Technical Guidance

Environmental Impact Assessment of Marine Dredging Proposals

Environmental Protection Authority

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1.0 Introduction and background

1.1 Purpose

This Technical Guidance describes the impact prediction and assessment framework that the EPA expects proponents and consultants to use so that predictions of the extent, severity and duration of impacts to benthic habitats associated with significant dredging activities are presented in a clear and consistent manner.

This is generic guidance that applies State-wide and as such, it does not differentiate between types of dredging proposals or regional environmental differences, nor does it provide specific technical guidance on impact prediction methodology for developing or using pressure-response thresholds for predicting environmental impacts.

The framework outlined in this guidance is not new and doesn't signal a fundamental shift from the approach outlined in the EPA's replaced Environmental Assessment Guideline for Marine Dredging Proposals (EAG 7) (EPA 2011). Applying the framework across different projects provides a common approach to setting environmental outcomes and for monitoring impacts, which could improve understanding and prediction of dredging related environmental effects.

It should be noted that while the framework outlined in this technical guidance is focused on the environmental impact assessment (EIA) of dredging related activities, the approach can also be applied to the EIA of other types of development proposals to address uncertainty around impact predictions.

1.2 Background

Dredging is an activity carried out at existing and new ports and the associated sediment plumes have the potential to influence large areas beyond port boundaries. The scale and number of significant dredging projects in WA is large by world standards and this places the EPA at the forefront of dealing with the environmental issues associated with this type of development. In addition to the large scale of dredging and the potential spatial extent of its influence, dredging projects often occur in sensitive environments with unique and/or generally poorly-understood biodiversity and ecology (e.g. understanding of the natural tolerances and susceptibilities of key biota). This uncertainty presents significant challenges for environmental impact assessment and management. The EPA acknowledges this uncertainty and has adopted a pragmatic approach that ensures the range of likely impacts are considered in EIA based on sound scientific principles. Furthermore, this approach should also help reduce uncertainty over time as monitoring data that present the actual impacts and effects become available and are used to calibrate predictive models.

The EPA also strongly supports the research being undertaken via the **Dredging Science Node** of the Western Australian Marine Science Institution (WAMSI). The Dredging Science Node is analysing available monitoring data and using the findings to guide targeted research programs. This combination of analysis and applied research is building an evidence base for proponents and regulators to use to better predict and manage the impacts of marine dredging campaigns. These initiatives should lead to more rigorous and timely assessment and more efficient and cost-effective monitoring and management.

Other legislation, regulations, management frameworks and guidance also exist for a number of key environmental issues relevant to the assessment, management and regulation of dredging proposals. These environmental issues include sea dumping, contaminated site assessments, and protection of wildlife. It is the responsibility of proponents to address the requirements of all relevant legislative and regulatory frameworks and guidance issued by other agencies. The EPA draws upon information presented by proponents in the context of these (and other) relevant regulatory frameworks and the advice of relevant regulators during its assessment of dredging proposals.

2.0 Context

2.1 What is dredging?

Dredging involves excavation of the seabed, typically underwater, but it may also occur in intertidal areas during low tide or behind constructed bunds designed to maintain a 'dry' dredge site.

A number of different types of dredges are typically used for significant dredging proposals in WA. These include hydraulic dredges such as cutter suction dredges and trailing suction hopper dredges, and mechanical dredges including bucket or grab dredges.

Most dredging proposals are carried out to provide navigable water depths for shipping in ports and harbours and associated shipping channels. Dredging of trenches for the placement of subsea pipelines is another relatively common practice. Dredging for marine mining operations that target calcium carbonate, diamonds and other resources is also proposed from time to time.

> For the purpose of this document, dredging refers to seabed excavation and dredge material placement activities that introduce sediments to the water column.

Once material is excavated from the seabed by a dredge, it can be handled in a number of different ways. Often dredged material is loaded into a hopper (part of the dredge itself or on a separate vessel) and transported to a disposal site where the contents of the hopper are emptied directly in the open ocean (i.e. *sea dumping*) or via a pipeline that allows the dredge material to be pumped to a location where it is used for 'alternative' purposes (e.g. *land reclamation*). Depending on the type of equipment being used and the substrates involved, dredged material is sometimes pumped directly from the dredge site to a disposal location either at sea or on land.

Material dredged for pipeline trenches is often placed temporarily on the seabed adjacent to the trench (i.e. *side-cast*) before being placed back into the trench to stabilise and protect the pipe after it has been laid. Less commonly, some dredging operations for port facilities involve dredged material being side-cast near the dredge site before it is picked up by another dredge and transported to the disposal site.

2.2 Environmental considerations

All dredging causes an environmental impact at dredge and disposal sites (Victoria EPA 2001, EPA 2013, Mills and Kemps 2016) and, potentially, also further afield (PIANC 2010). Some examples of the types of potential impacts associated with dredging proposals include:

Impacts to benthic communities and habitats

- direct loss of benthic communities and habitats by removal or burial
- indirect impacts on benthic communities and habitats from the effects of sediments introduced to the water column by the dredging and disposal

Other types of impacts

- changes to shorelines, bathymetry and habitats through modified ecological and physical processes
- introduction of invasive pest species translocated in dredging (or ancillary) equipment that can have both ecological and economic consequences
- adverse effects of contaminant release and dispersion (including impacts associated with reclamation or onshore disposal of acid sulphate soils) on marine environmental quality
- conflict with fisheries and impacts on fish, their habitats and fisheries production

- changes to coastal processes and water circulation that impact on the environmental values of the coast and coastal waters
- impacts on the behaviour and survival of marine wildlife, including specially protected species.

This document only provides guidance for the presentation of predicted impacts of dredging activities on benthic communities and habitats caused by direct removal, burial, or indirect impacts of suspended sediments.

Although the other types of impacts listed above are not addressed further in this document, this should not be taken to imply that they are not relevant or important. In some locations, dredging may have implications for marine conservation reserves and/or marine fauna, or for public uses of the environment such as commercial and/or recreational fishing. Where dredging involves contaminated sediments the disposal of those sediments could create a contaminated site which may need to be regulated.

2.2.1 Dredge-generated sediments and their effects

Dredging and spoil disposal introduces sediment to the water column to varying degrees from three principal sources:

1. from the mechanical interaction of the dredging equipment with the seabed substrates
2. from overflow associated with loading[1] of dredged material and land reclamation
3. from the disposal of dredge spoil.

The mechanical interaction of dredging equipment with the seabed causes sediment particles, in a range of particle sizes, to be introduced to the surrounding water column at the dredge site (e.g. loss from the cutting head of a cutter suction dredge or spillage from grab/bucket dredges). Limited under-keel clearance and turbulence from propellers can also disturb and lift sediments into the water column.

Hydraulic dredges produce slurries that comprise a fine sediment-water mixture and dredged solids. When the fine sediment-water mixture is allowed to escape during loading at the dredging site or from a land reclamation area, it can introduce significant loads of fine sediment to the water column. This sediment-laden discharge is the second principal source of sediment introduced to the water column by dredging and is commonly referred to as *overflow* or *spill* when discharged from vessels or *return water* when discharged from reclamation areas (see Mills and Kemps (2016) for an overview).

Some sediment is also introduced to the water column during disposal of dredged material at sea, although the proportion of fines retained in spoil is relatively low when overflow practices are used during loading. Accordingly, in many cases only a relatively modest proportion of all fine sediments produced by dredging is introduced to the water column during dumping at sea. Exceptions to this will arise where overflow at the dredge site is eliminated or highly controlled to manage release of contaminants or when dredging up-current of particularly important areas.

The effects of dredge generated suspended sediments on benthic communities and habitats are considered to be indirect effects in the context of this Technical Guidance. The primary environmental effects relate to:

1. decreased light transmission through the water column reducing the amount of light available at the seabed, leading to a lowering of primary production and even death of benthic primary producers if effects are acute or prolonged

[1] As defined in the *National Assessment Guidelines for Dredging*, Commonwealth of Australia, Canberra, 2009.

2. abrasion of membranes or clogging of breathing or filter feeding organs on some benthic invertebrates causing stress and even death of more sensitive species
3. increased rates of sediment deposition beyond natural levels leading to stress and in extreme cases mortality.

The characteristics of sediment introduced to the water column by dredging can be very different to the characteristics of natural substrates at a dredge site. The characteristics of sediments generated and released by dredging is influenced by a range of factors including the geotechnical characteristics of the substrates to be dredged, the type of dredge and its mode of operation, and the nature of the interaction between the dredge and seabed substrate.

> Predicting impacts of dredge-generated sediments relies on understanding the key factors that influence the generation, sources, physical characteristics and release rates of fine sediments.

3.0 Methodology

3.1 General approach

In the first instance the proponent assessment documentation should detail how the steps to impact mitigation described below have been considered in advance of presenting predictions of environmental impact.

1. There should be demonstrable consideration of options to avoid impacts on benthic communities due to dredging, for example, by providing the rationale for selection of the preferred site and the proposed dredging methods.
2. Where impacts cannot be avoided, then proposed project design should aim to minimise impacts (e.g. through iterative design and demonstrable application of Principle 3 below) and the proposed design should be justified in terms of operational needs and environmental constraints of the site.
3. Best efforts should be made to demonstrate in EIA documentation that all ' reasonable and practicable measures'[2] have been taken to prevent or minimise impact, including through design, selection of construction methods and environmental management aimed at minimising predictive uncertainty and environmental impacts.

> The level to which proponents demonstrate how they have considered impact avoidance and minimisation and application of all reasonable and practicable measures to prevent or minimise impacts in all aspects of their proposals will be taken into account when determining environmental acceptability of dredging proposals.

The assessment framework described in this Guidance is designed to impart clarity and consistency to the way predicted impacts are presented for assessment by the EPA. It establishes an approach for generating and presenting predictions of *the likely range* of environmental impacts, which in turn, provides the basis for facilitating the transfer of these predictions into recommended conditions and environmental monitoring and management strategies.

> In simple terms, the predictions are made by superimposing the dredging pressures (i.e. excavation, burial, sediment deposition and elevated turbidity) on the biological communities and determining the likely responses of communities to those pressures.

While it is not the intention of the EPA to mandate a specific methodology, in order to generate realistic impact predictions, proponents are encouraged to consider and apply guidance provided in the following sections:

- Describing benthic habitats (Section 3.1.1);
- Background environmental data (Section 3.1.2);
- Describing impacts (Section 3.2);
- Generating and representing predictions (Sections 3.3 and 3.4); and
- Integrating predictions with monitoring and management (Section 3.5).

[2] Some examples of 'reasonable and practicable measures' are outlined in Section 3.7.

3.1.1 Describing benthic habitats

An adequately detailed benthic habitat map is a critical piece of information for assessing the impacts associated with dredging.

The benthic habitat map (or series of maps) supplied by proponents must be at a sufficiently fine scale to provide confidence in the habitat boundaries which in turn reduces uncertainty in relation to the predictions of the areas of impact. Mapping should be undertaken as finely and accurately as possible considering the primary purpose and end use of the maps (e.g. to evaluate habitat impacts and losses and inform the location of monitoring and reference sites). Factors such as expected intensity of pressure and the types and uniformity (or heterogeneity) of existing biological communities should also be considered. For example, the main benthic habitat types might be defined on the basis of the abundance of dominant and sub-dominant functional groups.

Spatial coverage of benthic habitat surveys and mapping is an important consideration. As a general rule, mapping coverage should extend across any predicted Zones of High and Moderate Impact and the area of the Zone of Influence[3] immediately outside of the Zone of Moderate Impact. High quality data on the extent and distribution of benthic habitats in the Zone of Moderate Impact and adjacent Zone of Influence will be necessary for identifying suitable monitoring sites to manage environmental performance and assess compliance during project implementation. Knowledge developed through the survey work will also inform the selection of local biota that may be suitable surrogates or indicators for impact prediction and monitoring.

Technical reports that describe how benthic habitat surveys and mapping were conducted and how maps were produced must be supplied as part of the EIA documentation. Reports should clearly state any assumptions and consider their implications, and describe methodologies including those employed in the field for surveys and in the office to interpret data and prepare spatial products. Spatial data associated with the benthic habitat map and infrastructure outlines should be supplied to the EPA in a suitable GIS compatible format. Early advice should be sought from the OEPA regarding the preferred data format of spatial data and associated metadata statements.

> An understanding of the extent and distribution of benthic habitats is an integral requirement for the EIA of marine dredging proposals. Descriptions and maps of the different benthic habitats should be fit for purpose and accompanied by clear descriptions of methods used to generate them.

3.1.2 Background environmental data

Acquisition and analysis of background data is an integral part of any environmental impact assessment. For example, long-term background data sets for a suite of dredging-relevant environmental variables (e.g. underwater light climate, total suspended solids concentration, sediment deposition rate, correlations between these factors) can be used to develop knowledge about natural tolerances and susceptibilities of local benthic organisms. Furthermore, independent baseline data sets are critically important for calibration and validation of numerical models.

Proponents are strongly encouraged to seek specialist professional advice regarding the types of baseline data that should be collected to inform and maximise confidence in any predictions of the extent, severity and duration of dredge-related environmental impacts.

> Relevant background environmental data should be used to inform, validate and enhance confidence in predictions of environmental impacts.

[3] The terms Zone of High Impact, Zone of Moderate Impact and Zone of Influence are described in Section 3.4.

3.2 Describing impacts

Environmental impact assessment is based on predictions of the extent, severity and duration of environmental impacts, taking into account confidence around the predictions and the likely effectiveness of proposed monitoring and management strategies.

The EPA expects that both direct and indirect impacts are considered explicitly.

Direct impacts occur predominantly within and immediately adjacent to infrastructure footprints where dredges excavate the seabed and where rock armour and spoil is dumped. Direct impacts typically involve irreversible loss of benthic habitats and communities, where *irreversible* means 'lacking a capacity to return or recover to a state resembling that prior to being impacted within a timeframe of five years or less'.

Indirect impacts arise from effects of dredge-generated sediments and generally extend over areas surrounding infrastructure footprints, dredging sites and spoil disposal sites and occur when sediment deposition rates and/or elevated turbidity exceed the natural tolerance levels of benthic organisms exposed to those pressures. These indirect effects of dredge-generated sediments may restrict or inhibit key ecological processes and cause impacts that range in severity and duration from irreversible to readily-reversible.

> Both direct and indirect impacts, along with an assessment of the reversibility of those impacts, are to be included in predictions of impacts associated with dredging proposals.

3.3 Generating predictions

3.3.1 General

Predicting direct impacts of dredging is relatively straightforward as these impacts are generally tightly linked to the dredge area and/or disposal sites and immediately surrounding these areas.

Numerical modelling is most commonly used to inform predictions of the extent, intensity and persistence of dredge-generated sediment plumes, and the extent, severity and duration of resultant indirect impacts on benthic habitats. Modelling techniques are particularly valuable predictive tools for proposals where suitable empirical data from previous dredging campaigns are either not available or unsuitable for informing accurate predictions of environmental impacts.

In very simple terms the approach commonly applied to predict indirect impacts from dredge-generated sediments involves implementing three key types of predictive modelling in a logical sequence:

- hydrodynamic modelling
- sediment transport modelling
- ecological response modelling.

The EPA recognises the application of physical and ecological modelling to predict potential indirect impacts of dredge-generated sediments is challenging, but they provide important and useful information on the likely nature of sediment plumes generated by the proposal. Therefore, numerical modelling will continue to be an integral component of EIA (PIANC 2010, DEMG 2011, GBRMPA 2012).

Direct impacts are generally predicted based on a combination of information about the areas to be dredged and disposal areas. The extent, severity and duration of indirect impacts are generally predicted with the use of simulation models, sometimes supplemented with empirical data collected during previous dredging projects.

Proponents are strongly encouraged to seek early advice from suitably qualified specialists and the OEPA regarding the application of this guidance, including the use of predictive numerical simulation models, in the context of their proposals.

3.3.2 EIA and modelling

Clearly presented information regarding calibration and validation of numerical models, assumptions and sources of uncertainty and their associated implications for predictions will assist the EPA in forming judgements about reasonableness and the confidence it can place in predictions of environmental impacts.

The level of agreement between model outputs and data measured in the field will vary from application to application and depend on many factors. It is therefore not appropriate for the EPA to set a requirement that specifies the level of agreement between model outputs and observations to be achieved. Instead, the EPA expects proponents to set out the process and outcomes of calibration and validation exercises and relevant assumptions on a project-by-project basis.

To improve confidence in dredging EIA, numerical models should be calibrated and validated and any associated assumptions and implications of those assumptions should be clearly stated and evaluated.

In cases where all relevant proponent documentation is not provided, is ambiguous or includes unsubstantiated conclusions, the level of confidence in the prediction would generally be lower than if high quality, peer reviewed information is provided.

3.3.3 Peer review

While the EPA does not require that proponents commission peer reviews of all studies underpinning EIA, peer review by a suitably qualified expert can, in some situations, assist the EPA in achieving timely assessments. If proponents either choose to commission a peer review or are requested to do so by the EPA, it is beneficial to seek agreement with the EPA on the terms of reference and scope before commencing the review.

To maximize the effectiveness and transparency of the peer review process, the EPA expects to receive the peer reviewer's reports, including their 'close out' comments based on the document that is ultimately submitted for EIA.

Proponents should expect that information relating to the peer review, including the terms of reference and the peer reviewer's reports, may be made publicly available as part of the EIA process.

3.4 Describing impact predictions

3.4.1 Impact zonation scheme

The EPA has developed a spatially-based zonation scheme for proponents to use as a common basis to describe the predicted extent, severity and duration of impacts associated with their dredging proposals. The scheme consists of three zones that represent different levels of impact:

- ***Zone of High Impact (ZoHI)*** is the area where impacts on benthic communities or habitats are predicted to be *irreversible*. The term *irreversible* means 'lacking a capacity to return or recover to a state resembling that prior to being impacted within a timeframe of five years or less'. Areas within and immediately adjacent to proposed dredge and disposal sites are typically within zones of high impact.
- ***Zone of Moderate Impact (ZoMI)*** is the area within which predicted impacts on benthic organisms are recoverable within a period of five years following completion of the dredging activities. This zone abuts, and lies immediately outside of, the zone of high impact. Proponents should clearly explain what would be protected and what would be impacted within this zone, and present an appraisal of the potential implications for ecological integrity of the impacts over the timeframe from impact to recovery (e.g. through loss of productivity, food resources, shelter). Where recovery from the impact predicted in this zone is likely to result in an 'alternate state' compared with that present prior to development, then this outcome should be clearly stated in environmental assessment documents, along with justification as to why the predicted impacts should be included within this zone (rather than the Zone of High Impact) and an appraisal of the potential consequences for ecological integrity and biological diversity. The outer boundary of this zone is coincident with the inner boundary of the next zone, the Zone of Influence.
- ***Zone of Influence (ZoI)*** is the area within which changes in environmental quality associated with dredge plumes are predicted and anticipated during the dredging operations, but where these changes would not result in a detectible impact on benthic biota. These areas can be large, but at any point in time the dredge plumes are likely to be restricted to a relatively small portion of the Zone of Influence. The outer boundary of the Zone of Influence bounds the composite of all of the predicted maximum extents of dredge plumes and represents the point beyond which dredge-generated plumes should not be discernable from background conditions at any stage during the dredging campaign. Furthermore, this provides transparency for the public regarding where visible plumes may be present, albeit only occasionally, if the proposal is implemented. Reference sites for monitoring natural variability would ideally be located outside of the Zone of Influence of the dredging activities.

3.4.2 Presenting the zonation scheme

The system of zones is designed to be presented in a spatially-based map form. Figure 1 shows a zoomed out view of how the zonation scheme would be represented. It shows the relative sizes of the zones that are likely to be generated based on recent experiences and also shows that all effects of dredging should be captured by the outer boundary of the Zone of Influence.

In simple terms, the level of cumulative pressure on biota from dredge-generated sediments will generally decrease with distance from the dredging or disposal sites. As a result, the degree of impact would similarly be expected to decrease with distance from the dredge site. Figure 2 shows how the pressure and resultant degree of impact on benthic communities would change with distance from dredging, and how these changes can be represented by the zonation scheme described above.

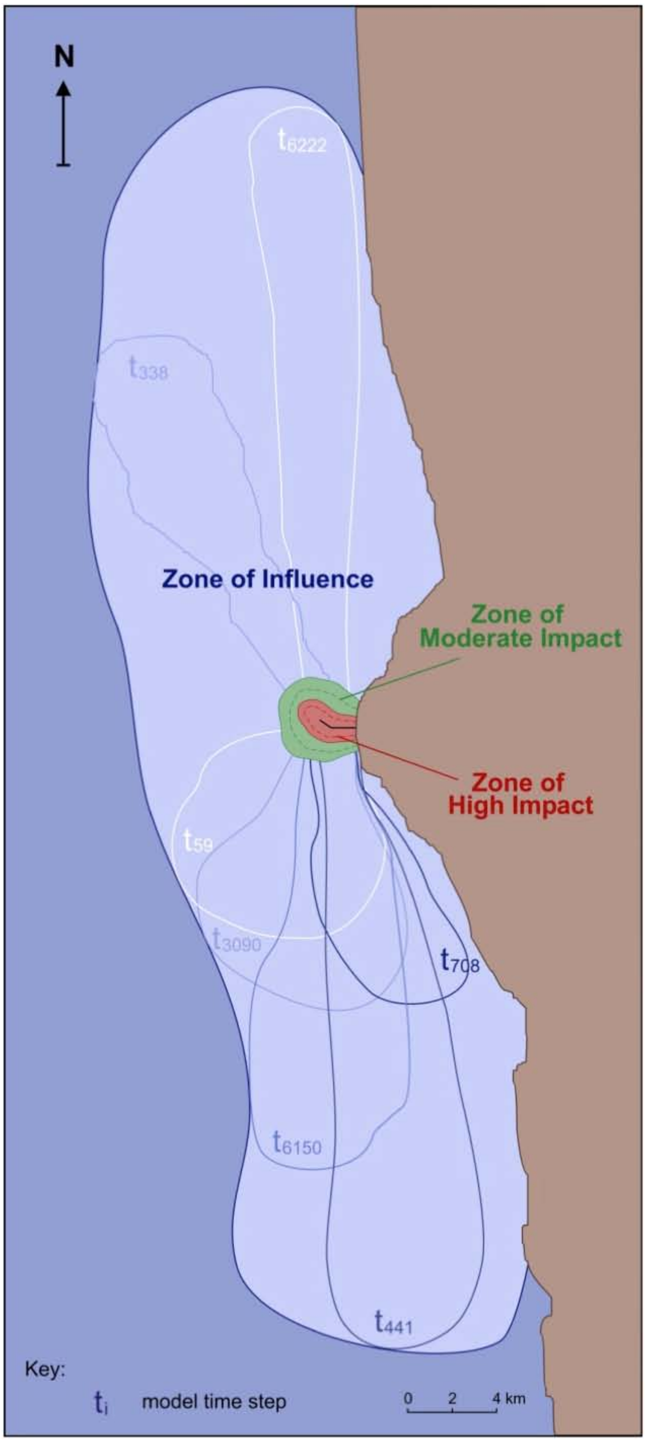

Figure 1: A schematic representation of the spatially based zonation scheme for representing dredging related impacts where red represents the Zone of High Impact, green represents the Zone of Moderate Impact and pale blue represents the Zone of Influence. The outer boundaries of individual dredge plumes are shown as blue shaded lines within the Zone of Influence at different time steps (t_n) during a simulated dredging campaign.

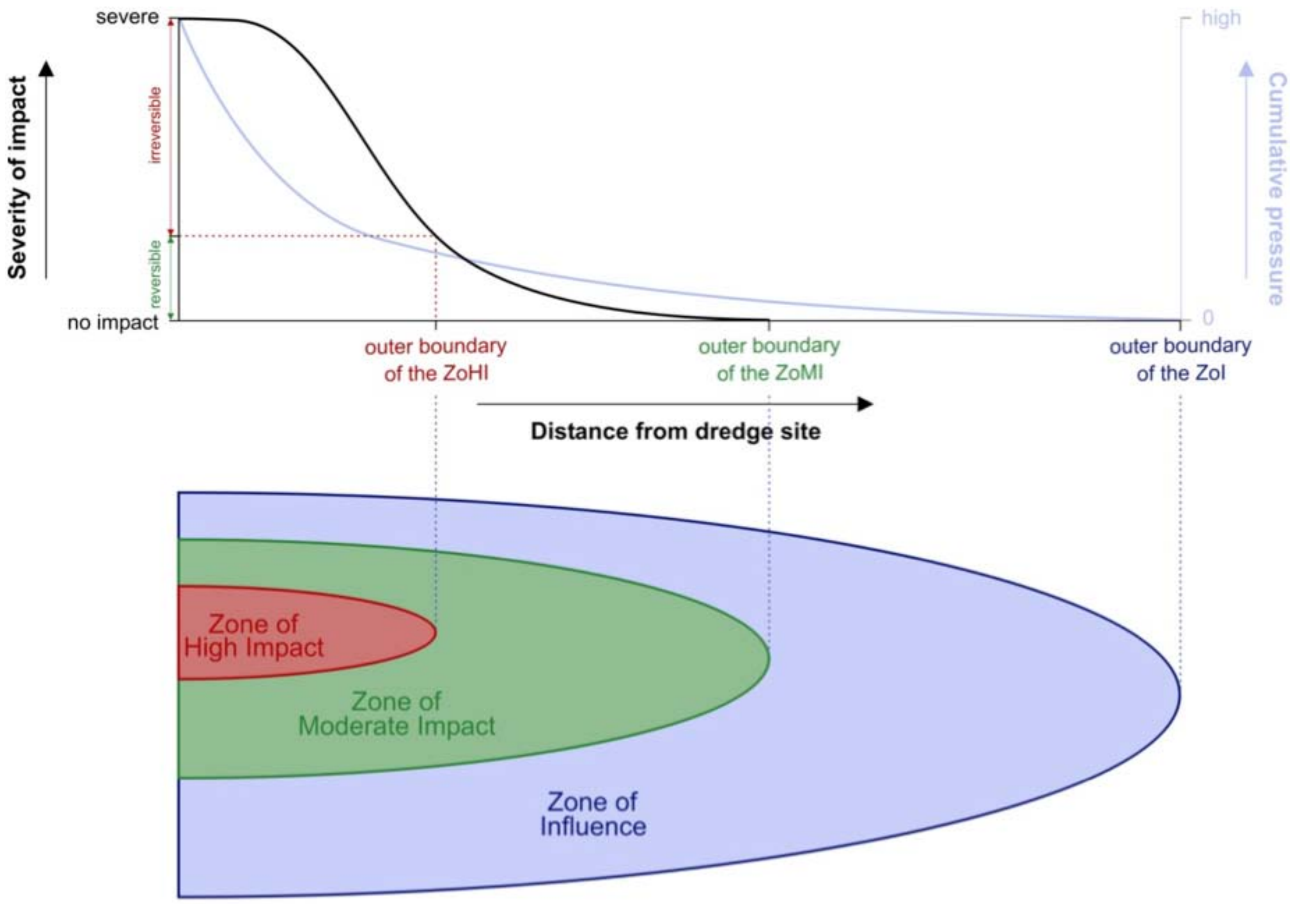

Figure 2: A schematic representation of the degree of change in environmental quality associated with dredging (grey line) and level of resultant impact to benthic communities (black line) along a transect extending away from the dredging site to the outer extremity of the Zone of Influence. The location of the outer boundaries of the Zone of High Impact (ZoHI), Zone of Moderate Impact (ZoMI) and Zone of Influence (ZoI) are shown relative to these predicted changes in environmental quality and impacts on biota.

The level of ecological impact associated with dredging would generally be expected to attenuate with distance from the dredge site as represented by the black line in Figure 2. This figure also shows the position of the outer boundaries of the Zones of High and Moderate Impact relative to the level of impact expressed as 'reversibility'. A key point to note is that all impacts relevant to a particular zone are attenuated within that zone before transition into the next zone further from the source of sediments. For the Zone of High Impact, this means that no irreversible impacts should be predicted to occur outside of this zone and the corollary is that not all impacts on all biota within this zone are predicted to be irreversible. Near to the boundary with the Zone of Moderate Impact, but still within the Zone of High Impact, the level of impact can logically be expected to be lower than closer to the dredge site and approaching the point where there are no irreversible impacts. Most importantly there should be no irreversible impacts on benthic communities in the Zone of Moderate Impact or beyond.

Similarly, moving further along the transect away from the dredging site a point would be reached near the Zone of Influence but still within the Zone of Moderate Impact where there would be practically no detectible impact on biota.

> The spatially-based zonation scheme provides a clear and consistent way of describing and presenting the extent, severity and duration of predicted impacts of dredging for environmental impact assessment.

3.4.3 Accounting for predictive uncertainty

Uncertainty is a factor inherent in all predictions and there is an array of sources of uncertainty associated with dredging impact predictions. In order to take account of this uncertainty in the EIA process, the final set of predictions may describe the lower and upper ends of the *likely* range of impacts associated with the proposal (i.e. the likely best case and the likely worst case). This range should be realistic and based on understanding of probable scenarios and their associated environmental outcomes. For the majority of proposals, the range of predictions to be considered should be conservative but not include unrealistic best or worst case (or other improbable) predictions.

This is illustrated conceptually in Figure 3, which shows the likely location of the outer boundaries of the high and moderate impact zones along a transect extending away from the dredging site. The transect line at the bottom of the figure has two sections marked 'likely range', which represent the range of possible positions of the boundary of each zone. The distances from the dredging site that correspond to the two ends of each marked section represent the likely 'best case' and likely 'worst case' positions of that boundary.

In order to take account of uncertainty in the EIA process, the final set of predictions may describe the lower (*likely* best case) and upper (*likely* worst case) ends of the *likely* range of positions of the boundaries that could reasonably be expected based on understanding of probable scenarios and their associated environmental outcomes.

In practice, the pair of boundaries might be generated by implementing a number of different approaches. Approaches might include modelling scenarios that capture variation in physical forcings (e.g. typical and atypical wind conditions, neap and spring tidal regimes), sediment release rates (e.g. more fines, less fines), and dredge operation and management scenarios (e.g. different dredge types and operating modes). Testing the sensitivity of ecological impact predictions to different pressure thresholds or considering seasonal effects may also be undertaken to understand the likely range of prediction outcomes. Furthermore, in recognition that different biota may display very different degrees of tolerance and susceptibility to the same level of sediment-related pressure, in many cases it may be appropriate to generate different predictions for the location of boundaries for different groups of benthic organisms or community/habitat types. In all cases there will need to be a degree of 'professional judgement' employed to establish the likely best case and likely worst case locations of the boundary for a zone.

The range of likely impact predictions should be based on the best available construction, design and management techniques and approaches being applied to dredging and its management.

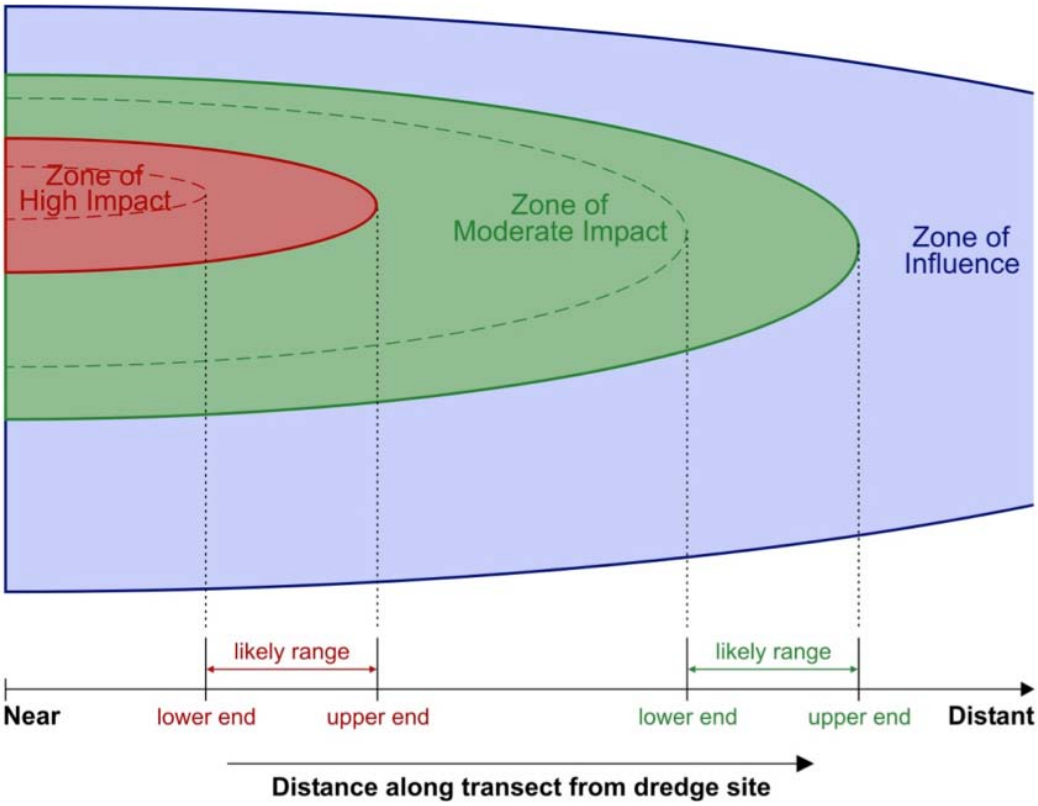

Figure 3: A conceptual representation of the 'likely' range of realistic locations for boundaries of the Zone of High Impact and Zone of Moderate Impact associated with a dredging proposal and how this is translated into the spatial zonation scheme for presenting impacts for environmental impact assessment.

3.4.4 Presenting realistic and likely predicted impacts

Boundaries that represent the range of likely environmental impacts should be presented in map form as shown in Figure 4. Figure 4 (a) shows the full extent of the predicted Zone of Influence and the Zones of High and Moderate Impact within it. Figure 4 (b) shows boundaries associated with the Zone of High Impact and Zone of Moderate Impact, where the broken and solid lines represent the likely best case and likely worst case respectively.

In making and presenting predictions in the manner shown in Figure 4, proponents should consider the likely best case as reflecting an outcome they are *hopeful* of achieving if all goes well and all reasonable and practicable measures to minimise or avoid impacts are applied to dredging and its management. The likely worst case on the other hand would reflect an outcome that the proponent is *confident* of achieving using all reasonable and practicable measures even if things do not go as well as hoped.

These maps serve a number of key purposes. Firstly, they present fundamental information for effective environmental impact assessment, including information about the extent, severity and duration of predicted impacts, and the full extent of the predicted Zone of Influence, which ensures there is a common basis for understanding the potential extent of sediment plumes anticipated during the dredging operations. These maps explain predictive uncertainty and clearly differentiate between the targets which the proponent will aim for and the outcomes that they are confident in achieving, through management of the project.

Proponents will be expected to consider the range of likely impacts when developing their proposed environmental monitoring and management strategies.

> The lower end of the range of likely impacts should reflect a likely best case that would become a target for management. The upper end of the range should reflect a likely worst case outcome that the proponent is both confident of achieving and prepared to be conditioned to.

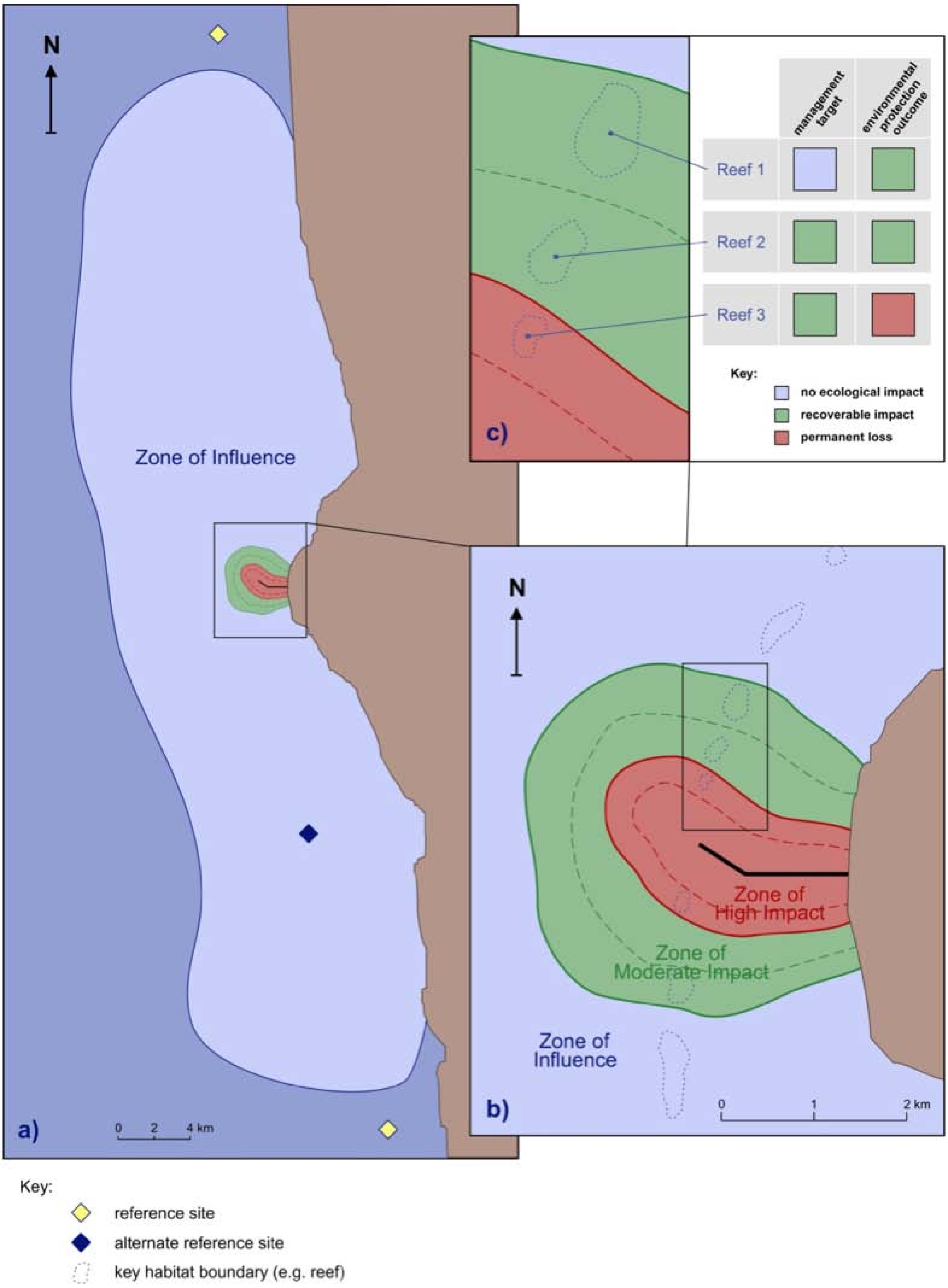

Figure 4: An example map-form presentation of: a) the predicted Zone of Influence and the predicted zones of High Impact and Moderate Impact associated with channel dredging (represented by the black line), b) closer view of the predicted Zones of High Impact and Moderate Impact, noting that the area between the broken lines (inner) and solid lines (outer) represents the uncertainty associated with the location of the zone boundary, and c) zoomed in section showing the management targets and expected environmental outcomes for the zones and the area of uncertainty within the zones.

3.5 Integrating predictions with monitoring and management

In an ideal world predictions would be 100% accurate, and this would facilitate straightforward EIA and reduce or negate the need for monitoring and reactive management. The reality, however, is different and a range of environmental monitoring and management strategies are employed to ensure that impacts are minimised during project implementation and to demonstrate compliance with any limits established through the approval process.

By presenting predictions that represent the lower and upper ends of the range of likely impacts, the framework establishes a logical and consistent basis for translating those predictions into monitoring and management strategies and conditions of approval. The likely best case predictions will be used in setting appropriate 'management' objectives (i.e. targets) whilst the likely worst case predictions would be more aligned with environmental protection outcomes (i.e. regulatory limits). Importantly this allows a distinction to be made between monitoring requirements for informing management of dredge operations and monitoring requirements for demonstrating compliance. This should allow a more efficient allocation of resources between the various monitoring and management tasks.

In simple terms, proponents can expect that the frequency and extent of compliance monitoring during the dredging programs will be inversely proportional to the overall confidence in the predictions of environmental impact. The environmental setting and the significance of the potential and likely impacts, and the effectiveness and responsiveness of the proposed environmental monitoring and management strategies, will also be considerations.

Developing the detail around proposed monitoring to inform adaptive management and determine if management targets are being achieved would generally be a task for proponents. However there may be cases where, based on its consideration of information provided for assessment, the EPA will make recommendations in this regard. When developing proposed environmental monitoring programs, in the first instance proponents should consider the monitoring required for adaptive management purposes separately from that necessary to demonstrate compliance, and then consider any efficiencies that could be realised by running the programs concurrently.

> Proponents could expect the highest monitoring and management burden in situations where environmental values are high and where there are high levels of predictive uncertainty.

Monitoring and adaptive management in the various zones will have differing objectives. The environmental significance of the area and the level of predictive uncertainty exposed during EIA will inform how much monitoring is required.

In addition to minimising impacts of dredging on benthic habitats and communities, an overarching objective of the assessment framework, outlined in the preceding sections, is to enhance the linkage between the environmental impact predictions made for EIA and the data generated through monitoring and management programs implemented post-approval. This should generate validation data which will further increase confidence over the prediction – management continuum.

This has already begun through the work of the WAMSI Dredging Science Node which is undertaking targeted scientific research on locally relevant species and that has been informed by analyses of dredge monitoring data sets. As contemporary understanding from these initiatives and from the results of more targeted monitoring of dredging pressures and impacts are applied in EIA, confidence in dredging-related impact predictions should increase allowing monitoring requirements to be reduced over time.

The EPA strongly supports greater public availability of environmental data collected for EIA and post-approval monitoring and management programs and may recommend conditions to facilitate this outcome.

3.5.1. Environmental monitoring and management plans

The fundamental purposes of an environmental monitoring and management plan (EMMP) are to minimise impact and ensure that the environmental protection outcomes established for a project are not compromised. The proponent should also consider structuring the EMMP so that the monitoring data are able to inform adaptive management of the dredging program to minimise the impacts and achieve the relevant management targets. As such, the EMMP should focus on the key threats posed by the project and the pathways by which those threats could cause the environmental protection outcomes to be compromised. The primary threats to the surrounding marine environment from dredge-generated sediment are shading caused by sediments suspended in the water column and smothering of benthic habitats and organisms caused by the deposition of these sediments.

The EMMP should be designed to achieve management targets that indicate a level of impact that is lower than the limits established as environmental protection outcomes. As such, the EMMP is designed to provide early warning of adverse trends and trigger pre-emptive management well before the environmental protection outcomes are compromised. The EMMP should also be designed to monitor and report on the important pressures generated by the dredging campaign so that any observed impacts can be attributed to the project and the impact prediction models can be validated and fine-tuned through improved understand of the cause/effect relationships.

> Environmental monitoring and management plans should be structured so that a focus on achieving the management targets would provide a high degree of confidence that the environmental protection outcomes are not compromised.

An EMMP should be clear and unambiguous and contain the following key elements:

- clearly stated objectives
- a monitoring/management feedback loop to achieve those objectives
- management triggers along pressure-response pathways
- monitoring regime including site locations and methods to provide data to allow assessment against the management triggers
- clearly set out data evaluation procedures to identify where and when management triggers have been reached
- contingency management strategies to be employed if triggers are reached
- a reporting process.

The EPA expects the most relevant scientific information to be used when preparing an EMMP which may require proponents to undertake pre-referral baseline monitoring to provide the necessary local context. Proponents should provide the EMMP for dredging as part of the documentation submitted for assessment. These plans should contain sufficient information to allow the monitoring methods, data interpretation and the efficacy of proposed management to be assessed.

> Environmental Monitoring and Management Plans are an integral part of the documentation submitted for EIA of dredging proposals.

3.5.2. Environmental monitoring locations and their purposes

Selection of locations for establishing monitoring and reference sites should be based on a number of considerations including the locations of predicted zone boundaries (including the area of uncertainty), the level of acceptable impact for each zone and the types and locations of benthic communities in those zones.

For example, because the Zone of High Impact is based on the extent of irreversible impacts and any approval that might be granted would recognise that, it would not be necessary to monitor the health of benthic communities in that zone for 'compliance' purposes. There would however, be significant benefit from monitoring both dredge-related 'pressure' and 'ecological response' along a gradient from near the dredging location through to the edge of this zone (and beyond). In the short term, the results of pressure and response monitoring would help to appraise and refine some of the early warning trigger criteria used for 'management' of impacts in the Zones of Moderate Impact and Influence during the course of the dredging campaign (i.e. adaptive management). In the longer term, benefits would be realised through improved understanding to inform assessments of future proposals for new capital or maintenance dredging.

The Zone of Moderate Impact is a key focus for monitoring and management as this is the transition zone between where permanent loss and no effects are predicted. Monitoring and management in the Zone of Moderate Impact serves dual purposes to 1) minimise impacts though informed adaptive management designed to at least achieve a management target, and 2) ensure that those impacts which do occur are reversible and not greater than approved (i.e. consistent with the environmental protection outcomes). In this zone it would be expected that monitoring would include both dredge-related 'pressure' and 'ecological response'.

The overarching objective of monitoring and management in the Zone of Influence is to ensure there are no detectible effects of dredging on benthic communities in that zone.

As a rule, monitoring locations for a zone should be as close as possible to the inner boundary for that zone. This is particularly important for the Zone of Influence, given its size, and so these monitoring locations should be established in suitable habitats as close to the Zone of Influence/Zone of Moderate Impact boundary as possible.

Reference sites should be located outside of the predicted Zone of Influence (Figure 4). However, given the potential scale of the Zone of Influence, it may prove to be logistically difficult to establish and regularly monitor sites that are very distant from the central area of activity. Furthermore, the environmental conditions outside of the Zone of Influence may be such that there are few appropriate areas that have the necessary degree of similarity to the impact monitoring sites to be appropriate as reference sites. In acknowledgement of these issues, the EPA will consider reference sites within the Zone of Influence, if well justified and where it can be demonstrated that the frequency and intensity of exposure to dredging plumes is low. Notwithstanding the above, the EPA would still expect reference sites to be established outside of the Zone of Influence as a safety measure, but would accept a lower monitoring frequency than at the operational reference sites.

> Reference sites should ideally be established outside the Zone of Influence but proposals for sites within this zone may be considered if well justified.

3.5.3. A risk-based environmental monitoring and management framework

The framework around which to design environmental monitoring programs should be risk-based using understanding of pressure-response pathways for key biota in the benthic communities to be monitored. Essentially this means that monitoring would be designed around indicators that signify progressively greater risk of unacceptable impact. For example, monitoring may take the following general risk-based form and apply suitable techniques to measure the responses in primary, secondary and tertiary indicators as set out below.

1. **Primary indicators** signify a very early warning of potential threat and low level of risk to the biota of interest. A primary indicator could be a measure directly linked to a pressure from dredging such as turbidity, light attenuation coefficient or sediment deposition rate. Exceeding a criteria linked to a primary indicator would trigger tier 1 management, which could include ***investigating the cause of the exceedance*** and ***increasing monitorin***g to include a secondary indicator.
2. **Secondary indicators** signify a moderate risk to the biota of interest and might include measures of biotic stress such as change in the colour of coral tissues or a reduction in the shoot density of seagrass. Exceeding a criterion linked to a secondary indicator would trigger tier 2 adaptive management, which could include implementation of measures to ***reduce dredge-related pressure*** and monitoring of a tertiary indicator.
3. **Tertiary indicators** signify a high and unacceptable level of risk to the biota of interest. A tertiary indicator would be a measure or measures that are immediate pre-cursors to an unacceptable impact. Exceeding criteria linked to a tertiary indicator would trigger strong management action to ***alleviate pressure***.

An objective of the integrated EIA and environmental monitoring and management approach is to provide for a more explicit description of environmental impact and outcome of dredging than has necessarily occurred in the past. Proponents should therefore expect that the EPA may incorporate the predicted zone boundaries into conditions it may recommend to the Minister for Environment.

The clear definition of project impacts (in terms of extent, severity and duration) and areas to be protected allows for unambiguous audit of project performance against approval conditions, which in turn reduces uncertainty around compliance or enforcement issues.

The strong links between predictions and approvals highlight the importance of robust model calibration and validation, and high-quality science – all targeted towards reducing predictive uncertainty. The EPA recognises that development of knowledge of pressure-response relationships in particular cannot occur immediately, but considers this is an important goal that should be strived towards collectively.

> Environmental Monitoring and Management Plans should reflect contemporary best available techniques and approaches and ideally be risk-based, using readily measureable indicators along the pressure-response pathway, to trigger management to prevent unacceptable impacts.

3.6 Critical windows of environmental sensitivity

When designing dredging proposals and making predictions of environmental impacts, proponents should consider *critical windows of environmental sensitivit*y. Critical windows of environmental sensitivity include times of the year or particular sites where key species or ecological communities or critical processes may be particularly vulnerable to pressures from dredging.

There are numerous examples of known critical windows of marine environmental sensitivity and it is likely that with further scientific research others will be identified. Some examples which the EPA has either considered previously in relation to dredging proposals, or is aware of supporting scientific data, include spawning and larval settlement periods for corals, habitat for spawning aggregations and juveniles of fish (e.g. pink snapper) and invertebrates (e.g. blue swimmer crabs), critical habitat for breeding of marine wildlife (e.g. turtles, dugong), the timing and routes for migration of specially-protected migratory species (e.g. JAMBA/CAMBA listed migratory birds and whales) and habitat that supports primary food resources for threatened marine fauna listed under State and Commonwealth legislation (e.g. seagrass areas in Shark Bay and Exmouth Gulf grazed by dugong).

Critical windows of environmental sensitivity should be addressed in the context of the overarching environmental protection principles set out in EPA (2016).

3.7 Contemporary construction, design and management approaches for minimising impacts of dredging

While the best and most appropriate measures to avoid or minimise dredging related impacts tend to be highly site and project specific, some examples include:

- Up-front design to minimise the need for dredging, considering the environmental setting and operational requirements.
- Dredge area design that aims to minimise direct and indirect impacts on key benthic habitats (e.g. design and locate marine infrastructure to avoid or reduce impacts on coral or algal reefs, seagrass and filter feeder habitats or mangroves).
- Using site-specific geotechnical data and understanding of dredge equipment-substrate interactions to help select *fit for purpose* dredging equipment and operating modes to minimise the environmental impacts.
- Using this knowledge of geotechnical conditions, and dredge equipment-substrate interactions to establish the likely physical characteristics and generation rates of fines produced by dredging at the site.
- Using validated hydrodynamic and sediment transport models to assess the dynamics and likely fate of sediment plumes.
- The use of silt curtains where they are operable and likely to be effective in controlling turbidity release and dispersion.
- Contracting dredges equipped with sediment management devices where these are found to minimise sediment generation and dispersion.
- A commitment to manage dredging in ways that minimise the release of sediments into the water column as much as practicable, particularly in situations where dredging-related sediments have the potential to impact sediment-sensitive benthic communities. Methodologies such as no overflow or planned commencement of overflow, piping dredge spoil direct to disposal sites or to transfer vessels stationed sufficient distances from sensitive receptors to eliminate or minimise risk pathways to those receptors may need to be considered.
- The application of near real-time data collection and interpretation methods (particularly for turbidity) to support environmental management of dredging. This should be determined on a hierarchical basis grading from small maintenance dredging campaigns in low sensitivity environments where real-time monitoring is not warranted through to major capital dredging projects where substantial commitments to monitoring and adaptive management, including the use of telemetered turbidity meters, are required. In addition to the scale and environmental settings of proposals, in all cases the degree of uncertainty in impact prediction will be considered when determining the appropriate level of near real-time data collection and interpretation required to manage project implementation.

4.0 DEFINITIONS

Word or phrase	Definition for the purpose of this EAG.
Dredge spoil	Seabed substrate material after it has been excavated from the seabed.
Dredging	Involves excavation of the seabed from the upper intertidal zone to the subtidal zone. Dredging in the sense of this EAG means both dredging and dredge spoil disposal activities.
Extent	The area over which an impact extends.
Functional groups	Groups of species (which are not necessarily related generically) that share similar important ecological characteristics and play equivalent roles in the functioning of the biological community.
Infrastructure	Shipping channels, turning basins, berth pockets, pipeline trenches, spoil disposal sites, sub-sea mine areas and land reclamations are some examples of infrastructure.
Irreversible	Lacking a capacity to return or recover to a state resembling that prior to being impacted within a timeframe of five years or less (also see reversible).
Near real-time	Refers to a system for monitoring and interpreting data where the time lag between collecting monitoring data and responding is sufficiently short to be considered as immediate as practicable.
Persistence	The period of time that an impact continues.
Prediction	A forecast of future outcomes.
Pressure threshold	Pressure thresholds signify a level of pressure (generally expressed in terms of intensity, frequency and duration) that equates to a pre-defined level of effect or impact to an organism or group of organisms of interest.
Recoverable	See reversible.
Reversible	A capacity to return or recover to a state resembling that prior to being impacted within a timeframe of five years or less.
Severity	The degree of harm caused. For example, the degree of harm or severity of impact to biota could range from sublethal effects to mortality or loss.
State coastal waters	The State coastal waters extend three nautical miles seaward from the territorial sea baseline.
Uncertainty	In relation to prediction is doubt or concern about the reliability of achieving predicted outcomes.

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National Relay Service
TTY: 133 677
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More information

Office of the Environmental Protection Authority
Level 8, The Atrium
168 St Georges Terrace
Perth WA 6000

Locked Bag 10,
East Perth WA 6872

p: 08 6145 0800
e: info@epa.wa.gov.au
w: www.epa.wa.gov.au