Appendix B: Draft Maintenance DSDMP– Expert Review

Ichthys Maintenance Dredging and Spoil Disposal Management Plan 2023-27: Peer Review

Technical Note

Client: INPEX

Author: Dr. Paul L.A. Erftemeijer

Perth, 12 June 2022

Ichthys Maintenance Dredging and Spoil Disposal Management Plan 2023-27

Peer Review

By: Dr. Paul L.A. Erftemeijer (DAMCO Consulting)

For: INPEX

June 2022

Background

This report provides a summary of the outcome of an 'expert peer review' by Dr Paul Erftemeijer (DAMCO Consulting Pty Ltd) of the Ichthys Maintenance Dredging and Disposal Management Plan 2023-27 by INPEX.

In 2018, INPEX Operations Australia Pty Ltd obtained relevant approvals to undertake maintenance dredging activities, as required, within the existing dredged footprint Darwin Harbour over a five-year period. To date no maintenance dredging activities have been required to be undertaken. However, with some 400,000 m^3 having accreted in the turning basin to date, it is anticipated that at some stage during the next five-years such activities would be required. Approvals associated with the original approved activity are due for renewal in in early 2023, as such INPEX is in the process of renewing these and this Maintenance Dredging and Spoil Disposal Management Plan (DSDMP) has been updated to support new and renewal approval applications. It is noted that this is the second 5-year cycle since the Ichthys project was conceived.

In accordance with Condition 10 (k) of the approval decision EPBC 2008/4208 and the Northern Territory Environment Protection Authority (NT EPA) Guidelines for the Environmental Assessment of Marine Dredging in the Northern Territory (NT EPA, 2013), independent experts were consulted in the development and review of the Maintenance DSDMP and associated monitoring program. The present Technical Note presents the outcome of one of such independent peer reviews, i.e. by Dr Paul Erftemeijer (DAMCO Consulting Pty Ltd). Dr Erftemeijer has been involved previously in the assessment and evaluation of environmental impacts and approvals process of the Ichthys Capital Dredging Program in 2012 and is thus well-familiar with the program's technical background, modelling approach and impact assessment process.

Dr Erftemeijer was contracted in late May 2022 by INPEX (Ref: PO4500110760) to deliver the following technical services:

- Expert peer review of the following:
    - Modelling and impact assessment, including hydrodynamic & sediment transport modelling and habitat impact assessment (all incorporated within the DSDMP)
    - Maintenance DSDMP (200-page document): entire document, noting specific focus on modelling, proposed monitoring and adaptive management
- Meetings and administration:
    - Meetings with INPEX to discuss the scope and findings of the review
    - Associated administration, including response to the comments register

The present Technical Note summarises the outcome of the peer review of the Maintenance DSDMP, commenting on the appropriateness of the modelling, proposed management and monitoring as described within the DSDMP. An annotated version of the Word document of the draft DSDMP, with comments in 'track changes', was also submitted to INPEX.

General Comments

Since I provided an exhaustive peer review of the previous 5-year Maintenance DSDMP for INPEX in 2018, which was approved by the NT-EPA following review and revision, I have focused my present review on the 'updates' that this new DSDMP has included. My review has (among other things) looked at the extent to which the authors have incorporated the latest insights from the most relevant 'new' scientific papers, technical reports and best practice guidelines on environmental aspects of dredging that were published since the previous DSDMP (i.e. since 2018). Where relevant, I have indicated in the Word document - in track changes - how some further findings and recommendations from these recent publications that are summarised below could be incorporated into the Maintenance DSDMP.

1. **Sustainability of (maintenance) dredging:**

There have been various recent developments towards a more sustainable long-term approach to maintenance dredging that are of relevance for this DSDMP:

- Sustainable Sediment Management (SSM) projects at the ports of Hay Point, Weipa & Amrun, Gladstone and Mackay in Queensland, summarised in a series of technical reports published by NQBP and GPC over the past few years (NQBP, 2017; GPC, 2018; NQBP, 2020). These have emphasised the benefits of approaching maintenance dredging and sediment management in port environments from a long-term sustainability perspective through increased understanding of the wider sediment dynamics by analysis of bathymetric evolution, exploring alternative designs/technologies to reduce maintenance dredging requirements (e.g. by modifications/alternative designs to existing navigation infrastructure or port entrances, periodic bed levelling through drag barring, creation of siltation trenches etc), consideration of options for beneficial reuse of dredged material, and accommodating for the effect of cyclones on sediment dynamics. Recent research projects have explored alternatives to conventional dredging, such as fixed sand by-passing plants and autonomous submerged dredgers (Bianchini et al., 2019; Curzi et al., 2021).
  One of the practical applications that could be explored for implementation in East Arm is periodic bed levelling in navigation areas / turning basin using a drag/sweep bar to regularly (e.g. once or twice a year) re-distribute accumulated sediment more evenly or into areas where it doesn't compromise navigation. This approach has been used effectively at various ports in Queensland to postpone the need for maintenance dredging and reduce its overall environmental impact (in the long term).
- New Maintenance Dredging Strategy for the Great Barrier Reef World Heritage Area Ports (Queensland Government, 2016). This strategic guidance document describes a similar long-term sustainable approach for maintenance dredging in the GBR region, echoing the need for such approach and describing its benefits for navigation and the environment.
- 'Dredging for Sustainable Infrastructure Development', a new 330-page book by a range of dredging professionals from CEDA/IADC that is entirely devoted to the sustainability of dredging projects, including in project initiation, planning and design, in equipment and methods, in dredged material management, and in modelling, monitoring and EIA.

- Nature-based Solutions, a range of innovative and more sustainable approaches to dredging and reclamation that are emerging across the globe as part of a paradigm shift in the waterborne infrastructure development industry, inspired by initiatives such as 'Building with Nature' in the Netherlands (www.ecoshape.org; Van Eekelen and Bouw, 2020), 'Engineering with Nature' in the USA (https://ewn.el.erdc.dren.mil; Bridges et al., 2018; Bridges et al., 2021) and 'Working with Nature' by PIANC (www.pianc.org/working-with-nature; PIANC, 2011).
- Although some of these emerging initiatives are perhaps beyond the scope of the present maintenance DSDMP, I strongly suggest INPEX to take note of these developments, keep an eye on further developments, devote a small section of the DSDMP report on sustainability with reference to some of these studies and reports.

2. New technical guidelines:

A range of new (relevant) technical and best practice guidelines for dredging have come out since the previous DSDMP, which appear not to have been considered in the DSDMP:

- New PIANC Guidelines (since 2018):
    - EnviCom WG 176: Guide for Applying *Working with Nature* to Navigation Infrastructure Projects (2018)
    - EnviCom 188: *Carbon Management* for Port and Navigation Infrastructure (2019)
    - EnviCom WG 175: A Practical Guide to *Environmental Risk Management* (ERM) for Navigation Infrastructure Projects (2019) (see 'adaptive management')
    - EnviCom WG 178: *Climate Change Adaptation* Planning for Ports and Inland Waterways (2020)
    - PTGCC Technical Note 1: Managing *Climate Change Uncertainties* in Selecting, Designing and Evaluating Options for Resilient Navigation Infrastructure (2022)
- New CEDA Information Papers (relevant ones, since 2018):
    - Sustainable Management of the *Beneficial Use* of Sediments - Case Studies Review (2019)
    - Assessing and Evaluating Environmental *Turbidity Limits* for Dredging (2020)
- New IADC publications:
    - Dredging for *Sustainable Infrastructure* Development (Laboyrie et al., 2018)
    - Fact Sheet on *Beneficial use* of Dredged Material (2019)
    - Fact Sheet on Environmental *Monitoring* (2019)
- U.S. Army Corps of Engineers (DOER) Technical Guidelines (+paper):
    - 'Evaluating Effects of Dredging-Induced *Underwater Sound* on Aquatic Species: A Literature Review' (Suedel et al., 2019; McQueens et al., 2020)
- While not really warranting any changes to the proposed approach for the maintenance dredging program at Darwin, it is recommended that INPEX takes note of these new guidelines and publications, makes adequate reference to some of these studies and reports in the DSDMP document (I made some suggestions in the text), and keeps up to date with such new developments in the years to come.

3. Carbon footprint of dredging

The carbon footprint (greenhouse gas emissions) of dredging (from fuel consumption and sediment disturbance) and possible strategies to minimise this, are not discussed in this plan. However, there is a strong drive in the dredging industry towards a carbon-neutral, zero-emission strategy (including development of technology needed to achieve that), and I see increasing efforts in EIA's and dredge permit applications where this is being discussed.

I recommend to devote a short paragraph on this issue in the DSDMP. The previously mentioned SSM reports, as well as the recent report by PIANC (2019) on the subject, could be a place to start. It is also worth noting that CEDA started a new technical working group on 'Energy efficiency in the dredging industry' (to reduce carbon emissions), while Wetlands International just issued a new strategic paper on the subject 'Reducing the ecosystem-based carbon footprint of coastal engineering projects' (Wetlands International, 2022). A multi-disciplinary team from TU Delft and Boskalis recently published a thesis on the subject 'Emission free maintenance dredging in a harbour environment' (Curzi et al., 2021). In all, an increasingly relevant subject indeed, especially in the context of climate change discussions.

4. Other new relevant publications/insights:

A number of additional (new) scientific papers/reports from the WAMSI Dredging Science program in WA have come out recently, some of which are worth quoting in this DSDMP. They include two papers/reports on impacts of dredging on fishes (Wenger et al., 2017; 2018), a paper on the risk of dredging on nearshore turbid reefs (Luter et al., 2021) and dredge plume modelling guidelines (Sun et al., 2020). I indicated in the text where to reference these.

A recent study in the port of Gladstone (Symmonds and Erftemeijer, in prep.) further points to a major importance of the process of flocculation in dredge plumes (without which modelling typically overestimates the extent and intensity of dredge plumes). This appears typically important in naturally turbid bays dominated by cohesive sediments (such as Darwin Harbour). Since these study results are not yet available, I do not suggest any changes to the DSDMP, but it is of relevance to note it here.

A recent survey of seagrasses in the waters around Darwin suggests that these are more diverse and more extensive than previously thought (not yet published, but see: https://www.cdu.edu.au/news/seagrass-habitats-more-diverse-and-expansive-expected-survey-reveals). Again, I do not suggest changes to the DSDMP, but it is relevant to note.

5. Additional comment:

- The permit application seeks approval for maintenance dredging to be allowed to be undertaken at any time within the approved five-year period (see Section 1.2 Scope, page 2). Can it be explained and justified more clearly why a seasonal approach to dredging (i.e. only during the wet season) - similar to what was proposed and approved for the East Arm capital dredging program - was not considered here?

Technical Comments

In addition to the general comments noted above, an annotated version of the draft Maintenance DSDMP Word document has been forwarded, which contains several technical comments and suggestions in the text.

Conclusions

The approach adopted by this (updated) Ichthys Maintenance Dredging and Spoil Disposal Management Plan 2023-27 follows that of the previous 5-year DSDMP and is largely based on the approach followed during the East Arm Capital Dredging Program (2012-2014), for which the assessment-, modelling-, dredging- and management approach was thoroughly evaluated, tested and refined. This approach has proven itself to be to be highly successful in avoiding significant environmental impacts from dredging activities, as demonstrated by the findings of the extensive environmental monitoring program before, during- and after the capital dredging (Cardno, 2014). Moreover, given the 20-fold smaller volume and 13-times shorter duration of the Maintenance Dredging Program, along with the previous experiences from the Capital Dredging Program, the risk of environmental impacts from the Maintenance Dredging Program – if following a similar management approach (as suggested) – is probably small. However, the greater %fines (~twice as high) of the material and the likely uptake of larger quantities of water during the maintenance dredging program (posing challenges to optimise the management of overflow) warrants appropriate care and attention regarding the environmental risks of this activity.

The Ichthys Maintenance DSDMP approach is of a high standard, incorporating what are internationally recognised as proven best practices in the environmental management of dredging and disposal operations. The 2023-27 DSDMP includes various updates up to 2021/22 of relevant datasets (e.g. rainfall) and has addressed the potential for cumulative impacts from other ongoing or planned dredging programs in Darwin Harbour. The dredge plume modelling and thresholds approach (including source terms assumptions and selection of scenarios) to assess potential environmental impacts associated with the maintenance dredging program is sound and appropriate for the intended purpose. The proposed environmental management frameworks and measures, water quality monitoring program and responsive management actions (in the case of exceedances) described in the DSDMP are adequate and will ensure that impacts on environmentally sensitive receptors (if any) will be as low as reasonably practicable (ALARP).

Provided that the comments and suggestions summarised in this expert peer review and the annotated version of the draft DSDMP document are taken into consideration in a revised version of the plan, I do not hesitate to accept this Maintenance Dredging and Disposal Management Plan as appropriate and of a high standard.

It is recommended that all monitoring data and reports from the maintenance dredging campaign be made publicly available and easily accessible, to allow further analysis of data and derive research opportunities and other potential benefits from such data sharing.

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EXPERT REVIEW COMMENTS REGISTER

Reviewer	Paul Erftemeijer
Review Document Title	Maintenance Dredging and Spoil Disposal Management Plan (DSDMP)
Company Document No#	L060-AH-PLN-70003
Document Revision No# / Date	Revision A / 12 May 2022
Reviewer Technical Note Title	Ichthys Maintenance Dredging and Spoil Disposal Management Plan (2023-2027): Peer Review

No.	Context	Reviewer Comment/Recommendation	INPEX Response	Reviewer acceptance/additional comments	INPEX Response	Reviewer acceptance/additional comments
1	Sustainability of (maintenance) dredging	There have been various recent developments towards a more sustainable long-term approach to maintenance dredging that are of relevance for this DSDMP. Although some of these emerging initiatives are perhaps beyond the scope of the present maintenance DSDMP, I strongly suggest INPEX to take note of these developments, keep an eye on further developments, devote a small section of the DSDMP report on sustainability with reference to some of these studies and reports.	INPEX has reviewed some of the available material referenced as part of your technical note and acknowledges the increased focus on sustainability, efficiency and where possible, reducing the need for maintenance dredging. A new sustainability considerations section has been included in the Maintenance DSDMP. Draft text is provided below in Attachment 1. Understanding sediment dynamics for Darwin Harbour is described in Section 5.4.3. Studies were also done as part of the Final EIS for Ichthys LNG, which indicated potential maintenance dredging frequency of 10 years. Section 5.4.3 notes that material that settles during favourable conditions (i.e. slack water) in the dredge area is likely to be remobilised and redistributed into areas where hydrodynamics are less turbulent than the dredge area. Hydrodynamic surveys to date have reflected this with ~410,000 m^3 of accretion over eight years with no need to maintenance dredge to date. This level of accretion and extended periods between maintenance dredging is considered sustainable by INPEX, especially in consideration of other maintenance dredging campaigns in Australia which have similar or greater volumes on an annual, biennial or triennial basis (e.g. Port of Brisbane, Port of Townsville and Port Hedland). As such, exploring alternative options is not considered further at this point in time as the reviewed publications typically relate to maintenance dredging campaigns with high frequencies (e.g. annual, biennial) or are best suited to design as part of capital dredging. Alternative uses of dredge spoil have also been previously considered as described in Appendix A.2.2. However, given the fine nature of materials to be dredged it is unsuitable for onshore infill and construction purposes. Further, Darwin Harbour is lined with over 26,000 ha of mangroves and the exposed coastal shorelines contain sensitive habitats such as seagrass. Use of dredge spoil in the Darwin Harbour region is not considered appropriate for things like beach nourishment (which may be an option in other areas) as the dredged material has different characteristics to local beaches and would potentially by remobilised and impact/influence nearby sensitive habitats.	I appreciate the elaborate response to this comment and consider it acceptable for the present purpose of this DSDMP. I encourage INPEX to keep an eye on the latest developments in the sphere of managing the sustainability of dredging and port operations (including its carbon footprint), both from initiatives within Australia as well as those reported in the world literature.	-	-
2	New technical guidelines	It is recommended that INPEX takes note of these new guidelines and publications, makes adequate reference to some of these studies and reports in the DSDMP document	As suggested, have incorporated and referenced publications where relevant.	Accepted	-	-

EXPERT REVIEW COMMENTS REGISTER

No.	Context	Reviewer Comment/Recommendation	INPEX Response	Reviewer acceptance/additional comments	INPEX Response	Reviewer acceptance/additional comments
3	Carbon footprint of dredging	I recommend a short paragraph on the carbon footprint of dredging be included in the DSDMP.	A new sustainability considerations section has been included in the Maintenance DSDMP. Draft text is provided below in Attachment 1. Greenhouse gas (GHGs) emissions from dredged sediment can be even more significant than those from the equipment used to undertake the dredging[1]. This is more generally associated with capital dredging material as opposed to maintenance dredging sediments, which are generally temporary in nature and routinely remobilised and redistributed and thus low carbon sequestration rates or have low levels of carbon compared to undisturbed sediments. Therefore, the main GHG emissions for the maintenance dredging program are primarily associated with emissions from the use of a TSHD.	While I agree that it is possible this is less of an issue with maintenance dredging sediments, I would need to have a look at the maintenance dredging sediment sampling and analysis report (INPEX, 2016) to confirm before accepting this response. [it would appear that what is being referred to as 'very low levels of organic compounds' actually refers to PAHs and hydrocarbons, not Organic C. It is the latter – not the former – that is of relevance for the discussion around GHG emissions]. Also, see some further comments in the text of Appendix 1 below.	A summary of total organic carbon (TOC) has now been included in Section 4.1.1 (Sediment quality - dredge area) to support the statement provided in Attachment 1: "*Total organic carbon concentrations have also been low, with average concentrations within the dredge area between 0.66% and 1.07% (average of 0.66% in 2016, 0.72% in 2019, 1.04% in 2020 and 1.07% in 2021).*" For information, the measured TOC within the dredge area surface sediments is slightly lower than reported TOC concentrations in East Arm[2] (average 1.46%) and West and Middle arms[3] (average 1.54%), although higher than Darwin Outer[4] (average 0.46%) concentrations.	Accepted
4	Other new relevant publications/insights	Incorporate WAMSI Dredging Node papers and other relevant literature and publications.	Papers and guidelines from the WAMSI Dredging Science Node referred to in your technical note and mark ups in the draft Maintenance DSDMP have been incorporated. However, the recent survey of seagrass has not been considered as this is from Limmen Bight in the Gulf of Carpentaria, therefore it is not relevant to the present DSDMP.	Accepted	-	-
5	Additional comment	The permit application seeks approval for maintenance dredging to be allowed to be undertaken at any time within the approved five-year period (see Section 1.2 Scope, page 2). Can it be explained and justified more clearly why a seasonal approach to dredging (i.e. only during the wet season) - similar to what was proposed and approved for the East Arm capital dredging program - was not considered here?	The decision to maintenance dredge will be informed by a range of factors, primarily ensuring the safe navigation of the channel is maintained and operational access to Ichthys LNG jetties are not restricted, as such the ability to undertake maintenance dredge at any time is required. Section 3.1 provides further details in regard to timing and need to be able to maintenance dredge in either wet or dry season. The majority of deposition to date has been measured in the jetty pockets; and given 3 to 4 product tankers visit every week a potential operational window for maintenance dredging is during a planned shutdown. During a shutdown there is a 4 to 5 week period of no offtakes/product tankers. Planned shutdowns occur in the dry season so restricting dredging to the wet season has not been considered. It is also noted that during the wet season natural phenomenon such marine heatwaves can naturally stress corals and avoiding these periods where possible has the potential to reduce or limit potential impacts to coral. Further, the coral spawning window for Darwin Harbour is predicted to occur in the wet season (April), as such avoidance of this period where possible is also preferrable.	The main intention of my comment was that INPEX should provide some text and explanation in the DSDMP report regarding the timing of the proposed maintenance dredging (how it takes note of potential seasonal constraints). Your explanation here is acceptable (though mainly for operational reasons). However, rather than explaining it here in this Comments Register, I recommend you include a brief section on this in the DSDMP report itself. Rather than fixing the discussion too much around wet or dry season, I suggest you state that INPEX seeks to maintain flexibility that would allow it to conduct maintenance dredging to be undertaken at any time within the approved five-year period, but that it will consider both operational constraints (e.g. operational use of jetties by visiting product tankers, planned shutdowns) and environmental windows (seasonality of water quality, coral spawning windows and marine heatwaves) to select the most suitable time period to conduct the maintenance dredging. In addition, it should be noted that this 'best intention' approach might suddenly have to change if a cyclone passes over and deposits	The primary drivers for maintenance dredging is ensuring the safe navigation of the channel based on hydrographic survey outcomes, other aspects that may also be considered to inform decision to maintenance dredge include the availability of dredge vessels (i.e. vessel of opportunity), planned shutdown periods for maintenance, and the operational schedule of Ichthys LNG. It is noted that environmental windows (e.g. coral spawning) occur at different times of the year and management actions or controls are already included as part of the Maintenance DSDMP environmental management frameworks to address these if dredging coincides to ensure dredging can be undertaken at any time. As such, these environmental windows may be considered when planning a maintenance dredging campaign. Revised wording in Section 3.1 has been provided: "*No decision has been made with regard to timing of the first maintenance dredging campaign. However hydrographic surveys, which monitor accretion and erosion of sediment within the dredge area are undertaken annually. The results of these surveys, in addition to other aspects such as, the availability of dredge*	Accepted

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EXPERT REVIEW COMMENTS REGISTER

No.	Context	Reviewer Comment/Recommendation	INPEX Response	Reviewer acceptance/additional comments	INPEX Response	Reviewer acceptance/additional comments
				large quantities of sediment in the channel and berthing pockets and compromises navigational safety, which would justify a more 'immediate' approach to maintenance dredging in response to such a cyclone-induced emergency situation.	*vessels, planned shutdown periods for maintenance, and the operational schedule of Ichthys LNG inform the decision for maintenance dredging campaign timing. Environmental windows (e.g. coral spawning) may also be considered when planning a maintenance dredging campaign."*	
6	Terms, abbreviations and acronyms	To avoid an unnecessary negative perception or bias towards dredging, it would have been my preference if the authors had considered using the term 'dredged material placement' rather than 'spoil disposal' (throughout the document), since this is natural seabed material that is moved from A to B within the environment from which it is taken, and as such does not constitute 'spoil' that requires 'disposal'.	Use of the term 'spoil disposal' is consistent with previous approvals for both capital and maintenance dredging in Darwin Harbour for which INPEX has undertaken stakeholder engagement and changing the term to 'dredged material placement' may cause confusion, noting there is no differentiation between the two. Other operators within Darwin Harbour also refer to it as 'spoil disposal', as such, to remain consistent and avoid potential confusion, the term 'spoil disposal' will continue to be used.	Accepted	-	-
7	Section 1	Since I have provided an exhaustive peer review of the previous Maintenance DSDMP for INPEX, which was approved by the NT-EPA following review and revision, I have focused my present review on the 'updates' that this new DSDMP has (or hasn't) included. My review has (among other things) looked at the extent to which the authors have incorporated the latest new insights from the most relevant 'new' scientific papers, technical reports and best practice guidelines on (environmental aspects of) dredging that have been published since the previous DSDMP (i.e. since 2018).	Noted.	Accepted	-	-
8	Section 1.2	"*These campaigns may be undertaken at any time within the approved five-year period*." Can it be justified here why this is not limited to dredging 'during the wet season only', similar to what was approved for the East Arm Capital Dredging Program in 2013-14, which successfully prevented environmental impacts?	See response to Comment 5	Accepted (note my recommendation to include a section on 'timing of the maintenance dredging' in the main text of the DSDMP report)	-	-
9	Section 3.2.2	Have alternatives (re: DSDA) been considered? Since the volumes for the maintenance dredging campaigns are much smaller than for the capital dredging, perhaps it could save money and fuel emissions if a much nearer DSDA was selected (45 km is a long distance to sail up and down). Other alternatives, such as beneficial reuse of dredged material (e.g. for habitat development) could also have been considered. See later comment on 'Sustainable Sediment Management' (SSM)...	An alternative DSDA has not been considered as the DSDA was originally selected based on stakeholder engagement feedback, modelling and distance (see Appendix A.2.2). Modelling demonstrates that fine sediment dispersion from the DSDA does not impinge on inshore habitats and provides for good long-term dispersal of sediments. Further, the DSDA is located away from commercial shipping channels/routes, therefore does not pose a risk/impact on under keel clearances. Investigations during the capital dredging program for alternative use of dredge spoil, such as land reclamation and use for construction purposes, found that dredge material was not suitable due to fines content. As described in Section 4.1.5 and 6.1, dredge material proposed to be dredged has a high fines content and therefore would not be suitable for infill or construction purposes.	Accepted	-	-
10	Section 3.4	*Seabed levelling* - Periodic bed levelling using a drag/sweep bar (regularly re-distributing accumulated sediment more evenly or towards	Seabed leveling is included in the draft Maintenance DSDMP as an option as it can be used to attain design	Accepted	-	-

No.	Context	Reviewer Comment/Recommendation	INPEX Response	Reviewer acceptance/additional comments	INPEX Response	Reviewer acceptance/additional comments
		areas where it doesn't compromise navigation) has been used effectively to postpone the need for maintenance dredging (and reduce overall environmental impacts in the long term) at several ports in Queensland, as part of ongoing longer-term strategic sediment management (SSM projects). Has such an approach been considered here?	requirements and aid safe and effective navigation, effectively prolonging the need to maintenance dredge. It is worth noting that the current draft Maintenance DSDMP is not associated with a planned maintenance dredging campaign, rather seeking approval to be able to undertake maintenance dredging (including seabed levelling) within a five-year period. Capital dredging was completed ~8 years ago and to date no maintenance dredging has been undertaken. INPEX will continue to review annual hydrographic survey outputs in consideration of operational constraints and to ensure safe navigable access to Ichthys LNG product loading jetties is maintained, which may include maintenance dredging, seabed leveling or combination of the two.			
11	Section 3.4	*"…seabed levelling will be used on an as needs basis"* Please consider expanding the text a bit here (under what circumstances?). Also see previous comment...	See response to Comment 10. Text has also been updated to provide examples: *"…seabed levelling will be used on an as needs basis, this may include but not limited to high spot removal during a maintenance campaign or ad hoc high spot removal (e.g. after the passing of storms or cyclones) to postpone the need for maintenance dredging."*	Accepted	-	-
12	Section 4.1.1	*Topical cyclones* - Perhaps the Severe Tropical Cyclone Marcus, which struck Darwin in March 2018, can be noted here… Was there any noticeable effect of this cyclone on the sediment accretion in the turning basin or other dredged areas?	Section 4.1.1 has been updated to include a brief statement on tropical cyclone (TC) Marcus - *"In 2018 Tropical Cyclone Marcus passed directly over Darwin Harbour as a category 2 cyclone; and was a very small cyclone at this point in time (BOM 2019). A 90 cm storm surge was recorded at the Darwin tidal gauge, although the passage of the cyclone coincided with a low tide, as such the surge did not exceed the highest astronomical tide."* Regarding accretion, Appendix A.1 details the timing of hydrographic surveys, with a hydrographic undertaken in April 2018, the month after TC Marcus passed over Darwin Harbour on 17 March 2018 as a category 2 cyclone. Previous hydrographic surveys had been completed in August 2015, May 2016 and June 2017. Although TC Marcus was the strongest cyclone to impact Darwin since TC Tracy (category 4 in 1974), TC Marcus was a very small cyclone with gale radii of 10-15 nm as it passed over Darwin[5]. The strongest wind gust recorded at Darwin Harbour was 70.4 kn, while a total of ~88 mm of rain was reported at Darwin airport between 17 and 19 March 2022. Table 3-1 presents the measured annual accretion between hydrographic surveys, and based on this data, the most accretion reported to date was between the 2017 and 2018 surveys. Indicating TC Marcus may have caused increased accretion. Review of surface difference plots indicates that the locations of greatest accretion (i.e. depth) between 2017 and 2018 occurred at the base of the batter in the northern corner of the turning basin and the base of the batters along the eastern and south-eastern sections of the jetty pocket (see Attachment 2 below). Average	Accepted. I am happy with this addition to the DSDMP (insightful and relevant). Please note a few additional comments on the text of Appendix 2, Which you may wish to accommodate.	-	-

[5] Bureau of Meteorology. 2019. Severe Tropical Cyclone Marcus: 14 – 25 March 2018. Report prepared by Bureau of Meteorology. Viewed online 20 June 2022 < http://www.bom.gov.au/cyclone/history/pdf/Marcus_Report.pdf>

No.	Context	Reviewer Comment/Recommendation	INPEX Response	Reviewer acceptance/additional comments	INPEX Response	Reviewer acceptance/additional comments
			accretion in the jetty pocket area was +22 cm. The location and depths of accretion are similar to previous years, for instance average accretion in the jetty pocket area was +14 cm between 2015 and 2016 and +20 cm between 2016 and 2017. Measured accretion in 2017 was also high compared to previous years similar to 2018, and review of rainfall data showed that rainfall in both 2017 (2,828 mm) and 2018 (2,249 mm) wet seasons was well above average (1,606 mm). In this instance, the rainfall is used as an indicator of episodic wet season events, which can cause significant increases in SSC and net sediment flux into the Harbour. Further, tidal catchment input is significantly greater than runoff, and advection of high SSC into the Harbour was observed during the capital dredging program, especially when these coincided with spring tides. Further information of East Arm sediment balance is provided in Section 5.4.3 of the draft Maintenance DSDMP, noting overall there is a landward net sediment balance in Darwin Harbour. Given the available information, it is inconclusive whether TC Marcus resulted in increased accretion and there were no notable areas of accretion in comparison of previous surveys. Appendix A.1 has been updated to include more information about TC Marcus – "*Higher levels of accretion were also noted at the base of the batters along the eastern and south-eastern sections of the jetty pocket. It is also worth noting that on 17 March 2018, just over one month prior to the final hydrographic survey by INPEX, Tropical Cyclone Marcus passed directly over Darwin Harbour as a very small category 2 cyclone (BOM 2019). A review of hydrographic survey data and measured accretion (see Section 3.1) indicates Marcus may have caused increased accretion. However, the location of accretion measured in 2018 was similar to previous years, as was the depth of accretion. Only a small increase in previously measured annual depths in the jetty pocket area (i.e. +14 cm in 2016, +20 cm in 2017 and +22 cm in 2018) were reported. Based on the available information it is not possible to ascertain if and to what extent Marcus had on measured accretion and further information is need to determine the impact periodic meteorological events such as cyclones have on accretion within the dredge area.*"			
13	Throughout document	Inclusion of relevant references throughout	References have been included throughout as indicated and where relevant.	Accepted	-	-
14	Section 5.4.3	*Long-term effects on East Arm sediment balance* - This would be an appropriate place to briefly elaborate on the need for (and benefits of) a long-term strategy towards sediment management in Darwin Harbour, and ways in which this DSDMP aims to address that. Particular reference is made to the long-term maintenance dredging strategy for the Great Barrier Reef region, as well as the various SSM project reports for the ports of Hay Point, Weipa/Amrun, Gladstone and Mackay, published by NQBP and GPC over the past few years. These have emphasised the benefits of analyses of bathymetric evolution, exploring alternative designs/technologies to reduce maintenance	The Northern Territory Government, namely Department of Infrastructure, Planning and Logistics (DIPL) is responsible for the development of a Darwin Harbour dredging strategy. INPEX has been aware of this strategy and offered to provide input as a key stakeholder having conducted the biggest capital dredging program in Darwin Harbour and having a requirement for ongoing maintenance dredging. However, to date INPEX has not been approached by DIPL to contribute to the strategy and it is unclear what progress has been made or potential release date. Numerous dredging projects (capital and maintenance) or other projects that may influence sediment dynamics in Darwin Harbour, are currently under assessment and the development of a Harbour wide strategy is the	Accepted. Your response is fair and it is unfortunate that INPEX has not been consulted by DIPL to provide input into the development of a Darwin Harbour-wide (long-term) Dredging Strategy, given your experience.	-	-

No.	Context	Reviewer Comment/Recommendation	INPEX Response	Reviewer acceptance/additional comments	INPEX Response	Reviewer acceptance/additional comments
		dredging requirements (such as modifications/alternative designs to existing navigation infrastructure, periodic bed levelling through drag barring, creation of siltation trenches), beneficial reuse of dredged material and accommodating for the effect of cyclones on sediment dynamics. While some of that may be beyond the scope of this DSDMP, it would be worth noting and some of these aspects and ideas may be worth exploring further in the case of East Arm in Darwin Harbour.	responsibility of the NTG, the NTG have oversite of all construction activities within Darwin Harbour. Given a strategy is already in development and without knowledge of the content, INPEX will await the release of the strategy before commenting on or including pertinent information into the draft Maintenance DSDMP. INPEX acknowledges that such a strategy would be beneficial, which is way INPEX has offered to provide input into the strategy.			
15	Section 6.1	*Section 6.1* - It would be appropriate here to make reference to the recently published 'Guideline on dredge plume modelling for environmental impact assessment' (Sun et al., 2020), which is an excellent best practice standard guideline for dredge plume modelling (for use in Australia and internationally). While the modelling approach followed in this DSDMP is largely (if not entirely) in compliance with these guidelines, they were not previously available in the form of such published guidelines. As such, this forms an excellent source reference that justifies and supports the approach followed in this DSDMP.	Section 6.2 has been updated to include acknowledgement of Sun et al. (2020). The following text has been included in the draft Maintenance DSDMP "*It is noted that after modelling for maintenance dredging was completed, a Guideline on Dredge Plume Modelling for Environmental Impact Assessment (Sun et al. 2020) has since been released. In review of this guideline, the modelling informing this Maintenance DSDMP is considered appropriate, as modelling is based on verified and validated data specific to Darwin Harbour which was collected during the capital dredging program; as described in the following sections.*"	Accepted	-	-
16		The Ichthys Maintenance DSDMP approach is of a high standard, incorporating what are internationally recognised as proven best practices in the environmental management of dredging and disposal operations. The 2023-27 DSDMP includes various updates up to 2021/22 of relevant datasets (e.g. rainfall) and has addressed the potential for cumulative impacts from other ongoing or planned dredging programs in Darwin Harbour. The dredge plume modelling and thresholds approach (including source terms assumptions and selection of scenarios) to assess potential environmental impacts associated with the maintenance dredging program is sound and appropriate for the intended purpose. The proposed environmental management frameworks and measures, water quality monitoring program and responsive management actions (in the case of exceedances) described in the DSDMP are adequate and will ensure that impacts on environmentally sensitive receptors (if any) will be as low as reasonably practicable (ALARP).	Noted. INPEX has also committed to reviewing available water quality data with the intent to incorporate light-based triggers into the draft Maintenance DSDMP adaptive management for sediment-related effects. This approach aligns with recommendations made in the WAMSI Dredge Node and requirements of regulators in some other jurisdictions (e.g. Western Australia and Queensland) with dredging guidelines or active dredging projects.	Accepted and noted. It is commendable that INPEX has agreed to consider developing light-based triggers – based on available water quality data - as part of its adaptive management program for the planned maintenance dredging. I'd be happy to review those, once developed, if required.	-	-
17		It is recommended that all monitoring data and reports from the maintenance dredging campaign be made publicly available and easily accessible, to allow further analysis of data and derive research opportunities and other potential benefits from such data sharing.	Noted.	Accepted	-	-

Attachment 1

Sustainability considerations

The physical impacts of climate change are likely to be felt in Australia in coming years. The CSIRO (2020) estimates the following impacts will be felt in Northern Australia:

- Continued substantial increases in projected mean, maximum and minimum temperatures in line with our understanding of the effect of further increases in greenhouse gas concentrations (very high confidence).
- Extreme temperatures are projected to increase at a similar rate to mean temperature, with a substantial increase in the temperature reached on hot days, the frequency of hot days, and the duration of warm spells (very high confidence).
- Future increase in the intensity of extreme rainfall events (high confidence).
- Mean sea level will continue to rise and height of extreme sea-level events will also increase (very high confidence).

Sustainability for dredging not only considers emissions from equipment and vessels but also potential emissions from the handling of dredge material (e.g. carbon stored in sediments) (Nieuwkamer et al. 2022). Sustainable management and beneficial use of dredged material and frequency of maintenance dredging are also important considerations. Emissions related to this Maintenance DSDMP are likely to be limited to operation of a single TSHD (e.g. dredging and transiting to and from DSDA) and support vessel/s. It is noted that the DSDA is located approximately 45 km from the dredge area, which may be considered far, however this has previously been determined to be the most suitable location given the environmental sensitives of Darwin Harbour (see Appendix A.2.2).

The sediment characterisation assessment undertaken for the proposed maintenance dredging program (see Section 4.1.5) found that silt and fine sands were the overall dominant fractions. Silt and fine sands are unsuitable for reuse purposes (e.g. infill and construction, beach nourishment). As such will be placed within the previously used DSDA.

During assessment of jetty design and the associated dredge a series of complex loading and navigation studies, geotechnical and environmental surveys, and safety risk assessments were completed. The Final EIS (INPEX 2010, 2011) also noted that maintenance dredging would be required throughout operations to maintain a safe and navigable channel including berthing and loading operations. Modelling indicated a potential frequency of approximately 10 years, although actual volume and frequency to be dredged would be determined based on annual hydrographic surveys and accessibility (e.g. transit, berthing and loading). As described in Section 3.1, no maintenance dredging has been required in the eight years since the completion of capital dredging and there has been no decision made in regard to timing of the first maintenance dredging campaign. Further, the ~410,000 m3 of accretion measured to date is within the range maintenance dredging campaigns around Australia[1], however these have a much higher maintenance dredging frequency (e.g. annual or biennial). In consideration of proposed maintenance dredging volume and frequency the proposed maintenance dredging approach is considered sustainable.

[1] Regular maintenance dredging volumes in Australian ports over the past decade ranged from <10,000 m^3 to as much as 1.3 Mm^3. For example, the Port of Brisbane requires annual maintenance dredging with volumes typically ranging from 426,000 m^3 to 766,000 m^3, although following significant flood events volumes can exceed 1.3 Mm^3 per year (HaskoningDHV, 2016). Port Hedland requires the removal of 114,000 m^3 to 730,000 m^3 every 3 to 4 years (Ports Australia 2014). The Port of Townsville required removal of ~814,000 m^3 in 2011 following the passage of Tropical Cyclone Yasi, which silted up channels and berths. This was significantly higher than its usual annual maintenance dredging requirement, which averaged ~363,000 m^3 per annum between 2004 and 2014 (State of Queensland (Department of Transport and Main Roads) 2016).

Attachment 2

Figure 1: Dredge area surface difference 2018 (+) compared to 2017 (-). Depth contour -13.5m LAT shown (white). Mean surface difference of +22 cm in black dashed area.

Australian Government

AUSTRALIAN INSTITUTE OF MARINE SCIENCE

Review of the Maintenance Dredging and Spoil Disposal Management Plan (2023-2027) Document No.: L060-AH-PLN-70003

prepared for INPEX Operations Australia Pty Ltd

Dr Ross Jones (r.jones@aims.gov.au) June 2022

Australian Institute of Marine Science

PMB No 3
Townsville MC Qld 4810

PO Box 41775
Casuarina NT 0811

Indian Ocean Marine Research Centre
University of Western Australia, M096
Crawley WA 6009

"The Australian Institute of Marine Science (AIMS) acknowledges the Traditional Owners as the ongoing custodians of country throughout Australia, and in particular across northern Australia where AIMS operates in partnership with Aboriginal and Torres Strait Islander peoples. AIMS acknowledges and celebrates their continued connection to country, including sea country, and pays respects to all elders past, present and future."

DISCLAIMER

Project Leader shall ensure that documents have been fully checked and approved prior to submittal to client				
Revision History:		Name	Date	Comments
1	Prepared by:	Ross Jones	30/05/2022	
	Reviewed by:	Claire Streten	1/6/2022	
	Approved by:	Cherie Motti	2/06/2022	

Cover photo:

Current picture 'RV Solander in Western Australia. Image: N. Thake

1. Background

INPEX currently holds a five-year approval for maintenance dredging for the existing dredged footprint associated with the Ichthys LNG onshore processing plant at Blaydin Point in Darwin Harbour (Northern Territory). The approvals associated with the original approved activity are due for renewal in early 2023. INPEX will be submitting an updated Maintenance Dredging and Spoil Disposal Management Plan (hereafter maintenance DSDMP) incorporating any new relevant information from the last ~5 years. This review is of the draft maintenance DSDMP Document No.: L060-AH-PLN-70003.

The review focus was on Sections: 5 – Environmental risk assessment, 6 – Sediment plume modelling and impact assessment, 8.1 – Management of sediment related effects and Section 9 – Water quality monitoring of the maintenance DSDMP.

The maintenance DSDMP referred to many client reports which were not open access, and which were requested from INPEX to complete the review. These include:

Cardno. 2015a. Water quality and subtidal sedimentation post-dredging report. Ichthys Nearshore Environmental Monitoring Program. Report prepared by Cardno (NSW/ACT) Pty Ltd, Sydney, New South Wales for INPEX Operations Australia Pty. Ltd., Perth, Western Australia.

Cardno. 2015b. Intertidal sedimentation and mangrove community health post-dredging report. Ichthys Nearshore Environmental Monitoring Program. Report prepared by Cardno (NSW/ACT) Pty Ltd, Sydney, New South Wales for INPEX Operations Australia Pty. Ltd., Perth, Western Australia.

Cardno. 2015c. Coral monitoring post-dredging report. Ichthys Nearshore Environmental Monitoring Program. Report prepared by Cardno (NSW/ACT) Pty Ltd, Sydney, New South Wales for INPEX Operations Australia Pty. Ltd., Perth, Western Australia.

Cardno. 2015d. Seagrass monitoring post-dredging report. Ichthys Nearshore Environmental Monitoring Program. Report prepared by Cardno (NSW/ACT) Pty Ltd, Sydney, New South Wales for INPEX Operations Australia Pty. Ltd., Perth, Western Australia these

2. General context

The Ichthys LNG capital dredging project (16.1 Mm^3, duration 16.5 months) was one of a series of major dredging projects in tropical Australia in the last decade on a parallel with Wheatstone (31.4 Mm^3, 2 years duration, Chevron), Barrow Island (7.6 Mm^3, 530 day duration, Chevron), Cape Lambert (14 Mm^3, 633 day duration, BHP), and Burrup Peninsula (Pluto, 12.5Mm^3, 911 days duration, Woodside)(Jones et al., 2015; Jones and Twomey, 2019).

The approaches used in these major dredging projects have been very similar to align to similar regulatory expectations. Currently, at the pre-dredging EIA stage modelling of the movement of sediment from capital and maintenance dredging (and spoil disposal) is achieved by combining hydrodynamic and sediment transport models using estimates of dredge type, mode of operation, volumes and production rates. The model outputs are as particle concentrations (suspended sediment concentrations, SSCs) and maps of likely excess SSCs are generated and superimposed on benthic maps habitats to show what could be affected. Ecological tolerance limits are then used to predict the fate of the underlying communities. During dredging, water quality monitoring is also conducted with the same (or similar) ecological tolerance limits and used to reactively manage the dredging programs.

Very relevant to this review is that concurrent with these dredging projects, the Western Australian Marine Science Institution (WAMSI) started and delivered on a $19 M research project – the Dredging Science Node - to enhance capacity within Government and the private sector to predict and manage the environmental impacts of dredging: https://wamsi.org.au/research/programs/dredging/

Much of the work in the Dredging Science Node was about modelling and monitoring plumes and using ecological or physiological thresholds to predict effects. Much of the work has been published recently in journals (and are still being published), in addition to reports on the WAMSI website (above).

With many or all of the large-scale dredging plans, SSCs are typically the lead parameter, i.e., the key parameter used to relate the hazard to a risk both in the modelling exercises and the water quality monitoring programs (where turbidity or water cloudiness is used as a proxy or surrogate for SSCs). What has been shown recently in the some of the WAMSI Dredging Science Node work with corals, is that suspended sediments do not cause harm *per se*, as long as the corals have enough light and sediment is not allowed to settle on corals (Bessell-Browne et al., 2017b; Jones et al., 2019a). Putting sediment deposition aside, it is the light attenuating properties of the suspended sediments that will cause harm to phototrophs such as corals and seagrasses i.e., it is the key cause-effect pathway. The maintenance DSDMP recognizes this all the way through - that it is the light attenuating property of suspended sediment that is important (see dedicated section to this is 9.4.2 on page 149) - but nevertheless the emphasis is still on turbidity for management triggers (see further below) not light (see further below).

The following sections discuss the limitations with turbidity as a proxy for SSCs for monitoring and turbidity as the lead indicator.

3. Turbidity as a proxy for light

Using turbidity for management triggers is less desirable than directly measuring light availability as the 'pressure parameter'. In terms of turbidity as a proxy for light there are many ways that turbidity (or SSCs) can be misleading: (1) high turbidity at night is irrelevant as there is no sun light to attenuate and yet night-time turbidity measurements are always used in water quality characterization, (2) turbidity during a cloudy day will have much more effect on benthic light availability than during a cloud-free day,(3) high turbidity during a spring tide high water would have much more effect on light availability (more light attenuation with a deeper water column) than a spring tide low water, (5) the coincidence of turbidity and timing of low tide or high tide (or solar noon) is also critically important.

The maintenance DSDMP recognizes all these issues and the factors controlling light and turbidity in the Darwin Harbour and the significance of macro tides, naturally turbid water, and clear wet and dry seasonality (4.14 water quality section). The analysis however really emphasizes the point that switching to light availability as a measuring parameter, as opposed to turbidity, will provide a much more reliable and credible assessment of the level of pressure being placed on benthic phototrophs.

As clearly stated in the maintenance DSDMP, the use of light-based thresholds for dredging is still in its infancy in Australia. This is correct. The field is more advanced for seagrasses, but recently light thresholds have been developed for corals from laboratory and field experiments for dredging projects in the turbid inshore areas of the central Great Barrier Reef (Jones et al., 2019a; Jones et al., 2019d; Luter et al., 2021). These thresholds are currently being used by the Port of Townsville for a capital dredging project in Cleveland Bay -and whilst turbidity is still being measured, the decisions are based on light.

<u>Information box: Light based thresholds and impact prediction - Cleveland Bay example</u>

For light-based monitoring programs it best to express light as daily light integrals (mol quanta m^2) and with sufficient baseline data, a matrix of data can be generated per site that characterises levels of light naturally over different periods i.e., running mean period from 1 d to 42 days (which is typical of a maintenance dredging program). In the Table below from Luter et al (2021) and Jones et al. (2019d) from a turbid inshore reef in Cleveland Bay off Townsville, it shows that, for example, of all the 7 d running mean periods throughout the baseline periods the worst (0th percentile) was 0.2 DLI and the best (100th percentile) was 15.1 DLI. Considering, for example, longer chronic periods such as the 28 d running mean period, it shows the worst (0th percentile) 28 d period was 1.5 DLI and the best (100th percentile) was 8.3 DLI.

With a simple data matrix such as the one below you should be able to examine the DLIs over the last few days, weeks or months or dredging and contextualize the light environment relative to normal.

	Daily light integral (mol photons m^2)									Turbidity (NTU)								
d	0th	5th	10th	20th	50th	80th	90th	95th	100th	0th	5th	10th	20th	50th	80th	90th	95th	100th
1 h	–	–	–	–	–	–	–	–	–	0.5	1.2	1.4	1.8	3.4	11.5	18.1	24.1	97.1
6 h	–	–	–	–	–	–	–	–	–	0.5	1.3	1.5	1.9	3.7	12.3	18.4	24.8	67.0
12 h	–	–	–	–	–	–	–	–	–	0.5	1.3	1.5	2.0	4.0	13.2	18.9	25.3	65.9
1 d	0.0	0.3	0.6	1.7	4.3	7.2	8.8	10.2	15.9	0.5	1.4	1.6	2.1	4.9	14.4	19.7	25.7	52.0
3 d	0.1	0.5	1.1	2.1	4.3	6.8	8.1	9.6	15.1	1.0	1.5	1.8	2.4	5.8	15.0	19.8	24.0	35.4
7 d	0.2	0.9	1.6	2.5	4.4	6.6	7.8	8.8	15.1	1.2	1.8	2.1	2.9	6.9	13.4	17.6	20.6	32.0
10 d	0.4	1.1	1.7	2.7	4.3	6.4	7.4	8.6	13.2	1.2	1.9	2.2	3.3	7.0	13.1	15.9	19.0	31.0
14 d	0.5	1.4	2.1	2.9	4.4	6.2	7.4	8.5	10.9	1.3	2.2	2.6	3.5	7.4	12.4	15.0	18.5	25.4
21d	0.7	1.6	2.7	3.2	4.2	5.9	7.0	8.0	10.3	1.8	2.8	3.4	4.7	7.8	12.3	14.7	17.6	20.9
28 d	1.5	2.2	3.0	3.4	4.2	5.5	6.8	7.4	8.3	2.3	4.0	4.5	5.9	7.9	12.5	15.2	16.8	17.5
35 d	1.6	2.2	3.1	3.5	4.2	5.3	6.8	7.3	8.2	4.0	4.7	5.2	5.8	9.3	13.1	14.7	15.2	16.7
42 d	1.7	2.5	3.2	3.5	4.3	5.1	6.8	7.3	8.2	4.7	5.0	5.4	6.3	9.6	13.0	14.1	15.3	16.2

The analysis can be done for light (left hand side above) and turbidity (NTU) (right hand side above, and see also further below re the IDF technique).

4. Turbidity as a proxy for sedimentation

For corals, sedimentation is one of the key cause effect pathways during dredging (Erftemeijer et al., 2012; Jones et al., 2016; Rogers, 1990). There has been a lot of recent work on sedimentation and corals in laboratory settings (Bessell-Browne et al., 2017a; Duckworth et al., 2017) and observations *in situ* studies during dredging programs (Jones et al., 2019b). These studies emphasize the significance of coral morphology and the significance of sediment collecting in surface hollows causing tissue smothering that determines the fate of colonies under high levels of sedimentation (Jones et al., 2019b).

The maintenance DSDMP plan refers to sedimentation monitoring instruments (sediment accumulation sensor) in development on page 148. The technique has now been published Whinney et al. (2016); Whinney et al. (2017); however, I agree with the conclusion in the maintenance DSDMP plan that it is too early to introduce the technique now without having an established a baseline using the instrumentation.

Turbidity is effectively being used in the maintenance DSDMP plan as a proxy for sedimentation as well (refer section 9.4.2). The relationship was examined in the WAMSI Dredging Science Node and discussed in Whinney et al. (2016); Whinney et al. (2017)) and also in Fisher et al. (2019).

The figure below is from Fisher et al. (2019) and shows that on a daily basis there is no real relationship between turbidity and sedimentation measured by sediment accumulation sensors (see also Whinney et al. (2017)). When averaging over long periods and grouping data from sites the relationship improves so turbidity could be considered a proxy of sedimentation but at any one instant in time the relationship is not strong.

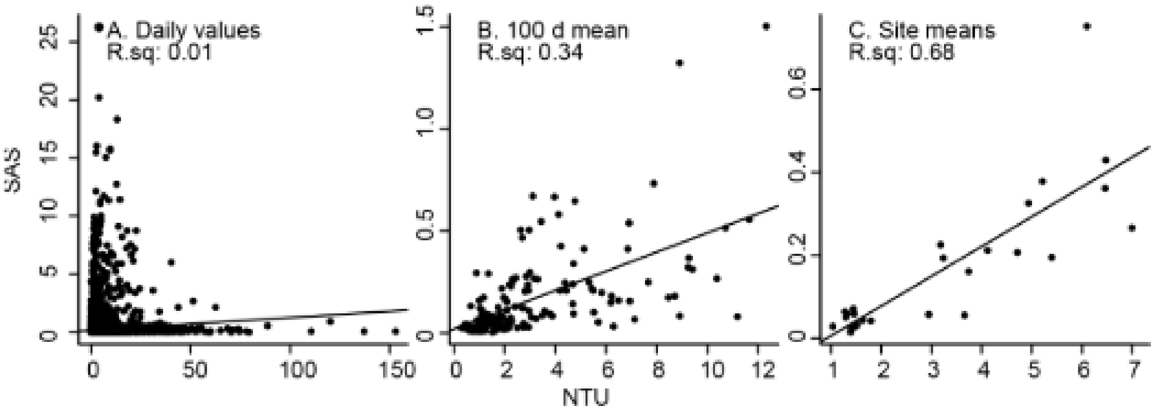

Figure 1. Correlations between sediment accumulation sensor (SAS) readings of settled surface sediment density and turbidity (as NTU from nephelometers) in the water column based on (a) daily average, (b) averages over 100 d, and (c) averages over 100 d at individual sites (from Fisher et al. (2019).

Sedimentation is an intractable problem for dredging because of difficulties in accurately measuring it. Evidence from the Barrow Island dreding project indicates that the effects on the water quality (i.e. elevated SSCs estimated via nephelometry and light reduction measured using PAR sensors) had decreased or dissipated from maximum to minimum by 90% by 20 km away from dredging) (Jones et al., 2019b). The distance was 14 km for sediment deposition (measured using optical backscatter sensors) and 3–3.3 km for smothering of some types of corals morphologies (where the build-up of pools of loose sediment on the surface that could not be removed by self-cleaning) (Jones et al., 2019b). So compared to where plumes can be seen and measured, the area where corals can be smothered is nearly and order of magnitude closer to dredging. The preceding analyses is empirically tied to the Barrow Island Project which was a very large project and with focal points of dredging and an unusual oceanographical setting involving a near unidirectional flow over most of the dredging. Neverthless, it is indicative of the relationship between where plumes can be seen/measured and where smothering of corals by excess SSCs can occur which is much closer to the source.

Overall the transition from using turbidity- to light-based monitoring is quite advanced for seagrasses and heading that way with corals, and is a recent recommendation of the WAMSI Dredging Science

Node and the National Environmental Science Program Tropical Water Quality (NESP TWQ) Hub funded research -see Jones R et al. (2021); Jones et al. (2020); Luter et al. (2021).

(see also https://nesptropical.edu.au/index.php/round-2-projects/project-2-1-9/.)

These are however very recent recommendations and although transitioning to using underwater light environment is desirable in Darwin Harbour at this stage there needs to be a complete characterisation of the light availability (see information box above) and an understanding of relationships of underwater light to tides and spring-neap cycles, seasonal changes and zenith angle and cloud cover. This information could be collected during the maintenance dredging and provide information that could be used in future maintenance or capital dredging projects in Darwin Harbour.

5. Reproductive cycle of corals (page 76)

Critical windows of environmental sensitivity (CWES) are a time(s) of the year, or sites, where key species or ecological communities or critical processes may be particularly vulnerable to pressures from dredging. The coral spawning CWES has been used in dredging projects in Queensland and Western Australia for several decades (Jones et al., 2017b).

There has been a lot of very recent experimental work of the effects of sediments on the reproductive cycle of corals (Ricardo et al., 2016a; Ricardo et al., 2018; Ricardo et al., 2015; Ricardo et al., 2016b; Ricardo et al., 2017b), especially new information on how elevated SSCs may directly impact the fertilisation stage where eggs and sperm are in the water column or at the water surface. The maintenance DSDMP doesn't acknowledge these recent papers especially the interaction of dredge plumes with gametes (Ricardo et al., 2015), which is a much more sensitive stage than when the coral larvae are in the water column (i.e., the references to Gilmour (1999); Humphrey et al. (2008)). This should mean reconsidering the risk profile in the DSDMP (page 76) and re-evaluating the pertinency of a coral spawning CWES.

The maintenance DSDMP says '*…Further, the potential additional "costs" (where Cost includes financial cost, time or duration, effort, occupational health and safety risks, or environmental impacts associated with implementing the control) of temporally restricting maintenance dredging (e.g. outside of spawning and settlement periods) would be grossly disproportionate to the risk. The risk from excess suspended sediment plumes on the reproductive cycle of corals is therefore considered ALARP*...'.

I am not sure this is correct as costs will only occur if maintenance is scheduled to coincide with a coral spawning time and then becomes restricted. The management implications of the studies described above have been discussed in Jones et al. (2017b); Ricardo et al. (2017a). It is comparatively easy to accommodate a coral spawning CWES during maintenance dredging and start earlier or preferably later, as opposed to extended (several years) capital dredging activities when dredging may be temporarily stopped.

6. Concurrent Harbour-wide dredging campaigns (Page 82)

It is very difficult to assess the information in the maintenance DSDMP with respect to overlapping or concurrent dredging (capital or maintenance) programs. The different dredging sites and zones of influence are not indicated on a map in the DSDMP (i.e., HMAS Coonwarra Harbour, Mandorah etc).

The known projects are also described in terms of maximum predicted SSC in mg/L but not in terms of duration of the projects (x mg/L for y days/weeks) which is also fundamentally important information (Jones et al., 2015).

The maintenance DSMP acknowledges there is potential to be areas of modelled excess SSC overlap if the most intensive dredging for dredging campaigns are undertaken simultaneously. Nevertheless, the potential cumulative impacts are '*…considered insignificant as they are not predicted to impact environmental values and sensitivities (e.g. marine ecosystems such as seagrass or coral)*...'.

The analyses behind these predictions (of insignificance) haven't been shown in the maintenance DSDMP. I am assuming that permission to commence maintenance dredging would be contingent upon closer scrutiny of other dredging activities (or 'turbidity generating activities') that could run concurrently. From a practical perspective I wonder if the information needed to do this i.e., volumes dredged, source terms, dredging equipment, durations, exact timing etc are, or will, be available to INPEX?

The wider implications here is if management thresholds are close to being exceeded, or have been exceeded, there is no possibility to intervene on behalf of INPEX in accordance with the maintenance DSDMP if the issue is co-caused by a neighbouring project. This is a complex area which INPEX would be aware of - and beyond the review scope - but suggests very coordinated efforts with neighbours and/or with regulators.

7. Coral bleaching

Coral bleaching events caused by marine heatwaves have been increasing in frequency in the last 25 years. Warm-water bleaching events have coincided with many long-term dredging projects in WA [1,2,3,4,] Australia (Jones, 2008), and the world (Miller et al., 2000) including in Darwin Harbour (see maintenance DSDMP section 4.2.2 page 52).

As noted in the WAMSI Dredging Science Node, the probability of a marine heatwave (and subsequent coral bleaching event) occurring during the baseline and operational phases of extended capital dredging projects has reached a point where it is recommended that consideration be given as to how to manage the project in the dredge plans should one occur.

Examples of how this can be done are described in Jones et al. (2019c) which could be referenced.

8. Sediment deposition maps (page 98)

'*…The model calculates the net thickness (in millimetres) of fine sediment deposited on to the seabed associated with the fine material released by the potential dredging activity for the entire duration of the maintenance dredging program…*'.

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[1] Pluto LNG Development, Burrup Peninsula: WA Environmental Protection Authority Bulletin 1259, Ministerial Statement No. 75734

[2] Cape Lambert B project: WA Environmental Protection Authority Bulletin 1357, Ministerial Statement 840

[3] Gorgon Gas Development Barrow Island Nature Reserve: WA Environmental Protection Authority Bulletin 1221 Ministerial Statement No. 800

[4] Wheatstone Development - Gas Processing, Export Facilities and Infrastructure: WA Environmental Protection Authority Bulletin 1404 Ministerial Statement No. 873

I do wonder with sedimentation prediction if this has ever been verified i.e., during the Capital program? was there ever an attempt to verify or confirm or measure in any way whether the predictions of sedimentation and the mm build-up of sediments correlate? If there hasn't been any attempt (model validation) then it is really questionable what the sedimentation maps mean – and even harder to turn them into risk by using ecological tolerance limits (see below).

It says the tolerance limits in Table 6.3 for SSC were derived from site-specific water quality monitoring which is ideal - but the same wasn't done for sedimentation? i.e. what instruments would be used? Sediment traps do not measure sedimentation (Whinney et al., 2016; Whinney et al., 2017) and they are more apt to provide an index of turbidity of the overlying water column than sedimentation *per se* (Storlazzi et al., 2011)).

Based on the information in the DSDMP the sedimentation maps have not been verified with field data, and the sedimentation thresholds for benthic organisms are not based on measurements *in situ* (to define a normal range) – and the default is therefore to use literature values. As discussed in the Jones et al. (2017a) review, it is questionable to apply literature values to predict impact during dredging because: (1) some studies have used carborundum powder, (2) others incorrect particle size distributions for the area of interest, (3) in some cases it is not possible to calculate the sedimentation rate or accumulation rate, and (4) stirring (water motion) also affects sediment clearance ability, tolerance to sedimentation varies by over and order of magnitude according to morphology (Jones et al., 2019a).

Overall, deposition maps from combining hydrodynamic and sediment transport models may be useful to identify approximately where deposition might be highest, and where to look for possible effects, but it is questionable whether ecological thresholds can be extracted from the laboratory or field-based experiments in a credible way to inform a risk assessment.

The logic given in the maintenance DSDMP for retaining the sedimentation thresholds in the impact prediction (modelling), and the connection back to capital project is acceptable and reasonable, but the relationship between sedimentation (mg cm^2 day) and nett accumulation for individual corals and coral habitats is an area that needs to be researched and developed for all future dredging projects.

Currently the most comprehensive study so far on the sediment clearance ability of corals, involving different species and morphologies, sediments, particle sizes and water motion is described in Duckworth et al. (2017).

9. Table 6-1: Tolerance limits for excess SSC and sedimentation (Page 100)

The Table 6.3 (page 100) is confusing because the tolerance limits did not have a time component. They were included in Table 8.5 on page 119 (perhaps Table 8.5 could be cross referenced in the Table 6.3 caption).

From pages 119-120 it says that the Intensity-Duration-Frequency (IDF) method of McArthur et al. (2002) is used. In this process the baseline data is interrogated, and an intensity (I) trigger set at the 95th percentile of turbidity data. The dataset is then examined to determine the number of consecutive times the intensity (I) value was exceeded. The 95th percentile was then calculated for the duration (D) of the individual events, providing an allowable number of consecutive hours that the intensity value can be exceeded. The McArthur et al. (2002) technique also has a frequency (F) criteria to make sure the conditions do not frequently exceed the I threshold but not long enough to exceed the D threshold.

The logic of the IDF technique is sound where it says that resident flora and fauna are adapted to local conditions but will be stressed if exposed to conditions that regularly exceed background concentrations. However, the McArthur et al. (2002) technique is based on individual readings (10-30 mins) and not based on a 24 h average as in the maintenance DSDMP. The maintenance DSDPM says '*…the frequency that background conditions are exceeded is also considered an important aspect...McArthur et al. (2002)…but due to the relatively short duration of a maintenance dredging campaign (in context of dredge volume), only acute triggers as they relate to intensity and duration were considered relevant...*'. But the 40 days is a chronic period (days to a week would be acute) and the situation would be different if 24 h averages weren't used. Removing the frequency criterion would allow multiple short term exceedances >95% and the generation of conditions which are well beyond a normal range.

Asides from the missing F threshold, the IDF technique can still generate conditions beyond which the habitats are adapted to without exceeding triggers normal (from the baseline). For example, the turbidity could be at the 90th percentile for the whole maintenance dredging program and would never trigger the intensity threshold, or if triggering the intensity threshold occurs it doesn't trigger the duration threshold hence leading to actions.

Overall, the problem with the IDF technique it is also very hard to test it. You never really know how much pressure you are putting on the habitats, and conversely how little pressure you are applying and what room you then have to increase production (and reduce the duration of dredging).

It is notable (page 122) that once a threshold has been exceeded, '*…normal operations can only recommence once turbidity returns to below the Level 1 turbidity trigger…*'. The turbidity trigger is at the 95th turbidity percentile which is really quite a high value to restart on? Similarly, on page 114, it says '*…For this Maintenance DSDMP, adaptive management is premised on maintaining or returning within the "desired" state of the environment, which is defined as the water quality envelope below the Level 1 turbidity triggers, as specified in Section 8.1.1…*' The 'desired' level is the 95 percentile of turbidity which is very high?

What has been discussed in various WAMSI publications is the same approach of determining different percentiles over different running mean intervals from 1d to 42 d for light (see information box) with turbidity (NTUs) also using the baseline data. With such as analysis you can assess all 1-42 d running mean values collected during a maintenance program and understand at multiple time periods (acute and chronic) how close you are coming to exceeding levels that corals or seagrasses (phototrophs) have not been subjected to before.

The advantage of this technique is greater surety that you are remaining in physiological boundaries for a site, and this may even allow quicker or more intense dredging (see below).

10. 6.6.2 Sedimentation tolerance limits (page 101)

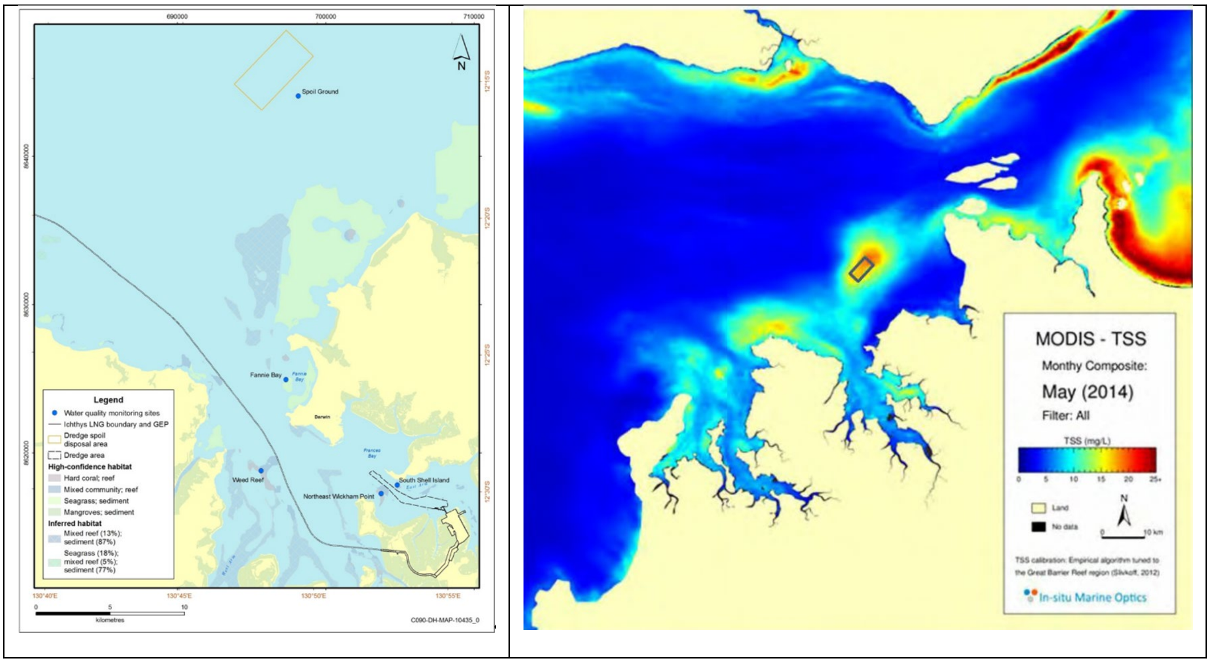
Note the revision of the seagrass sedimentation thresholds to 40 mm in the maintenance DSDMP are supported by laboratory-based experiments in the Western Australian Marine Science Institute (WAMSI) Dredging Science Node and should be references. See Statton et al. (2017).

11. 6.8 Habitat impact assessment outcomes page103

Firstly, wouldn't predictions to suggest that loss of some coral habitat (0.8 h) could occur during dry season be a reason for using an ecological window and dredging during the wet season?

Secondly, the upstream areas are outside the footprint and if the area upstream is identified as an area of concern, shouldn't there be a telemetering turbidity and light logger there?

There is one telemetered water quality monitoring site south of the spoil ground (maintenance DSDMP page 147 Figure 9.2, below left) and the site is informative within the maintenance DSDMP. This is a single site for a very large area and would it be covered better - in an informative sense - with MODIS imagery and analyses as shown on page 49 of Cardno (2014), below right). Would moving the telemetered monitoring site to the upstream area be more useful?



12. 8.1 Management of sediment-related effects

The maintenance DSDMP says '*…Further, Jones et al. (2019b) states the levels developed are not applicable for marginal reef sites such as turbid reef zones, therefor are not appropriate for Darwin Harbour. As such, the use of (site-specific) turbidity as the base metric for the derivation of adaptive management triggers, to protect coral and seagrass, is considered to be appropriate and sound….*'.

This is correct in what was said was the light-based thresholds for corals developed in the WAMSI Dredging Science Node '*…are empirically tied to the Barrow Island project, a clear water high diversity shallow water coral reef ecosystem, and the laboratory-based experiments in turn were based on the pressures characterized during the Barrow Island project. Although the approach of turbidity and light hazard profiling and using running means analyses during the dredging phase is suitable to equivalent environments, the absolute levels may not be applicable to more marginal reef sites such as turbid reef zones and also for much deeper reefs. Studies are currently underway for deriving thresholds for turbid water coral communities…*'.

Some thresholds have been since been derived experimentally (in aquaria) for turbid water corals (Luter et al., 2021) and these values tied back to *in situ* water quality (principally light reduction) in turbid reef environments – see Jones et al. (2020), Jones et al. (2021). However, the approach is very applicable to Darwin Harbour (see Conclusions).

Nevertheless, as noted above, the way forward a complete characterisation of the light availability and an understanding of relationships of underwater light to tides and spring-neap cycles, seasonal changes and zenith angle and cloud cover. This information could be collected during the maintenance dredging and provide information that could be used in future maintenance or capital dredging projects in Darwin Harbour.

13. 8.1 Management of sediment-related effects

The maintenance DSDMP says one of the objectives of adaptive management is to use turbidity data to inform changes to the dredging operations to:

'…decrease duration of the activity by increasing production in an environmentally responsible manner thereby minimising associated affects to environmental, social and cultural values.'.

As noted above, the IDF technique doesn't allow you to understand how much pressure you are putting on, i.e., how close you have come to causing a problem. The percentiles/running means analysis (see Information box and the end of Section 9) allows this to be achieved.

14. 8.1.2 Development of reactive management triggers

The maintenance DSDMP says '…*There were no recorded declines in coral and seagrass health attributed to dredging during the capital dredging program. As such ecologically relevant triggers, based on a conclusive link between dredging-induced changes in water quality and sensitive receptors within the Darwin region, could not be derived. As such, the established (conservative) method to setting management triggers based on turbidity adopted for the capital dredging program has been employed, as described below…*'.

However, the Nearshore Environmental Summary Report (page 56 of Cardno (2014)) reported '…*probable dredging-related health impacts were only observed at South Shell Island*, and Cardno (2015) noted that *'…with the exception of South Shell Island, which was predicted to be potentially impacted, the increases during the Dredging Phase were considered to be natural at all sites, with a potential dredge influence at South Shell Island recorded in the final Dredging survey D13* (June 2014)…'.

This is ambiguous and should be addressed in maintenance DSDMP.

Note that it would be possible to examine the light and turbidity levels (percentiles over different running mean intervals) at South Shell Island to identify conditions which could lead to effects (from light or turbidity). If you have these numbers they could be used in future modelling (and monitoring) in the harbour – the approach has been discussed in (Fisher R et al., 2019).

15. 9.4.2 Parameters (page 149) and 9.4.3 Quality control and assurance

The maintenance DSDMP says '…*The proposed water quality monitoring program for the protection of coral and seagrass focuses on near real-time measurements of turbidity. Photosynthetic active radiation (PAR), salinity, temperature and depth are secondary variables that will also be measured (<u>but not telemetered</u>) to provide context (e.g. influence of meteorological events on water quality)…*'.

Further below the paragraph it says '..*The quality and quantity of light received by sensitive receptors, measured in PAR, is a direct measure of potential impacts to coral and seagrass communities, as a result of altered water quality. This parameter is as an informative measure, which will be combined with turbidity data to determine whether changes in light climate are a consequence of dredging or spoil disposal activities or natural conditions*...'

Light quality can only be measured with multispectral or hyperspectral PAR sensors (Jones et al., 2021) and I don't think they have been selected. It is not possible for light data to provide context (attributability assessment) unless telemetered for near-time data transmission as with the turbidity.

This suggests PAR should be telemetered as well.

Where the DSDMP says '…a*s such, redundancy, in the form of an additional turbidity logger, will be maintained at each reactive site*…' Is this in terms of a second telemetered turbidity logger at the site or a second logger *in situ* but not telemetered? I agree that telemetering often fails whilst loggers are continuing to record and so the data can be recovered **-** but are there 2 separate telemetering systems per site to ensure data capture?

The maintenance DSDMP says '…*fixed instruments, where possible, should be positioned approximately one metre above the seabed as described in the NEMP (Cardno 2014a), so established methods of analysis and interpretative tools (e.g. empirical model) can be utilised. Further, as per the capital dredging program, the in situ water quality data loggers will be deployed adjacent to the sensitive receptor habitat rather than directly on them to prevent damage to the habitat during deployment and retrieval*….

(Note: The interpretive tool predicting NTU from the tidal movement is novel and has potential to identify periods of high sedimentation (i.e., 'overburdens', where NTU is higher than it should be for the given water column implying the chance of heavy sedimentation)). This was tried during the WAMSI Dredging Science but was not successful because there weren't enough turbidity events to train the model – see Stark et al. (2017).

Will the height of the loggers be still equivalent to the reef? Recording turbidity and light several metres deeper than the reef is not advisable.

The maintenance DSDMP says '…*where more than 24 hours of data loss occur… where possible a nearby monitoring site will be used as a surrogate until equipment repair/ replacement can occur*…

If there aren't 2 separate telemetered sensor packages per site, is there a commitment to rapidly deploy one? In one project I have seen conditions/expectations that a faulty logger (or telemetry unit) had to be replaced within 3 days (weather/safety permitting).

16. Conclusions

The Darwin Harbor Ichthys LNG capital dredging project was one of the first of several major dredging projects in Australia conducted at the same time as a $19 M research initiative, the WAMSI Dredging Science Node, started to provide research information to enhance capacity within Government and the private sector to predict and manage the environmental impacts of dredging. This is the first review of the maintenance dredging plan since the findings of the WAMSI Dredging Science Node became available.

One of the areas that has been developed in the Node and elsewhere is a move from turbidity-based to light-based thresholds for corals during the monitoring stages of maintenance projects (as has often occurred with seagrasses). Using light as the lead indicator to proactively manage maintenance dredging operations allows more direct and accurate assessment of the 'pressure' (light reduction) that is being put on habitats by dredging activities.

Irrespective of the lead indicator, what is clear is that the maintenance DSDMP is based on modelling and monitoring approaches developed and tested in the earlier capital dredging program. The approach worked in the capital dredging program Cardno (2014) (note Section 13 above). Although this does not allow an advancement in terms of deriving triggers for Darwin Harbour based on a conclusive link between dredging-induced changes in water quality and sensitive receptors, it does demonstrate the technique is conservative and therefore fit-for-purpose for a maintenance dredging program which is an order of magnitude smaller in terms of duration and volume than the capital program.

There are a number of proposed capital dredging campaigns in the Harbour and a clear need for future maintenance dredging including by the Northern Territory government to keep the main channel safe for shipping. It seems logical to use the maintenance dredging as an opportunity to learn more about the turbidity and light patterns in the Harbour with a view to (1) defining site specific light thresholds for monitoring in future projects, and (2) re examining turbidity profiles with a view to defining thresholds of effect for impact prediction at the EIS stage.

The driver (business case) here is by better knowing how much or little pressure you are applying you can determine whether you have room to increase production hence reduce the duration of dredging hence cost. This is possible using telemetered turbidity *and* light sensors (and surface PAR sensors) (Fisher et al., 2019) and can be done in conjunction with IDF technique.

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EXPERT REVIEW COMMENTS REGISTER

Reviewer	Ross Jones
Review Document Title	Maintenance Dredging and Spoil Disposal Management Plan (DSDMP)
Company Document No#	L060-AH-PLN-70003
Document Revision No# / Date	Revision A / 12 May 2022
Reviewer Technical Note Title	Review of the Maintenance Dredging and Spoil Disposal Management Plan (2023-2027) Document No.: L060-AH-PLN-70003

No.	**Context**	**Reviewer Comment/Recommendation**	**INPEX Response**	**Reviewer acceptance/additional comments**	**INPEX Response**	**Reviewer acceptance/ additional comments**
1	Turbidity as a proxy for light and sedimentation	Overall the transition from using turbidity- to light-based monitoring is quite advanced for seagrasses and heading that way with corals, and is a recent recommendation of the WAMSI Dredging Science Node and the National Environmental Science Program Tropical Water Quality (NESP TWQ) Hub funded research -see Jones et al. (2021); Jones et al. (2020); Luter et al. (2021). These are however very recent recommendations and although transitioning to using underwater light environment is desirable in Darwin Harbour at this stage there needs to be a complete characterisation of the light availability (see information box above) and an understanding of relationships of underwater light to tides and spring-neap cycles, seasonal changes and zenith angle and cloud cover. This information could be collected during the maintenance dredging and provide information that could be used in future maintenance or capital dredging projects in Darwin Harbour.	INPEX acknowledges these recent studies and that a transition from turbidity-based triggers to light-based triggers for monitoring during dredging is desirable. INPEX has also reviewed the WAMSI Dredging Science Node outcomes, scientific papers, dredging guidance from other Australian jurisdictions (e.g. Western Australia) as well as dredging management plans currently being implemented in other jurisdictions (i.e. Cleveland Bay in the Great Barrier Reef Marine Park). Based on this review it is clear the transition to light-based triggers is being and has been implemented in other jurisdictions. However, it is noted that the thresholds developed to support the use of these light-based currently being used in other jurisdictions are not appropriate for Darwin Harbour as the species are either not relevant to Darwin Harbour, and/or on review of light data collected during Ichthys LNG capital dredging program, light-based thresholds are typically greater than the background light levels measured in Darwin Harbour. As such, site specific characterisation of the light availability in Darwin Harbour is required so that meaningful light-based triggers can be established. This is a complex task requiring review of not only light data from the capital dredging program, but where possible, coral and seagrass data to inform the develop of meaningful light-based triggers. Once developed these would likely be appropriate for other dredging programs in Darwin Harbour, not just INPEX maintenance dredging. As such, given turbidity-based triggers were successfully used during capital dredging to prevent environmental impacts, and the current turbidity-based triggers have been developed form these capital dredging thresholds, INPEX proposes a staged approach to adopting light-based thresholds. INPEX proposes the current turbidity-based triggers are endorsed in the iterum while light-based triggers are developed, which once developed can be included and implemented in a revised Maintenance DSDMP. The complex nature of the task requires not only time (~18 months), but in INPEX's view, input from other stakeholders (e.g. other operators, regulators) to achieve the best outcomes for Darwin arbour. INPEX therefore proposes to have developed light-based triggers for integration into the Maintenance DSDMP by end of 2023.	Agreed/accepted: as shown by INPEX, Darwin Harbour is an extremely turbid environment and accordingly under water light levels are naturally very low. The truncation of bathymetric range of coral species to the upper few metres of the water column is testament to the significance of light for coral ecology. (Perhaps Darwin Harbour is the one of the most extreme examples world-wide of the ability of corals to tolerate turbidity and light reduction). Light thresholds have to be developed on a site-specific basis. Given the importance of light, the recommendation of moving to light-based thresholds and developing thresholds specific to the harbour and the time-frame suggested is acceptable.	-	-

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2	Reproductive cycle for corals	There has been a lot of very recent experimental work of the effects of sediments on the reproductive cycle of corals (Ricardo et al., 2016a; Ricardo et al., 2018; Ricardo et al., 2015; Ricardo et al., 2016b; Ricardo et al., 2017b), especially new information on how elevated SSCs may directly impact the fertilisation stage where eggs and sperm are in the water column or at the water surface. The maintenance DSDMP doesn't acknowledge these recent papers especially the interaction of dredge plumes with gametes (Ricardo et al., 2015), which is a much more sensitive stage than when the coral larvae are in the water column (i.e., the references to Gilmour (1999); Humphrey et al. (2008)). This should mean reconsidering the risk profile in the DSDMP (page 76) and re-evaluating the pertinency of a coral spawning CWES. The maintenance DSDMP says '…*Further, the potential additional "costs" (where Cost includes financial cost, time or duration, effort, occupational health and safety risks, or environmental impacts associated with implementing the control) of temporally restricting maintenance dredging (e.g. outside of spawning and settlement periods) would be grossly disproportionate to the risk. The risk from excess suspended sediment plumes on the reproductive cycle of corals is therefore considered ALARP...*'. I am not sure this is correct as costs will only occur if maintenance is scheduled to coincide with a coral spawning time and then becomes restricted. The management implications of the studies described above have been discussed in Jones et al. (2017b); Ricardo et al. (2017a). It is comparatively easy to accommodate a coral spawning CWES during maintenance dredging and start earlier or preferably later, as opposed to extended (several years) capital dredging activities when dredging may be temporarily stopped.	Sediment-related impacts on the reproductive cycle of corals has been updated in the maintenance DSDMP to include the recent papers referenced in your review. INPEX has also reconsidered its risk assessment of sediment-related impacts on the reproductive cycle of corals, based on this updated literature, and proposes to introduce a new control that will exclude the use of overflow three days prior to and for seven days post the potential coral spawning window in Darwin Harbour. Based on the information available this new control will be implemented four days after the first full moon in April. INPEX considers this a conservative approach given the limited coral reproductive data available for Darwin Harbour. Ceasing overflow will reduce the fines released within Darwin Harbour and subsequently SSCs that could potentially impact on coral reproduction.	Agreed/accepted:	-	-
3	Concurrent Harbour-wide dredging campaigns	The maintenance DSDMP acknowledges there is potential to be areas of modelled excess SSC overlap if the most intensive dredging for dredging campaigns are undertaken simultaneously. Nevertheless, the potential cumulative impacts are '…considered insignificant as they are not predicted to impact environmental values and sensitivities (e.g. marine ecosystems such as seagrass or coral)…'. The analyses behind these predictions (of insignificance) haven't been shown in the maintenance DSDMP. I am assuming that permission to commence maintenance dredging would be contingent upon closer scrutiny of other dredging activities (or 'turbidity generating activities') that could run concurrently. From a practical perspective I wonder if the information needed to do this i.e., volumes dredged, source terms, dredging equipment, durations, exact timing etc are, or will, be available to INPEX? The wider implications here is if management thresholds are close to being exceeded, or have been exceeded, there is no possibility to intervene on behalf of INPEX in accordance with the maintenance DSDMP if the issue is co-caused by a neighbouring project.	The assessment of cumulative impacts is relatively qualitative as the assessment is made on publicly available information presented in environmental impact assessments (EIAs) and referrals on the NT EPA website. INPEX also completed early stakeholder engagement requesting information from other Darwin Harbour stakeholders for cumulative impact assessment. Based on the information available and/or provided to INPEX, the timing of planned activities and impact assessment was considered in relation to INPEX's maintenance dredging scenario to determine potential cumulative impacts. This was primary done by assessing potential overlap of modelled excess SSC concentrations, and whether these occurred over known sensitive receptors (e.g. coral and seagrass). This is described in Section 5.4.2 of the Maintenance DSDMP. INPEX is aware of the wider implications of cumulative impacts and has previously worked with other operators in the Harbour in regard to the use of common monitoring sites and sharing of data for concurrent projects. There is also limited guidance in Darwin Harbour for thresholds for impact assessment and monitoring, and review of available EIAs and referrals	Agreed/accepted:	-	-

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		This is a complex area which INPEX would be aware of - and beyond the review scope - but suggests very coordinated efforts with neighbours and/or with regulators.	indicates most of the operators use different methods and thresholds. Regardless, during any maintenance dredging campaign INPEX will implement its planned water quality program and associated adaptive management triggers. If exceeded, INPEX will follow the adaptive management process outlined in Section 8.1 and implement responsive and contingency management actions if exceedances are found to be attributable to maintenance dredging, regardless of contribution (e.g. wholly or partially attributable). INPEX will also work closely with any other operators if concurrent dredging campaigns are being completed.			
4	Coral bleaching	As noted in the WAMSI Dredging Science Node, the probability of a marine heatwave (and subsequent coral bleaching event) occurring during the baseline and operational phases of extended capital dredging projects has reached a point where it is recommended that consideration be given as to how to manage the project in the dredge plans should one occur. Examples of how this can be done are described in Jones et al. (2019c) which could be referenced.	Patterns in coral bleaching observed in the Coral Monitoring Program during capital dredging indicate bleaching is likely to be an annual phenomenon in Darwin Harbour that can occur when water temperatures rise above 30°C. Water quality monitoring in Darwin Harbour has also shown that during the wet season water temperatures generally start to exceed 30°C in October and remain over 30°C until early May with extended periods above 31°C. During this period temperatures may also exceed 32°C. The most severe bleaching reported during the Coral Monitoring Program occurred following a prolonged period (i.e. more than two months) in which daily average water temperatures exceeded 31°C. In consideration of Bessell-Browne et al. (2017) INPEX proposes to introduce a new control ceasing overflow if the 21-day rolling daily average water temperature at all water quality sites adjacent to coral communities exceeds 31°C.	Agreed/accepted:	-	-
5	Sediment deposition maps	I do wonder with sedimentation prediction if this has ever been verified i.e., during the Capital program? was there ever an attempt to verify or confirm or measure in any way whether the predictions of sedimentation and the mm build-up of sediments correlate? If there hasn't been any attempt (model validation) then it is really questionable what the sedimentation maps mean – and even harder to turn them into risk by using ecological tolerance limits (see below). It says the tolerance limits in Table 6.3 for SSC were derived from site-specific water quality monitoring which is ideal - but the same wasn't done for sedimentation? i.e. what instruments would be used? Sediment traps do not measure sedimentation (Whinney et al., 2016; Whinney et al., 2017) and they are more apt to provide an index of turbidity of the overlying water column than sedimentation per se (Storlazzi et al., 2011)).	Modelling outputs were used to create sediment deposition figures. These figures underpinned the site selection process the mangrove and intertidal sediment monitoring programs during the capital dredging program, particularly where a sedimentation trigger was predicted for mangroves. Sediment heights were measured at mangroves sites, although the measured changes in sediment height did not reflect what was predicted (i.e. changes in sediment height were less than modelled). Sediment traps (1m 50mm PVC pipe with 100mm diameter mouth) were trialled during capital dredging program at coral and seagrass monitoring sites and used to calculate trap rates (cm^3/day, mg cm^2/day, PSD of trapped sediment) although there is no plan to use them in future programs as: • no clear relationships could be established between accumulation rates and turbidity recorded at the water quality sites • although there was considerable variability between sites, it generally appears that there was less sediment accumulated in traps deployed at the Darwin Harbour Outer sites than in traps deployed at the Darwin Harbour Inner sites. Significant differences exist between trap pairs at some locations as indicated by the Relative Standard Deviation (RSD). The high RSD values indicate considerable differences in the amount of material	Agreed/accepted: and in the WAMSI Dredging Science Node we too couldn't find sufficient evidence of a relationship between sediment trap accumulation rates and turbidity that could be used in an operational sense during dredging programs.	-	-

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			accumulated within the traps and results may not be reliable.			
6		The logic given in the maintenance DSDMP for retaining the sedimentation thresholds in the impact prediction (modelling), and the connection back to capital project is acceptable and reasonable, but the relationship between sedimentation (mg cm^2 day) and nett accumulation for individual corals and coral habitats is an area that needs to be researched and developed for all future dredging projects.	Noted, acceptable and reasonable use for impact predication. There is no intention to use sedimentation as lead indicator, as such INPEX does not believe this research is needed to inform the Maintenance DSDMP noting development of light-based triggers are proposed given they are considered to provide a better indication of dredging induced stress on sensitive receptors.	Agreed/accepted: –sedimentation should currently not be used as a lead indicator in dredging as the technology for reliable measurements is not yet ready.	-	-
7	Table 6 3: Tolerance limits for excess SSC and sedimentation (Page 100)	The Table 6.3 (page 100) is confusing because the tolerance limits did not have a time component. They were included in Table 8.5 on page 119 (perhaps Table 8.5 could be cross referenced in the Table 6.3 caption).	Table 6-3 is a conservative impact assessment approach and is the 95th percentile minus the median for a region of the Harbour to identify areas which may be impacted and influenced. This is done so the tolerance limits can be compared to modelling outputs which are excess SSC purely for an impact assessment perspective. While Table 8-5 considers sites specific data for intensity and duration, frequency was not considered given the proposed short duration of maintenance dredging. In consideration of your review, INPEX will include a frequency component to its turbidity-based triggers noting that as per Comment 1, light-based triggers are proposed to be developed over the next 18 months which would replace the turbidity-based triggers once developed.	Agreed/accepted	-	-
8		What has been discussed in various WAMSI publications is the same approach of determining different percentiles over different running mean intervals from 1d to 42 d for light (see information box) with turbidity (NTUs) also using the baseline data. With such an analysis you can assess all 1-42 d running mean values collected during a maintenance program and understand at multiple time periods (acute and chronic) how close you are coming to exceeding levels that corals or seagrasses (phototrophs) have not been subjected to before. The advantage of this technique is greater surety that you are remaining in physiological boundaries for a site, and this may even allow quicker or more intense dredging (see below).	See response to Comment 1	Agreed/accepted: see point 14	-	-
9	6.6.2 Sedimentation tolerance limits (page 101)	Supports seagrass sedimentation threshold of 40 mm.	Noted	Agreed/accepted: the WAMSI dredging Science Node tolerance limits for seagrasses sedimentation is in accordance with the sedimentation thresholds used.	-	-
10	6.8 Habitat impact assessment outcomes page103	Firstly, wouldn't predictions suggest that loss of some coral habitat (0.8 h) could occur during dry season be a reason for using an ecological window and dredging during the wet season?	The decision to maintenance dredge will be informed by a range of factors, primarily ensuring the safe navigation of the channel is maintained and operational access to Ichthys LNG jetties are not restricted, as such the ability to undertake maintenance dredge at any time is required. The majority of deposition to date has been measured in the jetty pockets; and given 3 to 4 product tankers visit every week the likely operational window for maintenance dredging is during a planned shutdown when there is a 4 to 5 week period of no offtakes/product tankers. Planned shutdowns occur in	Noted, and including point 11, below, avoiding potential bleaching periods (point 4) and coral spawning periods (point 2) and utilising planned shutdown periods is reasonable.	-	-

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			the dry season so restricting dredging to the wet season has not been considered. It is also noted that during the wet season natural phenomenon such marine heatwaves can naturally stress corals and avoiding these periods where possible has the potential to reduce or limit potential impacts to coral. Further, the coral spawning window for Darwin Harbour is predicted to occur in the wet season (April), as such avoidance of this period where possible is also preferrable.			
11		Secondly, the upstream areas are outside the footprint and if the area upstream is identified as an area of concern, shouldn't there be a telemetering turbidity and light logger there.	Monitoring of coral, seagrass and associated water quality parameters at sites with known habitat presence was completed during the capital dredging. The coral habitat upstream of the dredge area predicted to be impacted is modelled habitat and review of the raw data for these locations did not identify the presence of corals. As such, it is likely other attributes at these locations that infer the potential for corals to be present and thus identified as coral habitat rather than actual coral habitat. Therefore, monitoring at these locations upstream is not proposed. Monitoring sites used during the capital dredging program will again be utilised for maintenance dredging as site specific data exists as do other tools used to inform environmental monitoring (e.g. tidal empirical model).	See above	-	-
12		There is one telemetered water quality monitoring site south of the spoil ground (maintenance DSDMP page 147 Figure 9.2, below left) and the site is informative within the maintenance DSDMP. This is a single site for a very large area and would it be covered better - in an informative sense - with MODIS imagery and analyses as shown on page 49 of Cardno (2014), below right). Would moving the telemetered monitoring site to the upstream area be more useful?	During the capital dredging program there was limited MODIS imagery in wet season due to cloud cover. The composite MODIS imagery presented in Cardno (2014) is from May, which typically has clear skies as falls within the dry season. MODIS is still proposed to be used as an informative tool as part of the water quality monitoring program. Note the proposed water quality site near the spoil ground is an existing site from capital program. This site was used to monitor plume dispersion towards seagrass habitats at Lee Point, Casuarina etc..	Agreed/accepted	-	-
13	8.1 Management of sediment-related effects	Some thresholds have since been derived experimentally (in aquaria) for turbid water corals (Luter et al., 2021) and these values tied back to in situ water quality (principally light reduction) in turbid reef environments – see Jones et al. (2020), Jones et al. (2021). However, the approach is very applicable to Darwin Harbour (see Conclusions). Nevertheless, as noted above, the way forward a complete characterisation of the light availability and an understanding of relationships of underwater light to tides and spring-neap cycles, seasonal changes and zenith angle and cloud cover. This information could be collected during the maintenance dredging and provide information that could be used in future maintenance or capital dredging projects in Darwin Harbour .	See response to Comment 1	Agreed/accepted	-	-
14		The maintenance DSDMP says one of the objectives of adaptive management is to use turbidity data to inform changes to the dredging operations to: *'…decrease duration of the activity by increasing production in an environmentally responsible manner*	See response to Comment 1	This point about calculating percentiles/running means analysis is unrelated to the DSDMP, it was included to introduce a technique that could be used by INPEX to scientifically justify increasing production rates by knowing what	-	-

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		thereby minimising associated affects to environmental, social and cultural values.'. As noted above, the IDF technique doesn't allow you to understand how much pressure you are putting on, i.e., how close you have come to causing a problem. The percentiles/running means analysis (see Information box and the end of Section 9) allows this to be achieved.		the total pressure over multiple time frames that the dredging is putting on the ecosystems.		
15	8.1.2 Development of reactive management triggers	However, the Nearshore Environmental Summary Report (page 56 of Cardno (2014)) reported '…probable dredging-related health impacts were only observed at South Shell Island, and Cardno (2015) noted that '*…with the exception of South Shell Island, which was predicted to be potentially impacted, the increases during the Dredging Phase were considered to be natural at all sites, with a potential dredge influence at South Shell Island recorded in the final Dredging survey D13 (June 2014)…'.* This is ambiguous and should be addressed in maintenance DSDMP. Note that it would be possible to examine the light and turbidity levels (percentiles over different running mean intervals) at South Shell Island to identify conditions which could lead to effects (from light or turbidity). If you have these numbers they could be used in future modelling (and monitoring) in the harbour – the approach has been discussed in (Fisher R et al., 2019).	The statement *"There were no recorded declines in coral and seagrass health attributed to dredging during the capital dredging program"* refers to *coral* mortality of tagged corals monitored throughout the capital dredging program. In the final dredging coral health survey (June 2014) there was increased sediment cover on coral at South Shell Island, which is classified as mortality and what Cardno (2014) is referring to, as this report summarises results up to the end of dredging. There were four subsequent coral health surveys with results included in Cardno (2015). In this report it also states "*with a potential dredge influence at South Shell Island recorded in the final Dredging survey D13 (June 2014) …"* The influence refers to increased sediment cover, however the subsequent surveys indicated that was temporary and not actual coral mortality "*Rates of mortality at sites during the Dredging Phase were considered to be natural with the exception of South Shell Island between April 2014 (Dredging survey 11) and June 2014 (Dredging survey 13), which had a potential dredge influence and temporary increase in perceived mortality (sediment cover). As partial mortality decreased or remained unchanged in the subsequent surveys, this indicates the sediment cover was temporary and overlaying live coral tissue that was exposed in subsequent surveys*." (page iii, Cardno 2015). The statement *"There were no recorded declines in coral and seagrass health attributed to dredging during the capital dredging program"* is therefore appropriate.	Agreed/accepted: The response is satisfactory. I have seen this before in tagged coral monitoring programs in dredging projects in WA where corals temporarily covered in sediment had to be marked as 'mortality' and subsequently the sediment was resuspended and the tissue underneath was found to be alive.	-	-
16	9.4.2 Parameters (page 149) and 9.4.3 Quality control and assurance	Light quality can only be measured with multispectral or hyperspectral PAR sensors (Jones et al., 2021) and I don't think they have been selected. It is not possible for light data to provide context (attributability assessment) unless telemetered for near-time data transmission as with the turbidity. This suggests PAR should be telemetered as well.	Noted, will remove reference to quality and PAR will be telemetered.	Agreed/accepted	-	-
17		Where the DSDMP says '*…as such, redundancy, in the form of an additional turbidity logger, will be maintained at each reactive site…'* Is this in terms of a second telemetered turbidity logger at the site or a second logger in situ but not telemetered? I agree that telemetering often fails whilst loggers are continuing to record and so the data can be recovered - but are there 2 separate telemetering systems per site to ensure data capture?	Only one telemetered system per site, the redundancy refers to duplicate loggers.	See 20 below	-	-
18		(Note: The interpretive tool predicting NTU from the tidal movement is novel and has potential to identify periods of high sedimentation (i.e., 'overburdens', where NTU is higher than it should be for the given	Noted. However, for Darwin Harbour the empirical model developed during capital dredging was used with great success. This is largely due to macro-tidal environment being the primary driver of turbidity. This	Agreed/accepted	-	-

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		water column implying the chance of heavy sedimentation)). This was tried during the WAMSI Dredging Science but was not successful because there weren't enough turbidity events to train the model – see Stark et al. (2017).	model was used to associate dredging attributable increases in turbidity at sites as well as predict natural exceedances of water quality triggers. The model is site specific and the reason why the same monitoring locations from capital dredging are proposed for maintenance dredging.			
19		Will the height of the loggers be still equivalent to the reef? Recording turbidity and light several metres deeper than the reef is not advisable.	Agree, that measuring turbidity and light at different depth to the reef is not advisable. However, it is not possible to install loggers at coral sites due to uneven ground that prevent frame deployment and stability, and the increase likelihood of habitat damage from logger installation. During the capital dredging program PAR data was normalised to -3 m LAT using a light extinction coefficient to allow inter-site comparison and reflect the depth of coral and seagrass communities. It is proposed that the same analysis will be completed for the maintenance dredging program.	Agreed/accepted	-	-
20		The maintenance DSDMP says '*…where more than 24 hours of data loss occur… where possible a nearby monitoring site will be used as a surrogate until equipment repair/ replacement can occur…* If there aren't 2 separate telemetered sensor packages per site, is there a commitment to rapidly deploy one? In one project I have seen conditions/expectations that a faulty logger (or telemetry unit) had to be replaced within 3 days (weather/safety permitting).	As described in Section 9.3 no sensitive receptor monitoring sites are predicted to be impacted by excess SSC or sedimentation. Regardless reactive sites have been included for the purpose of adaptive management and verify modelling results. These locations were also monitoring during the capital dredging program that was an order of magnitude bigger in duration and intensity with no recorded declines in coral and seagrass health attributable to dredging. Given these sites are not predicted to be impacted and declines in health were not reported for the capital dredging program, INPEX has not committed to a time-based service frequency dependent on telemetered data availability as it is not warranted based on risk to the environment. For information, during capital dredging duplicate telemetry systems were used at reactive sites.	I do not agree with or understand the logic here as adaptive management of water quality can't occur without a near real-time data stream to base a decision upon. If instruments fail there is a commitment in the DSDMP for equipment repair/replacement (as written opposite) which doesn't seem to apply? If there is only 1 telemetering systems (with duplicate loggers) as opposed to during the Capital dredging when there were 2 complete telemetering systems (for redundancy), then there has to be a commitment for rapidly fixing the telemetering should it fail. In reality it means a complete telemetered system sitting on the shore ready to deploy within a few days. I agree the maintenance dredging is considerably smaller (volume and duration) than the capital dredging and the risk is accordingly less, but nevertheless the whole DSDMP is centred around telemetered data being available for management.	At reactive sites (i.e. sites that have triggers that if exceeded, and are attributable to dredging, initiate data review and/or responsive and contingency management practice/s) INPEX proposes to include a commitment that once a malfunction or instrument loss/damage is identified affecting the parameter with an associated trigger, equipment will be repaired or replaced within five (5) business days.	Agreed/accepted
21	Conclusions	One of the areas that has been developed in the Node and elsewhere is a move from turbidity-based to light-based thresholds for corals during the monitoring stages of maintenance projects (as has often occurred with seagrasses). Using light as the lead indicator to proactively manage maintenance dredging operations allows more direct and accurate assessment of the 'pressure' (light reduction) that is being put on habitats by dredging activities. Irrespective of the lead indicator, what is clear is that the maintenance DSDMP is based on modelling and monitoring approaches developed and tested in the earlier capital dredging program. The approach worked in the capital dredging program Cardno (2014) (note Section 13 above). Although this does not allow an advancement in terms of deriving triggers for Darwin Harbour based on a conclusive link between dredging-induced changes in water quality and sensitive receptors, it does demonstrate the technique is conservative and therefore fit-for-purpose for a	See response to Comment 1	Agreed/accepted	-	-

No.	Context	Reviewer Comment/Recommendation	INPEX Response	Reviewer acceptance/additional comments	INPEX Response	Reviewer acceptance/ additional comments
		maintenance dredging program which is an order of magnitude smaller in terms of duration and volume than the capital program.				
22		It seems logical to use the maintenance dredging as an opportunity to learn more about the turbidity and light patterns in the Harbour with a view to (1) defining site specific light thresholds for monitoring in future projects, and (2) re examining turbidity profiles with a view to defining thresholds of effect for impact prediction at the EIS stage	(1) See response to Comment 1 (2) This was done and what is used in Table 6-3 tolerance limits for excess SSC impact prediction. Data collected during any future maintenance dredging campaigns will be used to update future thresholds.	Agreed/accepted	-	-

Review of Dredging and Spoil Disposal Management Plan for Maintenance Dredging 2023 - 2027 in Darwin

Introduction

INPEX Operations Australia Pty Ltd has requested Pro Dredging and Marine Consultants to review the proposed draft for the Maintenance Dredging and Spoil Disposal Management Plan (DSDMP) 2023 – 2027 for future maintenance dredging in Darwin Harbour. The maintenance dredging is required to maintain the navigation depths in the access channel, the swinging basin and the berth pockets for the onshore LNG processing plant at Bladin Point at design depths.

Johan Pronk, Principal of Pro Dredging has been a member as the dredging expert of the independent IPDEP Panel, which provided amongst other tasks, advice to INPEX and stakeholders with regards to the execution of the capital dredging program between 2012 and 2014. Amongst other tasks, this engagement involved regular reviews of and providing comments for the various versions of the East Arm DSDMP which was prepared by INPEX for the capital dredging program.

INPEX has requested Pro Dredging in particular to review the appropriateness of the dredging methods and the management actions proposed in the Maintenance DSDMP, reference chapters 3 and 8 of the draft DSDMP.

1. General comments

The proposed draft Maintenance DSDMP 2023 – 2027 has been prepared by INPEX on the basis of the East Arm DSDMP which was approved for the capital dredging program and is a revised version of the DSDMP for the maintenance period 2017 - 2022. The Maintenance DSDMP provides an extensive description of methodology, environmental risk assessment, management actions to protect the environment, modelling and monitoring of water quality. It provides, in a thorough manner and in specific details, the implications of all aspects of the execution of a maintenance dredging program, which is in excess of what has been prepared for other maintenance dredging campaigns around the Australian Coast.

2. Technical comments

The Pro Dredging comments in this section focus in particular on the proposed methodology for maintenance dredging and the management actions in respect of the environmental management of the maintenance dredging campaign.

2.1 Dredging Methodology

Chapter 3 of the draft Maintenance DSDMP states that the content of PIANC Report 100 has been taken into account for the method of equipment selection for the maintenance dredging. The rationale has been explained in the DSDMP and Pro Dredging agrees with the recommendation in section 3.3.1 of the DSDMP that the **trailing suction hopper dredger** (TSHD) is the appropriate equipment and the best practice to carry out the maintenance dredging, as it is adequate for the removal of un-consolidated materials and sand and its operation is flexible with regards to the shipping operations within Darwin Harbour.

Chapter 4.1.5 provides a detailed description of the **sediments** to be dredged. Generally, the sediments have been described as sand and silts. Sampling campaigns during 2016, 2019, 2020 and 2021 have provided more information about the characteristics of the sediments to be dredged. In particular the materials accredited in the jetty pockets contain a high fines content (more than 75%).

The various sampling campaigns has also showed that the sediments deposited within the dredging are uncontaminated and do not require any special treatment.

Chapter 3.2.2 describes that the remaining capacity for **disposal** of dredged materials in the Dredge Spoil Disposal Area (DSDA) is 7 million m3. In view of the large quantity of materials already disposed from the capital dredging program, Pro Dredging recommends that a preferred area for disposal of maintenance dredging is allocated within the existing DSDA following on from a pre-dredge hydrographic survey. This will assist in managing available capacity for future dredging campaigns.

Chapter 3.3.2 discusses the duration of **overflowing** depending on actual conditions. Based on the experience during the capital works program, the maximum overflowing time has been set at 60 minutes. Pro Dredging considers this to be a prudent approach for sand which has been migrated in the turning basin. In the berth pockets however, the silt content is very high and it is recommended that overflowing in these particular materials is to be avoided.

The draft DSDMP prescribes that the **green valve** is to be used in the overflow funnel(s) of the TSHD as a best management practice in order to reduce the turbidity of the maintenance dredging.

In view of the long sailing distance (approximately 45 km) to the DSDA to the north of Darwin Harbour, which is located around 12 km northwest of Lee Point, it is indeed recommended that a **large TSHD** is used for the maintenance dredging.

In chapter 3.4 the Maintenance DSMP describes the utilisation of a **Bed Leveler** on an as needs basis. The bed leveler can provide as a best management practice a very effective solution in particular circumstances when storage capacity is available in nearby areas.

Pro Dredging agrees that **tickler chains or turtle deflectors** will need to be used on the dredging pipes of the TSHD in order to provide for the best possible protection for the marine turtles and avoid the entrapment of the animals.

Furthermore, a number of common practices for both dredging and disposal of materials are discussed and explained in chapter 3, which are all well described and do not require further comment.

2.2 Management of maintenance dredging program

Chapter 8 of the Maintenance DSDMP describes the various environmental management frameworks for the management of both sediment-related effects and dredging related impacts.

The adaptive management process of potential **sediment related effects** is described in chapter 8.1 by way of reviewing water quality monitoring data and identifying trends in turbidity to allow forecasting towards potential exceedance of turbidity triggers (level 1 and 2). The process of responsive management, including a listing of responsive management practices, is described thoroughly and in detail in the draft Maintenance DSDMP, using the experience of the capital works program. In addition, attention has been paid to the implementation of contingency options and the management of the available practices. This adaptive management process has proven to be an effective tool during the capital dredging program in 2012 - 2014 and Pro Dredging has no further comments on this process.

The management of **other dredging related aspects** other than those related to sediment are discussed in chapter 8.2. These include the management of the introduction of marine pests, the protection of marine megafauna, heritage and sacred sites, and furthermore the avoidance of mismanagement in the discharge of wastes, hydrocarbons and chemicals. These subjects are common within the dredging industry and are applicable to all dredging projects In Australia. The required management actions, including the risk assessment, have been described in detail, following again the East Arm DSDMP for the capital dredging program, and Pro Dredging confirms that it has no further comments.

3. Conclusion

Pro Dredging concludes that INPEX has prepared a comprehensive and thorough environmental management plan for the execution of the maintenance dredging.

In addition to the first DSDMP of 2017 additional data have been included from further surveys, investigations and sampling exercises, providing even more detailed information for the maintenance dredging to be carried out.

Pro Dredging considers this to be an appropriate document for the proposed methods and environmental management of the maintenance dredging campaign. Pro Dredging is also satisfied that all reasonable and practical measures have been taken by INPEX to manage the risks associated with the proposed maintenance dredging and disposal activities.

Pro Dredging and Marine Consultants

20 June 2022

EXPERT REVIEW COMMENTS REGISTER

Reviewer	Johan Pronk
Review Document Title	Maintenance Dredging and Spoil Disposal Management Plan (DSDMP)
Company Document No#	L060-AH-PLN-70003
Document Revision No# / Date	Revision A / 12 May 2022
Reviewer Technical Note Title	Review of Dredging and Spoil Disposal Management Plan for Maintenance Dredging 2023 - 2027 in Darwin

No.	Context	Reviewer Comment/Recommendation	INPEX Response	Reviewer acceptance/additional comments
1	Dredging methodology	Pro Dredging recommends that a preferred area for disposal of maintenance dredging is allocated within the existing DSDA following on from a pre-dredge hydrographic survey. This will assist in managing available capacity for future dredging campaigns.	When a maintenance dredging campaign is planned, INPEX will work with the successful Contractor to identify preferred area of disposal post pre-dredge hydrographic survey of DSDA.	INPEX comment accepted. This is indeed appropriate time to identify preferred area of disposal within DSDA.
2		In view of the long sailing distance (approximately 45 km) to the DSDA to the north of Darwin Harbour, which is located around 12 km northwest of Lee Point, it is indeed recommended that a large TSHD is used for the maintenance dredging.	Noted. Selection of a TSHD with sufficient hopper capacity will be a key consideration of any planned maintenance dredging campaign. A TSHD with large capacity hopper will likely reduce the number of trips required to DSDA and associated fuel consumption and emissions over the campaign. Modelling is also based on a medium to large TSHD. INPEX also notes that although a large TSHD is recommended, a smaller TSHD may be utilised if there is a TSHD of opportunity or if dredging is planned around operations (e.g. product tanker offtakes) which may be harder for a larger TSHD.	INPEX comment accepted. Please note that the category of large trailers are trailer dredgers with a hopper capacity of 8,000 to 16,000 m3. In view of distance to DSDA and economics Pro Dredging recommends not to go any smaller. TSHD's which carry out annual maintenance dredging on the Coast of NW Australia have generally been within this category in the past.