Defining project envelopes for marine energy projects: Review and Tidal energy test facility and marine mammals case study

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SMRU Consulting and NRW

Report No: 274

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Executive Summary

This report provides a detailed description of a set of guiding principles that should inform the development and definition of Project Design Envelopes (PDEs) for multiple technology marine energy sites. A PDE approach is a consenting approach that allows a project proponent to submit an assessment of the potential maximum impacts of a range of design parameters within its application. This is often required because at the time of consent application, the details of project design are not finalised. This allows the project proponent with the flexibility to build out a number of potential design options, as long as the project is constructed and operated within the range of parameters assessed.

This NRW Evidence Report is in three sections:

1. Executive Summary including summary of guiding principles
2. SMRU Consulting Report: Defining Project Design Envelopes for Marine Energy Projects
3. SMRU Consulting Annex One: Detailed review and case study

The guiding principles for designing Project Design Envelopes (PDE) are summarised under the following headings and are visually presented in Figure 1a:

1. PDEs and consenting and management regimes: highlighting the aspects of the legal process that dictate the development of PDEs.

2. PDEs and environmental assessments: highlighting the importance of identifying the likely most significant environmental issues and their influence on consenting.

3. PDEs and worst-case assessments: outlining the key environmental considerations for worst case scenarios and discussing how multiple worst cases can create unrealistic PDEs and highlighting the need for holistic assessment across a range of receptors and impact pathways. This also highlights the need for considerable detailed and early engagement between project engineering design and the environmental consenting team so that both parties fully understand the constraints each are working under.

4. The evidence needs for the definition of PDEs – PDEs should be based on a robust evidence base on impact pathways and sensitive receptors to avoid overly precautionary worst case PDEs. This highlights the need for efficient mechanisms to ensure monitoring findings are disseminated quickly and widely.

The three key points that have been identified as critical to the PDE process are:

1. Communication between engineering and environmental specialists
2. Early identification of key issues (environmental receptors and impact pathways)
3. **Pre-application evidence gathering should focus on key issues**

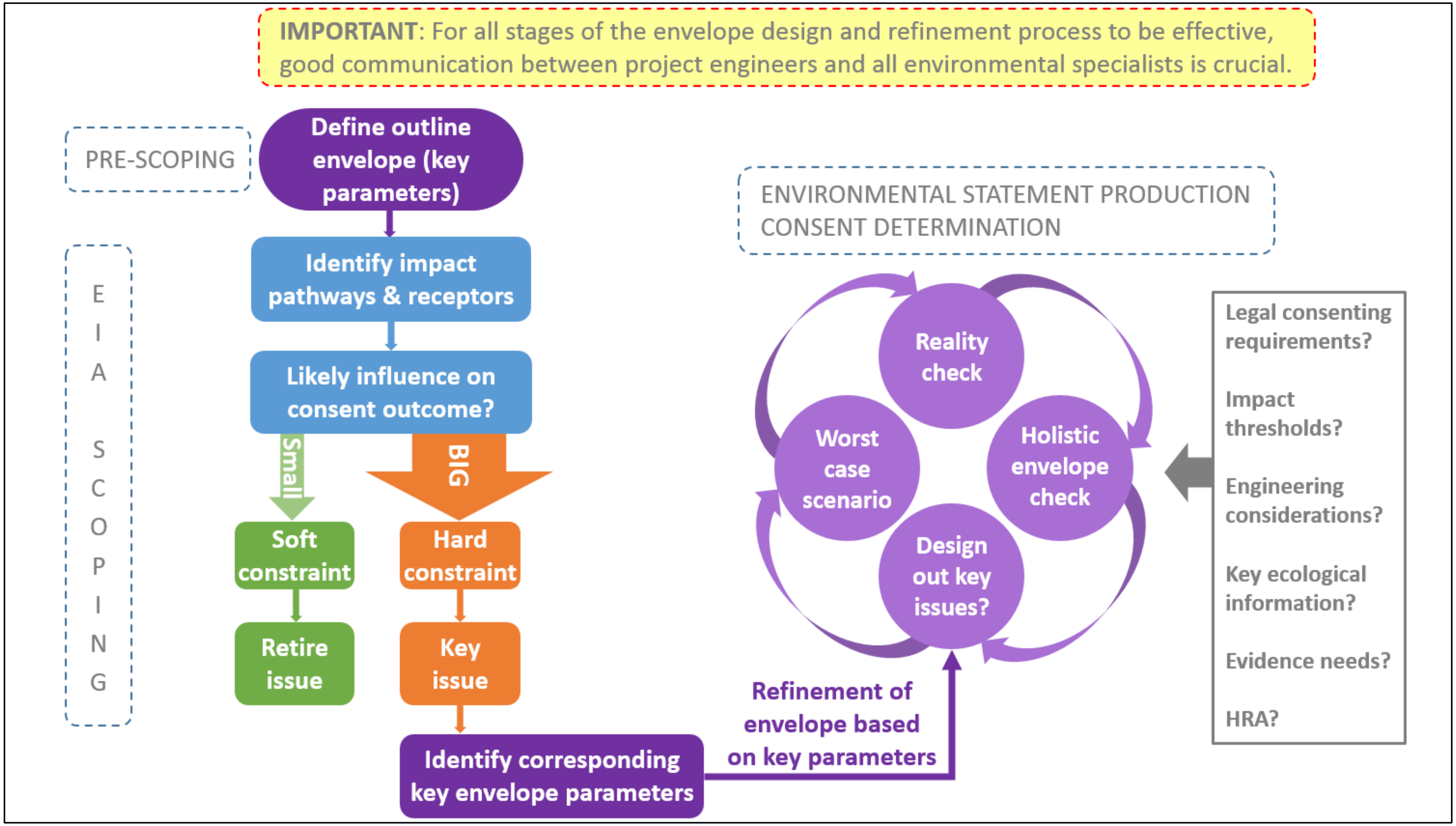

Figure 1a. Summary of guiding principles in relation to the process for the definition and refinement of project design envelopes

Crynodeb Gweithredol

Mae'r adroddiad hwn yn rhoi disgrifiad manwl o set o egwyddorion arweiniol a ddylai lywio'r gwaith o ddatblygu a diffinio Amlenni Dylunio Prosiect (PDEs) ar gyfer safleoedd ynni morol aml-dechnoleg. Mae dull PDE yn ddull cydsynio sy'n caniatáu i gynigydd y prosiect gyflwyno asesiad o effeithiau mwyaf posibl ystod o baramedrau dylunio o fewn ei gymhwysiad. Mae angen hyn yn aml oherwydd, ar adeg y cais am gydsyniad, nid yw manylion cynllun y prosiect wedi'u cwblhau. Mae hyn yn rhoi'r hyblygrwydd i gynigydd y prosiect i adeiladu nifer o opsiynau dylunio posibl, cyn belled â bod y prosiect yn cael ei adeiladu a'i weithredu o fewn yr ystod o baramedrau a aseswyd.

Mae tair adran i'r adroddiad hwn ar dystiolaeth Cyfoeth Naturiol Cymru:

1. Crynodeb gweithredol gan gynnwys crynodeb o'r egwyddorion arweiniol
2. Adroddiad ymgynghori SMRU: diffinio amlenni dylunio prosiect ar gyfer prosiectau ynni morol
3. Ymgynghoriad SMRU Atodiad un: adolygiad manwl ac astudiaeth achos

Mae'r egwyddorion arweiniol ar gyfer dylunio amlenni dylunio prosiect (PDE) wedi'u crynhoi o dan y penawdau canlynol ac fe'u cyflwynir yn weledol yn Ffigur 1a:

1. PDEs a chyfundrefnau cydsynio a rheoli: sy'n amlygu'r agweddau ar y broses gyfreithiol sy'n pennu datblygiad cynlluniau datblygu'r gyfraith.
2. PDEs ac asesiadau amgylcheddol: sy'n amlygu pwysigrwydd nodi'r materion amgylcheddol mwyaf arwyddocaol tebygol a'u dylanwad ar gydsynio.
3. PDEs ac asesiadau o’r achosion gwaethaf posibl: amlinellu'r ystyriaethau amgylcheddol allweddol ar gyfer y senarios gwaethaf a thrafod sut y gall sawl achos gwaethaf greu asesiadau afrealistig a phwysleisio'r angen am asesiad cyfannol ar draws ystod o dderbynyddion a llwybrau effaith. Mae hyn hefyd yn amlygu'r angen am ymgysylltu manwl a chynnar rhwng cynllun peirianneg prosiectau a'r tîm cydsynio amgylcheddol fel bod y ddau barti yn deall yn llawn y cyfyngiadau y mae pob un ohonynt yn gweithio oddi tanynt.
4. Tystiolaeth sydd ei hangen ar gyfer y diffiniad o PDEs – dylai’r PDEs fod yn seiliedig ar sylfaen dystiolaeth gadarn ar lwybrau effaith a derbynyddion sensitif er mwyn osgoi achosion gwaethaf PDEs sy’n rhy ragofalus. Mae hyn yn amlygu'r angen am fecanweithiau effeithlon i sicrhau bod canfyddiadau monitro yn cael eu lledaenu'n gyflym ac yn eang.

Dyma'r tri phwynt allweddol sydd wedi cael eu nodi fel rhai hollbwysig i'r broses.

1. Cyfathrebu rhwng arbenigwyr ym maes peirianneg ac amgylcheddol

2. Nodi materion allweddol yn gynnar (derbynyddion amgylcheddol a llwybrau effaith)

3. Dylai'r broses o gasglu tystiolaeth cyn ymgeisio ganolbwyntio ar faterion allweddol.

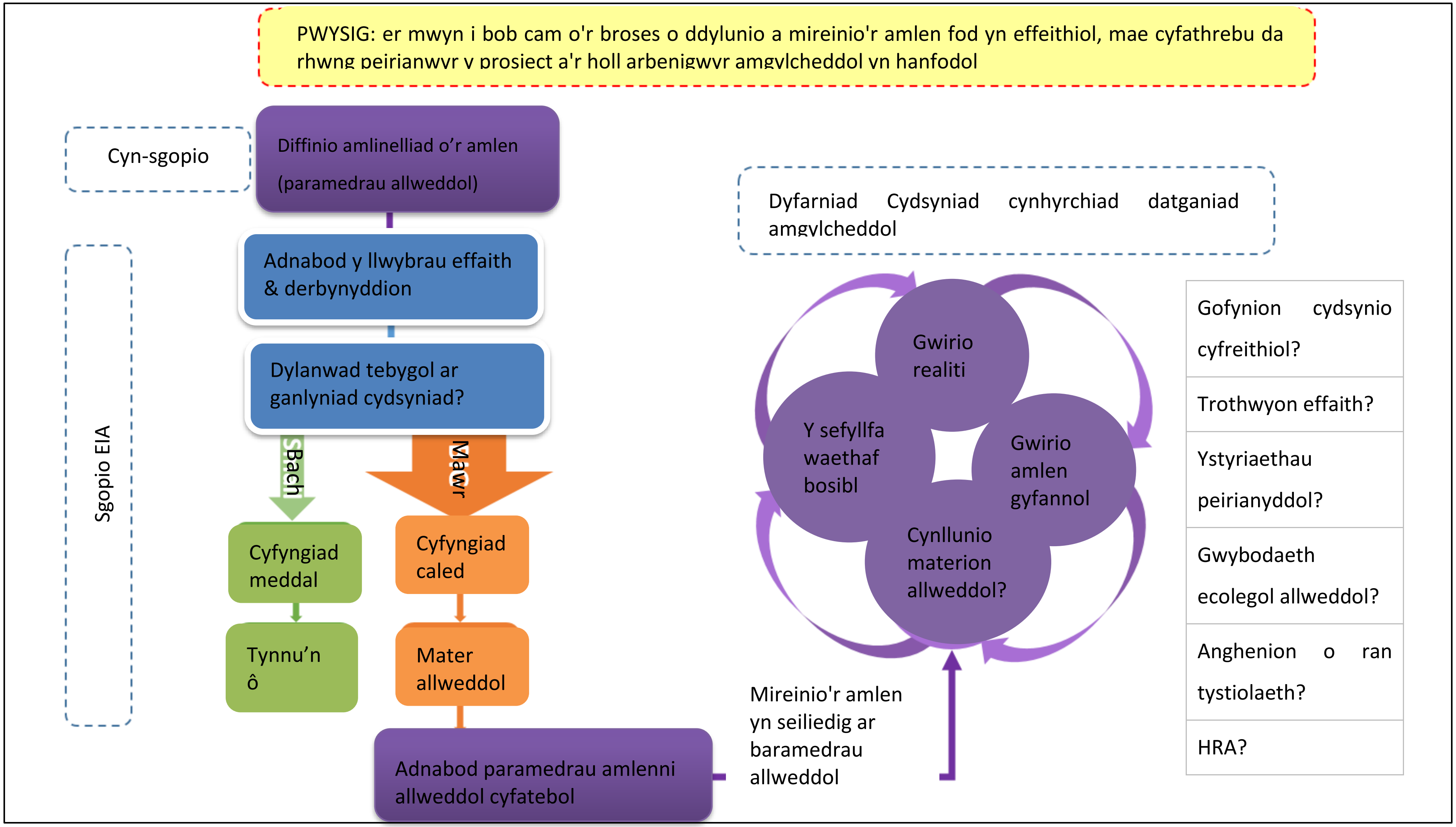

Figure 2a. . Crynodeb o'r egwyddorion arweiniol mewn perthynas â'r broses ar gyfer diffinio a mireinio amlenni dylunio prosiectau

Defining project envelopes for marine energy projects: Review and Tidal energy test facility and marine mammals case study

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Rev.	Date.	Reason for Issue.	Prep.	Chk.	Apr.	Client
1.0	01/06/2016	Draft interim report issued to project steering group for review and input	CES	RP	CES	KS
2.0	10/7/2017	New version revised as generic case study	CES	RP	CES	KS
2.1	23/11/2017	Revised in response to KS comments and addition of KS guiding principles	CES			
2.2	13/12/2017	Revisions by KS	KS			
3.0	15/12/2017	Restructuring by CES and small revisions of text	CES			
4	25/07/2018	Final version	CES		CES	
4.1	10/08/2018	Final version with infographic	CES		CES/KS	
4.2	13/02/2019	Final version with cover sheets	CES		CES/KS	

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1 Executive Summary

This report provides a detailed description of a set of guiding principles that should inform the development and definition of Project Design Envelopes (PDEs) for multiple technology marine energy sites. A PDE approach is a consenting approach that allows a project proponent to submit an assessment of the potential maximum impacts of a range of design parameters within its application. This is often required because at the time of consent application, the details of project design are not finalised. This allows the project proponent with the flexibility to build out a number of potential design options, as long as the project is constructed and operated within the range of parameters assessed.

The introductory sections of the report provide an overview of the background to the project and explain how this work was built upon a workshop held in 2015 and explains how a case study approach has been used to illustrate the guiding principles. The case study chosen was the development of a PDE for a marine energy test site, focusing on marine mammals as the key receptors.

The following section provides detail on each of the proposed guiding principles and highlights the elements of the case study that illustrate each of them. The guiding principles are summarised under the following headings:

1. Project Envelopes and consenting and management regimes: highlighting the aspects of the legal process that dictate the development of PDEs.
2. Project Envelopes and environmental assessments: highlighting the importance of identifying the likely most significant environmental issues and their influence on consenting.
3. Project Envelopes and worst case assessments: outlining the key environmental considerations for worst case scenarios and discussing how multiple worst cases can create unrealistic PDEs and highlighting the need for holistic assessment across a range of receptors and impact pathways. This also highlights the need for considerable detailed and early engagement between project engineering design and the environmental consenting team so that both parties fully understand the constraints each are working under.
4. The evidence needs for the definition of PDEs – this section discusses the fact that PDEs should be based on a robust evidence base on impact pathways and sensitive receptors to avoid overly precautionary worst case PDEs. This also highlights the need for efficient mechanisms to ensure monitoring findings are disseminated quickly and widely.

The report concludes with a call for a solutions based approach to the definition of PDEs, integrating engineering and environmental considerations alongside early identification of key impact pathways and sensitive receptors.

Annex One of the report provides a detailed review of previous approaches to the definition of broad PDEs across a range of projects, from multiple single device test centres such as EMEC and PTEC to multiple technology and technology neutral commercial development sites. The Annex also provides a detailed hypothetical example PDE definition for a hypothetical test demonstration site in Welsh waters, focussing on the considerations required for the assessment of impacts to marine mammals.

2 Introduction

2.1 Background to the project

Developers of offshore energy schemes and other marine developments commonly use Project Design Envelopes (PDE) to retain a broad but clearly defined envelope, allowing a flexible approach to be retained to various elements of project design within its parameters, while still enabling an appropriately precautionary assessment to be made. This approach has been used in applications for offshore energy projects, where finalising certain details prior to consent, such as device foundation type, technical device parameters, or installation methods, would be financially or technically unviable. By accounting for these unconfirmed elements of the project within a wider defined PDE, the application (and corresponding licence), allows flexibility to accommodate future developments and different technical parameters.

Broadly defined PDEs have been used by managers of marine energy test facilities such as the European Marine Energy Centre (EMEC) in Orkney, Wave Hub in Cornwall and the Perpetuus Tidal Energy Centre (PTEC) on the Isle of Wight. In these examples, a PDE approach has been used to facilitate overarching, site-wide licences, which provide for the deployment of multiple technologies, so reducing or removing the responsibility for the licensing process from individual technology developers. This approach is also being considered by managers of wave and tidal stream demonstration zones and test sites in Wales. Rather than define, at the point of licence application, the exact nature and type of marine energy devices which will be deployed within the zones, a series of broad 'realistic worst case scenario' parameters might define the range of likely activities and technology types.

Retaining flexibility for the final project design is an important part of the rationale for the use of a broad PDE. As well as the need to cover a range of defined technologies, a broad envelope can also attempt to cover likely future technology developments to ensure that consents awarded are not out of date (recognising that there is likely to be a gap of several years between the assessment and the time of final design and construction). Keeping multiple technology types within the envelope, allows the project developer to undertake competitive tendering for the project post consent and prior to construction.

Elements of a broad design envelope approach have been taken in offshore wind farm consenting for many years – for example, for assessment of the bird receptor/collision impact pathway a range of rotor diameter and tip heights will often be assessed to cover the range of potential turbine types. Similarly, a number of foundation installation techniques may be considered and assessed. This allows for 'future-proofing' of consents and allows for flexibility in future commercial decisions and for making decisions at a later stage based, for example on site conditions and evolving technology.

The assessment of a broad PDE can be challenging for tidal projects in the marine environment given the sparsity of information on the distribution of sensitive receptors and the lack of information about their sensitivities or vulnerabilities to impacts. There is limited information to inform predictions of potential impact in relation to key features of project design. PDEs must define key project features and parameters sufficiently well to enable the robust Environmental Impact Assessments (EIAs) which underpin licencing processes. If this approach is taken by managers of wave and tidal stream demonstration zones and test sites, balancing their need to retain the flexibility to accommodate a range of technologies with the need to define anticipated activities sufficiently well to meet the requirements of environmental legislation and the associated EIA processes will be a key challenge. Furthermore, for marine energy projects which often involve novel technologies, the uncertainty about the nature and significance of impact pathways presents an additional challenge in defining a PDE which is fit for purpose.

The challenges and opportunities presented by the use of PDEs for wave and tidal stream demonstration zones for which leases were issued in 2014 by The Crown Estate were discussed at a workshop in Cardiff in July 2015. The aim was to bring together parties with an interest in the wave and tidal stream sectors to discuss and share ideas about key practical consenting and research issues relevant to demonstration zones and test sites.

The workshop outputs (The Crown Estate 2015) identify principles of good practice and initial guidance to be used as a framework for developing detailed guidance for the industry on key issues. A number of recommendations and good practice principles relating to defining PDEs were identified. Those most relevant to this study are discussed in detail in Section 2.3, whilst some overall key points have been extracted below:

i. The use of a PDE which clearly distinguishes information relevant to different technologies and different project components allows flexibility to accommodate future developments and different technical parameters.
ii. The consenting authority(ies)[1] must be able to meet the requirements of the EIA Regulations in considering the significant effects of the proposed development including the impacts of changing technologies.
iii. The more clearly defined the PDE is, the easier it will be to consider whether significant effects of likely types of future development have been defined. This presents a challenge when technology is evolving rapidly and when detail at the time of application may change in the future. It will be important to focus on those issues which are potentially significant including the potential for cumulative effects.
iv. The PDE needs to balance being broad enough to accommodate technology unknowns with being sufficiently well-defined to enable an assessment of impacts including cumulative effects.
v. Defining a 'realistic worst case' PDE for each parameter may not be a realistic overall PDE. The envelope in itself may become restrictive to development by introducing a range of parameters which are too demanding to be helpful in consenting. Understanding and defining a realistic envelope is more helpful and allows mitigation to better be defined which is practical and deliverable.

[1] In the case of demonstration zones in Welsh waters with a maximum generation capacity of <100 MW, the consenting authorities, will be the Marine Management Organisation for Electricity Act Section 36 licences and Natural Resources Wales Marine Licensing Team for Marine Licences. The Wales Act 2017 provides Welsh Ministers with powers to consent energy generating stations up to 350 MW. These powers will come into force in April 2019 with Welsh Government administering Section 36 consents.

vi. A realistic PDE should make best use of existing information, remove uncertainty in an application whilst maintaining some flexibility. Clear parameters need to be defined within which development can evolve and be built out.

vii. A PDE should best be defined based on likely significant impacts from the development on key receptors. The understanding of the sensitivity of those receptors to the likely technology variations and various options for technical parameters needs to be understood and can be built up through an iterative process which will allow the PDE to become increasingly well defined.

viii. The focus in defining the PDE should be on likely interactions between the project and the receptor and not on the sensitivity of the receptor itself. This approach allows focus in defining the envelope on key issues and can reduce the potential for over complication. There is no need for an envelope approach for parameters where the potential for interactions and residual effects is not significant.

ix. A commitment to future monitoring measures should not be used to avoid work that is required to inform the PDE and an adequate assessment of its significant effects. The usefulness of future adaptive management measures is acknowledged but these in themselves need to be carefully defined and used robustly.

The workshop participants agreed that the emerging recommendations and principles of good practice need to be further developed and explored before guidance can be produced and agreed. No firm mechanisms were identified for progressing the issues, though various suggestions were made, as detailed in the workshop report.

As a response to the findings of the workshop and to progress thinking on this issue, Natural Resources Wales (NRW) commissioned this piece of work to undertake a detailed exploration of issues relating to flexible Project Design Envelopes and identify recommendations and principles for future good practice. This report presents the findings of an in-depth desk-based review of approaches that offshore energy projects have taken to date and goes on to use a hypothetical case study to enable a detailed and thorough exploration of issues. Focussing on a case study enables a detailed exploration of some of the specific environmental issues, challenges and opportunities associated with defining PDEs for marine projects. This includes identifying the key sensitive receptors and impact pathways of which the PDE must take account, as well as how to consider and incorporate existing data and evidence.

This report presents recommendations and principles on how key environmental issues can be incorporated into PDEs, whilst considering other important technical, economic and practical factors. The principles and recommendations that the review and case study have identified are presented in the main body of the report, whilst the supporting review and case study are provided as a Technical Annex. At the end of each relevant section of the Technical Annex, 'Principles boxes' are used to highlight the key principles or recommendations identified. There is some repetition of principles between the review and case study sections of the Technical Annex, where the case study provides clarification or illustration of what might otherwise be quite hypothetical principles. It is anticipated that the outputs of this report will have wider application to developing PDEs for marine projects in general and will inform the development of NRW's advice and guidance on this issue.

2.2 Case study approach

A hypothetical multiple technology tidal stream energy test facility in Wales, situated off the coast of Anglesey, provides the contemporary case study for this work which will enable an exploration of the complex issues surrounding defining a PDE. The chosen proposed location of this hypothetical scheme was driven purely by the availability of data for this area through a number of characterisation studies. It is important to note that this project does not intend to define a PDE for any proposed tidal energy scheme but that a case study approach has been adopted to identify principles that should be applied in such a definition.

The intention is that focussing on one key receptor group (marine mammals) for the purposes of the case study will enable a thorough exploration of associated issues, including data requirements and the role of existing evidence and options for incorporating mitigation and adaptive management within the PDE itself. It is anticipated that the use of a focussed case study will allow for the detailed consideration required, whilst also identifying and resolving issues more generally for defining PDEs, thus identifying some overarching principles which might apply to other marine activities and receptors.

This work draws upon existing marine mammal information available for the Anglesey area, including information held by NRW and detailed in Baines and Evans (2012). It considers the data requirements for developing robust but flexible PDEs, using a risk-based approach to identify key receptors and impact pathways (building on principles within Sparling et al. (2016).

It is anticipated that this project will help inform the ongoing process of defining the PDE for marine energy projects, by exploring how the envelope can best take account of key environmental issues and concerns and ultimately reduce consenting risk for schemes. Marine energy schemes are under no obligation to apply the principles and approaches outlined within this project to the development of their own PDE, although NRW may decide to use this report as the basis for producing guidance in the future.

The following organisations and individuals were involved in the development of this work:

Table 2.1 Organisations and individuals involved in the development of this work.

Project partner	Named contact	Role and input
NRW advisory	Kate Smith	Overall contract management and co-author of report
NRW Permitting Service, Marine Licensing Team	Jasmine Sharp	Input regulator's perspective (consenting process, regulatory requirements, etc.).
Morlais (and team)	James Orme, with support from Consultants	Input commercial and practical perspective as developers of a tidal demonstration zone (discussion of initial relevant PDE parameters, required flexibility, acceptable mitigation and adaptive management).
SEACAMS, Bangor University	Gemma Veneruso	Expert input on marine mammal local knowledge.
SMRU Consulting	Carol Sparling	Contractor responsible for delivery of the report.

2.3 Guiding Principles and challenges

The potential for impacts to marine mammals is a key area of focus in the consenting of tidal energy projects (Copping et al. 2016, ORJIP Ocean Energy 2016) and often forms the basis of post consent monitoring and mitigation requirements. Therefore, focussing on consenting from a purely marine mammal perspective will enable a thorough exploration of some of the main issues of flexible PDEs, including data requirements and the role of existing evidence and options for incorporating mitigation and adaptive management within the PDE itself. In relation to the general principles identified in the UK demonstration zones workshop in 2015 and outlined in Section 2.3, the key challenges that require addressing in relation to marine mammals are considered further below.

- A clear definition of PDE – the more clearly defined the PDE is, the easier it will be to consider likely significant effects. This presents a challenge when technology is evolving rapidly and when detail at the time of application may change in the future. Particularly where detailed site investigations that would inform aspects of project design and site layout, may not have been carried out pre-application.

- The worst case PDE may not be a realistic PDE – this is a problem particularly for very broad PDEs which retain full flexibility to deploy a wide range of technology types, and where there is a wide variation in the potential for impact between technology types. The whole envelope may need to be defined on a multiplication of the realistic worst cases for different aspects of the development or for different impact pathways and receptors, creating risks for consent. This will be particularly important for projects where there is uncertainty around the potential for lethal impacts to declining or vulnerable populations. An example of where this is currently an issue is the north of Scotland where uncertainty around collision risk from tidal energy projects and potential impacts on the declining harbour seal population could severely constrain the development of the tidal energy industry in the region. This also presents a challenge when the relationship between the PDE features and risk differs across receptors, or even with the same receptor for different impact pathways. Throughout the EIA process there will be a need to consider various potential worst case scenarios for different impact pathway/receptor combinations – for example the relationship between rotor depth and collision risk may be very different between birds, fish and marine mammals. Or there may be differences in the worst case for different impact pathways for the same receptor, for example the worst case scenario for underwater noise in terms of creating maximum disturbance would actually serve to reduce collision risk by ensuring devices are detectable and can be avoided. Multiple design scenarios may need to be considered for a full assessment and these may be contradictory. Discussion and agreement between project developers (and their advisers/consultants) and regulators and their advisers on a case by case basis will likely be required to agree on how the worst case scenario should be defined.

- The PDE needs to balance being broad enough to accommodate technology unknowns with being sufficiently well-defined to enable an assessment of impacts including cumulative effects. Here a key consideration is how to deal with uncertainties relating to the magnitude and severity of impact – defining data collection needs or an adaptive management and monitoring framework.

- A PDE should best be defined based on likely significant impacts from the development on key receptors. This requires key receptors to be identified at an early stage in the process. The understanding of the sensitivity of those receptors to the likely technology variations and various options for technical parameters needs to be understood and can be built up through an iterative process which will allow the PDE to become increasingly better defined. Key to this is developing an understanding of relationships between PDE features and impact for key receptors and pathways. This is considered in detail in Section 2 of Annex One.

- A commitment to post-consent monitoring to inform adaptive management in relation to key uncertainties should not be used to entirely avoid work to inform the project design envelope and an assessment of its significant effects. The usefulness of monitoring-led adaptive management measures are acknowledged but these in themselves need to be carefully defined and used robustly. The requirement for pre-consent survey or monitoring needs to be balanced against an assessment of how likely it is that additional work will remove uncertainty and inform an assessment of PDE effects. If a monitoring-led adaptive management approach is taken to consenting demonstration zones and test sites as a way of retaining flexibility in the PDE, this commitment to post-consent monitoring may deter potential customers. Conversely, it is likely that any post-consent monitoring will be ultimately of benefit to customers in their own plans to scale up at commercial sites elsewhere.

3 Guiding Principles

This section summarises the outcomes developed across the review and case study into a series of guiding principles, grouped under the following headings:

3.1 Project Envelopes and consenting and management regimes
3.2 Project Envelopes and environmental assessments
3.3 Project Envelope worst-case scenarios
3.4 Evidence needs for Project Envelopes
3.5 Priority drivers for defining the Project Envelope
3.6 A solutions-based approach to Project Envelopes

3.1 Project Envelopes and consenting and management regimes

i. Legal responsibilities of consenting authority(ies)

The consenting authority(ies) must be able to meet their legislative responsibilities in considering the significant effects of a proposed development, as required by the consent determination process. It is therefore important to understand the legal requirements of consenting and governance regimes for the proposed activity(ies) at an early stage in defining the project envelope. This includes consideration of how to complete a Habitats Regulations Assessment to fulfil the requirements of the Habitats Directive (see Principle 6.2 for further details).

ii. Flexibility within the consenting regime

It is important to understand whether the consenting regime allows for an iterative process of refinement of the design envelope as the environmental assessments underpinning consenting progress, or for post-consent project envelope refinement. For example, consent conditions requiring certain elements of the project and associated Construction and/or Operational Management Plans to be agreed and signed off prior to deployment, could enable final refinement of the project envelope and management of residual impacts which are realistic and based on the worst case parameters and best available evidence. This approach is already commonly used within consenting processes to manage certain elements of projects, for example, for post consent refinement of construction methodologies and management of their likely impacts. To apply it more widely to consenting processes for marine developments would require a degree of mutual commitment from the regulator and developer, as well as confidence that the approach is legally robust and can be adequately resourced by all parties.

iii. Discharge of consent conditions

The legal responsibility and governance regime for the discharge of consent conditions of relevance to the project envelope need to be understood. This is particularly pertinent for test facilities operated and managed by a third party, within which activities take place under a sub-letting arrangement and may be fully or partially pre-consented. The consenting and governance arrangements for such activities could have implications for the degree of refinement required, or possible, within the project envelope.

Project specific marine licence applications for activities within a partially 'pre-consented' site might allow iterative refinement of the project envelope and the associated environmental impacts to be considered and managed post-consent through the governance regime for activity sub-letting. As described in Section 6.1, this is the case at the EMEC test centre whereby there is a site-wide licence which was based on an envelope of known turbine types at the time of the application. Only developers wishing to deploy at EMEC whose devices lie outside of that envelope need to supply further information to support additional environmental appraisal work.

3.2 Project Envelopes and environmental assessments

i. Identifying significant environmental issues (receptors and impact pathways)

The development of the project envelope should be informed by early identification of the key likely impacts of the project on receptors, to ensure it is based on an understanding of environmental risks. Ideally, these key environmental risks should be agreed between the developer, regulator and key stakeholders.

Identifying key receptors (e.g. important or protected species, habitats and landscapes) and impact pathways or stressors (e.g. disturbance, physical loss, collision risk) will help identify the significant environmental issues on which the refinement of the project envelope should focus. The earlier this is done in the process, the easier it will be to ensure the envelope has accounted for key environmental constraints and, where possible, designed out elements which may present a risk or challenge to consenting. Without identifying key receptors and impact pathways, defining worst-case scenarios will be challenging and may lead to an overly complicated or precautionary approach to EIA and HRA. The review and case study illustrate that for marine mammals, collision risk is likely to be a significant driver of project envelope definition.

ii. Understanding the influence of environmental issues on consenting

Broadly establishing the influence that the key, or significant, environmental issues (receptors and impact pathways) are likely to exert on consenting will help determine how important it is that they are considered within the Project Envelope at an early stage.

Undertaking an assessment of key sensitive receptors and impacts pathways and their likely importance for the project envelope has several component stages, as follow;

a. Identifying connectivity of important or protected species, sites and their features with the project. Initial consideration of connectivity could draw on outputs from strategic planning processes (The Crown Estate's seabed leasing and corresponding environmental assessment processes), or tools such as IMPACT[2].
b. Identifying the legislative requirements relating to the protection of these sensitive receptors and relevant evidence or information, including;
c. Identifying information of relevance to those sensitive receptors, including Conservation Objectives.
d. Identifying the key impact pathways (and the corresponding receptors) that are likely to be the primary drivers of consent.

It is important to consider each of these stages in identifying the key receptors and impact pathways on which the refinement of the project envelope should focus. Ideally, these key sensitive receptors and impact pathways should be agreed between the developer and regulator, providing a mutually agreed basis on which to build the EIA and project envelope refinement process.

iii. Non-significant environmental issues

Equally important as identifying significant issues (impact pathways and receptors), is identifying (and agreeing) those receptors and impact pathways which are unlikely to have a significant influence on consent determination or conditions. This will enable the refinement of the project envelope to focus on those environmental issues likely to exert a significant material influence on the outcome of EIA and / or HRA and consent determination, and so on which the refinement of the envelope should focus. There should be no need for the project envelope definition to focus on defining very detailed parameters where the potential for interactions and residual environmental effects is not significant. An example for this from the review in Section 3 of Annex One is the PTEC site where a low occurrence of marine mammals meant that many of the detailed parameters of the design envelope pertaining

[2] IMPACT assessment tool, online: http://www.marine-impact.co.uk/assessment-tool.asp?cat=2

to issues such as collision risk and disturbance to marine mammals, did not have to be particularly refined and a number of precautionary assumptions were able to be adopted.

iv. Parameters of the project envelope most likely to influence key impacts

Once a project envelope has been partially defined and sensitive receptors and impact pathways identified, those parameters most likely to influence the magnitude of impacts identified as potentially significant should be identified. This is an important stage, as it highlights those issues or parameters of the PDE most likely exert a material influence on consent determination and conditions.

Parameters of the project envelope where variability is either likely to be limited, or less likely to influence the magnitude of impacts should also be identified. For these parameters, a simpler, semi-quantitative approach to the assessment of their environmental impacts might be sufficient.

v. Thresholds for acceptable environmental impacts

For some sensitive receptors, it may be possible to draw on conservation or management objectives and supporting evidence to identify thresholds or limits of acceptable impact. For example, for populations of protected species, Population Viability Analysis techniques and tools could be used to identify levels of disturbance or mortality likely to result in population level effects or consequences. In these instances, it might be possible to 'reverse engineer' the project envelope to 'design out' the magnitude of likely impact which would exceed the specified threshold. This approach would require early agreement from all parties on the thresholds and an agreement about how uncertainty in the quantitative predictions of impacts will be dealt with.

vi. Project Envelopes and Environmental Impact Assessment scoping

Recent amendments to the Environmental Impact Assessment Regulations in England and Wales place a greater emphasis on EIA screening/scoping as the stage(s) at which significant issues should be identified to focus subsequent effort. EIA scoping should be used intelligently to identity the key likely environmental impacts and sensitive receptors and elements and parameters of the design envelope most likely to influence the magnitude of the significant impacts of the project. Aligning project envelope refinement with EIA scoping would enable a greater focus on key issues and subsequent 'retirement' of non-significant issues, so reducing the potential for over-complication within assessment processes.

iv. Project Envelopes and Habitats Regulations Assessments

If the project is likely to affect the features of any European Protected Sites, regulator(s) will need to undertake Habitats Regulations Assessments of projects to fulfil the requirements of the Habitats Directive. These assessments will need to consider the 'realistic impacts' of the project, based on the Project Envelope. The tests required of HRAs are generally much more stringent than those for EIA, and so some additional post-submission refinement of the project envelope may be required, if a regulator's HRA is not able to conclude there will be 'no adverse effect on site integrity'.

3.3 Project Envelope worst-case scenarios

i. Key environmental considerations for worst-case scenarios

The project envelope approach can lead to multiple 'worst-case scenarios' against which to assess the impacts of projects. However, identifying significant environmental receptors and key impact pathways, along with their likely influence on consenting should reduce the potential for over-complication in assessments. For example, if an impact on a specific receptor is likely to be a key influence in consent determination including conditions, tightly defined worst-case scenarios are likely to be required. Conversely, for non-significant issues, there should be no need to define worst-case scenarios.

ii. Realistic vs absolute worst-case scenarios

Worst-case scenarios should be realistic and not absolute. They should achieve balance between precaution and pragmatism about what is technically or practically feasible or likely, and reflect the likely risk that the project or elements of it might cause in unacceptable impacts.

iii. Technical feasibility of worst-case scenarios

Feedback loops should be built into the refinement of the project envelope to ensure that the envelope parameters and worst-case scenarios are realistic and feasible from a technical, engineering and logistical perspective. Early and frequent engagement between consent specialists (across the range of receptors) and engineering and project management specialists is encouraged to ensure regular dialogue and a developing understanding of the primary constraints.

iv. Holistic assessment of worst-case scenarios

The relationship between impact pathways, envelope parameters and worst-case scenarios should be considered. Alterations to parameters of the project envelope might influence more than one worst-case scenario. An example of this is where choosing a different technology with rotors at a different depth may decrease the risk of collision for one receptor, but may increase the risk of collision for another receptor with a different depth distribution. Checks and feedback loops should be built into the envelope refinement process to enable holistic assessment across all elements of the project envelope to avoid inadvertently increasing the impact magnitude for one receptor by decreasing another. As above, early and regular communication between different specialists involved in the development of the project is strongly encouraged.

3.4 Evidence needs for Project Envelopes

i. Use of best available evidence

Project Envelopes and their definition should be based on the best available evidence about impact pathways and sensitive receptors to avoid overly precautionary or unrealistic worst-case scenarios and assessments. Where the evidence required to fully understand the links between project design features and likelihood and magnitude of impact is lacking, this should be highlighted and wider industry efforts should seek to collectively reduce these uncertainties. An example of this is where recent work at the Sea Mammal Research Unit is providing an evidence base for the link between rotor speed and the probability of mortality (Thompson et al. 2016), thus enabling a greater understanding of how a key project design parameter influences risk of impacts.

Mechanisms for ensuring that monitoring findings are disseminated quickly and widely, including through the use of licence conditions, should be encouraged. Initiatives such as the Tethys database and the ORJIP Ocean Energy Forward Look should continue to be utilised to facilitate feedback from learning into assessments.

ii. Pre-consent site or risk characterisation surveys

Any pre-application surveys or evidence gathering activities should focus on the key impact pathways and receptors, to best inform the iterative process of defining and refining the project envelope. This might include baseline information on key receptors, but also data and evidence to help contextualise the assessment of worst-case scenarios for elements of the envelope. For example, data on ambient noise is likely to be a significant consideration in the assessment of any worst-case scenario for noise-related impacts associated with a project envelope. Similarly, information on the functional importance of an area for marine mammals would be a significant consideration in the assessment of any worst-case scenario for disturbance-related impacts. In the absence of information on these factors, worst case assumptions would need to be made regarding the potential consequences of impact. It should be considered whether an assessment based on these assumptions would meet the needs of the consent. As such, proposed pre-consent survey or monitoring activities should be evaluated not only against the likelihood that they will remove uncertainty from assessments of likely impacts, but also the likelihood that they will help inform the refinement of the project envelope.

The greater the understanding about sensitive receptors likely to be affected by the project, the more flexibility it might be possible to retain for certain elements of the envelope. However, there is a risk that gathering expensive data or undertaking complex modelling will not lead to any reduction in uncertainty about impacts, or greater envelope flexibility, such that a precautionary approach based on limited data might be the most cost effective or preferred approach.

iii. Project envelopes and evidence plans

There could be value in projects developing formal 'evidence plans', replicating some elements of the Evidence Plan process for Nationally Important Infrastructure Projects, to agree up front what information is needed to support project consent applications, including the definition and refinement of the project envelope.

iv. Project Envelopes and uncertainty in the evidence base

It is important to be clear about any assumptions within the project envelope, where there is uncertainty or a gap in the evidence base. All parties should agree these assumptions at an early stage. The regulator must be provided with sufficient information about evidence gaps and assumptions to undertake a risk assessment. Some assumptions relating to defining the project envelope or worst-case scenarios might have limited material influence on the outcome of the EIA and consent determination, while others might be key determining factors.

It is important to understand the implications of limited evidence and the degree of precaution likely to be applied within consent determination and supporting assessment processes, including the definition of worst-case scenarios. This is especially important if the applicant has a desire to retain flexibility in elements of the project envelope around which there is a lot of uncertainty or complexity about likely impacts. **This highlights the importance of refining the understanding of impact pathways and sensitive receptors, to identify those key drivers for refining the project envelope, as well as evidence which might help refine the envelope or worst-case scenarios, so reducing the need for precaution**.

3.5 Priority drivers for defining the Project Envelope

i. Refinement vs flexibility

The more refined and tightly defined the project envelope, the more it should be possible to reduce complexity in EIA and HRA and consider whether the significant effects of likely development scenarios have been defined. Balanced against this will be the likely desire of the applicant to retain flexibility to maximise the commercial viability or future options for of the project, or elements of it. If the priority driver for the project envelope is to maintain flexibility and retain technical or engineering options for project parameters, assessing the environmental effects (including the cumulative) of the project will be challenging.

The applicant should decide whether refinement of the project envelope and an 'easier' route to consent, or greater flexibility in project parameters is their priority. This decision should be made with an awareness for its likely implications for consenting. This decision can apply to the entire project envelope, as well as to individual elements or parameters of it, if some are key.

ii. The influence of environmental considerations

A decision should be made about the importance placed on the influence of environmental issues on the definition of the project envelope. A project envelope which has fully considered environmental issues and 'designed out' significant impacts is more likely to have an 'easier' route to consent than one which has been driven primarily by engineering, cost and technical considerations. The consequences of not considering environmental issues and likely constraints when refining the envelope will probably be a more challenging consenting process and more restrictive mitigation requirements and operational restrictions. Such decisions about the importance placed on the influence of environmental issues on the definition of their project envelope would be usefully informed by an early identification of key environmental receptors and impact pathways, and a subsequent early review of the project design options in light of these. An example of this was at EMEC when the environmental appraisal for the site was largely based around the concern for the potential for collision, with an envelope defined that did not represent an absolute worst case across all available turbine types.

iii. Hard and soft constraints

Any hard constraints or elements of the project envelope for which there is limited, or no flexibility should be identified as early as possible. Similarly, any elements of the project envelope which can be more tightly defined should be. Those 'softer' constraints, for which some degree of flexibility is desirable or possible should also be identified. This distinction is important in identifying and understanding those project parameters for which an envelope approach is appropriate.

This distinction between hard and soft constraints could be undertaken from an engineering or an environmental perspective. If from an engineering perspective, it might be possible early in the project envelope definition process, since they may be 'non-negotiable' elements of the envelope. If done from an environmental perspective, it would need to be informed by an identification of 'significant' issue, to understand those most likely to exert a material influence on consent determination processes and conditions.

An example of a hard constraint from a project perspective might be water depth for micro-siting within a wider defined project area, or foundation type for offshore structures. An example of a hard constraint from an environmental perspective might be a small population of a highly protected species with the potential to interact with the project, or the occurrence of a highly protected and valued seabed habitat within the proposed development site.

In the case of managed test facilities, it is important to understand the distinction between hard and soft constraints at the overall 'project' or site level and at the individual technology or developer level. This needs to be understood in the context of the governance and consenting regime for such facilities.

3.6 A solutions-based approach to Project Envelopes

i. Integrating engineering and ecological/environmental considerations

Integrating engineering and environmental considerations when defining and refining the project envelope will have the following significant benefits;

a. It will facilitate a solutions-based approach to defining the project envelope - i.e. designing or engineering out significant environmental issues from the envelope and identifying where there are technical or engineering options to optimise the management of environmental risk.

b. It will help provide clarity and inform decisions about when environmental factors are the primary consideration for defining the project envelope and when engineering or technical factors are key and help balance the two.

c. It will ensure that worst case scenarios defined by environmental constraints are technically feasible, realistic and commercially viable.

This highlights the importance of establishing mechanisms to ensure good communication between topic specialists/EIA chapter leads and project engineers. This allows the whole team to develop a good understanding of the key risks and constraints from an engineering and environmental perspective and facilitates a solutions-based approach to defining and refining the project envelope.

ii. Designing out significant environmental issues

Integrating engineering and environmental considerations when defining and refining the project envelope could allow significant environmental issues to be reduced or removed. This might include identifying engineering or design solutions to remove issues entirely, or identifying where there are opportunities to optimise the management of environmental risk through technical or engineering solutions. To take this approach would require an understanding of the key sensitive receptors and impact pathways. It would also require the refinement of the project envelope to be an iterative process which integrates environmental and engineering considerations to resolve issues.

It won't always be possible to partially or entirely design out significant issues from the project envelope. In these cases, decisions about the envelope design could at least be made with an awareness of the likely need for mitigation to address these residual issues, such as operational restrictions or adaptive management.

iii. Project Envelopes and adaptive management

Any project envelope which is going to rely on a post-consent monitoring and adaptive management as an approach to reduce or remove environmental impacts must be deliverable. If a monitoring-led adaptive management approach is preferred by the developer, as a way of retaining flexibility in the project envelope, this commitment to post-consent monitoring may have financial implications for the project and its long-term viability. Care must be taken to ensure that adaptive management is fit for purpose and appropriately defined. Such decisions should be taken with an awareness of the potential implications, including the risk that the regulator may refuse any proposed post-consent adaptive management measures which would result in a non-viable consent.

3.7 Refinement of Project Envelopes

i. Pre-application iteration of the project envelope

Refinement of the project envelope is likely to be an iterative process which takes place during the pre-application stage of a project, alongside the developing EIA and associated evidence and data gathering activities. This iterative process with feedback loops between EIA and project envelope refinement would benefit from being set out and agreed between the developer and regulator(s), perhaps as part of an Evidence Plan type process. This should also help to clarify and formalise the relationship between the refinement of the project envelope, evidence gathering activities to support the EIA and the production of the Environmental Statement.

ii. Post application iteration of the project envelope

Further refinement of the project envelope may be beneficial after formal consent application(s) have been submitted, given that consent determination is itself an iterative process. It is unlikely that regulators would agree to expansion of the project design envelope post-submission, as this could undermine the assessments and conclusions within the Environmental Statement and the EIA process more generally. Narrowing the scope of the project envelope is likely to be acceptable to the regulator but once narrowed, allowing it to later re-expand could present problems to consenting.

iii. Refinement focussed on key environmental issues

For projects where the key impact pathways and receptors most likely to influence the outcome of the consent application are clear, where the requirement for flexibility allows, it could be beneficial to bias the refinement of the project envelope to the best scenario for minimising these impacts, even where this might increase other impacts, which are of lesser significance. This is especially the case where these other impacts are unlikely to exert a material influence on the consent outcome.

3.8 Summary of key Guiding Principles

A summary of the guiding principles and recommendations discussed in the preceding section is provided visually in Figure 3. Three key points have been identified as absolutely critical in the process and are reiterated below.

4. Communication between engineering and environmental specialists

It is essential that mechanisms be established at the earliest possible stage of project development, to enable effective communication between environmental specialists and project engineers. This will allow the whole project team to develop a good understanding for the key risks and constraints from an engineering and an environmental perspective. Equally important is establishing good communication between environmental receptor and topic specialists, to build understanding for the holistic effects of the envelope across all sensitive receptors into the refinement process. Establishing these good communication mechanisms will facilitate a holistic, realistic and solutions-based approach to defining and refining the project envelope.

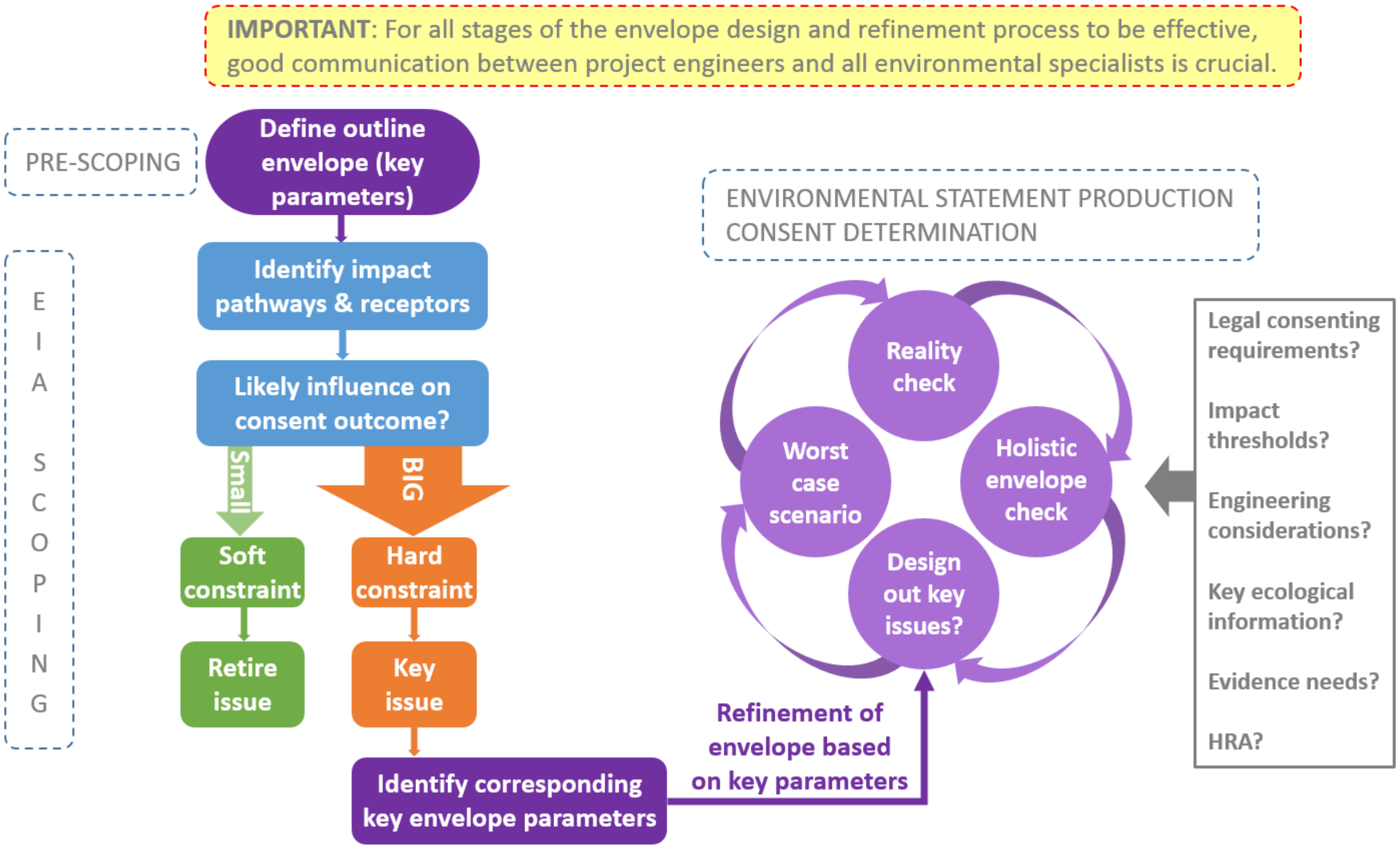
5. Early identification of key issues (environmental receptors and impact pathways)

The development of the project envelope should be informed by early identification of the key likely impacts of the project on sensitive receptors, to ensure it is based on an understanding of environmental risks. This will identify the significant environmental issues on which the refinement of the project envelope should focus. Equally important, is identifying the issues which are unlikely to have significant bearing on the consenting process and outcome. These issues should not be significant consideration for project envelope refinement and should also be 'retired' from the need for further detailed consideration in EIA. These significant and non-significant environmental issues and risks should be agreed between the developer and regulator, as part of EIA scoping.

6. Pre-application evidence gathering should focus on key issues

Pre-application evidence gathering, including survey and monitoring activities, should focus on reducing uncertainty about the key environmental issues (receptors and impact pathways). This will ensure that the resulting data best inform the iterative process of refining the project envelope, as well as the environmental assessments (including Environmental Impact Assessment and Habitats Regulations Assessment). Developing project evidence plan processes, like those already formally used for Nationally Significant Infrastructure Projects could help achieve this.

Figure 3. Summary of guiding principles in relation to the process for the definition and refinement of project design envelopes


IMPORTANT: For all stages of the envelope design and refinement process to be effective, good communication between project engineers and all environmental specialists is crucial.
PRE-SCOPING
Define outline envelope (key parameters)
EIA SCOPING
Identify impact pathways & receptors
Likely influence on consent outcome?
Small
BIG
Soft constraint
Hard constraint
Retire issue
Key issue
Identify corresponding key envelope parameters
Refinement of envelope based on key parameters
ENVIRONMENTAL STATEMENT PRODUCTION
CONSENT DETERMINATION
Reality check
Worst case scenario
Holistic envelope check
Design out key issues?
Legal consenting requirements?
Impact thresholds?
Engineering considerations?
Key ecological information?
Evidence needs?
HRA?

Annex One – detailed review and case study: marine mammals and marine energy consenting

1 Introduction

1.1 Background

In order to inform the development of guiding principles, this annex provides a detailed technical consideration of a number of elements relevant to the development of project design envelopes for marine energy projects, with a particular focus on marine mammals. The Appendix contains the following:

1) A section which provides a summary of the legal framework for consenting marine energy projects in Wales,
2) A section which introduces the primary impact pathways normally given detailed consideration during the consenting process for marine energy projects
3) A review of the approach to project envelope definition taken at a range of multi-technology marine energy sites
4) The Appendix ends with a detailed case study example of the considerations in project envelope design for an illustrative hypothetical marine energy project.

1.2 Legal framework

This section provides an overview of the legislative framework for the development of a tidal energy scheme in Wales and highlights the key environmental assessment requirements of this legislation. This section includes reference to elements of offshore energy consenting that have been further devolved to Wales, through provisions in the Wales Act (2017). At the time of writing, details surrounding some of the final and transitional arrangements for this further devolution are yet to be confirmed by Welsh Government. This section of the report should therefore not be interpreted as formal guidance on the consenting process for offshore energy projects in Wales; rather, it is provided for context only.

1.2.1 Electricity Act 1989 and Planning Act 2008

The Marine Management Organisation (MMO) is currently responsible for considering and determining applications for consent under section 36 of the Electricity Act 1989 for offshore generating stations with a generating capacity of more than 1 MW but less than or equal to 100 MW in Wales. The Wales Act (2017) transfers power to consent onshore and offshore generating stations with a generating capacity of up to 350MW to the Welsh Ministers, but at the time of writing, these changes have not yet come into effect.

The Planning Act (as amended by the Localism Act 2011) passed responsibility for dealing with development consent applications for Nationally Significant Infrastructure Projects (NSIPs) to the Planning Inspectorate. Offshore generating stations with a generating capacity of greater than 100 MW are classed as nationally significant infrastructure projects, or NSIPs (noting the changes above under the Wales Act (2017)). The Planning Inspectorate examines NSIP applications and make recommendations to the Secretary of State at Department for Business, Energy & Industrial Strategy (DBEIS) who makes the final consent decision.

1.2.2 Marine and Coastal Access Act 2009 (MCAA)

Under the MCAA, a Marine Licence is required for installing marine energy developments within waters. In Welsh waters, this licence is administered by Natural Resources Wales' Marine Licensing Team, on behalf of the Welsh Government. It is assumed that all components of the test site below Mean High Water Springs (MHWS) will require a Marine Licence issued by NRW.

1.2.3 EIA Directive (2014/52/EU) as amended

The EU Directive 2014/52/EU on the assessment of the effects of certain public and private projects on the environment (the 'Environmental Impact Assessment (EIA) Directive') applies to a wide range of public and private projects which are defined in Annexes I and II. Annex I projects require mandatory EIA, while Annex II projects are screened to determine if EIA is required.

For marine renewable energy schemes, this Directive is transposed into law in England and Wales predominantly via The Electricity Works (Environmental Impact Assessment) (England and Wales) Regulations 2000 (as amended) and the Marine Works (Environmental Impact Assessment) Regulations 2007 (as amended).

For marine renewable energy schemes which require an EIA, the EIA must be documented within an Environmental Statement (ES). The ES should include sufficient information to enable the licensing authority(ies) to determine the extent of any environmental impacts arising from the proposed scheme and should cover direct, indirect, secondary, cumulative, short, medium and long-term, permanent and temporary effects both within the boundary of the licensing authority, and the trans-boundary effects on other member states. The licensing authority must consider the impact of the project as a whole, rather than solely the marine aspect.

An important aspect of the EIA process is public consultation, allowing any member of the public to make representation regarding a development. This has direct implications for projects with complex PDE issues, which must be documented in a way this is understandable to a member of the public.

1.2.1 The Wildlife and Countryside Act (1981)

The Wildlife and Countryside Act (1981) consolidated and amended existing UK national legislation to implement the Bern Convention. The Act makes it an offence to intentionally kill, injure, take, possess or trade in any wild animal listed in Schedule 5 (which includes all cetaceans), and prohibits interference with places used for shelter or protection, or intentionally disturbing animals occupying such places.

1.2.2 The Habitats Directive 92/43/EEC

The main aim of the Habitats Directive is to promote the maintenance of biodiversity by requiring Member States to take measures to maintain or restore natural habitats and wild species listed on the Annexes to the Directive at a favourable conservation status. In the UK, the Habitats Directive is transposed into national law under the Conservation of Habitats and Species Regulations 2017 . The Regulations came into force on 30 October 1994 and have been subsequently amended several times. They apply to land and to territorial waters out to 12 nautical miles from the coast. The Conservation of Habitats and Species Regulations 2010 consolidate all the various amendments made to the 1994 Regulations in respect of England and Wales.

For UK offshore waters (i.e. from 12 nm from the coast out to 200 nm or to the limit of the UK Continental Shelf Designated Area), the Habitats Directive is transposed into UK law by The Conservation of Offshore Marine Habitats and Species Regulations 2017.

The following sections detail the protection afforded to marine mammals under these laws.

European Protected Species

All cetaceans found in Northern European waters are listed under Annex IV of the EU Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora (the Habitats Directive) as European Protected Species (EPS) of Community Interest and in need of strict protection.

The Habitats Regulations and the Offshore Marine Regulations make it an offence to deliberately kill, injure, capture or disturb any EPS. The UK Statutory Nature Conservation Bodies (SNCBs) have published guidance on the interpretation of these regulations and the circumstances in which an EPS licence is required (JNCC et al., 2010).

Mitigation measures should be put in place if there is a significant risk of an offence. If there is a reasonable expectation that there is risk of deliberately killing, injuring (including auditory injury), capturing or disturbing an EPS as defined above, despite mitigation plans, a derogation licence is required.

Regulators will grant such a licence if the following three tests are met:

1. The purpose of the work is for preserving public health or public safety or other imperative reasons of over-riding public interest including those of a social or economic nature and beneficial consequences of primary importance for the environment.
2. There is no satisfactory alternative to the activity.
3. The action authorised will not be detrimental to the maintenance of the population of the species concerned at a favourable conservation status (FCS) in their natural range.

Given this legislative requirement, it is clear why a good understanding of the potential magnitude of any impacts which might cause injury or death or affect the survival and fecundity of individuals and therefore consequences for cetacean populations is required.

Special Areas of Conservation and Habitats Regulations Assessment (HRA)

Harbour porpoise, bottlenose dolphins, grey and harbour seals are protected under Annex II of the Habitats Directive as species of Community Interest whose conservation requires the designation of

Special Areas of Conservation (SACs). As mentioned above, the Habitats Directive is transposed into UK legislation through the 2017 Habitats Regulations, whereby European Sites (e.g. SACs) are given protection. In Wales, sites have been designated for harbour porpoise, bottlenose dolphin and grey seal.

The 2017 Habitats Regulations require that the competent authority, before authorising a project likely to have a significant effect on a European site, 'must make an appropriate assessment of the implications for that site in view of that site's conservation objectives'. Anyone applying for development consent must provide the competent authority with such information as may reasonably be required 'for the purposes of the assessment' or 'to enable them to determine whether an appropriate assessment is required'. This information is normally provided within the ES, or in supplementary 'information to inform a Habitats Regulations Appraisal (HRA)' report.

In practice this places a burden on the applicant to 'prove' there will not be a 'Likely Significant Effect' (LSE) on the European site(s), either alone or in combination with other plans and projects.

Where LSEs on a European site cannot be discounted, the competent authority needs to consider whether those effects will adversely affect the integrity of the site in view of its conservation objectives. The HRA should therefore include evidence about the project's impacts on the integrity of protected sites and a description of any mitigation measures proposed which avoid or reduce each impact, and any residual effect.

For highly mobile species features, such as marine mammals, but also including birds and migratory fish, competent authorities typically consider the site to be affected if animals from a qualifying species that are connected to the site (and can therefore be considered as animals from the site) are affected by an activity, even if that activity may be some distance from the SAC itself.

As such, it is clear why a good understanding of the connectivity of a project site with any SAC with marine mammal features, and a good understanding of the magnitude of any potential impact that might affect survival and fecundity of individuals associated with that site is important to both the developer and the competent authority. Survival and fecundity (birth rate) are the two most important life history traits that contribute to the status and health of a population; the difference between mortality (the inverse of survival) and fecundity is the rate of change (decrease or increase) of a population. Since the majority of legislation protecting species and habitats is ultimately concerned with population level consequence, the consequences of any impacts on these two vital rates are often the focus of impact assessments.

2 Impact pathways

2.1 Introduction

There are a number of impact pathways that are generally considered in the assessment of the potential effects of tidal energy projects on marine mammals, covering construction/installation, operation, maintenance and decommissioning stages (**Error! Reference source not found.**Table 2.1). Examination of every potential impact pathway would be impractical for the purposes of this report, which therefore focusses on the key impact pathways of disturbance during both installation and operation, and collision during the operational phase of projects. These are the impact pathways that are most likely to be of significance, in terms of their influence on consent determination and any conditions, thus driving the definition of 'worst case scenarios' within EIA. It is unlikely that the other impact pathways would drive, or exert a significant influence on, project design definitions.

Table 2.1. Summary of impact pathways typically assessed in tidal energy marine mammal impact assessments. The impact pathways which are the focus of the subsequent case study sections of this report are in bold.

Stage	Impact Pathway
Construction/installation	**Disturbance and injury from installation noise (e.g. drilling)**
	Disturbance from the noise generated by installation vessels
	Collisions with installation vessels
Operation & Maintenance (O&M)	**Disturbance and injury from operational noise**
	Displacement leading to barrier effects from operational noise/physical presence of devices
	Collision with the moving parts of Tidal Energy Converters (TECs)
	Disturbance from the noise generated by O&M vessels
	Collisions with O&M vessels
	Indirect impacts mediated through the impacts of turbine operation on prey species

	Entanglement with device moorings
Decommissioning	Disturbance and injury from noise from decommissioning activities (e.g. cutting, shaped charges)
	Disturbance from the noise generated by decommissioning vessels
	Collisions with decommissioning vessels
	Accidental release of contaminants

2.2 Collisions with the moving parts of turbines during operation

The potential for marine mammals to collide with the moving parts of devices, particularly the rotors of tidal stream turbines, is a primary concern for the consenting and licencing of projects, and as such is often a major component of impact assessments (EIA and HRA). There is an absence of empirical data to determine the ability of animals to avoid coming into contact with devices, either through close-range evasion, where animals take last minute evasive action, or through avoidance, which may operate at a wider scale with animals avoiding the area the devices are located in. Predictions of the potential magnitude of collision risk rely on quantitative models that predict the potential rate of encounter between animals and turbines.

A number of different features of design envelopes for tidal projects are likely to have an effect on the magnitude of potential collision risk for marine mammals. The primary features are likely to be:

- The number and size of Tidal Energy Converters (TEC) moving parts (e.g. for horizontal axial flow designs; number of rotors and rotor dimensions and shape);
- The total number of devices with moving parts;
- The speed of movement of moving parts;
- The position of TECs in the water column (in relation to the depth distribution of marine mammals).

There are a number of existing quantitative models which have been used to assess the potential collision risk to marine mammals from tidal energy devices. These have been recently reviewed by Scottish Natural Heritage (2016), Copping et al. (2016), and Band et al. (2016). Band et al. (2016)

present a detailed analysis of the sensitivity of a modified Band collision risk model (CRM) to variation in a number of input parameters. This analysis revealed that whilst differences in the physical characteristics of the turbine rotors did have an effect on the magnitude of predicted collision risk, the differences were relatively small and other input parameters such as the density of animals, or the behaviour of animals in relation to the current, and in response to turbines, had a much bigger influence on overall predictions. Band et al. (2016) proposed a modification to incorporate a variable probability of mortality, relaxing the assumption made previously that every collision would result in mortality. This modification was based on the work by Thompson et al. (2016) who carried out empirical tests with grey seal carcasses and concluded that collisions at rotor speeds of 5.2 $m.s^{-1}$ or less[3] did not result in any significant muscle or skeletal damage and would be unlikely to result in serious injury or mortality. Incorporating this into the CRM resulted in a reduction of predicted collision risk across a range of simulations of between 20% and 75%, depending on the proportion of predicted collisions which are below this closing speed. Above this speed, the probability of death or serious injury will increase with rotor speed, as will the likelihood of a collision. Therefore rotor speeds and the relationship between rotor speed and current speed are clearly important factors. However, rotor speeds vary widely by device type and size. The size of moving parts, and therefore the area swept by them, is also an important determinant of the risk of collision. Larger blades obviously sweep a larger area, putting a higher proportion of animals at risk of collision. However, larger blades are also likely to be slower than smaller blades and therefore collision probability will be lower for a given passage rate and animal speed. The variety in collision probability as a result of variation in different turbine parameters is therefore difficult to predict.

The position of the devices in the water column will also have a significant bearing on the predicted collision risk. This is related to the degree that the moving parts of devices occupy the portion of the water column most used by marine mammals. The depth distribution of the marine mammals using a particular site is therefore an important part of site characterisation and will often vary by species and potentially between sites, therefore the worst case scenario in terms of a particular device will be highly variable depending on the characteristics of the site and the species concerned. Many marine mammals are benthic foragers and divide their time primarily between the surface to breathe, and the seabed to feed, with relatively less time spent mid-water. For example, a study of grey seal

[3] Due to methodological constraints in this study, speeds above this could not be tested.

juveniles tagged at Anglesey, Bardsey Island and Ramsey Sound found that tagged animals spent the majority of their time either at the surface or at the bottom of a dive with little time spent in the mid water depths. This study also showed that the tagged seals spent 76% of their time submerged (Thompson 2012). Unpublished data from these tags show that the grey seals dived to depths of >80 m when in areas deep enough to allow such dives (Dr Debbie Russell, Sea Mammal Research Unit pers. comm.). In areas where animals are foraging on the seabed, midwater devices with adequate clearance above and below will represent a lower risk than devices situated close to the seabed or the water surface.

Conversely, some species may spend considerable time in other parts of the water column. For example, Hastie et al. (2006) presented a depth distribution for bottlenose dolphins obtained from a vertical array of hydrophones and both Corkeron and Martin (2004) and Klatsky et al. (2007) presented bottlenose dolphin dive data from satellite-linked, time–depth recorders. The studies all reported that although occasionally much deeper dives were recorded (up to 1,500 m) bottlenose dolphins spent little time in waters deeper than 10 m. Similarly, data from Teilmann et al. (2007) and Teilmann et al. (2013) demonstrate that harbour porpoises spent about half their time within the top 2 m of the water column. Therefore, for species that spend a considerable amount of their time near the surface, such as bottlenose dolphins and harbour porpoises according to these studies, TECs mounted close to the surface would represent the worst case scenario for collision risk.

The Fair Head tidal array EIA incorporated the depth distributions of harbour porpoises and seals from the literature (Westgate et al. 1995, Teilmann et al. 2007) into the collision risk assessment. Collision risk was compared at two different values of minimum surface clearance (minimum distance between blade tips and the water surface) of 5 m and 8 m. There was very little difference in collision risk for seal species, which are generally more active within the top 2 m and at the seabed. However, for porpoises, the predicted encounter rate increased where turbines were located closer to the water's surface.

The total number of TECs will also be a major determinant of collision risk. Currently there is no way of realistically modelling the collision risk posed by multiple devices, other than simply multiplying the risk for a single device by the total number of devices. This is likely to be unrealistic for the principal reason that it is difficult to predict how animals might respond to an array of devices. The probability of avoidance is likely to be modified as a result of a close range encounters with preceding devices. Marine mammals are unlikely to move through the area at random or uniformly with respect to multiple devices. There is the possibility that animals might learn from encountering and avoiding the first device and then subsequently avoid additional devices at a greater distance. However, there is also the possibility that avoiding one device might bring an animal into the path of a subsequent device with an increased probability of collision, although this will depend on device spacing. Although collision risk may not scale linearly with the number of TECs in an array, given current uncertainty regarding marine mammal behaviour, and a lack of empirical data, most assessments make the assumption that there will be a linear increase in risk with the total number of devices installed.

BOX 1.1 KEY FEATURES OF TIDAL ENERGY PROJECT DESIGN INFLUENCING PREDICTIONS OF COLLISION RISK

Exactly which turbine parameters most influence predicted collision risk depends on the method/model used to predict risk. For a review of the most common models used, the required input parameters and sensitivities, see Scottish Natural Heritage (2016) and Band et al. (2016). However the technology-related factors most likely to influence collision risk are given below:

- Rotor size (diameter)
- Rotor speed
- Total number of rotors and total number of devices
- Position in the water column
- Proportion of time that a device is operational

The site-related factors most likely to influence collision risk are:

- Animal density (or passage rate)
- Animal depth distribution

The rate of individual turnover would also help the understanding of the potential magnitude of collision risk although this is not generally currently taken into account in the most widely used quantitative collision risk assessment models due to lack of data.

2.3 Disturbance during the construction and operational phases leading to displacement from important habitats or barrier effects

The construction and operational phases of tidal stream projects could lead to the physical displacement of animals away from the development location or disturbance which affects important life functions (e.g. breeding or feeding). Displacement can be considered one potential consequence of disturbance but it is important to note that animals can be disturbed with resulting consequences for survival and fecundity without being completely displaced. Displacement impact is often predicted as potentially resulting from acoustic disturbance during construction and O&M of devices. However, disturbance (including displacement) could be a result of a response to the general physical presence of devices and/or vessels and activity (during construction and/or maintenance). Any assessment of this impact needs to take into account the potential scale and magnitude of the disturbance (over how large an area might this occur and how many animals may be affected). The potential consequences of the disturbance for individual animals, and consequently for the population, need to be considered in assessing the significance of the impact. Worst case consequences of disturbance could include: 1) displacement from important habitat, e.g. a feeding ground, 2) disturbance at a breeding site leading to reduced breeding success, 3) disruption of social interaction, including mother-calf/pup relationships, and 4) displacement resulting in a 'barrier effect' across an important transit route/movement corridor. Although a barrier effect could be considered a consequence of displacement away from an area previously used for transit, it is often assessed as a separate impact pathway.

Although there is a limited evidence base to inform this, the magnitude of predicted disturbance is likely to be sensitive to a number of different features of design envelopes for tidal projects. The primary features are likely to be:

- The construction and installation techniques;
- The operational noise generated from each individual device type;
- The total number of devices and the physical footprint of the area occupied by devices;
- The spacing and layout of devices in an array, and in particular how they relate to the geography of the site and how the site is used by marine mammals;
- The position of devices in the water column and the amount of clearance above and below for passage.

The most obvious cause of disturbance related impacts is from the noise generated during construction and installation activities. Construction and installation activities are relatively short term in duration, compared to operational activities. Passive acoustic monitoring around construction of the SeaGen tidal turbine revealed that harbour porpoise were temporarily displaced from the Strangford Narrows during the construction period, but activity returned to baseline levels soon after and were unaffected during operation (Savidge et al. 2014). Construction activities should be relatively easy to characterise within a PDE and the relationship between different activities and the potential for impact is reasonably well understood.

Previous evidence suggests that the scale of disturbance from the few single operating tidal turbines has been at the scale of a few hundred metres (Hastie et al. 2017, Sparling et al. 2017a)). However, there is currently much uncertainty surrounding the potential for larger arrays of devices to cause displacement of marine mammals from important habitats, or disturbance leading to a reduced ability to carry out normal activities (e.g. breeding, feeding, etc). Recent guidance published by NRW suggests that the functional use of an area by marine mammals is likely to be a very important factor in assessing the significance of potential disturbance and displacement (Sparling et al. 2016). It is therefore difficult to determine the general design features within a PDE which represent a worst case scenario in isolation from an understanding of the site and the species or sensitive receptors found there. Once these potentially sensitive receptors are identified, it should be relatively straightforward to identify a worst case scenario. One complication with operational noise is that a certain amount of noise may be beneficial in terms of an animal's ability to detect and avoid collision with TECs. A completely silent array will present the 'worst case' scenario with respect to collision risk but the 'best case' scenario in terms of the potential for disturbance. There is likely to be some degree of intermediate level of operational noise. It is difficult to accommodate this formally or quantitatively in an impact assessment given the current standard approach of quantitative assessment of each impact separately.

It may be helpful to consider the PDEs for noise-related disturbance and collision together. However, creating project-wide single scenarios on which to base impact assessment will be extremely challenging given the typical structure of assessments and the requirement for later flexibility (and the lack of specific finalised design information at pre-consent stage). There may have to be an acceptance that there will be incompatibilities between the worst case envelope definitions across different parts of the assessment.

2.4 Conclusions

The variability in TEC designs and the complexity of the impact pathways present a challenge to defining flexible project envelopes for multi-technology test sites. The next section of this report provides a review of the approach taken at previous multi-technology sites with a view to identifying common solutions to these problems, or over-arching principles that could be applied in future.

Principles identified in this section;

- Identifying the key likely environmental impacts and sensitive receptors of a development proposal at an early stage will enable the design of the Project Envelope to take account of key impacts and consider 'designing out' significant issues. Similarly, it will prevent non-significant issues from having a disproportionate influence on the final design envelope and unrealistic worst-case scenarios.
- Identifying those parameters of the envelope most likely to influence the magnitude of key impacts on the identified receptors will ensure that the refinement of the design envelope focuses on the things most likely to have a material influence on consent determination and conditions.
- EIA scoping should be used intelligently to identity the key likely environmental impacts and sensitive receptors and elements and parameters of the design envelope most likely to influence the magnitude of the significant impacts of the project.

3 Previous approaches to consenting and PDE for multi-technology marine energy projects

3.1 European Marine Energy Centre (EMEC), Orkney

3.1.1 Approach to multi-technology consenting

EMEC provides purpose built, grid-connected, open-sea testing facilities for wave and tidal energy technologies. In 2005, to support its application for the development of a tidal test site at the Fall of Warness, Eday, EMEC carried out an EIA including the production of an Environmental Statement (Aurora Environmental Ltd 2005). The resulting consents secured the test site's grid connections and cables but did not cover the individual deployment of devices. As a consequence, developers wishing to deploy devices at the test site were required to submit their own applications to Marine Scotland for a Marine Licence and Electricity Act Section 36 consent. In support of these consent applications, developers were required to carry out an assessment of the risk of environmental impact of deploying, operating and decomissioning their devices. This led to an onerous process of each developer requiring a separate appraisal by Marine Scotland, including separate consultation with Scottish Natural Heritage (SNH) and other key consultees.

In recognition of the need to streamline this process,a site-wide environmental appraisal was undertaken in 2014 by EMEC, to support the consenting process for the deployment and operation of devices at the Fall of Warness. Marine Scotland drew upon this environmental appraisal to undertake an Appropriate Assessment (AA) for the test site. The appraisals described in EMEC (2014) and in Marine Scotland's AA together constitute an EIA and HRA to support any application for a Marine Licence or Section 36 consent for deployment at any of the berths in the Fall of Warness up until 2022. Provided proposed deployments fit within the agreed 'project envelope' defined in EMEC (2014) no further appraisal is required. If a project falls outside the agreed project envelope the developer may be required to provide further information to support any additional environmental appraisal and AA that may be required. Therefore the documentation provided within the EMEC environmental appraisal (EMEC 2014) is intended to facilitate and inform the consenting process for licence applications from individual developers, rather than replacing the need for those developers to apply for their own licences. The onus is on Marine Scotland to determine whether the details of any proposed project falls within the defined project envelope.

Importantly it was recognised that even within the project envelope, there were some activity/impact pathway-receptor combinations where pre-appraisal was deemed not to be possible and, as such, additional case by case appraisal and consultation likely to be necessary. These activity-receptor combinations were:

- Use of vessels with ducted propellors – potential for physical interaction leading to corkscrew injuries[4];

[4] Although considered a potential impact pathway at the time, subsequent research has attributed 'corkscrew' injuries to grey seal predation, and this issue has now been retired.

- Use of active acoustic equipment – underwater noise that may lead to disturbance of seals or cetaceans;
- Cable installation and associated vessel activity – may lead to disturbance, injury or death of otters.

In addition, the EMEC environmental appraisal stipulated that it was a live document and, as such, subject to periodic review and revision according to updates on the status of various receptors. Howerver no information on the mechanism or periodicity of such a review is given in the publically available documentation.

3.1.2 EMEC project envelope – marine mammals

The EMEC environmental appraisal (hereafter simply 'the appraisal') carried out separate impact appraisals for cetaceans and seals as well as an appraisal of the effects on Natura sites: SACs for seals. Impact pathways were separated into those likely during installation and those likely during device operation and maintenance[5]. The impact pathways that were given detailed consideration and the scenario used to define the project envelope for each are described in Table 3.1.

Table 3.1. The defined project envelope for each specified impact pathway for the EMEC environmental appraisal (EMEC, 2014).

Impact Pathway (applies to both cetaceans and seals unless otherwise stated)	Maximum (worst) case scenario
Underwater noise from foundation installation methods	Drilling and associated works at two separate berths at one time
Underwater noise from vessels during installation	Maximum number of vessels at any one time is 14
Underwater noise from operation of devices	Not explicitly defined although broadband RMS noise levels of up to 177 dB re 1 µPa @ 1m are mentioned

[5] Decommissioning was specifically excluded from the appraisal, the rationale being that it would be dealt with separately through requirements set out by the (then) Depart for Energy and Climate Change.

Collision with operating turbines	Two scenarios formed the basis of the use of quantitative collision risk models to predict the number of animals potentially colliding with the turbines: "Current scenario" (July 2014) wherein devices are installed or expected to be installed in the existing eight test berths. Two of the devices have two rotors and the devices are of various depths and diameters. "Maximum case" of a fully occupied test site with 12 devices across 9 berths of which 6 have a single bladed rotor, 6 have two 3-bladed rotors, thus totalling 18 rotors. This is considered to represent the 'maximum case' in terms of the maximum number and size of devices/rotors at any time. A single cut in (0.5 m/sec) and cut out (4 m/sec) and therefore based on 1 month of tidal data the assessment assumed that the turbines would be non-operational for 12.4% of time. No allowance was made for non-operation due to maintenance, development work or grid constraints. Vertical axis, venturi, Archimedes screws and any other unforeseen device designs were explicitly excluded from the appraisal and would require additional assessment. However, the assessment did consider the collision risk potentially arising from two less common device designs: 1. a single turbine with two contra-rotating rotors 2. an annular (ring) device
Entanglement	Maximum berths is 9, expected that most would be bottom mounted structures without mooring systems
Changes to hydrodynamic and sediment regime leading to effects on marine mammal prey species	Total of 1.5 % energy extraction
Presence of tidal devices and associated infrastructure leading to barrier effects	Maximum possible number of devices, intermittent operation (not specified)
Interaction with vessel propellers (seals only)	Unspecified but assume that similar to that of underwater noise from vessels of maximum of 14 vessels at any time.

As a result of legislative drivers (primarily the Marine Scotland Act 2010, which makes it an offence to kill, injure or take a seal at any time of year except to alleviate suffering or where a licence has been issued to do so by Marine Scotland, in addition to the proximity of seal SACs requiring an HRA) a detailed assessment of the potential effects on seal populations was carried out. The focus of the assessment was mainly on collision risk with the results placed in the context of the current level of Potential Biological Removals (PBR) set for each seal population. This assessment concluded that based on the predicted level of collision risk from the maximum scenario, assuming an avoidance rate of 98%, there would not be an adverse effect on the integrity of the Sanday or Faray and Holm of Faray SACs with respect to harbour seals and grey seals respectively. The likely presence of harbour porpoises (as they are EPS) at the site also required an assessment of the level of collision risk to harbour porpoises.

3.1.3 Monitoring and mitigation requirements

The appraisal concluded that monitoring for device interactions should be a fundamental component of monitoring efforts at the test site. Site-wide monitoring was proposed at strategic level (either by EMEC, The Crown Estate or Marine Scotland) rather than being the responsibility of individual developers. A number of potential mitigation and monitoring measures are suggested within the Environmental appraisal. These include, for disturbance impacts:

- the use of a marine mammal observer prior to commencement of drilling operations,
- acoustic monitoring of installation noise,
- short term monitoring of seal haul outs, and
- the use of appropriate vessel management plans.

For collision, the use of appropriate methods to detect collisions or near misses, and the monitoring of interactions between seals and operating devices is recommended.

3.2 Perpetuus Tidal Energy Centre (PTEC)

3.2.1 Approach to multi-technology consenting

PTEC is a tidal energy centre being developed to facilitate the commercial demonstration of TECs. The centre aims to support and accelerate the commercialisation of tidal technologies by providing facilities to allow technology developers to take the step from testing individual devices, to installing and optimising the performance, operation and maintenance of small arrays of up to 10 MW. The centre received consent from the Marine Management Organisation in April 2016 for up to 30 MW total installed generation capacity for a maximum period of twenty five years (maximum of twenty years' operation per tenant and up to five years for pre-construction, re-powering and decommissioning works). In contrast to the approach at EMEC, whereby individual developers are responsible for their own Marine Licences and Section 36 licences, the approach of PTEC was to obtain site-wide consents (Marine Licence and Section 36) that covered a range of development scenarios and included the range and flexibility to attract a wide spectrum of developers and devices. To this end there was a need to develop a carefully considered envelope of development scenarios and set workable limits on potential impacts.

A programme of developer consultation was undertaken to carry out a review of existing device types understand the range of device types that could be deployed at PTEC. This review also allowed the identification of realistic worst case parameters which were used to define the project envelope. This flexibility was deemed as crucial to allow the centre to adapt to future improvements as part of ongoing efforts to maximise industry viability.

A number of realistic worst case scenarios for each individual element of the project were defined. This included separate definitions of worst case scenarios for the device operation (defined separately for each device type), foundation installation (separately for each foundation installation technique), superstructures, array layout and spacing and cabling. Individual technical chapters detailed how these parameters were used in the assessment for each receptor and impact pathway.

3.2.2 PTEC project envelope – marine mammals

For marine mammals the key parameters of the project description that constitute the worst case scenario for each impact pathway are detailed in Table 3.2.

Table 3.2. The defined project envelope for each specified impact pathway for the PTEC marine mammal EIA (PTEC, 2015).

Impact Pathway (applies to both cetaceans and seals unless otherwise stated)	Maximum (worst) case scenario
Underwater noise from foundation installation methods	Monopile foundation installation by drilling for maximum pile diameter of 4m. Maximum of two monopiles for a single device. May be up to 10 devices per berth arranged in 2 rows of 5 devices requiring 12 monopiles per berth. Two concurrent drilling activities with maximum spacing (minimal overlap in noise impact footprints therefore maximum area of impact). Drilling consecutively for 300 days.

Underwater noise from vessels during construction	900 return journey movements per year during construction, over an 18 month period spread over three years – up to 1,350 total vessel movements.
Collision with vessels during construction	As above
Underwater noise from operation of devices	Noise modelling used to define maximum impact range for the maximum turbine size of 24 m rotor diameter (extrapolation to larger devices based on measurements of smaller devices) and then under a maximum design scenario of up to 60 devices, the assessment assumed a buffer around the whole development site equal to this impact range representing an area of total displacement.
Collision with vessels during operation	Unspecified small increase in vessel numbers for period of 25 years.
Collision with operating turbines	No quantitative collision risk modelling was carried out due to the very low densities of marine mammals found at the site. Large and complex variety of parameters defined for the different TEC types. *For open axial flow rotors:* • Max single rotor swept area of 452 m^2 • Max device swept area of 1884 m^2 (10 MW array) • Max array swept area of 19,782 m^2 (30 MW total) • Max tip speed of 41 m/s (for rotor diameters up to 16 m) • Max tip speed of 31 m/s (for rotor diameters up to 20 m) • Max tip speed of 12 m/s (for rotor diameters up to 24 m) • Minimum clearance for surface piercing device types of 3 m from rotor tips to surface at LAT • Minimum clearance for surface piercing device types of 6 m from rotor tips to surface at LAT • Minimum clearance of 3 m from rotor tips to the seabed *For ducted axial flow rotors:* • Max single rotor swept area of 201 m^2 • Max device swept area of 2010 m^2 (10 MW array) • Max array swept area of 6030 m^2 (30 MW total) • Max tip speed of 26 m/s • Minimum clearance of 6 m from ducted rotors to surface at LAT • Minimum clearance of 3 m from ducted rotors to the seabed *For transverse axis device types:* • Max single rotor swept area of 1350 m^2 (one rotor per device) • Max device swept area of 6000 m^2 (10 MW array) • Max array swept area of 12,000 m^2 (there will be a max of 2 berths of this type of device so the 10 MW berth option would be taken up with an axial TEC see parameters above) • Max tip speed of 18 m/s

	• Minimum clearance of 6 m from the rotor edge to the surface at LAT for seabed mounted devices • Minimum clearance of 3 m from the rotor edge to the surface at LAT for floating devices • Minimum clearance of 3 m from rotor edge to the seabed
Entanglement	20 midwater floating platforms. No other specific details are given in relation to the parameters that could directly affect entanglement risk such as mooring lines

In the PTEC assessment, the 'worst case' parameters influencing collision risk were all defined separately and there was no consideration of interactions between these different elements. For example a large rotor diameter will result in an increase in swept area which in isolation would increase risk, however larger diameters will also be slower which will serve to reduce risk. However as discussed above, it is difficult to determine across many possible combinations of TEC types what actually represents the worst case. No quantitative collision risk assessment was done for PTEC due to the low densities of marine mammals at the site, so there was no requirement for any direct link between the parameters and the impact assessment. However for areas where there are higher numbers of sensitive marine mammal receptors it may be more complex to define a worst case scenario (WCS) PDE on which to base a quantitative collision risk assessment.

3.2.3 Monitoring and mitigation requirements

There is a provision for Environmental Monitoring in Section 5.2.44 of the Marine Licence, including a stipulation for at least a 6 month period of baseline monitoring: "*To provide a robust baseline in order to measure the potential environmental impacts of the works*". Section 5.2.47 goes on to stipulate that the construction and post construction monitoring must include underwater noise although there is no mention of marine mammals specifically. Due to the low densities at the site and the limited potential for impact, there is no requirement for any monitoring in relation to collision related impacts or any other impacts on marine mammals.

3.3 West Islay Tidal Farm

3.3.1 Approach to multi-technology consenting

The West Islay Tidal Energy Park development will comprise of between 15 and 30 tidal energy TECs delivering a maximum installed capacity of 30 MW together with the associated infrastructure required to export the generated energy to the shore on Islay. The application for this project was submitted in 2013 and received a Marine Licence and Section 36 Licence from Marine Scotland in June 2017.

The approach taken within the Project EIA and described within the ES was technology and manufacturer neutral (West Islay Tidal 2013). Final device selection will be undertaken by the project developer post-consent and subject to a formal commercial tender process. This enables commercial agreements to be negotiated with technology suppliers at a point where financial close is imminent and tenders can be run in accordance with European procurement rules. It was not feasible for either the supplier to offer, or the developer to commit to, commercially competitive agreements prior to final consents being awarded. Clearly this situation is different for projects where the technology developer is also the project developer. A design envelope, or “Rochdale Principle”, approach was adopted for this consent application, allowing deferment of technology and manufacturer selection to the appropriate time.

This case study poses a different requirement for flexibility to that of a test site involving multiple technologies. It is likely that the development will be all of one type of technology, yet to be determined. Nonetheless there are similarities in the approach that are worth including in this review.

3.3.2 West Islay Project envelope

Two models of TEC were evaluated in detail in order to provide a reference design envelope for the project EIA. These are the Marine Current Turbines (MCT) SeaGen S Mk 2, a twin rotor 2 MW machine and the Tidal Generation Ltd (TGL) single rotor 1 MW turbine. Whilst these devices are used to inform the detailed baseline for the EIA, and can be considered as the most likely form of TEC solution to be used particularly in the early phases of developments, they could be substituted for other devices within the parameters of the design envelope defined. Both devices feature configurations based on horizontal axis, un-ducted, pitch controlled, three bladed rotor turbines. A number of other devices would fit within this design envelope and would be suitable for deployment including Voith Hydro and Hammerfest Strom. The key difference between the MCT and TGL devices is the support and foundation design and their operation and maintenance strategies. By considering both, the EIA was able to consider the impact of fully submerged and surface-piercing devices. It

The EIA attempted to identify the worst case scenarios based on either all surface piercing devices (e.g. MCT SeaGen S Mk2 or floating platforms) or all fully submerged devices (e.g. TGL TECs). Although a mixed site with both surface piercing and fully submerged devices was considered as a potential development scenario, no mixed site layouts were deemed to represent worst case for any of the impact pathways.

Table 3.3. Defined worst case scenario for each impact pathway for the West Islay Tidal Farm marine mammal EIA (West Islay Tidal, 2013).

Impact Pathway (applies to both cetaceans and seals unless otherwise stated)	Maximum (worst) case scenario
Underwater noise from foundation installation methods	Due to longer duration of installation of 30 TGL devices compared to 15 MCT 2 MW devices 124 drilled piles, at one pile per day, 124 days of drilling may be required (these are unlikely to be consecutive due to weather windows).
Underwater noise from vessels during installation	No specific worst case scenario defined
Underwater noise from operation of devices	Potential effect of both device scenarios assessed with no specific worst case defined.
Collision with operating turbines	Quantitative collision risk estimates were calculated for both the MCT and TGL devices (individual and array), to ensure that the worst case was accounted for in the assessment. The estimates adopted in the assessment were based on the MCT turbine design as the resulting encounter rates were slightly higher than the TGL turbine design, therefore representing the maximum possible impact. • Minimum water depth: 29 m • Rotor diameter: 20 m • Blade swept area: 314 m^2 • Height of structure above seabed: 15 m • Minimum clearance to sea surface: 6 m • Minimum clearance to the seabed: 3 m • Blade thickness: 0.61 m • Cut in speed: 1.0 $m.s^{-1}$ • Rated speed: 2.4 $m.s^{-1}$ • Cut out speed: 5 $m.s^{-1}$ • Tip speed ratio: 4.62
Changes to hydrodynamic and sediment regime leading to effects on marine mammal prey species	No specific worst case defined for marine mammals as effects were deemed to be insignificant for fish.
Presence of tidal devices and associated infrastructure leading to barrier effects	Not considered to be significant due to the unimportance of the area for marine mammals, no specific definition of worst case.
Interaction with vessel propellers (seals only)	No specific worst case scenario defined apart from specifying speeds would be less than 7 m/s

The definition of PDE and subsequent assessment of a worst case scenario was relatively straight forward in this example, as there were only two technology types to consider and for each impact where a quantitative assessment was made, the worst of the two were used. This meant that the worst case was different for different impact pathways so in one respect represents an unrealistic assessment but on the other hand it provides an assessment which allows for the flexibility required by a technology neutral developer. It is clearly in the interest of the developer to refine the selection of technology types as far as possible to reduce the complexity in assessments.

3.3.3 Monitoring and mitigation requirements

The Environmental Statement outlined a high level commitment to the development of an Environmental Management Plan (EMaP) and and Environmental Monitoring Plan (EMP) to be agreed with SNH and Marine Scotland. Monitoring “to the extent feasible for this site” was proposed to assess the actual level of impact in relation to collision with operating turbines. A condition requiring the Project to develop a programme to monitor interactions of marine mammals with operational turbines was included in the conditions attached to the consent for the project.

3.4 Fair Head Tidal Array

3.4.1 Approach to multi-technology consenting

Like the West Islay project, the Fair Head tidal array is a project developer-led commercial project, as opposed to a managed multi-developer test facility. A consent application was submitted to the Northern Ireland Department for Agriculture, Environment and Rural Affairs (DAERA) in February 2017 for an array of up to 100MW capacity. A total of three different technologies are under consideration for deployment at the site and the final 100 MW array configuration may contain a mixture of technologies across a number of suitable sites within the overall lease area. Therefore, the need for flexibility in the design of the project build out was a key part of the consenting process, both in terms of the technologies and the final development footprint. The total number of devices will be between 34 and 100. Recognising that a number of configuration options were possible a total of 8 ‘array configurations’ were defined within the consent application encompassing the ‘likely greatest effect’ including different combinations of turbine type and electrical hub options (subsea or surface piercing).

The assessment identified a number of key parameters relating to the assessment for each impact pathway and defined maximum values for each of these parameters with reference to the technology types being considered.

3.4.2 Fair Head Project Envelope – marine mammals

Twelve array design scenarios were defined and assessed. These are shown in Table 3.4. The marine mammal assessment defined a number of 'worst-case' 'maximum' values for each parameter in relation to each impact pathway. These are provided in Table 3.5.

Table 3.4. Array configuration design envelope for Fair Head Tidal Array EIA. The numbers indicate the proposed number of turbines of each type for each array design option.

Array Design option	ARL – 3 MW Streamtec	1.25 MW Andritz	1 MW Andritz	2 MW Schottell Triton	Surface Piercing electrical hub	Subsea electrical hub
1a	34				10	
1b	34					10
2	30			5		10
3a	2	76			10	
3b	2	76				10
4	2	68		5		10
5a		80			10	
5b		80				10
6		72		5		10
7a			100		10	
7b			100			10
8			90	5		10

Table 3.5. Summary of maximum ('worst-case') project parameters for the marine mammal impact assessment for the Fair Head Tidal Array.

Project parameter	'Maximum' value for impact assessment	Explanation of Maximum Project Parameter
Number of turbines	34-100 (depending on array configuration)	The final 100 MW array configuration may contain a mixture of technologies across a number of suitable sites within the AfL. **Collision Risk:** Assessment of the potential interaction with turbines through encounter risk modelling considers the environmental impacts associated with 8 technology mixes, which have been described within the design envelope. (Table 3.4) **Noise:** A prediction of the likely near-field sound field effects of each turbine type was carried out. The noise modelled for each turbine type was then extrapolated over a wider area (up to 20 km) using a far-field model. The resulting modelled sound fields were compared to ambient noise levels measured at the proposed site to determine the range at which the cumulative operational noise from the tidal devices is masked by the background noise. Three of the options outlined in **Error! Reference source not found.** were assessed w hich represented the noisiest combinations and was representative of the likely project technology mix. These options were: Option 2: 30 SeaGen and 5 Schottel devices Option 4: 2 SeaGen, 68 Andritz and 5 Schottel devices Option 5B: 80 Andritz turbines Modelling predicted Option 5B to be the quietest and Option 2 the loudest. Option 2 therefore represents the worst case technology mix from an operational noise perspective.
Number of rotors per turbine	1, 2, and 36	The design envelope contains a range of technologies, all three turbine types have been modelled to inform the impact assessment in relation to collision risk. The total risk posed by each of the 12 layout options could then be calculated assuming a direct linear relationship between the number of devices and the risk posed by a single device. The worst case scenario for collision risk is therefore the combination layout option which presents the highest overall collision risk.

Project parameter	'Maximum' value for impact assessment	Explanation of Maximum Project Parameter
Rotor diameter	5-26 m	The maximum rotor diameter being considered varies between technologies. This is relevant to encounter rate modelling (collision risk) and noise modelling. Each technology type is assessed.
Cut-in speed	0.8 – 1 m/ s	Turbines will be stationary in tidal flows of less than the cut-in speed, which is a relevant parameter for assessing encounter (collision) risk. The cut-in speed varies between technology types (Andritz, 0.8 m/s; SeaGen U20, 1 m/s; Schottel, 0.8m/s).
Seabed clearance from blade tip	6 – 15 m	This is used to calculate the position of the rotor swept area in the water column, which is relevant to the assessment of encounter (collision) risk, in particular which species are more at risk according to their behaviour. Sites suitable for power generation have been identified throughout Fair Head development area (100 in total). Depths within the Fair Head development area (AfL boundary) range from 40 to 75 m. As surface clearance from blade tip is assumed to be 5 and 8 m at all sites and technologies, encounter risk has been modelled using the minimum water depth across all deployment sites (40 m). Therefore the seabed clearance from the blade tip varies between technology types (Andritz device, 9 m or 6 m; SeaGen U20, 15 or 12 m). The Schottel device has four rows of turbines each spaced approximately 5 m apart. The bottom turbines have an average tip clearance from the seabed of 14.6 or 11.6 m.
Surface (LAT) clearance	5 and 8 m	This is used to calculate the position of the rotor swept area in the water column, which is relevant to the assessment of encounter risk, in particular which species are more at risk according to their behaviour. All technologies would be constructed with a 5 m clearance from chart datum
Noise from pin-pile installation in foundations	136 dB re. 1 µPa at 28 m up to 68 pin piles	The SeaGen U20 device will require the use of 2 x 2 m diameter pin-piles to secure it in position. Both the Andritz device and the Schottel device would be deployed using a gravity base where possible. However due to the harsh nature of this tidally energetic environment deployment may require the use of pin-pilling on occasion. Although significantly lower than pile-driving noise (large hammer used), drilling associated with pin-piles will produce noise during installation. The number of piles required

Project parameter	'Maximum' value for impact assessment	Explanation of Maximum Project Parameter
		ranges from 0 to 68 across the options being explored for the technologies used throughout the array. Therefore 68 pinpiles are considered the worst-case as drilling activities would be extended for each device and the impact assessment is focused on this. Measurements of noise from pin pile operations for similar devices have been used for this assessment.
Increase in vessel traffic	approximately 70 vessel movement to and from AfL	Worst-case estimates on vessel movement and durations required for installation include approximately 70 vessel movements to and from ports. The estimated total time for works has been estimated at 1320 days which would be spread over 6 years assuming March to September operations. This represents a moderate increase in vessel movement in the area compared to baseline conditions.

The EIA for the Fair Head Tidal Array highlights two key points in relation to the issues being considered in this report, as follows;

1. The process of defining and assessing the project design envelope can inform a process of refinement, or decisions about final PDE to reduce the predicted level of impact: "*We consider the worst case to be Option 8 (90x Andritz 1MW and 5x Schottel Triton devices), as the mixture of devices used results in the greatest estimated encounter rate (Table 10.21). It is important to note that other array options have been considered, and if implemented the estimated encounter rate for harbour porpoise could be cut by as much as 40%. Mitigation of this kind could lead to a significant reduction in collision risk*." And also: "*All of the turbines modelled were assumed to be mounted such that the turbine blade tips would have a minimum clearance of 5m from the sea surface at LAT. However, a surface clearance of 8m was also modelled to better understand the extent to which this important variable affects encounter rates for each technology, and thus allow an assessment of use as a possible mitigation measure*."

2. The uncertainty about how collision risk scales beyond single devices is one of the main uncertainties for consenting array scale projects: "*If animals were to only respond to turbines at very close range (i.e. only evade them), then it might be appropriate to multiply the estimated single turbine encounter rate by the number of turbines (Table 10.21). However, as the distance between an animal and a turbine increases, avoidance behaviour will become possible. In these cases, the behaviour of an*

animal will begin to be relevant to more than one turbine at a time. If avoidance operates for marine vertebrates at such scales then encounter rates are likely to scale more to the number of turbines at the perimeter approached, rather than the entire array. Due to the uncertainty around avoidance behaviour, only the maximum encounter rate for a specific technology mix has been considered (i.e. calculated by multiplying the estimated single turbine encounter rate by the total number of each turbine type within the array)."

Table 3.6. Estimated encounter rates for technology options proposed for the 100 MW Fair Head Tidal Array Project. Encounter rates for harbour porpoise, harbour seal and grey seal are presented using a 5 m and 8 m minimum clearance between the water surface and blade tips and a 0, 50 and 98 percent avoidance rates. In the absence of encounter rate information for the 1 MW Andritz device we assume both Andritz devices to have similar encounter rates when calculating the overall encounter rates for different array options (Option 7a, 7b and 8).

	100 MW Tidal Array Option	No. Devices				Encounter Rate (per year)								
						0% Avoidance			50% Avoidance			98% Avoidance		
		Streamtec (ARL-3 MW)	Andritz (1.25 MW)	Andritz (1 MW)	Schottel Triton (2 MW)	Harbour porpoise	Harbour Seal	Grey seal	Harbour porpoise	Harbour Seal	Grey seal	Harbour porpoise	Harbour Seal	Grey seal
5 m Minimum Clearance	1a	34				1700	146	187	850	73	94	34	3	4
	1b	34				1700	146	187	850	73	94	34	3	4
	2	30			5	2185	176	215	1093	88	108	44	4	4
	3a	2	76			2000	229	300	1000	115	150	40	5	6
	3b	2	76			2000	229	300	1000	115	150	40	5	6
	4	2	68		5	2485	253	319	1243	126	160	50	5	6
	5a		80			2000	232	304	1000	116	152	40	5	6
	5b		80			2000	232	304	1000	116	152	40	5	6
	6		72		5	2485	256	324	1243	128	162	50	5	6
	7a			100		2500	290	380	1250	145	190	50	6	8
	7b			100		2500	290	380	1250	145	190	50	6	8
	8			**90**	**5**	**2935**	**308**	**392**	**1468**	**154**	**196**	**59**	**6**	**8**
8 m Minimum Clearance	1a	34				1292	146	187	646	73	94	26	3	4
	1b	34				1292	146	187	646	73	94	26	3	4
	2	30			5	1625	176	220	813	88	110	33	4	4
	3a	2	76			1520	229	292	760	115	146	30	5	6
	3b	2	76			1520	229	292	760	115	146	30	5	6
	4	2	68		5	1853	253	318	927	126	159	37	5	6
	5a		80			1520	232	296	760	116	148	30	5	6
	5b		80			1520	232	296	760	116	148	30	5	6
	6		72		5	1853	256	321	927	128	161	37	5	6
	7a			100		1900	290	370	950	145	185	38	6	7
	7b			100		1900	290	370	950	145	185	38	6	7
	8			**90**	**5**	**2195**	**308**	**388**	**1098**	**154**	**194**	**44**	**6**	**8**

3.4.3 Monitoring and mitigation requirements

At the time of writing a consent decision on the Fair Head Tidal Array project has not been taken, therefore any statutory monitoring and mitigation requirements are currently unknown. However the Environmental Assessment report highlighted that the primary objective for any post-consent monitoring programme should focus on assessing avoidance and evasion rates for marine mammals. Large scale avoidance for harbour porpoise may be assessed by deploying an array of acoustic receivers (e.g. CPODs) both within and out-with the Project area (Benjamins et al. 2016). A relative reduction in harbour porpoise detections within the array compared to those made outside would support the argument that large scale avoidance is indeed taking place. The ES also suggested that small scale evasion might be assessed through the deployment of instrumentation on a small proportion of turbines (e.g. built in accelerometers and acoustic imaging technology).

Table 3.7. Summary of approaches taken for PDE definition for multi-technology sites

Site/project	Site type	Approach to PDE and consenting
EMEC	Single device test and demonstration centre	Site wide 'Environmental Appraisal' defines a wide PDE covering standard turbine types and all berths. Only developers whose devices fall outside this envelope would be required to carry out a separate assessment.
PTEC	Array demonstration centre	Site wide assessment carried out covering a range of array options and all technology types to gain consent for the whole operational period of the demonstration site.
West Islay Tidal Farm	Commercial array development: "Technology neutral"	Two models of TEC type were evaluated in the impact assessment – devices were chosen to be representative on the understanding that they could be substituted for other devices within the parameters defined.
Fair Head Tidal Array	Commercial array development	Three TEC types were considered as the most likely types to be installed at the site, although acknowledged that they could be

		substituted for other devices within the parameters of the design envelope defined. A total of 12 array design scenarios were assessed.

3.5 Other sectors – offshore wind

Flexible project envelopes are a standard approach used in the consenting of offshore wind farms. A wind farm would typically consent on a design envelope defined by turbines of a maximum rotor diameter, hub height and sound power levels etc. Parameters unlikely to be a key consideration in assessing environmental impacts such as generator, gearbox and control configuration specifications are generally not included within the scope of the PDE considered within the EIA.

The key project parameter in offshore wind relating to the potential for marine mammal impact is the method of turbine foundation installation. Applications for consent typically occur before the detailed ground condition and geotechnical surveys required to agree on foundation design and installation method parameters and broad envelopes are often defined containing many options. The flexibility required by offshore wind project developers in the future options for turbine foundation types and installation methods can often lead to similar issues as experienced in the tidal sector. For example, to 'future-proof' consents, and in recognition of an industry trend for larger turbines, developers often define maximum project envelopes based on large turbine sizes which may not even exist at the time of application, using maximum hammer energy parameters that have not been used previously

Basing consent applications and the supporting assessments on maximum parameters, with limited empirical information on the potential for impact across projects can result in a multiplication of precautionary assumptions and create potentially unrealistic cumulative and in-combination worst cases across a number of PDE parameters. This can lead to consenting risks and concerns particularly about predicting cumulative levels of impact if this multiplication of worst case occurs across multiple projects within a region. Recent operational experience on several offshore wind farm projects has revealed that parameters in relation to pile driving for foundation installation are often much lower than those assumed in the impact assessment and on which consents are based (Orsted 2018) . There is therefore a pressing need to ensure that this learning is fed into the process of defining project envelopes to ensure more realism is achieved while still ensuring a degree of future proofing of consents without the requirement for repeated consent variations.

Principles identified in this section;

- Decisions about Project Design Envelopes should be based on a good understanding for the consenting and governance regimes for the activity or activities in question.
- The consenting authority(ies) must be able to meet their legislative responsibilities in considering the effects of the proposal.
- It is important to understand the degree to which consenting and governance regimes allow for flexibility in design envelope to be retained or details to be finalised post-consent. This includes an understanding for the legal responsibility for the discharge of consent conditions.
- PDEs which have fully considered environmental issues and 'designed out' significant issues are more likely to have an easier route to consent than those driven purely by engineering and technical considerations.
- Decisions about PDEs should be based on the best available evidence about impact pathways and sensitive receptors to avoid overly precautionary or unrealistic worst case scenarios.
- Worst case scenarios should be as realistic as possible. They should achieve balance between precaution and pragmatism about what is practically feasible or likely and reflect the likely risk that the project or elements of it might cause in unacceptable impacts.
- Applicants should base decisions on refinement vs flexibility in the PDE (or elements of it) on an understanding for the implications for consenting. In general, the less well-defined the PDE, the more challenging the consenting process is likely to be.
- Refinement of the PDE should be an iterative process during the pre-application stage of a project. Feedback loops should be built to formalise the relationship between the refinement of the PDE, evidence gathering activities to support the EIA and production of the Environmental Statement.
- Identifying key environmental impacts and receptors early in the process of defining a project envelope should reduce the potential for over-complication in identifying and assessing multiple worst case scenarios or unrealistic worst case scenarios.

4 Case study

4.1 Project Description

This case study is based on a theoretical multiple technology tidal energy grid connected facility in Welsh coastal waters. The facility will provide communal infrastructure such as export cables and substations, for tidal technology developers to install and test single devices and small arrays. As the aim is to allow for the installation and testing of multiple technology types, the consent application needs to be based on a flexible design envelope. The total capacity of the test facility will be up to 100 MW.

The theoretical test facility is situated off the coast of Anglesey in north-west Wales, in the tidal channel between the mainland of Anglesey and the Skerries Islands to the north west. The facility covers an area of 40 km^2 and is located approximately 1 km at its nearest point from the coast.

Section 36 consent and a Marine Licence would be required for the test facility. If the intention is for the facility to be fully 'pre-consented', these consents would need to cover the installation, operation and decommissioning of all TEC arrays. Otherwise, individual consents may be required for technology deployments within the facility. Deployments may also require an EPS licence for cetacean disturbance or injury.

To retain the required flexibility, the test facility design envelope would need to incorporate a range of device types given the range of feasible and likely TEC designs. Based on a review of the current state of TEC technology there is a need to determine an inclusive design envelope based on:

- Deployed capacity may be up to, but will not exceed 100 MW;
- Surface floating, midwater column and seabed mounted technologies will all be included in the suite of technologies potentially installed at the site;
- Large scale surface piercing, pile based technologies (e.g. SeaGen) will not be included;
- It will include seabed mounted technologies;
- Drilled pile, gravity base and anchored foundation types will be included; and
- Surface piercing, monopile mounted substation/hubs will be included.

4.2 Sensitive receptors – marine mammals

A number of marine mammals have been recorded in the waters around north-west Wales with the main species being harbour porpoise, bottlenose dolphins, and grey seals. A number of other species have also been recorded in smaller numbers including minke whales, Risso's dolphin and common dolphin. **Error! Reference source not found.**Table 4.1 presents a summary of information on each of the relevant marine mammal Management Units (MUs), including their likely sensitivity to impacts.

Table 4.1. Sensitivity classification of Welsh marine mammal populations. Management units are from IAMMWG (2015) for cetaceans and from (IAMMWG 2013) for grey seals. Sensitivity rating and the rationale is taken from Sparling et al. (2016).

Species	MU	MU abundance (95% CI)	Sensitivity	Presence at site and distance to nearest SAC with species as qualifying feature	Rationale
Grey seal	**South west England and Wales**	**~6000**	**Low**	Present at site, approx. 60 km to nearest SAC (Pen Llyn a'r Sarnau SAC, qualifying feature but not primary reason for site selection)	Moderately large population Favourable condition (increasing population) Moderately fast maturing species Moderately long lived Wide ranging and mobile species
Bottlenose dolphin	**Irish Sea**	**397 (362-414)**	**High**	Present at site, more commonly in winter. Approx. 60 km to Pen Llyn a'r Sarnau SAC, (qualifying feature but not primary reason for site selection). Approx. 100 km to Cardigan Bay SAC (primary reason for site selection)	Small population Favourable condition (stable population) Moderately slow maturing Moderately long lived Not a highly mobile population
Harbour porpoise	**Celtic and Irish Sea**	**104,695 (56,774-193,065)**	**Medium**	Present at site, more commonly in winter. Site within cSAC (North Anglesey Marine cSAC).	Large population Favourable condition (unknown whether stable or increasing)

					Moderately fast maturing species Moderately long lived Wide ranging and mobile species

The portion of the bottlenose dolphin population regularly using the Cardigan Bay SAC is known to move around the Welsh coast (Veneruso and Evans 2012). Connectivity between Cardigan Bay and north-west Wales has been demonstrated from dedicated photo ID studies (Veneruso and Evans, 2012) which suggest that bottlenose dolphins from Cardigan Bay move north during the winter months. 95% of animals recorded during winter surveys in Anglesey (December-February) had been matched previously in Cardigan Bay. Although a number of identified animals known to range north of the Llyn Peninsula have never been recorded in the SAC (Veneruso and Evans, 2012).

There are a number of grey seal haul outs within foraging distance (~100 km) of the Site, including the Llŷn Peninsula and Sarnau SAC and a number of small haul outs along the Anglesey coast (Westcott and Stringell 2004, Stringell et al. 2013), although there are no recent accounts of seal haul outs in north-west Wales.

There are a number of elements of the PDE which would require an understanding of how marine mammals use the test facility area in order to define the worst case parameters (e.g. see discussion around impact pathways in Section 2). For example, the depth distribution of marine mammals is important in determining which type of device represents the worst case in terms of collision risk. Information to inform this for the area could be available from either site specific investigations, or by extrapolation from studies on the same species in other parts of the UK, preferably other tidal areas. A previous study of grey seal juveniles in tidal areas around Wales found that seals spent the majority of their time either at the surface or at the seabed with little time spent in the mid water depths (Thompson 2012). This is generally true for adult grey seals tagged in other areas also (SMRU, unpublished data), so it would be reasonable to assume they would demonstrate this behaviour within the test facility area.

4.3 Project Envelope Definition

This section identifies the primary impact pathways that would require consideration in the case study example test site and drawing from the discussion in Section 2 (Impact Pathways) highlights which elements of the PDE are informed by each.

4.3.1 Collision

Given the potential for marine mammals to be present within the test facility area, it is likely that a quantitative collision risk assessment will be required as part of any EIA and HRA to support consent application(s). Faced with such a complex picture of how collision risk varies with the design features of devices and arrays (discussed in section **Error! Reference source not found.**), defining a worst case P DE for the range of possible device types and the potential variability in facility layout is not straightforward.

The approach to PDE definition will clearly depend on whether elements of the envelope are effectively 'hard constraints'. For example, if individual technology developers/ device types have been determined for the test facility, or there are other physical constraints driving the placement of devices, less flexibility will be required/possible within the PDE.

There is not a simple scaling relationship between collision risk and any single feature of TEC types (see Section 3.2). The assessment of collision risk would therefore need to quantify risk based on the worst case parameters for every possible TEC type. This might be achieved by calculating the collision risk posed per device and then standardising per MW across each of a number of generic TEC types available. Alongside consideration of any identified constraints and preferences by the facility manager or individual technology developer(s), this approach could assess the collision risk posed by a variety of proposed array and device allocations among lease areas. This could help determine a realistic worst case scenario for berth and device allocation within the facility and so inform the final PDE.

The simplest worst case scenario is that 100% of generating capacity is provided by the TEC type with the highest standardised collision risk per MW. Whilst this approach might be reasonable for technology neutral commercial projects likely to involve a single technology type, it would be unrealistic for a test facility to base the PDE on 100% of one device type. Table 4.2 presents a range of hypothetical turbine types being considered for installation at our case study test facility. These have been selected and configured to represent a range of currently available horizontal axis type turbines and includes moored and bottom mounted devices, single rotor and multiple rotor designs.

Collision risk models have not been widely developed or used for TEC designs other than horizontal axis designs. One exception is the simulation based collision probability approach developed by SMRU Consulting for collision risk assessments for the Minesto tidal kite device (Booth et al. 2014, Booth et al. 2015). In order to calculate a standardised collision risk score for non-horizontal axis designs, this approach could be modified and extended with the use of additional models. For the full assessment of collision risk at a multi-technology test facility, including such non-horizontal axis designs, the development of comparative means of quantifying collision risk would be a priority. This highlights a general principle in that where quantitative assessment methodologies are generally applied, there needs to be a comparative means of quantifying the risk across a range of potential options for the PDE in order to determine and assess the worst case.

In order to calculate a standardised collision risk per MW for each TEC type, the ERM (Encounter Rate Model) developed by Wilson et al. (2007) has been applied, using the spreadsheets provided by Scottish Natural Heritage (2016). All site and species parameters were held constant between devices. The results are shown in Table 4.3. The encounter rate (predicted number of annual encounters between rotor blades and animals) is calculated on the basis of animal density, swim speed and rotor swept area and rotor speed, assuming no avoidance behaviour. In order to compare across device types in a standardised way, the TEC with the maximum calculated encounter rate per rotor was scaled to an encounter rate of 100, with the per-rotor values for the remaining TEC types scaled proportionately. Therefore, although the relative differences between devices are accurate, the absolute values do not reflect real numbers of animals at risk.

Table 4.2. Five different hypothetical tidal turbine types used to define Project Design Envelope for collision risk. NB these are all horizontal axis type turbines, as yet there are no standardised models for other types of turbines.

TEC	Type	Rotor diameter	Rotor minimum depth	Max rotor speed (rpm)	Number of blades per rotor	No of rotors per device	MW per device

A	Surface mounted, moored, dual rotor	16	6	16	2	2	2
B	Seabed mounted, single rotor	18	6	14	3	1	1.5
C	Multiple small rotors on seabed moored platform	5	5-20	8	2	40	2
D	Seabed mounted triple rotor	11	9.5	18	3	3	1
E	Single rotor, seabed moored	23	6	11	2	1	1

Table 4.3. Calculated annual encounter rates for harbour porpoise and grey seals from the TEC types in Table 4.2.. Encounter rates are presented per rotor, per device and per MW for both harbour porpoises and grey seals. Calculations have not been presented for bottlenose dolphins due to the lack of a density estimate at the appropriate scale.

TEC	MW per device	Harbour porpoise encounters per year, per device[6]	% of harbour porpoise at "at-risk" depth	HP encounters per MW	Ranked collision risk per MW harbour porpoise (1 = highest)	Grey seal encounters per year, per device	% of grey seals at "at-risk" depth	GS encounters per MW	Ranked collision risk per MW grey seal (1 = highest)
A	2	0.64	58	0.32	5	0.19	20	0.09	5
B	1.5	0.58	61	0.39	4	0.17	23	0.12	4
C	2	1	50[6]	0.5	3	1	37	0.5	1
D	1	0.92	44	0.92	1	0.25	14	0.25	2
E	1	0.61	66	0.61	2	0.24	32	0.24	3

Across both species, TEC type E has the highest 'per rotor' collision risk. This is due to the larger rotor diameter, coupled with its position in the water column; with the rotor swept area encompassing a relatively high proportion of the animals' depth distribution compared to the other TEC types. For harbour porpoise type E rotors encompasses 66% of the harbour porpoise vertical distribution, for grey seals, although type C has a slightly higher proportion of overlap with grey seal depth distribution (37% compared to 32%), the larger rotor diameter still results in this device typ ebeing highest per rotor. Considering devices with multiple rotors, for harbour porpoises, TEC type D has a higher 'per device' and higher 'per MW' collision risk than TEC type E, due to the multiple rotors per device. The smaller rotor size of 11 m compared to 23 m does not compensate for the additional rotors per device. Type C has the highest 'per device' collision risk, because of the high number of rotors per device (40). For porpoises this results in an intermediate 'risk per MW' compared to devices which are only 1 MW, however for grey seals, the relatively greater degree of overlap between the multiple rows of rotors

[6] Highest value scaled to 1, remaining values scaled proportionately – the highest value over both species ERM calculations was harbour porpoise for TEC type C – all other 'encounter per device' values have been scaled proportionately to this i.e. the value for harbour porpoise encounters for TEC B is 58% of the value for TEC C.

and the depths at which grey seals are found (relative to the other devices) means that this device remains the highest per MW. These results highlight the importance of taking all design envelope and animal parameters into account and that there are no simple relationships between any single turbine parameter and collision risk.

This also highlights that there is the potential for differences in worst case between species. For harbour porpoises the option providing the most flexibility for the project from the collision risk perspective would be to define the PDE based on 100% of TEC type D. For seals, the worst case option would be a site based on all TEC type C.

Single device design envelopes are much more likely for a technology neutral commercial site developer. However for a test site, it is more likely that other constraints (e.g. MW to be assigned to each potential developer) will need to guide the PDE definition. If the total 100 MW was split equally between these 5 TEC types then the PDE might look like as shown in Table 4.3. This assumes no differences in expected animal densities or depth distribution across different parts of the test facility area.

A PDE based on 100 MW of TEC type D would result in a relative predicted total site-wide standardised encounter rate for harbour porpoise of 92. This can be compared to the equivalent site-wide value of 57 (Table 4.4), which would result from an equal allocation of MW of generation capacity across all 5 TEC types within the test facility. For grey seals, given the difference in risk posed by type C compared to the rest, the difference is even greater. A design envelope based on 100 MW of device C would result in a predicted encounter rate of 100, whereas one where each device type was allocated 20 MW each would only be 24. Clearly there will be a number of other constraints that will need to be taken into account when deciding how to define a PDE for the assessment of collision risk, and these examples represent very simplified approaches – but these examples are illustrative of the implications of assuming absolute worst case values to ensure complete flexibility.

The process and rationale for how the significance of predicted impacts are assessed within consent decisions may also be an important consideration for PDE, particularly for impact pathways like collision risk where thresholds of impact may exist for relevant marine mammal populations. In Scotland and Wales, the concept of PBR has been used to inform consenting of tidal energy projects. The PBR concept (Wade 1998) is used to define the maximum number of mortalities that a population can withstand and still remain ‘healthy’ and sustainable. If such an approach, or indeed other population modelling approaches such as forms of Population Viability Analysis (PVA) are used to set population impact thresholds, then the definition of a PDE for collision assessment may follow an iterative process, whereby calculations of collision rates can be compared with thresholds and further refinements made in the PDE if required. This process will be easier if thresholds of acceptable level of impact can be defined and agreed by all parties.

Where there are uncertainties in the types of TECs to be installed at the stage of PDE definition, the parameters for a collision risk PDE will need to draw on the worst case across a range of turbine types – e.g. selecting the largest diameter blades with fastest tip speeds, in the part of the water column where the species at the site spend most of their time. As is common in the assessment of offshore wind farms, the selection of these features may lead to the specification of a combination of parameters that either do not currently exist or even may be technically unfeasible – turbine engineering expert input is therefore crucial at an early stage of PDE to ensure as realistic as possible definition of key parameters which have the potential to influence such a crucial aspect of the consenting process (i.e. marine mammal collision risk). It would be recommended that the tidal industry take steps to avoid the situation commonly encountered in the offshore wind industry where estimates of the level of impact (particularly when assessed cumulatively across projects) can possibly become unrealistic and precautious.

Table 4.4. Collision risk assessment for PDE worst case scenarios for a 100 MW test facility where 100 MW site wide capacity is split equally amongst 5 different TEC types. The values are standardised rate of encounters per year based on the standardised ERM values per rotor displayed in Table 4.3. The total for this combination is shown for comparison with the total value derived for each species from a worst case PDE based on 100% of the worst case TEC type.

TEC Type	Standardised Harbour porpoise encounter rate associated with 20 MW	Standardised grey seal encounter rate associated with 20 MW
A	7	2
B	8	2
C	11	10
D	18	5
E	12	5
Total	**57**	**24**
WC TEC PDE (all worst case)	**92**	**100**

4.3.2 Disturbance/Displacement

Construction

The relationship between the PDE features relating to construction and the potential for marine mammal impact is much more straightforward than for collision risk. The worst case scenario for construction and installation activities is likely to be the requirement for percussive drilling for pile installation for the foundations of TECs and therefore the worst case scenario is one which requires that all device foundations are drilled (given the rocky substrate at typical tidally energetic areas, pile driving is unlikely). Drilled foundations may be either monopiles or pin piles depending on the structure. Both foundations for seabed mounted devices and mooring structures for buoyant/mid-water devices may require pin pile fastening to the sea bed. For the purposes of this study, noise monitoring from recordings made during previously drilled installations have been used to predict the potential sound. This is the approach taken by PTEC, detailed in Subacoustech (2014). The worst case modelled was the use of a 520 kW percussive drill to install pin piles of up to 4 m in diameter. Subacoustech Environmental used measurements of the same type of percussive drilling technique (Subacoustech Report No. 810R0204 and 849R0108) in the PTEC assessment, where a smaller drill was used than the ones proposed for PTEC, for example measurements taken of drilling in Orkney installed a 0.9 m pile using a drill power of approximately 52 kW (Subacoustech, 2014). In order to estimate the expected noise from larger piles the assumed power of the drill necessary to install the three sizes of pin pile was extrapolated using measured drilling data from Subacoustech Environmental's database, assuming the manufacturers recommended power for the drill being used. The Subacoustech report provides very little detail on this extrapolation although it is assumed that a relationship between drill power and emitted noise was fitted to existing data (although no details of this relationship or model fit is provided) and then this relationship was used to predict the noise from larger power drills where data was lacking. This approach could be replicated to define the demo site construction noise worst case scenario although it is recommended that the existing data and the model fit that this extrapolation is based on, is provided to allow an assessment of how much of a data gap this represents. As more devices are deployed on other projects, valuable empirical data on the noise produced during installation will inform this process.

The worst case scenario in terms of the duration of the installation activities will depend on the likelihood that more than one foundation can be installed simultaneously, which will depend on the availability of suitable vessels. If multiple foundation installation is feasible, there will be a trade-off between the total size of the ensonified area at any one time and the overall duration of the activities. Concurrent installation will result in a shorter overall disturbance period, but a larger total ensonified area over which animals may be disturbed compared to single foundation installation. There is likely to be some overlap in the ensonified zones for simultaneous installations, which means that overall impact zone of two concurrent installations events will be less than double the area of a single installation. Final PDE definition will require an assessment of whether concurrent installation of more than one device foundation is likely, again emphasising the importance of ensuring that engineering and technical feasibility is considered at PDE stage.

Marine mammals also have the potential to be disturbed by the noise and activity created by construction vessels and other construction activities. There is unlikely to be significant variation in the types of vessel carrying out these activities, regardless of the variability in TEC type, so it would be reasonable for the worst case scenarios to be determined by the total maximum number of vessel movements and the overall duration of activities.

Operation

The nature and extent of disturbance during operation are more difficult to predict given that so little is known about how marine mammals will to respond to multiple devices. The only empirical data from an operating turbine suggests a small degree of local avoidance in harbour seals of up to approximately 250 m from the SeaGen turbine (Sparling et al. 2017a) In addition, data recently collected as part of the NERC RESPONSE study suggests that seals may respond to playbacks of underwater turbine noise out to ~300 m (Hastie et al. 2017). However, there is uncertainty about how animals may respond to an array of devices (and it is important to note that not all seals avoided to the same extent during these studies). In the absence of empirical data, the simplest worst case assumption is that animals will avoid individual turbines as a result of the noise that they emit and will respond at ranges predicted by published thresholds of avoidance.

Assessment using this approach relies on the availability of data which links the different TEC types to their operational noise footprint. Source data for the prediction of operational noise impact zones is generally lacking. Subacoustech (2014) based the modelling of the noise emissions of different TEC designs on previous measurements of the 300 kW SeaFlow device in Lynmouth (Parvin et al. 2005) and the 250 kW Open Hydro device at EMEC (Parvin and Brooker 2008). Subacoustech (2014) note that the operational noise levels increase with the size of the turbine based on these previous studies, and similarly to the approach for drilling noise, they extrapolated this relationship to predict the likely noise levels of larger turbines proposed in the PTEC quantitative noise impact assessment. This approach could be repeated for the case study with the addition of further data that is now available from the operating SeaGen device in Strangford Lough and from other devices measured at EMEC. As the Subacoustech report points out, this extrapolation is caveated with the fact that different turbine designs are likely to result in different noise characteristics. For example, the tonal characteristics of noise from the gearbox of the various different TEC designs, or the different types of rotors (open, ducted, transverse, etc.), may be different from the devices previously measured. In order to ascertain accurate frequency characteristics for the proposed tidal devices, specific operational noise survey data would be required for each of the device types to fully define the worst case project envelope. In the absence of this data, assumptions have to be made based on the available measured data from other devices and locations. It is important that any assumptions that are to be made in the assessment are transparent, that the limitations and uncertainties are clearly described and that agreement is sought on these with key stakeholders throughout the process.

An alternative approach is to predict the near-field sound that will be generated from each TEC type based on engineering parameters. The propagation of these source levels with distance from the turbine can be predicted using standard propagation models. This approach was taken for the Fair Head Tidal impact assessment: the near field sound fields produced by each device were calculated using a finite element model and then a three-dimensional sound field modelled extending up to 20 km from the devices. The design scenarios likely to produce the highest noise levels were identified and assessment was based on these as a worst case.

Whichever approach is chosen, it is important to take ambient noise into account to determine where modelled or predicted operational noise is likely to be masked by ambient noise and therefore undetectable by marine mammals. Modelling also needs to be site specific so that propagation conditions are taken into account. Factors that influence the distance over which sound will travel include depth, seabed substrate and roughness, coastal topography,

There are two primary options for defining the worst case project design envelope for operational noise:

1) The assessment could take the approach taken in the PTEC assessment where, there was the potential for up to 100 devices at unknown locations within the development site. A relatively simple, yet conservative approach was taken to apply the modelled maximum impact range

from the loudest operating device as a buffer around the entire development site and an assumption was made that this whole area (site plus buffer) was the area over which marine mammals would be displaced. This approach could enable a calculation of the number of animals potentially displaced from the site during the whole operational period. This number can be expressed as a proportion of the population of the relevant management unit to indicate the potential magnitude of the displacement.

2) Indicative lease area and berth layouts could be defined, enabling impact zones to be modelled around individual proposed TEC array locations based on information on research assessment, device types and required device spacing.

Approach 1) will afford the highest degree of flexibility for build out, but will be the most conservative and result in the largest predictions of impact. Approach 2) will provide a more realistic assessment of potential impact but requires much more work to define realistic worst case scenario layouts which are not too restrictive. Until the work is carried out for #2 it is difficult to assess how different the outcome might be, and therefore one potential outcome is a more restrictive PDE with no reduction in impact. In this respect this is similar to the two approaches described in the previous section for collision risk. Any approach requiring detail about site layout is likely to require resource assessments across the test facility, clarity on the potential total number and layout of test areas or berths and information on the potential number and layout TEC devices within these areas. Therefore for a more realistic and (potentially) less precautionary assessment more information is needed.

Where cumulative effects are potentially significant (i.e. where there may be a number of different schemes to consider that may all have the potential to affect the same population, caution must be exercised when defining highly precautionary worst case parameters – when assessing cumulatively across several projects, this precaution will be multiplied, potentially resulting in highly unrealistic predictions of cumulative effect.

Table 4.5 presents a basic illustration of approach 1) as applied to the test facility. It is important to note that the adoption of the dB_{ht} metric here has not been informed by a thorough review of the most appropriate behavioural threshold for predicting a behavioural response but has been adopted for ease of replicating the PTEC approach for illustrative purposes. There is currently limited empirical support for this metric in studies of marine mammal behavioural response and alternative thresholds and approaches could be adopted in any assessment. A complete review of appropriate behavioural response thresholds is outside the scope of this report.

Table 4.5. Illustrative example of a worst case displacement impact assessment, assuming a buffer around the whole site equivalent to the maximum impact range for strong avoidance from the PTEC marine mammal impact assessment (Subacoustech, 2014).

Species	Max impact range (m) for strong avoidance (90 dB_{ht}) for 24 m diameter turbine	Total displacement area (km^2)	Density, animals per km^2 (95% CI)	Number of animals potentially displaced (95% CI)	Percentage of the MU population (95% CI)
Harbour porpoise	610	48	0.575 (0.0.115-1.167)[7]	27.6 (5.5-56.0)	0.0581 (0.000393-0.000896)[8]
Bottlenose dolphin	95	37	0.008 0.0014–0.0199)[9]	0.3 (0.0-0.68)	0.0485 (0.00013-0.001855)[10]
Grey seal[11]	75	37	0.253 (0.0047-0.5053)[12]	9.4 (0.2-18.7)	0.156 (0.000293-0.003119)[13]

Given the limited evidence base on how marine mammals are likely to respond to multiple devices, of their movement patterns in most areas, barrier effects are difficult to assess, or consider in terms of the definition of a worst case design envelopes. Aligned with the approaches outlined above for displacement, the simplest worst case assumption is that animals will not pass through the entire potential noise impact footprint, though they may travel around the area if the desire to transit through the general area is strong enough. The assessment will rely more on an understanding of whether the area is important for transiting marine mammals and therefore whether preventing the

[7] Density estimate from Shucksmith et al. (2009)

[8] Celtic and Irish Sea MU (IAMMWG 2015)

[9] Density estimate from SCANS III Block E (Hammond et al. 2017)

[10] Irish Sea MU (IAMMWG 2015)

[11] Value presented for harbour seal in Subacoustech (2014) assumed to be similar for grey seal

[12] Density estimate from grey seal at sea usage data (Jones et al. 2015)

[13] The South and West England and Wales MU (SCOS 2016)

movement or transit of animals will result in significant detrimental effects on individuals and consequently on populations. One way to explore the potential for impact would be to estimate the additional energetic requirement of swimming around the impact area. It is unlikely that at the scale of the test facility, this would represent a significant additional energy requirement. However this could be different for very large arrays.

There is limited information on movement patterns of marine mammals through our hypothetical test facility. Grey seals are likely to move through the area while moving between the haul outs associated with the Pen Llŷn a'r Sarnau SAC to the South, and haul outs along the North Anglesey coast and along the north Welsh coast (and indeed further afield). But given the openness of the habitat to the west of the test facility area it is likely that seals will still travel between these areas even if they are displaced from the test facility footprint. A worst case scenario for barrier effects for seals (subject to final lease area position and array layout) would have to assume movement around the outside of the Anglesey Skerries. Bottlenose dolphins are known to move north from Cardigan Bay to Anglesey and north Wales in the winter months (Veneruso and Evans, 2012) and therefore the test facility could represent an area used for bottlenose dolphin transit. However, the openness of the habitat to the west is likely to allow alternative routes if transiting dolphins are displaced from the channel between the Anglesey Skerries and the mainland. Harbour porpoises are likely to be found in the test facility area year round but no information exists on wider movement patterns, but an understanding of the availability of alternative habitat in the vicinity would be required to assess the potential consequences of displacement at the scale of the case study test facility.

The potential for barrier effects is an issue where site layout may be particularly important. If the potential for barrier effects is a concern, then individual tenant lease areas within the test facility could be designed with buffers around them to allow the passage of transiting marine mammals, this would reduce the potential for barrier effects and allow a less conservative definition of the worst case scenario. The size of these buffers could be designed according to the modelled impact zones to provide confidence that animals would use them – lease areas would need to be at least the distance of the modelled impact zones (for the key species) apart (in the above example, 610 m apart for harbour porpoises, 95 m for bottlenose dolphins and 75 m for grey seals). However, introducing buffers could increase the overall footprint of the site which could have the potential to increase the potential for disturbance – this is another example of interactions between different impact pathways that need to be considered when developing project envelopes iteratively.

There is no general, 'best-practice' approach for assessing the potential consequences of any disturbance to individuals and ultimately at the population level. As a tool to help in the assessment of the impact of individual displacement during offshore wind farm construction to marine mammal populations, the interim Population Consequences of Disturbance (iPCoD) framework has been developed for the assessment of disturbance to UK marine mammal species[14] (Harwood et al. 2014, King et al. 2015, Booth et al. 2017) and a variety of population modelling approaches have been used to assess the impact of displacement to birds from offshore wind farms (Green 2014, Cook and Robinson 2017). However there are no examples of a quantitative population level assessment for the displacement of marine animals as a result of operational tidal energy projects. This is probably because of the relatively small scale of the devices consented to date. It is difficult to know at what scale would population level effects become apparent or of concern but population modelling tools could be used to explore this question. However as with many population level assessments, there is a lack of data linking individual responses to changes in vital rates (survival, fecundity etc.), therefore any attempt to quantify population level impacts will be associated with high levels of uncertainty. The iPCoD model was developed with piling noise in mind so would need to be adapted for use with long term habitat displacement as a result of tidal turbines.

An alternative may to develop more individual based modelling approaches, similar to DEPONS which is a simulation/individual based model which uses data from studies of harbour porpoise behaviour and energetic principles to predict the responsive movements and energetic consequences of those movements for individual porpoises in response to piling noise – by simulating many individuals over several years, the consequences for the population emerge from the impacts to simulated individuals. Data from the monitoring around individual turbines (e.g. Sparling et al. 2017b) or from playback response studies (Hastie et al. 2017)could be used alongside telemetry data on baseline movements and data from energetics studies to simulate individual behaviour and to predict the energetic consequence of avoidance behaviour, and ultimately population level changes as a result.

5 Synthesis

Developing PDEs for multi-technology marine energy projects to enable an assessment of the impacts on marine mammals is a complex task. There is a trade-off between retaining the required flexibility

[14] Primarily developed for harbour porpoise and seals.

and the degree of precaution necessary when defining a PDE. A broad PDE, e.g. at the earlier stages of PDE definition, needs to be more conservative, involving more worst case assumptions and will likely result in higher predicted impacts. This may be restrictive in areas where there is little environmental 'headroom' and lead to more onerous restrictions and requirements for monitoring and mitigation. However, feedback loops in the process of defining the PDE could enable this initial wide PDE to be refined in light of the likely operational restrictions and licence conditions it may impose on the project. **This highlights a clear need for Project Design to be an iterative process involving both engineering and environmental input, and to involve considerations of environmental impact at as early a stage as possible**.

Often in marine energy projects (and marine construction projects in general), the consideration of environmental constraints in project planning comes in at far too late a stage to meaningfully influence project design. There are two common implications of this;

1. There is often little flexibility by this point to alter key parameters to reduce risk (e.g. aspects of individual turbine design in relation to site specific issues); and,
2. Project budgets may not have enough scope for the level of monitoring and potentially mitigation that might be required as a result of environmental risks and uncertainties.

The opportunity to use the process of defining an initially broad project envelope to help refine and reduce impacts of the project, so developing understanding of how the features of the PDE influence the potential for impact as the PDE is refined may inform choices of lease area layout, device choice and device spacing. It may be a good idea to have a formal framework for the development of the PDE in this manner – involving the project developers, environmental specialists and Regulators and their Advisers. This could replicate some elements of the Evidence Plan process for Nationally Important Infrastructure Projects – which is an iterative process whereby elements of assessments, the information required, the evidence gathered, the methodology for assessment are discussed and agreed among the developers, their environmental specialists, the Regulators, statutory advisers and other key stakeholders.

There is also a clear need to develop a better understanding of how the features of the PDE influence predictions of impact and how individual elements of the PDE may interact to influence impacts. For each impact the features (receptors, parameters) most important in determining the magnitude and significance of impact should be identified. These should then be used as a basis to define PDE scenarios for assessment. This would also improve consistency in the way that worst case scenarios are defined between projects (e.g. an assessment of vessel related impacts based on total numbers of vessels in one case, whereas total vessel movements in another).

Different elements of the PDE will influence different impact pathways in different ways and there are likely to be trade-offs, inconsistencies and interactions between different elements of the PDE and different impact pathways. For example the noise emitted by underwater turbines may cause displacement but it may also alert animals to the device presence and therefore reduce collision risk. Similarly the worst case for displacement may predict that all animals are displaced from the area yet the worst case for collision assumes that there is zero displacement. Clearly both of these scenarios cannot be realised within the final project design. A practical example of this scenario can be seen in the Fair Head impact assessment – out of 8 potential scenarios worst cases for underwater noise leading to potential displacement were 2, 4 and 5b, whereas the worst cases for collision risk were 8, 4 and 6. If both of these combinations result in no significant impacts then there is no real issue as whatever will be built will not exceed the worst case for either. However if concerns about the worst case for one impact pathway results in the requirement for refinements of the envelope, care is required to ensure that any subsequent changes do not influence other receptors or impact pathways. In cases such as this there may need to be a decision about which impact pathway is going to be the determining factor for final project design, i.e. which is more likely to prevent a consent being issued.

At present each impact pathway and receptor is assessed largely in isolation and therefore can result a multiplication of precautionary PDEs and an overall unrealistic and implausible picture. However given the need to define the worst realistic case for each impact pathway it is difficult to see how the PDE could be harmonised across different elements in this case. In practice there is no expectation that the PDE would be the same for all elements of the assessment. However, where there may be an issue with this is if mitigation is considered to reduce impacts for one particular receptor or impact that may actually increase the potential for impact for another. Therefore it is crucial that the consequences of any refinements to PDE or any mitigation is considered across all potential receptors and impact pathways. We are likely to have to accept that overall the PDE envelopes defined for EIA are implausible, as this is necessary to ensure that each impact pathway is properly assessed in light of the flexibility required. However, there is the opportunity to carry out a second stage assessment, prior to determining licence conditions specifying mitigation and monitoring requirements once there has been more detailed investigation into site specific constraints and an ability to define a more detailed and specific Project Design and identify clear, achievable and robust mitigation and/or monitoring. However as noted above, any conditions on mitigation need to be implemented in consideration of their effect across all impact pathways and receptors.

There is a difference in approach between technology neutral site developers and developers of test and demo facilities in developing broad PDEs for consenting. The latter require a broad PDE to cover the wide variety of device types and array layouts which may be deployed during the lifetime of a test facility. The former are likely to opt for the deployment of a single technology type (or a small number of alternative devices) but flexibility is required because the procurement and contractual process cannot be completed before consent is issued. It is generally easier to define a PDE where the technology at a given site may be all one type or other and it is often a case of deciding which technology type provides the worst case for each impact pathway and basing the assessment on that. It is more complex where multiple technologies will be deployed at a single site. Both types of energy projects require a degree of flexibility as a result of uncertainty (at pre-consent stage) over ground conditions in the extent that they might influence design envelope parameters.

This work has highlighted that there are a number of crucial knowledge gaps in areas relevant to the definition of PDEs for marine energy projects, particularly where flexibility is required around the total number of devices, the methods of installation and their likely noise outputs. In particular, our lack of understanding of how marine mammals may respond to multiple devices makes it difficult to define a worst case PDE across a range of impact pathways as we don't know which features of project design may serve to reduce risk and which may result in the highest levels of risk.

This work has also highlighted shortcomings in the methodology currently used to carry out quantitative collision risk assessment, the simple linear multiplication of the risk posed by one device to the risk posed by many devices, is likely to be over simplistic. Therefore we would recommend that research into the scaling of collision risk is carried out. This could take the form of empirical measurement at existing array projects (e.g. MeyGen) to understand how individuals behave around multiple devices. This could be combined with individual based simulation modelling to explore the sensitivities of a range of different behavioural scenarios.

There are also limited tools available to assess the collision risk posed devices which differ from horizontal axis rotor designs, such as transverse axis rotors. Similarly this is an area requiring development to ensure that the prediction of the potential magnitude of collision risk can keep pace with the rapidly evolving technology types being proposed for deployment at marine energy sites.

Principles identified in this section;

- Early consideration of the key likely impacts of a project on receptors (e.g. important or protected species, habitats and landscapes) will identify the significant environmental issues on which the refinement of the project envelope should focus. The earlier this is done in the process, the easier it will be to ensure the envelope has accounted for key environmental constraints and, where possible, designed out elements which may present a risk or challenge to consenting. Without identifying key receptors and impact pathways, defining worst-case scenarios will be challenging and may lead to an overly complicated or precautionary approach to EIA and HRA.
- Non-significant issues should also be identified and agreed early. There should be no need for the project envelope and corresponding environmental assessments to focus on parameters where the potential for interactions and residual environmental effects is unlikely to be significant.
- Early refinement of understanding for impact pathways and sensitive receptors, to identify those key drivers for refining the project envelope, will also help define key evidence needs to refine the envelope or worst-case scenarios. This, in turn, should reduce the need for precaution in environmental assessments.
- Integrating engineering and environmental considerations when defining and refining the project envelope should have significant benefits and facilitate a solutions-based approach to defining the project envelope and consenting.
- Identifying and differentiating between hard and soft constraints (either from a technical, engineering or an environmental perspective) will help focus the refinement of the project envelope on the things that matter most and are most likely to influence the outcome of consenting.
- Any project envelope which relies on post- consent monitoring of adaptive management as a way of retaining flexibility must be deliverable and feasible from an economic and practical perspective.

- Evidence gaps, uncertainty about impacts and any assumptions within the project envelope and worst-case scenarios should be clearly stated to understand the implications for consenting and their likely influence.
- For some impacts, it might be possible to identify impact thresholds for sensitive receptors. In these instances, it might be possible to ‘reverse engineer’ the project envelope to ‘design out’ impact which are likely to exceed the threshold.
- The relationship between impact pathways, envelope parameters and worst-case scenarios should be considered. Alterations to parameters of the project envelope might influence more than one worst-case scenario. Checks and feedback loops should be built into the envelope refinement process to enable holistic assessment across all elements of the project envelope to avoid inadvertently increasing the impact magnitude for one receptor by decreasing another.
- For projects where the key impact pathways and receptors most likely to influence the outcome of the consent application are clear, it could be beneficial to bias the refinement of the project envelope to the best scenario for minimising these impacts, even where this might increase other impacts, which are of lesser significance. This is especially the case where these other impacts are unlikely to exert a material influence on the consent outcome.
- Pre-application survey and evidence gathering activities (e.g. baseline survey) should focus on the key impact pathways and receptors. This, in turn, will help inform the refinement of the design envelope. There could be value in projects developing formal ‘evidence plans’ to agree up front what information is needed to support project consent applications, including the refinement of the project envelope.
- Project developers may need to make cost-benefit decisions about the value in undertaking survey and evidence gathering activities to inform the refinement of the project envelope. The greater the understanding about sensitive receptors likely to be affected by the project, the more flexibility it might be possible to retain for certain elements of the envelope. However, there is a risk that gathering expensive data or undertaking complex modelling will not lead to any reduction in uncertainty about impacts, or greater envelope flexibility, such that a precautionary approach based on limited data might be the most cost effective or preferred approach.

- Feedback loops should be built into the refinement of the project envelope to ensure that the envelope parameters and worst-case scenarios are realistic and feasible from a technical, engineering and logistical perspective. Continued dialogue between environmental consenting specialists and engineering and economic specialists is important during development of the project design envelope to ensure that each element of the assessment is aware of the constraints of the other.

5.1 Post Consent implications

There is likely to be a requirement for post-consent monitoring of marine mammal impacts in relation to the uncertainties inherent in the assessment, although these will evolve through the process of assessment. Monitoring may be required to directly inform a programme of adaptive management to reduce or remove impacts or uncertainties about those impacts. If the assessment is based on a number of worst case scenarios that are likely to be unrealistic when viewed holistically, this might result in an overestimation of overall impact and result in overly restrictive and precautionary monitoring conditions. Depending on the nature of sub-letting agreements within the test facility, this requirement may be passed onto the technology developers at least for some impact pathways (e.g. collision, individual noise characterisation) whilst other monitoring might be conducted on a site wide basis by the test facility manager[15].

At EMEC, individual TEC developers are responsible for monitoring any fine-scale interactions between their devices and wildlife, whilst EMEC oversee a programme of wildlife observations to determine any wider scale disturbance and displacement. This also similar to the Fundy Ocean Research Centre for Energy (FORCE), the tidal turbine test site in the Bay of Fundy, Canada. The FORCE site managers are responsible for a site wide Environmental Effects monitoring programme, primarily to date focussing on the collection of baseline data, but with the objective of monitoring the effects of turbines site-wide (within the FORCE Crown Lease Area, CLA) as devices are deployed. Individual berth holders are responsible for monitoring within a 100 m radius of their turbines (near-field effects) while FORCE is responsible for monitoring outside of this zone, within the CLA (mid-field effects). All of the monitoring at the FORCE site is overseen by an Environmental Monitoring Advisory Committee (EMAC) which is made up of independent scientific experts and representatives from First Nations and the local fishing industry. Monitoring at FORCE will be managed adaptively, with programs being adjusted where necessary in light of ongoing results.

[15] If the test facility is fully pre-consented such that technology developers are not responsible for project specific consents for deploying their TECs within the facility, the legal responsibility for discharging any conditions relating to post-consent monitoring will lie with the licence holder (i.e. the facility manager).

Mitigation options to bring predicted marine mammal collision rates for tidal energy array projects below thresholds that would be considered acceptable by the Regulator and their statutory advisers include altering the configurations, numbers and types of devices. Although the options for this may be limited for a test facility with agreements in place with specific developers with specific technologies requiring deployment but site heterogeneity with respect to animal occurrence could also be considered, e.g. by placing the highest risk devices into lowest density areas (if other constraints such as water depth allow). This approach requires robust, reliable information on expected encounter rate at a fine spatial scale, with data collected over a long enough period to ensure that temporal variability is adequately established, as well as flexibility from a site layout and engineering perspective to optimise the management of risk in this way. For more information on pre-consent monitoring approaches and costs benefits of different approaches see Sparling et al. (2011) and Sparling et al. (2016). Where particular sensitive species are of concern, site wide (or even beyond the site to act as an early warning of presence), real time monitoring systems (e.g. passive acoustic monitoring for species of echolocating cetaceans such as harbour porpoise or bottlenose dolphins) may be considered to provide a site wide indication of the presence of those species during operation. It is likely that because of the uncertainty surrounding current ability to confidently predict collision risk, until empirical data emerges from studies elsewhere to inform likely avoidance and evasion rates, some near field monitoring of marine mammal interactions at the scale of individual devices will be required, at the very least near field encounter rates can be monitored and rates compared with those used in predictions of collision risk. It is likely that following the approach at EMEC and at FORCE that at a test facility, individual developers should be responsible for this near field monitoring, though the legal responsibility may lie with the test facility manager.

Monitoring for disturbance related effects – e.g. site wide changes in marine mammal abundance and distribution in response to devices, could either be carried out visually (if the site is close enough to a land based vantage point, e.g. the approach taken at EMEC), or with remote monitoring methods such as passive acoustic monitoring systems for echolocating cetaceans, such as the study carried out by Benjamins et al. (2016), or with individual tracking studies such as Sparling et al. (2017b). The power of such monitoring systems need to be carefully considered before implementation to ensure that any change that would be considered biologically significant, would be detected.

Mitigation options for any predicted (or uncertain) disturbance effects could include 'corridors' between berth areas as discussed above to ensure that animals still have the opportunity to move through large areas of deployed devices. Where this option is applied, monitoring may be required to validate the approach for future projects.

6 Literature Cited

Aurora Environmental Ltd. 2005. EMEC tidal test facility fall of warness Eday, Orkney environmental statement. Orkney.

Baines, M. E., and P. G. H. Evans. 2012. Atlas of the Marine Mammals of Wales. Countryside Council for Wales.

Band, B., C. Sparling, D. Thompson, J. Onoufriou, E. San Martin, and N. West. 2016. Refining Estimates of Collision Risk for Harbour Seals and Tidal Turbines. Scottish Marine and Freshwater Science **7**.

Benjamins, S., N. van Geel, G. Hastie, J. Elliott, and B. Wilson. 2016. Harbour porpoise distribution can vary at small spatiotemporal scales in energetic habitats. Deep Sea Research Part II: Topical Studies in Oceanography.

Booth, C., J. Harwood, R. Plunkett, S. Mendes, and R. Walker. 2017. Using The Interim PCoD Framework To Assess The Potential Effects Of Planned Offshore Wind Developments In Eastern English Waters On Harbour Porpoises In The North Sea – Final Report. SMRUC-NEN-2017-007, Provided to Natural England and the Joint Nature Conservation Committee, March 2017, SMRU Consulting.

Booth, C. G., C. E. Sparling, R. Plunkett, L. Scott-Hayward, and E. Rexstad. 2015. Collision Risk Simulation Modelling: Marine Mammals and Deep Green Device at Holyhead Deep. SMRUCMIN-2015-007.

Booth, C. G., C. E. Sparling, L. Scott-Hayward, E. Rexstad, and R. Plunkett. 2014. Collision Risk Simulation Modelling: Harbour seals and Deep Green Device at Strangford Lough. Report Number SMRUM-MIN-2014-011 Provided To Minesto Uk Ltd, October 2014 (Unpublished).

Cook, A. S., and R. A. Robinson. 2017. Towards a framework for quantifying the population-level consequences of anthropogenic pressures on the environment: The case of seabirds and windfarms. Journal of Environmental Management **190**:113-121.

Copping, A., N. Sather, L. Hanna, J. Whiting, G. Zydlewsk, G. Staines, A. Gill, I. Hutchison, A. M. O'Hagan, T. Simas, J. Bald, S. C., J. Wood, and E. Masden. 2016. Annex IV 2016 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World.

Corkeron, P. J., and A. R. Martin. 2004. Ranging and diving behaviour of two 'offshore'bottlenose dolphins, Tursiops sp., off eastern Australia. Journal of the Marine Biological Association of the United Kingdom **84**:465-468.

EMEC. 2014. EMEC Fall of Warness Test Site: Environmental Appraisal. . European Marine Energy Centre, Orkney.

Green, R. E. 2014. Misleading use of science in the assessment of probable effects of offshore wind projects on populations of seabirds in Scotland.

Hammond, P., C. Lacey, A. Gilles, S. Viquerat, P. Börjesson, H. Herr, K. Macleod, V. Ridoux, M. Santos, M. Scheidat, J. Teilmann, J. Vingada, and N. Øien. 2017. Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys.

Harwood, J., S. King, R. Schick, C. Donovan, and C. Booth. 2014. A Protocol For Implementing The Interim Population Consequences Of Disturbance (PCoD) Approach: Quantifying And Assessing The Effects Of Uk Offshore Renewable Energy Developments On Marine Mammal Populations. Report Number SMRUL-TCE-2013-014. Scottish Marine And Freshwater Science, 5(2).

Hastie, G., B. Wilson, and P. Thompson. 2006. Diving deep in a foraging hotspot: acoustic insights into bottlenose dolphin dive depths and feeding behaviour. Marine Biology **148**:1181-1188.

Hastie, G. D., D. J. Russell, P. Lepper, J. Elliott, B. Wilson, S. Benjamins, and D. Thompson. 2017. Harbour seals avoid tidal turbine noise: implications for collision risk. Journal of Applied Ecology.

IAMMWG. 2013. Draft Management Units for marine mammals in UK waters (June 2013). JNCC.

IAMMWG. 2015. Management Units for cetaceans in UK waters. JNCC Report 547, ISSN 0963-8091.

Jones, E. L., B. J. McConnell, S. Smout, P. S. Hammond, C. D. Duck, C. D. Morris, D. Thompson, D. J. Russell, C. Vincent, and M. Cronin. 2015. Patterns of space use in sympatric marine colonial predators reveal scales of spatial partitioning. Marine Ecology Progress Series **534**:235-249.

King, S. L., R. S. Schick, C. Donovan, C. G. Booth, M. Burgman, L. Thomas, and J. Harwood. 2015. An interim framework for assessing the population consequences of disturbance. Methods in Ecology and Evolution **6**:1150-1158.

Klatsky, L. J., R. S. Wells, and J. C. Sweeney. 2007. Offshore bottlenose dolphins (Tursiops truncatus): Movement and dive behavior near the Bermuda Pedestal. Journal of Mammalogy **88**:59-66.

ORJIP Ocean Energy. 2016. The Forward Look; An Ocean Energy Environmental Research Strategy for the UK. Report to: The Crown Estate, Marine Scotland and Welsh Government. Aquatera Ltd and MarineSpace Ltd.

Orsted. 2018. Appendix 14 to Deadline I Submission - A review of precaution in the marine mammal assessment. https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010080/EN010080-001132-DI_HOW03_Appendix%2014.pdf.

Parvin, S. J., and A. G. Brooker. 2008. Measurement and assessment of underwater noise from the Openhydro tidal turbine device at the EMEC facility, Orkney. Subacoustech Report No. 812R0207 to Openhydro Ltd. .

Parvin, S. J., R. Workman, P. Bourke, and J. Nedwell. 2005. Assessment of Tidal Current Turbine Noise at the Lynmouth site and predicted impact of underwater noise at Strangford Lough. Subacoustech Report No. 628R0104 to CMACS Ltd. .

Savidge, G., D. Ainsworth, S. Bearhop, N. Christen, B. Elsaesser, F. Fortune, R. Inger, R. Kennedy, A. McRobert, K. E. Plummer, D. Pritchard, C. Sparling, and T. Whittaker. 2014. Strangford Lough and the SeaGen Tidal Turbine. Pages 153-172 Marine Renewable Energy Technology and Environmental Interactions. Springer.

SCOS. 2016. Scientific Advice on Matters Related to the Management of Seal Populations: 2016.

Scottish Natural Heritage. 2016. Assessing collision risk between underwater turbines and marine wildlife.

Shucksmith, R., N. H. Jones, G. W. Stoyle, A. Davies, and E. F. Dicks. 2009. Abundance and distribution of the harbour porpoise (Phocoena phocoena) on the north coast of Anglesey, Wales, UK. Journal of the Marine Biological Association of the United Kingdom **89**:1051-1058.

Sparling, C., K. Grellier, E. Philpott, K. Macleod, and J. Wilson. 2011. Guidance on survey and monitoring in relation to marine renewables deployments in Scotland. Volume 3. Seals.

Sparling, C., M. Lonergan, and B. McConnell. 2017a. Harbour seals (Phoca vitulina) around an operational tidal turbine in Strangford Narrows: No barrier effect but small changes in transit behaviour. Aquatic Conservation: Marine and Freshwater Ecosystems.

Sparling, C., K. Smith, S. Benjamins, B. Wilson, J. Gordon, T. Stringell, C. Morris, G. Hastie, D. Thompson, and P. Pomeroy. 2016. Guidance to inform marine mammal site characterisation requirements at wave and tidal stream energy sites in Wales. NRW Evidence Report Number 82. SMRUC-NRW-2015-012.

Sparling, C. E., M. Lonergan, and B. McConnell. 2017b. Harbour seals (*Phoca vitulina*) around an operational tidal turbine in Strangford Narrows: No barrier effect but small changes in transit behaviour. Aquatic Conservation: Marine and Freshwater Ecosystems **In Press**.

Stringell, T. B., C. P. Millar, W. G. Sanderson, S. M. Westcott, and M. J. McMath. 2013. When aerial surveys will not do: grey seal pup production in cryptic habitats of Wales. Journal of the Marine Biological Association of the United Kingdom:1-5.

Subacoustech. 2014. Underwater noise modelling of tidal devices and other associated noise at the Perpetuus Tidal Energy Centre off the coast of the Isle of Wight, England. Subacoustech Report No. E432R0105.

Teilmann, J., C. T. Christiansen, S. Kjellerup, R. Dietz, and G. Nachman. 2013. Geographic, seasonal, and diurnal surface behavior of harbor porpoises. Marine Mammal Science **29**:E60-E76.

Teilmann, J., F. Larsen, and G. Desportes. 2007. Time allocation and diving behaviour of harbour porpoises (Phocoena phocoena) in Danish and adjacent waters. Journal of Cetacean Research and Management **9**:201-210.

The Crown Estate. 2015. UK Wave and Tidal Demonstration Zones Workshop Report. .

Thompson, D. 2012. Assessment of Risk to Marine Mammals from Underwater Marine Renewable Devices in Welsh waters (on behalf of the Welsh Government). Phase 2: Studies of Marine Mammals in Welsh High Tidal Waters. Annex 1 Movements and Diving Behaviour of Juvenile Grey Seals in Areas of High Tidal Energy. RPS document reference: JER3688 R 120712 HT.

Thompson, D., A. Brownlow, J. Onoufriou, and S. Moss. 2016. Collision risk and impact study: field tests of turbine blade-seal carcass collisions. Report to Scottish Government No MR 5.

Veneruso, G., and P. G. Evans. 2012. Bottlenose Dolphin and Harbour Porpoise Monitoring in Cardigan Bay and Pen Llŷn a'r Sarnau Special Areas of Conservation. CCW Monit Rep **95**:65-165.

Wade, P. R. 1998. Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. Marine Mammal Science **14**:1-37.

West Islay Tidal. 2013 West Islay Tidal Energy Park Volume 2 Environmental Statement. July 2013.

Westcott, S., and T. Stringell. 2004. Grey seal distribution and abundance in North Wales, 2002-2003. Countryside Council for Wales.

Westgate, A. J., A. J. Head, P. Berggren, H. N. Koopman, and D. E. Gaskin. 1995. Diving behaviour of harbour porpoises, Phocoena phocoena. Canadian Journal of Fisheries and Aquatic Sciences **52**:1064-1073.

Wilson, B., R. Batty, F. Daunt, and C. Carter. 2007. Collision risks between marine renewable energy devices and mammals, fish and diving birds., Scottish Association for Marine Science, Oban.

7 Glossary of Terms, Acronyms and Abbreviations

Term	Description
AA	Appropriate Assessment
CRM	Collision Risk Model
DBEIS	Department for Business, Energy & Industrial Strategy
DEPONS	Disturbance Effects on the harbour Porpoise population in the North Sea
EIA	Environmental Impact Assessment
EMEC	European Marine Energy Centre
EPS	European Protected Species
ES	Environmental Statement
FCS	Favourable conservation status
HRA	Habitats Regulations Appraisal
LSE	Likely Significant Effect
MCAA	Marine and Coastal Access Act
MHWS	Mean High Water Springs
MMO	Marine Management Organisation
MU	Management Unit
NRW	Natural Resources Wales
NSIP	Nationally Significant Infrastructure Projects
O&M	Operation & Maintenance
ORJIP	Offshore Renewables Joint Industry Project
PBR	Potential Biological Removal
PCoD	Population Consequences of Disturbance

PDE	Project Design Envelope
PTEC	Perpetuus Tidal Energy Centre
PVA	Population Viability analysis
SAC	Special Area of Conservation
SNCB	Statutory Nature Conservation Bodies
SNH	Scottish Natural Heritage
TEC	Tidal Energy Converter
WADZ	West Anglesey Demonstration Zone
WCS	Worst Case Scenario

8 Annex Two: Recommendations on Project Design Envelopes from 2015 UK Wave & Tidal Demonstration Zones workshop.

- Project Design Envelope (PDE) is a more suitable term than Rochdale Envelope, which has little relevance to marine projects.
- A clear understanding of the consenting process and regime is required to allow appropriate guidance to be agreed for PDE.
- If the PDE approach is not used robustly it can bring risks into the consents process and in delivering projects on site post-consent.
- The consenting authority must be able to meet the requirements of the EIA and Habitats Regulations in considering the significant effects of the proposed development including the impacts of developing proposals and changing technologies.
- Confidence amongst Regulators in a PDE approach might be increased through use of mechanisms within consent conditions to ensure activities fall within the PDE under which they were consented (e.g. construction method statements, etc). This would require an agreement about when a change from a consented envelope is material, which might be perceived differently by parties involved.
- The consideration of the potential for cumulative effects between different projects can also be challenging. The workshop indicated the differences in views of regulators and developers where regulatory responsibilities may lead to more precautionary approaches.
- A mechanism is required for sharing learning on PDE, either within or between sectors. The evidence base from projects which are developed should be established to enable better definition of realistic PDE in the future (acknowledging the challenges associated with sharing such information).
- Good practice for defining PDE should be established, building on experience and discussion to date.
- Guidance on PDE should be user-friendly, focussed and consider the implications of the PDE through the whole process from pre-application including EIA through consents to post-consent construction and operation.
- In defining a PDE it is important to consider the whole process from pre-application, through to post-consent implications. The conditions of any permission will set the parameters within which development can proceed.
- Defining a 'worst case' PDE may not be a 'realistic' PDE. The PDE may become restrictive to development by introducing a range of parameters which are too demanding to be helpful in consenting. Understanding and defining a realistic envelope is more helpful and allows mitigation to better be defined which is practical and deliverable.
- A realistic PDE should be used appropriate to the development location and its environmental sensitivities.
- The PDE focus should be on definition of a realistic envelope which is agreed with developers, engineers, Regulators and consultees to ensure understanding for the variations in technology and

a broad understanding for the environmental implications of any variation. A common understanding of what might be an acceptable PDE in principle should be agreed, pre-application.

- The definition of a PDE should clearly recognise the difference between flexibility in project technology and flexibility in project components to allow flexibility to accommodate future developments and different technical parameters.
- Defining the PDE for sectors or project components where technology is evolving rapidly and when detail at the time of application may change in the future is challenging. The unknowns of developing technologies are hard and the PDE will need to define worst case parameters within which technology can evolve.
- A realistic PDE should be defined making best use of available evidence and information, to remove uncertainty in an application whilst maintaining some flexibility. The key question will always be whether sufficient information is available to define significant effects and to understand what the implications of these effects might be. A precautionary approach will be likely to prevail where the evidence base is limited, although it is important to consider that only sufficient information to identify significant effects under the EIA and Habitats Regulations is required in considering applications.
- A narrow PDE could be restrictive to development by being commercially unattractive and overly restrictive, but the more clearly defined the envelope, the easier it is to be able to consider whether significant effects of likely types of future development have been defined. Such an approach could be appropriate in a sensitive environment. A broad envelope retains maximum flexibility, but can present consenting risks or even sterilise parts of a site as an over precautionary approach to consents may result.
- Early discussion between the developer, Regulators and statutory bodies should establish early contact and exchange of information, to begin to agree an appropriate approach to defining the PDE and the expectations and requirements of the consents process (including EIA, HRA, EPS).
- An initial ‘evidence plan’ should be agreed between the developer, Regulators and statutory bodies, which can be broadened out during the process, to inform the development of the PDE and approach to EIA, to agree a proportionate approach to data gathering.
- The definition of the PDE should be carefully linked in with the EIA process which should take account of information from the developing engineering design from an early stage but also be mindful of future challenges post consent of new and developing technologies which may need to be considered within the PDE.
- A PDE should be defined based on likely significant impacts from the development on key environmental receptors. The understanding of the sensitivity of those receptors to the likely technology and project component variations and options for technical parameters needs to be understood and can be built up through an iterative process which will allow the PDE to become increasingly well defined.
- Sensitivities and vulnerabilities of environmental receptors to the proposed development should be the focus of concern in defining a realistic PDE, rather than on the receptors wider sensitivities, if these are not relevant to the proposed development. This allows focus in defining the PDE on things which matter and can reduce the potential for over complication. There is no need for an envelope approach for parameters where the potential for interactions and residual effects is not significant.
- The EIA scoping process is a useful tool to define sensitivities of environmental receptors and to identify key risks, as well as what can be scoped out of the envelope.
- Use should be made of all available information in considering what is important and what should be taken into account including strategic level assessments and plan-level HRAs.

- Regulators and SNCBs need to give clear guidance to developers about the sensitivities of receptors or what is required to help better understand them. Characterisation and monitoring studies should only be asked for where there is a clear need and rationale. Where studies are asked for, it should be made clear how, where and when the data will be used to inform EIA/HRA and the determination process.
- PDE should be clearly defined in Environmental Statements and used appropriately in the reported EIAs and HRAs. What is included in the PDE and what has been excluded and why should be clear to the reader.
- The implications of using different PDE parameters in realistic worst-case assessments of impacts on different receptors should be explained. How these differences in assumptions will be brought together for different project components in EIA/HRA should be clearly explained.
- A commitment to future monitoring measures should not be used to avoid work that is required to inform an adequate definition of a PDE and an assessment of significant effects. The usefulness of future adaptive management measures is acknowledged but these in themselves need to be carefully defined and used robustly.

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