Appendix B: Information Paper – Acoustic impact evaluation and management

NOPSEMA

Information paper

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Acoustic impact evaluation and management

Summary

The Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Environment Regulations) require a titleholder to have an accepted environment plan (EP) in place for any petroleum activity or greenhouse gas activity in Commonwealth waters. This information paper provides advice to titleholders to assist with preparing EPs for marine seismic survey activities, and in particular the components of an EP that relate to detailing, evaluating and managing impacts from acoustic emissions.

A range of deficiencies have been commonly identified by NOPSEMA in the environmental impact assessment (EIA) process for acoustic emissions from seismic surveys. These deficiencies have contributed to protracted assessment timeframes, reduced operational flexibility and challenges to industry's social license to operate.

This information paper was developed to provide advice to improve the quality of EIA for marine seismic surveys and ensure common deficiencies are avoided. The common deficiencies are listed throughout the document within the relevant EIA process steps and are followed by advice in the form of 'considerations' to assist with ensuring these deficiencies are addressed during the EIA process.

Following the advice in this information paper is not a regulatory requirement but will assist with ensuring that EP submissions are able to demonstrate that impacts from acoustic emissions are managed to as low as reasonably practicable (ALARP) and acceptable levels in a timely manner.

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Abbreviations/acronyms

ALARP	As Low as Reasonably Practicable
AMP	Australian Marine Park
BIA	Biologically Important Area
CPUE	Catch per unit effort
DoEE	Department of the Environment and Energy
DPIRD	Department of Primary Industries and Regional Development
EIA	Environmental Impact Assessment
EP	Environment Plan
EPBC	Environment Protection and Biodiversity Protection
KEF	Key ecological feature
IUCN	International Union for the Conservation of Nature
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NZ	New Zealand
OPGGS Act	Offshore Petroleum and Greenhouse Gas Storage Act 2006
SEL	Sound exposure level
VFA	Victorian Fisheries Authority

1. Introduction

1.1. Information paper series

This Information Paper forms part of a series of documents published by the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) that provide information relevant to the environmental management of offshore petroleum and greenhouse gas storage activities in Commonwealth waters. These activities are subject to the provisions of the Commonwealth *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGGS Act) and the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (the Environment Regulations).

The Information Paper series outlines aspects of good environmental management practice relevant to Australia's offshore petroleum industry. This particular Information Paper provides general advice to assist titleholders address underwater sound impacts when preparing seismic survey environment plans (EPs). It should be read in conjunction with other relevant information available on the NOPSEMA website, particularly the Guidance Note on Environment Plan Content Requirements (GN1344) and the Guideline on Environment Plan Decision Making (GL1721).

NOPSEMA encourages the use of this advice when preparing EPs, however applying it is not a regulatory requirement. The early consideration of this advice should assist in the assessment process by improving the quality of EP submissions for seismic surveys and reduce the timeframes between initial submission and final acceptance.

1.2. Rationale

Following the assessment of more than 100 EPs for marine seismic surveys over five years of regulation, NOPSEMA has identified some trends in terms of common deficiencies in the environmental impact assessment process that are regularly addressed during the EP assessment process. Of particular note, Regulation 13(5) is by far the most common regulation against which EP deficiencies are raised. Regulation 13(5) requires the detailing and evaluation of environmental impacts as well as the details of control measures that will be used to reduce the impacts of the activity to as low as reasonably practicable (ALARP) and an acceptable level and this is the primary focus of this information paper. The common deficiencies identified during the assessment of seismic survey EPs have been incorporated into relevant sections of this paper.

The deficiencies in the EIA process identified on first submission of marine seismic survey EPs result in protracted assessment timeframes and reduced stakeholder confidence in industry's ability to manage the impacts it generates. Providing written advice is one tool that NOPSEMA will use to proactively communicate advice on addressing these deficiencies to support the development of seismic survey EPs that meet regulatory requirements. This paper should be utilised in conjunction with targeted research and technological advancements to address the challenges faced by titleholders in predicting and managing the impacts from underwater acoustic emissions.

1.3. Purpose of this paper

The purpose of this paper is to:

- Provide good practice advice for the assessment and management of environmental impacts from acoustic emissions generated by seismic activities.

- Facilitate continuous improvement in the quality, clarity and consistency of EP submissions for seismic activities and enhance efficiency and effectiveness of the environmental management authorisation process by promoting the importance of:
    - Applying the best available science, contemporary standards, policies and statutory management instruments.
    - A robust process for defining and achieving an acceptable level of environmental impact through appropriate impact evaluation, and commitment to mitigation and measures to verify management effectiveness.

This information paper does not prescribe any particular environmental management approach, but will assist industry in developing an approach that is suited to their specific activity circumstances and meets the requirements of the Environment Regulations. Importantly, the purpose of the paper is not to prescribe that all aspects of the paper should be applied to all sound generating activities. Rather, the considerations that apply will be determined by the nature and scale of the particular activity and the receptors it is predicted to interact with.

1.4. Scope

The scope of the paper is the EIA process for acoustic emissions, starting at establishing the context through to evaluating environmental impacts and detailing how those impacts will be managed to ensure they are reduced to ALARP and acceptable levels (refer to blue boxes in Figure 1 below).

The paper's primary focus is on evaluating and managing the environmental impacts due to sound emissions from marine seismic surveys, however some of the advice may also be relevant to considering environmental impacts from other noise generating petroleum activities. As such the guidance includes reference to aspects of EIA that are unique to marine seismic surveys, e.g. describing airgun array design and outputs. However, much of the information presented will also have broad relevance to other sound generating activities in the offshore petroleum sector such as pile driving (e.g. describing the environment and detailing relevant impacts). The extent to which this guidance document is applied to other sound generating activities should be determined by the nature and scale of the particular activity.

It is also important to note that, in addition to environmental impacts associated with acoustic emissions, an EP for a marine seismic survey must address all other environmental impacts and risks relevant to the activity, e.g. invasive marine species risks. These aspects of marine seismic survey EPs are not addressed in this information paper, but general guidance is provided in the Environment Plan Content Requirements Guidance Note (GN1344).

In addition, the paper does not extend to providing guidance on setting levels of environmental performance or implementation strategy elements (i.e. Regulations 13(7) and 14). However, the guidance provided on evaluating and managing impacts does provide relevant context for defining environmental performance outcomes and standards and developing specific implementation strategy elements. Relevant guidance on these aspects of EPs is available in existing NOPSEMA environment resources; Environment Plan Decision Making Guideline (GL1721) and Environment Plan Content Requirements Guidance Note (GN1344).

Further, this paper does not provide 'how to' guidance on technical aspects of acoustic emissions EIA, monitoring and management, e.g. sound exposure modelling, validation of received sound levels or design of cetacean detection measures. However, examples of further reading are provided for some of these more technical aspects.

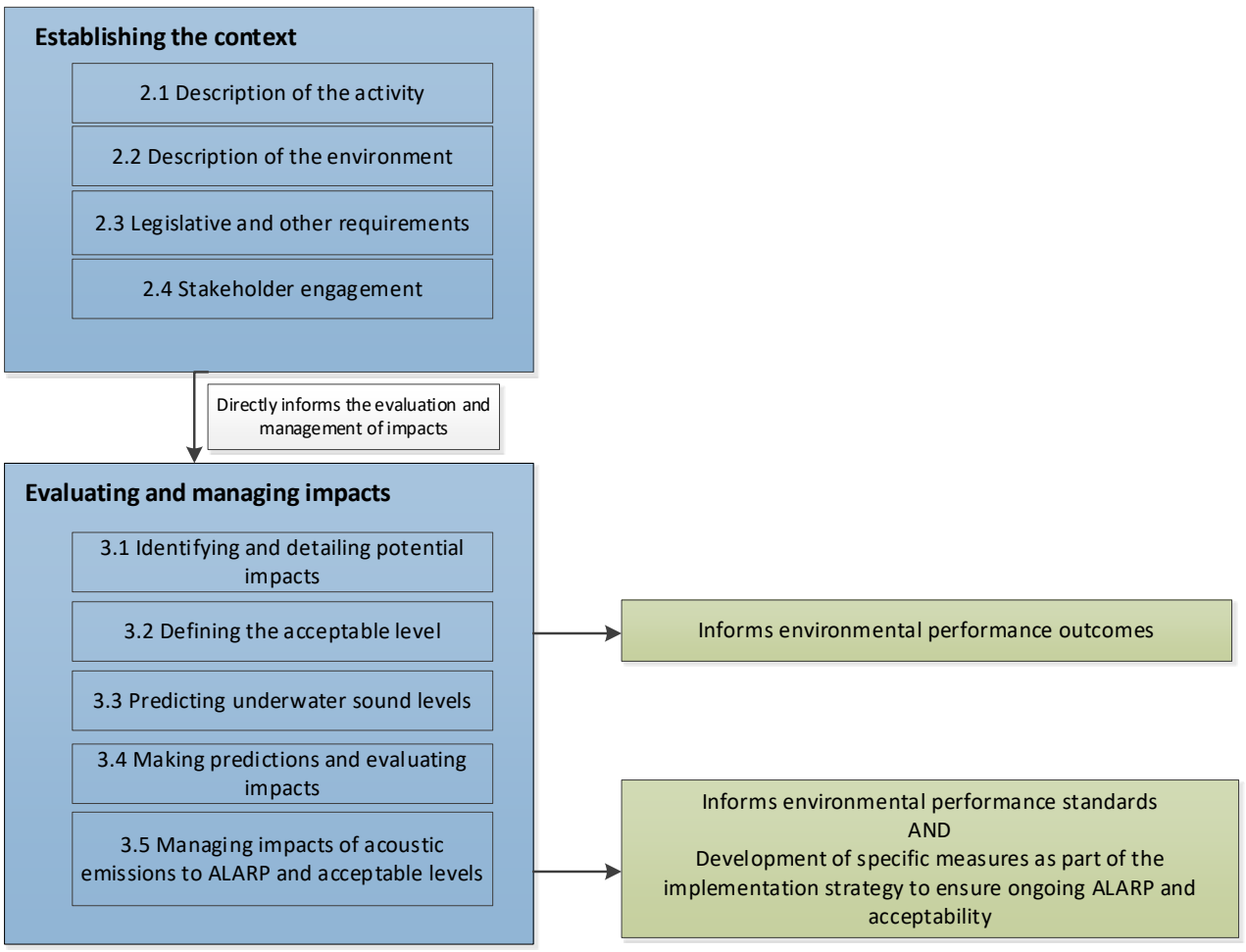

Figure 1 Outline structure of this information paper (blue boxes) and relationship with other aspects of Environment Plan development (green boxes).

1.5. Content and structure

The structure of the paper is based around the content requirements of the Environment Regulations. The order of the sections is intended to represent a logical sequence of steps that may be followed during the preparation of an EP. The structure is divided into two main sections; establishing the context and evaluating and managing impacts. In addition, a compilation of the core concepts for each of the environmental impact assessment steps and NOPSEMA insights on the common deficiencies at each of these steps is provided at Appendix 1.

The information paper incorporates core concepts, common deficiencies and considerations which should be considered during the development of EPs for sound generating offshore petroleum activities. Table 1 provides an overview of the intent of each of these terms that are used consistently throughout the paper.

Table 1 **The intent of core concepts, common deficiencies and considerations as they relate to this Information Paper**

Term	Intent in context of this information paper
Core concept	Advice on ensuring that regulatory requirements are met as they relate to the evaluation and management of acoustic impacts from petroleum activities in the Commonwealth marine environment.
Common deficiencies	Assist titleholders with identifying aspects of environment plan submissions for seismic surveys that are commonly deficient and require particular attention.
Considerations	Discussion of common considerations that may assist with ensuring that the EIA process is undertaken in a robust manner with common deficiencies avoided.

Break out boxes are provided that contain 'further reading' or examples of the application of core concepts or considerations. This material should not be considered as the only additional relevant context as it provides examples only. Titleholders should continue to ensure that EPs are informed by the best available science and most recent standards, policies, management plans etc. that are relevant to the activity being proposed.

2. Establishing the context to inform impact evaluation and management

This section provides guidance on determining the key information required to inform the evaluation of impacts associated with sound generated by offshore petroleum activities. Establishing the context is important to enable an evaluation of the extent, severity and duration of impacts and in order to define an acceptable level(s) of impact and demonstrate it can be met. Relevant context for undertaking impact assessment and evaluation is provided by:

- Describing the activity including sound source characteristics;
- Identifying and describing the biota in the environment that may be affected by sound;
- Identifying and describing relevant legislation, guidance and other requirements; and
- Considering and addressing stakeholder claims, objections and expectations.

2.1. Description of the activity

Core concept
The environment plan should identify and describe all aspects of the activity that influence the intensity, duration and extent of acoustic emissions in detail sufficient to inform the evaluation of impacts.

2.1.1. Common deficiencies

- The aspects of the activity that will influence received sound levels and potential for impact such as acquisition line spacing and sound source (size and output) are not described in sufficient detail.
- The activity is not clearly defined in terms of temporal and spatial extent, creating uncertainty as to the required scope of the description of the environment and the detailing and evaluation of impacts.

- The sound exposure regime associated with line turns, airgun testing and ramp-up in the operational area are not adequately described.

2.1.2. Considerations

- A thorough understanding of activity aspects that influence acoustic emissions in the marine environment is a key initial step in the EIA process.
- The activity description should include activity- and equipment-specific information on sound sources to inform the prediction of received sound levels.
- Where there is uncertainty as to the sound exposure regime, e.g. duration or intensity of the sound source, the activity description should be clear on the worst case scenario or upper limit and this should be carried through to the evaluation of impacts.
- Where there is uncertainty during EP preparation as to the extent and location of the acoustic emissions themselves, the EP should describe the activity in terms of its full potential extent and all locations where sound emissions may be generated.
- The EP should provide clarity in relation to the proposed activity that may be authorised. For example, details given for the activity should clearly scope and bound what is proposed in terms of timing, duration and spatial extent. Where flexibility is sought, greater levels of detail are required in the evaluation of impacts to cover all potential scenarios for how the activity may be undertaken.

Understanding the nature of the acoustic emissions (e.g. frequency range, intensity, extent and duration) generated by petroleum activities is crucial to informing the evaluation of impacts. As such, the description of the activity in an EP should include information on:

- The areas where sound emissions will occur, e.g. for a seismic survey the areas where line run ins and run outs, vessel turning circles, bubble testing or other forms of array testing and where the sound source will be operated at full power should be clearly delineated.
- Specific areas and/or times where sound emissions have been excluded so as to avoid temporal or spatial sensitivities – this information may arise from the evaluation of environmental impacts.
- The number of individual surveys/activity phases to be conducted, number of vessels and types of sound sources to be used and whether there will be multiple sound sources, e.g. concurrent seismic surveys.
- In relation to seismic surveys:
    - Whether the method of data acquisition will be a two, three or four dimensional survey or a combination.
    - Whether the survey is isolated or part of a broader series of surveys that may occur over a longer period of time.
    - The proposed line spacing and direction and streamer length and number.
- The parameters of the sound source that will influence acoustic emissions based on the best available information, e.g. for a seismic airgun array relevant parameters may include source level, array volume and configuration, operating pressure, operating depth, shot point interval and source spectrum, waveform and directivity. Noting that these activity parameters are key inputs to any received sound level prediction exercise.

ISO 18405:2017 – Underwater acoustics – Terminology

ISO 18405:2017 defines terms and expressions used in relation to natural, biological and anthropogenic underwater sound. It includes terms relevant to the generation, propagation and reception of underwater sound as well as aspects of the effects of underwater sound on receptors within the aquatic environment. To foster consistency and uniformity in referencing sound units, consideration of this ISO Standard is encouraged during the preparation of EPs and in undertaking predictions of received sound levels and impacts on biota.

2.2. Description of the environment

Core concept

The presence, seasonal variability in abundance, particular life stages and behaviours for relevant biota must be sufficiently described to inform the evaluation of impacts.
Socio-economic activities that will be directly or indirectly affected by impacts of acoustic emissions should also be described.

2.2.1. Common deficiencies

- The spatial extent of the environment description is not informed by the results of received sound level predictions and therefore not aligned with the extent of the area that is predicted to be affected by acoustic emissions.
- Superfluous information is provided on receptors that are not predicted to be affected, confusing the scope of the evaluation of impacts.
- There is an over-reliance on tools such as the National Conservation Values Atlas to identify important habitats for marine fauna. For example, a lack of a defined 'biologically important area' results in a conclusion that there are no important habitats for a particular species.
- The information provided is not of sufficient detail or granularity to inform an analysis of how particular values and sensitivities will be affected by sound.

2.2.2. Considerations

- The scope and focus of the description of the biological and socio-economic environment should be defined by the area that may be affected and the sound sensitivity and conservation status/value of receptors in that area.
- The description of the environment should include statements relating to the reliability of data and knowledge including degree of review or known gaps in data, currency of information and uncertainties in data accuracy.
- Data gaps (e.g. in distribution, habitat, behaviour, hearing sensitivity or trophic interactions) should be explicitly acknowledged. In the absence of data, speculation should be avoided, and comparisons across taxa and environments must be justified with rigorous peer reviewed references. If assumptions are made, these should be clearly stated and their implications considered in the EP.

- For surveys that occur over particularly sensitive areas/times and involve a high degree of uncertainty with respect to the presence of marine fauna and associated life stages and behaviours, it may be beneficial to undertake targeted biological surveys prior to or during the activity. Enhanced up-front understanding of the environment may lead to a lower reliance on precautionary measures implemented during the activity implementation in order to demonstrate impacts are acceptable and reduced to ALARP.
- Information on biological receptors should be presented in logical format with a focus on information that will be relevant to inform the evaluation of impacts. For example, a description of any features that may make a population more sensitive to disturbance such as important life stages (e.g. planktonic larval dispersion, breeding, migration) or stock structure and stock status.
- Recently completed and / or simultaneous surveys, associated seasons, durations and sound exposure regimes should be detailed in order to provide relevant context for assessing potential cumulative impacts from the additive effects of other surveys within the area that may be affected by the activity.
- Descriptions of relevant species, fauna groups and habitats within the environment that may be affected should be supported by relevant references, including relevant information from the DoEE website for matters protected under Part 3 of the EPBC Act.
- Distribution and abundance of many species (e.g. fin whales, sei whales, sperm whales, plankton) are often not well described in Australian waters. Relevant references might reveal presence of species in one area, but should not be used to infer absence in other areas where there is a lack of survey effort.

The following environmental attributes of the area that may be affected should be identified and described, as relevant to the activity location:

- Aspects of the physical environment that affect sound propagation, e.g. water temperature, seabed type and bathymetry.
- The range of receptors that are potentially affected by acoustic emissions from the activity including, but not limited to plankton, marine mammals (cetaceans, pinnipeds, sirenians), birds (e.g. penguins, diving seabirds), fish (benthic, demersal and pelagic), invertebrates (e.g. crustaceans, molluscs) and reptiles (turtles and seasnakes).
- For all identified receptors, their values (e.g. conservation, commercial, social, cultural), habitats and habitat use within the area that may be affected by sound emissions.
- Specially protected places such as World Heritage areas, Australian Marine Parks and State marine reserves/parks, Ramsar wetlands and listed heritage places and the associated biological, social, economic and cultural values of these places.
- Socio-economic features affected such as fisheries (presence, key fished species and best available data on fishing areas, catch effort, stock status and fishing season) and tourism, divers and swimmers (presence, timing) and aquaculture (presence, species, key important times).
- It should be noted that relevant fisheries management agencies may be able to assist with providing relevant fisheries information, e.g. the DPIRD in WA have launched a database called FishCube and the VFA in Victoria also hold a catch and effort database.
- The ambient soundscape including contributions from existing anthropogenic noise, e.g. median daily sound pressure level with minimum and maximum bounds, where data available.

- For vocalising fauna such as whales, the frequency of vocalization and hearing sensitivity, where known, in order to inform the impact assessment, e.g. potential for communication masking or sensitivity relative to the frequency spectrum of relevant sound sources.
- Habitat associations of relevant marine fauna, e.g. demersal fish species and marine turtles, and their ability to avoid / move away from a source.
- The known timing, location and spatial extent of particularly sensitive life stages and behaviours, such as:
    - Marine mammals – calving, mating, migration, foraging, resting, lactating.
    - Marine reptiles – foraging, mating / nesting, inter-nesting, migration.
    - Fish – spawning / breeding, feeding aggregations, migration.
    - Invertebrates – spawning/breeding, migration.
- Trophic interactions to ensure an understanding of potential for indirect effects on fauna, e.g. prey displacement or depletion.
- Whether particular species are resident or migrating through the area that may be affected, e.g. resident foraging turtles or habitat specific sea-snakes.
- The biology, ecology or anatomy of biota that may render them more sensitive to underwater acoustic impacts, for example:
    - Fish with swim bladders involved in hearing are more sensitive to sound than fish without swim bladders.
    - Cetaceans are generally more sensitive to sound during important life stages such as calving.
- Behaviours that may influence susceptibility to sound impacts e.g. surface feeding, feeding at depth, deep diving, timing between surface intervals.
- Statutory levels of protection for biota that may be affected need to be explicitly described. For example, the EP needs to clearly identify the listing category and describe the presence of EPBC Act listed threatened species and listed migratory species that may be affected. Similarly, where values and sensitivities that may be affected are among the values of Australian marine parks, national heritage places or World Heritage properties, and/or elements of the ecological character of Ramsar wetlands these things should be clearly documented.
- Descriptions of listed species and places should be informed by threatened species recovery plans, conservation advices, marine bioregional plans, wildlife conservation plans, marine protected area management plans and other relevant published documentation provided by the DoEE and / or State / Territory wildlife or fisheries departments.
- Relevant tools should be used to identify important species and habitats likely to be present within a proposed survey/activity area and biologically important areas for protected and other species. For example, the DoEE Protected Matters Search Tool and National Conservation Values Atlas, Atlas of Living Australia and the Ocean Biogeographic Information System.

2.3. Legislative and other requirements

Core concept

A comprehensive understanding of relevant legislative and other requirements is necessary to inform the focus of the impact assessment process, define acceptable levels of impact and select appropriate control measures (including spatial and temporal restrictions).

2.3.1. Common deficiencies

- Relevant context from EPBC Act statutory instruments for protected fauna such as relevant actions and objectives are not described and applied to relevant aspects such as defining acceptable levels, evaluating impacts and designing control measures.
- An over-reliance on the standard and additional management procedures set out in EPBC Policy Statement 2.1 for the management of seismic survey impacts on whales can limit the development of activity specific controls that are directly informed by the evaluation of impacts.

2.3.2. Considerations

- Relevant legislative requirements, statutory management instruments and other government publications may provide context in terms of Australian government expectations for the management of underwater acoustic emissions.
- Legislative and other requirements are important for informing any spatial or temporal restrictions that may apply to the activity at the outset and form an important aspect of the context setting for the EIA process and defining acceptable levels of impact.
- The OPGGSA legislative regime provides flexibility to consider any environmental management approach including those set out in policies, guidelines and standards in other jurisdictions or as supported by relevant, contemporary research.
- The key guidance document in the Australian jurisdiction for managing impacts of underwater acoustic emissions is the EPBC Policy Statement 2.1. This document is specific to interaction of seismic surveys with whales and sets out important considerations for determining the level of mitigation required as well as a set of ‘standard’ and ‘additional’ management measures.
- EPBC PS 2.1 was published in 2008 and since that time there have been technological and scientific advancements that warrant consideration in relation to management of seismic surveys. In this respect, there are a number of policy, legislative and guidance documents from international jurisdictions that may provide relevant context (see examples in further reading box in Section 3.5.1).
- There are also a range of plans of management made under the EPBC Act that provide relevant context for impact evaluation and establishing acceptable levels of impact, including:
    - Recovery plans - recovery plans for listed threatened species are statutory instruments and in some cases specify acoustic disturbance as a threat and provide specific management actions for underwater sound.
    - Relevant plans of management – these may include plans for world heritage areas, Ramsar wetlands, Australian marine parks (AMPs) or listed national or commonwealth heritage places.
    - Australian marine park management plans.

- Conservation advices, marine bioregional plans, wildlife conservation plans, threat abatement plans and Ramsar wetland Ecological Character Descriptions may also provide important information to inform acceptable levels of impact.

- See NOPSEMA guidance note on Petroleum Activities and AMPs (GN1785) for information relevant to managing activities that may affect AMPs, noting that seismic surveys are only allowable in some zones of the parks.

2.4. Stakeholder engagement

Core Concept

Stakeholder objections, claims or expectations in relation to acoustic emissions impacts on environmental values of interest need to be identified and adequately understood to inform the impact assessment process and define acceptable levels of impact.

2.4.1. Common deficiencies

- The approach to consultation is to provide generic information that is not of sufficient detail to inform an assessment of consequence on particular functions, interests or activities.
- The consultation process does not encourage stakeholders to provide information of relevance to the environmental management of the activity.
- Relevant information on the environmental values and sensitivities in the area that may be affected is provided by stakeholders but not incorporated into the detailing and evaluation of impacts.
- Where claims are made about the potential for impacts on particular receptors and/or the need to implement specific controls, the assessment of merits is not adequately supported by relevant information in the EP.
- Control measures identified and agreed during the consultation process are not incorporated into the environmental performance standards within the environment plan.

2.4.2. Considerations

Stakeholder consultation provides an important avenue for early identification of potential impacts that require evaluation and control measures that require consideration and may also inform the acceptability of impacts in relation to biological, social, economic and / or cultural values of the marine environment. In addition, it can facilitate the provision of information to address knowledge gaps in relation to the environment that may be affected.

NOPSEMA has published a suite of guidance that provides advice on conducting appropriate and effective stakeholder engagement that meets the intent of the Environment Regulations. The advice and considerations for stakeholder engagement in the below referenced NOPSEMA guidance documents should be read in conjunction with this information paper:

- Guidance Note on Environment Plan Content Requirements (GN1344)
- Guideline on Environment Plan Decision Making (GL1721)
- Information Paper on Consultation Requirements (IP1411)
- Guidance Note on Petroleum Activities and Australian Marine Parks (GN1785) [for guidance on consulting with Director of National Parks]

3. Evaluating and managing impacts

This section of the Information Paper discusses important considerations to be taken into account during the detailing and evaluating of impacts from acoustic emissions, determining appropriate control measures and providing a defensible demonstration that impacts will be of an acceptable level and managed to as low as reasonably practicable (ALARP).

3.1. Identifying and detailing potential impacts

Core Concept

The potential impacts of an activity must be comprehensively identified and detailed for all receptors that might be exposed to acoustic emissions. The level of detail presented should demonstrate that potential impacts are suitably understood to allow a robust evaluation of impacts (Section 3.4).

3.1.1. Common deficiencies

- The level of rigour in the detailing of impacts is not matched to the complexity of the receiving environment and the flexibility inherent in some activities (e.g. strategic activities covering multiple surveys and years) resulting in receptors and/or impacts being missed.
- Inadequate consideration of the potential for sound to propagate into sensitive areas adjacent to the survey area and the potential impacts that may result.
- The detailing of impacts for socio-economic values does not adequately consider the indirect effects of sound exposure to relevant biota, e.g. indirect effects on a fishery.

3.1.2. Considerations

- An analysis of the potential interactions between the activity and its acoustic emissions (as described in section 2.1) with the biota in the receiving environment (as described in section 2.2) should be used to identify potential impacts. The EIA should explain, in sufficient detail, the potential impact posed by all activity phases on each receptor and habitat.
- The best available contemporary science on marine sound impacts, including relevant literature reviews, should be utilised to support the identification and discussion of potential impacts.
- When considering the best available contemporary scientific literature the focus should be on published peer reviewed papers and studies that are most applicable to the activity circumstances, e.g. comparability of sound exposure regime, receptors and types of impact.
- Impacts should be detailed at the appropriate biological/ecological level. The appropriate level will depend on the particular receptors and environment (e.g. level of protection afforded by relevant legislation) and the extent and severity of potential impacts, but may include: individual organism, population, community, or ecosystem.
- In general, the larger the spatial and temporal overlap with sensitive areas/periods, the more comprehensive the identification and detailing of impacts will need to be.
- Marine fauna impacts that may be attributed to acoustic emissions in the marine environment include mortality, physical injury, hearing loss (permanent or temporary), stress, diminished health, masking of communication, displacement from important habitats and behavioural disturbance.
- Indirect impacts should also be considered where relevant, for example:

  - Impacts on other trophic levels, e.g. prey displacement or depletion.
  - Reduced catchability or stock availability of commercially targeted fish species.
  - Reduced reproductive success.
- Details provided on each potential impact must be sufficient to inform the next sections of the EIA: defining the acceptable level (Section 3.2), and making predictions and evaluating impacts (Section 3.4).
- Greater levels of detail are required for receptors with: greater sensitivity to sound, greater stakeholder concern, higher levels of statutory protection, greater potential for interactions, and/or where there is significant uncertainty associated with the potential impact.
- The detailed scoping of relevant impacts from acoustic emissions from a particular activity should be informed by the nature of the receptors/species that are present in the area that may be affected by sound emissions, the range of behaviours/life stages that may be affected over the timescale of the proposed activity and the way they are expected to be affected by sound. For example;
  - Effects such as reduced or increased catchability of fished species will only be relevant where active fishing operations are overlapped by, or adjacent to, the activity.
  - Effects such as displacement or behavioural changes will be more relevant and have larger implications if they affect important or restricted habitats during biologically important periods. This is particularly important where biologically important areas are small, e.g. coastal dolphin species and pinnipeds.
- The identification and detailing of impacts for a particular activity can be complex, particularly for large operational areas over longer timescales. A conceptual model such as the one provided at Figure 2 provides an example of the complex interactions that need to be considered.
- The ways which marine fauna are affected by sound are complex and the science in this field is rapidly evolving. It is therefore important that the process for identifying impacts of relevance for a particular activity is sufficiently robust and informed by the best available information. Relevant sources of information may include:
  - Peer reviewed scientific literature, including literature reviews on the topic of sound and marine life. For example, a published critical review of the potential impacts of marine seismic surveys on fish and invertebrates (Carroll et al., 2017).
  - A detailed description of the marine fauna likely to be present in or adjacent to the survey area (refer Section 2.2).
  - Specific studies that explore noise impact pathways on particular receptors such as marine mammals, fish and invertebrates and suggested threshold criteria (typically a sound level) for impact.
  - Catch and effort data for fisheries target species.
- There is also a need to consider the potential for cumulative impacts. Cumulative sound exposure will influence the severity of particular impacts and this potential should be identified early to ensure cumulative sound levels are appropriately predicted to inform the evaluation of impacts (see Section 2.2). When considering the potential for cumulative impacts the status or health of the populations/stocks that may be affected should be considered. The cumulative impact scenarios to consider may include:

- Multiple exposures over the duration of one activity, e.g. consecutive parts of an activity.
- Multiple exposures from consecutive activities.
- Cumulative impacts over a large area where there are two or more simultaneous sound generating activities.
- Cumulative impacts over consecutive seasons in areas that are considered biologically important for certain receptors.
- Cumulative impacts from multiple, different sources of sound.
- Interactions between sound and other stressors.

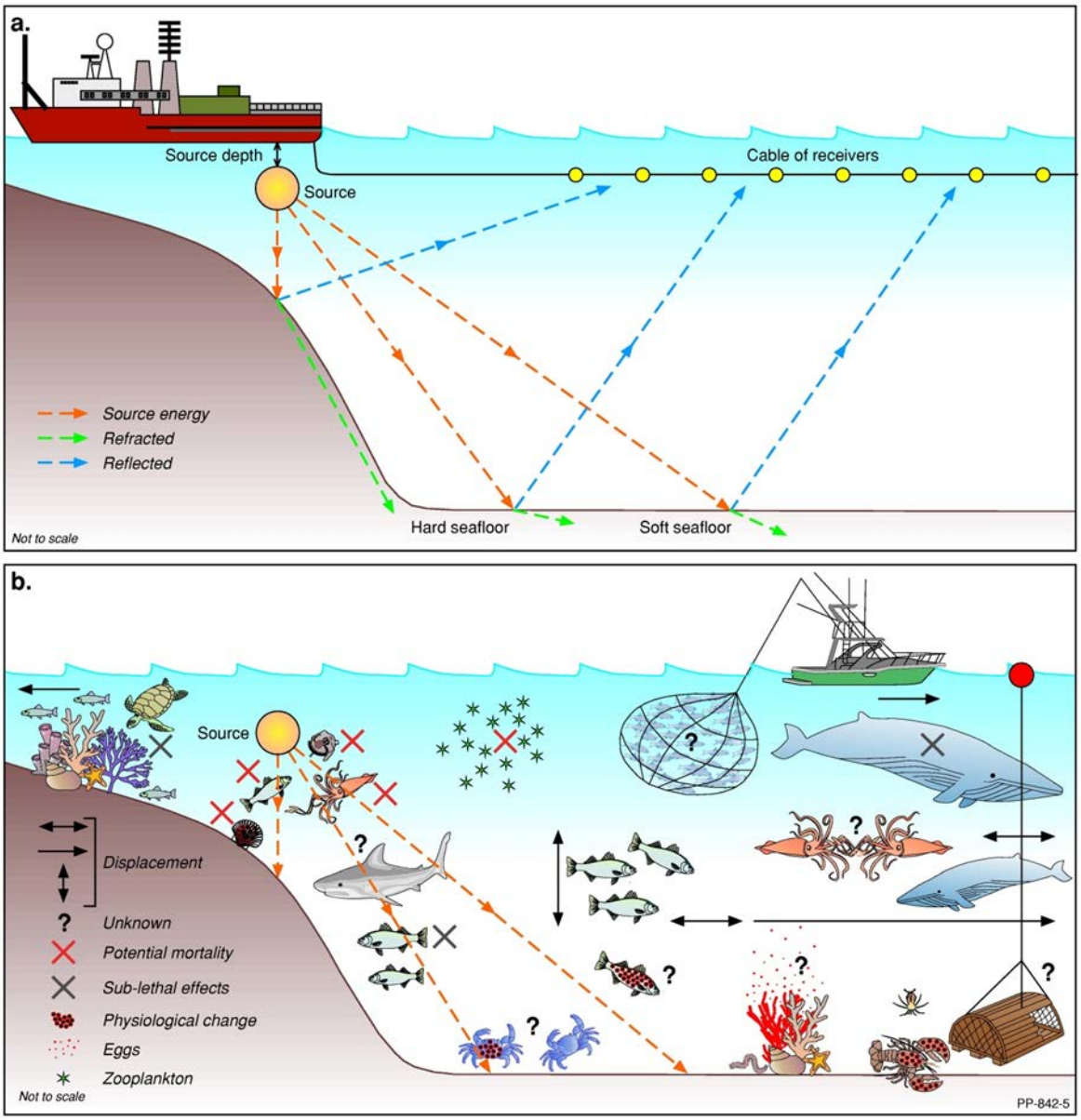

Figure 2. Example of a conceptual model illustrating the potential complex interactions between sound propagating from an airgun array and the various sensitive receptors that may be affected. A model such as this may be a useful tool to identify the impacts that are relevant to a particular activity circumstance in combination with robust science (Adapted from Carroll et al., 2017).

3.2. Defining the acceptable level

Core concept

The acceptable level(s) of impact should be defined for each relevant receptor group. Acceptable levels must be justified with regard to the biology and ecology of affected biota, conservation status of the species or area, conservation management plans and stakeholder feedback.

3.2.1. Common deficiencies

- No meaningful attempt to define acceptable levels of impact even where relevant context is available.
- Where acceptable levels of impact are defined, they are not adequately informed by stakeholder input or DoEE plans of management.
- The defined acceptable level is too broad and does not take into account directly relevant context for receptors that may be affected.
- The acceptable level for receptors that do not have statutory context is not adequately reasoned and supported in relation to potential regional/population/fishery consequence.

3.2.2. Considerations

- It is likely that multiple acceptable levels of impact will need to be defined to address differences in environmental sensitivity across an operational area and between fauna groups.
- The acceptable level should define the extent, severity and duration of impact that would be acceptable at an appropriate spatial/temporal scale.
- The defined acceptable levels of impact may be qualitative or quantitative but must be suitable to compare with predicted or measured impacts.
- In all cases, the acceptable level of impact should be unambiguous and well-informed by relevant external context that is specific to activity circumstances.
- The environment plan must demonstrate that the acceptable levels will be met through either providing evidence that proposed control measures will be effective or committing to measuring relevant parameters in the environment or both (Section 3.5.2).

Relationship with environmental performance outcomes

- The defined acceptable levels of impact should be reflected in the environmental performance outcomes as a measurable level of performance that will be used a basis for managing impacts to an acceptable level.
- Refer to Sections 4 and 5 of NOPSEMAs Decision Making Guideline (GL1721) for further general considerations on defining acceptable levels of impact and setting levels of environmental performance.

- The suite of acceptable levels required for a particular activity will be influenced by the diversity of noise sensitive receptors that may be affected as well as temporal and/or life stage sensitivities that may be affected.

- Acceptable levels of impact should be defined for specific receptors or fauna groups, e.g. AMP values and threatened cetacean species. Further, for environmental receptors that have commercial value, e.g. commercially fished species, there may be a need to define acceptable levels of impact that address both ecological and socio-economic considerations.
- The process for determining and defining the acceptable levels of impact for particular fauna groups should consider all relevant effects from sound (behavioural disturbance, physical effects etc.) and consider what would be acceptable at a local, broader population, ecological and/or socio-economic and regional context.
- It is important to consider that the acceptable level of impact may vary depending on the habitat and life stage that pertains to the location and timing of the activity. For example, it may be acceptable for an activity to result in some level of behavioural impact on individual fauna outside of an aggregation area or feeding habitat, though it may not be acceptable to have the same level of impact to individuals within a habitat or life stage that is critical to survival, e.g. as defined in a recovery plan.
- The statutory level of protection of a species or place will directly affect the acceptable level of acoustic emissions impact. For example, the acceptable level of impact may be higher in parts of the Commonwealth marine area that do not have a specific level of statutory protection or do not represent important habitats for threatened or migratory species than it would be for an area with statutory protection such as an AMP.
- In the context of acoustic emissions in AMPs, the acceptable level of impact is likely to differ between the assigned zone categories e.g. the acceptable level of impact for Ia or II zones is likely to be more conservative compared to a category VI zone and context from the Australian IUCN reserve management principles and/or the AMP management plan should be used to inform the acceptable level definition.
- Statutory instrumentation such as EPBC Act Policy Statements, plans of management for Australian marine parks and State marine parks and reserves and recovery plans and conservation advices for EPBC listed threatened / migratory species are relevant to defining the acceptable level of impact for matters protected under Part 3 of the EPBC Act, e.g. examples for pygmy blue whales and marine turtles in Table 2 below.
- There may be other forms of published documentation that may not necessarily be in the form of statutory management instruments that may inform the acceptable level of impact. For example, guidance published by State government agencies or relevant scientific research in relation to marine sound impacts.
- Within a licensed commercial fishing area, a productive location with high fishing effort may have a different acceptable level of impact compared to an area that is not actively fished/productive.
- The acceptable level of impact for a commercially fished resource may also be influenced by the stock status as determined by the relevant fisheries management agency.
- Relevant information from stakeholders who may be affected should inform the definition of acceptable levels and alignment with stakeholder views, although not mandatory, will strengthen the case that the level defined is in fact an acceptable one.
- Table 2 provides some examples of relevant context and aspects relevant to defining acceptable levels of impact for different receptors.

Table 2 Examples of how relevant external context may be used to define acceptable levels of acoustic emissions impact.

Receptor description	Relevant context	Examples of aspects relevant to defining an acceptable level of impact*
Pygmy blue whale (in biologically important area)	Actions to address anthropogenic noise in the Conservation Management Plan for the Blue Whale 2015-2025 http://www.environment.gov.au/system/files/resources/9c058c02-afd1-4e5d-abff-11cac2ebc486/files/blue-whale-conservation-management-plan.pdf	Injury (e.g. permanent threshold shift in hearing) to whales within biologically important areas. Disturbance to whales within defined foraging areas.
Marine turtles (during nesting period)	Recovery Plan for Marine Turtles in Australia 2017-2027 http://www.environment.gov.au/system/files/resources/46eedcfc-204b-43de-99c5-4d6f6e72704f/files/recovery-plan-marine-turtles-2017.pdf	Behavioural disturbance to or displacement of marine turtles within identified internesting habitats critical to survival of the species (as defined in Table 6 of the recovery plan).
Australian marine parks and their values	Management plans for Australian Marine Parks, marine bioregional plans, relevant published scientific studies, Guidance Note on Offshore Petroleum Activities and Australian Marine Parks (GN1785)	Class Approvals for mining operations. Specific marine park values and their vulnerability to impact associated with acoustic emissions.
Ningaloo World Heritage Area	The specific outstanding universal values for which the World Heritage area was proclaimed. Australian World Heritage Management Principles and management plans for the property.	Disturbance to whale shark and marine turtle aggregations during the foraging and nesting periods, respectively. Note: It is a requirement of the Environment Regulations that no activity occurs within a World Heritage Area (Regulation 10A(f)).
Demersal fish associated with a Key Ecological Feature (KEF)	Stakeholder feedback, location specific environment description (benthic habitat and demersal fish), relevant marine bioregional plan, DoEE SPRAT database, relevant published scientific studies.	Physical injury to demersal fish within important fish habitat.
Demersal fish as a fishery resource	Fisheries Status Reports from relevant fisheries management agency, e.g. DPIRD State of the Fisheries reports: http://www.fish.wa.gov.au/About-Us/Publications/Pages/State-of-the-Fisheries-report.asp, scientific studies on seismic impacts on catch and stakeholder feedback.	Spatial and temporal extent of overlap with important fishing areas/times.
Scallop	Scallop population dynamics research, seismic effects studies and local fishery context (e.g. stock assessments and CPUE data)	Scallop mortality relative to the level of documented natural variability.

* Note: the relevant context and defined acceptable levels are examples only and NOPSEMA expects that acceptable level definitions for an environment plan are developed on a case by case basis, considering all relevant external context for specific activity circumstances.

3.3. Predicting underwater sound levels

Core concept

The method used to predict source and received sound levels should be appropriate for the sound source, local environmental characteristics and potential impacts, and informed by expert advice.

Before making predictions of impact to compare with the defined acceptable levels it is critically important that the EP includes appropriate predictions of the underwater sound levels that will be generated by the activity. These predicted sound levels at various ranges from the sound source are typically compared with published biological effect thresholds and they must therefore carry an appropriate level of accuracy to inform the evaluation of impacts and design of controls. The modelling and prediction of underwater sound is technically complex and requires an appropriate level of subject matter expertise. The guidance set out below is not intended to be a technical 'how to' but rather sets out important considerations for deciding on an appropriate approach to generating sound level predictions that are fit for purpose for particular activity circumstances. A general guide for determining an approach that is appropriate to the nature and scale of a particular activity is provided at Figure 3.

3.3.1. Common deficiencies

- In a complex and/or sensitive environment, selecting a point source and spreading law propagation model rather than an appropriate 2D or 3D numerical model.
- Poorly justified inputs to the modelling, e.g. source level and frequency spectrum, bathymetry and acoustic properties of the seabed.
- The results of the detailing of impacts are not used to inform the scoping of received sound level predictions, in particular ensuring that units applied to predictions are comparable with appropriate impact thresholds.
- Predictions are at a spatial scale that are not aligned with the area that may be affected, e.g. no predictions in vertical plane or horizontal predictions not appropriately expansive.

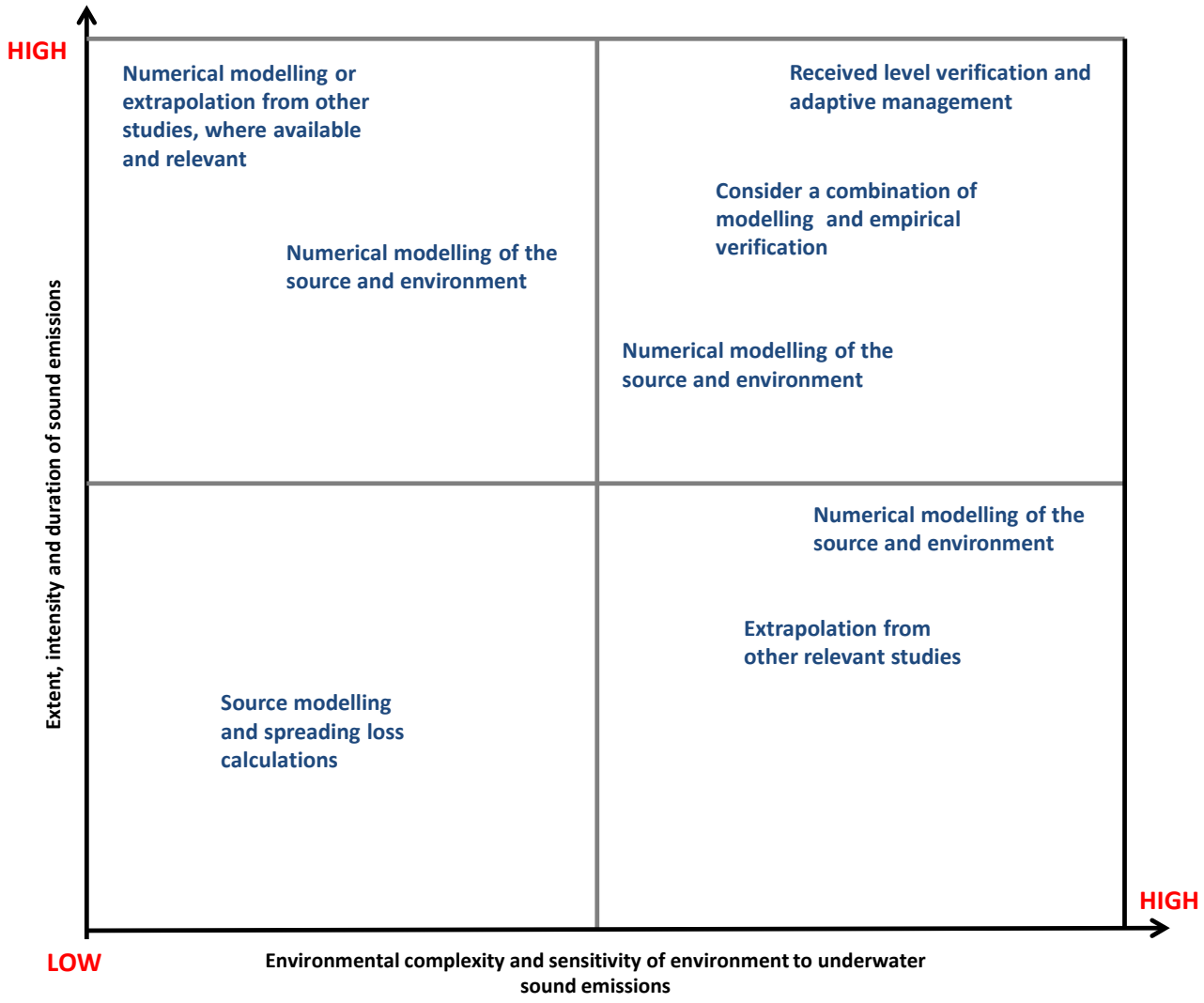

Figure 3: A general guide to selecting an approach to predicting underwater sound levels relative to an activity's sound exposure regime and sensitivity of the receiving environment.

Note: This is a qualitative and generic guide only. The selection of an appropriate sound prediction tool must be undertaken on a case by case basis to ensure fit for purpose for the particular activity circumstances.

3.3.2. Considerations

- The level of accuracy and rigour required in the prediction of received sound levels will be informed by the intensity and duration of acoustic emissions in combination with the complexity and sensitivity of the receiving environment.
- In all cases, there should be a clearly described justification as to why a particular approach has been taken to predict received sound levels including why this approach is appropriate in the context of:
    - Biological sound receptors in the receiving environment.
    - The spatial and temporal scale of the activity and the nature/intensity of the sound source.
    - The complexity of the operating environment and its potential to influence sound propagation.
- It is important that the personnel undertaking the sound prediction exercise have sufficient knowledge and experience with underwater sound modelling and the physics of underwater acoustic propagation

to ensure a) they are using the right models/methods, and b) that input parameters are appropriate and results are accurate and make physical sense for the particular activity circumstances.

- The outputs (measures and units) from the received sound level prediction exercise should be appropriate to inform the evaluation of impacts. In particular, the outputs should be comparable with appropriate thresholds for predicting the biological effects identified through an activity specific detailing of impacts.
- The outputs should be at an appropriate spatial scale for estimating sound exposure and associated impacts to all relevant biota and their habitats. For example, consideration for the minimum distance between the sound source and sensitive fauna habitats and the position of relevant fauna/habitats relative to the sound source (e.g. seabed below the source and shoals adjacent to the source).
- The relevant area for modelling should be determined based on the spatial extent of the activity; the spatial extent of potential impacts; and the importance of biological habitats and socio-economic areas.
- Regardless of modelling approach, predictions of received sound level that directly inform conclusions regarding the likely effectiveness of controls or the demonstration of acceptable impacts should be supported by a desktop evaluation of the validity (i.e. accuracy and precision) of the predictions, e.g. sensitivity analysis of assumed environmental parameters and benchmarking against actual measured data.
- Sites / areas selected for modelling should be representative of the environmental parameters for which modelling results may be applied (e.g. bathymetry, salinity, seabed composition and temperature) and for many activities more than one modelling site may be required.
- Limitations and caveats with the chosen modelling/prediction approach should be clearly described.
- Point-source models with simple acoustic spreading laws are unlikely to be appropriate models for predicting received sound levels from seismic airgun arrays in complex marine environments (see Table 3).
- Numerical models are likely to be appropriate for predicting received sound levels in units of biological relevance to receptors.
- There are many numerical models that have been developed to predict sound propagation in the marine environment. The selection of the most suitable method will be influenced by factors such as the sound frequency of the emitting source, the complexity of bathymetry, seabed properties and water depth. More detailed context on numerical model selection is available in a New Zealand Department of Conservation report (DoC, 2016):
- https://www.doc.govt.nz/Documents/conservation/marine-and-coastal/seismic-surveys-code-of-conduct/twg-reports-2016/05-scr-sound-mod.pdf
- In circumstances where there is considerable uncertainty in relation to model inputs, model outputs, and the model's limitations, some form of model verification and / or a conservative mitigation approach is likely to be warranted, particularly where the effectiveness of controls relies on accurate sound level predictions.
- Sufficient information on the methods, inputs, assumptions, limitations and uncertainties of predictions of received sound levels should be clearly presented in EPs and is important for transparency and accurate interpretation.

- It is generally not appropriate to assume that the results of a sound prediction model from one activity scenario can be sensibly applied or extrapolated to provide accurate predictions for another. The availability and suitability of previous modelling and/or sound field verification exercises should be considered when choosing both source and environmental models, however these historic modelling exercises should only be utilized in appropriate circumstances which will be informed by the similarities in the acoustic source, bathymetry and geo-acoustic properties of the receiving environment.
- Predictions of received sound levels should be presented in such a way that it is clear what levels may be received at the seabed directly below a source as well as laterally (endfire and broadside) at the seabed and in the water column.
- Note: Specific considerations for a number of commonly used predictive tools are outlined in Table 3.

Measures of sound and associated units

- Decibels (dB) are not a fully formed stand-alone unit and all measurements of underwater sound levels for EIA purposes require specification of the reference value, time range, frequency range, and weighting (where applicable).
- Common sound measures relevant to EIAs may include (equivalent) source level, propagation loss, sound exposure level, (root-mean-square) sound pressure level, particle velocity level, and peak sound pressure level (ISO 2017b; ANSI 2013).
- For complex real-world signals, there is no universally correct analytical formula to convert different measurements of sound level e.g. sound exposure level or root-mean-square sound pressure level to peak sound pressure levels. Instead these quantities should each be measured from the actual sound or calculated from the modelled waveform or spectrum (Madsen 2005).
- The sound measurements most applicable to evaluating impacts to certain biota may shift between and within faunal groups. For example:
    - It has been suggested that thresholds for mitigation of temporary and permanent threshold shift for marine mammals should include independent criteria for both sound exposure levels and peak sound pressure levels (Southall *et al.* 2007; NOAA 2016; Finneran 2015)
    - Scientific literature generally specifies the use of sound exposure levels (SEL) or RMS for determining behavioural disturbance to marine mammals, but peak levels may also be appropriately considered where data are available (Southall *et al.* 2007; Southall *et al.* 2016).
    - The sensitivity of hearing in pinnipeds differs between families and this difference should be reflected in the impact thresholds applied to different species of pinniped (CMS, 2017b).
    - For some fish and invertebrates greater consideration of particle motion may be more biologically relevant than sound pressure (Popper and Hawkins, 2018; Nedelec *et al.*, 2016). Noting that further research is required to determine thresholds for effects.

Table 3: Key considerations associated with various underwater sound prediction tools and model validation

Predictive methods	Key considerations
Simple spreading loss calculations	• Represents a simple approach to calculating propagation loss using simple equations derived from geometric theory and generally only yield accurate results in simple scenarios (Lurton, 2010). • If used in inappropriate circumstances, can lead to significant underestimates or overestimates of the transmission loss and consequently inaccurate predictions of received sound levels. • This method is unlikely to be appropriate when predicting impacts in environments with variable bathymetry and inadequate mixing of the water column (Duncan and Parsons, 2011).
Source modelling	• Source modelling can provide accurate measures of sound in the near field (within close proximity to the source) and can be valuable model inputs for acoustic footprint modelling purposes in the vertical and horizontal planes. • The use of source modelling to predict far field signature from an airgun by applying geometric spreading scales does not account for critical sound propagation factors such as sound speed variation, seabed properties and bathymetry. Consequently, this may result in underestimating received levels in the far field and are unlikely to be appropriate in variable and sensitive environments.
Extrapolation from other studies	• Requires input parameters representative of environments for which the model is to be applied. • The justification of the application of modelling across a broader area should include comparability between site characteristics, explanation of any differences in the acoustic source size and intensity and whether model outputs are applicable for determining appropriate received levels for sensitivities at other locations. • Limitations, assumptions and uncertainties are to be adequately accounted for through conservative application of management measures.
Underwater acoustic modelling	• Accurate and comprehensive model inputs are critically important for successful prediction of sound levels. The nature of the environment, in particular the bathymetry, composition of the seabed, and the sound speed profile of the water column, strongly affect the propagation and attenuation of sound (Farcas et al. 2016). • Model inputs should be robustly measured or estimated, contain sufficient spatial coverage and resolution throughout the area being modelled, and should be accompanied by explicitly stated measures of certainty and variability. • Sufficient characterisation of sound source is required for an accurate output and poorly justified or incorrect assumptions regarding the source level, spectrum, and directionality of a sound source are to be avoided.

Model validation	• Comparison of predictions with measured sound levels provides a direct and holistic means of assessing the validity of a model and should be considered when modeling exercises are likely to underestimate received levels due to information gaps and assumptions. Validation data may come from previous recordings of the sound source in the modelled area or from in-situ measurements. • In cases where environments are highly sensitivity to sound, verification of model outputs may be necessary in order to provide feedback to sound propagation models in order to improve their accuracy and inform adaptations to control measures to ensure they remain effective. • For successful validation, ideally measurements would be sampled at sufficient resolution over the full range of environmental conditions covered by the model using appropriately calibrated sound monitoring equipment.

3.4. Making predictions and evaluating impacts

Core concept

The impact evaluation process is used to predict the extent, duration and severity of impacts through a comprehensive analysis of the interaction of activity-generated sound with relevant biota and socio-economic values.
The evaluation must also acknowledge uncertainty associated with predictions of impact.

3.4.1. Common deficiencies

- The submission includes very limited activity specific evaluation of impacts and is largely focussed on the detailing of impacts by summarising relevant literature.
- For large scale, long duration activities, the comprehensiveness and granularity of the evaluation of impacts is not commensurate and does not adequately consider interactions of the activity with particular sensitive areas, times and/or receptors.
- The scope and effort in cumulative impact evaluation is not representative of the flexibility in the activity description.
- The evaluation of impacts is limited to predicting the received sound level at a particular sensitive area without analysing the ecological consequence of this exposure.
- The predictions of impact are not sufficiently detailed to inform the consideration and design of controls for different seasons and environmental features.

3.4.2. Considerations

- The evaluation of impacts must be activity specific and integrate all relevant contextual information such as the sound exposure regime, the nature of the receiving environment, legislative and other requirements, the details of impacts, predicted received sound levels and stakeholder expectations (refer Section 2) in order to make robust and defensible predictions of impact.
- Greater effort and rigour in impact evaluation is required for:
    - Species or places with conservation or socio-economic significance, e.g. listed threatened species or productive fishing area for high value fishery.
    - Receptors for which there is greatest potential for impact, greater stakeholder concern and/or significant uncertainty in potential for impact.
- The scope of the impact evaluation process should be underpinned by the results of the detailing of impacts and definition of acceptable levels of impact.
- The evaluation and prediction of impacts from acoustic emissions should be supported by the best available science, i.e. relevant, applicable, contemporary, peer reviewed and published by reputable sources.
- In circumstances where the impact prediction method is untested, has a high level of uncertainty or where the activity occurs in a highly sensitive environment, the veracity of the impact assessment process and appropriateness of control measures should be reviewed by an independent expert(s) with suitable qualifications and expertise.

- The conclusions of the evaluation of impacts should be of a nature that allows comparison with the defined acceptable levels of impact.
- The evaluation of acoustic emissions impacts typically requires comparison between received sound level predictions and threshold criteria for effects. Where there are multiple published thresholds for the same effect, the selected thresholds need to be justified as suitably relevant for the receptor and effect that is being evaluated in the context of the best available science.
- In referencing scientific studies during the impact evaluation process, the relevance of the study to the activity under assessment should be clearly established, e.g. relevance to specific fauna groups and species affected by the activity and the activity's sound exposure regime, and limitations should be acknowledged.
- An evaluation to determine whether sound thresholds for particular fauna groups will be exceeded represents one component of the assessment process. Thresholds may be used to estimate the distance from the sound source at which a particular effect may occur on individuals, however the evaluation must also assess the cumulative effects from the full activity scope and the biological or ecological consequence of all relevant effects at an appropriate spatial scale.
- The evaluation of impacts should also consider the potential for cumulative effects from multiple noise sources, either concurrent or sequential in the region of the proposed activity. This evaluation should use the best available information on proposals for significant noise generating activities, e.g. the 'Activity Status and Summaries' page on NOPSEMAs website.
- In cases where the activity is temporally and/or spatially expansive and/or there is flexibility as to the size/output of the sound source, the evaluation of impacts will need to carefully analyse all potential interactions between acoustic emissions and receptors within the scope and bounds of the described activity. For example, interactions:
    - At sensitive times of year, e.g. breeding.
    - Over the most sensitive habitats of the operational area, e.g. foraging areas.
    - Over extended durations and sequential seasons.
    - That involve the use of the sound source with the highest output.
    - Of a cumulative nature, e.g. sequential surveys over the same area.
- For activities that are expansive in duration and spatial extent, the impact assessment process should account for the different biophysical environments and receptors that may be exposed throughout the area during all relevant seasons. It may be logical to evaluate impacts for different areas that have been delineated into meaningful and relevant sound emission impact areas for EIA purposes. These areas could be based on fauna habitat attributes, bathymetry and geophysical properties, key ecological features and / or marine protected areas.
- Limitations in the quality of contextual information and assumptions made during the prediction of impacts that may increase uncertainty in predictions should be clearly identified so that they can be taken into account in the consideration of practicable controls and measures to ensure impacts will be of acceptable levels (see Section 3.5 below).

3.5. Managing impacts of acoustic emissions from seismic surveys

The Environment Regulations include two criteria relating to managing impacts that must be met before an Environment Plan can be accepted, i.e. it must be demonstrated that impacts will be reduced to both as low as reasonably practicable (ALARP) and acceptable levels. Considerations for ensuring that these two tests are met are outlined in Sections 3.5.1 and 3.5.2.

3.5.1. Managing impacts to as low as reasonably practicable (ALARP)

Core concept

The consideration of what control measures are reasonably practicable should be directly informed by a thorough understanding of the extent, severity, duration and uncertainty of predicted impacts (untreated), and thus the benefit of reducing these impacts for different biota.

Common deficiencies

- The design of controls is not adequately informed by the prediction of impacts, e.g. precaution zone size relative to range at which relevant effects are predicted to occur.
- The analysis of the practicability of control measures does not clearly consider the environmental benefit(s) gained through implementing controls relative to their time, effort and monetary cost.
- The level of protection afforded by controls does not consider the level of uncertainty in impact predictions.
- The practicability of controls is only considered at a coarse level, i.e. is the control practical to implement over entire area and duration, with no consideration of the practicability of additional/more effective controls for more sensitive areas and/or times.
- Inadequate evaluation of the practicability of improving performance of identified controls, e.g. additional marine fauna observers, longer fauna observation times or larger buffer zones.

Considerations

- Reducing impacts and risks to ALARP is based on the concept of reasonable practicability; the weighing up of the magnitude of impact or risk reduction against the cost of that reduction. In this context, a titleholder is required to implement all available control measures where the cost is not grossly disproportionate to the environmental benefit gained from implementing the control measure (NOPSEMAs Environment Plan Decision Making Guidelines: GL1721).
- The identification of available controls should consider a hierarchy of control measures which typically includes, in order of priority and effectiveness: elimination, substitution, reduction and mitigation.
- The process of identifying potential controls should consider all relevant context including Australian policy and guidance documents and plans of management for relevant species and areas.
- The level of rigor required in the ALARP demonstration will be directly influenced by the magnitude of the predicted impacts from acoustic emissions and the sensitivity of the receptors and areas affected.
- The identification and evaluation of control measures should consider differences between fauna groups, and even species, to determine required effectiveness of controls at reducing impacts from acoustic emissions.

- The ALARP demonstration should ensure that the environmental benefit of adopting incremental improvements in identified control measures is explored, e.g. increasing size of a precaution zone.
- The ALARP demonstration should include identification and discussion of alternative survey methods including methods with lower sound source levels and/or restricted frequency output with clear justification as to why they have or have not been adopted.
- The control measures and practices that are implemented in an international context should also be considered to demonstrate that all reasonably practicable controls have been considered to reduce impacts (see further reading below).
- In all cases, considerable emphasis should be placed on the design of a petroleum activity so that particularly important or sensitive areas and seasons can be avoided during the early stages of project planning. This may include the exclusion of an activity from areas that are known to provide habitat for high conservation value fauna or periods that are important from a species life history perspective (e.g. foraging aggregations or spawning habitat). This avoidance will limit the need for specific controls to reduce sound exposure to sensitive biota during sensitive periods.
- In the case of seismic surveys, options that should be considered for reducing acoustic emission intensity and extent may include use of a smaller/lower output source, changes to array configurations to minimise horizontal sound propagation, variation to air gun design to minimise unnecessary sound frequencies (i.e. high frequency wavelengths), increased line separation combined with additional streamers to reduce acquisition duration and cumulative noise effects, or even substitution for a non-airgun source (consideration of emerging technologies).
- In circumstances where controls to eliminate, substitute and / or engineer project aspects to reduce activity generated sound in the marine environment have been exhausted, the use of administrative or procedural controls may be required to ensure that residual impacts can be sufficiently mitigated.
- The evaluation of control measures should consider practicability of implementing additional or more effective controls during particularly sensitive seasons and/or areas. This is particularly important where the proposed activity is expansive spatially and/or temporally or where there is substantial flexibility as to when or where a survey may occur.
- Key areas of predictive uncertainty identified during the evaluation of impacts need to be addressed. This can be achieved through specific measures to increase effectiveness of controls, development of adaptive management controls or measures to validate predictions (refer Table 3 for specific examples).
- The EPBC Policy Statement 2.1 provides important and relevant context for identifying and designing control measures to mitigate impacts to cetaceans.
- For activities with a higher potential for impact (overlap with sensitive fauna habitats and times), the ALARP demonstration should evaluate the relevance and practicability of control measures recommended by international guidelines and other relevant peer reviewed literature, e.g. advancements in science and technology.
- The most commonly implemented controls for seismic surveys to mitigate impacts to cetaceans are precaution zones (e.g. EPBC PS 2.1 and NZ Seismic Code of Conduct). These controls rely on effective detection of cetaceans during a survey to inform seismic airgun shutdown and/or power down. There are numerous reviews on the effectiveness of cetacean detection methods (e.g. recent review by Verfuss et al. (2018)) that provide useful context.

- Where precaution zones are proposed their effectiveness should be supported by comparison between sound level predictions and relevant effect thresholds and the behavior of the biota they are intending to protect.
- Decisions on the cetacean detection methods that will be effective and appropriate for a particular activity should consider the biology of relevant cetaceans (e.g. vocalisation frequencies and diving behaviour), the physical environment (e.g. water depth and prevailing weather) as well as the design and configuration of viewing platforms (e.g. obstructions to 360 degree visibility).
- The effectiveness of fauna detection measures will also be influenced by the training and competency of the personnel implementing them. Consideration should be given to minimum competency requirements and personnel numbers relative to expected level of fauna encounters and the measures being applied, e.g. passive acoustic monitoring or visual observations.
- Although specific control measures required or recommended around the world will vary, control measures will typically involve a combination of:
    - Spatial or temporal restrictions to avoid biologically important habitats or biologically important periods.
    - Minimising the intensity of received sound levels by reducing source size and output.
    - Limiting sound exposure to specific places or fauna groups by implementing exclusion zones, buffer zones or noise reduction zones.

Further reading:

CMS (2017) Technical Support Information to the CMS Family Guidelines on Environmental Impact Assessment for Marine Noise-generating Activities', Convention on Migratory Species of Wild Animals, Bonn

DCE (2015) DCE (Danish Centre for Environment and Energy) (2015) Offshore seismic surveys in Greenland – Guidelines to best environmental practices, environmental impact assessments and environmental mitigation assessments.

Discovery of Sound in the Sea (DOSITS): https://dosits.org/

Department of Conservation (2013) Code of conduct for minimising acoustic disturbance to marine mammals from seismic survey operations. Department of Conservation, Wellington, New Zealand.

Department of Conservation (2016) Various Technical Working Group reports relating to the environmental impacts assessment and management of seismic surveys: https://www.doc.govt.nz/our-work/seismic-surveys-code-of-conduct/work-of-the-technical-working-groups/

Nowacek and Southall (2016). Effective planning strategies for managing environmental risk associated with geophysical and other imaging surveys. Gland, Switzerland: IUCN. 42pp.

Hawkins, A.D. & Popper, A.N., 2016. A sound approach to assessing the impact of underwater noise on marine fishes and invertebrates. ICES Journal of Marine Science: Journal du Conseil, 74(3), pp.635–651. Available at: http://icesjms.oxfordjournals.org/lookup/doi/10.1093/icesjms/fsw205.

3.5.2. Managing impacts to acceptable levels

Core concept

To demonstrate that the acceptable level(s) will be met, the evaluation should compare the predicted treated (residual) acoustic emissions impacts with the pre-defined acceptable levels of impact and in cases where the predicted levels will or may exceed the acceptable level of impact, additional verification measures, control measures or activity alterations will be required to make the impacts acceptable.

Common deficiencies

- The impact predictions for marine protected areas are not compared with acceptable level context provided by the IUNC reserve management principles or management plan objectives/actions.
- The demonstration of acceptable levels of impact is not supported by information contained in the details, evaluation and prediction of impacts.
- Where activities are proposed in sensitive environments and impact predictions carry substantial uncertainty inadequate consideration is given to measures to verify effectiveness of controls and/or accuracy of predictions.
- Where uncertainty in impact predictions is addressed through increasing effectiveness of control measures there is no clear link between the conclusions of the impact evaluation and the design of controls to show that control measures will be effective in reducing impacts to an acceptable level.

Considerations

- Where the comparison of residual (treated) impacts with the defined acceptable level(s) indicate that this level(s) will or may be exceeded suitable measures should be evaluated and if needed committed to in order to ensure impacts are acceptable (e.g. such measures may include further mitigation and/or study to validate that predictions are accurate).
- A comparison of treated impacts with a defined acceptable level of impact should carefully consider the degree of confidence in the impact predictions and effectiveness of proposed controls by acknowledging key assumptions and limitations. Predictive uncertainty that creates doubt as to whether the acceptable level(s) will be met should be addressed.
- Where it is unclear as to whether the acceptable level of impact will be exceeded due to predictive uncertainty there are a range of measures that may be considered to address this, including:
    - Enhancing effectiveness of control measures.
    - In-situ measurement of received sound levels to validate sound level predictions.
    - In-situ field studies to determine presence, abundance and behaviour of biota or validate predictions of impact on biota.
    - Implement adaptive management measures in response to information collected during activity implementation.
- Following the comparison of predicted impacts with acceptable levels of impact, the impact evaluation and mitigation process should focus on fauna groups where the acceptable level is predicted to be exceeded or where there is uncertainty as to whether the acceptable level will be exceeded.

- In some cases and depending on factors such as the magnitude and importance of predicted impacts and/or scientific uncertainty around achievability of the acceptable level, it may be necessary to commit to undertake field based or in-situ monitoring or model validation studies in order to ensure that environmental impacts are within the acceptable level during implementation. Decision guidance is provided below in Table 3 to inform decisions on when to implement these measures.
- In other circumstances, measures to ensure control measures are being effectively implemented may be sufficient to demonstrate that the acceptable level is being met.
- Where specific measures are employed to test predictions and ensure impacts will be of an acceptable level, an adaptive management framework or similar will be required to ensure that control measures remain effective and can be adapted over the life of the activity in response to new information.
- Adaptive management is commonly implemented for seismic surveys to manage uncertainty associated with received sound levels, predictions of impact, effectiveness of controls and/or the level of fauna interaction. An effective adaptive management process should clearly describe:
    - The key performance aspects of measures that will be employed to test accuracy of predictions, e.g. equipment specifications, calibration and training and competency of personnel for sound level verification.
    - The process for appropriately assessing and applying the results to environmental management.
    - The criteria to be used to decide if and when defined action will be taken in response to results to ensure environmental impacts remain acceptable and are continually reduced to ALARP, e.g. implementation of new or revised control measures.

Table 3: Examples of measures to address predictive uncertainty and decision guidance on implementation

Examples of measures to address predictive uncertainty	Factors that may be relevant when considering adoption of specific measures
In-situ measurement of received sound levels at sensitive locations during activity implementation.	• Underwater sound levels within sensitive fauna habitat are predicted to be close to levels of concern for particular species and life stages. • The conclusion regarding the effectiveness of a control measure or the case that impacts will be of acceptable levels is heavily reliant on sound level predictions, which carry uncertainty. • Sound level predictions are confounded by limited local geoacoustic data or simplistic prediction methods are applied to complex operational and environmental circumstances. • There is potential to adaptively manage the activity in response to underwater sound measurement results or benefit in confirming that a particular sound level of concern will not be exceeded. • No or limited previous sound validation data for similar sound source and operating environment. • There are no further reasonably practicable controls available.
Field studies to determine presence, abundance and behaviour of biota	• There is limited baseline data on distribution, abundance and behaviour for key sensitive species.

	• There is potential for data to be collected before or during the activity to inform management decisions. • Additional precautionary management measures are not reasonably practicable. • Marine mammal observations from the survey vessel may not be effective in collecting the required data, e.g. where important whale habitat is beyond effective observation distance but there is potential for disturbance at this range. • Reduced survey cost with improved knowledge and certainty regarding the presence/absence of a receptor.
Field studies to validate predictions of impact on biota	• Absence of or conflicting scientific studies to inform impact predictions for relevant receptors. • Impact predictions indicate that an acceptable level of impact may be exceeded when conservative assumptions are applied to account for scientific uncertainty. • There is potential for results to inform management of future activity phases or benefit in confirming that a particular level of impact has not been exceeded. • There are no further reasonably practicable controls available.
Development of adaptive management measures	• There are gaps in important data underpinning impact predictions that can be filled by monitoring, with results used to inform timely management actions that will ensure impacts continue to be managed to ALARP and acceptable levels during activity implementation. • Monitoring data (e.g. fauna abundance or received sound levels) can be applied to risk-based decisions regarding the implementation of additional/more effective controls.

Ongoing ALARP and acceptability

The scope of this information paper does not extend to implementation strategy elements. However, it is worth highlighting the importance of ongoing measures to ensure that impacts continue to be managed to ALARP and acceptable levels for the duration of the activity. This includes processes to identify and evaluate changes in the knowledge base that underpins ongoing management of environmental impacts. Examples include:

- changes to management instruments for protected places or species such as statutory plans of management for Australian marine parks, recovery plans for threatened species, and management plans for World Heritage areas, new published literature on effects of sound on relevant marine life, new information on the presence (abundance and distribution) of noise sensitive receptors or new information from stakeholders during the implementation of the activity must be considered and responded to appropriately.
- New information to indicate that received sound level predictions were inaccurate, such as in situ monitoring or additional modelling results. This new information must be considered in the context of the suitability of the adopted controls for managing acoustic emissions impacts to ALARP and acceptable levels.

For further guidance, refer to Section 6 of NOPSEMAs Decision Making Guideline (GL1721) and Environment Plan Content Requirements Guidance Note (GN1344).

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Note: All regulatory references contained within this Information Paper are from the Commonwealth Offshore Petroleum and Greenhouse Gas Storage Act 2006 and the associated Commonwealth regulations. For facilities located in designated coastal waters, please refer to the relevant State or Northern Territory Petroleum (Submerged Lands) Act 1982 and the associated regulations.

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