HORIZON
NUCLEAR POWER

WYLFA NEWYDD

ENERGY WORKING FOR BRITAIN

Wylfa Newydd Project

Ecological Enhancements Mitigation Report

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1 Introduction

1.1 Overview

1.1.1 As part of the Wylfa Newydd DCO Project ("the Project"), there is a requirement to carry out Marine Works which would include the construction of temporary and permanent structures, and the dredging and excavation of the harbour created within Porth-y-pistyll (see chapter D1 [APP120] of the Environmental Statement).

1.1.2 The Marine Works would result in the direct loss of approximately 31.1ha of marine habitats, 20ha of which is considered to represent rocky reef habitat listed on Annex I of the Habitats Directive (92/43/EEC). The Environmental Impact Assessment (EIA)PM concluded that this impact would result in a medium magnitude of change and a moderate significant adverse effect to marine habitats and species of conservation importance (see paragraph 13.6.148, chapter D13 [APP-132] of the Environmental Statement).

1.1.3 Furthermore, the Water Framework Directive (WFD) Compliance Assessment [APP-444] concluded that the footprint of the Marine Works may result in a risk of deterioration in the status of the 'morphological conditions' quality element in The Skerries coastal water body. This is because at present The Skerries coastal water body is classified as having high status; it has minimal modifications and is therefore considered to align with the normative description of 'totally undisturbed or nearly totally undisturbed' conditions. The total marine habitat loss which is predicted to occur in The Skerries coastal water body (30.5ha) equates to 0.51% and 3.6% of its total subtidal and intertidal area, respectively. Taking account of the draft UKTAG guidance (UKTAG, 2008) and interpretation of case law namely the 'Bund case' (Court for Case C-461/13 (Bund für Umwelt und Naturschutz Deutschland e.V. v Bundesrepublik Deutschland), Horizon has submitted information to inform a derogation under Article 4(7) of the WFD with respect to impact of the Marine Works footprint on the hydromorphology (morphological conditions) of The Skerries water body [APP-445].

1.1.4 To address the impact of the Marine Works footprint, Horizon proposed additional mitigation including restoration of the intertidal zone following removal of the temporary causeway, and ecological enhancement mitigation. This mitigation was secured in the Draft Development Consent Order (DCO) application via the ecology and landscape management strategy detailed in the Marine Works sub-Code of Construction Practice (sub-CoCP) [APP-416].

1.1.5 Through the Statement of Common Ground (SoCG) process and DCO Pre-Examination period, Natural Resources Wales (NRW) along with other non-statutory consultees including National Trust, North Wales Wildlife Trust and the Royal Society for the Protection of Birds, have raised repeated concerns regarding the level of commitment and information presented in the Draft DCO application with respect to this mitigation. To address these concerns, a technical memo was issued to stakeholders on the 3 September

2018 providing further information, including details of the options appraisal which was undertaken to inform the mitigation proposal.

1.1.6 Despite this, further concerns from stakeholders have been expressed through the DCO Examination process, the most recent being through the written representations submitted at Deadline 2 (4 December 2018) [REP2-325]. With regards to the EIA, NRW reiterated that they "*do not consider that sufficient information on the proposed marine ecological enhancement measures has been presented in the ES* [Environmental Statement] *to demonstrate that the impacts on benthic habitats will be offset*".

1.1.7 With regard to the report outlining the WFD Information to Support Article 4(7) Derogation [APP-445], NRW stated that they "*do not consider that sufficient information has been presented on proposed marine ecological enhancement measures to demonstrate that all practical steps are being taken to mitigate adverse impacts on benthic habitats*".

1.1.8 Noting these concerns, Horizon has continued to engage with its environmental and engineering contractors by way of a more detailed options appraisal process for the shoreline protection and ecological enhancement mitigation. This has included revisiting the design of the Marine Works to explore whether more can be done to offset impacts through eco-engineering (i.e. to embed ecological enhancement features within the project design) as well as adding ecological enhancement features, retrospectively.

1.1.9 The outcome of this process is a revised mitigation proposal which builds upon the commitment communicated to stakeholders on the 3 September 2018. This revised mitigation proposal will be secured in the DCO application through an update to the Marine Works sub-CoCP which will be submitted into the DCO Examination process at Deadline 5 (12 February 2019).

1.1.10 This report sets out details of Horizon's increased commitment to marine ecological enhancement mitigation and the additional information that has been requested by statutory and non-statutory stakeholders. The information contained within this report has given regard to oral and written comments made through:

- the relevant representations received on 21 August 2018;
- written response to the marine ecological enhancement mitigation memo dated 3 September 2018;
- the consultation meeting held on 11 October 2018;
- the first written questions received on 6 November 2018; and
- the written representations received on 4 December 2018.

1.2 Aims and objectives

1.2.1 The aim of this report is to provide sufficient information to demonstrate that Horizon has appropriately considered the impacts of the Project footprint within the marine environment and has made satisfactory commitment to mitigation to reduce the significance of effect to subtidal and intertidal habitats of conservation importance from a moderate adverse significant effect to a minor adverse non-significant residual effect.

1.2.2 To achieve this aim, the report seeks to accomplish the following objectives:

- to demonstrate that a robust two-stage options appraisal has been undertaken for both the design of the Marine Works and the ecological enhancement mitigation, and that all practicable steps have been taken to minimise, mitigate and offset the adverse impact associated with the Marine Works footprint;
- to demonstrate that the ecological enhancement mitigation measures proposed are likely to be effective in meeting their ecological objectives and delivering these within reasonable timescales;
- to demonstrate that, in combination with other mitigation already secured in the Draft DCO application (i.e. shoreline protection and restoration method statement), the ecological enhancement mitigation measures proposed:
  - provide sufficient offsets in terms of the amount, type and quality of habitats loss;
  - reduce biodiversity loss as far as practicable; and
  - enhance ecosystem resilience; and finally,
- to demonstrate sufficient commitment to monitoring and remedial action through an adaptive management approach.

1.3 Considerations

1.3.1 The content of this report is relevant to both the Marine Licence and DCO applications. As the examining authority for the Marine Licence and the discharging authority in respect to those DCO requirements relating to the Marine Works, specific regard has been given to the views expressed by NRW during the SoCG and DCO Examination process.

1.3.2 In accordance with the Marine Licence application, any mitigation possessing a physical presence within the marine environment would be limited to within the Order Limits for the Wylfa Newydd Development Area (WNDA) [APP-009].

1.3.3 Ecological enhancement of artificial structures in the marine environment is an action that restores biodiversity and ecological habitat in the local environment. The aim of ecological enhancement is therefore directly aligned with marine restoration, with both measures seeking to mitigate or offset the direct loss and/or physical disturbance of marine habitats and species.

Consequently, the combined benefits of the shoreline protection and restoration method statement, and marine ecological enhancement measures which both form a component of the ecology and landscape management strategy secured in the Marine Works sub-CoCP [APP-416], has been considered in this report in order to assess the significance of residual adverse effects to marine habitats and species from direct loss under the footprint of the Marine Works.

1.3.4 Quoted values (i.e. areal extent of offsets) and engineering drawings relevant to the design of the Marine Works are based upon preliminary information and should be regarded as indicative.

1.4 Report structure

1.4.1 The report is divided into the following sections:

- **Section 2**: outlines the legislative, policy and precedential drivers for considering ecological enhancement as statutory mitigation for the Project.
- **Section 3**: details the principles of eco-engineering and summarises the academic literature which has formed the basis of Horizon's knowledge and assessment of ecological enhancement measures.
- **Section 4**: sets out the option appraisals which were undertaken to determine the requirement, location, and initial eco-engineering design of the Marine Works.
- **Section 5**: outlines the Marine Works design which formed the basis of assessments presented in the Draft DCO application.
- **Section 6**: summarises the assessment of effects to marine habitats and species from the Marine Works footprint in the context of the EIA and the WFD.
- **Section 7**: sets out further information related to the shoreline protection and restoration method statement, including the implications to the assessment of effects.
- **Section 8**: introduces the concept of marine offsetting and outlines key considerations as well as the aims and objectives of the ecological enhancement mitigation.
- **Section 9**: outlines the numerous ecological enhancement measures known to exist including those at the conceptual stage, undergoing experimental and commercial trials, and which have been implemented as statutory mitigation for other infrastructure projects. This section also sets out the detailed options appraisal which was undertaken to further examine the ecological enhancement potential of the Marine Works.

- **Section 10**: provides details of the revised ecological enhancement mitigation proposal for mitigating effects to marine habitats and species under the footprint of the Marine Works
- **Section 11**: briefly summarises the conclusions of the report.

2 Legislative, policy and precedential drivers

2.1.1 The following information outlines the legislative, policy and precedential drivers underpinning the requirement to give appropriate consideration to mitigating the direct loss of marine habitats and species.

2.1.2 The Infrastructure Planning (Environmental Impact Assessment) Regulations 2009 as amended (the EIA Regulations), the Marine Works (Environmental Impact Assessment) Regulations 2007 and the Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 represent key legislative drivers underpinning the need to consider mitigating effects to marine habitats and species. The Marine and Coastal Access Act 2009 is also a key legislative driver when considering this matter in the context of Marine Licensing.

2.1.3 As part of the Draft DCO and Marine Licence application, it is acknowledged that Horizon must demonstrate appropriate application of the mitigation hierarchy (Figure 2-1) in accordance with the EIA Regulations. Furthermore, Horizon must also demonstrate compliance with the WFD Regulations which are generally regarded as being more prescriptive than the EIA Regulations. The European Commission advises that the wording "*all practicable steps*" is analogous with the term "*practicable*" used in other legislation. It suggests mitigation measures should be technically feasible, do not lead to disproportionate costs, and are compatible with the new modification or sustainable human development activity [RD1].

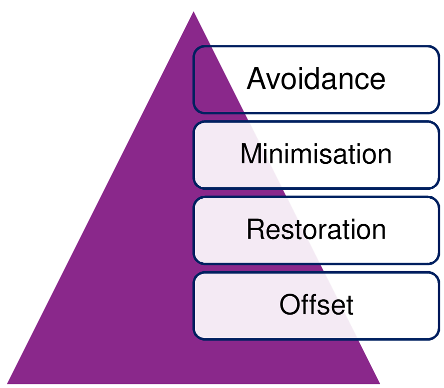


Figure 2-1 The Mitigation Hierarchy

2.1.4 Whilst the area predicted to be impacted by the Marine Works footprint associated with the Project is not classified as a European Designated Site, The Conservation of Habitats and Species Regulations 2010 as amended is also regarded as a significant legislative driver on account that the Environmental Statement and Water Framework Compliance Assessment [APP-444], which both support the Wylfa Newydd Draft DCO and Marine Licence applications, concluded that construction of the Marine Works would result in significant impact to habitats and species protected under this legislation.

2.1.5 Other legislation relevant to the subject of this report includes the, Environment (Wales) Act 2016, the Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic 1998, and the Well Being & Future Generations Act 2015, which promote sustainable management of natural resources and the need to conserve and enhance biodiversity and ecosystem resilience.

2.1.6 In terms of policy, the Overarching National Policy Statement for Energy [EN-1] [NPS EN-1] outlines the requirement for Horizon to demonstrate that the Project has "*taken advantage of opportunities to conserve and enhance biodiversity and geological conservation interest*" which can be done through "*building-in beneficial biodiversity or ecological features as part of good design*" [RD2]. This policy makes specific reference to the restoration of habitats following the completion of construction works and whilst not explicitly stated, alludes to the use of eco-engineering to offset or compensate for adverse impacts.

2.1.7 There are a number of other national and local plans or policy drivers of relevance including Planning Policy Wales [RD3], the Draft Welsh Marine Plan [RD4], TAN 5 [RD5] and the Anglesey Joint Local Development Plan [RD6] which share broadly the same objectives as described in paragraph 2.1.5, namely the requirement for sustainable development and the need to conserve and enhance undeveloped coast by minimising, mitigating and offsetting unavoidable harm.

2.1.8 Ecological enhancement has emerged as a concept which can help address the need for more sustainable developments in the marine environment and over the last decade, has received considerable academic attention [RD7, 8]. There is now a wealth of literature which has examined the ecological value of natural rocky shore compared to artificial materials and structures; offering effective solutions for modifying man-made structures to improve their ecological value and ability to offset adverse effects [RD9-11].

2.1.9 As a consequence of legislative and policy drivers and coupled with advances in scientific understanding, there is now an emerging market for off-the-shelf eco-enhancement products (e.g. ecologically enhanced prefabricated concrete units and rock pools) demonstrating that ecological enhancement mitigation measures can be both technically feasible and ecological-effective, although examples of large-scale commercial installations using these products remain limited.

2.1.10 In the UK there are just four operational structures which have ecological enhancement measures incorporated to provide statutory environmental mitigation (the Shaldon and Ringmore Tidal Defence Scheme and sea defence schemes at Hartlepool, the Isle of Wight and Bournemouth) however, these represent predominately experimental trials. Whilst post-construction monitoring has identified positive ecological results [RD12, 13], there remains very little published information regarding the extent to which these ecological enhancement measures offset impacts and the ecological objectives against which the success of the mitigation has/will be assessed.

2.1.11 Perhaps the most ambitious ecological enhancement mitigation plan to date was that which was developed for the Swansea Bay Tidal Lagoon Project in Wales and secured through a consent order in 2015. However, the efficacy of this plan and the more novel measures proposed remain unknown and untested following the UK Government's decision in July 2018 to refuse financially backing for the Project. Thus, there remains little precedent for implementation of ecological enhancement mitigation for significant infrastructure projects in the UK.

2.1.12 The European and worldwide status of ecological enhancement mitigation is comparable to the UK; whilst reasonably large scale operational examples are known to exist (e.g. the Elliot Bay Seaway Project in Seattle, USA; Brooklyn Bridge Park in New York, USA; Haifa Breakwater, Israel; and Sydney Harbour, Australia), these remain predominately experimental trials.

3 Eco-engineering principles

3.1.1 Hard man-made structures constructed in the marine environment have long been known to function as artificial rocky reefs however, historical designs have demonstrated to be poor surrogates for natural rocky shores. They generally lack surface and structural heterogeneity, therefore often supporting lower species diversity and higher densities of opportunistic and invasive non-natives species (INNS) [RD10]. In the last 20 years, there has been significant research into the chemical, physical and morphological characteristics of artificial structures and how these can be manipulated (i.e. eco-engineered) to enhance the ecological potential and therefore value of these structures to promote more sustainable development.

3.1.2 A report published in 2011 by the Environment Agency's Evidence Directorate is a key piece of guidance which sets out the principals of eco-engineering of artificial coastal structures to enhance biodiversity [RD10]. The Manual on the Use of Rock in Hydraulic Engineering [RD9] also gives some broad considerations, as well as specific recommendations, but the most substantial piece of work on ecological enhancement of structures in Europe to date is the Environmental Design of Low-crested Coastal Defence Structures (DELOS) project (www.delos.unibo.it), which ran as an international collaboration between 1998 and 2002 [RD11].

3.1.3 Research into rocky shore ecology is also of key importance as this environment is considered the nearest natural equivalent to artificial structures and can therefore help identify which features of structures could be manipulated for ecological gain [RD14-17].

3.1.4 Engineering characteristics which can be manipulated through design include:

- position in the tidal frame;
- gradient;
- orientation and exposure to prevailing wind and wave conditions;
- material and surface heterogeneity; and
- structural heterogeneity.

3.1.5 Further information related to the ecological enhancement principles ("EEPs") is provided under the following subheadings.

3.2 EEP1: Position in the tidal frame

EEP1 – to ensure artificial structures are positioned as low in the tidal frame as possible to maximise ecological diversity and biomass opportunities

3.2.1 Sessile, intertidal fauna and flora are able to withstand different degrees of stress (emersion, immersion) and therefore will only occupy a certain position along environmental gradients (e.g. high to low water mark, wave exposed to sheltered, etc.) within the intertidal zone. Very few sessile species are found ubiquitously throughout the rocky shore. This phenomenon is known as zonation.

3.2.2 The intertidal zone is classified as the region of a shore between the subtidal (sublittoral) and the supratidal (supralittoral) zones. The supratidal zone is rarely inundated (the exception being storm surges) and conversely the subtidal region is rarely exposed [RD18]. The intertidal zone can be further subdivided into high tidal flats, which occur between mean high water springs (MHWS) and mean high water neap (MHWN) tides and are intermittently inundated; middle tidal flats which occur between MHWN and mean low water neap (MLWN) and are inundated by every tide; and low tidal flats which are situated below the MLWN tide and are only intermittently exposed (Figure 3-1).

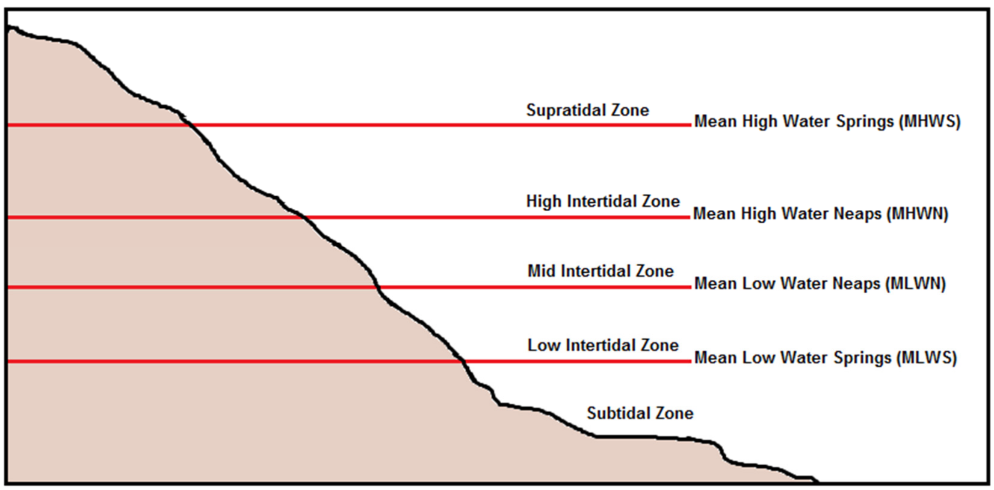


Figure 3-1 A schematic of the biotic zones characterising a rocky shore

3.2.3 The main factor influencing zonation and the community composition observed on artificial structures is position within the tidal frame (i.e. the area exposed/immersed) [RD19]. If a larger proportion of the structure is located below mean tidal level then biological communities colonising the structure will be dominated by taxa such as kelps, which occur lower in the intertidal zone because of their limited tolerance to desiccation and thermal stress [RD20]. Conversely, if a structure sits higher within the tidal frame, with the majority of the surface area being intermittently exposed, then biological communities may be dominated by taxa such as barnacles which are outcompeted at lower shore heights but are able to tolerate prolonged emersion on the high shore [RD21].

3.2.4 The diversity of flora and fauna communities differs greatly between biotic zones, with lower regions of the shore generally exhibiting greater diversity and biomass [RD22, 23]. Mid-tidal zones, or higher, tend to have lower biodiversity, abundance and lower biomass. Using information relating to position within the tidal frame, it is possible to broadly predict the community and distribution of species that are likely to colonise the structure.

Furthermore, the relative predictability of rocky shore zonation allows structures to be designed with certain taxa and communities in mind (i.e. “gardening” for desired species).

3.3 EEP2: Gradient

EEP2 – to minimise the gradient of artificial structures with the purpose of increasing the surface area available within the three intertidal zones (lower, mid and upper)

3.3.1 Most naturally occurring rocky shores have a gentler gradient than artificial structures like breakwaters and steep sea walls. Studies have found that vertical substrates support fewer mobile marine organisms due to the smaller extent of intertidal habitat available for colonisation [RD15, 24]. In addition, species resident on gentle gradients may not be able to survive on vertical surfaces, especially when the effects of wave action are significant. Steeper intertidal surfaces may, therefore, reduce habitat quality in addition to available area, resulting in differences in the composition of the associated communities [RD24-27]. Whorff *et al*. [RD28] showed that the invertebrates and algal epiphytes associated with intertidal algal turfs were strongly influenced by the gradient of the substratum, possibly because of the amount of sediment trapped in the algal fronds.

3.4 EEP3: Orientation and exposure

EEP3 – to ensure a range of orientation and exposure conditions are available

3.4.1 Orientation and exposure can influence the wave and water flow dynamics around the structures [RD17]. Orientation can also influence the degree of shading on epibenthic (surface) communities [RD29].

3.4.2 The physical conditions experienced by organisms can differ greatly between wave exposed and wave sheltered parts of breakwater structures, enabling different species to colonise particular areas while others may be excluded [RD15, 30]. For example, reduced water movements on the harbour side of a breakwater could promote the growth of certain seaweeds (e.g. *Ascophyllum nodosum* and *Fucus* spp.). Conversely increased water movement could suppress seaweed growth whilst promoting the presence of filter feeders such as mussels and barnacles.

3.4.3 There are often significant interactions between the effects of position and exposure, with greater numbers of taxa and functional groups associated with rock pools positioned lower down in the tidal frame and those located in more exposed areas [RD31].

3.5 EPP4: Materials and surface heterogeneity

EEP4 – maximise surface heterogeneity to promote increased rates of colonisation and development of complex communities

3.5.1 The geology (i.e. material and surface texture) has been shown to influence intertidal and subtidal assemblages at finer scales (millimetres) [RD17, 32, 33]. Rock type and texture can influence water drainage and ponding, which can generate microclimates as well as provide refuge for animals and plants from waves, predation, heat and desiccation stress. Moreover, a complex surface texture can increase the boundary layer near the surface thus increasing the likelihood of larval settlement compared to smooth surfaces [RD34]. Substratum roughness is widely known to influence the initial settlement of marine invertebrate larvae and the subsequent development of epibenthic communities [RD35-38].

3.5.2 Colonisation by barnacles, for example, is known to be strongly influenced by substratum texture [RD39-41] with settlement and recruitment of barnacles and algal spores typically greater on rougher surfaces [RD38, 42, 43]. The grazing efficiency of molluscs is also affected by surface roughness [RD44].

3.5.3 On natural rocky shores, fine scale habitat heterogeneity is created by weathering and erosion [RD41]. Whilst engineering materials are subject to the same weathering processes as in situ rock [RD41], they are inevitably 'newer', less weathered and less physically complex on a number of spatial scales than natural rocky shores. Although concrete typically lacks fine-scale topographic complexity when produced using standard moulding techniques [RD45], developments in casting techniques with ecological enhancement in mind have been able to generate more complex concrete matrices [RD46].

3.6 EEP5: Structural heterogeneity

EEP5 – maximise structural heterogeneity particularly within the intertidal and subtidal zone through the generation of cracks, crevices, overhangs and rock pools

3.6.1 Microhabitats such as small pits and crevices are important for rocky shore biota, providing shade and refuge from desiccation, predation and disturbance [RD47-49]. Structural heterogeneity not only increases the amount of surface area available for colonisation but also presents an increased edge effect, which facilitates the attachment and growth of benthic communities on the substrate [RD50].

3.6.2 Rock pools have been found to support more than twice the number of species than emergent areas [RD51]. Similarly, more than three times the number of species (belonging to a greater number of taxonomic classes) has been found within crevices compared to adjacent rock surface. The presence of rock pools within the mid-intertidal zone can also increase the range of lower shore flora and fauna due to the removal of desiccation stress [RD22]. This not only acts to increase the productivity of the upper regions of an artificial structure but may also allow low intertidal flora and fauna to expand upwards, therefore, decreasing the potential net loss of habitat area within higher biotic zones.

4 Options appraisal process for the Marine Works DCO design

4.1.1 During the early design phase of the Project, a series of option appraisals were undertaken to determine the requirement, location, and engineering design of the Marine Works (Figure 4-1). Much of this information is already outlined in the WFD Information to support Article 4(7) Derogation as a requirement of tests (a) and (d) for The Skerries coastal water body [APP-445]. However, further design information which was not available prior to submission of the Draft DCO application is provided below.

4.1.2 The criteria for test (a) is to demonstrate that "*all practicable steps are taken to mitigate the adverse impact on the water body concerned*". The criteria for test (d) is to demonstrate that "*the beneficial objectives served by those modifications or alterations of the water body cannot for reasons of technical feasibility or disproportionate cost be achieved by other means, which are a significantly better environmental option*".

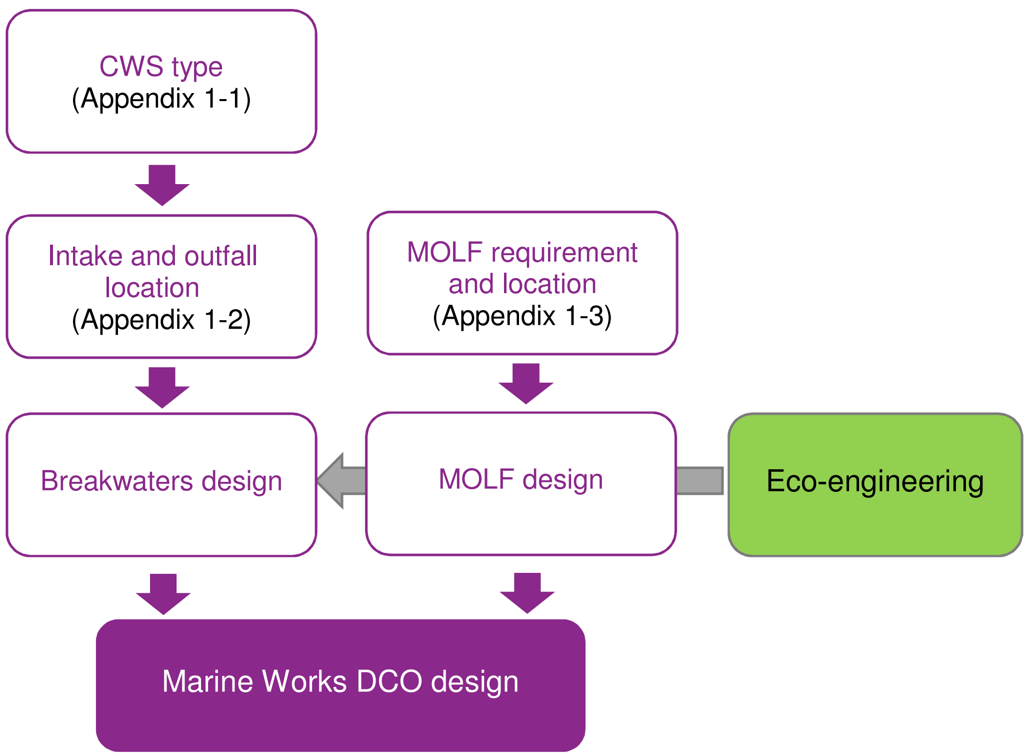


Figure 4-1 Options appraisal process for the Marine Works design which was presented and assessed in the Draft DCO application

4.1.3 The first options appraisal was for the Cooling Water System (CWS) design which compared cooling technologies for the Advanced Boiling Water Reactors based on Best Available Technique (BAT) [RD52]. As outlined in Appendix 1-1, direct sea cooling was identified as the preferred CWS design and as such, a further options appraisal was necessary to determine the most appropriate location for the CWS intake and outfall structures [RD53-57];

details are provided within Appendix 1-2. Considering environmental effects, engineering feasibility, costs and sustainability, Porth-y-pistyll was identified as the preferred site for the CWS intake although this location would require a breakwater for protection from onshore wind and waves.

4.1.4 An option appraisal was also carried out to determine the best mode of delivering construction materials to the Power Station Site (Appendix 1-3). In accordance with NPS EN-1 and the policy set out by the Department of Transport, delivery by sea was identified as the best option environmentally. Current estimates predict that between 60% and 80% of all construction materials (by weight) will be delivered to Wylfa via the Marine Off-Loading Facility (MOLF), including the majority of Abnormal Indivisible Loads.

4.1.5 A concurrent options appraisal to the one described in paragraph 4.1.3 was carried out to ascertain the requirement and optimal location of the MOLF and associated structures [RD53-56]. The option to co-locate the CWS intake and MOLF within Porth-y-pistyll was identified as the preferred choice, allowing both structures to benefit from the protection afforded by the breakwater. This option also minimised the overall footprint of the Marine Works (on land and in the marine environment) and avoided impacts to Cemaes Bay which is an important nursery ground for several fish species and a EU-designated bathing water.

4.2 Initial eco-engineering options appraisal

4.2.1 Early in the options appraisal process, it was established that the requirement for Marine Works would result in the direct loss of marine habitats and species under the footprint of the temporary and permanent structures, and associated construction activities (e.g. dredging).

4.2.2 Recognising that the breakwaters could serve to function as an artificial reef, Horizon began exploring eco-engineering opportunities to offset and therefore mitigate some of the habitat and species loss predicted to occur. Initial discussions between environmental and engineering contractors were focused around the ecological enhancement principles outlined in section 3, with the aim of identifying whether there were any potential aspects of the Marine Works design that could be manipulated or enhanced for ecological gain.

4.2.3 As the principal marine structures, consideration of eco-engineering formed a component of the engineering design options appraisal process for the breakwaters and MOLF design [RD13-16].

MOLF design

4.2.4 By nature of its purpose, the position of the MOLF within the tidal frame (EEP1) was governed by the depth necessary for the size (i.e. draught) of vessel that would be required for delivering AILs and bulk materials. However, it was acknowledged that dredging to increase water depth would provide greater surface area on the MOLF within the subtidal zone for colonisation of marine flora and fauna, potential offsetting to some degree the habitat loss associated with this structure and dredging. Similarly, it was considered necessary for the gradient of the structure (EEP2) to be vertical to permit safe berthing and loading/unloading of vessels.

4.2.5 Orientation and exposure (EEP3) of the MOLF to prevailing weather and sea conditions was also dictated by the location of this structure; based on the options appraisal outlined in Appendix 1-3, it was not considered possible to alter these aspects of the MOLF design for ecological gain.

4.2.6 During the concept and initial design phase, Horizon's engineering contractor did not consider it feasible to alter the construction material from nor embed any surface or structural heterogenous features (EEP4 and EEP5) within the MOLF wall itself. Concerns principally related to the cost of manufacturing using alternative materials, the efficacy of off-the-shelf products that were on the market at the time and the risks these potentially presented to the structural integrity and operability of the MOLF. There was also concern that sub-contractors would not be prepared to take on these risks, limiting Horizon's procurement options during construction.

Breakwater design

4.2.7 As part of a more detailed options appraisal which looked specifically at co-locating the CWS intake and MOLF, various breakwater configurations were examined. Aspects included the size of harbour, length of breakwaters and attachment/isolation from the land. The size of breakwaters under consideration ranged from a total length of 630m to 1,340m, whilst the dredged area ranged from 250,000m^3 to 592,000m^3 [RD58].

4.2.8 With the primary focus of the design being the location of the CWS intake at E1 (see Figure 12-1), configurations of the MOLF and breakwaters around this were limited and focussed on the eastern side of Porth-y-pistyll to avoid impacts to the Afon Cafnan. Nonetheless further modelling was carried out to reduce the footprint of the breakwaters as much as possible whilst ensuring the safe operability of the CWS intake.

4.2.9 The design of the breakwaters was also optimised to minimise the crest level whilst ensuring that overtopping would not damage the landward side of the breakwaters and lead to significant wave conditions above 2m at the entrance to the CWS intake. This design aspect (i.e. reducing the footprint of the breakwaters as far as practicable) formed an embedded mitigation measure which was secured in volume 2 of the Design and Access Statement [APP-408].

4.2.10 The position of the breakwaters in the tidal frame (EEP1), and their orientation and exposure (EEP3) to prevailing weather and sea conditions was dictated by the primary requirements of these structures which was to:

- provide suitable wave conditions within the intake channel to meet the operational requirements of the CWS;

- provide shelter to the MOLF quays for the unloading of bulk construction materials and AILs;
- to provide shelter to vessels manoeuvring within the harbour; and
- to limit quay wall overtopping to acceptable levels.

4.2.11 As such, it was not considered possible to alter these aspects of the design although it was noted that most of the breakwater structures would be positioned below MHWS, providing substrate for colonisation from the high intertidal down to the subtidal zone.

4.2.12 In accordance with EEP2, it was acknowledged that breakwaters with a gentler profile would increase the surface area available and the number of species likely to be able to colonise the structures. However, to reduce the gradient of the breakwater design, the footprint would have to be significantly increased resulting in greater habitat and species loss. With the priority being to avoid impact to the marine environment, it was considered a better environmental option to have a smaller footprint but a steeper gradient. The gradient of the breakwaters was therefore maximised to reduce as much as possible, the footprint of these structures. This effort is demonstrated by the DCO breakwater design which has a total combined length of 550m; this is significantly less that earlier design options (see paragraph 4.2.7).

4.2.13 Early concept designs suggested that the breakwater structures would likely be constructed of excavated or imported rock, pre-cast concrete units, or a rubble mound and caisson type construction. At this stage, the use of armour rock was identified as the preferred eco-engineering design option as it was expected that this material could be won from the site, thereby reducing the amount of material requiring disposal; would facilitate the establishment of flora and fauna more readily on account of there likely being biota already present on the rock material; and would provide greater surface and structural heterogeneity (EPP05) at the millimetre to metre scale. However, hydrodynamic modelling identified that to achieve the necessary level of stability, the armour rock units would need to each weigh on average 30 tonnes. The engineering contractor confirmed that it would be highly unlikely that rock of this size would be won from the site. Furthermore, it was also not considered practical to source and import rock of this size, as armour rock units weighing only 15 tonnes are often challenging to source readily.

4.2.14 Considering this, the option of pre-cast concrete units was explored further. Modular concrete blocks were quickly identified as the preferred material and type of structure as the inter-locking design would allow for smaller sized units (up to 16 m^3) to be used yet still resist the large wave heights, forces and extreme weather, remaining stable in a 1 in 200-year storm event. Other pre-cast concrete block types were explored but armour rock was conclusively ruled out as a feasible option. Whilst the inclusion of armour rock on the breakwaters in isolated areas not considered critical for overall stability of the structures, was considered, this design aspect could not be confirmed during the initial eco-engineering design phase.

4.2.15 As with the MOLF, Horizon's engineering contractor did not consider it feasible to embed any additional surface or structural heterogenous features within the breakwaters themselves. Concerns principally related to the cost of manufacturing, the ability to source alternative materials, the efficacy of off-the-shelf products that were on the market at the time, the risks these potentially presented to the structural integrity of the breakwaters, and the need to maintain the inter-locking configuration of the units. There was also concern that sub-contractors would not be prepared to take on this risk, limiting Horizons procurement options for construction.

4.3 Summary

4.3.1 The Marine Works design which was presented and assessed in the Draft DCO application is outlined in section 5.

4.3.2 In accordance with the WFD article 4(7) test (d), a number of different technologies, materials, designs, locations and configurations for the Marine Works was examined through a series of options appraisals (see Appendix 1-1, Appendix 1-2 and Appendix 1-3) to identify a design which was feasible, cost effective, and minimised environmental impacts.

4.3.3 During the options appraisal process, key design decisions were also made to avoid and reduce adverse impacts to The Skerries coastal water body in accordance with the WFD Article 4(7) test (a). This primarily includes minimising the footprint of the Marine Works to avoid and reduce impacts to benthic habitats and species; this was presented as an embedded mitigation measure within the Draft DCO application and secured in volume 2 of the Design and Access Statement [APP-408].

4.3.4 During the initial design phase, few eco-engineering opportunities to assist the offsetting of impacts associated with the footprint of the Marine Works were considered feasible. One of the principal challenges faced was brokering knowledge of ecological enhancement. For many parties, this was a new concept therefore concerns were raised about the practical application and engineering feasibility of the eco-engineering options. The lack of precedent for the implementation of ecological enhancement mitigation for significant infrastructure projects in the UK caused further unease about the effectiveness and resilience of measures.

4.3.5 Acknowledging this, and to address significant adverse effects identified in the Draft DCO application, additional mitigation was proposed and secured in the Draft DCO application with the Marine Works sub-CoCP [APP-416]. These included:

- the provision of shore protection which included restoration of the intertidal zone underneath the footprint of the temporary causeway following removal of this structure; and
- the provision of ecological enhancement measures in suitable locations unconstrained by engineering design and functionality, to include pre-cast ecological (e.g. rock pools or features similar to bio-blocks) and

modification of the permanent artificial structures (e.g. construction material).

4.3.6 Since submission of the Draft DCO application, Horizon has continued to engage with its engineering and environmental contractors to re-examine eco-engineering opportunities in light of detailed design developments, additional hydrodynamic modelling data, and emerging literature, case studies and proof of concept. This second stage is referred to as the 'detailed eco-engineering options appraisal' and is outlined in section 9.

4.3.7 The detailed options appraisal sets out additional information and rationale behind the enhanced mitigation proposal presented in section 10. To support the detailed options appraisal, further assessment of the ecological impacts of the Marine Works footprint, marine restoration, the principles of marine offsetting and the potential ecological enhancement measures available has been carried out in sections 6, 7, 8 and 9, respectively.

5 Marine Works DCO design

5.1.1 The Marine Works consists of temporary structures and construction activities required for the construction of the marine facilities and the permanent structures. Those elements relevant to this report are described in Table 5-1; excluded is the pontoon which will be a floating structure and the aids to navigation which will also be floating but with a small footprint on the seabed. Further details of the Marine Works design can be found in chapter D1 [APP-120] of the Environmental Statement.

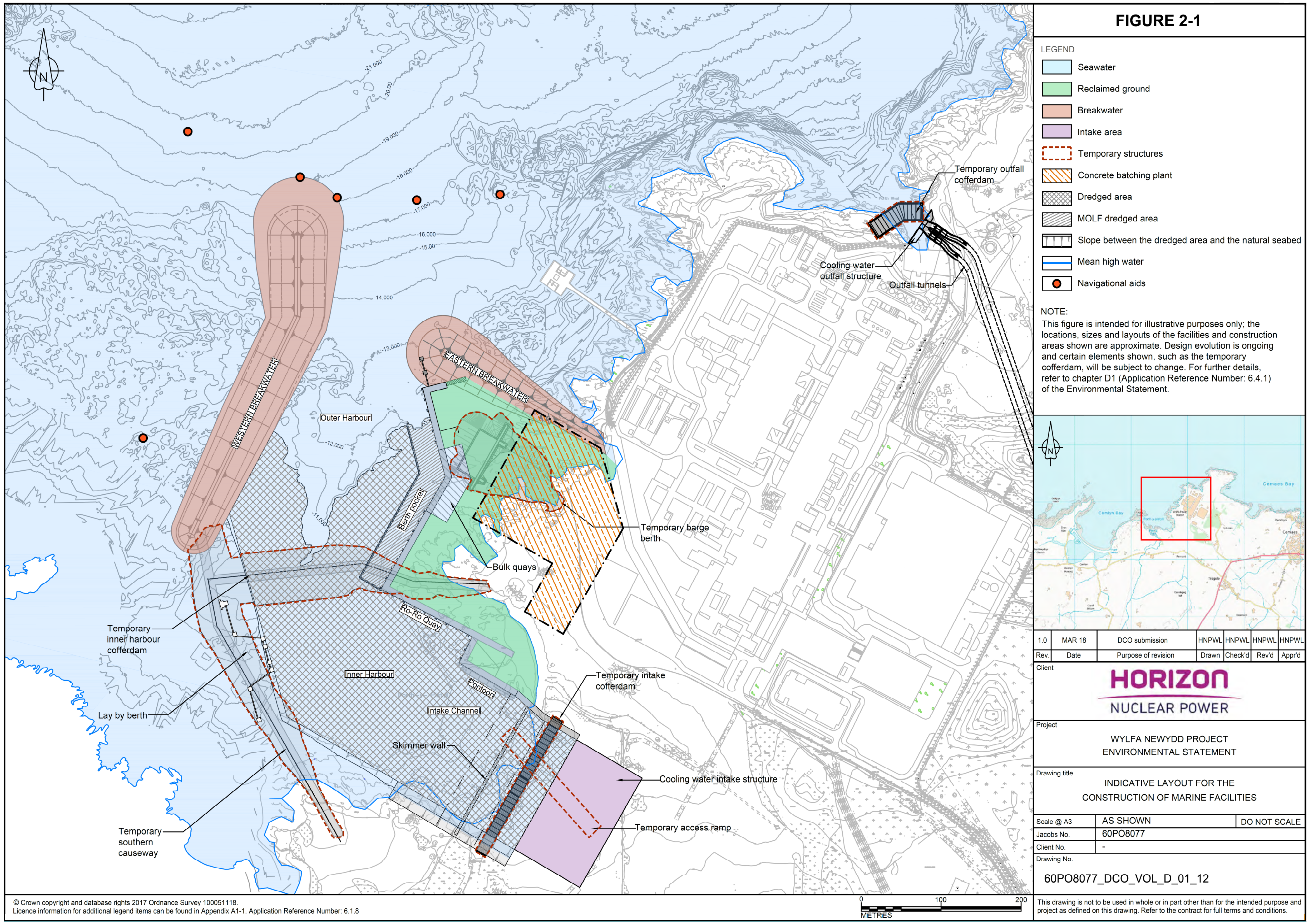
5.1.2 The layout of the Marine Works is shown in Figure 5-1.

Table 5-1 Details of the Marine Works

Marine Works element	Description
Temporary Marine Works	
Access ramp	Would be constructed at the southern end of Porth-y-pistyll to form a slipway for the import of large scale construction plant. Once built, it is anticipated that the ramp would remain in place for a limited period of time (up to one year).
Barge berth and unloading facility	Would be constructed to the south (and adjacent to) the planned site of the eastern breakwater within an area of reclaimed land to accommodate barges importing construction materials for the subsequent Marine Work (e.g. quay wall materials for the MOLF). Once the MOLF is part-constructed, the temporary barge berth would no longer be required, but would be left in situ and built over.
Cofferdams and causeway	The temporary cofferdam, approximately 350m long, and a causeway, approximately 400m long, would be constructed in Porth-y-pistyll to create a watertight seal inside which the inner harbour would be dewatered and excavated in the dry. These structures will remain in place for approximately two years. The temporary causeway would also be used to create a haul road between the land and the southern end of the western breakwater to facilitate construction. A temporary cofferdam approximately 240m long would be constructed in front of the CWS outfall to enable construction to take place in the dry.
Construction activities	
Dredging and excavation	Superficial soft sediments would be dredged from the outer harbour to provide a solid foundation for the breakwaters and MOLF, and to ready the area for dredging of rock which is also required to create sufficient depth for the intake channel and inner harbour. The total area that will be excavated and dredged in the harbour (inner and outer) equates to approximately 17.0ha.
Removal of the temporary works (access ramp, temporary cofferdam and causeway)	On completion of the works in the inner harbour, the temporary cofferdam and the southern causeway would need to be removed. This is expected to extend over a period of 12 months. The temporary structures would be removed in reverse of the installation method.

Marine Works element	Description
Permanent Marine Works	
CWS intake (including screening, fish deterrents and a skimmer wall)	Would be located in the south-east corner of Porth-y-pistyll and include an intake channel and forebay structure with screening fish deterrents and a skimmer wall) The footprint of these structures in the intertidal and subtidal area is estimated to be 5.4ha.
CWS outfall	Would be located in Porth Wnal adjacent to the Existing Power Station outfall and would take the form of a reinforced concrete open spillway channel sloping down from two tunnel outlets. The footprint of these structures in the intertidal and subtidal area (including the temporary cofferdam) is estimated 0.6ha.
MOLF	Would be comprised of two quays (bulk quay and Roll-on-Roll off (Ro-Ro) quay) and a layby berth. The bulk quay would be comprised of two berthing platforms, each with four mooring dolphins (i.e. eight in total). The area between the two platforms would represent shore protection comprising either rock revetment with a 1 in 1.5 slope or a continuous vertical quay wall with a total area of 1,171m^2 (0.1ha). The Ro-Ro quay represents a 100m long quay wall whereas the layby berth would consist of a series of berthing and mooring dolphin structures. It is anticipated that the walls of the bulk berthing platforms and Ro-Ro quay would be constructed of pre-cast mass concrete blockwork structures. The mooring dolphins would either be similarly constructed in pre-cast mass concrete blocks or using large diameter steel mono piles socketed into the seabed or multi pile dolphins similarly socketed into the seabed. The MOLF (bulk quay and Ro-Ro quay) will be retained following completion of the construction of the Wylfa Newydd Project and will provide the capability to import replacement Power Station plant (e.g. AILs) during the Power Station's operation.
Breakwaters	Would include two breakwater structures which would be rubble mound, overlaid with pre-cast concrete armoured Xblocs. The western breakwater would be 400m long, comprising a 300m southern element unconnected to the coast and a 100m northern element. The eastern breakwater would be approximately 150m long at the crest and connected to the shoreline by shore protection made of armour rock; the slope of armour rock and the breakwaters would be 1 in 4/3 (1 in 1.5 along the 300m harbour side of the western breakwater). The footprint of the breakwaters is approximately 3,512 m^2 (3.5ha). The structures have a combined surface area of approximately 58,899m^2 (5.9ha). A small region on the harbour side of the western breakwater (approximately 4,755m^2 (0.5ha)) would also be comprised of armour rock.
Shore protection (excluding the region comprising part of the MOLF)	Would be located to the east of the eastern breakwater and would take the form of rock revetment. The toe of this structure would be located below Mean Low Water Springs at approximately -10m AOD or at the existing seabed level if there was no requirement to dredge the area in front of the shore protection.

Figure 5-1 Layout of the Marine Works



6 Assessment of effects to marine habitats and species under the footprint of the Marine Works

6.1.1 In accordance with the Infrastructure Planning (Environmental Impact Assessment) Regulations 2009 as amended (the EIA Regulations), the Marine Works (Environmental Impact Assessment) Regulations 2007 and the Water Environment (Water Framework Directive) (England and Wales) Regulations 2017, effects to marine habitats and species under the footprint of the Marine Works were assessed in the Draft DCO application as part of the EIA (as reported in the Environmental Statement, chapter D13 [APP-132]) and WFD Compliance Assessment [APP-444]. Further information is also provided in support of the Article 4(7) derogation [APP-444].

6.1.2 These assessments are summarised within sections 6.3 and 6.4 below.

6.2 Basis of the assessments

6.2.1 As outlined in section 5, the Marine Works consists of several temporary structures and construction activities required for the construction of the permanent structures. For the purpose of assessment, a worst-case approach was taken which assumed that the total area under the temporary and permanent activities associated with the Marine Works would be permanently lost. This totalled an area of approximately 31.1ha, the majority of which (30.5ha), representing losses which would occur in Porth-y-pistyll.

6.2.2 In reality, only 14.1ha would be lost under the footprint of the permanent structures. The remaining extent comprising the dredge area and footprint of the temporary causeway and cofferdam (17.0ha) will be impacted for a period of approximately two years. Any subsequent impacts from for example, potential maintenance dredging would be limited to the CWS intake channel.

6.2.3 It was acknowledged as part of the assessments, and in the Phasing Strategy [APP-447] that the design of the breakwater structures will introduce new hard surfaces which could potentially have the capacity to function as an artificial rocky reef, providing new colonisation opportunities for species dependent on hard substrate. Table 6-1 summarises the amount of new hard surface which would become available on the breakwaters in the intertidal and subtidal zone. The surface area of the MOLF was not considered as part of the assessments as few taxa were expected to colonise this smooth vertical structural and therefore its capacity to function as an artificial rocky reef would be limited.

Table 6-1 Surface area gained on the breakwater structures in relation to each of the construction elements

Structural element	Area in the intertidal zone (ha)	Area in the subtidal zone (ha)	Total area (ha)
Western breakwater	1.13	1.44	2.57
Pre-cast concrete units	0.65	0.32	0.97
Armour rock	0.23	0.07	0.30
Toe rock	0.25	1.05	1.30
Eastern breakwater	0.25	0.45	0.70
Pre-cast concrete units	0.22	0.08	0.30
Toe rock	0.03	0.37	0.40

6.2.4 Of the total habitat loss predicted to occur, 7.6ha represents intertidal habitats whilst the remaining 23.5ha represent subtidal habitats. As the presence of the breakwaters alone would only offset a small area compared to that which would be lost under the footprint of the Marine Works (Table 6-2), its consideration did not materially change the outcome of the assessments.

6.2.5 As outlined in paragraph 6.2.2 above, a degree of recovery in the dredged area would be expected to occur following completion of Main Construction. Whilst the Draft DCO application assumed this area would be permanently lost, had it been considered a temporary effect the total subtidal area lost under the footprint of the Marine Works would be reduced to 8.9ha.

Table 6-2 Total area lost under the footprint of the Marine Works versus the area gained on the breakwater structures

Structural element	Area in the intertidal zone (ha)	Area in the subtidal zone (ha)
Total area lost under the footprint of the Marine Works	-7.6	-23.5
Total area gained on the breakwater structures	+1.4	+1.9
Net loss	-6.2	-21.6

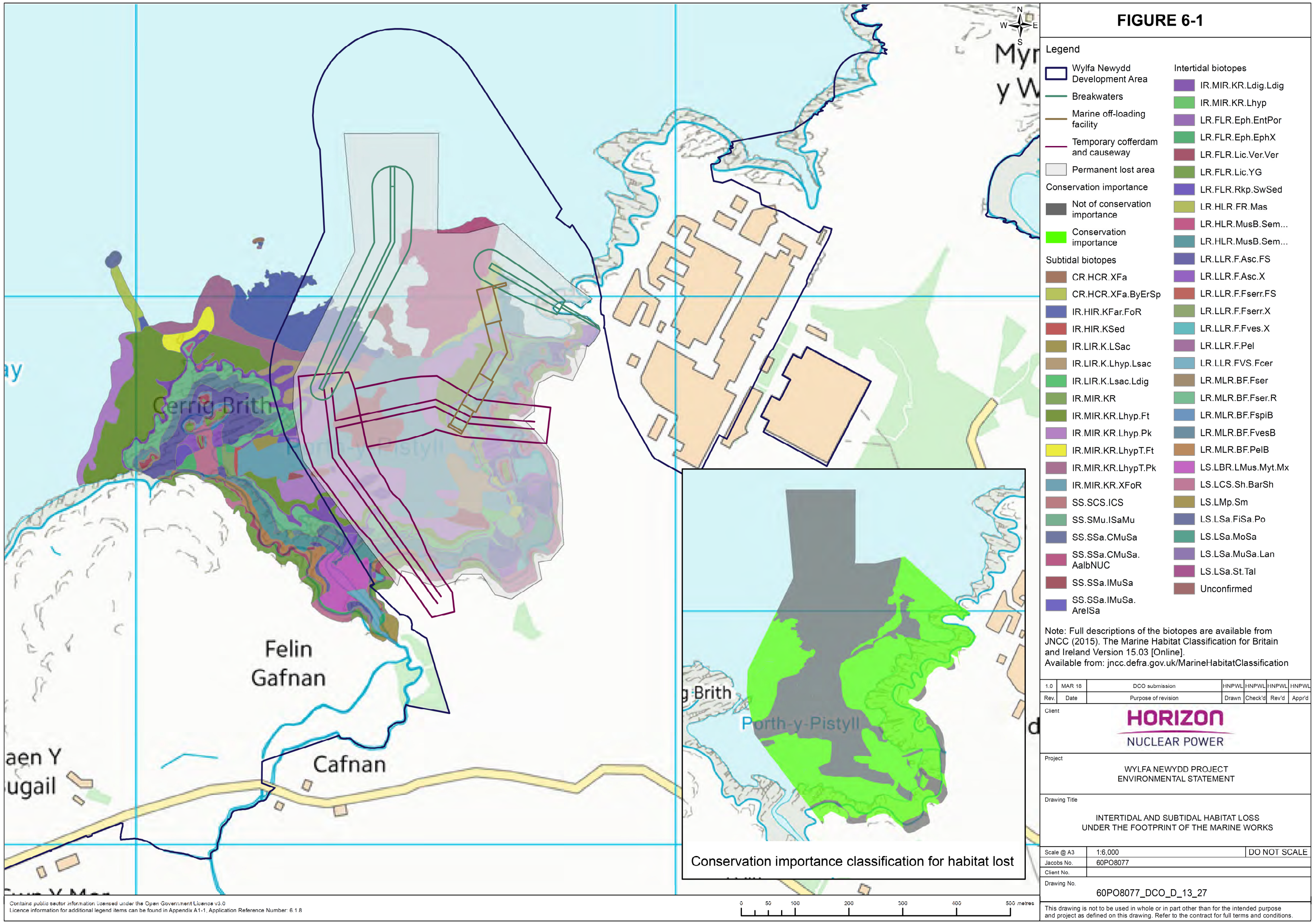
6.3 Assessment of effects in the context of EIA

6.3.1 In 2014, extensive efforts were made to map the biotopes within Porth-y-pistyll and the adjacent coastline, such that habitat and species loss under the footprint of the Marine Works could be assessment with a high degree of certainty [APP-221]. The biotope map covered 72% of the footprint of the Marine Works.

Table 6-3 The approximate area (ha) of intertidal and subtidal biotope complexes present within the footprint of the Marine Works (excludes the CWS outfall construction footprint)

Biotope complex code	Biotope description	Approximate area of habitat under the footprint of the Marine Works (ha)
Intertidal habitats		
LR.LLR.F	Fucoids on sheltered marine shores	1.95
LR.MLR.BF	Barnacles and fucoids on moderately exposed shores	1.81
LR.FLR.Lic	Lichens or small green algae on supralittoral and littoral fringe rock	1.00
LR.HLR.MusB	Mussel and/or barnacle communities	0.97
LS.LCS.Sh	Shingle (pebble) and gravel shores	0.54
LS.LSa.FiSa	Polychaete/amphipod-dominated fine sand shores	0.18
LR.FLR.Eph	Ephemeral green or red seaweed communities (freshwater or sand-influenced)	0.13
LS.LSa.MoSa	Barren or amphipod-dominated mobile sand shores	0.12
LS.LSa.St	Strandline	0.08
LR.HLR.FR	Robust fucoid and/or red seaweed communities	0.08
LS.LSa.MuSa	Polychaete/bivalve-dominated muddy sand shores	0.01
Subtidal habitats		
IR.MIR.KR	Kelp and red seaweeds (moderate energy infralittoral rock)	9.33
SS.SSa.CMuSa	Circalittoral muddy sand	2.76
SS.SSa.IMuSa	Infralittoral muddy sand	1.34
IR.LIR.K	Silted kelp communities (sheltered infralittoral rock)	1.06
IR.HIR.KFaR	Kelp with cushion fauna and/or foliose red seaweeds	0.70
CR.HCR.XFa	Mixed faunal turf communities	0.35
SS.SCS.ICS	Infralittoral coarse sediment	0.02
SS.SMu.ISaMu	Infralittoral sandy mud	0.02

Figure 6-1 Intertidal and subtidal habitat loss under the footprint of the Marine Works



6.3.2 Intertidal habitats predicted to be lost primarily represented littoral rock (5.9ha) with some littoral sediment (LS) (0.9ha) habitats. Approximately 55% of intertidal habitats within the footprint fall into two biotope complexes; 'Fucoids on sheltered marine shores' (LR.LLR.F) and 'Barnacles and fucoids on moderately exposed shores' (LR.MLR.BF). Habitats within the biotope complexes 'Lichens or small green algae on supralittoral and littoral fringe rock' (LR.FLR.Lic) and 'Mussel and/or barnacle communities' (LR.HLR.MusB) comprise a further 29% of the intertidal area that would be lost in Porth-y-pistyll whilst littoral sediment (LS) biotope complexes contribute 14%. The remaining area is characterised by 'ephemeral green or red seaweed communities' (LR.FLR.Eph) and 'robust fucoid and/or red seaweed communities' (LR.HLR.FR), contributing 2% and 1%, respectively.

6.3.3 Construction within the intertidal zone in Porth-y-pistyll would result in the direct loss of approximately 20 rock pools greater than 1m^2 that are characterised by a number of biotopes. 'Seaweed and sediment-floored rock pools' (LR.FLR.Rkp.SwSed) are the most common, representing 11 of the total number of rock pools present within the footprint of the Marine Works (see appendix D13-3, [APP-221]).

6.3.4 Approximately 60% of the subtidal area predicted to be lost is characterised by habitats within the biotope complex 'Kelp and red seaweeds (moderate energy infralittoral rock)' (IR.MIR.KR). 'Circalittoral muddy sand' (SS.SSa.CMuSa), which includes the biotope '*Abra alba* and *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment' (SS.SSa.CMuSa.AalbNUC), contributes a further 18% (Table 6-3). Of the remaining area, 14% represents the biotope complexes 'Silted kelp communities (sheltered infralittoral rock)' (IR.LIR.K), 'Kelp with cushion fauna and/or foliose red seaweeds' (IR.HIR.KFaR) and 'Mixed faunal turf communities' (CR.HCR.XFa), whilst 9% represents sublittoral sediments (SS.SCS and SS.SSa).

6.3.5 As worst case it was assumed that the intertidal area not classified as a biotope, represented rocky reef habitat. Based on the analysis of data from drop-down camera, dive and grabbing surveys (see appendix D13-3 [APP-221] of the Environmental Statement) it was also assumed that the subtidal area which was located under the western breakwater and to the north represented sublittoral sediments, whilst the area to the east of the eastern breakwater and around the CWS outfall comprised of predominately high and moderate energy littoral rock habitats (LR.HLR and LR.MLR).

6.3.6 Although not a qualifying feature of any nearby designated site, 20ha of the total area predicted to be lost under the Marine Works, is considered to represent rocky reef habitat listed on Annex I of the Habitats Directive (92/43/EEC); 6.7ha occurring intertidally and 13.3ha occurring subtidally. All remaining intertidal and subtidal habitats are either not considered to be of conservation importance or are considered to represent such large habitat resources at the local and regional scale that the direct loss predicted to occur under the footprint of the Marine Works would not affect the integrity of these habitats around the north coast of Anglesey and the United Kingdom.

6.3.7 Even when considering the direct loss of intertidal and subtidal habitats of conservation importance alone, the addition of hard substrate associated with the breakwaters still does not offset the spatial extent of rocky reef habitat loss predicted to occur (Table 6-4).

6.3.8 Subtidal habitats of conservation importance which fall within the dredged area represent approximately 6.7ha. Although the assessment presented in the Environmental Statement is worst case as it assumes permanent loss of the dredged area. In reality, a degree of recovery would be expected within this area following completion of Main Construction. Considering the area of subtidal habitats of conservation importance which fall within the dredged area (6.7ha), the total loss of subtidal habitats under the footprint of the Marine Works would be reduced to 6.6ha, resulting in a net loss of 4.7ha.

Table 6-4 Total area of rocky reef habitat predicted to be lost under the footprint of the Marine Works versus the area gained on the breakwater structures

Structural element	Area in the intertidal zone (ha)	Area in the subtidal zone (ha)
Total area lost under the footprint of the Marine Works	-6.7	-13.3
Total area gained on the breakwater structures	+1.4	+1.9
Net loss	-5.3	-11.4

6.3.9 On this basis, the assessment of effects presented in chapter D13 of the Environmental Statement [APP-132] concluded that the direct loss of subtidal and intertidal habitats of conservation importance under the footprint of the Marine Works would result in a medium magnitude of change and a moderate adverse effect. The magnitude of change to the remaining intertidal and subtidal habitats and communities is predicted to be small and therefore the effect of the Marine Works footprint would be negligible to these receptors.

6.3.10 The provision of marine ecological habitat enhancements in suitable locations and a marine restoration plan for the intertidal area under the footprint of the temporary causeway is proposed as additional mitigation to address the moderate adverse effect to intertidal and subtidal habitats of conservation importance.

6.4 Assessment of effects in the context of WFD

6.4.1 The Water Framework Directive Compliance Assessment [APP-444] concluded that the Wylfa Newydd Project may result in a risk of deterioration in the status of the 'morphological conditions' quality element in The Skerries coastal water body. This is because at present The Skerries coastal water body is classified as having high status; it has minimal modifications and is therefore considered to align with the normative description of 'totally undisturbed or nearly totally undisturbed' conditions. The total marine habitat loss which is predicted to occur in The Skerries coastal water body (30.5ha) equates to 3.5% and 0.5% of its total subtidal and intertidal area, respectively (Table 6-5).

6.4.2 The assessment of subtidal effects is considered worst case as a degree of recovery would be expected in the dredged area following completion of Main Construction. Had this been considered within the assessment the total loss of subtidal habitats under the footprint of the Marine Works would have been reduced to 8.9ha representing a net loss of 7.0ha (0.2% of the subtidal area of The Skerries coastal water body).

Table 6-5 Proportion of The Skerries coastal water body lost under the footprint of the Marine Works versus the area gained on the breakwater structures

Structural element	Area in the intertidal zone (ha)	Area in the subtidal zone (ha)
The Skerries coastal water body	210	4,513
Total area lost under the footprint of the Marine Works	-7.3	-23.2
Percentage of The Skerries coastal water body lost	3.5%	0.5%
Total area gained on the breakwater structures	+1.4	+1.9
Net loss	-5.9	-21.3
Percentage of The Skerries coastal water body lost	2.8%	0.5%

6.4.3 Although the estimated loss of intertidal area is below the 5% condition limit threshold stated in the draft UKTAG guidance (UKTAG, 2008) in both cases (including and excluding the surface area gained on the breakwater structures), compliance with the objectives of the WFD is informed by the interpretation of case law namely the 'Bund case' (Court for Case C-461/13 (Bund für Umwelt und Naturschutz Deutschland e.V. v Bundesrepublik Deutschland). The judgement states that where there may be a risk of deterioration (i.e. where the status of any quality element could be jeopardised) that consent may not be granted. It is not possible to definitively conclude that the new modifications would only result in minor anthropogenic change and would therefore constitute within class rather than between class deterioration. Considering the wording of the judgement it is concluded that there is a risk that the morphological conditions quality element could deteriorate from high to good status.

6.4.4 Consequently, Horizon has submitted information to inform a derogation under Article 4(7) of the WFD with respect to the hydromorphology (morphological conditions) of The Skerries coastal water body [APP-445]. To be granted this derogation, Horizon must demonstrate that among other things, all practicable steps have been taken to mitigate the adverse impact (i.e. test (a)). Thus, marine ecological habitat enhancement and a marine restoration plan for the intertidal area under the footprint of the temporary causeway is proposed as additional mitigation.

7 Marine restoration

7.1.1 Given the timescales for construction of the Marine Works (i.e. approximately two years), the assessments presented above assumed that the entire area under the footprint of the Marine Works (as shown in Figure 6-1) would be permanently lost. This approach is precautionary as the Marine Works include a number of temporary structures, collectively known as the Temporary Marine Works[1] which would be removed during Main Construction having served their purpose. Although not explicitly stated within the Draft DCO application, it was assumed that following removal of the Temporary Marine Works, natural recovery of marine habitats and species would occur in the area underneath and adjacent to the footprint.

7.1.2 'Natural recovery' is the process by which habitats and environments return to a past state following cessation of some impact or alteration. Depending of the magnitude of the impact, this can be a slow process taking decades or longer [RD59]. Identification of specific recovery inhibitors, and intervention to remove or reduce the effect of these, can significantly reduce the time taken for natural recovery to occur. This is, by definition, ecological restoration; i.e. the process of assisting the natural recovery of damaged, degraded, or destroyed habitats or environments [RD60].

7.1.3 Ecological restoration has long been a successful management tool for terrestrial ecosystems and it has been shown that the basic principles and attributes can be applied to marine habitat restoration [RD61, 62]. Examples include mangrove forests, salt marshes, bivalve beds and seagrass meadows [RD63-65]. Of relevance to this Project is restoration of shallow hard kelp/macroalgal beds or forests which are known to be present under the footprint of the Marine Works. The Marine Ecosystem Restoration in Changing European Seas (MERCES) Project outlines restoration potential in European Seas and details several case studies [RD66]. Most notably is the highly successful LIFE BlueReef project which restored offshore cavernous boulder reefs (with macroalgae) in shallow waters in Kattegat, creating a stable system both structurally and functionally (https://naturstyrelsen.dk/naturbeskyttelse/naturprojekter/blue-reef).

7.2 Shoreline protection and restoration method statement

7.2.1 As part of the shoreline protection and restoration method statement which is secured through the Marine Works sub-CoCP [APP-416], Horizon proposes to place a protective layer over the shoreline prior to construction of the temporary causeway.

7.2.2 It will be the responsibility of the Marine Contractor to design and install the protective layer and as such, specific details are not yet available. However, generally this protective layer will be designed to facilitate the removal of the temporary causeway with minimal resulting damage to the underlying

[1] The Temporary Marine Works include temporary cofferdams, a temporary access ramp, navigation aids, temporary outfalls and a temporary barge berth.

shoreline rock strata. Several construction solutions may be proposed; it is envisaged that this could involve techniques such as vacuum excavation to remove the designed protective sand/aggregate layer. In this solution it is normal to install a physical barrier such as a Geotextile product before placement of the protective materials and subsequent main construction material.

7.2.3 The depth of the protective layer will be determined by the designer and incorporated into the contractor's construction design of the temporary causeway.

7.2.4 In addition to this measure, Horizon also proposes to restore the intertidal and subtidal area located under the footprint of the temporary causeway following removal of this structure, and the adjacent intertidal area to the east where disturbance of habitats is also likely to occur.

7.2.5 The rationale for the shoreline protection method statement in the context of marine restoration is to compensate for the direct loss of habitat and species associated with the Marine Works. The intention would be to restore a total area of 4.0ha; 2.9ha would be located subtidally whilst the remaining 1.1ha would be located intertidally (i.e. on the foreshore). The biotopes known to be present in the area as identified during the 2014 biotope mapping survey (see appendix D13-3, [APP-221]) as shown in Figure 7-1.

7.2.6 Of the total area that would be restored, 3.6ha is considered to be of conservation importance representing Annex I rocky reef habitat. This excludes 'silted kelp communities' (sheltered infralittoral rock) (R.LIR.K), infralittoral muddy sand (SS.SSa.IMuSa) and, shingle (pebble) and gravel shores (LS.LCS.Sh) listed in Table 7-1 below.

Table 7-1 The approximate area (ha) of subtidal and intertidal biotope complexes current present in the area proposed for restoration

Biotope	Area (ha)
Subtidal	
Kelp and red seaweeds (moderate energy infralittoral rock) (IR.MIR.KR)	2.4
Silted kelp communities (sheltered infralittoral rock) (R.LIR.K)	0.1
Infralittoral muddy sand (SS.SSa.IMuSa)	0.3
Intertidal	
Lichens or small green algae on supralittoral and littoral fringe rock (LR.FLR.Lic)	0.3
Mussel and/or barnacle communities (LR.HLR.MusB)	0.2
Fucoids on sheltered marine shores (LR.LLR.F)	0.1
Barnacles and fucoids on moderately exposed shores (LR.MLR.BF)	0.5
Shingle (pebble) and gravel shores (LS.LCS.Sh)	0.1

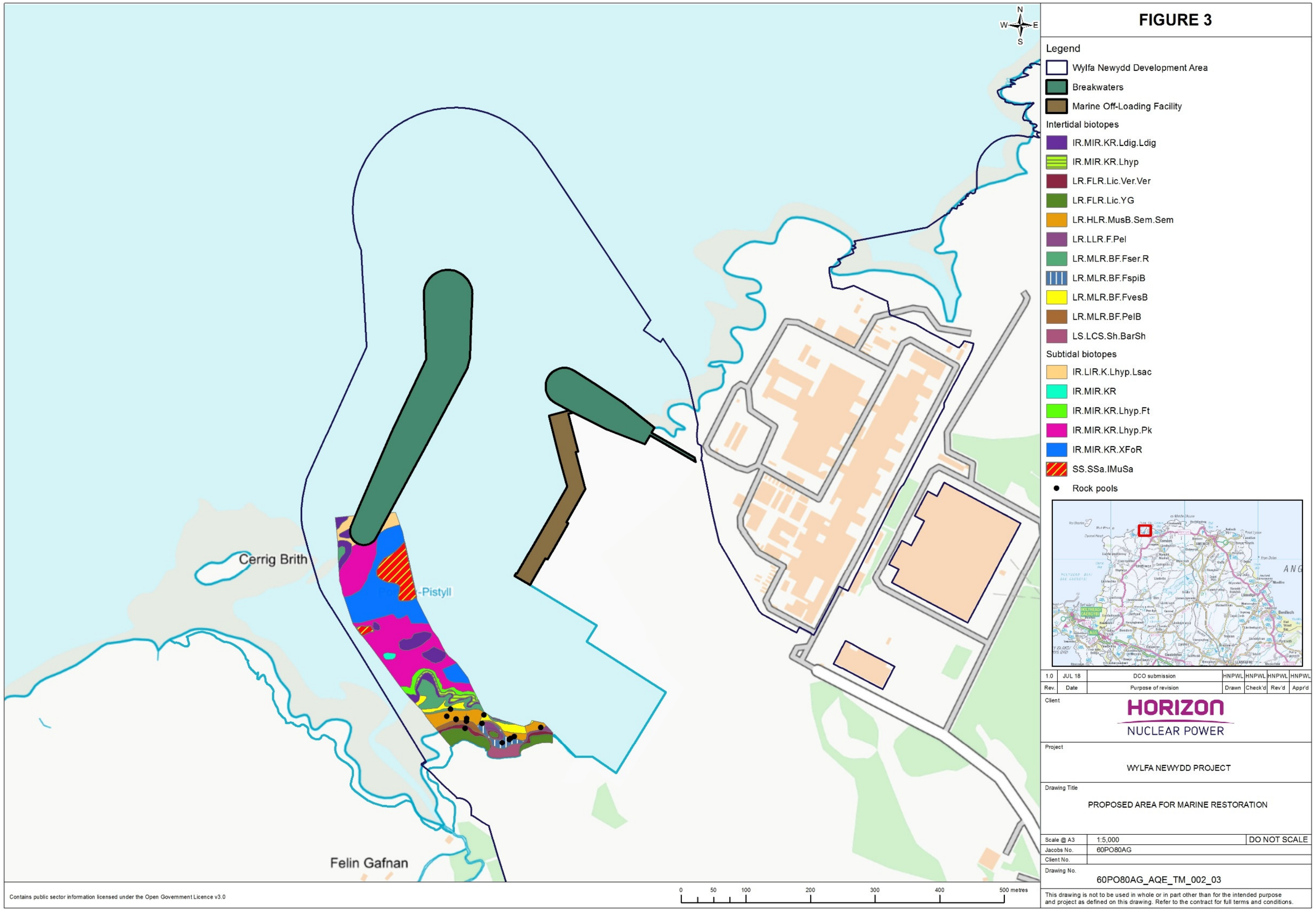
7.2.7 In addition, 15 rock pools greater than 1m^2 are known to be present in the area representing the following biotopes:

- 'rock pools' (LR.FLR.Rkp);

- ‘coralline crust-dominated shallow eulittoral rock pools’ (LR.FLR.Rkp.Cor);
- ‘fucoids and kelp in deep eulittoral rock pools’ (LR.FLR.Rkp.FK);
- ‘green seaweeds (*Enteromorpha* spp. and *Cladophora* spp.) in shallow upper shore rock pools’ (LR.FLR.Rkp.G); and
- ‘seaweeds in sediment-floored eulittoral rock pools’ (LR.FLR.Rkp.SwSed).

7.2.8 In accordance with the shoreline protection and restoration method statement outlined in the updated Marine Works sub-CoCP [REP2-033] submitted into Examination at Deadline 2 (4 December 2018), marine restoration would also seek to restore as much as possible, the natural appearance of the shoreline.

Figure 7-1 Proposed area for marine restoration



Aims and objectives

7.2.9 The main aim of ecological restoration is often to return a habitat or environment to its past natural state. Although the current, wave and exposure conditions within Porth-y-pistyll will be altered following construction of the Marine Works, analysis of numerical and physical hydrodynamic modelling has shown that a range of conditions (including sheltered, moderately and fully exposed) will continue to occur in the area. Furthermore, flows within the harbour will remain dynamic with good flushing of water through the gap between the coastline and the southern end of the western breakwater. It is therefore considered possible to restore the same or similar functioning biotopes currently present in Porth-y-pistyll and under the footprint of the temporary causeway.

7.2.10 If in practise it is found that contemporary constraints and conditions result in the development of different biotopes to that observed historically, the aim would be to facilitate recovery towards another desired state, or to repair the structure and function of degraded habitats or environments to whatever form possible.

7.2.11 On this basis, the shoreline protection and restoration method statement would aim to achieve the following:

- to restore the topography of the substrate including gradient and structural heterogeneity;
- to reinstate the 15 rock pools measuring greater than 1m^2 that are currently known to be present within the area; and
- to develop the same or similar functioning biotopes to those currently known to be present within the area over reasonable timescales (e.g. up to 10 years following cessation of the impact).

7.2.12 More specific objectives for determining whether restoration has been accomplished will be developed in consultation with NRW and as part of a more detailed shoreline protection and restoration method statement. It can be expected however, that these objectives will align broadly with those outlined by the Society for Ecological Restoration Science and Policy Working Group [RD60] which considers a habitat or environment to be recovered when:

- it contains a characteristic assemblage of species that occurred in the area historically;
- it consists of native species to the greatest practicable extent;
- it contains all functional groups necessary for continuous development and/or stability or, if absent, the missing groups have the potential to colonise by natural means;
- the physical environment can sustain reproductive populations;
- it is suitably integrated into the larger ecological matrix or landscape;
- potential threats to its health and integrity have been eliminated or reduced as much as possible;

- it is sufficiently resilient to endure the normal periodic stress events characteristic of the area; and
- it is self-sustaining to the same degree as reference habitats or environments and has the potential to persist indefinitely under existing environmental conditions.

7.2.13 Marine restoration would also have additional attributes such as the provision of aesthetic amenities. It is often recommended that ecosystem services and socio-economic attributes are integrated into the planning, execution, evaluation or monitoring of restoration plans [RD61].

Implementation

7.2.14 Marine restoration will be integrated into the removal or decommissioning process for the Temporary Marine Works; this will be subject to detailed design with further information provided in subsequent iterations of the shoreline protection and restoration method statement. This would be expected to be delivered in two phases; phase 1 - restoration of the area under the footprint of the temporary causeway following removal of this structure; and phase 2 - restoration of the adjacent intertidal area following removal of the temporary CWS intake structure cofferdam and construction of the skimmer wall.

7.2.15 Removal of the temporary causeway will take place following construction of the CWS intake channel and western breakwater. These removal works are expected to take 12 months and will generally follow the reverse of the construction works (see paragraphs 2.6.12 to 2.6.19 of Project Description/Schedule of Licensable Activities, Document Reference Number: ML-PLD-01-PDR for a detailed description). The only difference is that divers using underwater cutting equipment will cut the steel pile wall at bed level, leaving in place below bed level either the lower sections of the sheet and/or tubular piles and gravel filled trench, depending on the form of the sheet, tubular or combi pile wall.

7.2.16 To achieve the aims set out in paragraph 7.2.11 above, a survey will be carried out prior to construction to develop a detailed topography profile of the area intended to be restored. Once the overlying structure is removed, material used in its construction will be re-used if suitable, to restore the original topography. This may involve cementing rock in place to avoid the material being washed away. A thin veneer of rock material would be overlaid on the piling trench to provide more natural substrate for colonisation in this area.

7.2.17 The fifteen rock pools measuring greater than $1m^2$ would be reinstated by either using material generated from the decommissioning of the temporary causeway or using prefabricated rock pool units. In either case, these features would possess surface and structural heterogeneity to facilitate colonisation and establishments of marine flora and fauna. The rock pools would be restored in approximately the same location as originally lost however, if this is not possible, locations characterised by the same features e.g. position in the tidal frame, gradient, orientation and exposure, will be identified to maximise the likelihood of similar functioning biotopes becoming established.

7.2.18 Through the removal of recovery inhibitors (i.e. the presence of the Temporary Marine Works) and the active restoration of natural rock material, topography and morphological features such as rock pools, it is expected that recovery of the same or similar functioning biotopes to those currently known to be present within the area would be able to occur naturally. However, active ecological enhancement may be implemented within the area indicated in Figure 7-1 if these measures are expected to facilitate restoration. Details of the ecological enhancement measures which would be implemented as additional mitigation for the Project can be found in section 10.

7.2.19 Monitoring of the progress and success of the shoreline protection and restoration method statement against a set of pre-defined objectives will be delivered as part of Horizon's current commitment to marine monitoring for non-native species and ecological enhancement mitigation which is secured in the Marine Works sub-CoCP [APP-416].

7.2.20 Furthermore, an adaptive management protocol would be developed as part of the wider ecological and landscape management strategy (which is again secured in the Marine Works sub-CoCP [APP-416]) and implemented to deliver remedial action in the event that the shoreline protection and restoration method statement fails to deliver against one or more of its pre-defined aims and objectives. This would include active measures such as reseeding with seaweed species (e.g. kelp) if for example, it is found that the establishment and development of marine flora known to be important ecosystem engineers is not being achieved within a reasonable period of time. The definition of 'reasonable timescales' will be agreed through consultation with NRW.

Implication to the assessment of effects

7.2.21 Table 7-2 and Table 7-3 below set out the implications of marine restoration to the assessment of effects in the context of EIA and WFD, respectively. This assumes that the full areal extent intended to be restored is achieved.

7.2.22 In the context of the EIA, the presence of the breakwater structures and marine restoration would offset approximately 38% and 36% of the intertidal and subtidal habitat loss predicted to occur under the footprint of the Marine Works, respectively.

Table 7-2 EIA assessment: the area of rocky reef habitat predicted to be lost under the footprint of the Marine Works versus the area gained on the breakwater structures and following implementation of the marine restoration plan. Values in brackets takes into consideration potential recovery of subtidal habitats within the dredged area

Structural element	Area in the intertidal zone (ha)	Area in the subtidal zone (ha)
Total area lost under the footprint of the Marine Works	-6.7	-13.3 (-6.7)
Total area gained on the breakwater structures	+1.4	+1.9
Total area gained from following restoration	+1.1	+2.9
Net loss	-4.2	-8.5 (-1.9)

7.2.23 In the context of the WFD assessment, the presence of the breakwater structures and marine restoration would offset approximately 34% and 21% of the intertidal and subtidal habitat loss predicted to occur under the footprint of the Marine Works, respectively.

Table 7-3 WFD assessment: proportion of The Skerries water body lost under the footprint of the Marine Works versus the area gained on the breakwater structures and following implementation of the marine restoration plan. Values in brackets takes into consideration potential recovery of subtidal habitats within the dredged area

Structural element	Area in the intertidal zone (ha)	Area in the subtidal zone (ha)
Total area lost under the footprint of the Marine Works	-7.3	-23.2 (-8.9)
Total area gained on the breakwater structures	+1.4	+1.9
Total area gained from following restoration	+1.1	+2.9
Net loss	-5.9	-18.4 (-4.1)
Percentage of The Skerries water body lost	2.3%	0.4% (0.1%)

8 Marine offsetting

8.1.1 Following the initial eco-engineering options appraisal which was intended to avoid and minimise impacts, and maximise the ecological 'value' of the Marine Works design (see section 4.2), it was identified that further mitigation was required to offset or compensate for the habitat loss under the footprint of the Marine Works (see section 6).

8.1.2 Offsetting in the marine environment is relatively novel and there remains no formalised regulatory framework for implementation in the UK [RD67-69]. Nonetheless, the UK and Wales specifically has several national planning policies such as the Planning Policy Wales and TAN 5 which does provide scope to trigger and enable biodiversity offsetting. With this in mind, ecological enhancement measures are considered as part of the Project in the form of additional mitigation to further offset habitat loss associated with the Marine Works.

8.1.3 For the Project, ecological enhancement mitigation is intended to operate as an offsetting measure through the creation of habitat on the permanent marine structures that would not otherwise exist and through averting the increased risk of invasive non-native species becoming established in the area [RD69]. Further information about the aims and objectives of the ecological enhancement mitigation are outlined in section 8.5, with the methods necessary to determine the scale and effectiveness of ecological enhancement mitigation set out below.

8.2 Quantifying the scale and effectiveness of offsetting measures

8.2.1 One of the principle challenges associated with quantifying and assessing the effectiveness of offsetting measures is the choice of metrics used as losses and gains need to be expressed in the same units. In the majority of cases metrics are based upon some version of the following:

Area x "Quality"

8.2.2 Area relates to the loss of habitat provision or species range and is relatively straight forward to measure particularly in relation to the Project on account that areal losses and gains are known with a high degree of certainty.

8.2.3 Quality however, is often open to much greater interpretation and can include:

- presence of characteristic or indicator species;
- absence of invasive non-native species;
- absolute or relative diversity;
- biomass production or capacity;
- species density;
- population size;
- carrying capacity; and
- connectivity.

8.2.4 Offsetting in the marine environment to date has typically been employed on a like-for-like basis (e.g. impacts on one habitat / biotope should be offset through actions benefitting the same habitat / biotope). However, there are examples of 'trade-ups' in which offsets provide features of greater conservation importance.

8.3 Timescales

8.3.1 In determining equivalency, timescales of recovery or development must also be considered. The construction phase of the Marine Works would represent a period of net ecological loss, the magnitude of which would be determined by the duration. Furthermore, there would be a time lag between the effects of construction and the marine ecological enhancement measures achieving their ecological objectives. To estimate the potential duration of this time lag, it is necessary to understand rates of colonisation and community succession; these are discussed below.

8.3.2 The type of ecological enhancement measures and the timing of implementation can greatly influence recovery or development timescales and therefore the assessment of net loss.

One to five years

8.3.3 Encrusting species such as *Corallina officinalis* and crustose brown algae of the family Ralfsiaceae, are believed to exhibit good recruitment and settlement rates on artificial surfaces [RD70]. Studies have shown that new bases have appeared on sterilised plots within six months and 10% cover was reached within 12 months [RD71]. A number of studies have shown similar recovery rates, although it is unclear whether the more resistant crustose bases were thoroughly removed from the rock [RD72]. Evans *et al*. [RD73] found coralline algae were notably absent following a 30-month monitoring period of artificial rock pools with only a small amount of *Lithothamnia* crust present in one artificial pool during the final survey, 30 months after construction. It is likely to take up to five years for encrusting species to become fully established on marine structures.

8.3.4 *Ulva* spp. are ephemeral seaweeds that are believed to be among the first to colonise newly available substrate, usually within weeks, depending upon availability of spores [RD74]. It is, therefore, likely that species of *Ulva* and *Cladophora* would have a considerable capacity for recovery, as both genera are widespread and release motile gametes and spores making dispersal and attachment to the breakwater structures highly likely within a few years. Jackson [RD51] observed a dominance of *Ulva* spp. within a year.

8.3.5 Fucoids (e.g. *Fucus serratus* and *Fucus vesiculosus*) recruit readily to barren areas, especially in the absence of grazers [RD75]. Jackson [RD51] found fucoids replaced *Ulva* spp. on concrete armour units within one year. Although, whilst it is thought recruitment is likely to be reasonably rapid, recovery to a mature community structure is likely to take some years [RD76]. This is likely to be especially true for *Ascophyllum nodosum* which is a slow-growing species that generally exhibits poor recruitment. The reason for such poor recruitment is unclear; this species invests the same high level of energy in reproduction as other fucoids and is extremely fertile every year [RD77]. However, the reproductive period only lasts for about two months which is much shorter than for other fucoids.

8.3.6 Within the subtidal zone, red algae have been found to colonise cleared concrete blocks within 26 weeks in the shallow subtidal (0.8m) and 33 weeks at a depth of 4.4m [RD78]. Red algae persist throughout the early colonisation phase and have been found to increase in biomass from 0.04% to 1.5% within the first four years [RD78]. Red algae produce non-motile spores and most recruitment is thought to occur within 10m of the parent plants [RD79]. This would likely delay colonisation of red algae on the marine structures, particularly for the more remote areas (e.g. western breakwater), although it is reasonable to assume red algae would be able to colonise the breakwaters within five years.

8.3.7 Kelp is a common subtidal species present within the footprint of the Marine Works and dominates a number of biotopes which cumulatively represent 20.0% of the total area. Kain [RD78] examined recolonisation of cleared concrete blocks in a subtidal kelp forest and found a standing crop of *Laminaria hypoborea* similar to that of a virgin forest, present within 2.5 years of the blocks being cleared. Kelp species colonise at different rates which can vary temporally. Within the same study, blocks cleared in August 1969 were initially colonised primarily by *Laminaria saccharina* but subsequently colonised by *L. hypoborea*. Kain [RD78] also observed temporal variations in the dominant colonists of cleared concrete blocks with brown algae dominant in the spring, green algae in the summer and red most important in the autumn and winter. The timing of construction could, therefore, have important implications for early settlers and the trajectory of community development.

8.3.8 Recruitment to rock pools is likely to be sporadic and variable [RD80]. Initial colonisers of these environments are likely to be present within a year, whilst the development of recognisable rock pool biotopes may take up to five years. Evans *et al*. [RD73] found total species richness on emergent rock reached carrying capacity (an asymptote population) after six months (24 species) but species accumulation curves for the artificial rock pools did not reach an asymptote even after 30 months of monitoring. This suggested that whilst artificial rock pools supported resident communities, they were also being used at different times of the year by transient and ephemeral taxa. It is thought that kelps could potentially colonise low shore rock pools within three to four years, depending on grazing and competition for space [RD78]. Recovery of species such as *Chondrus crispus*, which is generally found on the middle to lower rocky shore and in rock pools, is likely to be relatively slow as holdfasts need to generate before thalli can grow [RD81]. However, Minchinton *et al*. [RD82] documented the recovery of *C. crispus* after a rocky shore in Nova Scotia, Canada, was totally denuded by ice scouring and found that this species had re-established approximately 50% cover on the lower shore within two years.

8.3.9 In terms of fauna, gastropods and other mobile grazers (e.g. amphipods, isopods) are likely to be attracted by developing microalgae and macroalgae and could return quickly by either migration or larval recruitment. Epifaunal species vary in their recruitment rates; Sebens [RD83, 84] reported that rapid colonisers such as encrusting bryozoans, amphipods and tubeworms recolonised cleared rock surfaces within one to four months. Ascidians such as *Aplidium* spp. achieved significant cover in less than a year, and, together with *Halichondria panicea*, had reached pre-clearance levels of cover after two years. Anemones are thought to be able to colonise within four years [RD84] but may take longer to reach mature abundances. The anemone *Urticina felina* exhibits poor recoverability due to limited dispersal and slow growth [RD85], though populations may recover within five years. *Mytilus edulis* populations are also considered to have a strong ability to recover from environmental disturbance [RD86, 87].

8.3.10 The DELOS project [RD11] found the most commonly recorded fauna on low crested structures within two years of construction included barnacles (predominately *Semibalanus balanoides* and *Elminius modestus*), limpets (*Patella vulgata* and *P. depressa*) and littorinids (*Littorina littorea* and *L. saxatilis).* On the northern coast of northern Denmark, structures located within the lower tidal frame were found to be dominated by the mussel *M. edulis*, particularly juveniles (<2 cm standard length) and the locally abundant bryozoan, *Electra pilosa*. Jackson [RD51] reported similar findings and also observed an increase in the biomass of limpets over five years; although from four to five years, the numbers declined while the biomass still increased indicating inter-size competition [RD88].

Five to 15 years

8.3.11 A number of taxa currently present within the footprint of the Marine Works are likely to take considerably longer to colonise the marine structures. For example, although the sexual spores and asexual propagules of lichens are probably widely dispersed by the wind and mobile invertebrates making colonisation of the breakwater structures likely, crustose lichen species exhibit low growth rates (0.5 - 1 mm/year) while foliose species may grow up to 2-5 mm/year. Fletcher [RD89] suggests that newly exposed substratum needs to be modified by weathering and that initiation of new thalli is thought to take several years. Whilst increased surface heterogeneity may increase the colonisation rate of lichens to the breakwater structures, it is believed that it would take in excess of five years [RD81].

8.3.12 For benthic fauna within the dredged/excavated area, the rate of recovery is dependent on a number of factors including the original faunal composition, sediment characteristics, proximity to 'healthy' populations, the size of dredge area, hydrodynamic regime and the programme of maintenance dredging [RD90]. The shortest recoveries occur in areas of highly mobile sands under conditions of strong tidal stress. These environments are characterised by opportunistic 'colonisation communities' which can recover very quickly (within six months in some instances [RD91]). The longest recoveries occur in habitats that are less dynamic, particularly coarse sediments in areas of weak or moderate tidal stress. These environments are characterised by mature communities that include long-lived species such as bryozoans and large bivalves e.g. *Pecten* spp., *Chlamys* spp. [RD90]. The dominance of muddy sands and sandy muds within the footprint of the Marine Works coupled with the decrease in tidal stress (<1 knot) due to the presence of the breakwaters suggests that recovery is likely to take in excess of five years.

8.4 Invasive non-native species (INNS)

8.4.1 Chapter D13 of the Environmental Statement [APP-132] concluded that the risks posed by the introduction of non-native species (outcompeting native species) associated with construction of the Project would result in a medium magnitude of change and a moderate adverse effect. Implementation of a monitoring programme for non-native species (this additional is mitigation already secured in the Draft DCO), reduced this to a small magnitude of change and a minor adverse effect but nevertheless, invasive non-native species (INNS) are known to be a key concern for statutory and non-statutory stakeholders. In particular, the carpet sea squirt, *Didemnum vexillum* which is classified as a high impact species under the WFD and proliferates on shallow artificial structures occurring in sheltered environments (e.g. marinas).

8.4.2 Hard artificial structures are known to be particularly susceptible to colonisation by INNS and often support a greater number of INNS than natural habitats as their surfaces are generally characterized by an absence of competition and predation [RD92, 93]. They are also frequently constructed in highly disturbed environments that further favour the establishment of opportunistic species [RD10]. When multiple artificial structures are built relatively close to one another along stretches of coast comprising predominantly soft sediments, these structures can sometimes function as pathways or stepping stones, facilitating the spread and connectivity of both native and non-native marine species [RD94].

8.4.3 On the basis of the diversity resistance hypothesis, it is widely acknowledged that more complex or diverse communities can reduce the establishment of INNS [RD7, 95-97]. This, therefore, provides further argument for implementing ecological enhancement measures as part of the Project as these can improve the resistance of artificial structures to the establishment of INNS.

8.4.4 Understanding how the design of Marine Works can facilitate the introduction and establishment of key INNS of concern, and how ecological enhancement mitigation measures can be used to interrupt or obstruct interactions, could help reduce the impact of INNS on marine benthic habitats and species arising from the Project. For example, the green alga, *Codium fragile* (sub sp. *tomentosoides*) has been recorded within the WNDA since 2015 and is known to rapidly colonise artificial structures such as breakwaters, preferring the more sheltered harbour side [RD92, 98]. Many other INNS considered to be key species of concern for the Project, also proliferate in sheltered harbour environments including, the leathery sea squirt, *Styela clava*, the wireweed *Sargassum muticum*, and the carpet sea squirt, *Didemnum vexillum* [RD99]. With this in mind, it may be wise to consider ecological enhancement measures which could be implemented at appropriate locations on the harbour side of the breakwater structures with the dual purpose of enhancing the ecology (i.e. habitat complexity) and minimising the risk of INNS becoming established within this region of the structures.

8.4.5 This illustrates the importance of considering in detail the interaction between the design of artificial structures (including ecological enhancement measures) and both the current and future ecology of the marine environment. The biosecurity risk assessment strategy for the Project outlines all the invasive non-native species of concern in north Wales [RD99]. For a vast majority of these species, their life history strategies and habitat requirements are well known and therefore it would be possible to make assumptions about what ecological enhancement and other management measures could be implemented to minimise the risks presented by these particular INNS. It is also considered that this information should be used to help inform the type, location and extent of ecological enhancement proposed as part of the Project as well as the ecological objectives defined for these additional mitigation measures.

8.5 Aims and objectives of the ecological enhancement mitigation

8.5.1 The primary aim of the ecological enhancement mitigation (which is already secured in the Draft DCO application) is to further offset the habitat loss under the footprint of the Marine Works which can be achieved by:

1. increasing the area gained versus that which is predicted to be lost; and
2. increasing the 'ecological value' of the surface area of the Permanent Marine Works.

8.5.2 'Ecological value' in this instance means to:

- increase the number of species that can colonise the Permanent Marine Works so that more complex habitats/communities (and the associated ecosystem services that they provide) akin to natural rocky reefs in terms of structure and species composition can develop which are expected to be more resilient to the establishment and spread of INNS; and
- increase the rate of species colonisation so that habitats/communities can develop on the Permanent Marine Works quicker (i.e. within 5-15 years opposed to decades) so to minimise the time lag during which there will be a net ecological loss in the area (e.g. degradation and fragmentation).

8.5.3 It is considered that these aims, and objectives can be met using the five ecological enhancement principles set out in section 3 to devise a suite of ecological enhancement options. There would be a requirement to monitor these mitigation measures following implementation (see section 10) to determine their success against more specific set of ecological objectives which are outlined in Table 8-1.

8.5.4 There are few species-specific objectives because, with the exception of a single ocean quahog (*Arctica islandica*) (a species of edible clam), no species of conservation or commercial importance was recorded under the footprint of the Marine Works (see appendix D13-2 and D13-3 [APP-220] and [APP-221], respectively) of the Environmental Statement). The focus has therefore been placed on more general and habitat-specific objectives.

Table 8-1 Objectives of the ecological enhancement mitigation proposed for the Project

Number	Objective	Justification	Potential metric
General objectives			
O1	Ecological enhancement mitigation will be focussed in the intertidal zone	Habitat loss in the intertidal zone is of principal importance to the WFD Compliance Assessment [APP-444] and the derogation being sought with respect to potential deterioration of the morphological conditions of The Skerries water body Although in the context of the EIA, the greatest loss of habitat of conservation importance is predicted to occur subtidally, a large proportion (6.7ha) is expected to recover following completion of Main Construction. The frequency of maintenance dredging is expected to be low and limited to the CWS intake channel. Furthermore, dredging works will not scrape the harbour smooth with surface heterogeneity (±250mm) remaining. Thus, ecological enhancement measures should be focused between MHWS and MLWS (EEP1).	Areal extent of enhancement measures
O2	General increase in the structural complexity of the Permanent Marine Works	The Permanent Marine Works remain predominately characterised by smooth pre-cast concrete which is known to be the least ecologically favourable according to EEP4 and EEP5. To address impacts to the hydromorphology of The Skerries water body, morphological features (e.g. substrate type, depth variation and structure) similar to those currently found in the area should be created. This would include features such as rock pools, cracks, crevices and overhangs. As the derogation being sought by Horizon with respect to The Skerries water body principally relates to effects to intertidal habitats, in the context of WFD, ecological enhancement mitigation should be focused within the intertidal zone [APP-445].	Areal extent of enhancement measures
O3	Increase rates of colonisation	To improve the ecological value of the Permanent Marine Works and reduce the time lag between the impact of construction and the implementation of mitigation, it is necessary to implement ecological enhancement measures which facilitate	Assess rates of colonisation in enhanced and non-enhanced regions of the Permanent Marine Works

Number	Objective	Justification	Potential metric
		colonisation. This can be achieved in accordance with EEP4.	
O4	Maximise biodiversity	As demonstrated by Figure 6-1, Porth-y-pistyll is characterised by a diverse compliment of biotopes (and associated communities) which is considered to represent a key feature of the area and the wider coastline. Ecological enhancement measures should be implemented on the Permanent Marine Works in accordance with EEP1-5 to maximise their potential to support diverse habitat and communities similar to that which are known to occur naturally in the area under similar conditions.	Level of diversity (species richness and abundance) including Alpha and Beta diversity could be used but it can often be challenging to quantify diversity as trends in abundance can vary significant over time, making it difficult to demonstrate the gains associated with offsetting measures. Other similarity indicatives may be appropriate to test achievement of a 'like-for-like' outcome over time
O5	Maximise productivity	As shown in Table 6-3, biotopes under the footprint of the Marine Works are characterised by dense macroalgae canopies which create three-dimensional habitats known to provide food, shelter, and habitat for a large number of species of invertebrates and fish. Kelp parks and forests also play a major role in the carbon cycle and therefore ecological enhancement measures should be implemented on the Permanent Marine Works in accordance with EEP1-5 to facilitate the re-establishment of current levels of productivity, providing this does not disrupt operation of the Power Station.	Weight of biological material/biomass produced
O6	Maximise the connectivity of habitats (including cross-fertilisation) or provisioning for species migrations	Porth-y-pistyll is part of the wider north Anglesey coastline characterised by hard rocky habitats; the permanent loss of this substrate and the associated habitats and species would result in fragmentation. The Permanent Marine Works are considered capable of functioning as artificial rocky reefs and so increasing their ecological value in accordance with EEP1-5 and the other objectives set out in this table, connectivity could be restored.	Distribution of habitats and species on artificial structures relative to that which occurs at the local and regional scale
Habitat-specific objectives			

Number	Objective	Justification	Potential metric
O7	To create a minimum of five intertidal rock pools measuring 1m² in size	During the 2014 biotope survey it was identified that five rock pools measuring 1m² will be irreversible lost under the footprint of the Permanent Marine Works. Creating similar features elsewhere which support the sample or similar functioning biotopes would directly offset this loss.	Presence and morphological characteristics (e.g. EEP1-5)
O8	Re-establishment of the biotope '*Porphyra purpurea* and *Enteromorpha* spp. on sand-scoured mid or lower eulittoral rock' (LR.FLR.Eph. EntPor)	This intertidal biotope is considered to be an example of rocky reef habitat listed under Annex I of the Habitats Directive and in accordance with Section 7 of The Environment (Wales) Act 2016. Its localised extent is notable (0.13 ha) and falls entirely within the footprint of the Marine Works resulting in fragmentation of this habitat and associated species populations. Through study of the physical and biological characteristics of this biotope (and associated species), EEP1-5 should be used to create ecological enhancement features which can facilitate establishment on the Permanent Marine Works.	Presence of biotope
O9	Re-establishment of the biotope '*Laminaria hyperborea* and foliose red seaweeds on moderately exposed infralittoral rock' (IR.MIR.KR.Lhyp)	This subtidal biotope is considered to be an example of rocky reef habitat listed under Annex I of the Habitats Directive and in accordance with Section 7 of The Environment (Wales) Act 2016. Its localised extent is notable (0.31 ha) and falls entirely within the footprint of the Marine Works resulting in fragmentation of this habitat and associated species populations. Through study of the physical and biological characteristics of this biotope (and associated species), EEP1-5 should be used to create ecological enhancement features which can facilitate establishment on the Permanent Marine Works.	Presence of biotope
Species-specific objectives			
O10	No increase in the level of marine INNS in the WNDA	As outlined in section 8.4, INNS are a key concern for the Project; Porth-y-pistyll represents the focal point of marine activities and is therefore likely to be a point of introduction and/or transfer. Furthermore, hard artificial structures are known to be particularly susceptible to colonisation by INNS [RD92, 93]. Thus, a key objective of	Presence, population size or distribution of marine INNS. Proportion of marine INNS in a community.

Number	Objective	Justification	Potential metric
		the ecological enhancement mitigation will be to facilitate no increase in the level of INNS through the rapid establishment of more complex communities to improve the resistance of the Permanent Marine Works to the establishment of INNS.	
Landscape and visual objective			
O11	To restore as much as possible the natural appearance of the shoreline	Landscape and visual impacts were the principal driver of the shoreline protection method statement which was secured in the Draft DCO application within the Marine Works sub-CoCP [APP-416]. A key focus for stakeholders is also softening of the appearance of the breakwaters.	Qualitative basis

9 Detailed eco-engineering options appraisal

9.1 Ecological enhancement options

9.1.1 As part of the more detailed eco-engineering options appraisal, several ecological enhancement options (denoted by the prefix "EEO") were re-examined with particular consideration given to those which could be incorporated retrospectively in order to overcome engineering and Project constraints previously identified during the initial eco-engineering options appraisal.

9.1.2 Alongside engineering and practical feasibility, environmental benefits, and impact to Project schedule, costs of the various ecological enhancement options have also been considered (Table 9-1).

Table 9-1 Cost indication of the ecological enhancement options

Cost indication	Value	Classification
£	<£25,000	Small
££	£25,000-£100,000	Small
£££	£100,000-£250,000	Medium
££££	£250,000-500,000	Medium
£££££	£500,000-£1.0 million	Medium
££££££	£1.0-£1.5 million	Large
£££££££	>£1.5 million	Large

9.1.3 Case studies of commercial trials and installations have also been investigated further to better demonstrate "proof of concept" with respect to ecological enhancement mitigation.

9.1.4 This information is presented in Table 9-2 and supports the detailed eco-engineering options appraisal outlined below. The focus of this options appraisal remains the ecological enhancement of the Permanent Marine Works, notably the breakwaters and MOLF.

9.2 EEO1: To select ecologically favourable construction materials

9.2.1 As shown by EEP4, the chemistry and surface composition of construction materials can have varying ecological benefits, influencing colonisation rates and the diversity of organisms which can be supported by artificial materials in the marine environment. Natural rock units are expected to be non-uniform in shape and are therefore likely to possess greater structural heterogeneity at the millimetre to metre scale (EEP5) than man-made products (e.g. pre-cast concrete).

9.2.2 To facilitate achievement of the ecological enhancement mitigation objectives O3-O6 and O8-O11, the materials which are intended to be used to construct the Permanent Marine Works were re-examined to see if ecological gains (i.e.

offsetting through improved habitat “quality”) could be made through eco-engineering refinements.

9.2.3 As identified during the initial eco-engineering options appraisal, the use of natural rock won from the site (the most ecologically favourable construction material) was ruled out on the grounds of engineering feasibility (see paragraph 4.2.13). Importation of other metamorphic or more ecological favourable rock materials such as limestone was also ruled out on the basis that it would be impractical (logistically) to source the necessary sized rock units; a requirement to do so would also significantly increase costs, with potential impacts to the construction schedule for the Marine Works. It was also identified that the use of rock material would require the breakwaters to possess a greater footprint that currently assessed in the Draft DCO application to achieve the required stability.

9.2.4 The aforementioned challenges were the primary reasons for the decision to use concrete armour units for the breakwater design. There are a range of types/brands of concrete armour units. Xbloc was chosen due to its previous performance record in the UK and Europe.

9.2.5 Through the detailed design process, it was identified that a proportion of the western breakwater on the harbour side was not critical to the overall stability of the structure. As such, it was considered feasible to seed this area with natural rock units weighing 3-6 tonnes each at negligible additional cost to the Project. This armour rock (Figure 9-1) would cover a total area of 0.3ha; of this 0.2ha would occur within the intertidal zone whilst the remaining 0.1ha would occur subtidally.

9.2.6 It is extremely difficult to predict with any certainty, the size of material which would be won from excavating the harbour as this is influenced by bedrock geology, method of removal (e.g. dredging or excavating) and equipment used. However, any rock material weighing 3-6 tonnes which is won from the outer harbour would be retained for use as armour rock on the western breakwater. If possible and necessary (i.e. if rock units weighing 3-6 tonnes are not won directly), larger material will be broken down to the required size for retention and use. As a last resort (i.e. if all rock units excavated weighs less than three tonnes), rock akin to that which occurs naturally in the area will be imported for use as armour rock.

9.2.7 The Draft DCO design of the MOLF (bulk berthing platforms and Ro-Ro quay) would be constructed of pre-cast concrete blockwork structures (Table 5-1) which would be manufactured onsite at the concrete batching plant. It is not considered practical (financially or logistically) to import block work made of more ecologically favourably construction material.

9.2.8 The bulk quay will comprise either a continuous bulk quay or a split quay with a revetment. Both designs options have pros and cons from an offsetting perspective. Rock won from the site could in theory be used to create the revetment located between the split quay (i.e. implementation of EEO1), although this would be subject to the same challenges outlined in paragraph 9.2.6. Alternatively, a continuous quay wall would increase the surface area available for the implementation of alternative ecological enhancement options (e.g. EEO2 or EEO6) and may be preferable if for example, armour rock of a suitable size cannot be won from the site.

9.2.9 Recognising that concrete is often the preferred construction material, recent academic research has been focused on developing biogenic or ecologically sensitive concrete matrices with some manufacturers incorporating more ecologically sensitive materials into off-the-shelf products [RD46, 100]. However, its use remains limited to “patches” on structures made from normal concrete – see EEO3 (section 9.4) for further information. Manufacturers have confirmed to Horizon that it is not yet feasible or economical to construct large-scale marine structures out of biogenic concrete and as such, this option has been ruled out.

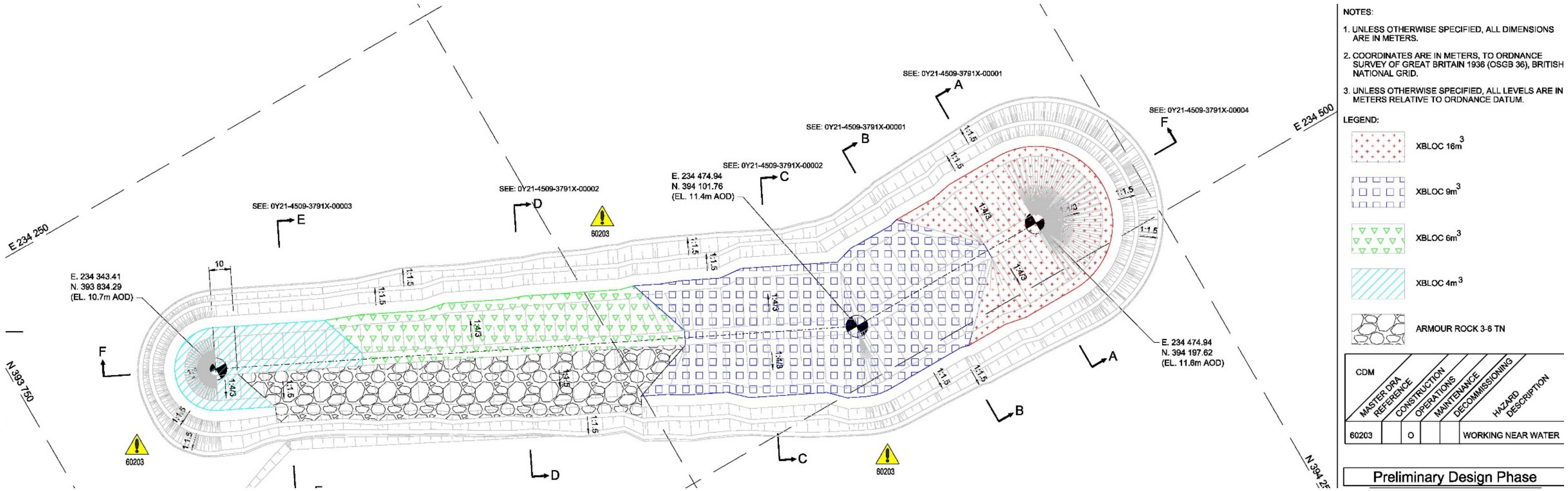
9.2.10 In light of the information presented, seeding the Permanent Marine Works with natural rock where practicable is considered to be the only form of EEO1 which has been taken forward for further consideration in the revised ecological enhancement mitigation proposal.

Table 9-2 Ecological enhancement options, including example installations, engineering performance and ecological benefits.

Ecological enhancement option	Description	Ecological purpose	Example installations	Engineering performance	Ecological benefits
EEO1: To select ecologically favourable construction materials (e.g. limestone over granite or smooth pre-cast concrete)	Can be implemented across the whole structure or at specific locations depending on engineering constraints	To increase surface heterogeneity at the millimetre to centimetre scale with the purpose of stimulating colonisation	Seawall at Hartlepool, UK (commercial trial)	Granite was selected over more ecologically preferable (but expensive) local limestone. This construction material met the engineering performance requirements for its intended use.	Monitoring 12-18 months post installation showed that the enhanced rock revetment supported quicker succession and had the same biotope and supported similar species densities as the baseline natural shore platform [RD13].
EEO2: To use textured armour or pre-cast units to stimulate colonisation	Textured armour units such as specially selected natural textured rocks or pre-cast units such as ECOPODE™ manufactured by Concrete Layer Innovations (CLI) and Eco Xbloc-I manufactured by Delta Marine Consultants (DMC).	To increase surface heterogeneity at the millimetre to centimetre scale with the purpose of encouraging colonisation.	ECOPODE™ units have been added to breakwaters in the Ospdaletti marina, Italy and coastal protection at Garachico, Tenerife (commercial trials)	ECOPODE™ units have been subject to extensive testing to ensure their structural integrity is comparable to any other unit. Tests have included hydraulic stability, robustness and concrete strength, the results of which are available on their website (http://www.concretelayer.com/).	ECOPODE™ has been found to be naturally effective for marine life, with fish and other species rapidly recruiting to these structures due to the variety of difference sized shelters (CLI, pers. comm.).
		Pre-cast units available in a range of sizes (e.g. ECOPODE™) can also add structural heterogeneity at the centimetre to metre scale.	Eco Xbloc-I have been trialled on a breakwater in Ijmuiden, the Netherlands (experimental trial)	The use of Eco-Xbloc-I is not considered to have a significant impact on the structural stability or the overtopping performance of the armour units.	The study in the Netherlands showed this measure to be effective in low and highly dynamic environments [RD101].
EEO3: To use pre-cast panel walls or units with tiles fitted to provide surface and structural heterogeneity	This is the addition of textured marine or cement based concrete tiles. Often installed on smooth plain cast concrete structures. DMC produce pre-cast Xbloc units with the embedded concrete tiles (e.g. Eco-Xbloc-II).	To increase surface heterogeneity at the millimetre to centimetre scale with the purpose of encouraging colonisation.	Seawall at Hartlepool, UK (commercial trial) Seawall at Saltcoats harbour, Scotland (experimental trial)	Commercial and experimental installations at Hartlepool and Saltcoasts were not considered to compromise the engineering performance of the structures as they were affixed onto the existing surface using natural cement and/or marine epoxy.	Ecologically enhanced tiles have been found to support greater habitat complexity, abundance and species richness compared to standard smooth plain cast concrete [RD13].
			Eco Xbloc-II have been trialled on a breakwater in Ijmuiden, the Netherlands (experimental trial)	Pre-cast units with integrated tiles (e.g. Eco-Xbloc-II) have a lower mass than conventional units. DMC has proposed increasing the thickness of the main body of the block proportionally to the number of tiles fitted; and increasing the mass density of the concrete itself to improve engineering performance. Small alterations to the size of the Eco Xblocs are not considered to affect their ability to interlock with one another and with conventional Xblocs.	Establishment and growth of algae occurred almost immediately after placement and were found to be effective in low and highly dynamic environments [RD101].
			Seawall, Seattle, USA (commercial installation)	Installation of the ecologically enhanced tiles were not considered to affect the engineering performance of the structure.	Different organisms showed different responses to surface texture (e.g. mussels preferred cobbled textures over smooth surfaces) [RD102].
			Rock rubble breakwater, Elmer, East Sussex, UK (experimental trial)	Installation of the ecologically enhanced tiles were not considered to affect the engineering performance of the structure.	Holes increased diversity of species two-fold compared to smooth concrete panels [RD17].
EEO4: To retro-fit pits, cracks, crevices and grooves	This can be achieved by drilling or scoring or adding tiles to armour rock or pre-cast concrete units	To increase surface heterogeneity at the millimetre to centimetre scale with the purpose of encouraging colonisation	Coastal defence structures at Runswick Bay, North Yorkshire, Plymouth Sound, Boscombe, Poole Bay, Dorset (experimental trials)	The size and density of the features was such that it was not considered to adversely affect the engineering performance of the armour rock.	A significant increase in species richness and species diversity was found on the ecologically enhanced rock amour compared to unenhanced controls [RD51, 103].
			Shaldon and Ringmore Tidal Defence Scheme (commercial installation)	Monitoring has shown no negative effects on material integrity due to the presence of niche habitats.	Eighteen months following installation, nine invertebrate species were found associated with the enhancements.

Ecological enhancement option	Description	Ecological purpose	Example installations	Engineering performance	Ecological benefits
					Overall, the enhancements increased abundance and diversity [RD8].
EEO5: To retro fit rock pools to armour rock	Water retaining features can be created by coring rock pools into armour rock.	To increase structural heterogeneity at the centimetre to metre scale.	Armoured breakwater at Tywyn, Wales (experimental trial)	The size and density of the features was such that it was not considered to adversely affect the engineering performance of the armour rock.	The pools supported higher biodiversity than surrounding surfaces without water retaining features. When comparing to natural rock pools, the artificial rock pools supported a similar number of species; however, community structure differed [RD19].
EEO6: To install prefabricated rock pools or rock pool features during design	Installation of prefabricated units such as those offered by ECOncrete® and Vertipools by Artecology. These are fixed (cemented) into existing rock structures.	To increase structural heterogeneity from the centimetre to metre scale.	ECOncrete®'s rock pools installed at the Brooklyn Bridge Park, USA (experimental trial)	Rock pools have also developed in line with the performance requirements of specific projects. For example, in New York, rock pools were specifically designed to have up to 5 8% of air (freeze and thaw) resistance, 40 MPa and anti-crack structural fibres.	Found to create well-defined local ecosystems that mimic natural rock pools typical to rocky coasts, and increase local biodiversity and biological productivity (Perkol Finkel, pers. comm.).
			Vertipools on seawall, Isle of Wight (commercial installation)	The size and density of the features was such that it was not considered to adversely affect the engineering performance of the armour rock.	Field testing has demonstrated that these features provide refuge for key species and support higher species richness than natural shore pools [RD103].
			Artificial pools in a vertical sand stone wall, Sydney Harbour, Australia (commercial trial)	The size and density of the features was such that it was not considered to adversely affect the engineering performance of the armour rock.	Invertebrate species richness was increased after one year, with pool biodiversity greater than adjacent walls [RD104].
EEO7: To install prefabricated ecologically enhanced units	Pre-cast concrete units (e.g. BIOBLOCKS™ and ECOncrete®'s armouring units) are designed to incorporate multiple habitat types on the different faces of the block. These units can be placed between existing rocks on the structures.	To increase surface and structural heterogeneity from the millimetre to metre scale.	BIOBLOCKs at Colwyn Bay, West Wales (academic trial)	Although constructed from marine grade concrete, no formal assessment of the structural integrity of BIOBLOCKS™ has been conducted to date. BIOBLOCKS™ were positioned on the opposite side of a groyne to the prevailing current to ensure their presence did not compromise the functioning of the breakwater as a coastal defence structure.	The BIOBLOCK™ was found to support a greater biodiversity than the surrounding rock revetment [RD12].

Figure 9-1 Preliminary engineering design of the western breakwater showing the area of armour rock.



9.3 EEO2: To use textured armour or pre-cast units

9.3.1 In accordance with EEP4, it has been shown that increasing surface heterogeneity at the millimetre scale can facilitate colonisation of marine flora and fauna and development of more complex habitats and communities [RD17, 32, 33]. Roughened surfaces are also considered to provide aesthetic benefits.

9.3.2 To facilitate achievement of all ecological enhancement mitigation objectives set out in Table 8-1 (O1-O6 and O8-O11), opportunities to embed increased surface texture into the design the Permanent Marine Works were re-examined to see if ecological gains (i.e. offsetting through improved habitat "quality") could be made through eco-engineering refinements.

9.3.3 Table 9-2 outlines several off-the-shelf products available which are consistent with this ecological enhancement option. Given the decision to use Xbloc for the construction of the breakwaters, it was considered necessary to revisit the option to use Eco-Xbloc-I which is an off-the-shelf product produced by the same manufacturer.

9.3.4 Eco-Xbloc-I possess roughened surfaces created by inserting NOEPlast liners inside standard Xbloc moulds. Eco-Xbloc-I can be inserted in place of standard Xbloc units with no impact to the stability nor overtopping performance of the breakwater structures. Thus, this option is considered feasible from an engineering perspective. However, although installations have been piloted on the breakwater in Ijmuiden, the Netherlands, since 2008, Eco-Xbloc-I have yet to be used in a commercial context.

9.3.5 The use of other textured armour or pre-cast units remains ruled out on the grounds of engineering feasibility as it would not be possible to insert these between the Xbloc units. Although pre-cast units could be inserted within the region of armour rock on the western breakwater, the ecological value of this measure is deemed to be less than the use of natural rock and so the latter remains the preferred ecological enhancement option at this location.

9.3.6 The use of off-the-shelf products such as Eco-Xbloc-I to provide textured surfaces is desirable from an ecological perspective as this maximises the extent of ecological enhancement. As this measure is embedded into the eco-engineering design of the Permanent Marine Works, offsetting can commence immediately following construction, minimising the time lag between the impact and the implementation of this mitigation.

9.3.7 However, there is a significant cost implication associated with this option as a single NOEPlast liner can only be used to cast several Eco-Xblocs before it needs replacing inside the mould. The magnitude of the cost depends on the number of units cast and the number of times the liner needs to be replaced. It is considered most cost effective to cast Eco-Xbloc-I all of one size, thereby reducing the number of different sized liners required.

9.3.8 Table 9-3 shows an estimated cost benefit analysis breakdown for the different sized Xbloc units. To convert 100% of Xblocs to Eco-Xbloc-I, it is estimated to cost in excess of £3 million. Analysis of loss versus gains in an ecological sense indicates that for some sized units the cost of Eco-Xbloc-I is disproportionate. For example, enhancing $4m^3$ Xbloc units at a cost of approximately £500,000 only increases the ecological value of 0.09ha intertidally (£555 per m^2) with no benefits delivered to subtidal habitats. Similarly, the ecologically benefits (i.e. area enhanced) delivered by ecologically enhancing the $6m^3$ is much lower than the $16m^3$ but the cost is approximately the same, therefore the overall cost benefit of enhancing the $16m^3$ units is over 3.5 times greater than enhancing the $6m^3$ units. The $9m^3$ Xblocs represent 43% of the unit share on the breakwaters and so there is a high capital cost associated with enhancing this sized Xbloc although the potential ecological benefits both intertidally and subtidally would be notable.

Table 9-3 Cost-benefit analysis of Eco-Xbloc-I

Xbloc unit size (m^3)	Approximate unit count	Total volume (m^3)	Cost indication[1]	Intertidal area (ha) ecologically enhanced	Subtidal area (ha) ecologically enhanced
16	980	15,860	£££££	0.31	0.25
9	2,050	18,450	££££££	0.33	0.12
6	1,130	6,780	£££££	0.14	0.03
4	580	2,320	££££	0.09	-

[1] See Table 9-1 for an explanation of these symbols.

9.3.9 Whilst EEO2 is proven to offer ecological benefits and would facilitate achievement of the ecological enhancement mitigation objectives set out in section 8.5, it remains questionable whether other lower cost measures might be more effective in increasing habitat "quality" (i.e. value) but across a smaller area.

9.3.10 Owing to the lack of commercial precedent for Eco-Xbloc-I, there is also considered to be a degree of uncertainty associated with the production process of Eco-Xbloc-I at the potential scale required for the Project with possible implications to cost (e.g. if NEOPlast liners are required to be replaced more frequently) and the construction schedule for the Marine Works. Contingency has been factored into the cost-benefit analysis presented in Table 9-3 but as a precautionary approach, there is considered to be potential for a small impact to the construction schedule from this ecological enhancement option.

9.3.11 Nonetheless, EEO2 has been taken forward for further consideration in the revised ecological enhancement mitigation proposal.

9.4 EEO3: To use pre-cast concrete panel walls or units with embedded surface features (e.g. tiles)

9.4.1 In accordance with EEP5, it has been shown that increasing structural heterogeneity at the centimetre scale can increase habitat complexity and create more diverse gradient (EEP2), orientation (EEP3) and exposure conditions (EPP4) at the millimetre to centimetre scale. Structural heterogeneity can be embedded into the design of pre-cast panel walls or through installation of pre-cast units with either embedded surface features (e.g. tiles). Table 9-2 outlines several off-the-shelf products and less prescribed measures available which are consistent with this ecological enhancement option. The net effect has shown to demonstrate significant ecological benefits [RD13, 101].

9.4.2 To facilitate achievement of all ecological enhancement mitigation objectives set out in Table 8-1 (O1-O6 and O8-O11), opportunities to embed increased structural heterogeneity within the design of the Permanent Marine Works were re-examined to see if ecological gains (i.e. offsetting through improved habitat "quality") could be made through eco-engineering refinements.

EEO3a Modify the surface of the pre-cast concrete blockwork for the MOLF to increase surface and structural heterogeneity

9.4.3 With respect to the Project, the surface of the pre-cast concrete block work for the MOLF structure could be modified below MHWS to include either surface or structural heterogenous features (EEO3a). This option is likely to increase the number of species which can colonise this vertical structure thereby delivering against ecological enhancement mitigation objectives O1- O6 and O10.

9.4.4 Application of this option across the maximum possible extent of the MOLF (0.09ha) is likely to have a medium cost impact (£££-££££). Whilst a small amount of time would be required to set up the bespoke mould for the block work, the impact to the construction schedule for the Marine Works is expected to be negligible.

9.4.5 Despite the apparent advantages of this option, Horizon's engineering contractor remain concerned about the feasibility (logistically) of implementation and the implications to engineering stability of the MOLF. Whilst discussions with respect to this option remain ongoing, at the present time EEO3a has been ruled out from further consideration in the revised ecological enhancement mitigation proposal.

EEO3b Eco-Xbloc-II or equivalent

9.4.6 Given the decision to use Xbloc for the construction of the breakwaters, it was considered necessary to revisit the option to use Eco-Xbloc-II (EEO3b) which is an off-the-shelf product produced by the same manufacturer.

9.4.7 Eco-Xbloc-II is made from textured or ecological concrete tiles which are inserted into the Xbloc moulds before they are filled with conventional marine concrete. Eco-Xbloc-II is therefore made from structurally robust concrete with "patches" of ecological concrete. Considering this design, Eco-Xbloc-II would be expected to deliver ecological enhancement across a smaller spatial extent to that shown for Eco-Xbloc-I (Table 9-3).

9.4.8 Eco-Xbloc-II units have also been trialled on the Ijmuiden breakwater since 2008 with even greater positive ecological results than Eco-Xbloc-I (Bakker, pers. comm.), and therefore determining which option would be the most effective offsetting measure (area versus quality) remains challenging. Like Eco-Xbloc-I, Eco-Xbloc-II has yet to be used in a commercial context.

9.4.9 The cost impact associated with EO03b is expected to be significantly greater than that associated with Eco-Xbloc-I (Table 9-3) owing to the following requirements:

- production of the ecological concrete tiles (by specialist contractor);
- adjustment of one or more of the Xbloc moulds to allow installation of the tiles inside the moulds; and
- man-hours to install the tiles during production.

9.4.10 As for option EEO2, the potential impact to the construction schedule is considered to be small.

9.4.11 Also, critically the addition of tiles would decrease the overall mass of the units and may have implications for their hydraulic stability. Whilst manufacturers of off-the-shelf products suggest marginally increasing the thickness of the main units to address this issue, there is an additional concern that the tiles could themselves compromise the structural integrity of the individuals causing them to become unstable. Whilst the manufacturer of Eco-Xbloc-II is now “very confident” with the performance of their latest concrete formula, to date they have been unable to share any information with Horizon that would give confidence in the engineering feasibility of the product.

9.4.12 In-line with British Standards (BS 6349-1-1:20013) [RD105], the breakwaters are considered to be structures that cannot be easily repaired or maintained, and therefore an extended design life of 100 years is necessary to support the lifetime duration of the Power Station (60 years). Considering this, in combination with the lack of commercial precedent for Eco-Xbloc-II and supporting information for the structural integrity of these units, EEO3b is ruled out on the basis that engineering feasibility, potential maintenance costs and operational risk to the Project is unknown.

9.5 EEO4: To retro-fit pits, cracks, crevices, grooves and rock pools

9.5.1 Retro-engineering structural heterogeneity (EEP5) is one of the more common forms of ecological enhancement and has demonstrated promising ecological outcomes [RD19, 73, 106, 107]. It can be achieved by either drilling pits, cracks, crevices, grooves and rock pools into pre-existing structures (EEO4a) or retro-fitting tiles containing these features (EEO4b).

9.5.2 To facilitate achievement of nearly all ecological enhancement mitigation objectives set out in Table 8-1 (O1-6 and O8-O11), opportunities to retro-fit increased to the permanent marine structures has been re-examined to see if ecological gains (i.e. offsetting through improved habitat “quality”) could be made through eco-engineering refinements.

EEO4a: Retro-fitting pits, cracks, crevices, grooves and rock pools to the Permanent Marine Works

9.5.3 Like EEO3, option EEO4a would decrease the mass density of armour rock units and could have implications to their hydraulic stability. Although it has been shown through case studies (see Table 9-2) that a low number of modifications are unlikely to present a significant risk to engineering performance, there is concern that to offset the residual impacts associated with the footprint of the Marine Works, this measure would need to be implemented to such an extent that overall, the structural integrity of armour rock or pre-cast concrete would be compromised.

9.5.4 EEO4a is also considered to be a more haphazard way of adding structural heterogeneity which may fail to maximise the ecological potential of the Permanent Marine Works if not applied to the correct location or in sufficient quantity.

9.5.5 Another limitation of this option is the size of the rock pools which could be retro-fitted. Some of the rock pools present in Porth-y-pistyll are up to $70m^2$ [RD57] and therefore could not be recreated using this approach. It is not considered feasible that this ecological enhancement option would be able to generate rock pools measuring $1m^2$ in size (ecological enhancement objective O7).

9.5.6 The cost implication of this measure is dependant largely on the method and scale of implementation (i.e. the number and size of features). Retrofitting individual features in sufficient quantity could require a significant number of man-hours and therefore costs are likely to be notable (££-£££), although significantly lower than that associated with EEO2 and EEO3b. As this option is a retrospective measure, there would be no impact to the construction schedule for the Marine Works although there are health and safety implications which are likely to dictate when this option could be implemented.

9.5.7 Considering issues of scale (i.e. marine offsetting being sought) and the practical feasibility of implementing this option without compromising the structural integrity of the armour rock, EEO4a has been ruled out from further consideration in the revised ecological enhancement mitigation proposal.

EEO4b: Retro-fitting tiles with pits, cracks, crevices, grooves and rock pools to the Permanent Marine Works

9.5.8 Following a review of the hydrodynamic conditions predicted to occur in the harbour, there is considered to be a medium to high risk that tiles retrofitted to the breakwaters and MOLF (EEO4b) could become de-bonded over time creating weakness planes which could cause individual units to become unstable. Considering the information presented in paragraph 9.4.12, the greatest risk is associated with implementation on the breakwaters.

9.5.9 Questions have also been raised about the resilience and longevity of this ecological enhancement option in terms of offsetting impacts. To provide long-term enhancements which deliver against ecological objectives set out in Table 8-1 (except for EEO7), it would be necessary for the tiles to withstand wave and current action over time. However, if for example the objective of this measure was to facilitate colonisation only (O3), then tiles with a design life of 1-5 years may be acceptable. The feasibility of this measure is therefore primarily dependant on the ecological objective(s) it intends to achieve.

9.5.10 The cost impact of this option is dependent on the scale of implementation (i.e. the number and size of tiles fitted). It is expected to be in the region if not slightly higher than EEO4a to account for production and delivery of the tiles (££-£££) although costs could be significantly reduced by manufacturing the tiles on site. As this option is a retrospective measure, there would be no impact to the construction schedule for the Marine Works although there are health and safety implications which are likely to dictate when this option could be implemented.

9.5.11 Whilst discussions with respect to this option remain ongoing, considering the practical feasibility of implementing this option without compromising the structural integrity of the Permanent Marine Works and the potential resilience of this measure in achieving the ecological objectives set out in Table 9-4 below, at the present time EEO4b has been ruled out from further consideration in the revised ecological enhancement mitigation proposal.

9.6 EEO5: To install prefabricated rock pools on the Permanent Marine Works

9.6.1 In accordance with EEP5, it has been shown that increasing structural heterogeneity at the millimetre to metre scale can increase habitat complexity by creating more diverse gradient (EEP2), orientation (EEP3) and exposure conditions (EPP4). Rock pools in particular have been found to offer significant ecological benefits, particularly in the intertidal zone as they provide water retaining microhabitats for a greater diversity of species [RD19, 51, 73].

9.6.2 The use of prefabricated rock pools offers a simple solution to facilitate the achievement of all ecological objectives set out in Table 8-1 (O1-O11). These structures can be manufactured in a range of sizes, materials and shapes which allows for some of the variables such as pool depth, surface area, internal topography and volume to be controlled. Furthermore, careful consideration when siting the rock pools can further control factors such as orientation to sunlight, shading, wave exposure and shore height. Coupled with information relating to localised hydrodynamic conditions, this enables the ecological outcomes of these structures to be predicted with reasonably high degree of certainty, making it easier to demonstrate equivalence. Rock pools of varying sizes and depths would be required to reflect the heterogeneous nature of rock pools located within Porth-y-pistyll presently.

9.6.3 No engineering constraints have been identified in relation to the installation of prefabricated rock pools on the Permanent Marine Works, although careful consideration of their location would be required to ensure guaranteed resilience and longevity of this measure (i.e. the units would not be lost due to wave and current action). Depending on the scale of implementation, the cost impact of this option is expected to be small (£-££). This is partly due to the ease of implementation and the availability of several manufacturers creating a more competitive market for off-the-shelf products (Table 9-2).

9.6.4 As this option is a retrospective measure, there would be no impact to the construction schedule for the Marine Works. Depending on the intended location of prefabricated rock pools, there would also be versatility in the timing of implementation. Staged installation as construction of the Marine Works and Main Construction was completed, would minimise the time lag between the impact and the implementation of this offsetting measure.

9.6.5 Potential locations for installation of prefabricated rock pools include the armour rock on the harbour side of the western breakwater and the MOLF, including either the continuous bulk quay or a split quay with a revetment.

9.6.6 Through the detailed design process for the MOLF, it was identified that there would be sufficient space (several metres) between and below the fenders to permit the installation of prefabricated rock pools. The fenders themselves would be approximately 120cm deep. Assuming a maximum design compression of 72%, the depth of rock pools located between the fenders could be no more than 30cm.

9.6.7 Following completion of the Main Construction, Horizons engineering contractor has confirmed that the fenders will be removed from the MOLF structure, thereby freeing up additional space for ecological enhancement. There would potentially be greater flexibility in the shape and design of any rock pools fitted retrospectively to the MOLF following completion of Main Construction. However, care would need to be taken not to compromise the operability of the MOLF bulk quay which will be retained following completion of the construction of the Project to provide capability to import replacement Power Station plant (e.g. AILs) during the Power Station's operation.

9.6.8 Considering the information presented, EEO5 has been taken forward for further consideration in the revised ecological enhancement mitigation proposal. As a minimum, the ecological enhancement mitigation proposal should seek to replace the five intertidal rock pools measuring 1m^2 in size which will be irreversibly lost under the footprint of the Permanent Marine Works. Owing to their high ecological status, it would be desirable to install more at different locations that represent a range of bio-physical conditions with the aim of "trading up" from some of the less productive or diverse biotopes located within the footprint of the Marine Works presently.

9.7 EEO6: To install prefabricated ecologically enhanced pre-cast units on the Permanent Marine Works

9.7.1 In accordance with EEP5, this option provides another approach for increasing structural heterogeneity at the millimetre to metre scale which can in turn increase habitat complexity by creating more diverse gradient (EEP2), orientation (EEP3) and exposure conditions (EPP4). On this basis, EEO6 has the potential to facilitate achievement of several of the ecological objectives set out in Table 8-1 including O1-O6, O10-O11, and potentially O8-O9 depending on the location of implementation.

9.7.2 The most well-known example of this option relevant to the Project is BIOBLOCKS^{TM} which was installed at Colwyn Bay, West Wales as part of an academic trial. Other comparative products are in existence (Table 9-2).

9.7.3 Given the requirement to use Xblocs over much of the surface area of the breakwaters and given the reasons described above for EEO1, it would only be possible to use other textured pre-cast units in the areas of armour rock. However, to allow the pre-cast units to be inserted in place of armour rock units, they would need to possess the same mass density (e.g. 3-6 tonnes). Pre-cast units possessing a smaller mass density than the armour rock units could be added on top of the structure, but it is considered a high risk that these would be washed away during storm conditions.

9.7.4 Opportunities to incorporate this option into the design of the Marine Works are limited and therefore the potential cost impact to the Project is expected to be small to medium. There is likely to be no impact to the construction schedule as the units could be easily inserted into the armour rock.

9.7.5 Noting the potentially limited scope for implementation, EEO6 has been taken forward for further consideration in the revised ecological enhancement mitigation proposal.

9.8 EEO7: Seeding or transplanting of marine kelp

9.8.1 Over 50% of the subtidal area which falls under the footprint of the Marine Works and considered to be of conservation importance is dominated by kelp. This marine flora forms a substantial component of the marine biomass in the Porth-y-pistyll and is known to provide a number of ecosystem services including carbon sequestration [RD108], The localised extent of '*Laminaria hyperborea* and foliose red seaweeds on moderately exposed infralittoral rock' (IR.MIR.KR.Lhyp) (0.31ha) falls entirely within the footprint of the Marine Works.

9.8.2 Kelp parks and forests create three-dimensional habitats which provide food, shelter, and habitat for a large number of species of invertebrates and fish. They also create a range of morphological (gradient, orientation, exposure and surface heterogeneity) conditions at the millimetre to hectares scale and thus, EEO7 is considered to align with EEP2-5.

9.8.3 Seeding or transplanting of marine kelp would principally seek to facilitate achievement of the ecological enhancement mitigation objectives O4-O6, O9-O11.

9.8.4 Whilst cases studies are known to exist in the UK with respect to the seeding of salt marshes (e.g. Barking Creek project [RD109]), to date there have been no experimental or commercial trials for seeding and transplanting marine kelp. Seeding or transplanting of marine kelp species characteristic of UK waters as a form of statutory mitigation is therefore considered novel and as such, does not feature in Table 9-2 as a proof of concept.

9.8.5 Worldwide however, there are extensive examples due to the mariculture industry which exists predominately in China and Japan and cultivates kelp (*Saccharina japonica*) on a large scale [RD110]. More recently, it has been shown that open-sea cultivation of the European species *S.latissima* is possible using transplanting methods tried and tested on a commercial scale [RD111].

9.8.6 Considering the residual impacts of the Project that require offsetting (as summarised in paragraph 9.8.1), there is a need to explore more novel techniques when trying to reduce as far as practicable, net loss within reasonable timescales. This is especially as only a handful of tried and tested techniques which have been re-examined are practicable when considered in the context of the Project (Table 9-4). As such, the novelty of this option should not preclude its consideration within the revised ecological enhancement mitigation proposal providing it is technically feasible in principle (as demonstrated elsewhere in the world) and does not lead to disproportionate costs.

9.8.7 Further consideration needs to be given to various factors including the following to further determine feasibility and cost implications:

- life history dynamics of different species of kelp known to be currently present in the area;
- potential source of seed material,
- requisite attachment substrate required;
- method of seeding or transplanting;
- location of implementation;
- timing of implementation (highly depending on the life cycle of the target species); and
- scale of implementation.

9.8.8 Re-seeding and transplanting off kelp as part of large-scale restoration projects is known to be expensive [RD112]. Costs can be moderated by the scale of implementation. To further moderate costs and to maximise chances of success, it would be advantageous to deliver this option in collaboration with an academic institution or specialist organisation which has experience in seeding or transplanting of marine flora.

9.8.9 It is considered important to emphasise that the specific objectives of this measure and any associated adaptive management measures would need to be reasonable to reflect the novelty of the approach.

9.8.10 There is considered to be no impact to the construction schedule as acknowledging potential health and safety issues, this option would be implemented retrospectively following construction of the Marine Works.

9.8.11 Whilst discussions with respect to this option remain ongoing, there is a reasonable possibility that the implementation of EEO7 would be feasible (practically). As such, it has been taken forward for potential consideration in the ecological enhancement mitigation proposal.

9.9 Summary

9.9.1 Table 9-4 provides a summary matrix detailing the outcome of the detailed engineering options appraisal and the measures which have been taken forward for further consideration in the revised ecological enhancement mitigation proposal outlined in section 10.

Table 9-4 Summary of the detailed eco-engineering options appraisal

Ecological enhancement option	Practically feasible	Cost impact	Construction schedule impact	Addresses ecological enhancement objective											Conclusion
				O1	O2	O3	O4	O5	O6	O7	O8	O9	O10	O11	
EEO1: Inclusion of areas of armour rock in place of pre-cast concrete units	Yes – in regions of armour rock only	Negligible	Negligible			Y	Y	Y	Y		Y	Y	Y	Y	Accepted
EEO2: Embed a roughened surface into the design of pre-cast concrete units	Yes	Large	Small	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Accepted – subject to scale of implementation
EEO3a: Embed a roughened surface or surface features (e.g. tiles) into the design of the pre-cast concrete block work for the MOLF	Possibly	Medium	Negligible	Y	Y	Y	Y	Y	Y				Y	Y	Rejected – subject to ongoing engineering review
EEO3b: Embed surface features (e.g. tiles) into the design of pre-cast concrete units	No	Large	Small	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Rejected
EEO4a: Retro-fit surface features to the Permanent Marine Works	No	Small/ medium	No impact	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Rejected
EEO4b: Retro-fit tiles with surface features to the Permanent Marine Works	Possibly	Small/ medium	No impact			Y								Y	Rejected – subject to ongoing engineering review
EEO5: Install prefabricated rock pools	Yes	Small	No impact	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Accepted

Ecological enhancement option	Practically feasible	Cost impact	Construction schedule impact	Addresses ecological enhancement objective											Conclusion
				O1	O2	O3	O4	O5	O6	O7	O8	O9	O10	O11	
EEO6: Install prefabricated ecologically enhanced pre-cast units on the Permanent Marine Works	Yes	Small/ medium	No impact	Y	Y	Y	Y	Y	Y				Y	Y	Accepted
EEO7: Seeding or transplanting of marine kelp	Possibly	Medium	No impact				Y	Y	Y			Y	Y	Y	Accepted in principle – subject to ongoing ecological review

10 Revised ecological enhancement mitigation proposal

10.1.1 This revised ecological enhancement mitigation proposal is intended to offset the residual impacts associated with the footprint of the Marine Works.

10.1.2 The residual impact has been determined taking the following into consideration.

- The ability of the breakwater structures to function as artificial rocky reefs even in the absence of ecological enhancement. In assessing equivalency (or offsetting), the area is already claimed by the presence of the structures in the marine environment.
- The area of marine habitats which will be restored in accordance with the shoreline protection and restoration statement.
- The assumption that a degree of recovery is expected to occur within the dredged area.

10.1.3 The rationale behind the revised ecological enhancement mitigation proposal is to provide a suite of measures which can offset not just the area, but the quality of habitats predicted to be lost under the footprint of the Marine Works. Whilst it is desirable to maximise quantity and quality, in practice there is often a trade-off between the two.

10.1.4 In the absence of any standardised marine biodiversity calculators, it is not possible to reliably quantify the contribution of the proposed ecological enhancement measures to improving quality and therefore overall ability to offset the impacts (i.e. equivalence = area x quality). As a result, the scale and potential effectiveness of each measure is considered on a qualitative basis; where there is a spatial component, estimated areas are shown.

10.1.5 Table 9-4 summarises the revised ecological enhancement mitigation proposal with further detail set out under the subsequent headings.

10.2 Areas of armour rock to be seeded with natural rock won from the site where practicable

10.2.1 This measure would be implemented during the construction of the Marine Works. There are three potential locations where seeding with natural rock would be expected to occur; these include:

1. harbour side of the western breakwater in the region of armour rock (Figure 9-1);
2. shore protection adjacent to the eastern breakwater (see Drawing WN0907-HZCON-LAP-DRG-00007 Rev 2.0 of the Marine Licence application); and
3. potential revetment between the MOLF split quay (see Drawing WN0907-HZCON-LAP-DRG-00010 Rev 2.0 of the Marine Licence application)

10.2.2 Aesthetic benefits of using natural rock would be realised at all three locations, with marine ecological benefits also occurring at one location, including the harbour side of the western breakwater. The shore protection adjacent to the eastern breakwater and the potential revetment between the MOLF split quay (one of two design options considered in the Draft DCO application, the other being a continuous quay wall) are located predominately above MHWS and therefore the use of natural rock at these locations would offer little to no benefits to marine ecology. Thus, the assessment of ecological offsets has not taken these areas into account.

10.2.3 On the western breakwater, this measure would ecologically enhance 11.8% of the area located below MHWS. It would be expected to improve the quality of habitats which would likely to have been otherwise associated with pre-cast concrete. Areas of natural rock are expected to be able to eventually deliver aesthetic and ecological benefits on a like-for-like basis (i.e. similar to that of a natural rocky shoreline).

10.2.4 This measure would be implemented during construction of the Marine Works. Considering this and the fact that the use of natural rock is expected to facilitate greater rates of colonisation, the timescales of recovery are expected to minimal.

10.3 Ecological enhancement of the 16m^3 pre-cast concrete units on the breakwaters to include a roughened surface

10.3.1 The cost-benefit analysis of this ecological enhancement measure varies between different sized units, being greatest for 16m^3 units and least for 4m^3 (see paragraph 9.3.8). The overall cost of implementing this measure across the entire breakwaters is considered to be disproportionate to the benefits.

10.3.2 Furthermore, although the benefit of enhancing surface heterogeneity to increase rates of colonisation is indisputable in literature, it is widely acknowledged that enhancing structural heterogeneity (i.e. surface heterogeneity but at a larger scale (>centimetre scale)) can achieve much greater ecological benefits spanning a broader spectrum of quality measures (see paragraph 8.2.3). Thus, other potentially less expensive ecological enhancement options are considered to be more effective in achieving the ecological objectives outlined for the mitigation. However, the spatial extent to which these measures can be implemented is considered less than using textured pre-cast concrete units on the breakwaters. Consequently, there is a trade-off between area and quality which also needs to be considered within the cost-benefit analysis of the wider ecological enhancement mitigation proposal. This is the rationale behind proposing a suite of measures rather than adopting a one-size-fits-all approach.

10.3.3 On this basis, it is proposed that only the 16m^3 pre-cast concrete units should be ecologically enhanced to include a roughened surface. This sized unit has been selected because it represents the greatest surface area of the four sized blocks, occurring on both the western and eastern breakwaters, and is most cost effective (Table 9-3). This sized unit also features on both sides of the breakwaters, providing ecological enhancement at a range of orientation and exposure conditions.

10.3.4 This measure would be implemented during construction of the Marine Works, reducing the time lag between losses (i.e. impact) and gains (i.e. realised ecological benefits).

10.3.5 Roughening the surface of the $16m^3$ pre-cast concrete units on both breakwaters and the inclusion of rock armour on the western breakwater would ecologically enhance approximately 55% of the breakwaters surface area which sits below MHWS. Further ecological enhancement of the western breakwater using pre-fabricated rock pools is also proposed; this measure is described below.

10.4 Installation of pre-fabricated rock pools

10.4.1 The installation of pre-fabricated rock pools is one of the preferred measures for incorporating ecological enhancement on the basis that it is relatively low cost, can be implemented retrospectively following construction and supports a range of ecological enhancement principles and objectives.

10.4.2 As demonstrated in section 9, there are few practical options for installing pre-fabricated rock pools on the breakwaters. The only area where this measure is considered feasible is within the region of armour rock on the harbour side of the western breakwater. It is therefore proposed that 10 pre-fabricated rock pools will be installed at this location. The principal objective of this measure is to offset the five intertidal rock pools measuring $1m^2$ in size which will be permanently lost under the footprint of the Marine Works. Thus, the pre-fabricated rock pools installed will be equivalent in size and location. A further five rock pools will be installed to support other ecological objectives (see Table 10-1); these pre-fabricated rock pools will vary in size and form but will be also be located intertidally.

10.4.3 The MOLF was recognised as being of low ecological value because of its vertical nature. However, being approximately 380m long, it presents a significant surface area which could be ecologically enhanced to facilitate the colonisation and establishment of marine organisms and habitats. It is therefore proposed that 90 pre-fabricated rock pools are installed on the MOLF. These will be primarily implemented intertidally in two stages; a proportion will be installed between the fenders immediately following construction of the MOLF, with additional rock pools installed following completion of Main Construction and removal of the fenders.

10.4.4 Although ecological enhancement measures have been intentionally focussed within the intertidal zone it is acknowledged that subtidal impacts also require consideration. The detailed eco-engineering options appraisal identified few practical options for implementing subtidal ecological enhancement measures. However, one option is to install features on the MOLF wall within the subtidal zone. It is therefore proposed that off the 90 pre-fabricated rock pools which will be installed on the MOLF wall, a proportion will be implemented subtidally either immediately following construction of the MOLF or following completion of Main Construction. Whilst it is acknowledged that these features wont function as rock pools in the traditional sense, they will provide surface and structural heterogeneity, facilitating the establishment and growth of marine flora and fauna.

10.4.5 The pre-fabricated rock pools will be characterised by a range of sizes and forms which will be constrained by the depth of the fenders and the need to maintain operability of the MOLF. They will possess both internal and external surface and structural heterogeneity in order to maximise their potential ecological value. It is considered that this measure would contribute to offsetting both the area and quality of residual habitat lost under the footprint of the Marine Works.

10.4.6 Rock pool environments vary considerably depending on factors such as depth, surface area, volume, orientation to sunlight, shading, internal topography, sediment content and type, together with wave exposure and shore height [RD113]. Therefore, no two rock pools are considered the same, even when situated at the same shore height [RD80, 114, 115]. Despite this, the physical and biological information collected from five rock pools sampled in Porth-y-pistyll during the 2014 biotope survey (see appendix D13-3, [APP-221]) will prove useful when designing rock pools for the breakwater structures in an effort to exercise equivalence. Furthermore, it provides important baseline data against which rock pools created on the breakwater structures can be compared. When ascertaining equivalence, emphasis should be placed on the generation of rock pools of equivalent ecological or ecosystem value rather than the generation of like-for-like owing to their complex physical and biological nature.

10.5 Seeding or transplanting of kelp to be implemented as part of an academic project part funded by Horizon

10.5.1 As outlined in section 9.8, seeding or transplanting of kelp, particularly as a means of statutory mitigation remains a highly novel concept. Whilst it is considered practically feasible, further work is required by way of a detailed method statement, to develop information such as location, scale and timing of implementation. However, it is likely that this measure will be implemented as part of the shoreline protection method statement in the area under the footprint of the temporary causeway. Furthermore, the scale of implementation would be constrained to avoid potential risks posed to the operation of the CWS intake from increasing algal biomass in the harbour (i.e. floral ingress).

10.5.2 Seeding or transplanting of kelp as part of marine restoration projects has been found to be inherently expensive reaching in to millions of pounds depending on the scale of implementation. To moderate costs and to maximise the probability of achieving the intended ecological objectives, it is proposed that this measure be implemented as part of an academic project funded by Horizon.

Table 10-1 Revised ecological enhancement mitigation proposal

Mitigation measure	Location	Timing of implementation	Quantity/size/area	Ecological objectives	Constraints
Areas of armour rock to be seeded with natural rock won from the site where practicable (alternatively, imported material akin to natural rock will be used)	1. Harbour side of the western breakwater 2. Adjacent to the eastern breakwater 3. Potential revetment between the MOLF split quay	During construction of the Permanent Marine Works	~300m long, with a total area below MHWS of 0.3ha ~80m long, none of this armour rock would sit below MHWS ~50m long, none of this armour rock would sit below MHWS	• Increase rates of colonisation (O3) • Assist in maximising biodiversity O4), productivity (O5) or connectively (O6) of habitats • Facilitate the re-establishment of the intertidal biotope '*Porphyra purpurea* and *Enteromorpha* spp. on sand-scoured mid or lower eulittoral rock' (O8) and the subtidal biotope '*Laminaria hyperborea* and foliose red seaweeds on moderately exposed infralittoral rock' (O9) • Facilitate the achievement of no increase in the level of marine INNS in the WNDA (O10)	Use of material won from site dependent on the size of rock which is excavated. If no material ≥3 tonnes won from the site, then imported material akin to natural rock will be used instead
Ecological enhancement of the 16m^3 pre-cast concrete units on the breakwaters to include a roughened surface	Eastern and western breakwaters	During construction of the Permanent Marine Works	To cover 0.56ha; 0.31ha would occur intertidally and 0.25ha would occur subtidally	• To deliver ecological enhancement in the intertidal zone (O1) • To increase structural complexity of the Permanent Marine Works (O2) • Increase rates of colonisation (O3) • Assist in maximising biodiversity (O4), productivity (O5) or connectively (O6) of habitats	None

Mitigation measure	Location	Timing of implementation	Quantity/size/area	Ecological objectives	Constraints
				• Facilitate the re-establishment of the intertidal biotope '*Porphyra purpurea* and *Enteromorpha* spp. on sand-scoured mid or lower eulittoral rock' (O8) and the subtidal biotope '*Laminaria hyperborea* and foliose red seaweeds on moderately exposed infralittoral rock' (O9) • Facilitate the achievement of no increase in the level of marine INNS in the WNDA (O10)	
Installation of pre-fabricated rock pools on the Permanent Marine Works	MOLF quay wall and area of armour rock on the harbour side of the western breakwater, at a range of tidal heights	Staged implementation to include: a proportion will be installed following construction of the Permanent Marine Works, whilst the remaining will be installed following completion of Main Construction	100 pre-fabricated rock pool Various sizes (e.g. 0.3 to 1.0m wide) and volumes (e.g. 0.003 to 0.012m^3)	• To deliver ecological enhancement in the intertidal zone (O1) • To increase structural complexity of the Permanent Marine Works (O2) • Increase rates of colonisation (O3) • Assist in maximising biodiversity (O4), productivity (O5) or connectively (O6) of habitats • Create a minimum of five intertidal rock pools measuring 1m^2 in size (O7) • Facilitate the re-establishment of the intertidal biotope '*Porphyra purpurea* and *Enteromorpha* spp. on sand-	Potential locations for rock pools on the MOLF wall include between and below the fenders (to be added following construction of the Marine Works) and in place of the fenders once these are removed (following completion of Main Construction). Care will need to be taken in siting the rock pools to ensure they do not compromise the operability of the MOLF is bulk quay.

Mitigation measure	Location	Timing of implementation	Quantity/size/area	Ecological objectives	Constraints
				scoured mid or lower eulittoral rock' (O8) and the subtidal biotope '*Laminaria hyperborea* and foliose red seaweeds on moderately exposed infralittoral rock' (O9) • Facilitate the achievement of no increase in the level of marine INNS in the WNDA (O10)	
Seeding or transplanting of kelp to be implemented as part of an academic project part-funded by Horizon	Exact location(s) to be identified within a more detailed method statement but may potentially include the area under the footprint of the temporary causeway	Following construction of the Marine Works and/or removal of the temporary causeway	This information will be developed as part of a more detailed method statement.	• To deliver ecological enhancement in the intertidal zone (O1) • To increase structural complexity of the Permanent Marine Works (O2) • Increase rates of colonisation (O3) • Assist in maximising biodiversity (O4), productivity (O5) or connectively (O6) of habitats • Facilitate the achievement of no increase in the level of marine INNS in the WNDA (O10)	It is preferable to implement this option following construction of the Marine Works but depending on the location, health and safety risks may delay implementation until later in the Main Construction programme. The scale of implementation would be constrained to avoid potential risks to CWS intake operation from increased algal biomass in the harbour. All constraints associated with this ecological enhancement measure are not fully understood but will be developed as part of a specific method statement.

10.6 Monitoring and adaptive management measures

10.6.1 Within the Draft DCO application, Horizon has made a commitment to implement a monitoring programme for INNS (see the Marine Works sub-CoCP, [APP-416]. As detailed in Section 8.4, ecological enhancement measures which facilitate the development of more complex habitats can help reduce the establishment and spread of the INNS.

10.6.2 Given the relationship between INNS and ecological enhancement, Horizon has confirmed that the current commitment to monitoring for INNS would include monitoring of the ecological enhancement measures. This was secured in the Draft DCO application by way of an update to the Marine Works sub-CoCP [REP2-033] which was submitted into Examination at Deadline 2 (4 December 2018).

10.6.3 This monitoring programme would have the dual purpose of assessing the benefits of ecological enhancement in relation to INNS whilst also assessing the effectiveness of the enhancement measures against the suite of ecological objectives (see Section 8.5). The monitoring data would be used to permit adaptive management and inform the decision to implement further enhancement if necessary.

10.6.4 It is acknowledged that further information related to monitoring techniques (linked to established guidance), monitoring frequency and adaptive management measures deemed necessary, is required. A detailed monitoring method statement will be developed in consultation with NRW.

11 Summary

11.1.1 In summary, the revised ecological enhancement proposal includes the following measures:

- 90 precast vertical rockpools will be installed at various heights on the MOLF wall (initial installations will be immediately following construction of the MOLF, with final installations occurring at the end of Main Construction);
- 10 precast rockpools will be installed in armour rock on the western breakwater;
- areas of armour rock (including the harbour side of the western breakwater, and any rock revetment) will be seeded with natural rock won from the site, where practicable (alternatively, imported material akin to natural rock will be used);
- ecological enhancement of $16m^3$ precast concrete units on the breakwaters, to include textured surfaces;
- retaining surface roughness within the dredged area to promote recolonisation;
- seeding or transplanting of marine kelp of subtidal areas;
- a monitoring programme to assess the effectiveness of the enhancement measures against a suite of clearly defined ecological objectives; and
- provision of relevant monitoring data to local schools and universities to promote ecological enhancement of the marine environment.

11.1.2 The aim of this report was to expand upon information previous shared with stakeholders through the SoCG process to demonstrate that Horizon has appropriately considered the impacts of the Project footprint within the marine environment and has made satisfactory commitment to mitigating this impact.

11.1.3 Through presentation of the two-stage options appraisal process and provision of more detailed information related to the revised ecological enhancement mitigation proposal (e.g. ecological objectives, location, quantity, etc.), it is considered that this aim has been achieved.

11.1.4 Within the constraint of the WNDA Order limits, it is not physically possible to fully offset the area of habitat loss under the footprint of the Marine Works. Therefore, to reduce net loss as far as practicable, the enhanced ecological enhancement mitigation proposal has been focused on improving quality as well as maximising the spatial extent of enhancements over the greatest practical (i.e. logistically and financially) extent.

11.1.5 Considering all the information presented in this report, it has been shown that all practicable and feasible steps have been taken to minimise and offset the impacts of the Marine Works footprint with respect to EIA and WFD.

12 References

Table 12-1 Schedule of references

ID	Reference
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Appendix 1-1 CWS type options appraisal

12-1.1.1 As part of the options appraisal to determine the most appropriate method for cooling the ABWRs [RD52], the following technologies were subject to review:

- direct seawater cooling (max 12℃ temperature rise);
- natural draught cooling towers;
- induced draught cooling towers;
- low plume (hybrid) induced draught cooling towers;
- low plume (hybrid) fan assisted natural draught cooling towers; and
- air cooled condensers.

12-1.1.2 The options appraisal included a thermodynamic modelling assessment; capital cost modelling assessment; and an assessment of the potential environmental effects associated with each option.

12-1.1.3 It was concluded that direct cooling using seawater provides the greatest net power output to the National Grid and has the lowest capital and operating costs. In addition to higher costs, the other technologies all reduce the output of the plant which requires the power to be generated from additional investment in other sources of energy, with a loss of revenue.

12-1.1.4 Significant difficulties were identified in relation to the cooling tower and air--cooled condenser options. A major constraint was the amount of land that would be required and the topography of the land available. Development of a level site of sufficient area was considered difficult, expensive and with potentially significant environment (e.g. loss of terrestrial habitats and species, impacts to hydrology, landscape and visual, public access and recreation, etc.) and socio economic (e.g. tourism) effects.

12-1.1.5 The visual effect of natural draught cooling towers and the plume was also considered to be significant with up to two 165m high and 152m wide towers necessary for natural draught cooling. This was considered to be an unacceptable landscape and visual impact. All the other cooling tower options would reduce the amount of power available for export. Furthermore, the air-cooled condenser was not considered proven technology for the scale and type of application that would be required for this Project.

12-1.1.6 The use of direct cooling has both environmental and commercial benefits, provided that the effects of habitat loss, water abstraction and the thermal discharge can be reduced as far as practicable. The conclusion of the options appraisal was supported by assessment of the cooling options for this type of plant made by the Environment Agency [RD53] and the strategic siting assessment carried out by the UK Government [RD54]. The Existing Power Station also successfully used direct cooling with low reported effect for over 40 years of operation (see appendices D13-5 [APP-223] and D13-10 [APP-228] of the Environmental Statement).

12-1.1.7 As the benefits of direct cooling from the sea could not be achieved by other means, which are significantly better environmental options (test (d)), this was the preferred choice of cooling technology for the two ABWRs taken forward into the Draft DCO application.

Appendix 1-2 CWS intake and outfall location options appraisal

12.1.2 Since the 1980s, 15 and 16 possible locations for the Project's CWS intake and outfall have been considered over the course of a series of options appraisals [RD53-57]. The locations are shown in Figure 12-1.

12.1.3 In 2011, a steering group made up of engineers, modellers and both terrestrial and marine ecologists re-examined a number of the possible locations as well as additional options not previously appraised [RD56]. A detailed review of marine and terrestrial baseline conditions was undertaken to identify receptors which might be impacted by the various proposed locations for the CWS intake and outfall. This was followed by a high-level impact assessment which drew upon preliminary hydrodynamic modelling and took account of BAT mitigation to determine the option that was likely to result in the lowest overall residual environmental effect.

12.1.4 The outcome of this options appraisal identified E1 as the preferred site for the CWS intake although other nearshore locations were considered viable (C1 and F4). The big disadvantage of these sites was the requirement for a breakwater to protect them from wave surges. There would also be loss of littoral habitats. However, one of the advantages was that a CWS intake located at E1 was considered to facilitate the implementation of several mitigation options available to reduce mortality associated with entrapment (e.g. acoustic fish deterrents, FRR system, etc.). Furthermore, there would be no requirement for a deep tunnel passage and therefore entrapped organisms would not be subject to significant hydrostatic pressure changes or prolonged exposure to biocides, thereby increasing the likelihood of survival. Porth-y-pistyll does not support particularly high abundances of fish compared to elsewhere on the north Anglesey coastline with few species of commercial or conservational importance recorded in this area. The fish community known to be present is characteristic of a sheltered rocky habitat (see appendix D13-4 [APP-222] of the Environmental Statement).

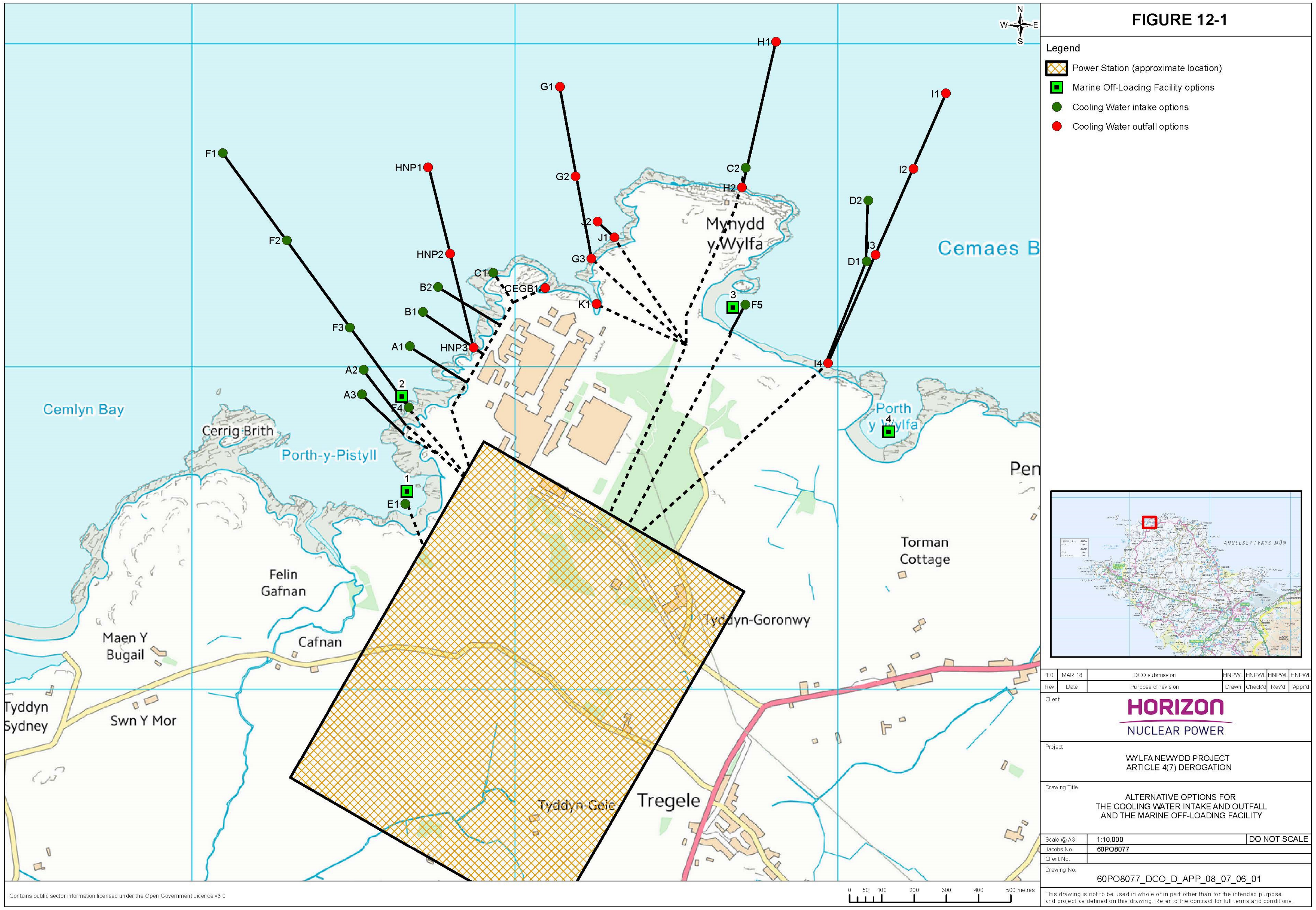
12.1.5 Several offshore locations (A1, B1, B2, C2 and F3) were also considered viable although these would take longer to construct as there would be a requirement to excavate a deep tunnel using either drill and blast process or tunnelling boring; and construction/operation (i.e. project scheduling) was considered more difficult to predict in tidally-swept environments. There are also the negative impacts to marine organisms entrapped at offshore intakes (e.g. exposure to high hydrostatic pressure which can cause barotrauma, and biocides which can have acute toxic effects resulting in mortality).

12.1.6 Other sites (D1, D2 and F5) were ruled out as they would create a large footprint of habitat loss and disturbance. These sites are also located in an area known to be an important fish nursery grounds for flatfish and used by migratory sea trout (see appendix D13-4 [APP-222] of the Environmental Statement). Furthermore, these three options would require the construction of infrastructure on the foreshore which may encroach on the Tre'r Gof Site of Special Scientific Interest and areas of reptile habitat and chough foraging habitat. Even in light of the potential impacts associated with the Site Campus, these environmental concerns remain valid.

12.1.7 Options for the CWS outfall which were considered feasible were options HNP1-2, G1-2 and H1, we well as nearshore options HNP3, G3, J2 and H2, and the onshore locations J1, K1 and CEGB1. Sites I1-4 were ruled out owing to the potential effects to Cemaes Bay including habitat loss and thermal discharge effects to ecological receptors and the EU-Designated bathing water.

12.1.8 Further ecological options appraisal confirmed site E1 as the preferred location for the CWS intake whilst the preferred option for the CWS outfall was site K1 [RD57]. With further consideration of cost, engineering feasibility and sustainability (i.e. reuse of existing structures for the Existing Power Station), these sites were selected for the final design. Of the alternatives examined, none were considered to represent a significantly better environmental option (test (d)).

Figure 12-1 Options appraisal for the CWS intake and outfall location



Appendix 1-3 MOLF requirement and location options appraisal

12.1.9 One of the key decisions which informed the development of alternative options involved consideration of alternative means for transporting materials. The Project has significant requirements in terms of the transportation of AILs and bulk materials.

12.1.10 Section 5.13 of NPS EN-1 sets out the traffic and transport policies that should be considered when developing a Draft DCO application and states that "*Water-borne or rail transport is preferred over road transport at all stages of the project, where cost-effective*" [RD12]. The Department of Transport also operates a policy to encourage the transportation of AIL away from roads and rail and towards marine solutions. Considering this policy together with technical feasibility, costs and environmental impacts, it was determined that delivery of AILs and bulk material to the Wylfa Newydd Development Area via a MOLF was the preferred option. Of the transportation alternatives examined, none were considered to represent a significantly better environmental option (test (d)).

12.1.11 A strategic study carried out by Halcrow [RD116] to investigate options for the delivery of AILs to site and identified four potential locations. Site 1 was in Porth-y-pistyll (adjacent to site E1 for the CWS intake), site 2 was further along the coast to the northeast, site 3 was in Cemaes Bay and site 4 in Porth Wylfa (Figure 12-1).

12.1.12 Site 2 was initially discounted on the basis of the exposed nature of the site with the potential for considerable engineering required to make it both workable and accessible [RD56]. Site 4 was also discounted on the basis of site exposure and a narrow inlet channel making is unsuitable for the delivery of AILs.

12.1.13 It was recognised that site 3 would result in development occurring in two bays rather than one, increasing the overall area affected by construction and potential impacts to ecological receptors and the bathing water in Cemaes Bay. Furthermore, integrating the MOLF structure with the breakwater structures for the CWS intake was considered to reduce the footprint of construction activities on the foreshore. Through further iterations of this options appraisal, the latter option remained the preferred approach with more detailed options appraisals examining the configuration of the CWS intake, MOLF and breakwaters within Porth-y-pistyll converging on the design taken forward into the Draft DCO application [RD57, 58].