approximately 100m on the SSSI's eastern side. Although there would be some work inside the buffer this would be limited to the installation of drainage on the northern side of the SSSI associated with the Site Campus and drainage around the southern side of the SSSI to manage runoff from the landscape mounds. The drainage around the northern side of the SSSI would seek to maintain the shallow groundwater flow to the SSSI.

12.2.2 The landscape mounding has been designed to avoid changes in catchment boundaries as far as practicable, although some changes do result from the mounding.

12.2.3 In addition, the drainage design (appendix D8-8 (Application Reference Number: 6.4.33)) has incorporated the following features around the Tre'r Gof SSSI:

- The use of a permeable drainage blanket made up of inert rock material beneath the Mound A to the south and east of the Tre'r Gof SSSI. This would allow the shallow groundwater and surface water runoff flowing from the south and east of Mound A to flow under the mound into the SSSI as it currently does.
- The use of overflow pipes at 50m intervals in the drainage ditch to the north and west of Mound A. This would mean that during times of higher rainfall, water would flow from the ditch to the ground adjacent to the drain to allow surface water overland flow to the SSSI to be maintained. Monitoring and control weirs in the overflow pipes would be used to control the flow to the SSSI via this mechanism to ensure that neither too much nor too little water flows into the SSSI.
- The drainage system has been designed to incorporate as much flexibility as possible so that changes can be made to water treatment and to the

volume of water being released to various discharge points during the construction period.

12.2.4 The drainage strategy for operation of the Site Campus includes two main discharge routes, the first is via the western watercourse that flows into Tre'r Gof SSSI and the second is via infiltration to ground. The direct flow into the SSSI would include attenuation using a geocellular attenuation tank or similar in order to reduce the potential for flooding and to try to match baseline conditions. The second component would be to recharge rainfall runoff to the northern side of Tre'r Gof via infiltration trenches, 'reno mattress', swales or similar. This mitigation would reduce potential hydrological effects on the SSSI arising from changes to land use within the Tre'r Gof Catchment.

12.2.5 In addition to the above mitigation, it is proposed to construct the Site Campus in a staged manner to reduce the potential effect on the SSSI. The first construction would be to the north-west of, and as far as practicable from, the Tre'r Gof SSSI.

12.2.6 Wherever practicable, permeable surfacing would be used for minor tracks, haul roads, compounds and laydown areas in order to avoid any increase in flood risk.

12.2.7 To encourage groundwater recharge, a SuDS approach has been adopted for the outline drainage system design following guidance as set out in CIRIA guidance, The SuDS Manual [RD21]. The outline design includes unlined settlement ponds and ditches with open drains (swales) in the base to allow groundwater recharge. However, due to the generally low permeability shallow soils, recharge to the groundwater from the drainage system is likely to be relatively low.

12.2.8 Installation of French drains or modification to the Power Station's passive drainage system would be used to prevent groundwater levels rising above the created platforms during the construction phase.

12.2.9 Mounds would be seeded with grass upon completion of earthworks, or where mounds would be left bare for more than 60 days to re-establish vegetation, reduce silt-laden runoff and slow surface water flows.

12.3 Embedded mitigation during operation

12.3.1 The Power Station Site foul water drainage system would divert all foul water from the Power Station to the marine environment following appropriate treatment and would not discharge to the surface water environment. Surface water drainage would also discharge to the sea.

12.3.2 The mound drainage would be converted to a passive drainage system, which would require no maintenance. The outline drainage design (appendix D8-8 (Application Reference Number: 6.4.33)) includes appropriate attenuation to prevent any increases to flood risk off-site and it includes swales and other features to try to match current surface water flows and groundwater recharge.

12.4 Embedded mitigation during decommissioning

12.4.1 Mitigation embedded into the design has been taken into consideration in determining the potential effects of the decommissioning works, although given that much of these works would not be undertaken for at least another 70 years, the mitigation measures have not been fully developed.

12.4.2 The Power Station Site, once hardstanding has been removed, would incorporate appropriate drainage channels. These would be installed in parallel with the removal of the operational Power Station drainage whenever practicable.

12.4.3 Landscaped areas outside of the Power Station Site, including landscape mounding and associated pasture and planting, would be retained, with no removal of topsoil, or major earthworks. Following decommissioning, no major restoration works would therefore be required to areas outside of the Power Station Site, because landscaping created during construction would not be affected by decommissioning works. After completion of construction a passive drainage system of the permanent mounds would be in place. Such drainage system would incorporate appropriate attenuation to prevent any increases to flood risk offsite and reduce significant effects on water availability.

12.4.4 No new impermeable areas would be developed as part of the decommissioning works, with any compound or buildings sited on existing hardstanding or permeable areas.

12.5 Additional Mitigation

12.5.1 Upstream of Cemaes village there is an increase in fluvial and surface water flood depths across a variety of events for the construction and operation phases respectively. With Brookside Garages and a residential property at increased risk additional mitigation is needed. There are also minor increases in flood level downstream of Cemlyn Road in Cemaes, with an identified impact to a property on Ffordd Y Traeth and also increased levels affecting gardens and undeveloped land.

12.5.2 The change in risk is principally due to the effects of the development though construction and operation on catchment areas from the landscape mounds and from the associated drainage. Currently the drainage design is at an outline stage and further design work is required to refine the drainage scheme to remove the impact on fluvial and pluvial flood risks identified by the modelling. The drainage scheme would continue to be developed and re-modelled to ensure that high risks are reduced and until there is no increase in flood risk to properties and other vulnerable receptors.

12.5.3 There is also an increased risk to Cemlyn Road from the Afon Cafnan. However, after the granting of the Development Consent Order the property at Cafnan that is accessed by Cemlyn Road at this point would become owned by Horizon. It would be unoccupied during the construction period and only leased during the operational period if appropriate (i.e. any flood risk could be mitigated). Use of the road would be limited during operation and therefore exposure to this increased flood risk is expected to be significantly reduced. No additional mitigation measures are therefore proposed.

12.5.4 An increased risk is also noted in Nant Cemlyn where it discharges to Cemlyn Lagoon. However, as the stream is small and Cemlyn Lagoon is large, the potential magnitude of change in water level in the lagoon is negligible and the flood risk to Cemlyn Lagoon is also negligible. No additional mitigation measures are therefore proposed.

12.6 Residual Risks

12.6.1 Residual risks are the risks that remain after taking into account the embedded, good practice and additional mitigation. Tables of the residual effects and their significance are provided in chapter D8 (Application Reference Number: 6.4.8).

12.6.2 Hydraulic modelling has been conducted for fluvial and pluvial scenarios up to the 0.1% AEP event for the construction, operation and decommissioning phases, including allowances for climate change where relevant over the lifetime of the development. Generally, the modelled extents have shown only minor changes in flood extents, minor differences in flood depths with no additional receptors at risk compared to the baseline. The embedded mitigation measures largely address the flood risks, with suggested additional mitigation measures to be developed during the development of a detailed drainage design that are expected to result in neutral impacts on key offsite receptors.

12.6.3 In light of the above, no additional residual risks are anticipated during the construction, operation and decommissioning phases from a fluvial, pluvial or groundwater flood risk perspective.

13 Conclusions

13.1.1 The flood consequences associated with the Wylfa Newydd Development Area, including the Site Campus have been assessed for all potential sources of flooding. The key conclusions are outlined below.

Construction

13.1.2 During construction, the flood risk is considered low for the majority of the potential sources of flooding. Those risks identified as greater than low are:

- The onshore elements of the MOLF are at a moderate risk of flooding from the Irish Sea, but no mitigation is required.
- Moderate and high risks have been identified from fluvial and pluvial sources to Cemlyn Lagoon, Cemaes village and Cemlyn Road, but based on professional judgement these have been reduced to low.
- There are high risks of flooding to properties upstream of Cemaes village and further mitigation is required to mitigate these risks. This mitigation would include modifications to the drainage design and re-modelling to check that the effects have been reduced to negligible.

Operation

13.1.3 During operation of the Power Station, the flood risk is considered low for the majority of the sources. Those flood risks identified as greater than low are:

- Moderate and high risks have been identified from fluvial and pluvial flooding to property in Cemaes village and Cemlyn Road. However, based on professional judgement these have been reduced to low.
- There are high risks of flooding to properties upstream of Cemaes village. The mitigation required to address the construction phase risks would address these risks so that they are no longer significant.

Decommissioning

13.1.4 During the decommissioning of the Power Station, the flood risk is considered low for the majority of the potential sources of flooding. The only risks identified as greater than low are to properties upstream of Cemaes village. The mitigation required to address the construction phase risks would address these risks so that they are no longer significant.

Site Campus

13.1.5 During construction, operation and decommissioning of the Site Campus, the flood risk is considered low for the majority of sources of flooding. The only flood risks identified as greater than low are to the Site Campus from pluvial sources and these would be mitigated in the detailed design.

14 References

Table D8-4-19 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/
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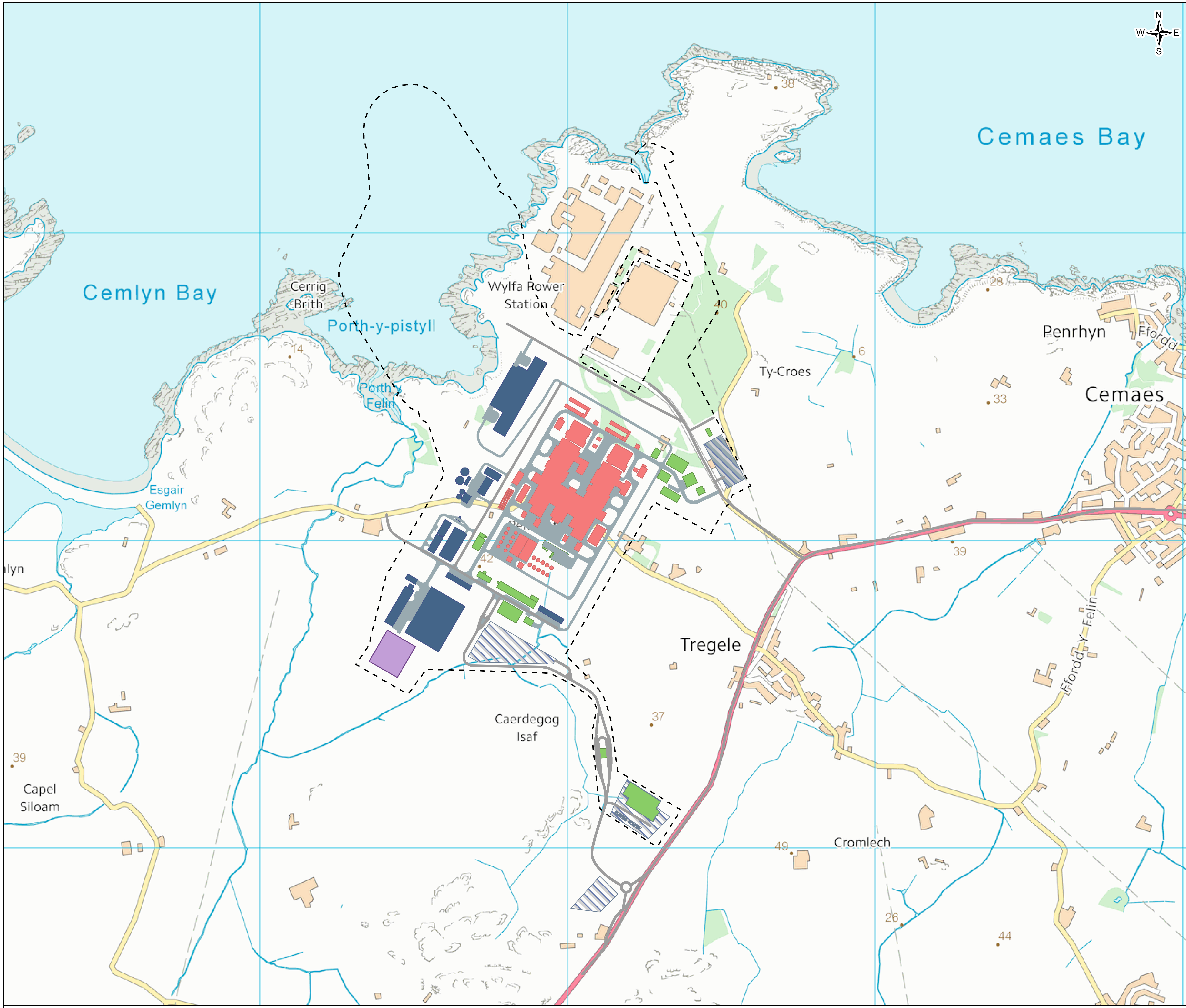
RD9	Isle of Anglesey County Council. N.d. *Preliminary Flood Risk Assessment*. [Online] [Accessed: October 2016] Available from: http://webarchive.nationalarchives.gov.uk/20140328084622/http://cdn.environment-agency.gov.uk/flho1111bvfk-e-e.pdf
RD10	Isle of Anglesey County Council. 2013. *Anglesey Local 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	Meteorological Office. 2017. UK Climate - historic station data. [Online] [Accessed October 2017] Available from: https://www.metoffice.gov.uk/public/weather/climate-historic/#?tab=climateHistoric

ID	Reference
RD13	WRc plc. 2012. Sewers for Adoption: A Design & Construction Guide for Developers. 7th Edition. Swindon: WRc plc.
RD14	Amec Foster Wheeler. Nuclear Safety, Meteorological and Hydrological Hazards Assessment (NSMHHA)
RD15	Department of Energy and Climate Change. 2011. *Overarching National Policy Statement for Energy* (EN-1) (NPS EN-1).
RD16	Department of Energy and Climate Change. 2011. *National Policy Statement for Nuclear Power Generation* (EN-6) (NPS EN-6).
RD17	Delft University of Technology. 2017. *Simulating Waves Nearshore* (SWAN). http://swanmodel.sourceforge.net/
RD18	ARTEMIS wave propagation model, available on line from: http://www.opentelemac.org/index.php/presentation?id=19
RD19	Innovyze. 2017. Infoworks ICM (Integrated Catchment Modelling) v 5.7.7, available from: http://www.innovyze.com/products/infoworks_icm/
RD20	Lancaster, J.W., Preene, M. and Marshall, C.T. 2004. *Development and Flood Risk – Guidance for the Construction Industry* (C624). London: CIRIA.
RD21	Woods Ballard. B, Wilson S., Udale-Clarke H., Illman S., Scott T., Ashley R. and Kellagher R. 2015. *The SuDS Manual* (C753). London: CIRIA.

Appendix D8-4-1 Figures

FIGURE D8-4-1



Legend

- Power Station Site
- Main plant
- Preferred location of decommissioning waste storage and processing facilities
- Supporting facilities, buildings, structures and
- Power Station internal road layout
- Common plant

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

Client

HORIZON NUCLEAR POWER

Project

WYLFA NEWYDD PROJECT
FLOOD CONSEQUENCE ASSESSMENT

Drawing Title

POWER STATION SITE LAYOUT

Scale @ A3	1:12,000	DO NOT SCALE
Jacobs No.	60PO8077	
Client No.		
Drawing No.	60PO8077_DCO_VOL_D_APP_08_04_01	

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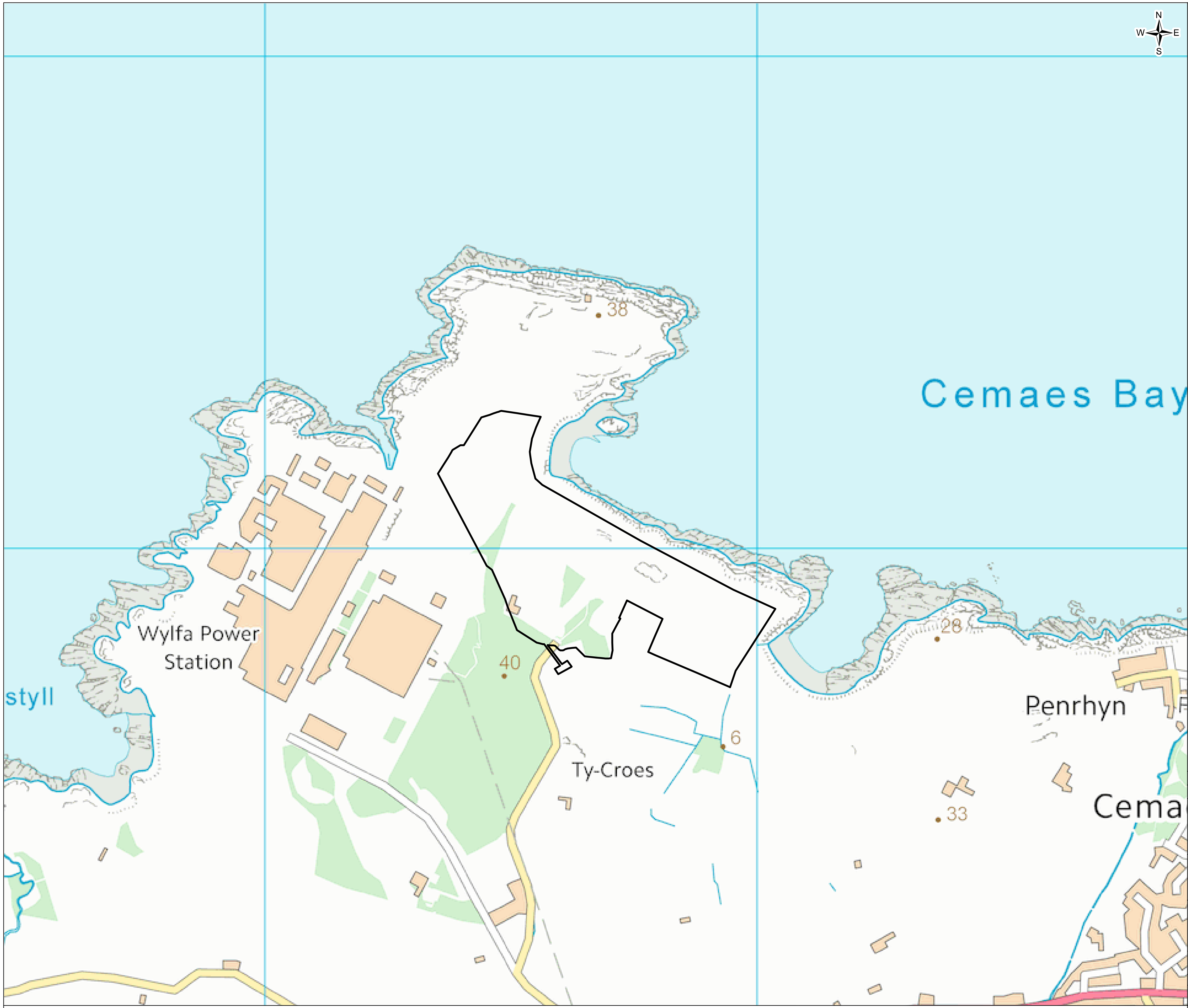
FIGURE D8-4-2



Legend

Site Campus

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

Client

HORIZON NUCLEAR POWER

Project

WYLFA NEWYDD PROJECT
FLOOD CONSEQUENCE ASSESSMENT

Drawing Title

SITE CAMPUS

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Jacobs No.	60PO8077	
Client No.		
Drawing No.	60PO8077_DCO_VOL_D_APP_08_04_02	

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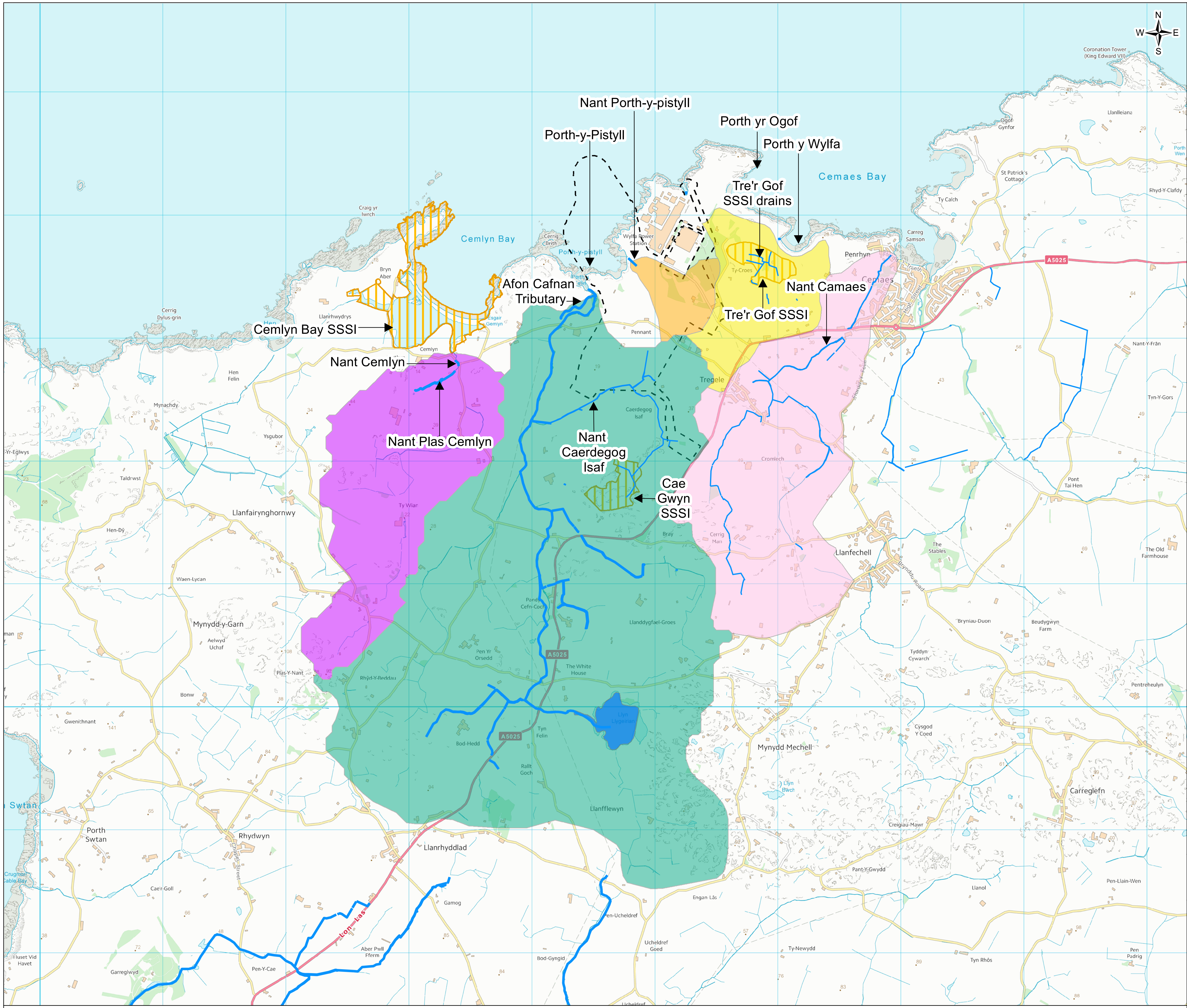
FIGURE D8-4-3



Legend

- Power Station Site
- Lacustrine WFD water body
- Main rivers
- Ordinary watercourses
- Afon Cafnan Catchment
- Cemaes Catchment
- Cemlyn Catchment
- Power Station Catchment
- Tre'r Gof Catchment
- Sites of Special Scientific Interest (SSSI)

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

Client: HORIZON NUCLEAR POWER

Project: WYLFA NEWYDD PROJECT FLOOD CONSEQUENCE ASSESSMENT

Drawing Title: POWER STATION SITE AND SURFACE WATER FEATURES

Scale @ A3: 1:30,000 DO NOT SCALE

Jacobs No.: 60PO8077

Client No.:

Drawing No.: 60PO8077_DCO_VOL_D_APP_08_04_03

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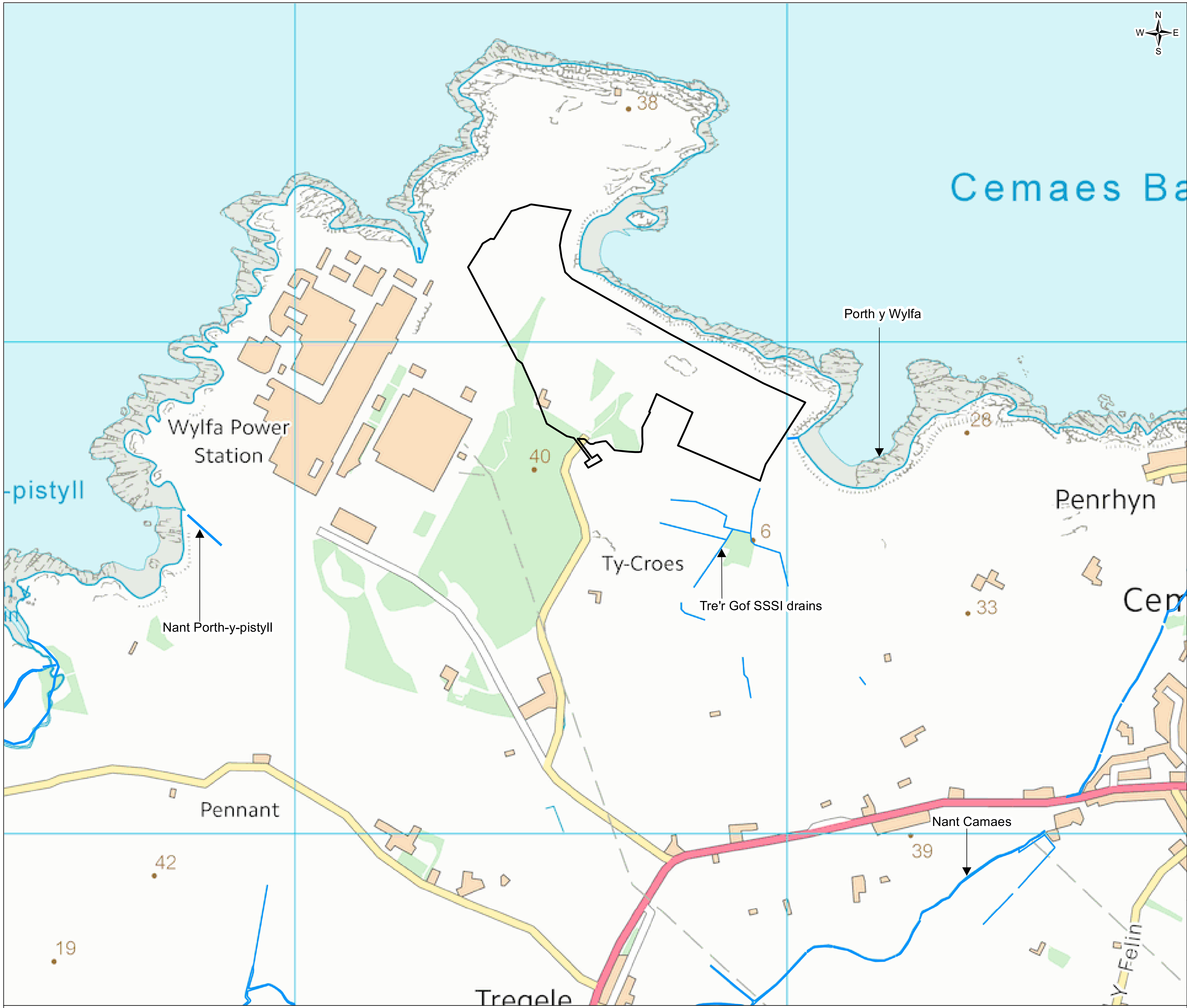
FIGURE D8-4-4



Legend
- Site Campus
- Main rivers
- Ordinary watercourses

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

Client
HORIZON NUCLEAR POWER

Project
WYLFA NEWYDD PROJECT
FLOOD CONSEQUENCE ASSESSMENT

Drawing Title
SITE CAMPUS SURFACE WATER FEATURES

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Client No.		
Drawing No.	60PO8077_DCO_VOL_D_APP_08_04_04	

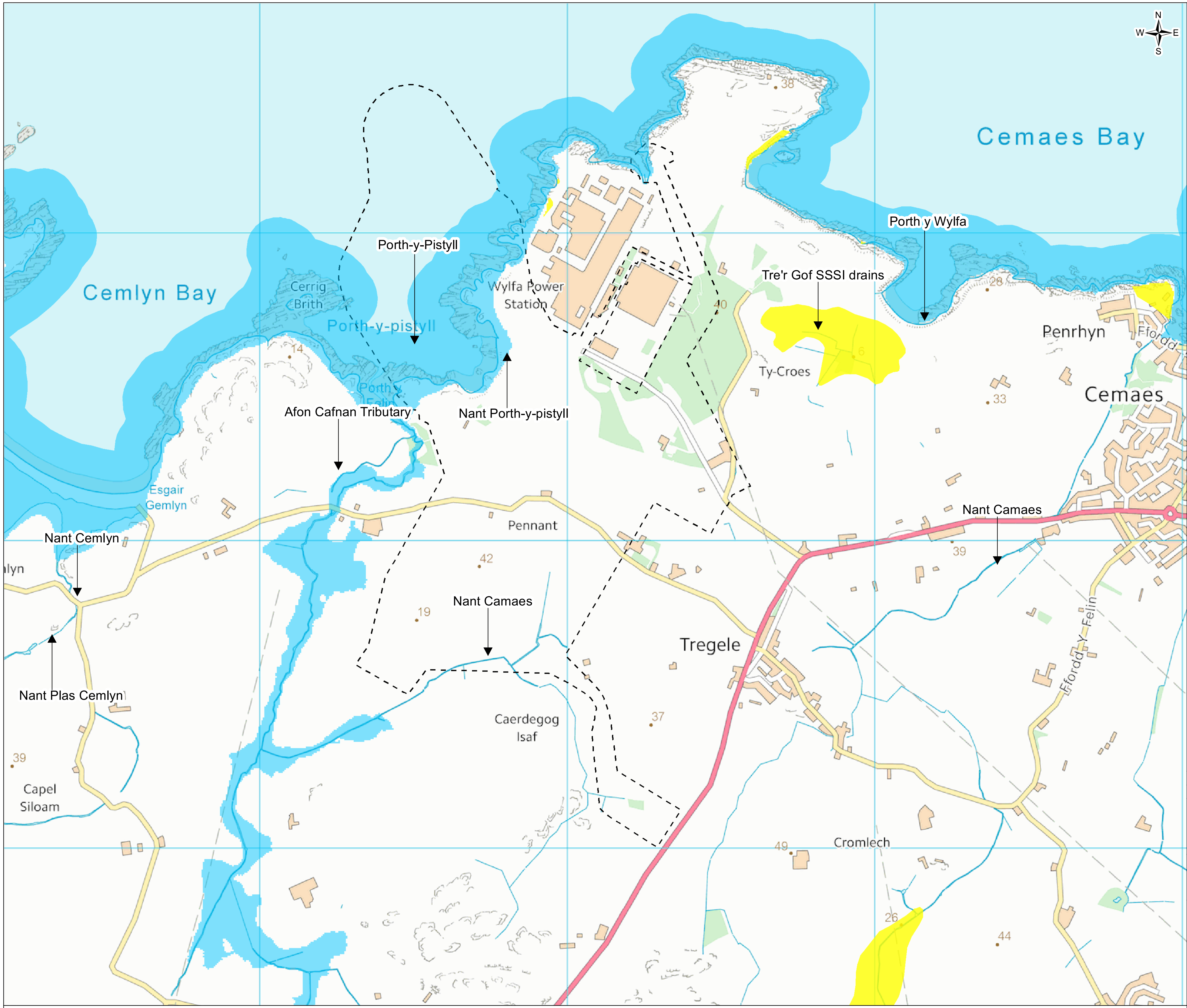

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FIGURE D8-4-5

Legend

- Power Station Site
- Flood Zone B
- Flood Zone C2

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Client

HORIZON NUCLEAR POWER

Project

WYLFA NEWYDD PROJECT
FLOOD CONSEQUENCE ASSESSMENT

Drawing Title

POWER STATION SITE LAYOUT
RISK OF FLOODING FROM RIVERS AND SEA

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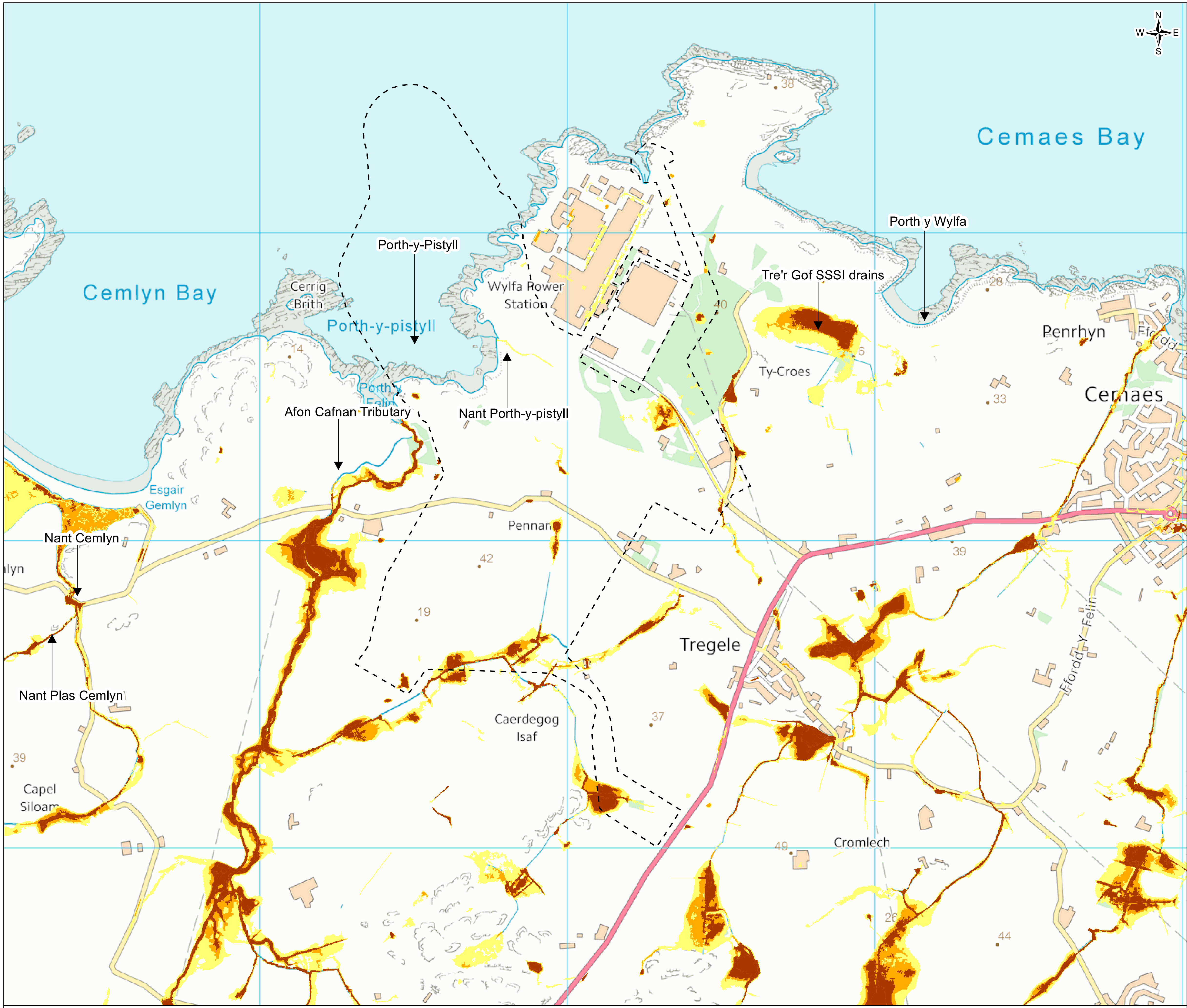
FIGURE D8-4-6



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0 50 100 200 300 400 500 Metres

Legend

- Power Station Site
- High surface water flood risk - extent
- Medium surface water flood risk - extent
- Low surface water flood risk - extent

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Client

HORIZON NUCLEAR POWER

Project

WYLFA NEWYDD PROJECT
FLOOD CONSEQUENCE ASSESSMENT

Drawing Title

POWER STATION SITE
RISK OF FLOODING FROM SURFACE WATER

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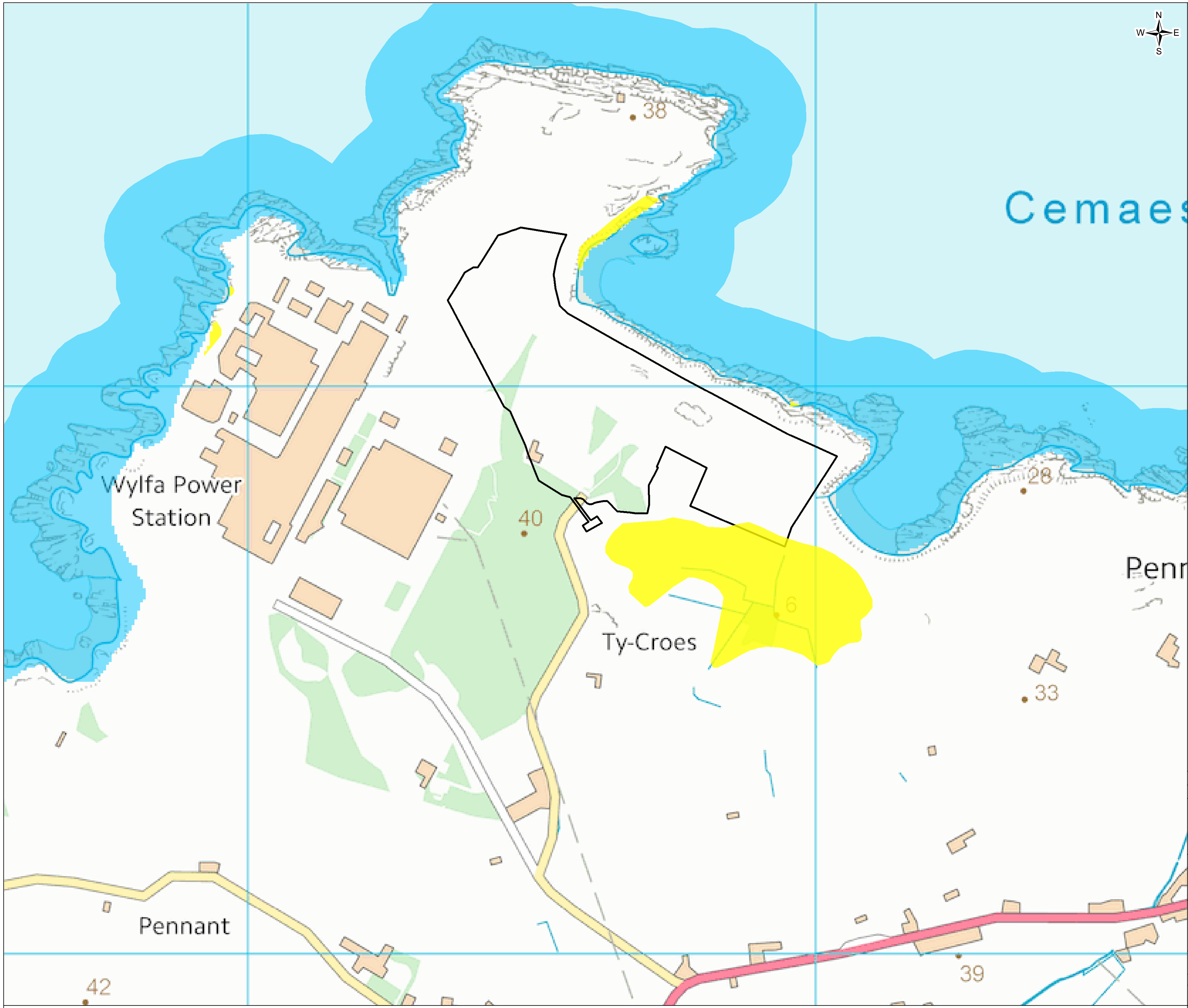

FIGURE D8-4-7

Legend

- Site Campus
- Flood Zone B
- Flood Zone C2

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

Client

HORIZON NUCLEAR POWER

Project

WYLFA NEWYDD PROJECT
FLOOD CONSEQUENCE ASSESSMENT

Drawing Title

SITE CAMPUS RISK OF FLOODING FROM RIVERS AND SEA

Scale @ A3	1:6,500	DO NOT SCALE
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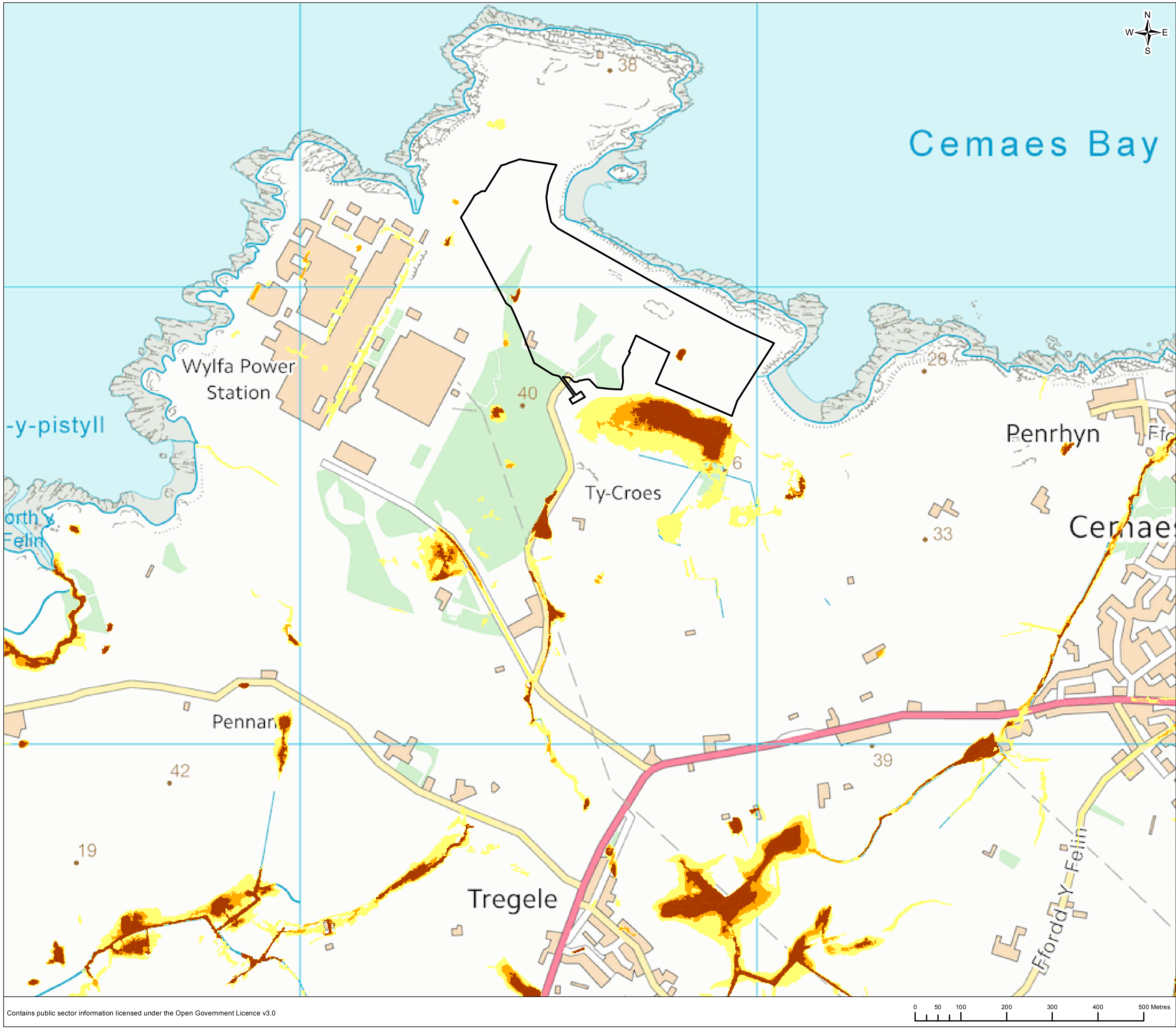
FIGURE D8-4-8



Legend

- Site Campus
- 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	RM	AJ	SH	RB

Client

HORIZON NUCLEAR POWER

Project

WYLFA NEWYDD PROJECT
FLOOD CONSEQUENCE ASSESSMENT

Drawing Title

SITE CAMPUS RISK OF FLOODING FROM SURFACE WATER

Scale @ A3	1:8,000	DO NOT SCALE
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Client No.		
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Appendix D8-4-2 Assessment methodology

Assessment methodology

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 [RD20]. The key to the classification is that the designation of flood 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 (i.e. the potential 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

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 D8-4-20.

Table D8-4-20 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 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

To classify the severity of the potential 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.

Given this, the severity of the potential flooding (hazard) is then ranked in terms of its magnitude as shown below in table D8-4-21.

Table D8-4-21 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

The magnitude of the hazard and the sensitivity of the receptor are combined using a matrix (shown below in table D8-4-22) to determine the significance of the potential effect, if realised.

Table D8-4-22 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

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 classifications used for defining the likelihood of a potential effect occurring are as shown below in table D8-4-23.

Table D8-4-23 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 would ever arise.

It should be noted that in circumstances where sites have 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, age, condition, maintenance, exposure and other external pressures.

Risk assessment

Once the significance of the potential effect and likelihood of occurrence have been assessed, these are then combined using a risk matrix (table D8-4-24) to assess the flood risk of each potential effect.

Table D8-4-24 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

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, as set out in chapter B8 (Application Reference Number: 6.2.8) and additional mitigation measures would be required to facilitate development.

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.

Appendix D8-4-3 Wave modelling report

HR Wallingford
Working with water

Wylfa Newydd

Main site wave modelling

DEM7943-RT004-R04-00

February 2018

Summary

HR Wallingford undertook wave modelling and associated extremes analysis, climate change assessment and estimation of overtopping rates, during the recent Nuclear Safety, Meteorological and Hydrological Hazards Assessment (NSMHHA, Amec, 2015) for Wylfa Newydd. HR Wallingford subsequently undertook detailed wave modelling during the recent Phase 1 study, including calibration of a SWAN wave model against measured wave data. The model and results then served as a baseline starting point, without the presence of Wylfa Newydd structures and without allowances for climate change.

The present study includes the Wylfa Newydd marine structures, future climate change scenarios and new nearshore wave prediction points. It is intended primarily to support environmental impact assessment and environmental permits. However, some parts are relevant to studies related to design of structures, sea defences and the proposed harbour at Wylfa. The scope of work includes wave overtopping rate calculations in addition to wave modelling, analysis, reporting and discussion.

The purpose of the present study is to address the wave modelling, analysis and results required for environmental and permitting issues. These issues include coastal processes, and any impacts caused by the Wylfa Newydd developments, although such impact studies are themselves outside the scope of this report. The permissions comprise the Marine Licence (ML), Development Consent Order (DCO), Habitats Regulations Assessment (HRA), Environment Impact Assessment (EIA) and Flood Consequence Assessment (FCA).

An earlier Phase 1 study produced results designated Offshore, meaning offshore of the proposed Wylfa Newydd structures. The present study, the results of which are designated Nearshore, introduces the Wylfa Newydd structures, the climate change scenarios and extremes analysis for multiple nearshore points.

A SWAN wave transformation model was used to assess wave conditions close to the site. The SWAN model area includes all of the north coast of Anglesey, and was used to transform a 35-year time series of offshore wave data to equivalent information at ten nearshore points. It was run for three layouts (baseline, developed and part-built), and for three future climate changed scenarios in addition to present-day. The wave modelling provides wave climate information. Sensitivity tests including one additional construction layout are also presented.

An ARTEMIS model was used to assess wave disturbance within the harbour area. It was run to transform joint exceedence wave and sea level extremes from its boundary to positions within the harbour at which overtopping rates are estimated.

The main topics of this report are the inclusion of marine structures and climate change scenarios into existing wave models, nearshore wave predictions at points within a finer nearshore grid, summary wave climates and extremes, the joint probability of large waves and high sea levels, and overtopping rate estimation.

Contents

Figures

Tables

1. Introduction

1.1. Background

HR Wallingford undertook wave modelling and associated extremes analysis, climate change assessment and estimation of overtopping rates, during the flood hazard assessment (NSMHHA, Amec, 2015) for Wylfa Newydd. HR Wallingford subsequently undertook further wave modelling during the Phase 1 study, including calibration of a SWAN wave transformation model against measured wave data. The model and results then served as a baseline starting point, without Wylfa Newydd structures and without allowances for climate change and uncertainty, for any subsequent wave modelling studies for Wylfa Newydd. This study therefore produced results designated "Offshore", meaning offshore of the proposed Wylfa Newydd structures.

Amec Foster Wheeler Environment & Infrastructure UK Limited requested the present update of the earlier wave modelling and analysis, based on the latest harbour layout plans and focusing on results specifically required for use in other studies. This includes model outputs to support the Marine Licence (ML), Development Consent Order (DCO), Habitats Regulations Assessment (HRA), Environment Impact Assessment (EIA) and Flood Consequence Assessment (FCA).

The SWAN model area includes all of the north coast of Anglesey, and was used to transform the 35-year time series of offshore wave data to equivalent information at ten nearshore points. It was run for three layouts (baseline, part-built and fully-built), and for three future climate-changed scenarios in addition to present-day. The wave modelling provides wave climate information to coastal process and environmental impact assessments. In addition, a further construction layout configuration, representing a larger structure footprint from an environmental perspective has been modelled as a sensitivity test.

An ARTEMIS wave model is also used to assess wave disturbance within the harbour area. It was run to transform joint exceedence wave and sea level extremes from its boundary to positions within the harbour at which overtopping rates were estimated.

1.2. Scope of Work

Update earlier wave modelling and analysis to provide results for the baseline, and for the fully-built and part-built harbour layouts. Use a two-stage modelling approach, consisting of:

- A spectral coastal area transformation model (SWAN), to transform offshore waves to nearshore locations around the proposed harbour layout;
- A local phase-resolving wave disturbance model (ARTEMIS), to generate wave conditions inside the harbour.

This combined modelling approach is required to provide nearshore time series, extreme wave conditions, high-water joint probability for waves and sea levels, and wave overtopping rate estimates at nearshore locations around and inside the proposed harbour to support the ML, DCO, HRA/EIA and FCA. Provide results for several combinations of harbour layout and climate-changed conditions, including changes in wave conditions that would be caused by construction of the harbour.

1.3. Coordinate systems

The horizontal coordinate system used in this report is British National Grid. The model vertical datum is Chart Datum (CD) at Cemaes Bay, which is 3.6m below Ordnance Datum (OD).

1.4. Structure of report

Chapters 2 and 3 introduce the revised harbour layouts and climate-changed scenarios, respectively. Chapters 4, 5 and 6 describe the SWAN, ARTEMIS and overtopping rate modelling and results, respectively.

2. Marine structure layouts

The marine harbour design layouts are based on RHDHV's 400m-option Western Breakwater design layouts. The description of the fully-built and part-built layouts is given below.

2.1. Part-built layout

The part-built layout and dredging plan used in the wave model were extracted from the drawing *PB6454-300-007* supplied for the study by RHDHV (Figure 2.1). Features of the layout include:

- Partially-built Western breakwater:
  - The first 300m from the cofferdam built up to create a haul road along the crest. The crest elevation of the structure is +4m AOD with a width of 14m. The side slopes are 1 in 1.33 and will be protected with concrete armour units (Xbloc);
  - The last 100m submerged rubble mound with a crest level of -4.5mAOD.
- Causeway in place joining the Western breakwater to the coast.
- The cofferdam in place with a crest level of +5mAOD.
- The crest length of the Eastern breakwater is approximately 150m long, with shore protection connecting the structure and the shoreline, and side slopes of 1:4/3.
- The design bed level within the harbour is -10mAOD.
- The MOLF consists of two berths, made of a vertical block wall structure fronted by mooring and berthing dolphins.
- The rock revetment along the MOLF quay has a slope of 1 in 1.5, and a crest elevation of +5mAOD.
- The berth pocket along Berths 1 and 2 is dredged to -11.9mAOD.

In addition, a sensitivity test was carried out to represent the effect of a 'worst-case' construction layout in terms of changes to waves. This layout included the full Western Breakwater but with the cofferdam and causeway still in place. Results from this layout are presented in Section 4.5.7.

2.2. Fully-built layout

The fully-built layout and dredging plan used in the wave model were extracted from the drawing *PB6454-300-008* supplied for the study by RHDHV (Figure 2.2). Features of the layout include:

- The Western breakwater is 400m long, comprising a 300m southern element unconnected to the coast and oriented approximately NNE-SSW and a 100m northern element oriented North-South.
- The crest length of the Eastern breakwater is approximately 150m long, with shore protection connecting the structure and the shoreline, and side slopes of 1:4/3.
- The design bed level within the harbour is -10mAOD.
- The MOLF consists of two berths, made of a vertical block wall structure fronted by mooring and berthing dolphins.
- The berth pocket along Berths 1 and 2 is dredged to -11.9mAOD.
- The rock revetment along the MOLF quay has a slope of 1 in 1.5, and a crest elevation of +5mAOD.
- The Eastern and Western breakwaters are fully-built, with:
  - Side slopes of 1:4/3;
  - The crest elevation of the Western breakwater varies between +10.7mAOD and +11.6mAOD;
  - The crest elevation of the Eastern breakwater is +11.1mAOD.

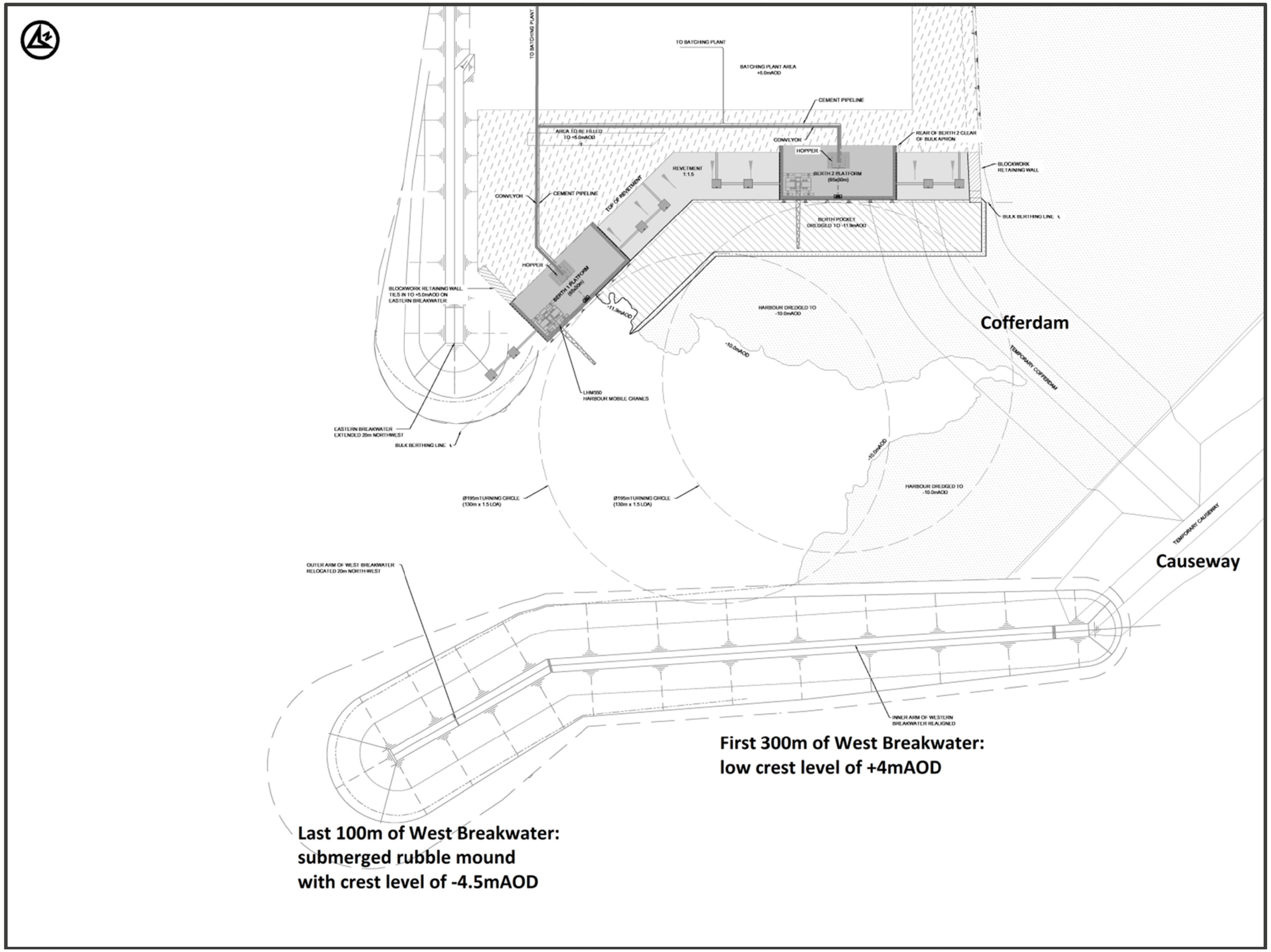


Figure 2.1: Part-built layout, 400m Western breakwater case, based on RHDHV PB6454-300-007 drawing

Source: RHDHV

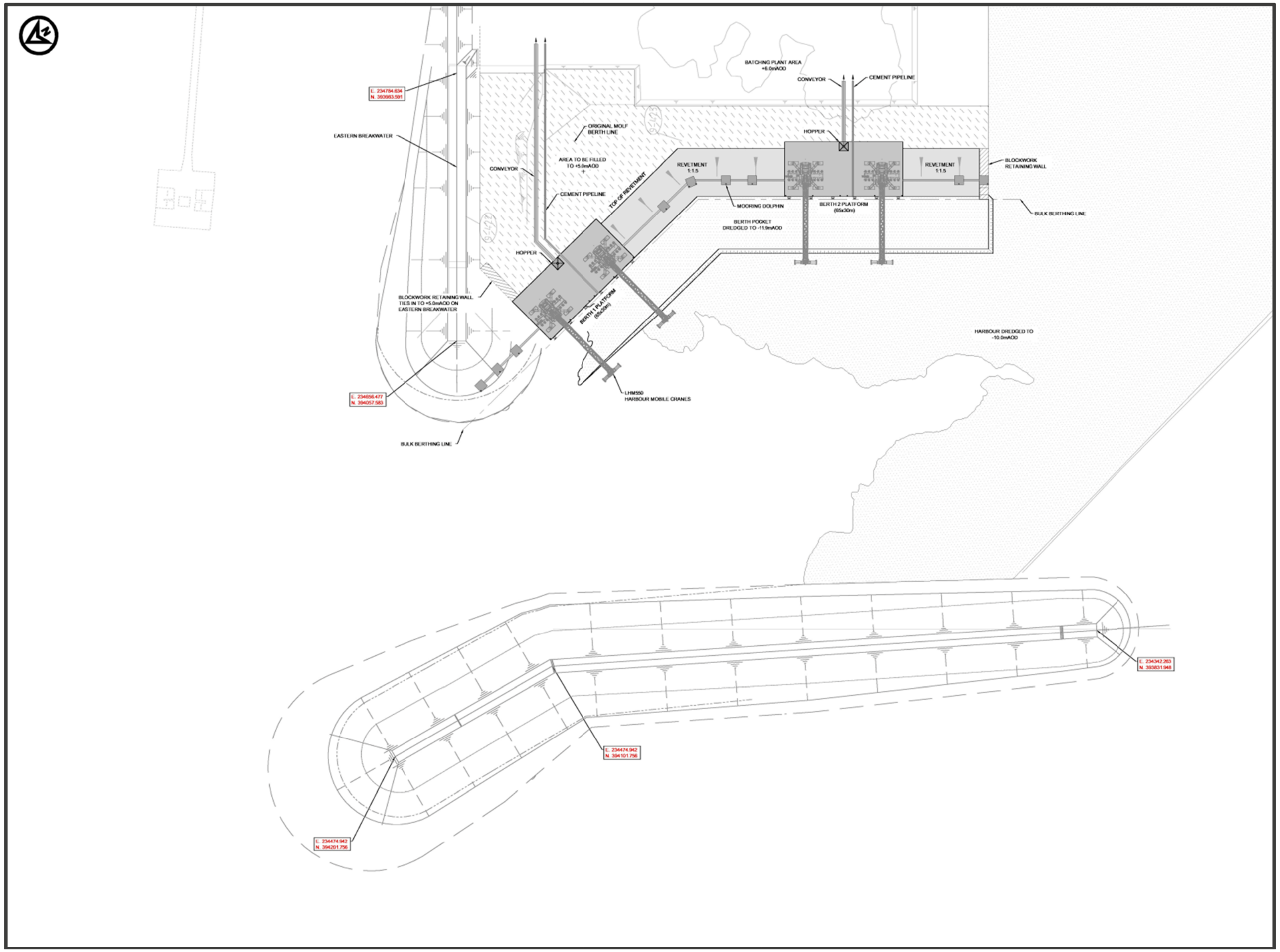


Figure 2.2: Fully-built layout, 400m Western breakwater case, based on RHDHV PB6454-300-008 drawing

Source: RHDHV

3. Climate-changed scenarios

3.1. Introduction

Two future scenarios are considered, representing “reasonably foreseeable” and “credible maximum” conditions. Present-day is taken as 2023. The future date of 2087 is taken to represent the end of power generation and 2187 to represent the end of de-commissioning. Metocean variables relevant to wave, sea level and overtopping prediction, potentially subject to future climate change, are mean sea level, surge, wave height (and period) and wind speed.

In addition to present-day, three of the four combinations of scenario and future date were applied to wave modelling for the baseline and fully-built layouts. Only the present-day scenario is relevant for the part-built layout.

The general approach to representation of climate-changed scenarios was originally developed during the NSMHHA flood hazard study (HR Wallingford, 2013; Amec, 2015). NSMHHA reviews several sources of extreme sea level and climate change information and several regulatory documents. For the purposes of the extreme sea levels derived in NSMHHA, the base date was taken to be 2008. The reasonably foreseeable scenario was based on the 95%ile (upper) projections for the Medium Emissions scenario of UKCP09 (United Kingdom Climate Impacts Program, 2009). The credible maximum scenario was based on the High plus plus approach of UKCP09. The present study bases its reasonably foreseeable case, instead, on more recent Welsh government (2016) advice on future climate change allowances.

3.2. Development of the appropriate allowances

3.2.1. Reasonably foreseeable

Figure 3.1, reproduced from Welsh government (2016), summarises how future sea level rise allowances should be developed. The 3.5mm/year rate of rise 2009-2025 is only fractionally higher than the present globally-averaged measured rate of rise, but the rapid increases from 2026 are fractionally higher than the highest (95%ile High Emissions) projections in UKCIP (2009).

Period	***2009-2025***	***2026-2055***	***2056-2085***	***2086-2116***	***Cumulative rise to 2116***
Annual change (mm/yr)	3.5	8.0	11.5	14.5	
Total increase	59.5 mm	240mm	345mm	449.5mm	1094mm

Figure 3.1: Welsh government (2016) advice on future mean sea level rise allowances

Source: Image from Welsh government (2016); later in the same document it is noted that 14.5mm/year should continue to be used beyond the 2116 end date

As the primary source of the present-day extreme high sea levels used for Wylfa Newydd is the Environment Agency (2011) coastal boundary conditions report, the base year, and hence the start date for climate change adjustment, is 2008. Based on Figure 3.1, the “reasonably foreseeable” future sea level rise allowances from 2008 to 2023, to 2087 and to 2187 are 0.05m, 0.67m and 2.12m, respectively.

3.2.2. Credible maximum

The “High plus plus” source information (UKCIP, 2009) is summarised as a possible rise in mean sea level of 0.93-1.90m between 1980-1999 and 2095, with the possibility of an additional one metre of surge for extreme conditions. As in NSMHHA, the mean sea level rise amount is doubled for the period 2008 to 2187, and for the new period of 2008 to 2087, both components are factored down by 20% to reflect the end of generation date (from 2103 to 2087). In keeping with the “credible maximum” concept, only the top end of the range of possible mean sea level rise was adopted for the purpose of this assessment. The allowances used the study are summarised in Table 3.1.

3.2.3. Waves and winds

Projections of future wave climate suggest very little change from present-day, but a 10% increase in wave heights is often recommended as a precautionary allowance (for example NSMHHA, Amec, 2015). This 10% increase (and a corresponding 5% increase in wave periods) is applied in all the climate-changed scenarios considered here.

3.3. Appropriate allowances and the resulting sea levels

Table 3.1 summarises the climate change allowances to be used here, between 2008 and 2087, and between 2008 and 2187, appropriate to each scenario to be considered; also, for the reasonably foreseeable scenario only, the adjustment from 2008 to 2023. (Although the 2187 credible maximum scenario is not used within the present report, it is included here for completeness as it has been used in some of the earlier Wylfa Newydd wave modelling reports.) “Commonly occurring” (implying no significant surge component) was taken to refer to sea levels up to Mean High Water Springs, and “extreme” to refer to levels with a return period of 50 years or more. A sliding scale was applied between those two levels, meaning that the 1-year and 10-year levels would take 66% and 87%, respectively, of the extra surge allowance.

Table 3.1: Summary of climate-changed scenarios and allowances considered: between 2008 and 2023 (reasonably foreseeable only); between 2008 and 2087; and between 2008 and 2187

Future scenario	Add (metres) to commonly occurring sea levels			Add (metres) to extreme sea levels			Add (%) to offshore wave heights and wind speeds		
	2008 to 2023	2008 to 2087	2008 to 2187	2008 to 2023	2008 to 2087	2008 to 2187	2008 to 2023	2008 to 2087	2008 to 2187
‘reasonably foreseeable’	0.05	0.67	2.12	--	--	--	0	10%	10%
‘credible maximum’	--	1.5	3.8	--	2.3	4.8	--	10%	10%

Source: Based on Welsh government (2016) and UKCIP (2009); plus interpretation developed in HR Wallingford (2013) and Amec (2015)

Note: Ranges are given for the credible maximum sea level rise in the source document (UKCIP, 2009, but only the upper limit of the range is used in the wave modelling.

The three climate-changed cases used in this report were taken to have 0.67, 2.12 and 1.5 higher mean sea levels than in 2008 (and the 2187 credible maximum, not used here, would have 3.8m higher mean sea level), each with all offshore wave heights and winds increased by 10% (and wave periods increased by 5%). (The additional surge component of climate-changed sea level was added, where appropriate, during subsequent joint probability analysis.)

Extreme sea levels for a base year of 2008 listed in the top row of Table 3.2 are taken from NSMHHA, which took them from Environment Agency (2011). These are increased by 0.05m, 0.67m, 2.12m, 2.3m and 4.8m, respectively (slightly less for the 1 year level as it does not take the full surge allowance) to represent the five climate-changed cases of interest. Again, these were not used in the SWAN wave climate modelling (which used the MHWS levels also listed in Table 3.2) but were introduced, where appropriate, into the subsequent extremes and joint probability analysis.

Table 3.2: Summary MHWS and extreme sea levels for Wylfa

Scenario	Sea level (m ODN) for given scenario and return period (years)						
	MHWS	1	50	100	200	1000	10000
"EA3" (2008)	N/A	3.81	4.23	4.30	4.36	4.50	4.67
"Present-day" (2023)	3.05	3.86	4.28	4.35	4.41	4.55	4.72
2087, reasonably foreseeable	3.67	4.48	4.90	4.97	5.03	5.17	5.34
2187, reasonably foreseeable	5.12	5.93	6.35	6.42	6.48	6.62	6.79
2087, maximum credible	4.50	5.84	6.53	6.60	6.66	6.80	6.97
2187, maximum credible	6.80	8.27	9.03	9.10	9.16	9.30	9.47

3.4. Combinations of harbour layout and climate-change

The following seven combinations of harbour layout and climate change are considered in this report:

- Baseline, 2023 "present-day" conditions;
- Baseline, 2087 "reasonably foreseeable" conditions;
- Part-built layout, 2023 "present-day" conditions;
- Fully-built layout, 2023 "present-day" conditions;
- Fully-built layout, 2087 "reasonably foreseeable" conditions;
- Fully-built layout, 2087 "credible maximum" conditions;
- Fully-built layout, 2187 "reasonably foreseeable" conditions.

The 'credible maximum' condition was derived to provide a bounding case to support the FCA. The FCA is primarily concerned with conditions within the Harbour, not the wider environment. As such the 'credible maximum' scenario was only run through the ARTEMIS wave disturbance model (the model used for conditions inside the harbour) presented in Section 5.

All other assessments (HRA and EIA) required 'reasonably foreseeable' estimates of climate change to be modelled.

4. Wave conditions outside the harbour

The existing Phase 1 SWAN wave model was taken as the starting point. The model covers the northern half of Anglesey, to about ten kilometres offshore. It includes four nested model grids giving increasing spatial resolution nearer to Wylfa.

The 20m inner model grid was extended both westward and eastward to provide more detail in Cemaes and Cemlyn Bays. As the model changed slightly from the version validated during Phase 1, the wave model validation against wave measurements close to Wylfa was repeated using the refined model. The Wylfa Newydd marine structures and future climate-changed sea conditions were introduced into the model. Nearshore wave conditions are summarised at ten nearshore locations for relevant baseline, part-built and fully-built layouts, and for present-day and for relevant climate-changed conditions.

The purposes of the modelling were to provide wave climates at positions of direct interest in other studies and reports being prepared for regulatory approvals. Results include changes in nearshore wave conditions resulting from the Wylfa Newydd structures, and boundary conditions to a local wave disturbance model of the area immediately around the harbour.

A note on the local wave parameters used in this report

In all cases, significant wave height, mean wave period and mean wave direction are energy-averaged over all frequency and direction components of the wave energy spectrum, at the particular wave prediction point and for the particular layout and climate change scenario which they represent. As waves propagate from offshore to inshore, they can change direction, tending to become more normal to the bed contours. Where a headland or structure either provides an obstacle to wave propagation and/or generates a reflected component of wave energy, mean wave direction can change suddenly. In assessment of changes in wave height caused by introduction of structures, it would be fair to compare individual wave conditions, or to compare the overall distribution of wave height, before and after construction, but not to compare the distribution of wave height within an individual direction bin because individual wave conditions may move between bins.

4.1. The SWAN wave model

As waves propagate towards the site they are modified by the processes of depth refraction and shoaling as they travel through increasingly shallow water. Wave models that simulate the nearshore wave transformation processes are well established and for the present study the SWAN (Simulating WAves Nearshore, Booij et al., 1999) model has been used.

SWAN is a 3rd generation spectral wave model which simulates the transformation of random directional waves considering the following processes:

- Wave shoaling;
- Wave refraction by the bathymetry and by currents;
- Wave blocking by currents;
- Depth-induced breaking, bottom friction and whitecapping;
- Wave growth due to the wind;
- Wave reflections from structures or rocky shorelines;
- Far-field wave diffraction around headlands.

The SWAN model has been extensively validated and is suited to the transformation of wave energy spectra in relatively large coastal areas. This is particularly true where the features of the seabed, such as offshore banks and reefs, result in depth-induced wave breaking and wave-wave interactions. The model also includes wave generation by the wind within the model area. SWAN is, therefore, especially useful in regions such as the shallow area near to the site where wave conditions may comprise a combination of refracted offshore waves and those generated locally by winds. More details of the SWAN model are given in Appendix B.

4.1.1. Application of the SWAN model to Wylfa

The SWAN model was set up to represent wave propagation from offshore. Four nested grids were used:

- The outer grid (Grid 1) covers a wide area approximately 29km x 53km offshore and along the coasts, at a grid resolution of 500m;
- The second grid (Grid 2), further inshore, at a grid resolution of 200m;
- The third grid (Grid 3) covers an area further inshore at a grid resolution of 50m;
- The inner grid (Grid 4) covers the area near the site with a grid resolution of 20m.

The model bathymetry was defined using information obtained from SeaZone TruDepth bathymetry data, supplemented with the local survey data supplied for the study (HR Wallingford, 2013). The data sets were reviewed and corrected to Chart Datum and then merged to provide the model bathymetry used in SWAN. The resulting bathymetry has been incorporated into the model grids.

The extent of the model, arrangement of its four grids, and the positions at which results were summarised in Phase 1, are shown in Figure 4.1.

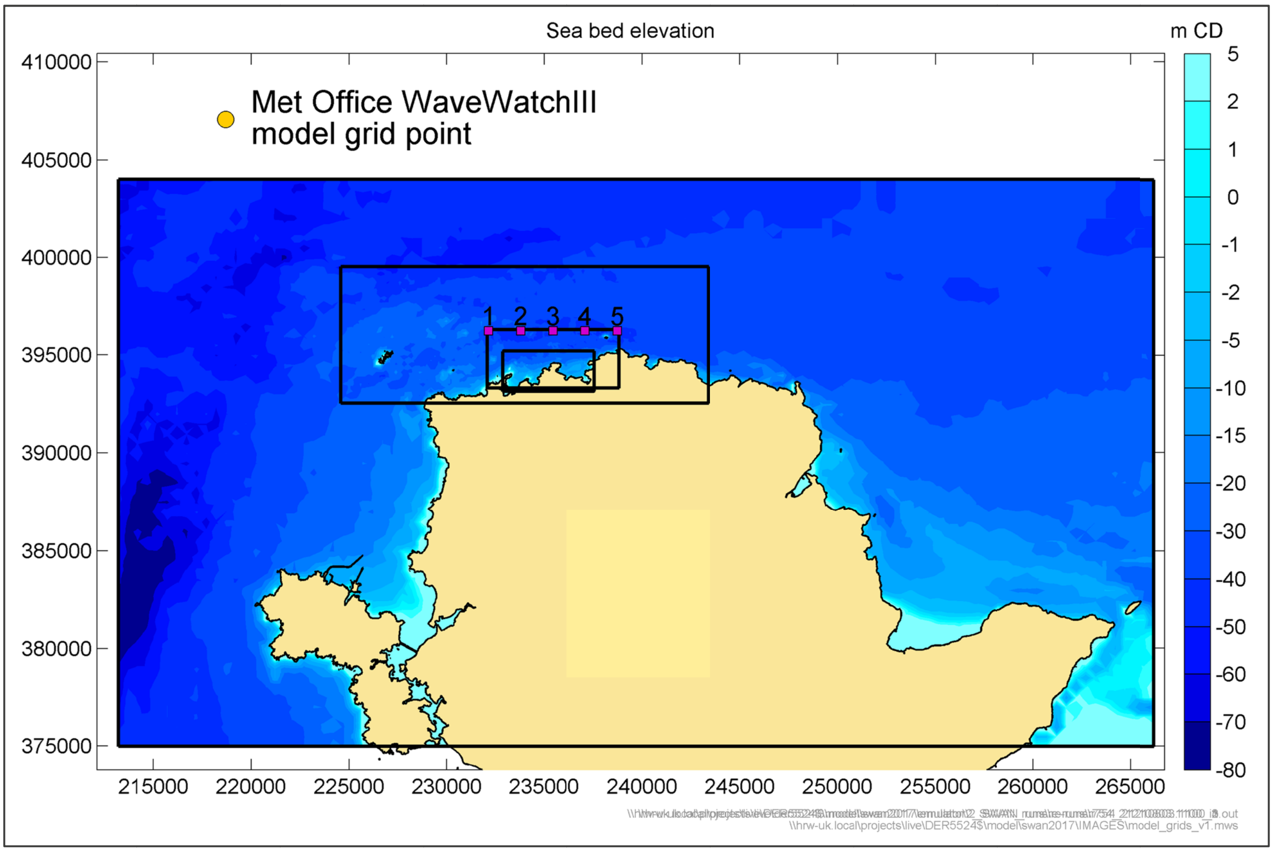


Figure 4.1: Extent of the SWAN wave model outer (500m) grid, also showing its three inner (200, 50 and 20m) grids and Points 1 to 5 at which results were summarised during Phase 1

Source: HR Wallingford

4.1.2. Boundary conditions

The SWAN model was run applying offshore waves, obtained from the 35-year WaveWatchIII Met Office wave and wind model, along the seaward boundary and forced with coincident wind conditions applied spatially uniformly across the whole model domain. The SWAN model was run both for a constant high sea level and for realistically varying tidal sea levels.

4.1.3. Reflection coefficients

The reflection properties of the boundaries were represented in the SWAN model by assigning an appropriate reflection coefficient to each of the boundary types within the model. A reflection coefficient of 1.0 would indicate that all the incident wave energy will be reflected, while a lower reflection coefficient would indicate that some wave energy will be dissipated.

Appropriate wave reflection coefficients were defined for the coastline, breakwaters, quays and other structures depending upon the form of the structures and the wave conditions (Allsop, 1990). The reflection coefficients used for the study are summarised in Table 4.1. Reflections were applied only within the inner model grid.

Table 4.1: Reflection coefficients used in the SWAN model

Boundary types	Reflection coefficient
Rocky coastline	0.4
Beach coastline	0.2
Breakwater (1:4/3 slope)	0.45
Vertical structures along the quays	0.95
Cofferdam (1:1.5 slope)	0.35

4.1.4. Transmission coefficients

In the part-built layout (Figure 2.1), the Western breakwater is partially constructed with a crest elevation of +4mAOD. The difference between the crest level and the present-day MHWS water level is only one metre. Therefore, the breakwater was represented as a partially transmissive structure in the SWAN model.

The wave transmission coefficient was estimated based upon the wave conditions incident on the breakwater and an empirical relationship derived from a physical model database (HR Wallingford, 2009). A transmission coefficient of 1.0 would indicate full transmission. The transmission coefficient used in the model for the partially constructed Western breakwater is 0.35, which is a relatively conservative estimate of transmission for the MHWS present-day conditions.

4.2. Model validation

The model was calibrated and validated against wave measurements at four locations within the two inner model grids during Phase 1 (HR Wallingford, 2015). The approach to wave model validation is that developed, applied and published during a recent National Flood Risk Assessment (NaFRA) State of the Nation in 24 regions covering the whole coast of England (HR Wallingford, 2015b).

The model validation was based upon comparisons between measured and modelled storm peak wave conditions for 18 selected storms for which measured wave conditions are available at some or all of four locations (S2, S4, S9 and S11; see Figure 4.2). The time-varying wind velocity, sea level and spectral representation of the wave conditions were used for each storm. The period of the measurements was generally rather calm (HR Wallingford, 2013; Amec, 2015). The selected storms include a set of winter and summer conditions, covering a range from approximately 1 year return period conditions down to 10 to 20 times a year conditions.

4.2.1. Validation against peak storm events

As the present study is intended primarily to investigate the environmental impact of the schemes, reflection from the coastline is now included in the model. Therefore, the model validation was repeated for the new model (for the baseline case) to ensure its performance was unchanged from Phase 1. The model was run for the selected storms with the same model settings. Table 4.2 to Table 4.5 compare measured (where available) and modelled storm peak wave conditions for each of the eighteen storms. Model validation results are very similar to those of Phase 1 and, if anything, are fractionally improved for S4 and S11.

Comparing with the validation statistics of the NaFRA State of the Nation study for wave height and wave period, the Root Mean Square Error statistics in Table 4.2 to Table 4.5 fall within the range of the best 12 of the equivalent 24 State of the Nation results for wave height, and within the overall range for wave period. In addition, Section 4.5.3 of Environment Agency (2016) refers to the NaFRA State of the Nation wave models as being of an appropriate standard for use in wave forecasting, and provides criteria against which the accuracy of other models can be judged. The validation results for wave height summarised in Table 4.2 to Table 4.5 meet the criteria of the highest accuracy category for wave height for all four measurement sites, and for wave period for three of four measurement sites (the fourth meeting the criteria of the second accuracy category).

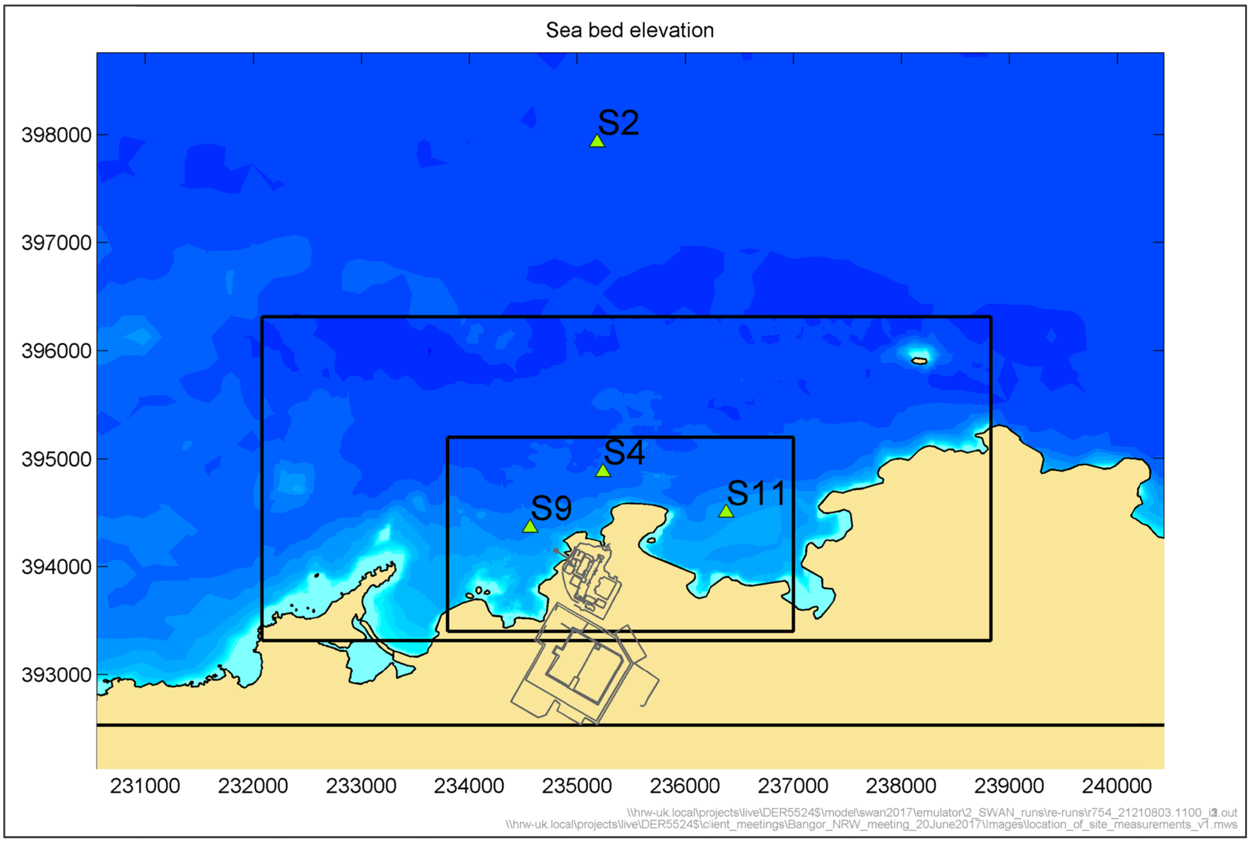


Figure 4.2: Location map for Horizon wave measurements close to Wylfa

Note: The locations of S2, S4, S9 and S11, marked by green triangles on the map, are approximate, as the exact positions varied between successive 3-4 month deployments.

Table 4.2: Validation of the SWAN model for storm peak wave conditions at S2

Storm No.	S2 measured storm peaks			S2 modelled storm peaks		
	H_s (m)	T_m (s)	D_m (°N)	H_s (m)	T_m (s)	D_m (°N)
2	2.59	5.4	331	2.36	5.1	345
4	3.14	5.8	42	2.82	5.5	14
5	2.45	5.2	1	2.12	4.8	343
6	2.14	5.3	254	2.47	4.5	206
8	2.93	5.8	44	2.51	5.2	14
9	3.25	5.6	295	3.65	6.1	344
10	2.46	5.8	271	2.6	4.8	246
11	2.59	5.0	254	3.1	5.3	250
12	3.33	5.4	243	3.23	5.5	264
14	2.99	6.2	268	2.62	5.3	287
15	3.06	5.9	274	3.16	5.6	270
16	3.17	5.9	280	3.28	5.7	258

Storm peak summary statistics		
H_s (m)	Bias: mean of model error	-0.02
	MAE: mean absolute error	0.28
	RMSE: root mean square model error	0.31
	Std. error: standard deviation model error	0.31
	MAD: median absolute deviation	0.32
T_m (s)	Bias: mean of model error	-0.32
	MAE: mean absolute error	0.48
	RMSE: root mean square model error	0.56
	Std. error: standard deviation model error	0.46
	MAD: median absolute deviation	0.39

Source: HR Wallingford

Table 4.3: Validation of the SWAN model for storm peak wave conditions at S4

Storm No.	S4 measured storm peaks			S4 modelled storm peaks		
	H_s (m)	T_m (s)	D_m (°N)	H_s (m)	T_m (s)	D_m (°N)
2	3.05	5.8	308	2.41	5.1	346
3	2.89	5.8	281	2.78	5.5	284
4	3.09	5.5	28	2.83	5.5	15
5	2.44	5.1	16	2.18	4.9	343
7	4.18	6.2	289	4.73	6.9	285
8	3.08	5.8	43	2.55	5.2	15
9	3.02	5.5	326	3.67	6.2	345
10	2.05	6.3	254	2.04	4.0	258
11	2.21	6.2	250	2.49	4.8	263
12	3.39	6.7	269	2.97	5.3	285
15	2.90	5.7	297	2.59	5.1	289
16	2.64	6.2	262	2.44	4.9	287

Storm peak summary statistics		
H_s (m)	Bias: mean of model error	-0.10
	MAE: mean absolute error	0.35
	RMSE: root mean square model error	0.40
	Std. error: standard deviation model error	0.39
	MAD: median absolute deviation	0.30
T_m (s)	Bias: mean of model error	-0.61
	MAE: mean absolute error	0.84
	RMSE: root mean square model error	1.04
	Std. error: standard deviation model error	0.84
	MAD: median absolute deviation	0.66

Source: HR Wallingford

Table 4.4: Validation of the SWAN model for storm peak wave conditions at S9

Storm No.	S9 measured storm peaks			S9 modelled storm peaks			Storm peak summary statistics		
	H_s (m)	T_m (s)	D_m (°N)	H_s (m)	T_m (s)	D_m (°N)	H_s (m)	Bias: mean of model error	0.18
1	1.76	4.9	360	1.90	4.7	337		MAE: mean absolute error	0.20
2	2.37	5.3	350	2.33	5.1	347		RMSE: root mean square model error	0.35
3	1.92	5.1	306	2.18	4.9	302		Std. error: standard deviation model error	0.30
4	2.54	5.1	18	2.70	5.5	12		MAD: median absolute deviation	0.09
5	2.13	5.1	355	2.12	4.9	345	T_m (s)	Bias: mean of model error	-0.40
6	1.05	5.6	348	1.10	3.1	299		MAE: mean absolute error	0.67
7	3.10	5.5	294	3.62	6.2	307		RMSE: root mean square model error	0.90
8	2.45	5.5	21	2.44	5.2	12		Std. error: standard deviation model error	0.81
9	2.38	5.3	333	3.48	6.1	347		MAD: median absolute deviation	0.45
11	1.40	4.2	292	1.50	3.4	284			
12	2.40	5.7	324	2.43	4.7	300			
13	1.59	4.3	300	1.71	4.2	297			
14	2.08	5.3	305	2.01	4.8	304			
16	1.99	5.8	277	2.02	4.4	298			
17	2.63	5.5	308	3.17	5.8	308			
18	1.95	5.5	293	1.86	4.3	300			

Source: HR Wallingford

Table 4.5: Validation of the SWAN model for storm peak wave conditions at S11

Storm No.	S11 measured storm peaks			S11 modelled storm peaks			Storm peak summary statistics		
	H_s (m)	T_m (s)	D_m (°N)	H_s (m)	T_m (s)	D_m (°N)	H_s (m)	Bias: mean of model error	-0.03
2	2.27	5.3	349	2.33	5.1	346	H_s (m)	MAE: mean absolute error	0.24
3	2.09	5.8	301	2.25	5.1	302	H_s (m)	RMSE: root mean square model error	0.28
4	2.46	5.3	9	2.62	5.4	7	H_s (m)	Std. error: standard deviation model error	0.28
5	2.30	5.1	358	2.12	4.9	343	H_s (m)	MAD: median absolute deviation	0.18
6	1.16	5.2	336	1.10	3.1	299	T_m (s)	Bias: mean of model error	-0.81
7	4.24*	4.8*	318	3.79	6.4	306	T_m (s)	MAE: mean absolute error	1.06
8	2.55	5.3	22	2.36	5.2	8	T_m (s)	RMSE: root mean square model error	1.52
9	3.19	6.3	295	3.53	6.2	345	T_m (s)	Std. error: standard deviation model error	1.28
11	1.49	6.6	311	1.17	2.9	296	T_m (s)	MAD: median absolute deviation	0.69
12	2.60	6.7	308	2.15	4.5	309			
13	1.65	6.4	309	1.51	4.0	305			
14	1.80	4.9	339	2.05	4.9	306			
15	2.26	5.7	304	2.21	4.8	301			
16	1.56	5.2	309	2.05	4.6	299			

Source: HR Wallingford

Note: The reported measured H_s and T_m for Storm 7 are incompatible in terms of wave steepness, but the record is retained as it corresponds with the time of maximum wave height at S9 and at the WaveWatchIII point.*

4.2.2. Validation against everyday conditions

Comparison for more frequent,lower wave heights has been carried out at the measurement location S9, nearest to the site which has the best quality in the wave measurement records. A significant number of the wave height records of S2 and S4 had to be filtered out from the measured data following quality control checks and the resulting datasets were therefore not used in the assessment.

Figure 4.3 shows a comparison of the percentage of exceedence of wave heights (H_s) measured and the SWAN wave model predictions for the period of measurements at the S9 location. This indicates that the measurements and model prediction exceedence curves show close agreement for low wave heights (lower than 2m), with a slight over-estimate from the model.

The modelled time-series used for this comparison was generated with the model emulation approach (see details in Section 4.4.1) and does not include the better representation of the peak storm data applying partitioned offshore wave spectra to the boundary of the model, since the comparison focusses on more frequent lower wave heights events. Therefore the comparison for large events (Hs > 2.5m) should not be drawn based on the exceedence curve comparison shown in Figure 4.3 but from the model validation undertaken in Section 4.2.1 which makes use of the more accurate storm data in the model and therefore provides a better comparison between storm peaks and the model.

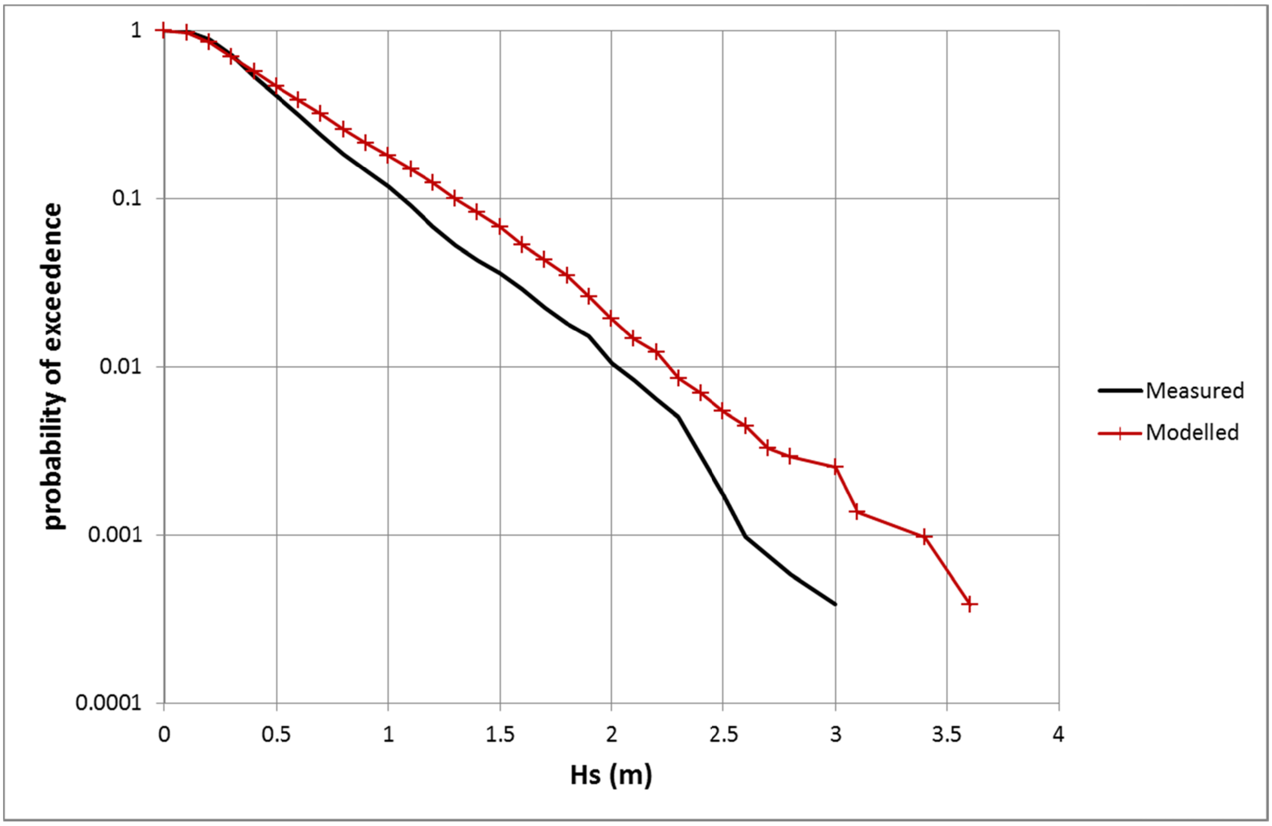


Figure 4.3: Significant wave height exceedence, measured wave data and wave model predictions, S9 location

4.3. Nearshore wave prediction points

Results were collated at ten nearshore wave prediction points shown in Figure 4.4 and defined in Table 4.6.

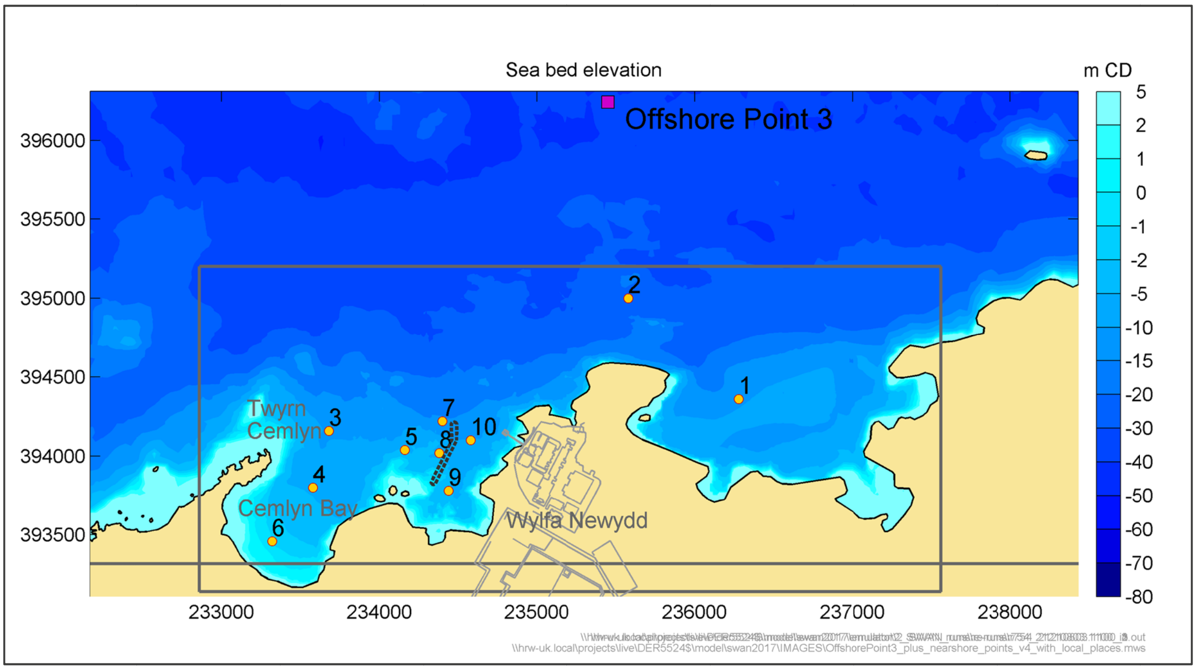


Figure 4.4: Locations of the Offshore Point 3 and the ten nearshore wave prediction points

Note: The grey rectangles indicate the extent of the 50m and the 20m SWAN model grids

Table 4.6: Locations and bed levels of the ten SWAN nearshore wave prediction points (baseline bathymetry)

Point ID	Easting (m)	Northing (m)	Bed level	
1	236280	394360	-11.5mCD	-15.1mOD
2	235580	395000	-21.5mCD	-25.1mOD
3	233680	394160	-11.0mCD	-14.6mOD
4	233580	393800	-5.4mCD	-9.0mOD
5	234160	394040	-4.8mCD	-8.4mOD
6	233320	393460	-1.1mCD	-4.7mOD
7	234400	394220	-13.8mCD	-17.4mOD
8	234380	394020	-6.0mCD	-9.6mOD
9	234440	393780	-5.2mCD	-8.8mOD
10	234580	394100	-10.0mCD	-13.6mOD

4.4. Wave climate results

It is envisaged that the results presented in this chapter will be used for environmental impact assessment. It is understood from Horizon NP, that this type of result should be prepared without deliberate conservatism. Hence, the wave modelling was undertaken at actual sea levels appropriate to each record, with no mark-up of offshore wave and wind conditions beyond that determined during the wave model calibration, and with no allowance for uncertainty.

The results presented in this chapter are intended to be used for environmental impact assessment and not for design.

The modelling reported here responds to a proposed design layout, rather than the model as reported being used to inform or validate the design. The design validation work package is a separate report not forming part of the DCO submission.

4.4.1. Nearshore wave time series

For the wave transformation modelling a model emulation approach was used, whereby the SWAN model is run not for every offshore record, but for a large subset of events. These are then combined with sophisticated interpolation techniques (Camus et al., 2013; Gouldby et al., 2014) to develop a robust simulation that represents the range of multivariate conditions present in the offshore data. The emulator training runs were carefully selected to cover the complete range of offshore boundary conditions (including climate-changed conditions) using six parameters: significant wave height (H_s), mean wave period (T_{m-10}), wave direction, water levels, wind speed and wind direction.

Using the model emulation, 35-year (3-hourly) nearshore time series were generated at varying water levels at the ten nearshore locations for the following layout / scenario conditions:

- baseline, 2023 “present-day” conditions;
- baseline, 2087 “reasonably foreseeable” conditions;
- part-built layout, 2023 “present-day” conditions;
- fully-built layout, 2023 “present-day” conditions;
- fully-built layout, 2087 “reasonably foreseeable” conditions;
- fully-built layout, 2187 “reasonably foreseeable” conditions;
- fully-built layout, 2087 “credible maximum” conditions.

The time series at the temporary cofferdam location (Point 9) was generated for baseline conditions only.

The time series are not presented directly in this report. Instead, they were issued separately in digital editable format for further use in other studies. Note that the date labels for the climate-changed scenario time-series are dummy labels.

4.4.2. Nearshore wave climates

Nearshore wave conditions are summarised at the ten locations along the breakwater structures and along the coastline shown in Figure 4.4 and listed in Table 4.6. For illustration, annual wave roses at Point 5 are shown in Figure 4.5 for the 2023 “present-day” conditions, for the baseline, part-built and fully-built layouts, and in Figure 4.6 for the fully-built layout 2087 “reasonably foreseeable”, 2187 “reasonably foreseeable” and 2087 “credible maximum” conditions. Table 4.7 and Table 4.8 show the distribution of significant wave height against mean wave direction and against mean wave period at Point 5 for 2023 “present-day” baseline conditions.

For all layouts, frequency tables (annual and seasonal) are provided at the nearshore points in digital format. Annual and seasonal wave roses and frequency tables for the nearshore locations are provided in Appendix C.

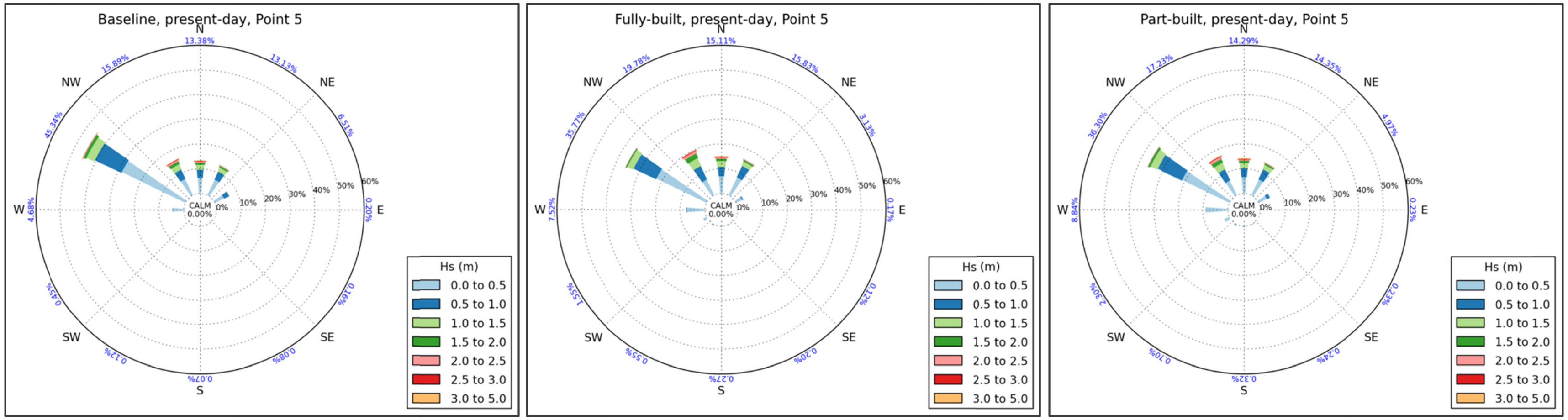


Figure 4.5: Annual wave roses for nearshore prediction Point 5, present-day, baseline, fully-built and part-built layouts

Source: HR Wallingford, SWAN wave transformation and Met Office WW3 offshore data, 1980-2015

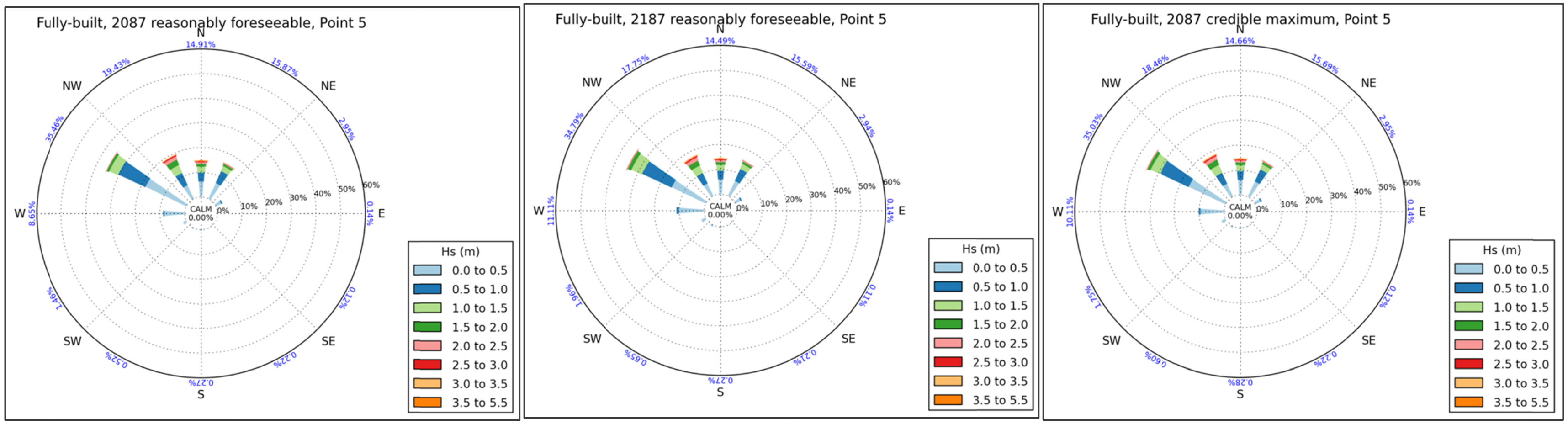


Figure 4.6: Annual wave roses for nearshore prediction Point 5, fully-built layout, future climate-changed scenario conditions

Source: HR Wallingford, SWAN wave transformation and Met Office WW3 offshore data, 1980-2015

Table 4.7: Annual wave climate at Point 5, baseline, 2023 "present-day", significant wave height (H_s) against mean wave direction

			Parts per hundred thousand in the given wave height (m) and wave direction (degrees True North) bin											
			-15	15	45	75	105	135	165	195	225	255	285	315
H_{s1} (m)	H_{s2} (m)	$P(H_s>H_{s1})$	15	45	75	105	135	165	195	225	255	285	315	345
0.0	0.5	100.00%	6326	6922	4032	196	158	80	69	122	449	4648	28498	7248
0.5	1.0	41.25%	3318	3506	2283	-	<1	-	<1	<1	-	34	11874	4111
1.0	1.5	16.13%	1967	1713	185	-	-	-	-	-	-	-	3462	2273
1.5	2.0	6.53%	904	668	8	-	-	-	-	-	-	-	1136	1196
2.0	2.5	2.61%	403	243	-	-	-	-	-	-	-	-	286	641
2.5	3.0	1.04%	243	61	-	-	-	-	-	-	-	-	66	298
3.0	3.5	0.37%	124	13	-	-	-	-	-	-	-	-	14	101
3.5	4.0	0.12%	66	7	-	-	-	-	-	-	-	-	1	15
4.0	4.5	0.03%	21	<1	-	-	-	-	-	-	-	-	-	4
4.5	5.0	0.01%	7	-	-	-	-	-	-	-	-	-	-	-
Percentage occurrence			13.38%	15.77%	13.38%	13.13%	6.51%	0.20%	0.16%	0.08%	0.07%	0.12%	0.45%	4.68%

Source: HR Wallingford, SWAN wave transformation and Met Office WW3 offshore data, 1980-2015; occurrence is in parts per hundred thousand

Table 4.8: Annual wave climate at Point 5, baseline, 2023 “present-day”, significant wave height (H_s) against mean wave period

			Parts per hundred thousand in the given wave height (m) and mean wave period (T_{m-10}, seconds) bin													
			0	1	2	3	4	5	6	7	8	9	10	11	12	13
H_{s1} (m)	H_{s2} (m)	$P(H_s>H_{s1})$	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.0	0.5	100.00%	8	2173	19091	23865	10464	2464	504	124	33	7	6	5	2	2
0.5	1.0	41.25%	-	3	303	8703	11594	3048	1246	218	10	1	-	-	-	-
1.0	1.5	16.13%	-	-	4	117	5167	3410	493	292	105	12	-	-	-	-
1.5	2.0	6.53%	-	-	-	3	173	2913	708	83	22	10	1	-	-	-
2.0	2.5	2.61%	-	-	-	<1	3	399	1003	151	12	5	-	-	-	-
2.5	3.0	1.04%	-	-	-	-	-	5	365	273	17	4	3	-	-	-
3.0	3.5	0.37%	-	-	-	-	-	-	10	211	23	5	2	-	-	-
3.5	4.0	0.12%	-	-	-	-	-	-	<1	32	54	2	<1	-	-	-
4.0	4.5	0.03%	-	-	-	-	-	-	-	1	21	3	<1	-	-	-
4.5	5.0	0.01%	-	-	-	-	-	-	-	<1	4	3	-	-	-	-
Percentage occurrence			0.01%	2.18%	19.40%	32.69%	27.40%	12.24%	4.33%	1.39%	0.30%	0.05%	0.01%	0.01%	0.00%	0.00%

Source: *HR Wallingford, SWAN wave transformation and Met Office WW3 offshore data, 1980-2015; occurrence is in parts per hundred thousand*

4.5. Sensitivity of wave height to structures

4.5.1. Representative winter and summer conditions

For the 2023 “present-day” and 2087 “reasonably foreseeable” conditions, and for representative summer and winter conditions, the effects of the structures on wave height are illustrated by comparing the predicted significant wave heights for the part-built and fully-built layouts against those for the baseline conditions.

Typical summer and winter conditions were selected based on the wave climate, for present-day conditions, predicted in HR Wallingford (2015) for Offshore Point 3 (see Figure 4.4). Table 4.11 and Table 4.12 show the summer and winter distribution of significant wave height against mean wave direction at Offshore Point 3 for 2023 “present day” baseline conditions. The summer and winter periods are defined as April to September (inclusive) and October to March (inclusive), respectively.

The representative typical summer wave condition was selected from the wave height and direction bin containing the most records in the Offshore Point 3 summer wave frequency climate tables. For the present-day conditions, this corresponds to a significant wave height of 0.6m from the 225-255°N sector. Winter conditions were defined as selected percentiles, representative of an average winter condition (50%), and more severe winter storm conditions of 90% and 99% within each of the NW, N and NE sectors.

Table 4.9 and Table 4.10 summarise the summer and winter present-day wave conditions used in the model. The “2087 reasonably foreseeable” conditions were obtained from the present-day conditions by applying a 10% increase in wave heights (and corresponding 5% in wave periods) and wind speeds to reflect the future climate change allowances. They were also run in the model, at water levels increased by 0.62m to allow for climate change.

Table 4.9: Representative present-day frequently-occurring Summer wave condition at Offshore Point 3

Condition	H_s (m)	T_{m-10} (s)	Dir (°N)
Summer condition, present-day	0.60	3.3	254

Source: HR Wallingford analysis at Offshore Point 3

Table 4.10: Representative present-day Winter storm wave conditions at Offshore Point 3

Sector	Event	H_s (m)	T_{m-10} (s)	Dir (°N)
N	50th percentile	0.93	4.1	360
	90th percentile	2.49	6.0	343
	99th percentile	4.21	7.8	345
NE	50th percentile	0.89	4.0	57
	90th percentile	2.29	5.9	39
	99th percentile	3.48	6.9	36
NW	50th percentile	1.17	4.4	309
	90th percentile	2.76	6.5	329
	99th percentile	4.03	7.5	303

Source: HR Wallingford analysis at Offshore Point 3

To illustrate the difference in predicted significant wave height between the baseline and the fully-built layout, sample difference plots are shown in Figure 4.7 to Figure 4.10, for the summer present-day conditions, and for the 99th percentile winter "2087 reasonably foreseeable" conditions from the NW, N and NE sectors, respectively. Each figure is in three parts, and represents just one wave condition. The top pane of each figure shows the baseline significant wave height for the area around Wylfa, and the middle pane the corresponding wave heights after introduction of the fully-built layout. The bottom pane shows the difference in significant wave height between the runs with and without structures. Yellow and orange shades show increases in wave height of at least ten centimetres. Blue and green shades show reductions in wave height of at least ten centimetres.

Sample difference plots between the baseline and the part-built layout (as defined in Figure 2.1, including a partially built western breakwater), are shown in Figure 4.11 to Figure 4.14, for the summer present-day conditions, and for the 99th percentile winter "present-day" conditions from the NW, N and NE sectors, respectively.

The extents of the differences in significant wave height (higher than +/- 10cm) due to the structures is localised around the proposed structures. For the largest waves from the NW sector for the fully-built layout "2087 reasonably foreseeable" conditions (see Figure 4.8), the differences extend up to Cemlyn Bay. For this sector, the directions and heights of the reflected waves from the two sections of the Western Breakwater, coupled with refraction and shoaling effects as they approach the coast, appear to be causing a small amount of refocussing of the wave energy in Cemlyn Bay to give a localised area of increase in H_s of just above 10 centimetres. No differences in significant wave height higher than +/- 10cm is predicted in Cemlyn Bay for the "present-day" conditions tested with either the fully-built or part-built layouts.

The additional summer and winter wave conditions cases have been provided in digital format.

The refocussing of the wave energy in Cemlyn Bay is sensitive to the wave direction and further sensitivity tests have been carried out in Section 4.5.2.

Table 4.11: Summer wave climate at Offshore Point 3, baseline, 2023 “present-day”, significant wave height (H_s) against mean wave direction

			Wave direction (°N)											
			-15	15	45	75	105	135	165	195	225	255	285	315
H_{s1} (m)	H_{s2} (m)	$P(H_s>H_{s1})$	15	45	75	105	135	165	195	225	255	285	315	345
0.0	0.5	100.00%	4383	2258	4530	3070	995	791	1172	3746	8164	4909	3145	4503
0.5	1.0	58.33%	3038	1552	3238	2354	516	420	560	2089	10495	5794	2880	3688
1.0	1.5	21.71%	1078	706	1330	882	79	42	87	296	3194	2362	1579	2141
1.5	2.0	7.93%	331	271	676	231	-	2	4	19	541	1240	874	984
2.0	2.5	2.76%	177	171	202	4	-	-	-	-	12	347	435	395
2.5	3.0	1.02%	83	100	62	-	-	-	-	-	2	83	175	181
3.0	3.5	0.33%	27	42	46	-	-	-	-	-	-	13	39	81
3.5	4.0	0.09%	2	19	21	-	-	-	-	-	-	-	4	10
4.0	4.5	0.03%	2	12	4	-	-	-	-	-	-	-	-	-
4.5	5.0	0.01%	2	4	2	-	-	-	-	-	-	-	-	-
5.0	5.5	0.01%	4	2	-	-	-	-	-	-	-	-	-	-
5.5	6.0	0.00%	-	-	-	-	-	-	-	-	-	-	-	-
Percentage occurrence			9.13%	5.14%	10.11%	6.54%	1.59%	1.26%	1.82%	6.15%	22.41%	14.75%	9.13%	11.98%

Source: HR Wallingford, SWAN wave transformation (Phase 1) and Met Office WW3 offshore data, 1980-2015; occurrence is in parts per hundred thousand

Table 4.12: Winter wave climate at Offshore Point 3, baseline, 2023 “present day”, significant wave height (Hs) against mean wave direction

			Wave direction (°N)							
			-22.5	22.5	67.5	112.5	157.5	202.5	247.5	292.5
H_{s1} (m)	H_{s2} (m)	$P(H_s>H_{s1})$	22.5	67.5	112.5	157.5	202.5	247.5	292.5	337.5
0	0.5	100.00%	2043	1629	3455	941	1026	2918	3513	2139
0.5	1	82.34%	2238	1975	5513	1335	1395	8160	7963	3098
1	1.5	50.66%	1426	1163	3395	456	464	5878	8197	2278
1.5	2	27.40%	974	752	1704	100	81	1459	7959	1662
2	2.5	12.71%	568	512	500	-	-	48	3588	1310
2.5	3	6.18%	336	305	272	-	-	-	1600	926
3	3.5	2.74%	224	112	62	-	-	-	756	444
3.5	4	1.14%	126	33	12	-	-	-	317	280
4	4.5	0.38%	70	23	4	-	-	-	79	112
4.5	5	0.09%	29	4	4	-	-	-	12	21
5	5.5	0.02%	10	-	2	-	-	-	2	2
5.5	6	0.00%	2	-	-	-	-	-	2	-
	Percentage Occurrence		8.04%	6.51%	14.92%	2.83%	2.97%	18.46%	33.99%	12.27%

Source: HR Wallingford, SWAN wave transformation (Phase 1) and Met Office WW3 offshore data, 1980-2015; occurrence is in parts per hundred thousand

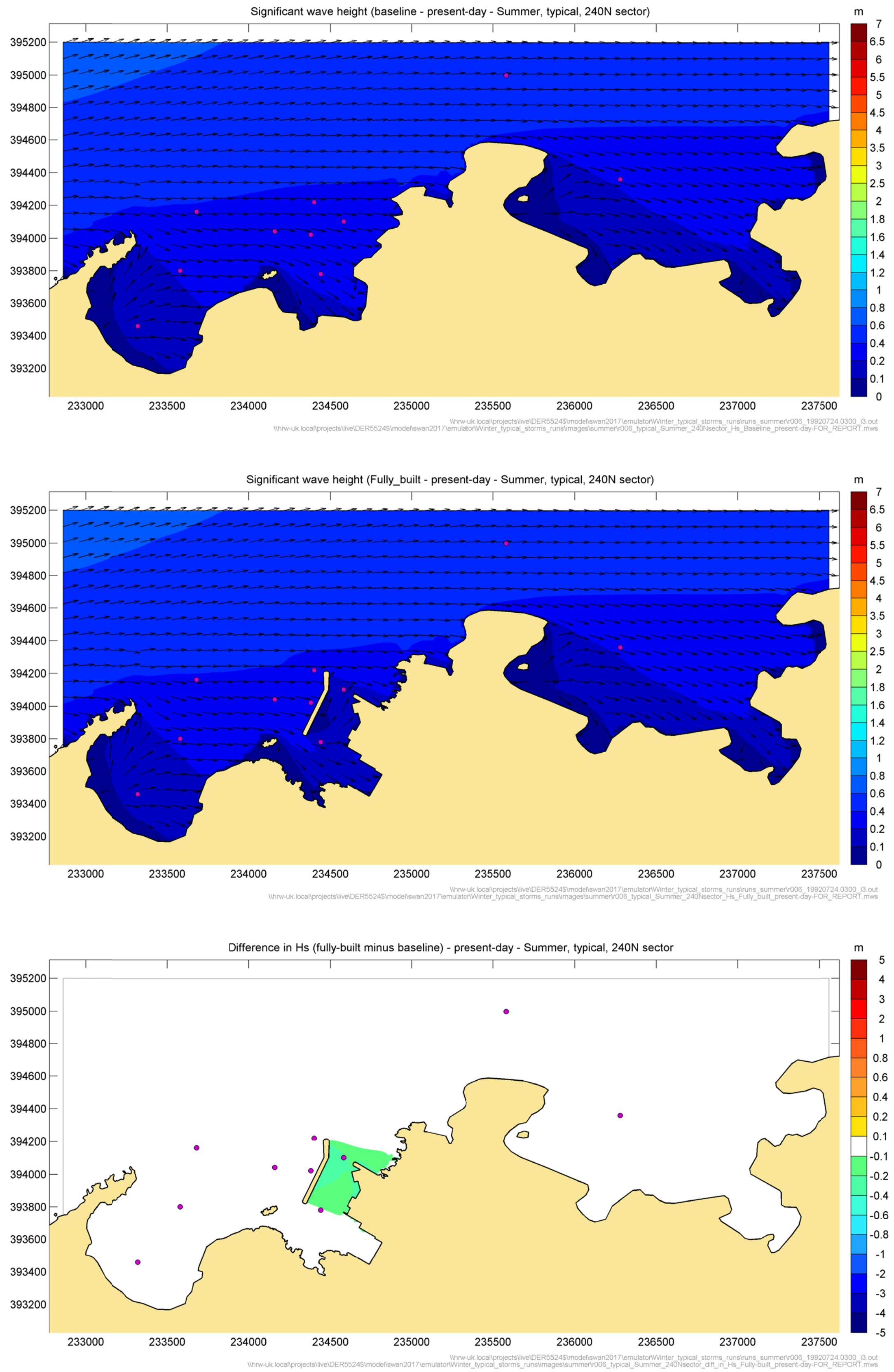


Figure 4.7: Difference in significant wave height, fully-built compared to baseline, typical summer wave condition, 2023 "present-day"

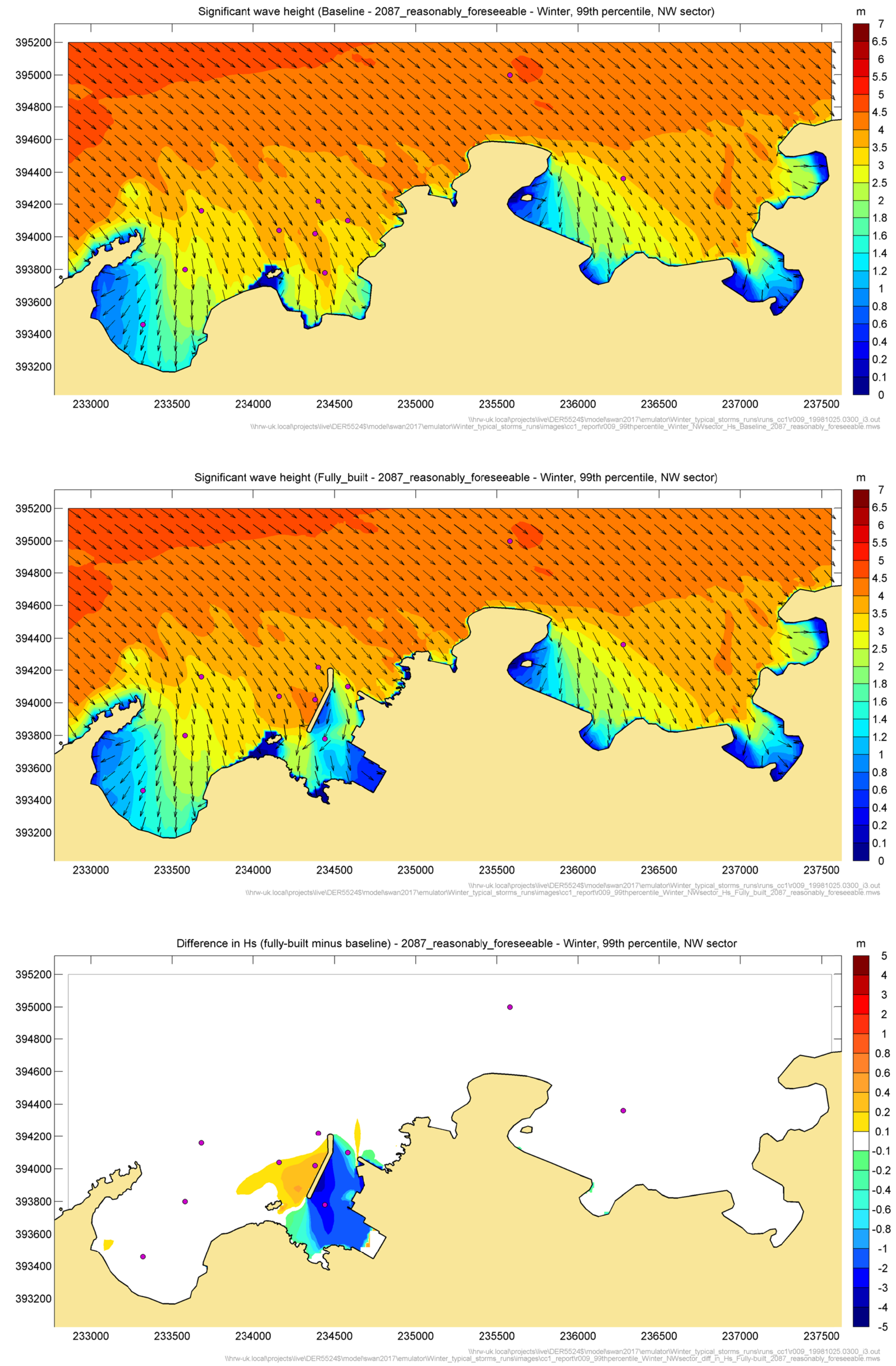


Figure 4.8: Difference in significant wave height, fully-built compared to baseline, 99th percentile winter wave condition, from the NW sector, "2087 reasonably foreseeable"

Source: HR Wallingford SWAN wave model; Wave predictions in the lee of the breakwater are included for illustration only. The HR Wallingford ARTEMIS model is used to provide reliable wave conditions behind the breakwater.

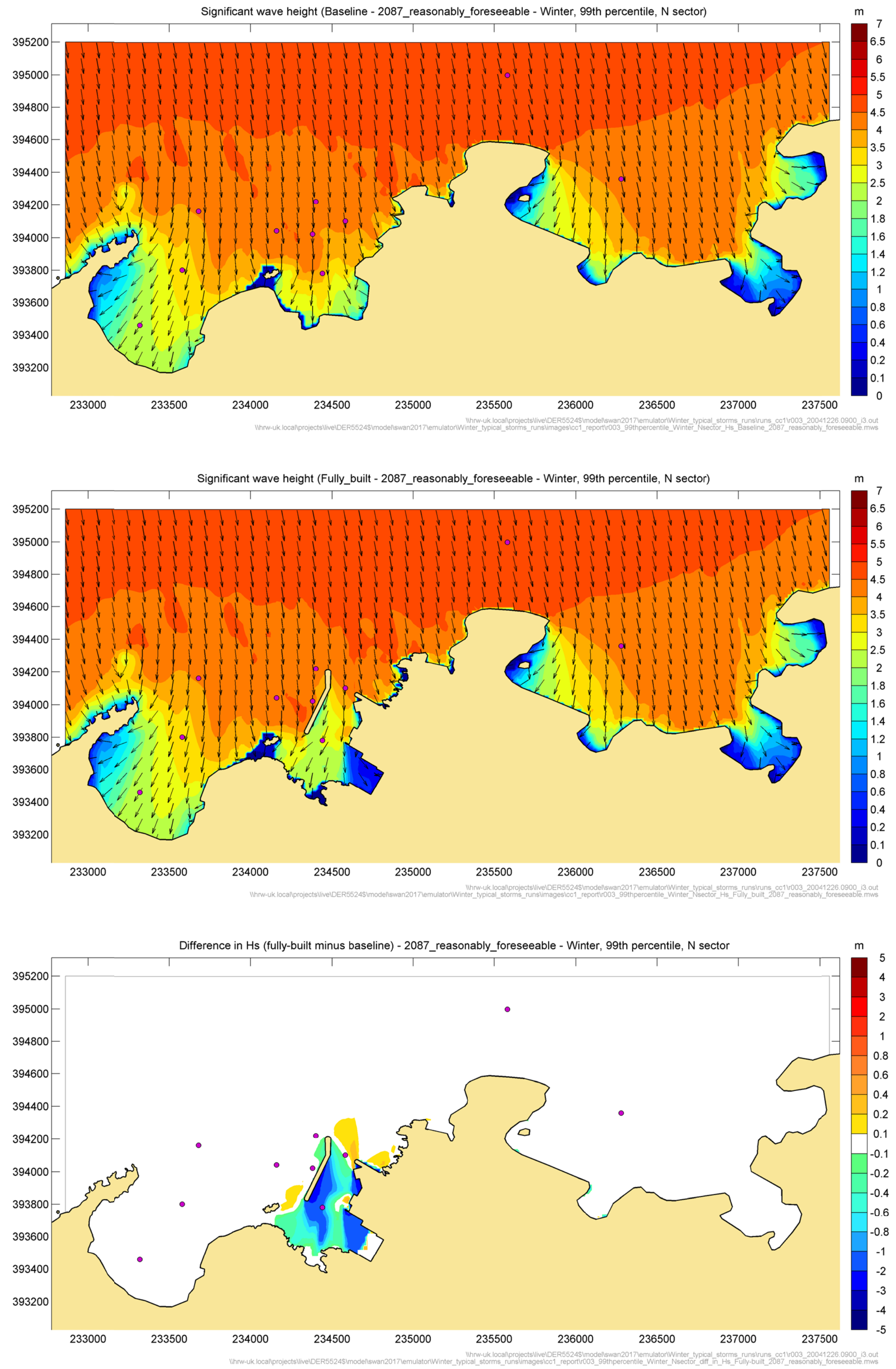


Figure 4.9: Difference in significant wave height, fully-built compared to baseline, 99th percentile winter wave condition, from the N sector, “2087 reasonably foreseeable”

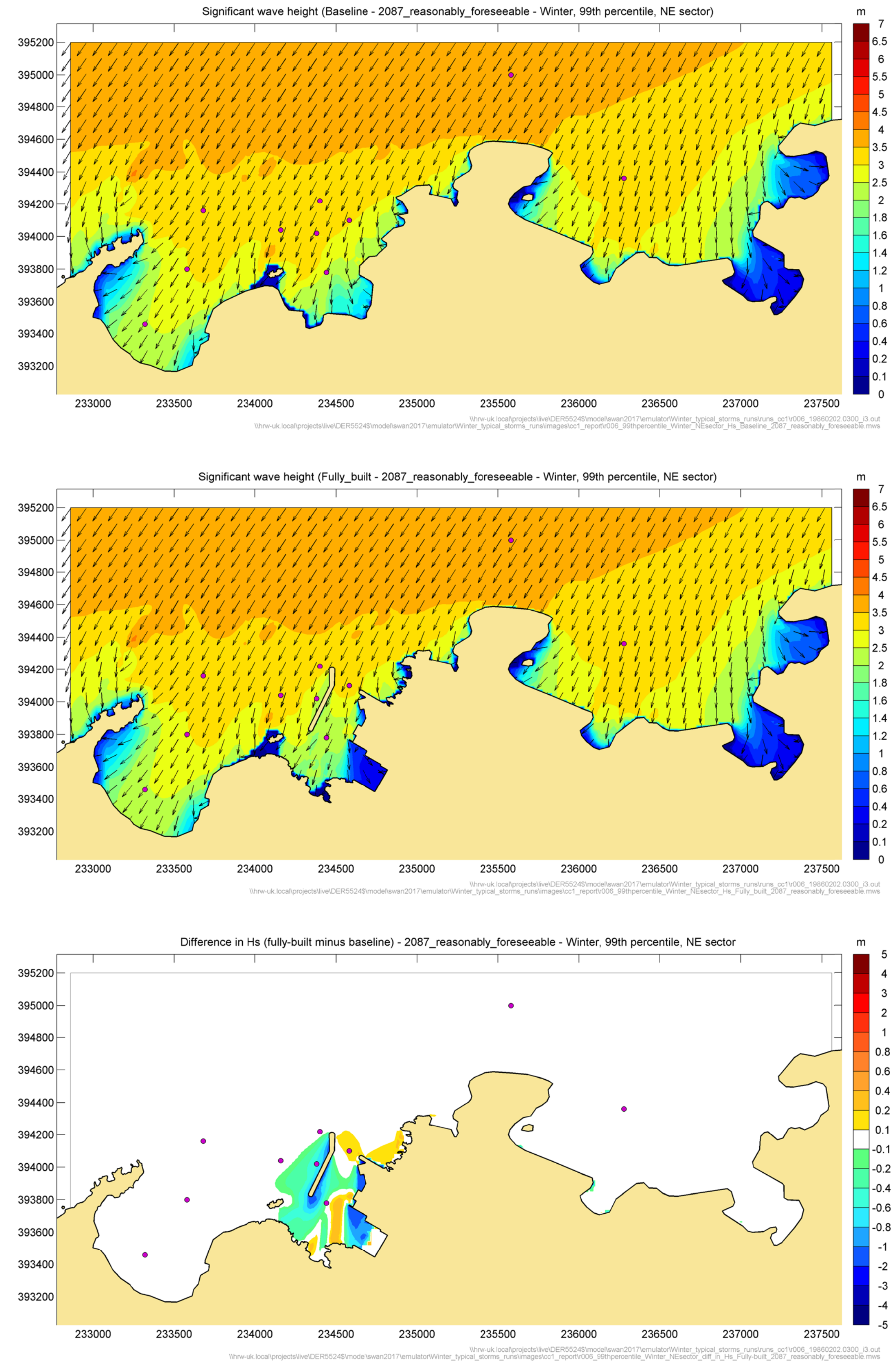


Figure 4.10: Difference in significant wave height, fully-built compared to baseline, 99th percentile winter wave condition, from the NE sector, “2087 reasonably foreseeable”

Source: HR Wallingford SWAN wave model; Wave predictions in the lee of the breakwater are included for illustration only. The HR Wallingford ARTEMIS model is used to provide reliable wave conditions behind the breakwater.

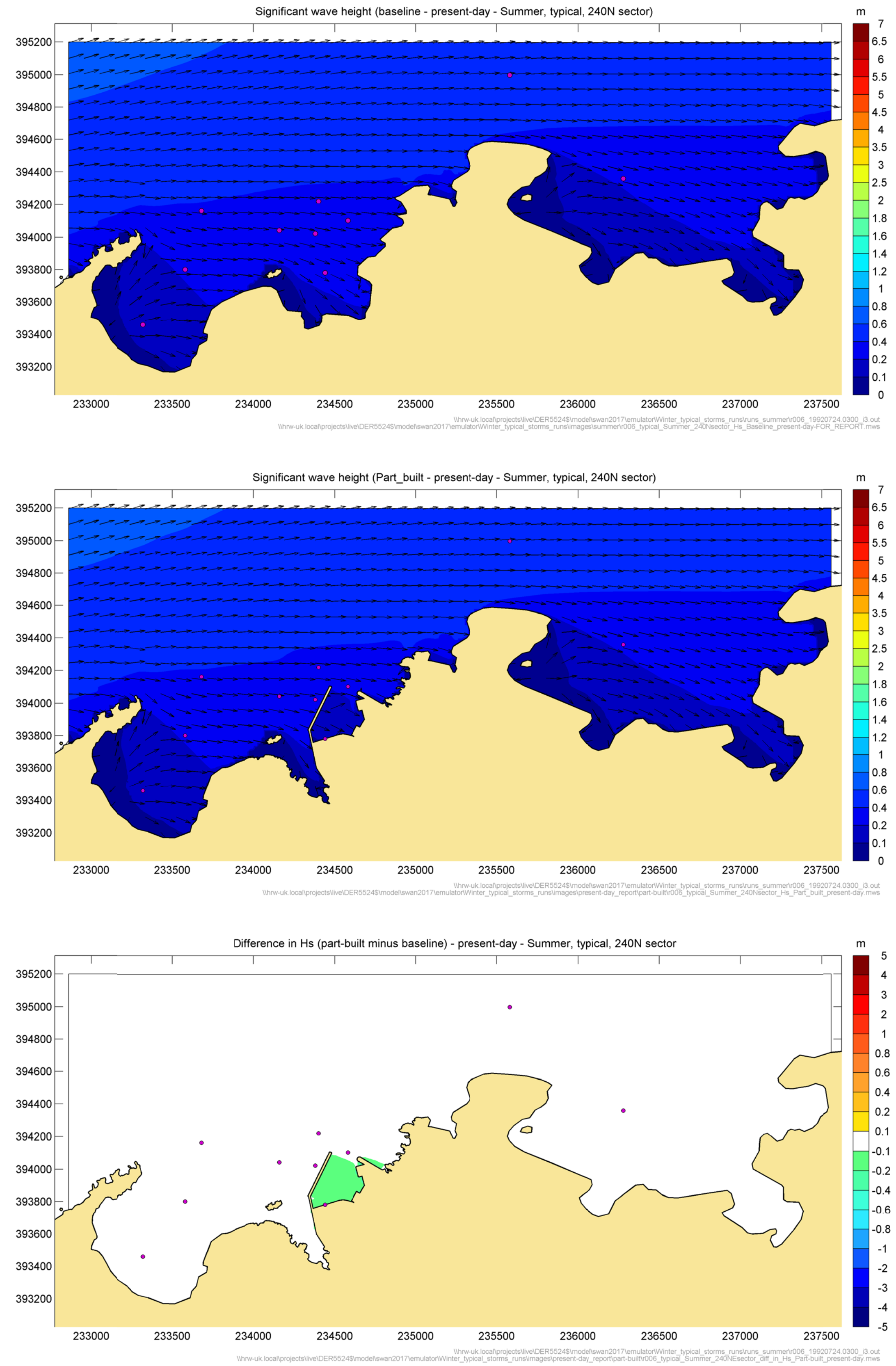


Figure 4.11: Difference in significant wave height, part-built compared to baseline, typical summer wave condition, 2023 "present-day"

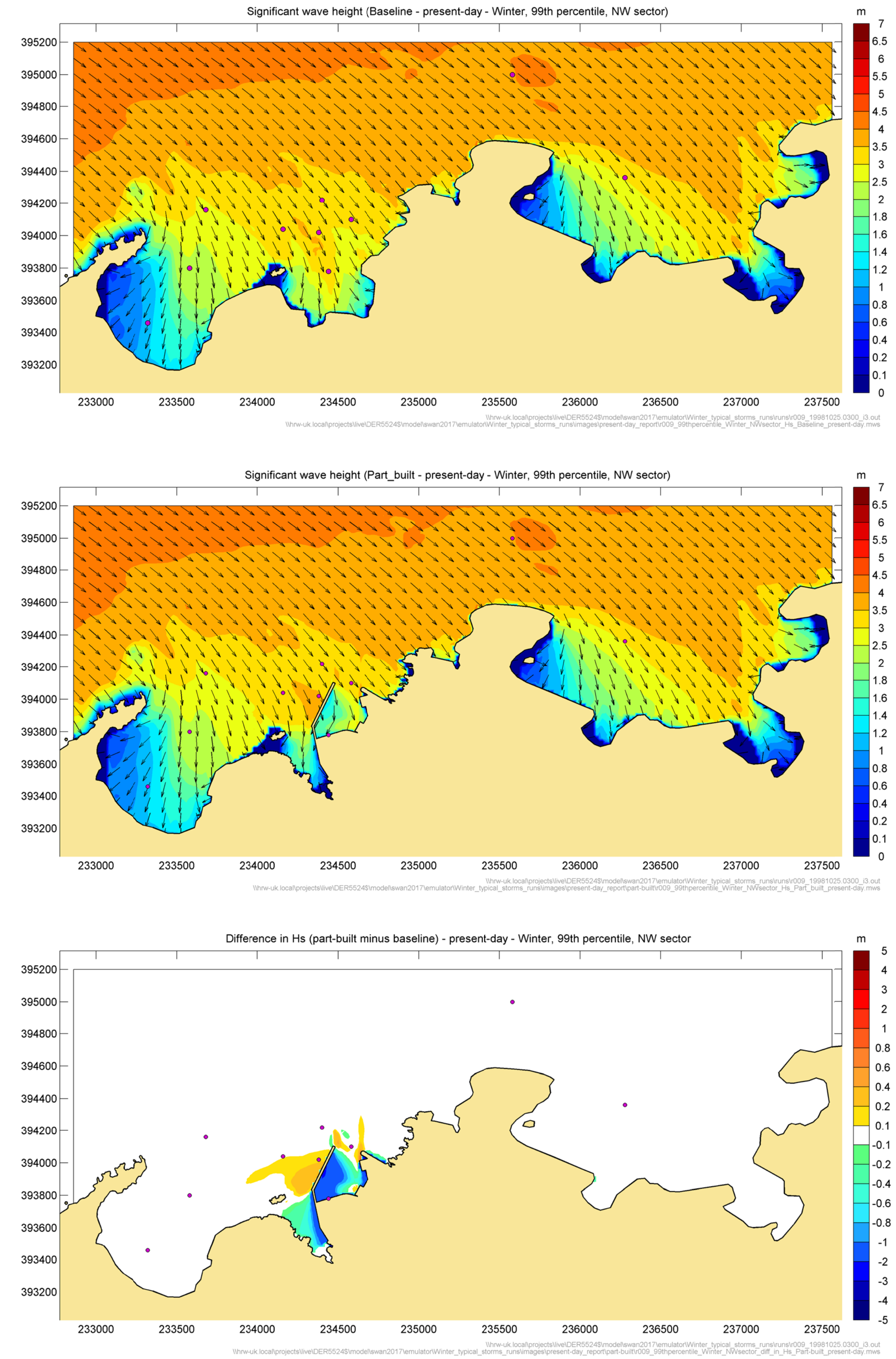


Figure 4.12: Difference in significant wave height, part-built compared to baseline, 99th percentile winter wave condition, from the NW sector, "2023 present-day"

Source: HR Wallingford SWAN wave model; Wave predictions in the lee of the breakwater are included for illustration only. The HR Wallingford ARTEMIS model is used to provide reliable wave conditions behind the breakwater.

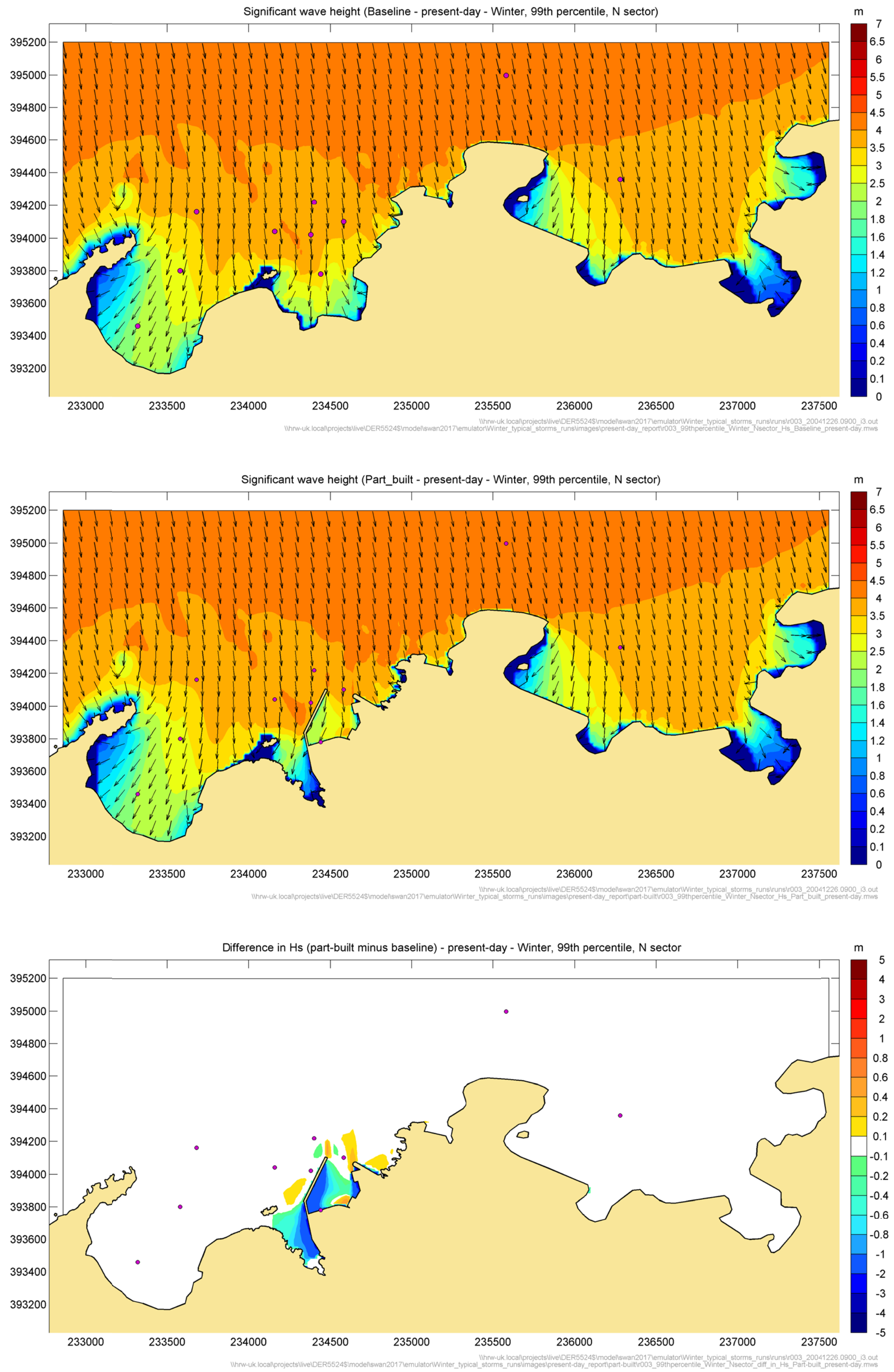


Figure 4.13: Difference in significant wave height, part-built compared to baseline, 99th percentile winter wave condition, from the N sector, "2023 present-day"

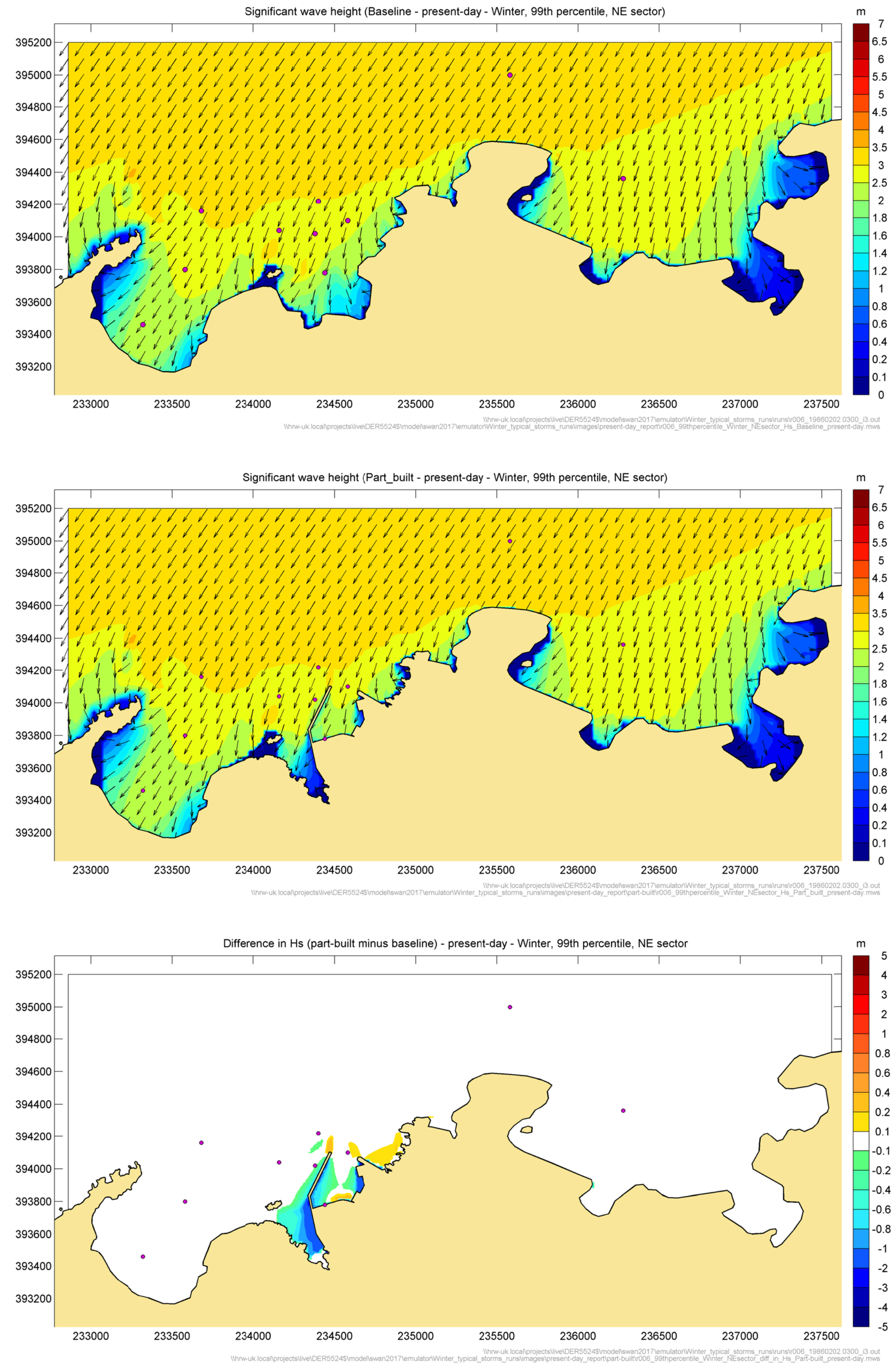


Figure 4.14: Difference in significant wave height, part-built compared to baseline, 99th percentile winter wave condition, from the NE sector, "2023 present-day"

Source: HR Wallingford SWAN wave model; Wave predictions in the lee of the breakwater are included for illustration only. The HR Wallingford ARTEMIS model is used to provide reliable wave conditions behind the breakwater.

4.5.2. Further sensitivity tests to assess refocussing of wave energy in Cemlyn Bay

In order to investigate further the refocussing of wave energy highlighted in the “2087 reasonably foreseeable” 99th winter conditions model runs, a suite of simulations was conducted to explore sensitivity to offshore wave direction at the outer model boundary.

Table 4.13 summarises the original winter present-day wave conditions at Offshore Point 3 used in the model. The “2087 reasonably foreseeable” conditions were obtained from the present-day conditions by applying a 10% increase in wave heights (and corresponding 5% in wave periods) and wind speeds to reflect the future climate change allowances. They were also run in the model, at water levels increased by 0.62m to allow for climate change. Although not originally requested, conditions from the West sector were also tested for completeness.

Table 4.13: Representative present-day Winter storm wave conditions at Offshore Point 3 and corresponding offshore wave direction at the model boundary

Sector	Event	H_s (m)	T_{m-10} (s)	Wave Direction (°N) at Point 3	Corresponding offshore wave direction (°N)	Wind Direction (°N)
NE	99th percentile	3.48	6.9	36	35	37
N	99th percentile	4.21	7.8	345	342	359
NW	99th percentile	4.03	7.5	303	290	294
W	99th percentile	3.58	7.3	275	246	260

Source: HR Wallingford analysis at Offshore Point 3

These simulations were run at a 5° interval in the offshore wave direction within the W, NW, N and NE sectors, for the “2087 reasonably foreseeable” conditions, applying the same wind conditions as for the original selected representative 99th percentile condition in the sector.

The differences in significant wave height between the fully-built layout and the baseline from the offshore wave direction sensitivity runs are shown in Figure 4.15 to Figure 4.18.

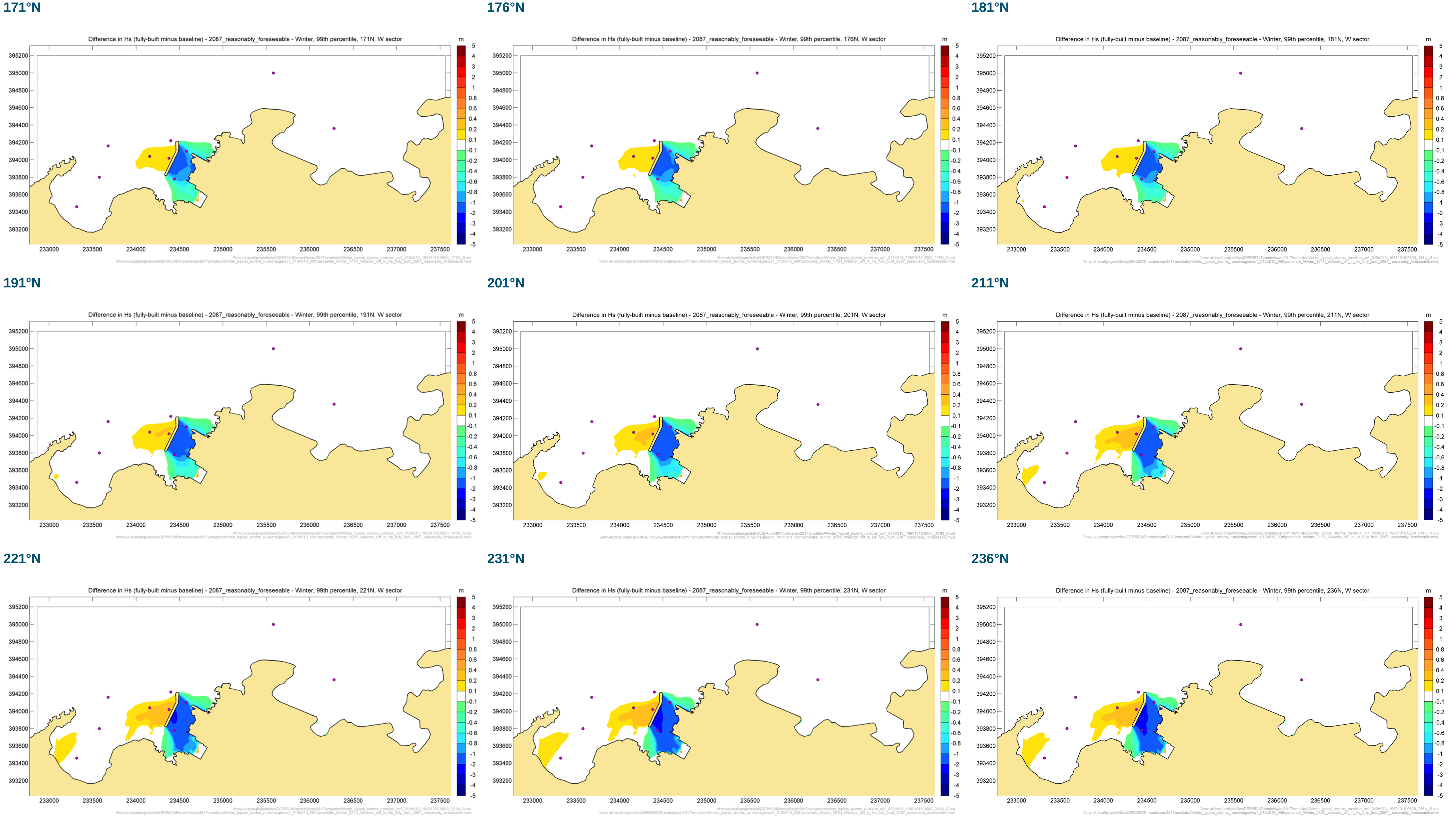


Figure 4.15: Difference in significant wave height fully-built layout compared to baseline, “2087 reasonably foreseeable” conditions, sensitivity runs offshore wave direction 171°N to 236°N

Note: the purple dots on the plots represent the location of the nearshore wave output points (Figure 4.4).

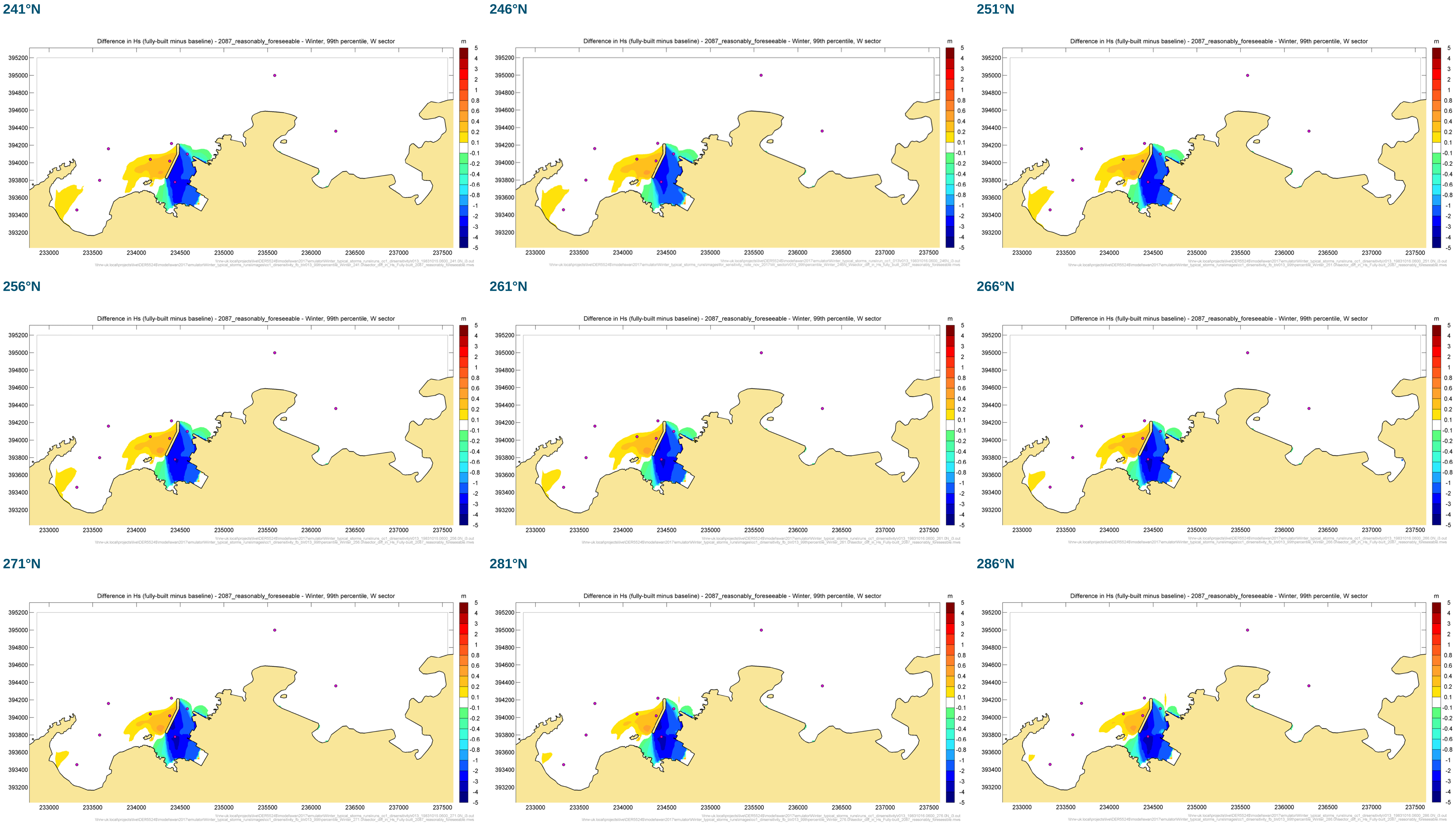
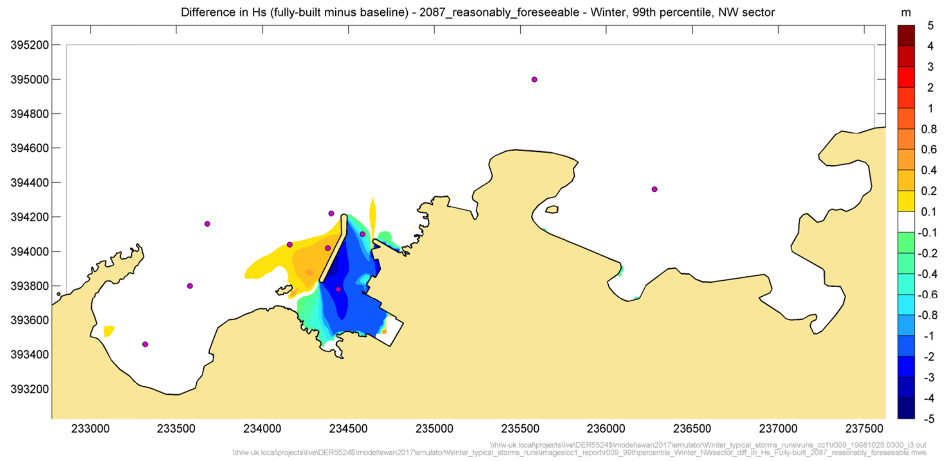
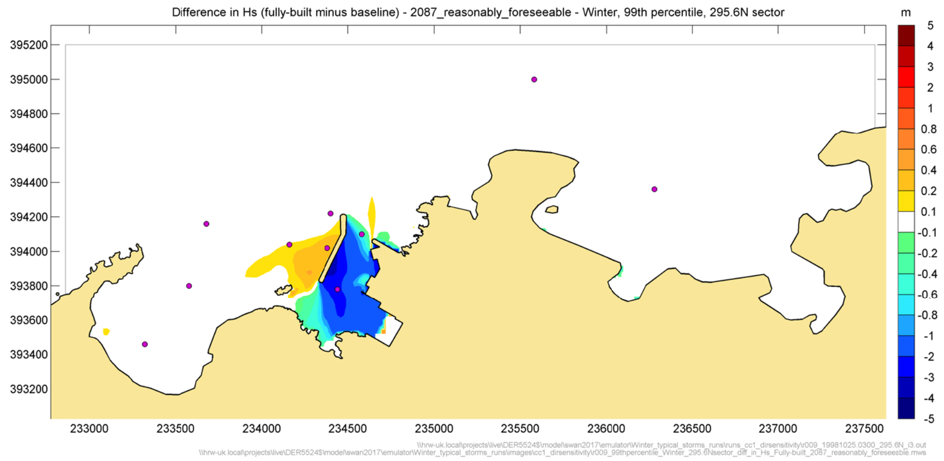


Figure 4.16: Difference in significant wave height fully-built layout compared to baseline, “2087 reasonably foreseeable” conditions, sensitivity runs offshore wave direction 245°N to 286°N

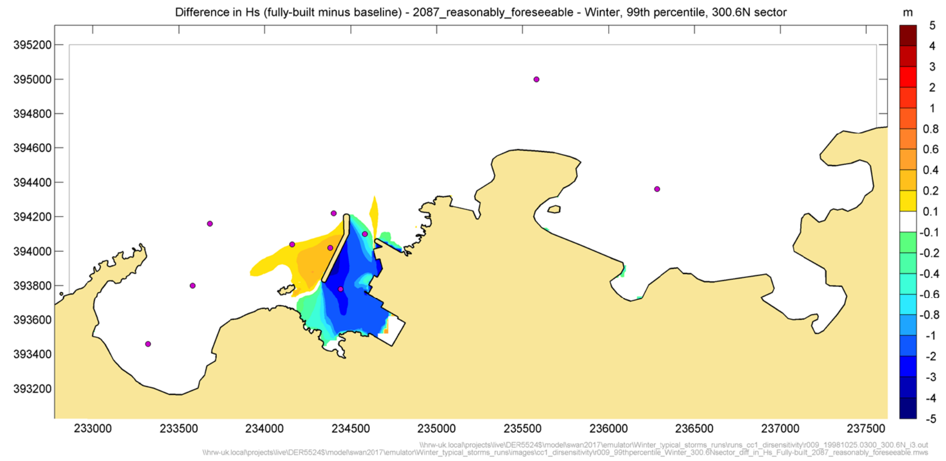
290°N



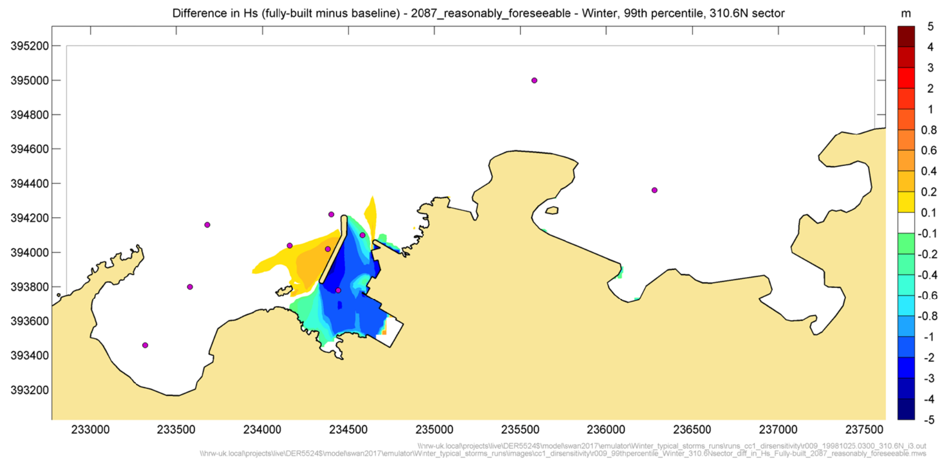
295°N



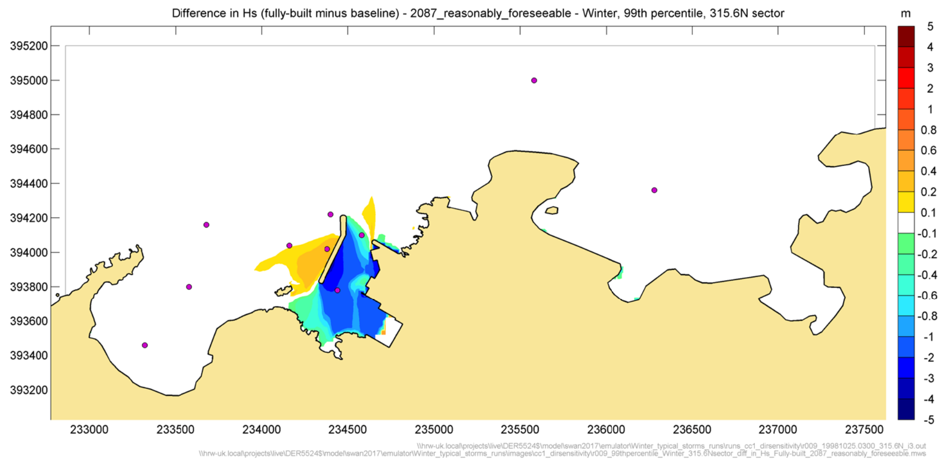
300°N



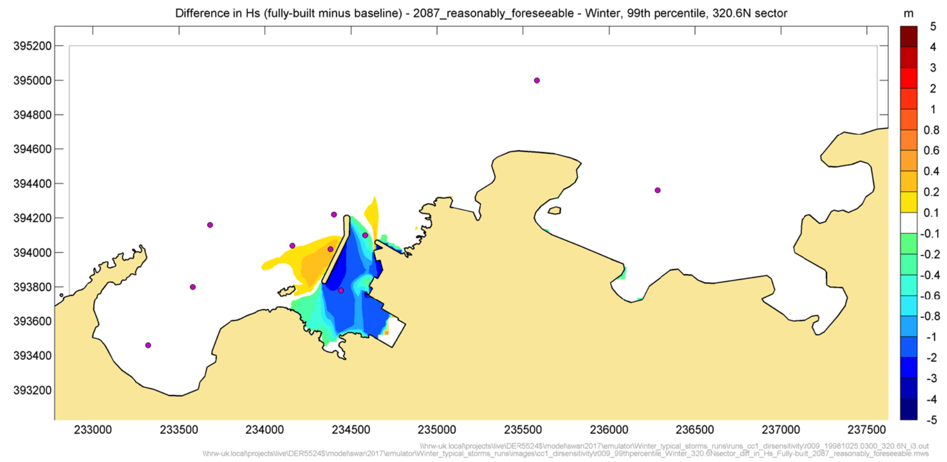
310°N



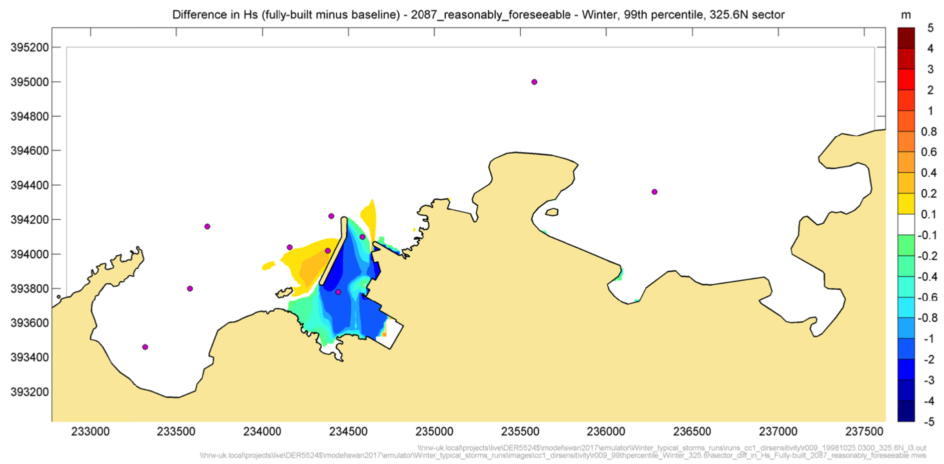
315°N



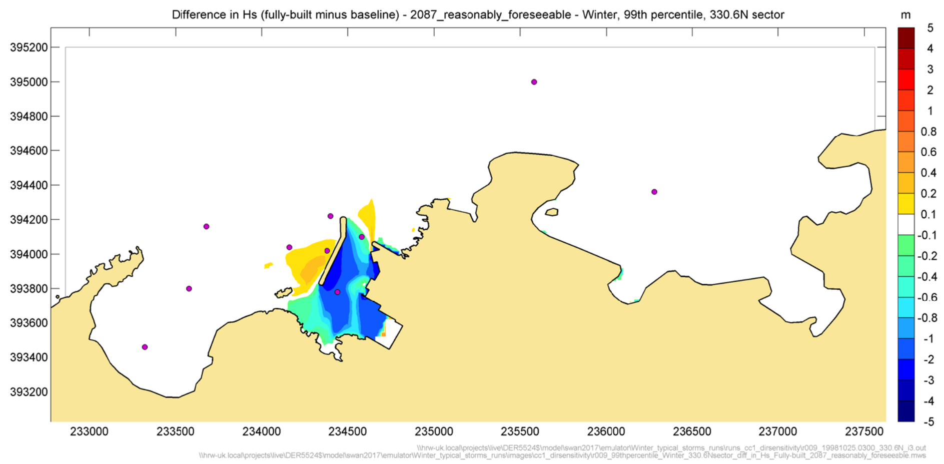
320°N



325°N



330°N



335°N

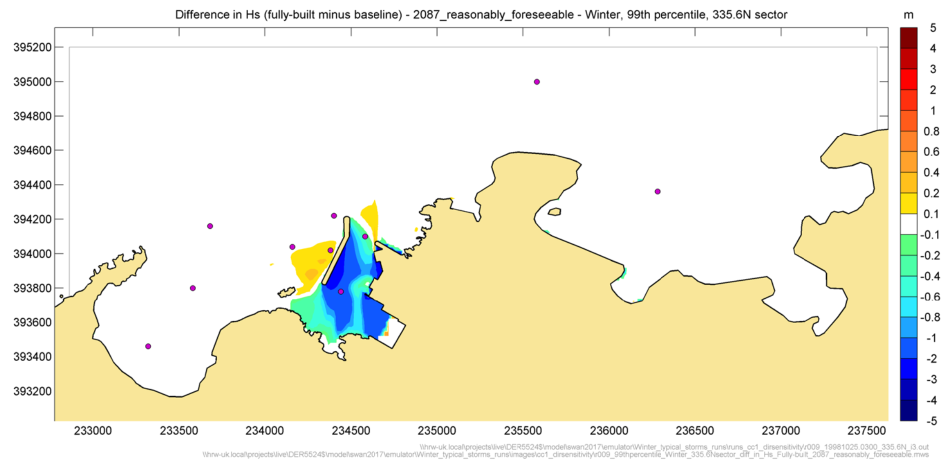
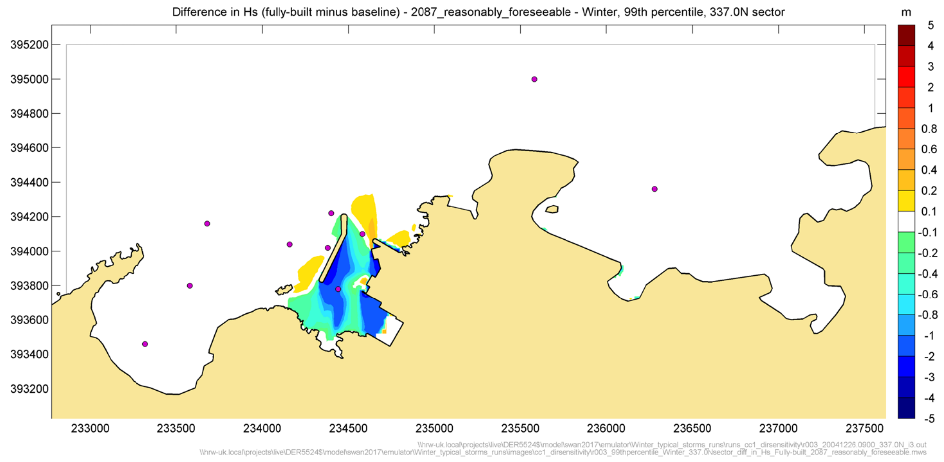
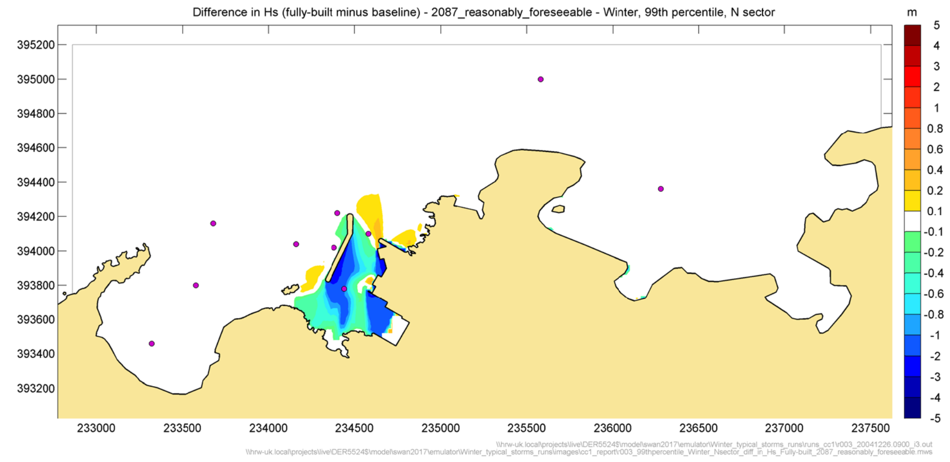


Figure 4.17: Difference in significant wave height fully-built layout compared to baseline, “2087 reasonably foreseeable” conditions, sensitivity runs offshore wave direction 295°N to 335°N

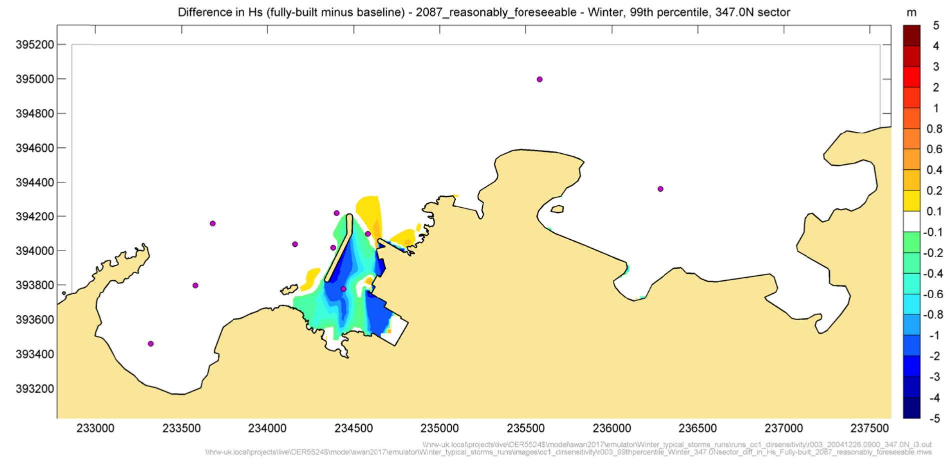
337°N



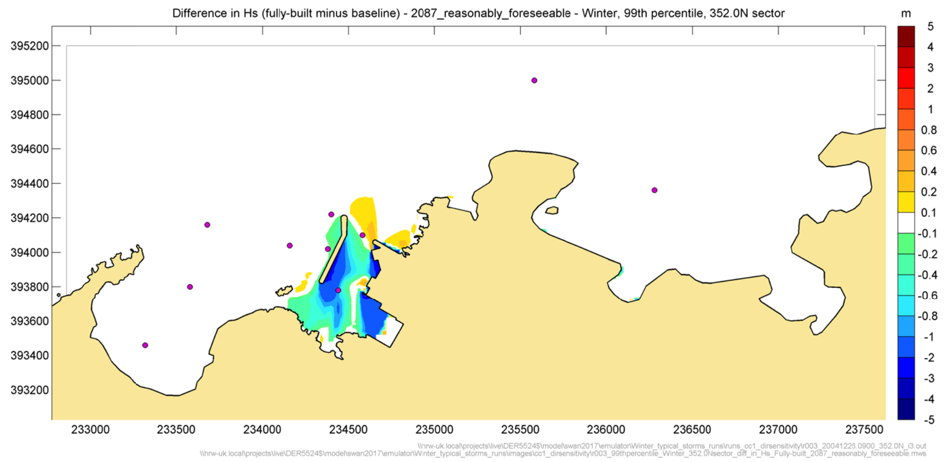
342°N



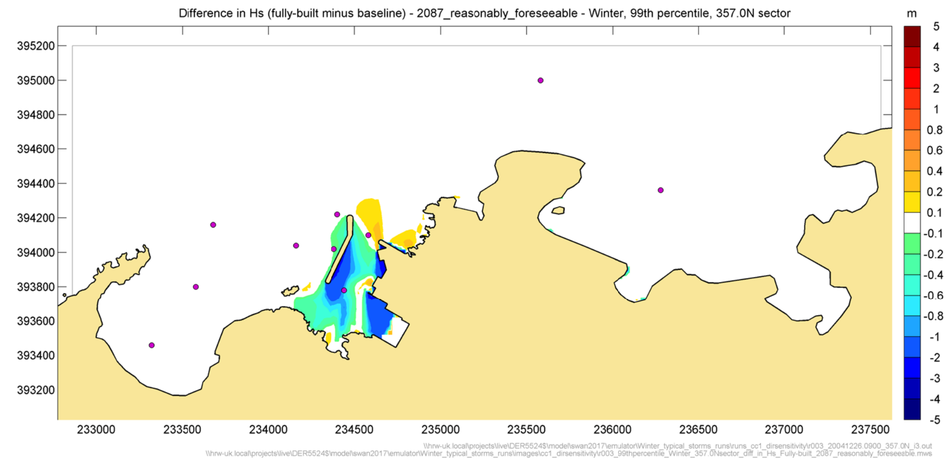
347°N



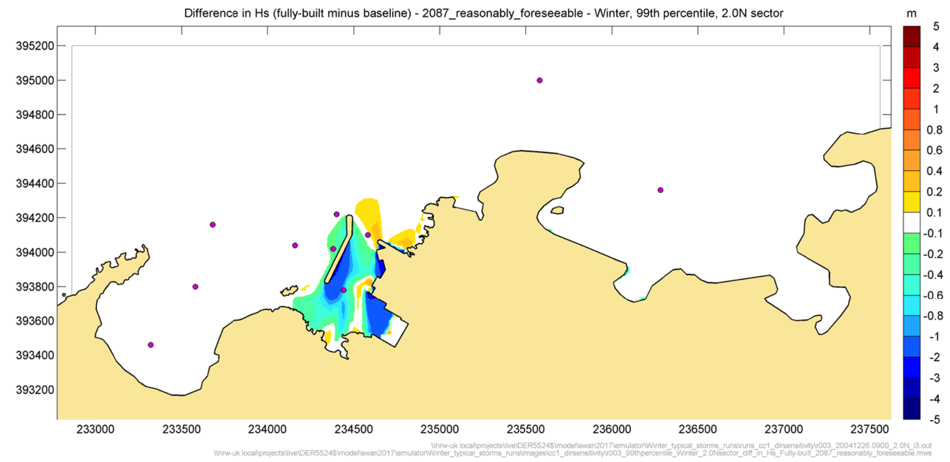
352°N



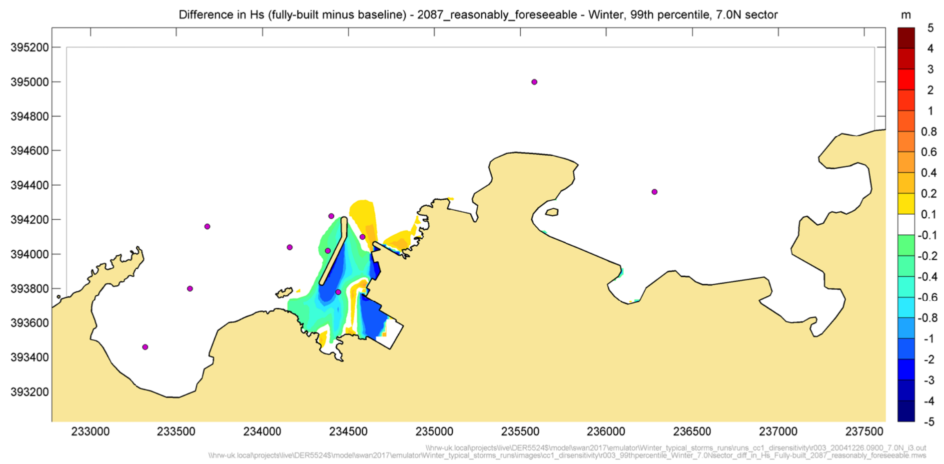
357°N



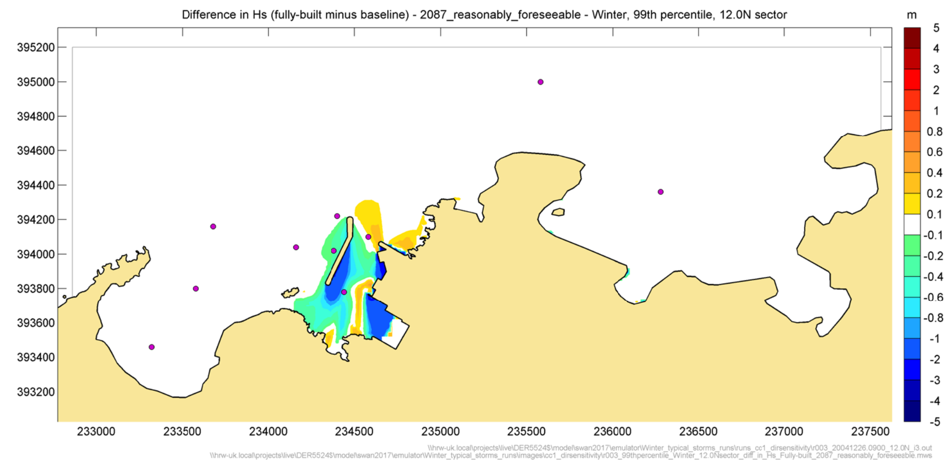
2°N



7°N



12°N



17°N

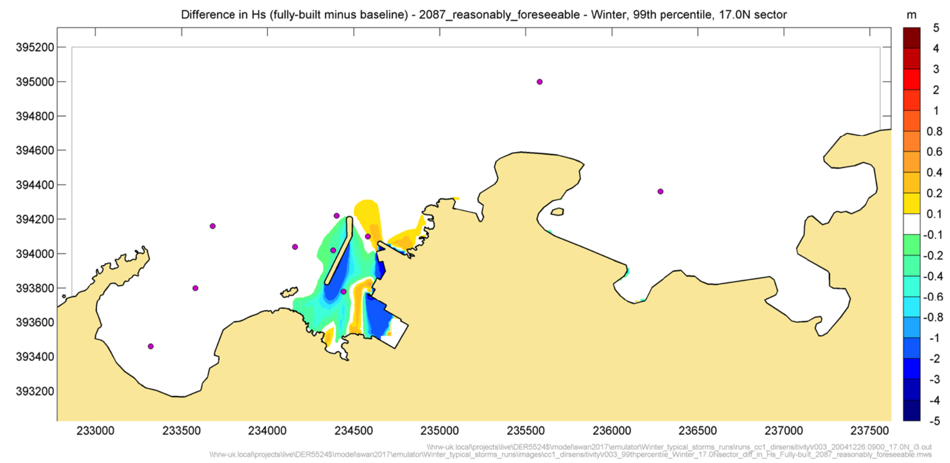


Figure 4.18: Difference in significant wave height fully-built layout compared to baseline, “2087 reasonably foreseeable” conditions, sensitivity runs offshore wave direction 337°N to 17°N

The influence of these additional directions was examined and the condition, within each 45° sector that had the largest influence on wave heights at Cemlyn Bay was chosen as the representative condition in that sector.

The effect of refocussing in Cemlyn Bay is observed for offshore wave directions from 176°N to 295°N, when the wind is from the West or North-West. Offshore conditions originating from the West sector refract towards the land. As illustrated in Figure 4.19 and Figure 4.20, varying the offshore wave direction at the boundary by 40° (from 246°N to 286°N) for the same wave conditions (significant wave height and wave period) only varies the wave direction at the Offshore Point 3 by 13°. The variation in offshore wave direction does have an effect on the magnitude of the waves at the site but less on the mean direction of the waves due to refraction.

Based on the sensitivity tests, the chosen directions for each sector are presented in Table 4.14, although results are generally similar to those from the representative directions shown in Section 4.5.

Table 4.14: Selected representative winter offshore wave directions applied at the SWAN boundary

Sector	Event	Representative Offshore Direction (°N)	Worst Direction from sensitivity study (°N)
NE	99th percentile	35	45
N	99th percentile	342	337
NW	99th percentile	290	286
W	99th percentile	246	246

Source: HR Wallingford

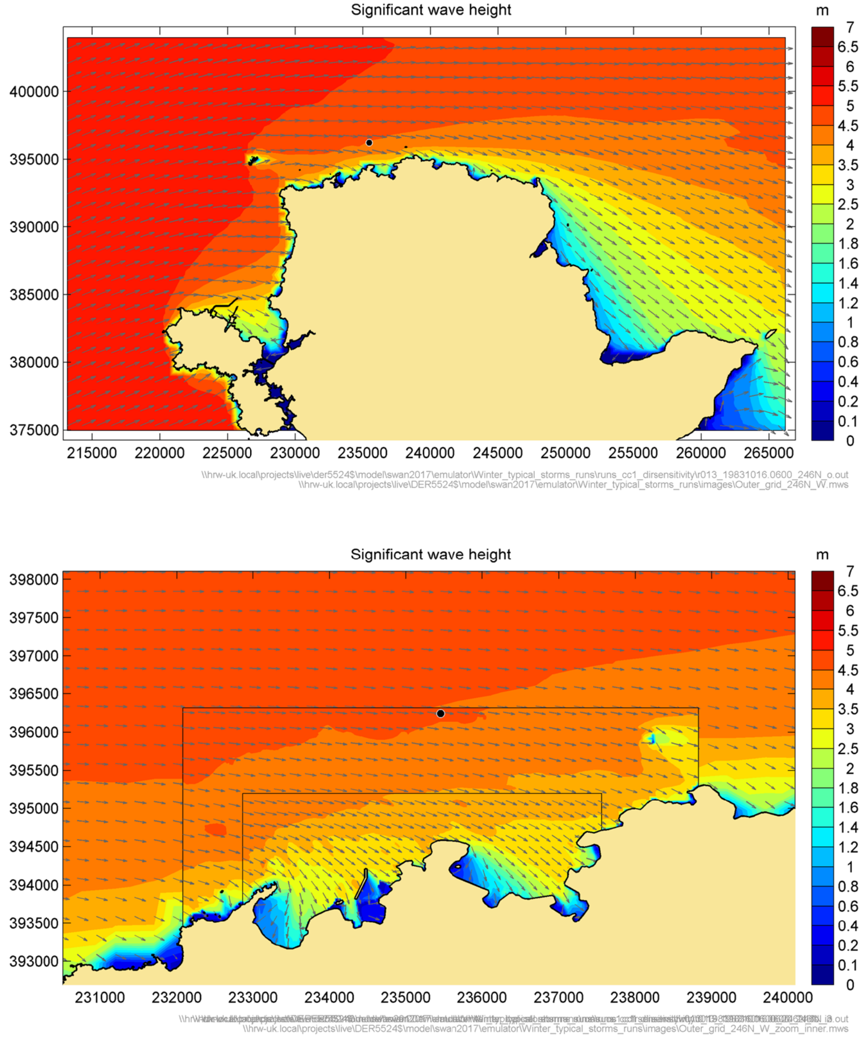


Figure 4.19: W sector conditions with offshore boundary wave direction of 246°N

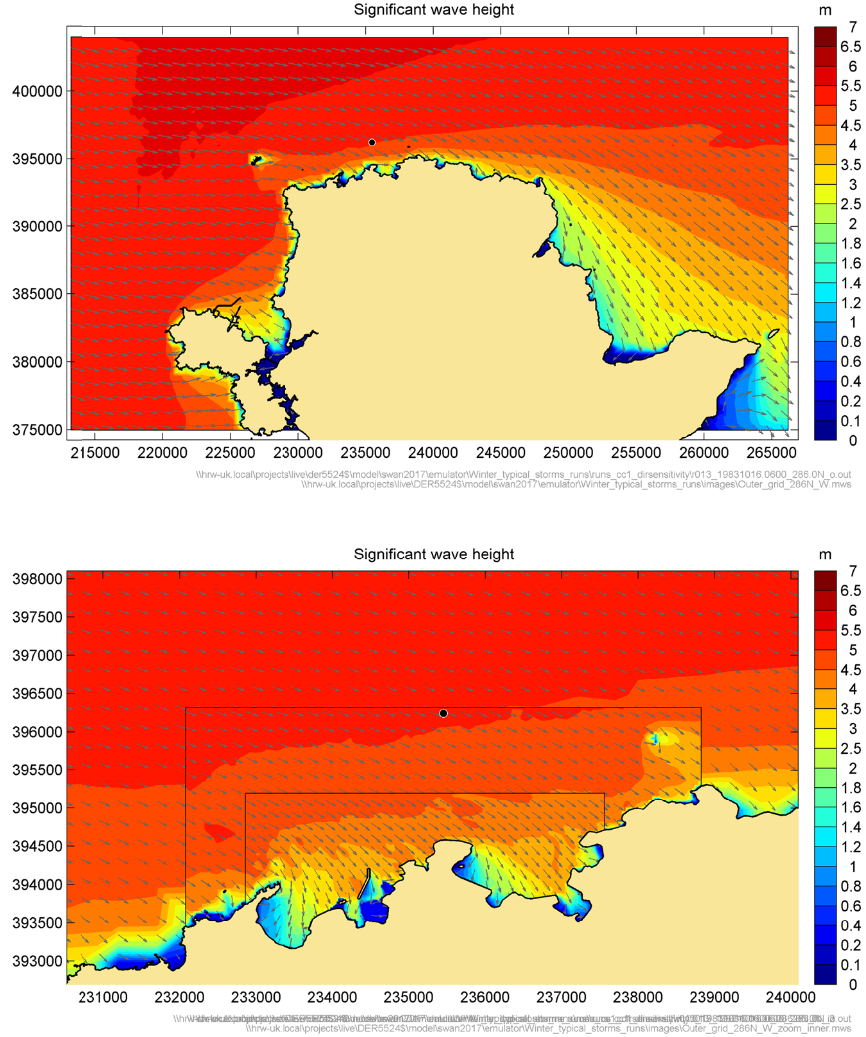


Figure 4.20: W sector conditions with offshore boundary wave direction of 286°N

4.5.3. How frequently the effect is likely to occur

To estimate how frequently a refocusing of wave energy due to the proposed marine structures in Cemlyn Bay is likely to occur, the offshore wave height that gives 10cm difference in significant wave height in Cemlyn Bay were determined for each 5° sector based on the sensitivity runs that give more than 10cm difference (i.e. with offshore wave direction from 176°N to 295°N). All occurrences in the all-year offshore climate table above these conditions were then summed up to give an estimate of the proportion of the time a difference in significant wave height of 10cm or above in Cemlyn Bay will occur.

This analysis was carried out for the "2087 reasonably foreseeable" conditions and the proportion of the time a difference in significant wave height of 10cm or above in Cemlyn Bay is estimated to be 4.9%. This is perhaps a slightly conservative estimate because the worst direction (westerly) wind was applied with all wave directions between 176°N and 291°N.

4.5.4. Selected 99th percentile Winter conditions, difference in significant wave height maps – Fully-built layout

Following the sensitivity tests to the offshore wave directions, the worst directions in each sector were selected to revise the representative 99th percentile winter "2087 reasonably foreseeable" conditions (Table 4.14). The corresponding difference plots (difference in predicted significant wave height between the fully-built layout and the baseline) from the NE, N, NW and W sectors are shown in Figure 4.21 and Figure 4.22.

Each figure is in three parts, and represents just one wave condition. The top pane of each figure shows the baseline significant wave height for the area around Wylfa, the middle pane the corresponding wave heights for the fully-built layout. The bottom pane shows the difference in significant wave height between the runs with and without structures. Yellow and orange shades show increases in significant wave height of at least 10 centimetres. Blue and green shades show reductions in wave height of at least 10 centimetres.

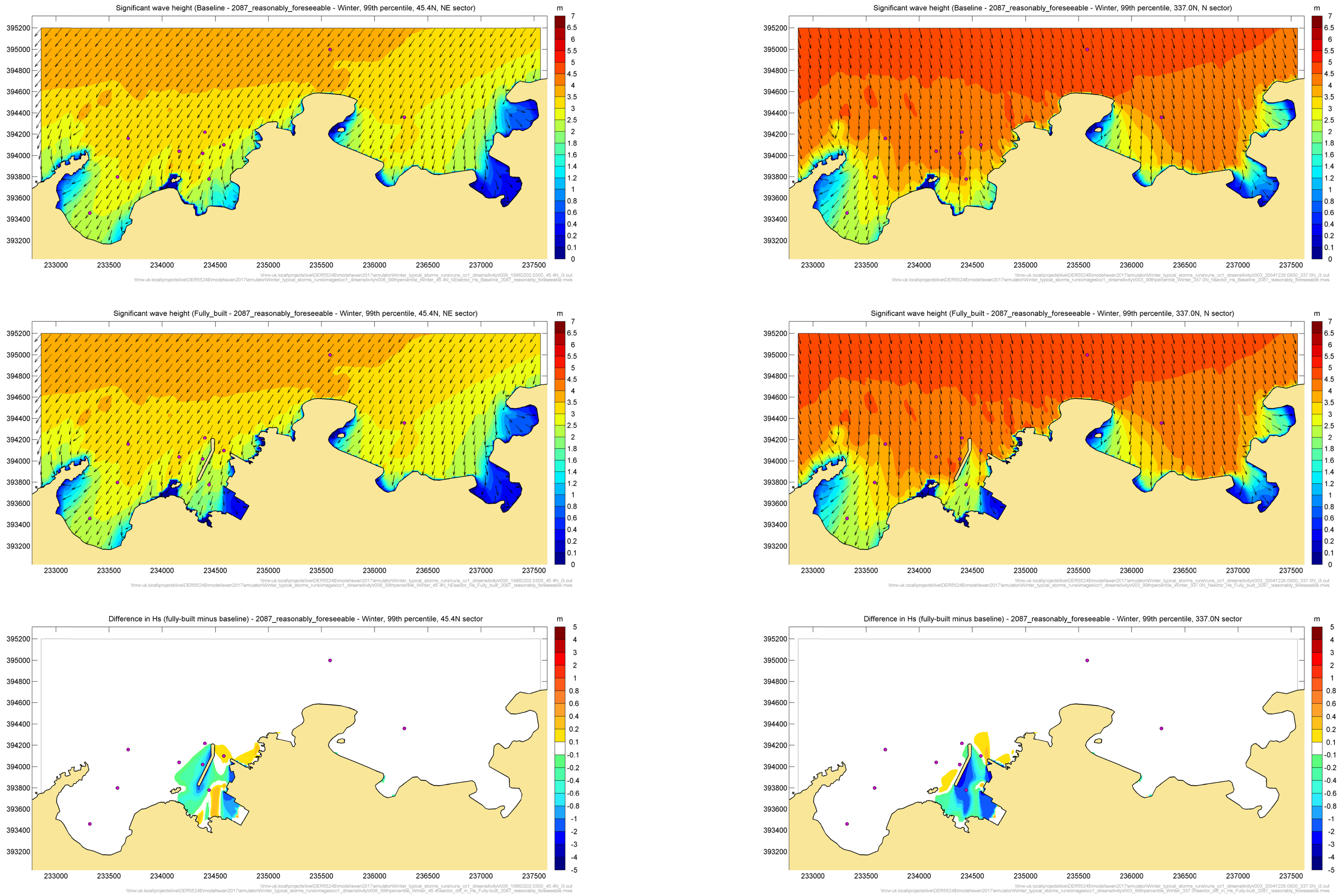


Figure 4.21: Difference in significant wave height, fully-built compared to baseline case, “2087 reasonably foreseeable conditions, NE (left) and N (right) sectors

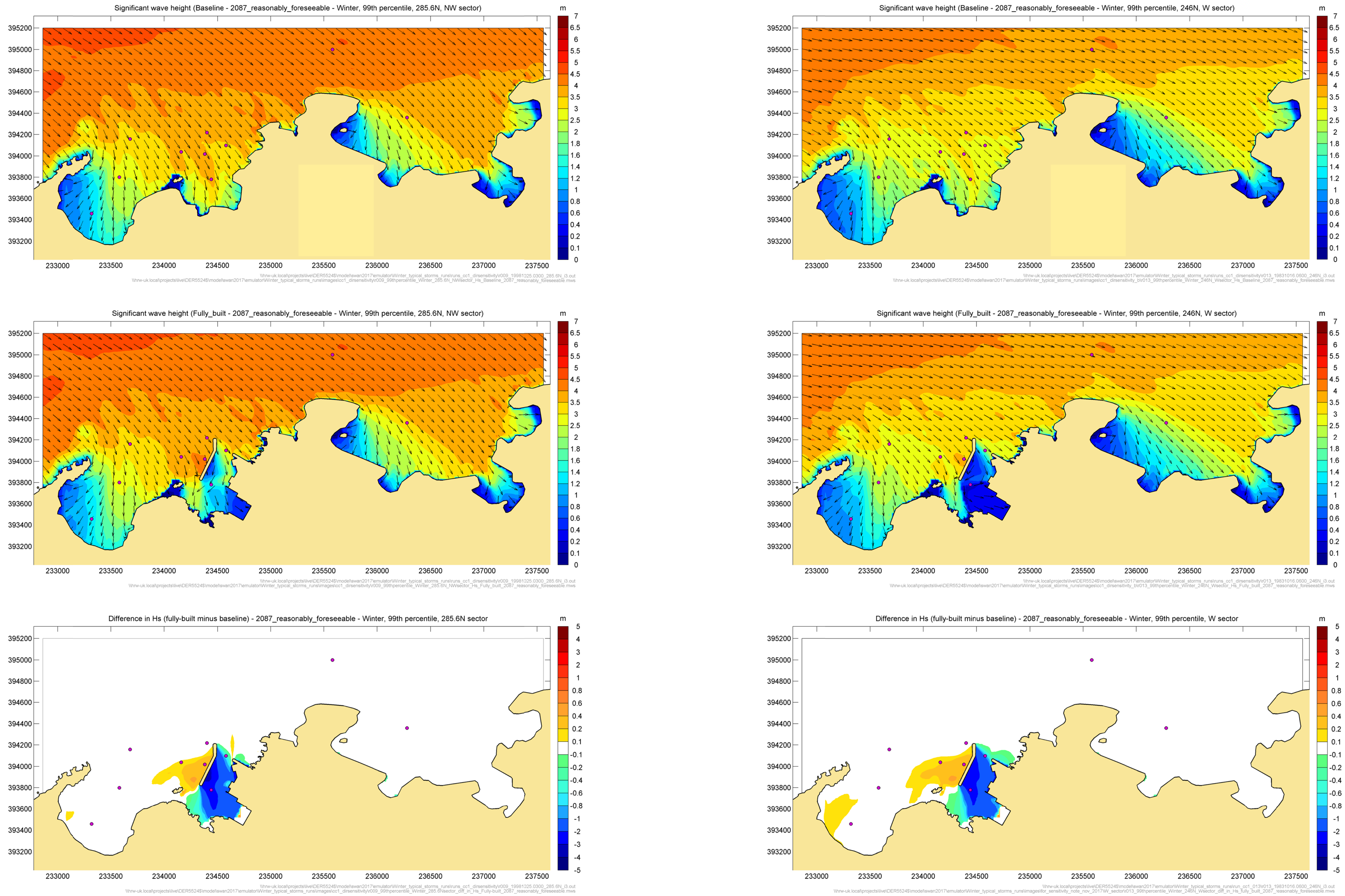


Figure 4.22: Difference in significant wave height, fully-built compared to baseline case, "2087 reasonably foreseeable conditions, NW (left) and W (right) sectors

4.5.5. Wave conditions in Cemlyn Bay

The differences in significant wave height in Cemlyn Bay due to the marine structures are predicted to be less than 20cm for the “2087 reasonably foreseeable” 99th percentile winter conditions.

To illustrate the effects of the marine structures in Cemlyn Bay, in addition to the individual winter conditions, a comparison between the annual wave climates at the nearshore wave output Point 6 (see Figure 4.4) with and without the proposed development in place is presented. Table 4.15 and Table 4.16 show the distribution of significant wave height against mean wave direction at Point 6, for the “present-day” baseline and the “present-day” fully-built layout, respectively. Table 4.17 and Table 4.18 are the corresponding distribution of significant wave height against mean wave period.

The climates show:

- Little difference in wave distributions with and without the proposed marine structures in:
  - Changes in the distribution of waves against mean wave direction are due to the shelter / blockage or the wave reflections from the Western Breakwater.
  - The distribution against mean wave periods is very similar between the two layouts.
- The distribution of large waves (H_s > 2m) against mean wave directions and mean wave periods is similar in both layouts.

The wave conditions in Cemlyn Bay can be summarised as:

- The offshore wave conditions from North / North-East give the largest waves in the Bay and very little change is predicted due to the proposed marine structures.
- Offshore wave conditions from North-West / West are sheltered by the Twyrn Cemlyn headland and give lower wave heights than the North and North-East sectors. They are the most affected by the western breakwater (increase in H_s between 10 and 20cm), but give smaller wave conditions than conditions from North / North –East.
- The main cause of focussing of wave energy in the bay is the reflections from the western breakwater.
- The proportion of the time a difference in H_s of 10cm or above in Cemlyn Bay is estimated to be 4.9%.
- The largest storms will still come from North / North-East.

Table 4.15: Annual wave climate at Point 6, baseline, “2087 reasonably foreseeable”, significant wave height (Hs) against mean wave direction

			Wave direction (°N)											
			-15	15	45	75	105	135	165	195	225	255	285	315
H_{s1} (m)	H_{s2} (m)	$P(H_s>H_{s1})$	15	45	75	105	135	165	195	225	255	285	315	345
0	0.5	100.00%	15394	32201	15741	5676	4037	2864	1635	785	658	449	494	1245
0.5	1	18.82%	1388	9491	3974	41	5	<1	-	-	-	-	-	-
1	1.5	3.92%	36	2282	688	-	-	-	-	-	-	-	-	-
1.5	2	0.92%	-	512	198	-	-	-	-	-	-	-	-	-
2	2.5	0.21%	-	144	33	-	-	-	-	-	-	-	-	-
2.5	3	0.03%	-	22	2	-	-	-	-	-	-	-	-	-
3	3.5	0.00%	-	4	-	-	-	-	-	-	-	-	-	-
Percentage Occurrence			16.82%	44.66%	20.64%	5.72%	4.04%	2.86%	1.64%	0.79%	0.66%	0.45%	0.49%	1.25%

Source: HR Wallingford, SWAN wave transformation and Met Office WW3 offshore data, 1980-2015; occurrence is in parts per hundred thousand

Table 4.16: Annual wave climate at Point 6, fully-built, “2087 reasonably foreseeable”, significant wave height (Hs) against mean wave direction

			Wave direction (°N)											
			-15	15	45	75	105	135	165	195	225	255	285	315
H_{s1} (m)	H_{s2} (m)	$P(H_s>H_{s1})$	15	45	75	105	135	165	195	225	255	285	315	345
0	0.5	100.00%	7638	36126	17286	7498	5823	3087	1083	535	394	283	285	627
0.5	1	19.34%	258	11219	3841	57	5	2	-	-	-	-	-	-
1	1.5	3.95%	-	2407	630	-	-	-	-	-	-	-	-	-
1.5	2	0.92%	-	547	167	-	-	-	-	-	-	-	-	-
2	2.5	0.20%	-	144	30	-	-	-	-	-	-	-	-	-
2.5	3	0.03%	-	24	2	-	-	-	-	-	-	-	-	-
3	3.5	0.00%	-	4	-	-	-	-	-	-	-	-	-	-
Percentage Occurrence			7.90%	50.47%	21.96%	7.56%	5.83%	3.09%	1.08%	0.53%	0.39%	0.28%	0.28%	0.63%

Source: HR Wallingford, SWAN wave transformation and Met Office WW3 offshore data, 1980-2015; occurrence is in parts per hundred thousand

Table 4.17: Annual wave climate at Point 6, baseline, “2087 reasonably foreseeable”, significant wave height (Hs) against mean wave period

			Mean Wave Period (T_{m-10}) in Seconds														
			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
H_{s1} (m)	H_{s2} (m)	$P(H_s>H_{s1})$	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0.5	100.00%	211	6193	19675	26462	18673	7179	2112	532	114	15	7	2	3	2	<1
0.5	1	18.82%	-	16	646	3890	4874	3309	1368	582	159	46	7	<1	-	-	-
1	1.5	3.92%	-	-	3	138	939	1071	573	227	37	12	5	<1	-	-	-
1.5	2	0.92%	-	-	-	<1	44	254	218	149	39	5	<1	-	-	-	-
2	2.5	0.21%	-	-	-	-	-	31	72	48	26	1	-	-	-	-	-
2.5	3	0.03%	-	-	-	-	-	-	3	12	8	2	-	-	-	-	-
3	3.5	0.00%	-	-	-	-	-	-	-	2	2	-	-	-	-	-	-
Percentage Occurrence			0.21%	6.21%	20.32%	30.49%	24.53%	11.84%	4.35%	1.55%	0.38%	0.08%	0.02%	0.00%	0.00%	0.00%	0.00%

Source: HR Wallingford, SWAN wave transformation and Met Office WW3 offshore data, 1980-2015; occurrence is in parts per hundred thousand

Table 4.18: Annual wave climate at Point 6, fully-built, “2087 reasonably foreseeable”, significant wave height (Hs) against mean wave period

			Mean Wave Period (T_{m-10}) in Seconds														
			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
H_{s1} (m)	H_{s2} (m)	$P(H_s>H_{s1})$	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0.5	100.00%	169	5776	19416	26722	18736	7105	2071	530	111	16	5	2	3	2	<1
0.5	1	19.34%	-	14	609	3848	5049	3574	1456	607	169	49	6	<1	-	-	-
1	1.5	3.95%	-	-	2	125	928	1099	587	240	37	13	5	<1	-	-	-
1.5	2	0.92%	-	-	-	<1	39	252	223	155	39	5	<1	-	-	-	-
2	2.5	0.20%	-	-	-	-	-	27	71	49	26	1	-	-	-	-	-
2.5	3	0.03%	-	-	-	-	-	-	3	12	9	2	-	-	-	-	-
3	3.5	0.00%	-	-	-	-	-	-	-	2	2	-	-	-	-	-	-
Percentage Occurrence			0.17%	5.79%	20.03%	30.70%	24.75%	12.06%	4.41%	1.60%	0.39%	0.09%	0.02%	0.00%	0.00%	0.00%	0.00%

Source: HR Wallingford, SWAN wave transformation and Met Office WW3 offshore data, 1980-2015; occurrence is in parts per hundred thousand

4.5.6. December 2013 storm

The comparison between the baseline and the fully-built layout was also carried out for the December 2013 storm.

Figure 4.23 shows the variation in offshore wave and wind conditions through the storm at the Met Office offshore data point. The offshore conditions from the Met Office model point corresponding to the peak of the storm are listed in Table 4.19.

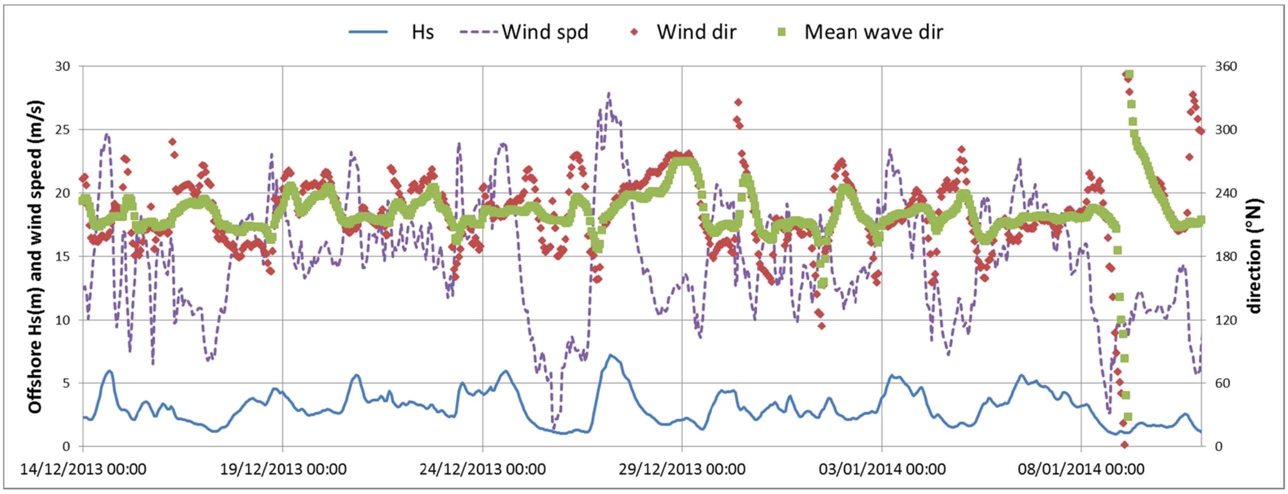


Figure 4.23: Offshore conditions from the Met Office model point data set during the December 2013 storm

Source: Met Office WW3 offshore data, 1980 - 2015

Table 4.19: Offshore conditions at the peak of the December 2013 storm

	H_s (m)	T_{m-10} (s)	Mean Wave Direction (°N)	Wind speed (m/s)	Wind direction (°N)
27/12/2013 05:00	7.24	9.5	220	27.2	217

Source: Met Office WW3 offshore data, 1980 - 2015

Predicted significant wave height through the storm event at Point 6 in Cemlyn Bay is shown in Figure 4.24 for the baseline and fully-built layout. There is only a small difference in significant wave height between the two layouts.

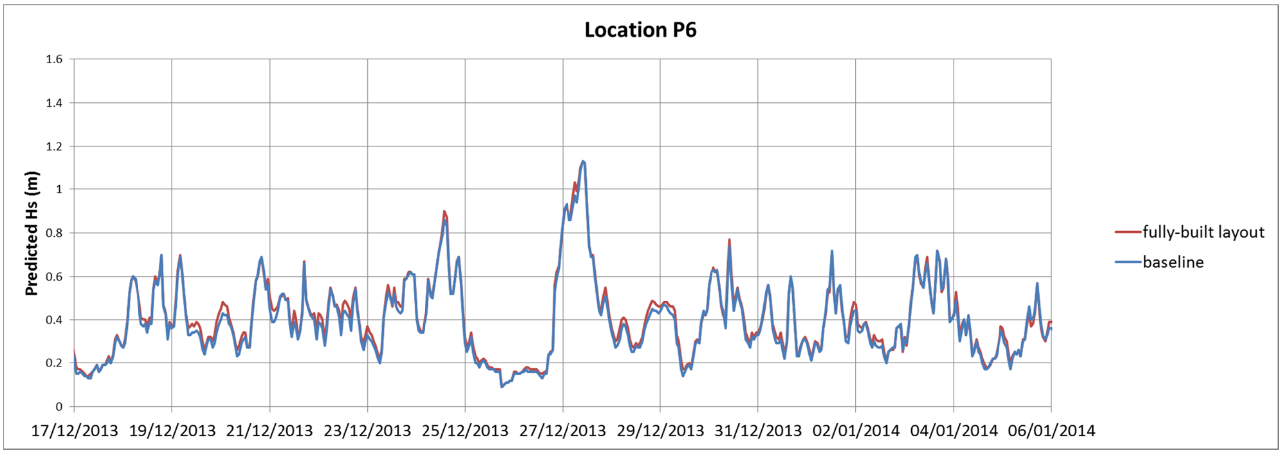


Figure 4.24: Predicted significant wave heights, baseline and fully-built layout, December 2013 storm

Source: HR Wallingford, SWAN wave transformation and Met Office WW3 offshore data, 1980 - 2015

4.5.7. Selected 99th percentile Winter conditions, difference in significant wave height maps – additional 'worst-case' construction layout

One additional part-built layout has been considered for potential impact. It is chosen to represent the "worst-case" construction layout for potential impact and consists of the full Western Breakwater in place with the cofferdam and causeway.

The resulting model layout and bathymetry is shown in Figure 4.25.

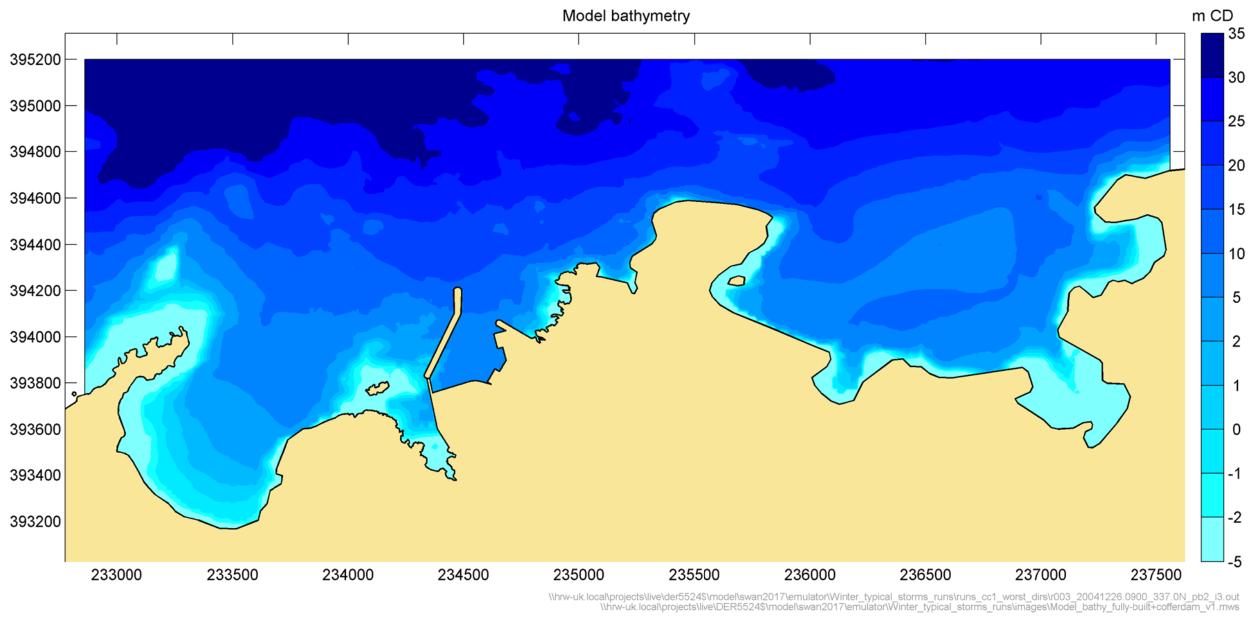


Figure 4.25: SWAN model bathymetry, "worst-case" construction layout

The difference plots (difference in predicted significant wave height between the “worst-case” construction layout and the baseline) for the selected 99th percentile winter “2087 reasonably foreseeable” conditions from the NE, N, NW and W sectors, are shown in Figure 4.26 and Figure 4.27.

Each figure is in three parts, and represents just one wave condition. The top pane of each figure shows the baseline significant wave height for the area around Wylfa, the middle pane the corresponding wave heights for the “worst-case” construction layout. The bottom pane shows the difference in significant wave height between the runs with and without structures. Yellow and orange shades show increases in significant wave height of at least 10 centimetres. Blue and green shades show reductions in wave height of at least 10 centimetres.

Figure 4.26 and Figure 4.27 are directly comparable with Figure 4.21 and Figure 4.22 for the fully-built layout. The effects in Cemlyn Bay are almost identical to the effects predicted for the fully-built layout, which is expected since the main cause of the refocussing of wave energy in Cemlyn Bay comes from the reflections from the western breakwater. The predicted differences with the “worst-case” construction layout are not higher than the ones predicted with the fully-built layout.

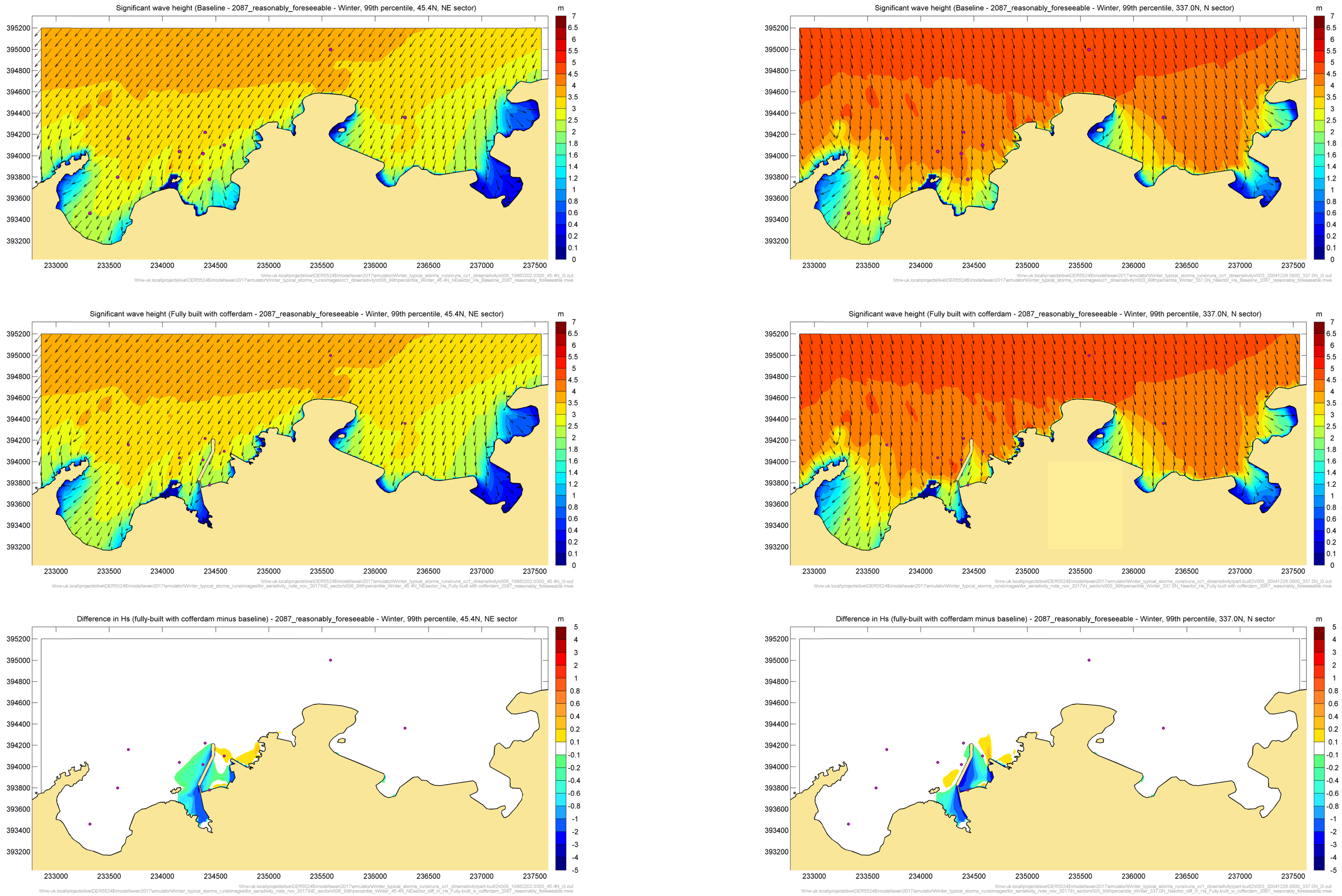


Figure 4.26: Difference in significant wave height, “worst-case” construction layout compared to baseline case, “2087 reasonably foreseeable conditions, NE (left) and N (right) sectors

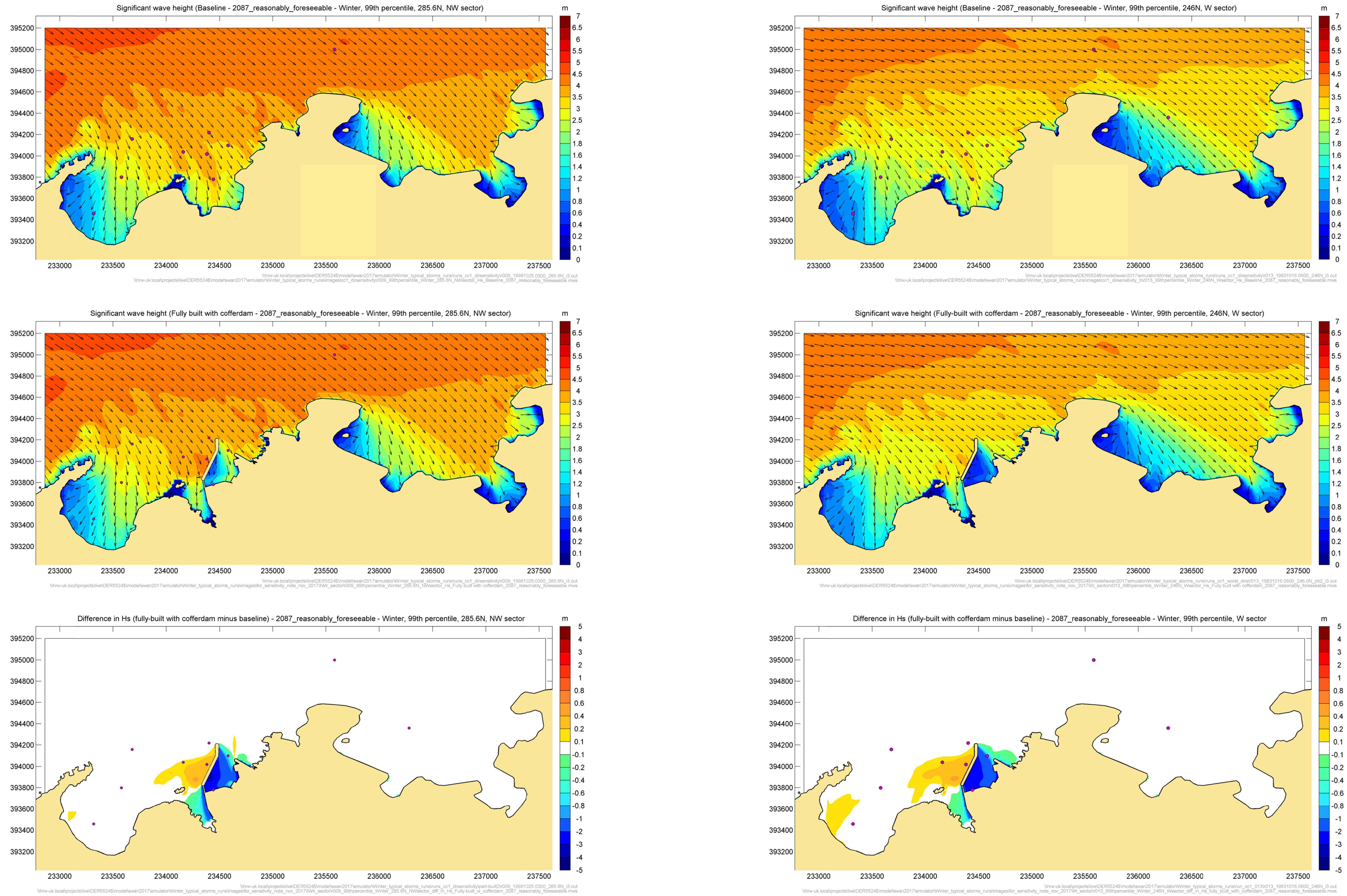


Figure 4.27: Difference in significant wave height, “worst-case” construction layout compared to baseline case, “2087 reasonably foreseeable conditions, NW (left) and W (right) sectors

For completeness, the difference plots (difference in predicted significant wave height between the "worst-case" construction layout and the baseline) for the selected 99th percentile winter "present-day" conditions are shown in Figure 4.28 and Figure 4.29. This comparison is more relevant since the construction layout will not be in place for the 2087 future conditions.

The predicted differences for the "present-day" conditions follow the same pattern as for the "2087 reasonably foreseeable" conditions, but are smaller in magnitude.

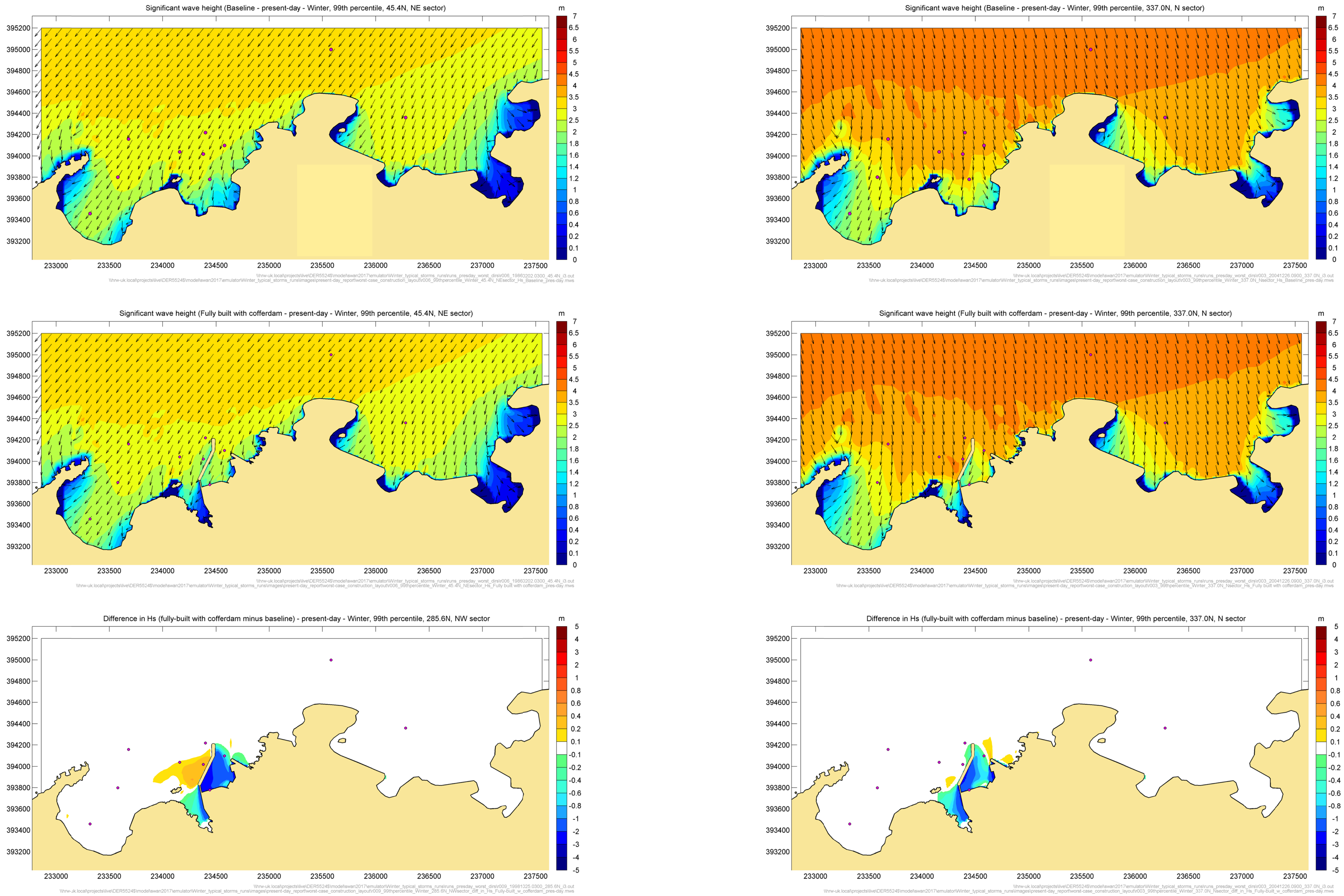


Figure 4.28: Difference in significant wave height, “worst-case” construction layout compared to baseline case, “present-day” conditions, NE (left) and N (right) sectors

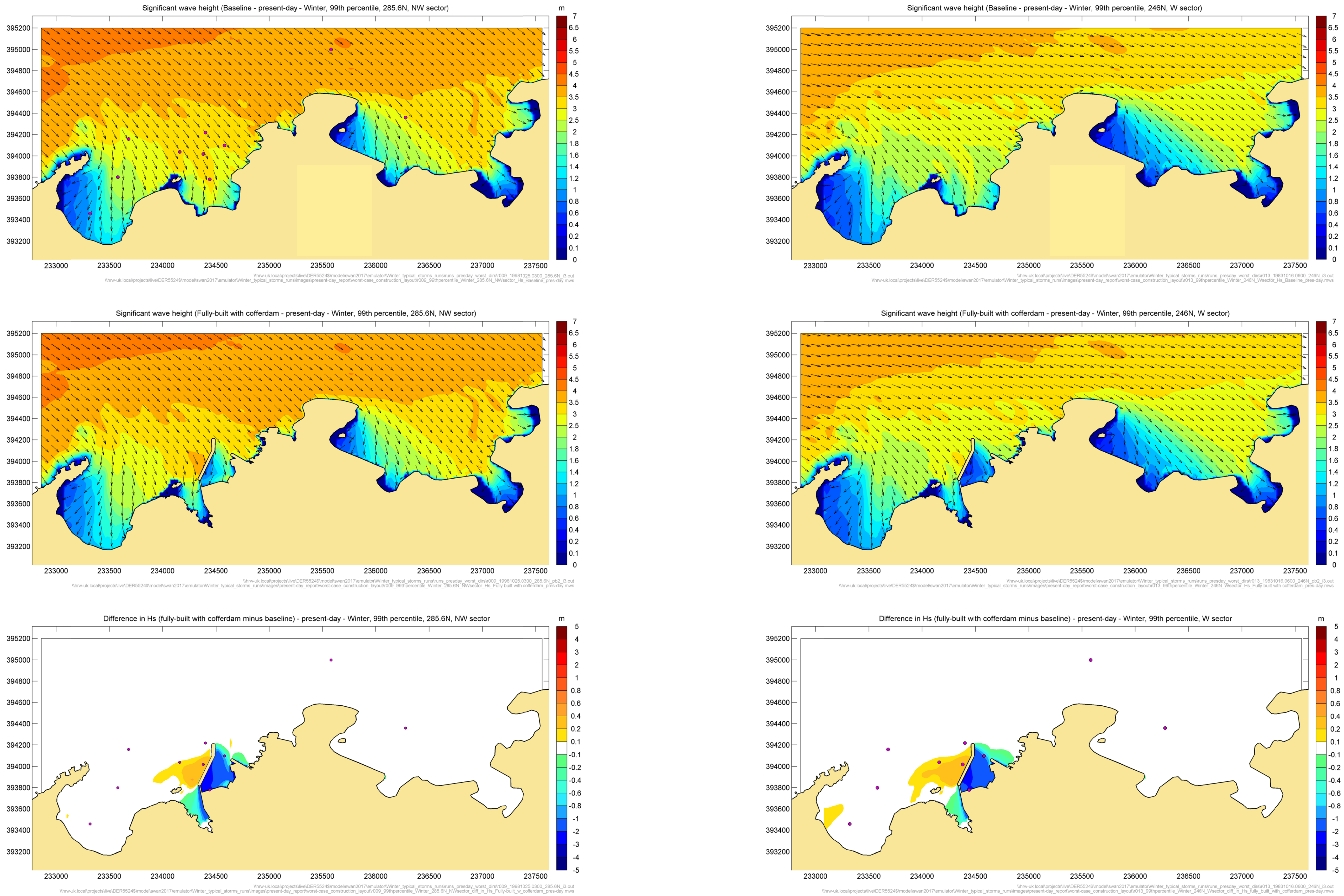


Figure 4.29: Difference in significant wave height, “worst-case” construction layout compared to baseline case, “present-day” conditions, NW (left) and W (right) sectors

5. Wave conditions inside the harbour

Although the SWAN model represents far-field diffraction and reflection of waves, it is a phase–averaged coastal area model that is not designed for use inside harbour areas where more complex wave interference between diffracted and reflected waves may occur. For modelling inside harbours, a local phase-resolving wave disturbance model is required.

Wave disturbance refers to wave conditions within a small area (up to a few kilometres across) protected from incoming waves, usually by breakwaters or headlands. In this instance it relates to the area in the lee of the Wylfa Newydd breakwaters, including the Materials Off-Loading Facility (MOLF), the cofferdam and the cooling water intake. It is required to produce wave conditions to be used to estimate overtopping rates at the two MOLF berths and at the cofferdam, to feed into a flood risk assessment.

The model runs and results from the disturbance modelling focus on marginal and joint exceedence return periods at the MOLF berths and the cofferdam for the 2087 “reasonably foreseeable”, 2087 “credible maximum” and 2187 “reasonably foreseeable” climate-changed scenarios, for the fully-built layout, and for the 2023 “present-day” climate change scenario for the part-built layout. The probabilities of occurrence of interest correspond to return periods of 5, 25, 75, 200 and 1000 years.

5.1. The ARTEMIS wave model

The ARTEMIS model is based on the finite element solution of the Mild Slope Equation. It was developed by the National Hydraulics Laboratory (LNH) of the Research and Development Division of the French Electricity Board (EDF-DER) as part of the TELEMAC finite element hydraulic modelling system. It represents transformation of random waves, including the following effects:

- wave shoaling;
- wave refraction;
- partial reflections from for example the breakwater or quays;
- wave diffraction;
- energy dissipation due to depth-limited wave breaking and seabed friction;
- wave resonance effects.

Further details of the ARTEMIS model are included in Appendix D.

5.1.1. Application of the ARTEMIS model to Wylfa

A local ARTEMIS wave disturbance model was set up to represent the waves inside the harbour area. The model was set up for the part-built layout and the fully-built layout, including the two main breakwaters and the lowering of the bed level within the harbour area relative to present-day levels.

Figure 5.1 and Figure 5.2 show the ARTEMIS model area and bathymetry which was obtained from the local surveys, supplemented with charted data points, for both layouts. The model mesh is unstructured, with a typical spatial resolution of 1.4m in order to resolve the wavelengths of the waves of interest. Note that the bathymetry to the south-west of the southern tip of the western breakwater has been refined relative to that used for the SWAN model, both because this area is critical for wave energy entering the harbour and because the ARTEMIS model grid is finer than that of the SWAN model.

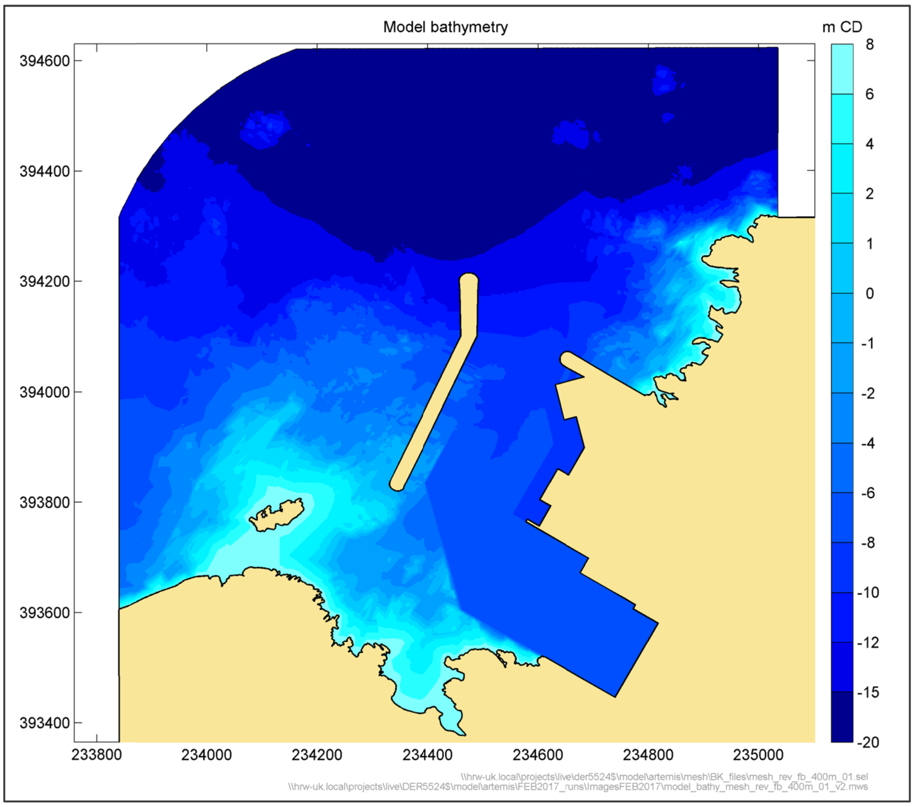


Figure 5.1: ARTEMIS model extent and bathymetry, fully-built layout

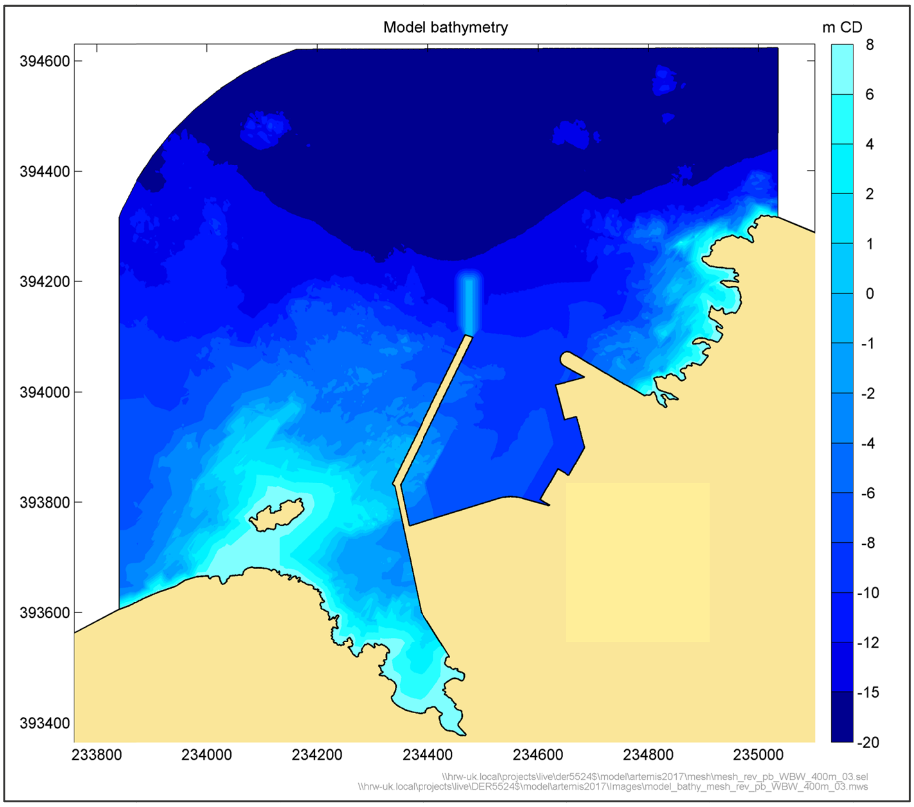


Figure 5.2: ARTEMIS model extent and bathymetry, part-built layout

5.2. Boundary wave conditions

5.2.1. Point P1 at which to estimate boundary conditions

Boundary conditions for the ARTEMIS model were extracted from the SWAN model on the ARTEMIS model boundary (Figure 5.3). Initially, two points / directions were considered as potentially leading to the greatest wave agitation in the harbour: P1 on the northern model boundary and P2 on the north-west model boundary. Selection of the more appropriate boundary point depended on some sensitivity tests.

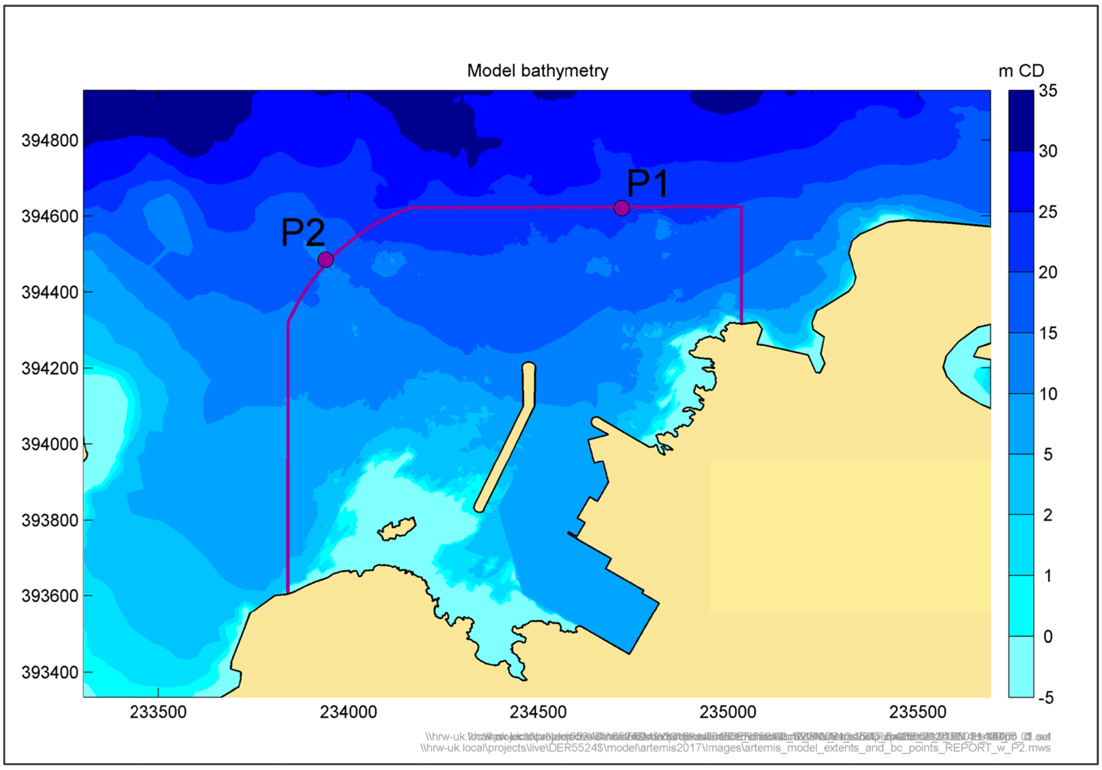


Figure 5.3: Locations of the ARTEMIS model boundary point

An earlier wave modelling study (Amec, 2015) showed that the highest waves close to the coast at Wylfa come from the north, and that they originated broadly from the north. As the harbour entrance faces north, it might be expected that the highest wave conditions within the harbour would also come from the north. However, there is the possibility that waves approaching the harbour from the north-west would also enter the harbour, through the shallow water between the southern tip of the western breakwater and the land. The sensitivity test described here was designed to check that waves from the north-west would not significantly affect the extreme wave conditions predicted within the harbour.

The four storms from the north causing the highest waves at Point P1 and the four storms from the north-west causing the highest waves at Point P2 were identified based on the SWAN model predictions for Points P1 and P2. For the fully-built layout, the wave heights within the harbour area were larger for each of the northerly storms than for any of the north-westerly storms. As a further check, the largest storm from each sector was run through ARTEMIS (for an earlier harbour design layout), both storms being run at a 1 year return period sea level. The results are shown in Figure 5.4, in which the waves for the northerly storm are significant higher within the harbour than those for the north-westerly storm. Subsequent analysis is based on waves for all sectors combined, but with the assumption that the highest waves will approach the harbour approximately from the north at Point P1.

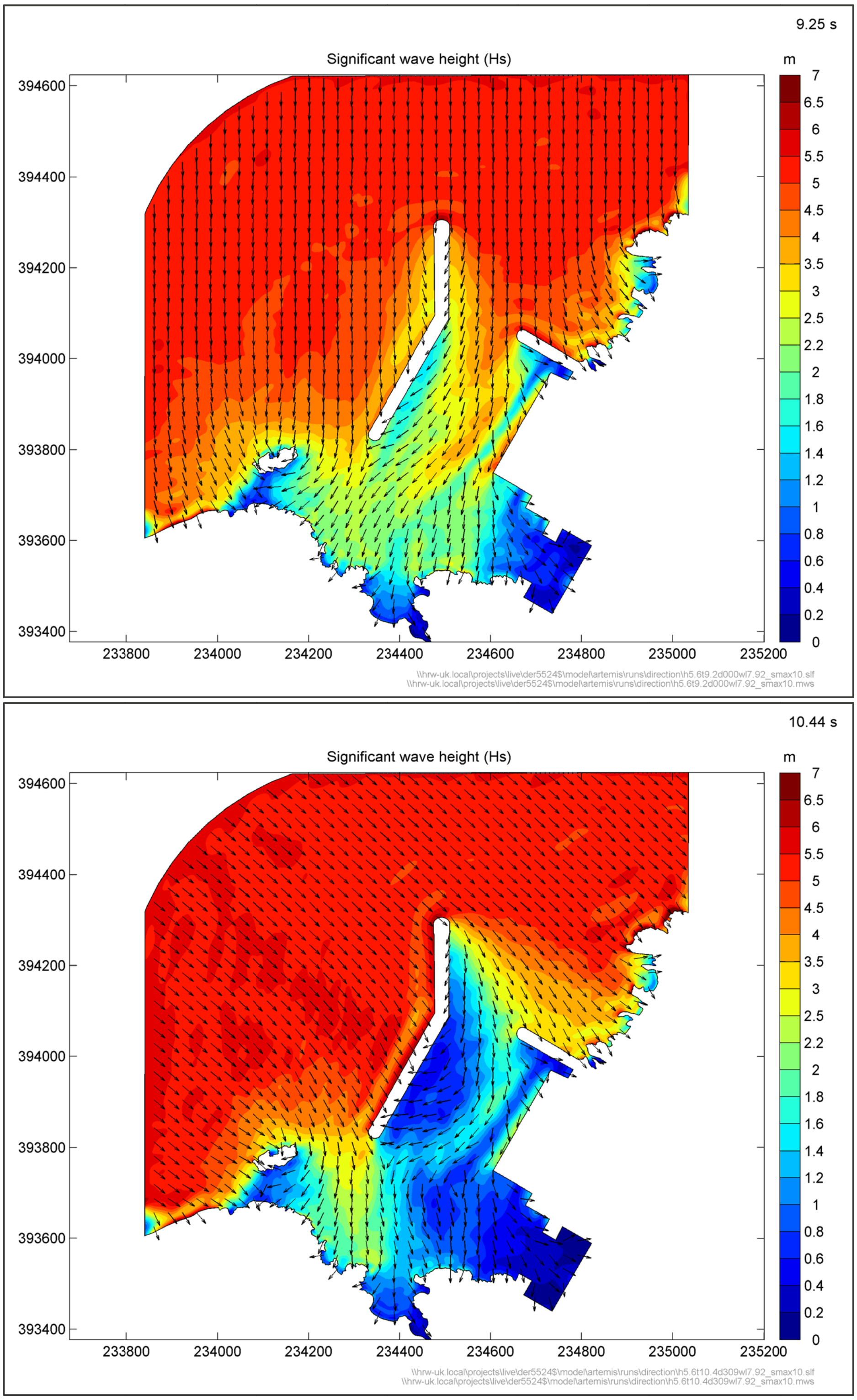


Figure 5.4: Significant wave heights from the most severe storms in the 35-year time series at Point P1 (top) from the north and (bottom) from the north-west sectors

Source: ARTEMIS model; based on an earlier harbour design (2015 layout drawings)

5.2.2. Boundary wave direction

The distribution of significant wave height against mean wave direction at Point P1 is shown in Figure 5.5. This is based on the SWAN model runs for the “2087 reasonably foreseeable” climate-changed scenario, applying partitioned offshore wave spectra, and covering only the highest ten percent of wave heights offshore.

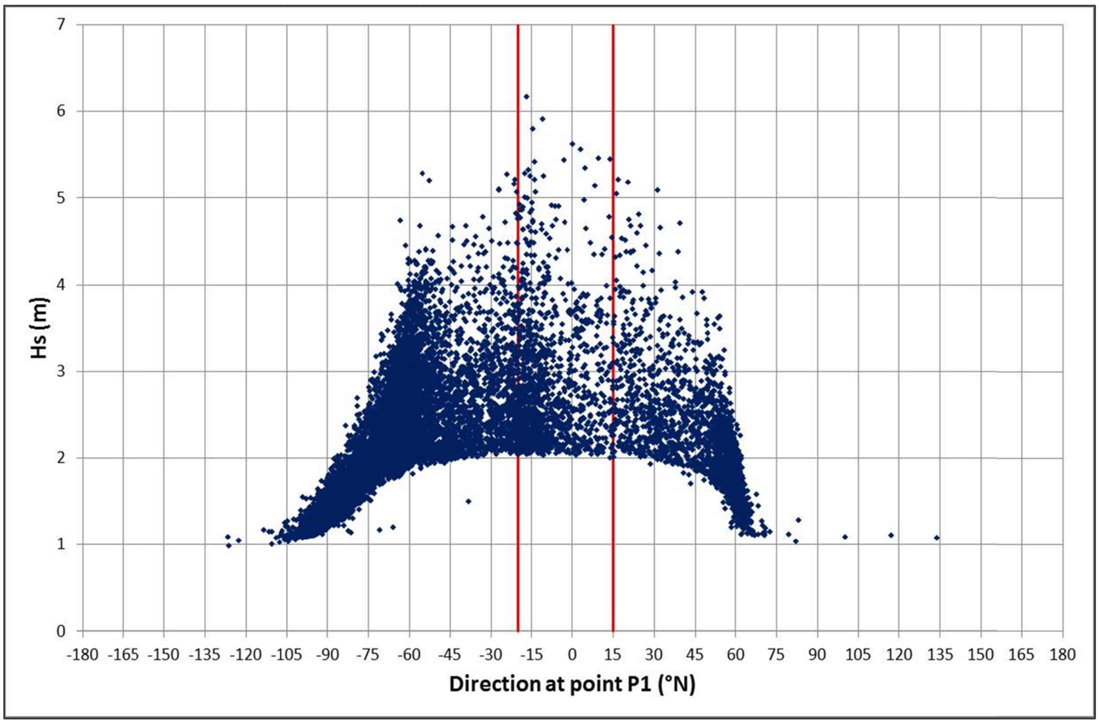


Figure 5.5: Distribution of significant wave height against mean wave direction at the ARTEMIS model boundary Point P1

Source: SWAN model runs of the highest 10% storm events offshore and Met Office WW3 offshore data, 1980-2015, including future climate change allowance

Although the prevailing wave direction is approximately north-west, the highest waves at Point P1 are predicted to come from close to north (-20°N to +15°N, as indicated by the red lines in Figure 5.5). The extreme wave conditions were tested as coming from due north at Point P1 and from directions ten degrees either side of due north. Due north was adopted as the worst case offshore direction for wave heights within the harbour.

Based on the highest four northerly wave conditions modelled with SWAN, the directional spread was found to be of order 30-35°, represented in ARTEMIS by setting model parameter S_{max} to a value of 10.

5.2.3. Boundary wave heights and periods

The derivation of wave extremes and the joint probability with high water levels at Point P1 for the “2087 reasonably foreseeable” climate-changed scenario, undertaken during earlier work, is described in Appendix E.

The tangent-based joint exceedence curves at Point P1 provide conditions to run in the ARTEMIS model. The joint exceedence curves are curves of joint extreme combinations of significant wave height and water level. The tangent-based method refers to the approach used to derive the contours, in which the joint exceedence curve for a given probability or return period is defined by the property that wave height / water level combinations exceeding the tangent to the curve at any point have the required probability of exceedence (Huseby et al., 2013). This approach ensures that for example at every point along the 200-year curve, the probability of the wave /water level combination being outside the tangent to this curve is once in 200 years. The method is described in more detail in Appendix E.2.

Present-day and future climate changed conditions were derived from the “2087 reasonably foreseeable” conditions.

The “2087 reasonably foreseeable” joint exceedence curves at P1 for return periods of 5, 25, 75, 200 and 1000 years are presented in Figure 5.6. The information is also tabulated in Table E.2 (the first row of each block of data representing the marginal extreme wave condition for that return period).

Twenty representative conditions (4 combinations of wave height and water level per return period) were selected for each climate-changed scenario, to be run in ARTEMIS, in order to transform the whole set of joint exceedence curves (shown in Figure 5.6). The twenty representative conditions run in the ARTEMIS model were selected to be sufficient to scale the joint-exceedence curves at the entrance to the joint-exceedence curves at the points inside the harbour.

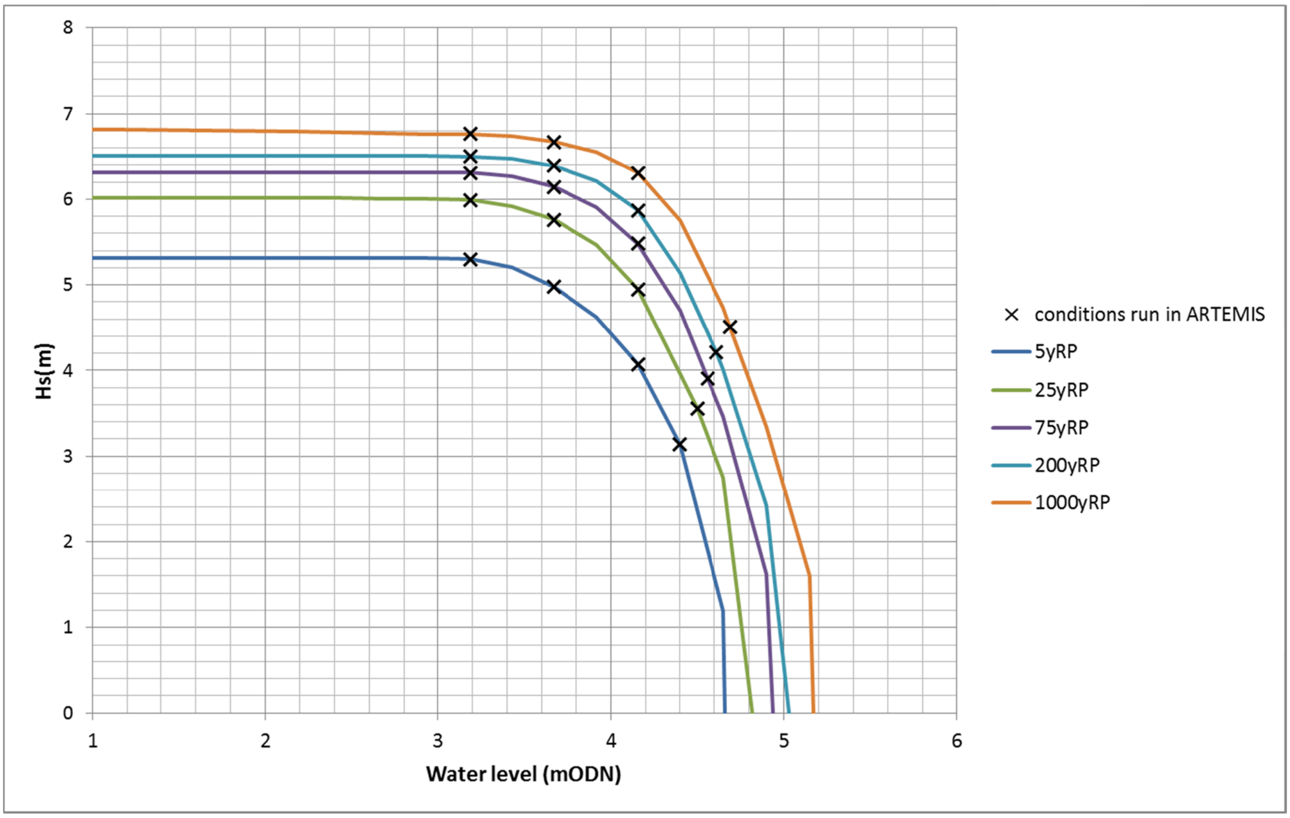


Figure 5.6: High water joint probability, Point P1, fully-built “2087 reasonably foreseeable” conditions

Source: HR Wallingford analysis; SWAN modelling

For consistency, so as to achieve best estimates of *differences* between the different climate change scenarios, the “2087 reasonably foreseeable” joint probability curves at Point P1 were used for each scenario, but with the following adjustments for the new climate-changed scenarios.

Water level

Remove the “2087 reasonably foreseeable” future climate change allowance and replace it with the relevant allowance, to account for the climate change allowances revision from UKCP09 guidance, used in earlier wave modelling work, to the Welsh Guidance 2016 used in the present modelling and summarised in Table 3.1.

Wave height

Tests showed little sensitivity of wave height at Point P1 to high-tide sea level (the water level makes more difference in shallower water closer inshore).

Therefore, wave conditions leading to the highest ten percent of wave heights at any or all of the five offshore locations (Figure 4.1) were selected to be the largest storm events for the site in the 35-year time series. These storms were run in SWAN and transformed to Point P1 at four different sea levels, with and without the wave height climate change allowance, to estimate the adjustments to apply to the “2087 reasonably foreseeable” joint probability curves at Point P1 for the new climate-changed scenarios. The four different sea levels considered are the four UKCP09 climate change scenarios (UKCIP, 2009) (used in previous modelling):

- “2087 reasonable foreseeable”: 3.48mOD [1];
- “2187 reasonable foreseeable”: taken as 2087 credible maximum as only a few cms difference;
- “2087 credible maximum”: 4.5mOD;
- “2187 credible maximum”: 6.8mOD

Sensitivity to sea level was logged in units of percentage change in wave height per additional metre of sea level. Results lay in the range -0.3%/m to +1.4%/m with an average (for high waves only) of 0.7%/m. For sea levels above that of the “2087 reasonably foreseeable” case, this result was captured in the form of a uniform adjustment of 1.0% increase per additional metre of sea level, applied to all wave heights. Sensitivity to offshore wave height was logged in units of percentage change in wave height per percentage change in offshore wave height. For the present-day case, the future climate change allowance applied to wave height (10% increase offshore) was removed by decreasing all “2087 reasonably foreseeable” wave heights by 8% (and corresponding wave periods by 3.25%).

The resulting high-water joint-exceedence curves at P1 for return periods of 5, 25, 75, 200 and 1000 years, for the “present-day”, “2187 reasonably foreseeable” and “2087 credible maximum” cases, are presented in Figure 5.7 to Figure 5.9.

1 With climate change allowances based on UKCIP, 2009 guidelines, as used in previous wave modelling (HR Wallingford (2015)).

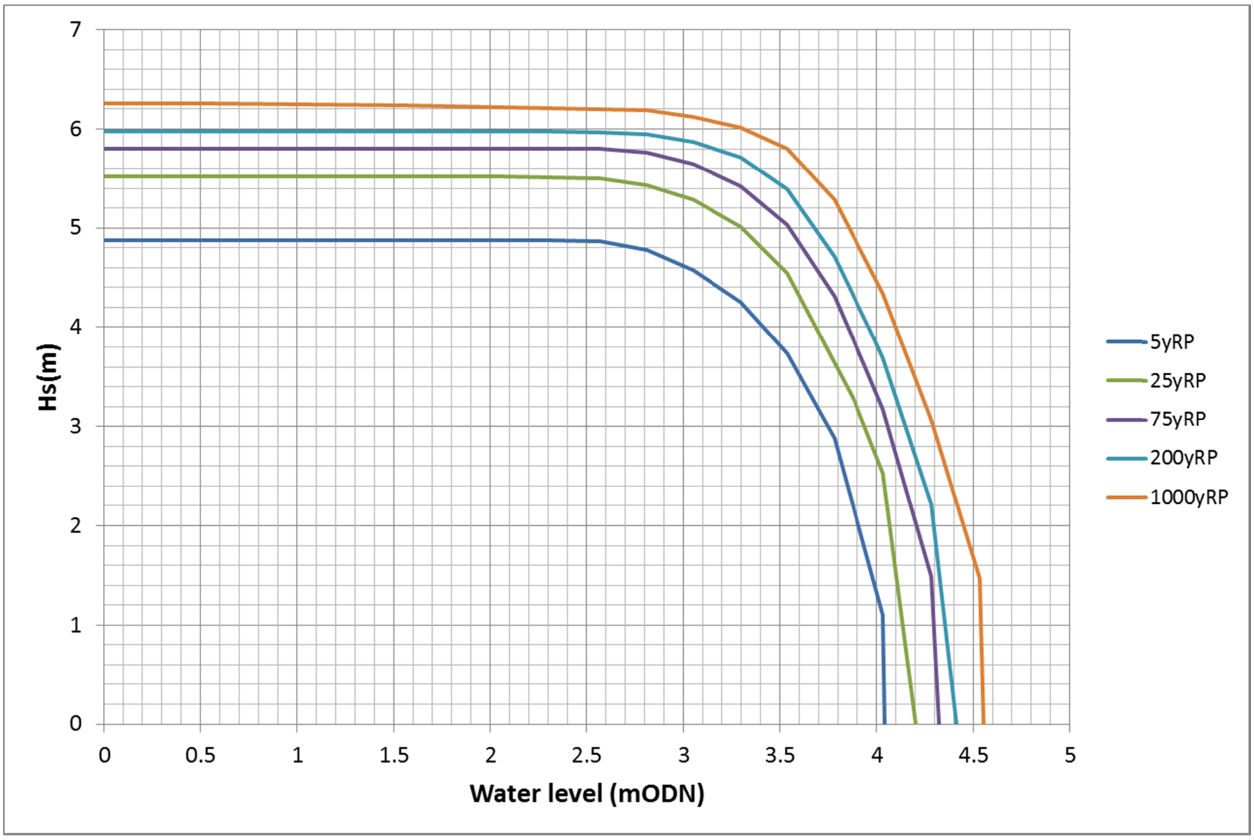


Figure 5.7: High water joint probability, Point P1, “2023 present-day” conditions

Source: HR Wallingford analysis; SWAN modelling

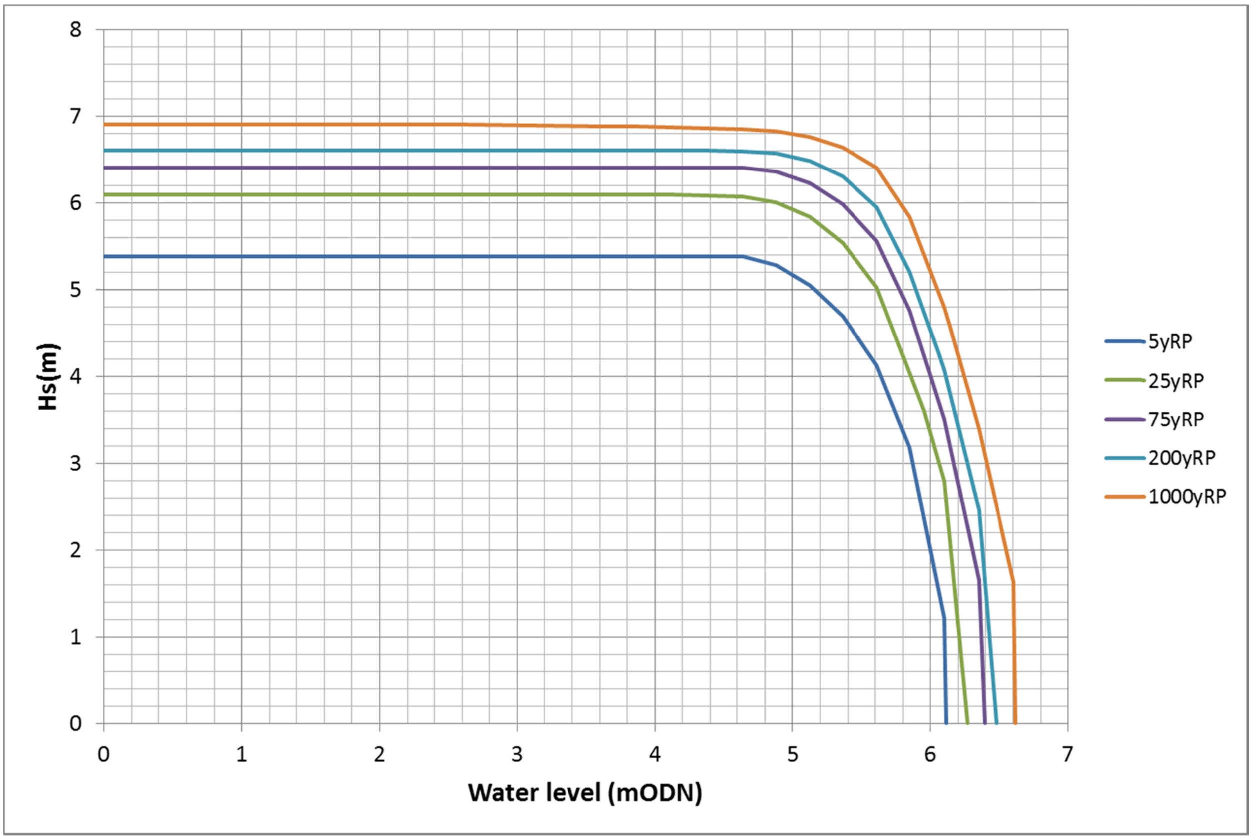


Figure 5.8: High water joint probability, Point P1, “2187 reasonably foreseeable” conditions

Source: HR Wallingford analysis; SWAN modelling

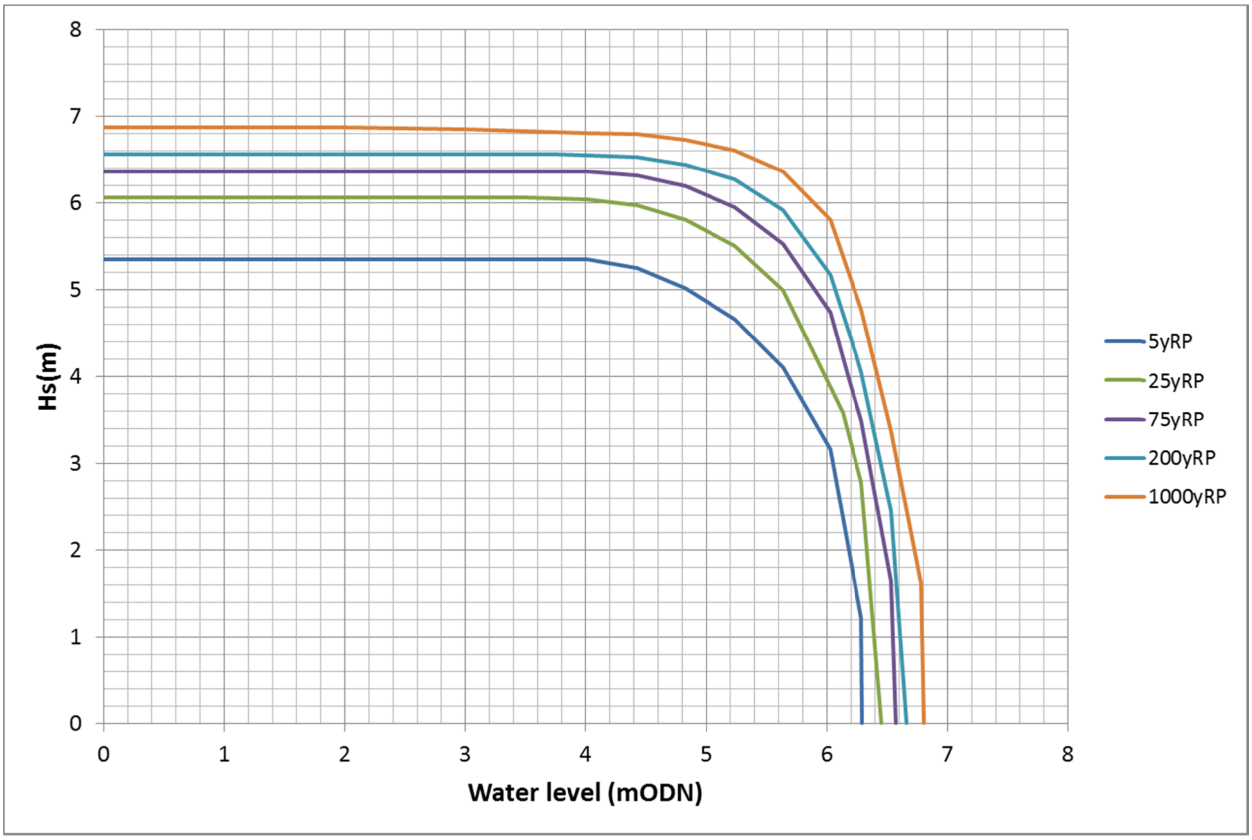


Figure 5.9: High water joint probability, Point P1, “2087 credible maximum” conditions

Source: HR Wallingford analysis; SWAN modelling

5.2.4. Transmission coefficient

In the part-built layout, the Western breakwater is partially constructed with a crest elevation of +4mAOD. The difference between the crest level and the present-day MHWS water level is only one metre. Therefore, the breakwater was represented as a partially transmissive structure in the ARTEMIS model.

The wave transmission coefficient was estimated based upon the wave conditions incident to the breakwater and an empirical relationship derived from a physical model database (HR Wallingford, 2009). A transmission coefficient of 1.0 would indicate full transmission. The transmission coefficient used in the model for the partially constructed Western breakwater is 0.35, which is a relatively conservative estimate of transmission for the MHWS present-day conditions.

5.2.5. Reflection coefficients

The reflection properties of the boundaries were represented in the ARTEMIS model by assigning appropriate wave reflection coefficients to each of the boundary types within the model, e.g. coastline, breakwaters, quays and other structures, depending on the form of the structure and the wave conditions (Allsop, 1990). A reflection coefficient of 1.0 would indicate reflection of all the incident wave energy, while a lower reflection coefficient would be indicative of some wave energy being dissipated.

The reflection coefficients used for the study are summarised in Table 5.1, and also shown in Figure 5.11 and Figure 5.12. The model runs include allowance for almost total reflection from the vertical front face of the intake structure (Figure 5.10).

Wave conditions (incident waves) are imposed at the circular segment boundary.

Table 5.1: Reflection coefficients used in the ARTEMIS model

Boundary types	Reflection coefficient
Rocky coastline	0.4
Vertical structures along the quay	0.95
CW intake	0.95
Breakwater (1:4/3 slope)	0.4
Rock revetment slope (1:1.5)	0.35
Absorbing or open structures	0.0

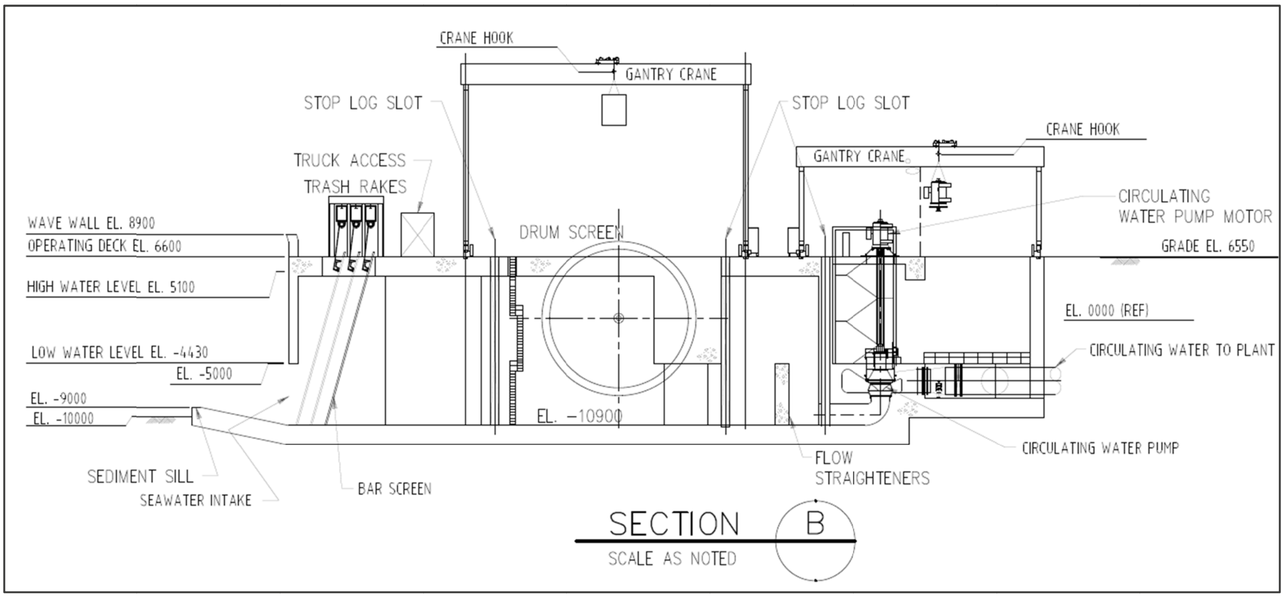


Figure 5.10: Cross-section through the intake

Source: Bechtel

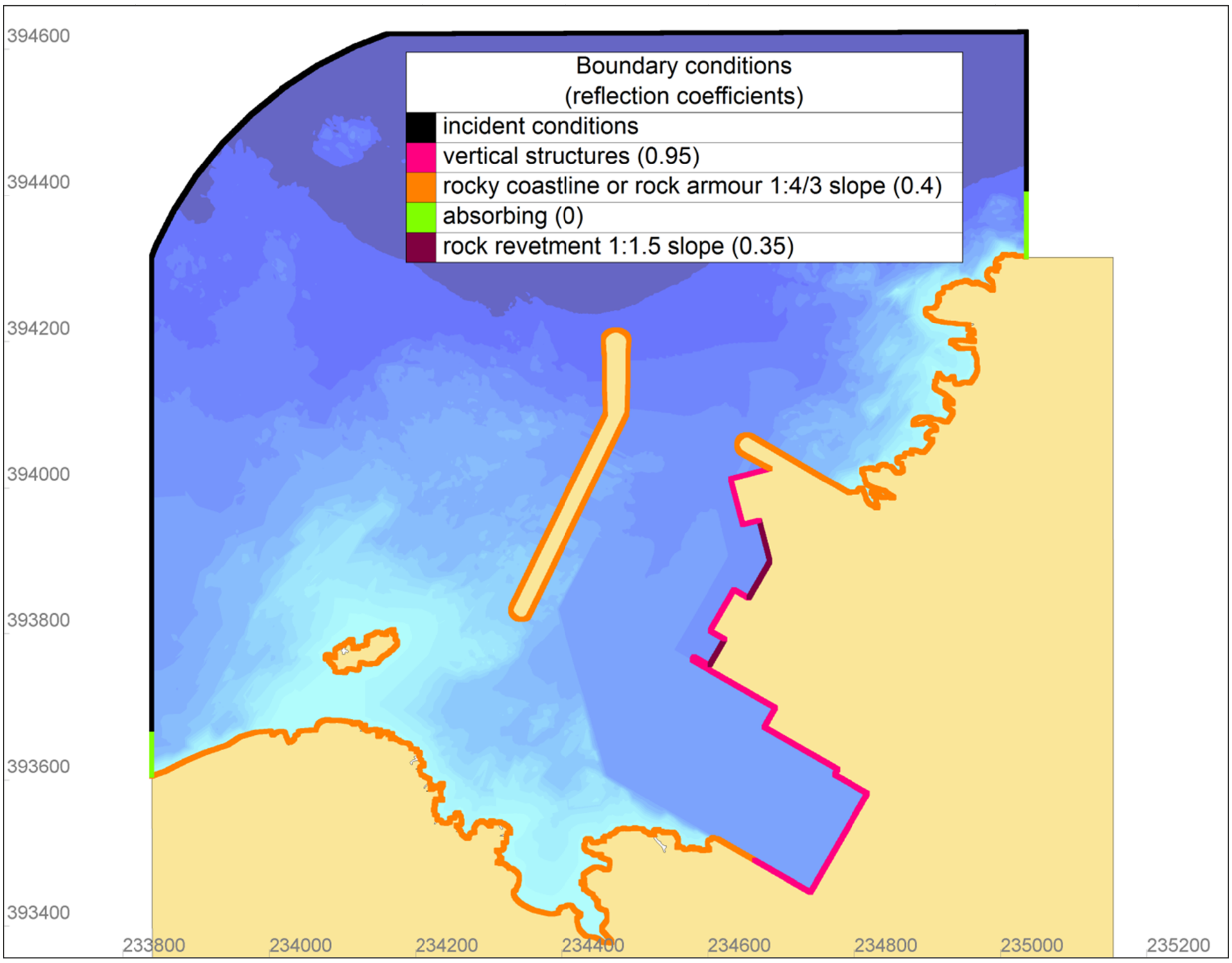


Figure 5.11: ARTEMIS model reflection coefficients and model boundaries for the fully-built layout (400m Western breakwater)

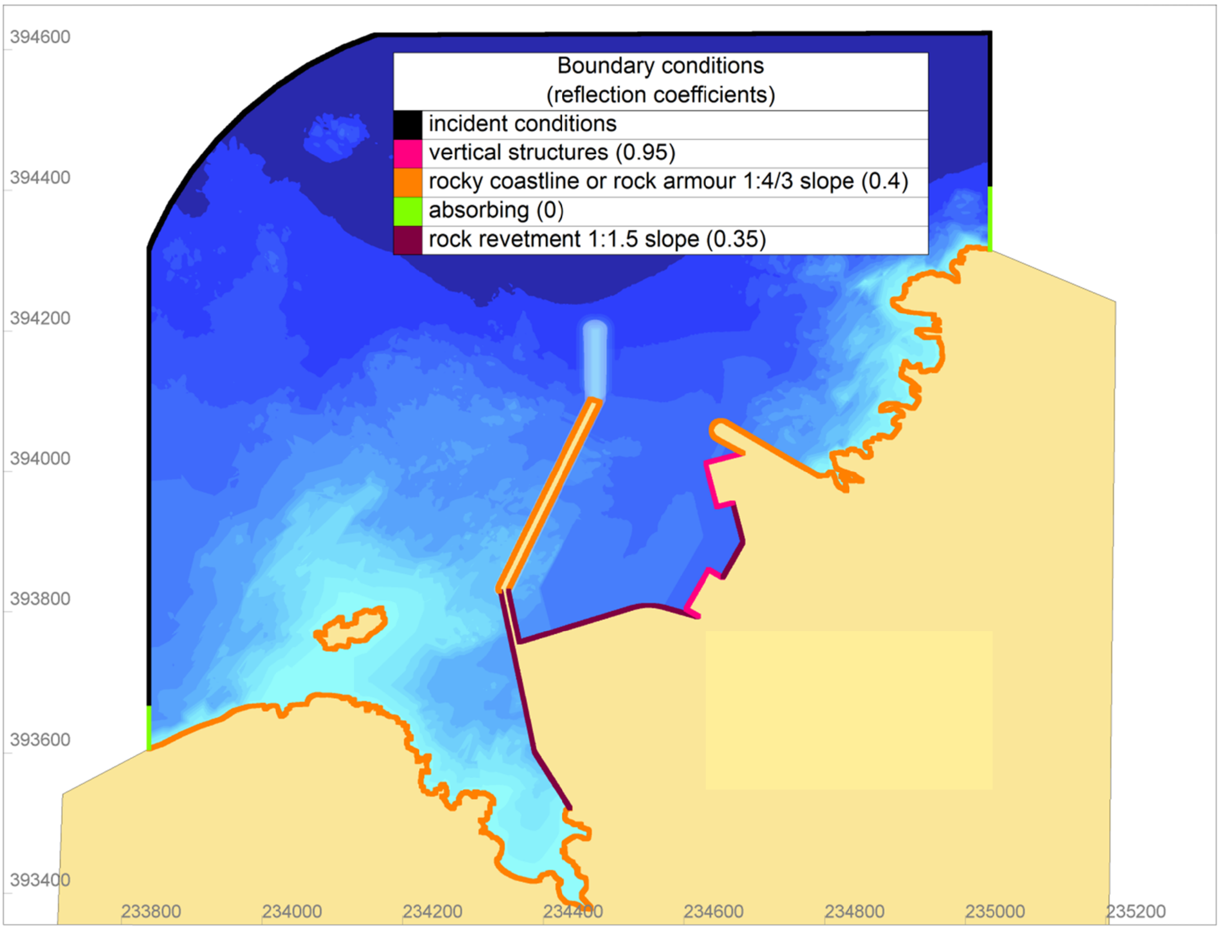


Figure 5.12: ARTEMIS model reflection coefficients and model boundaries for the part-built layout (400m Western breakwater)

5.3. Nearshore wave prediction points

Although ARTEMIS produces results across the whole model area, the greatest interest is in waves at Positions A1-A3, representative of the two MOLF quays and the cofferdam. These are shown in Figure 5.13:

- A1, the northern MOLF quay;
- A2, the southern MOLF quay;
- A3a and A3b, the cofferdam.

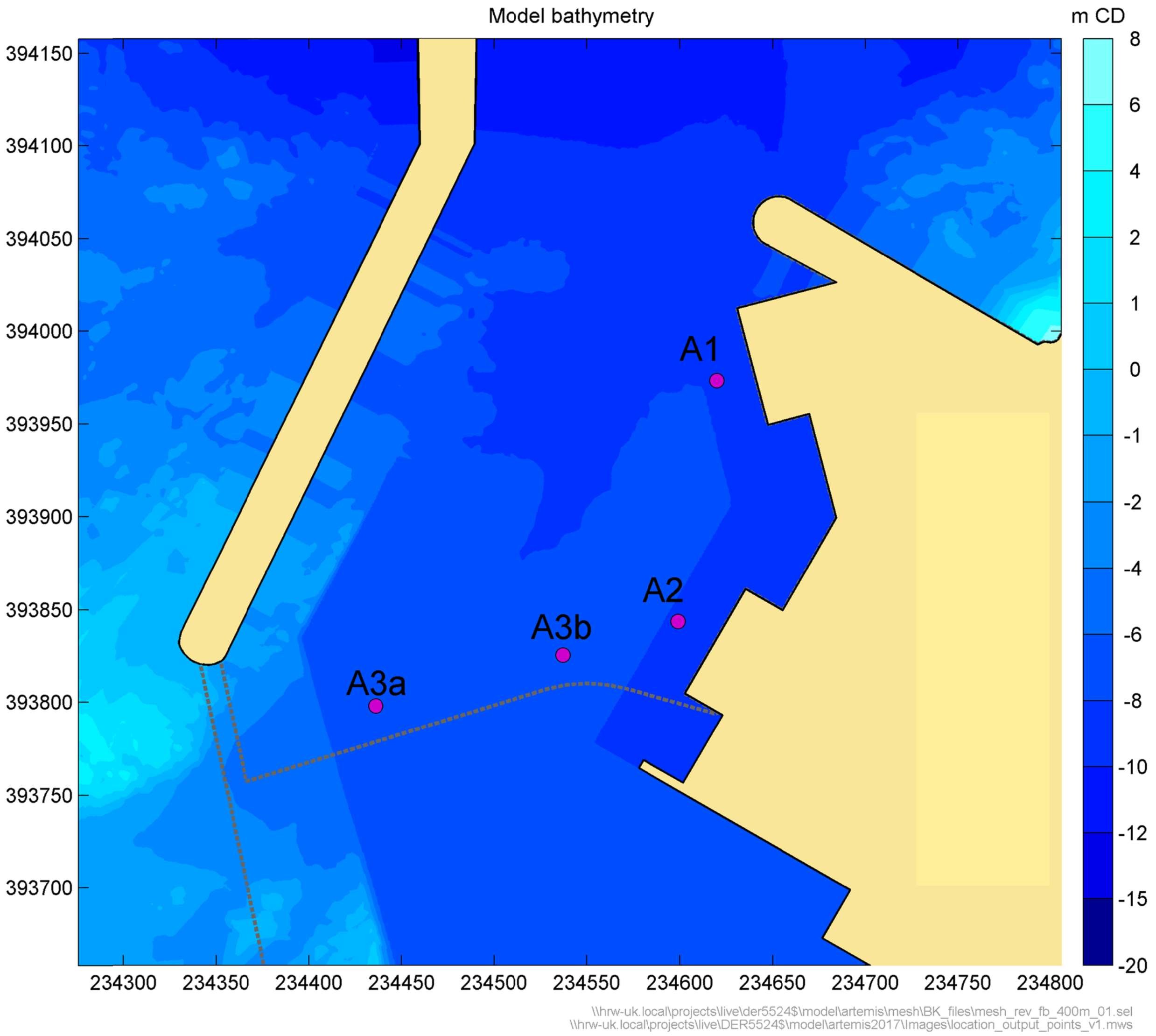


Figure 5.13: Positions at which the ARTEMIS model results are summarised

5.4. Wave extremes results

Wave and sea level conditions with joint exceedence return periods of 5, 25, 75, 200 and 1000 years on the ARTEMIS model boundary were transformed to corresponding conditions within the model area, for the harbour layouts. The list of conditions run is summarised in Table 5.2. The mean wave direction associated with the extreme runs is North, which has been selected, based on the earlier modelling, as the worst case offshore direction for wave heights within the harbour.

Table 5.2: Conditions run in the ARTEMIS model

Return Period (years)	2023 "present-day"			"2087 reasonably foreseeable"			"2187 reasonably foreseeable"			"2087 credible maximum"		
	H_s (m)	T_p (s)	Sea level (mOD)	H_s (m)	T_p (s)	Sea level (mOD)	H_s (m)	T_p (s)	Sea level (mOD)	H_s (m)	T_p (s)	Sea level (mOD)
5	4.9	9.2	2.6	5.3	9.6	3.2	5.4	9.6	4.6	5.3	9.6	4.0
5	4.6	8.9	3.1	5.0	9.3	3.7	5.1	9.3	5.1	5.0	9.3	4.8
5	3.7	8.1	3.5	4.1	8.4	4.2	4.1	8.4	5.6	4.1	8.4	5.6
5	2.9	7.1	3.8	3.1	7.4	4.4	3.2	7.4	5.9	3.2	7.4	6.0
25	5.5	9.8	2.6	6.0	10.2	3.2	6.1	10.2	4.6	6.0	10.2	4.0
25	5.3	9.6	3.1	5.8	10.0	3.7	5.8	10.0	5.1	5.8	10.0	4.8
25	4.6	8.9	3.5	5.0	9.2	4.2	5.0	9.3	5.6	5.0	9.3	5.6
25	3.3	7.6	3.9	3.6	7.8	4.5	3.6	7.9	6.0	3.6	7.9	6.1
75	5.8	10.1	2.6	6.3	10.4	3.2	6.4	10.5	4.6	6.4	10.5	4.0
75	5.6	9.9	3.1	6.1	10.3	3.7	6.2	10.4	5.1	6.2	10.3	4.8
75	5.0	9.4	3.5	5.5	9.7	4.2	5.6	9.8	5.6	5.5	9.8	5.6
75	3.6	7.9	3.9	3.9	8.2	4.6	4.0	8.3	6.0	3.9	8.2	6.2
200	6.0	10.2	2.6	6.5	10.6	3.2	6.6	10.7	4.6	6.6	10.6	4.0
200	5.9	10.1	3.1	6.4	10.5	3.7	6.5	10.6	5.1	6.4	10.5	4.8
200	5.4	9.7	3.5	5.9	10.1	4.2	6.0	10.1	5.6	5.9	10.1	5.6
200	3.9	8.2	4.0	4.2	8.5	4.6	4.3	8.6	6.1	4.2	8.5	6.2
1000	6.2	10.4	2.6	6.8	10.8	3.2	6.9	10.9	4.6	6.8	10.8	4.0
1000	6.1	10.4	3.1	6.7	10.7	3.7	6.8	10.8	5.1	6.7	10.8	4.8
1000	5.8	10.1	3.5	6.3	10.4	4.2	6.4	10.5	5.6	6.4	10.5	5.6
1000	4.1	8.5	4.1	4.5	8.8	4.7	4.6	8.9	6.1	4.5	8.8	6.3

Figure 5.14 to Figure 5.17 are example area plots of predicted significant wave heights and wave direction for the ARTEMIS model runs for the part-built and fully-built layouts, corresponding to the 1000-year wave conditions with the highest wave (first line of the 1000 year conditions in Table 5.2). Colour contours indicate significant wave height and arrows indicate mean wave direction. They highlight the variability of the predicted significant wave heights along the MOLF quays and along the cofferdam sections.

Results were extracted at the nearshore locations by averaging wave heights over circles or along a profile so as to obtain the most representative case to be used in assessing the average overtopping rate along each section of quay.

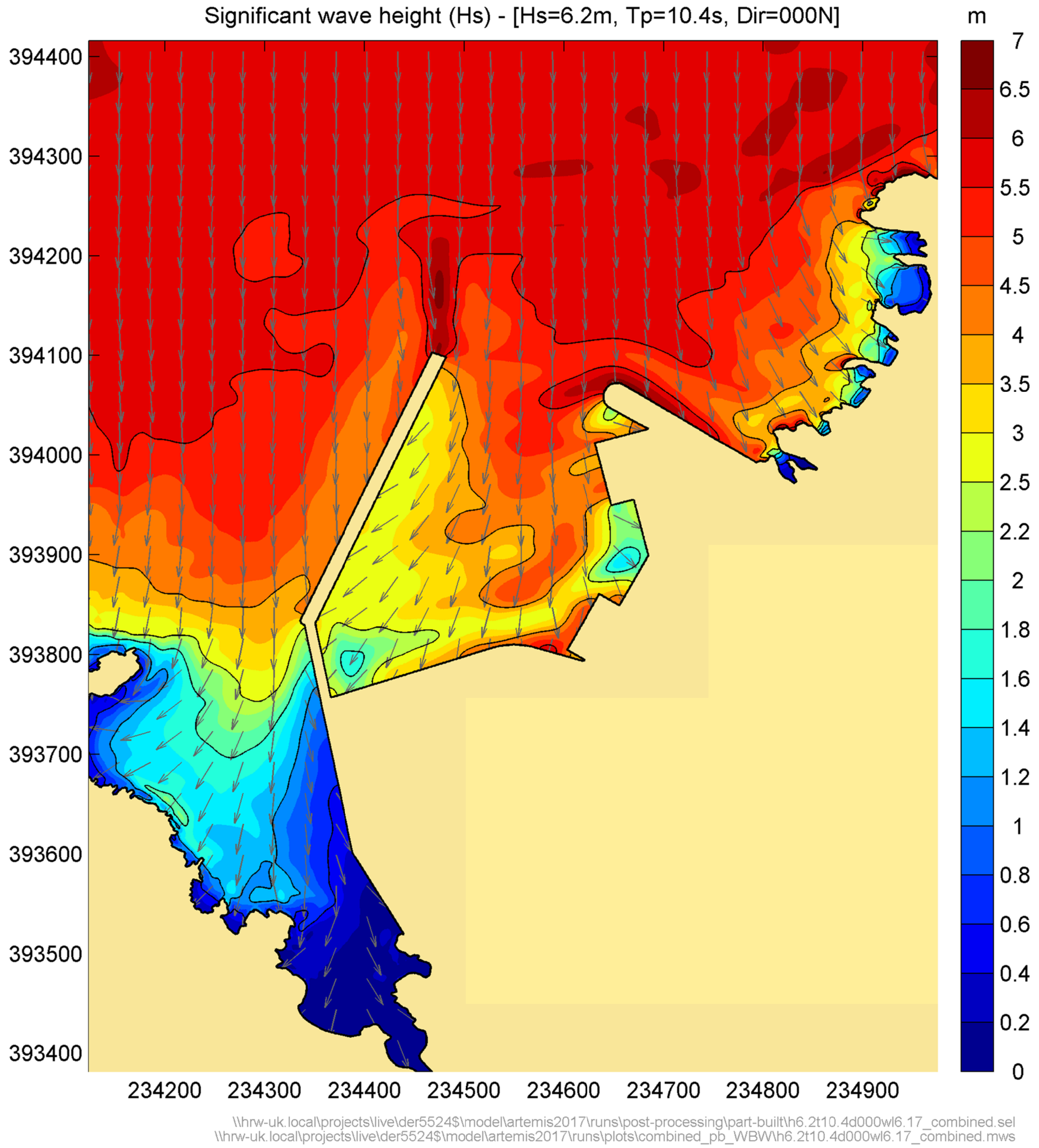


Figure 5.14: Example of predicted significant wave height and mean wave direction for the part-built layout, 1000-year present-day conditions

Source: HR Wallingford ARTEMIS modelling

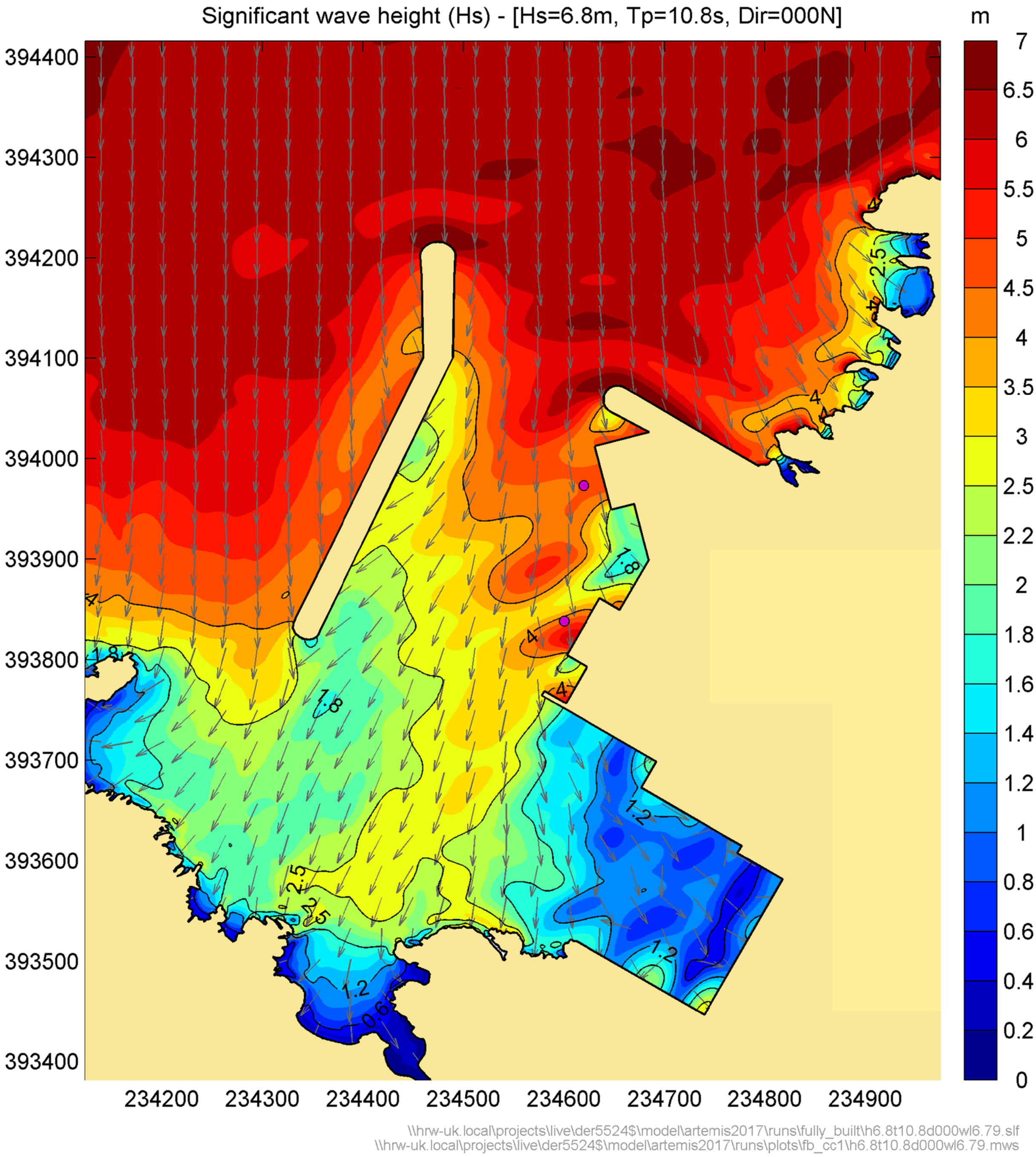


Figure 5.15: Example of predicted significant wave height and mean wave direction for the fully-built layout, 1000-year “2087 reasonably foreseeable” conditions

Source: HR Wallingford ARTEMIS modelling