Stantec

Memo

Project:	Department of Infrastructure, Planning and Logistics – Mandorah Marine Facilities	**Project No:**	304700560
To:	Suzanne Dunkerton	**Date:**	22/06/2023
From:	Amber Evans		

RE: Response to NT EPA direction to provide additional information to the SER

Table 1. Additional information to be provided in accordance with Regulation 124. Black font represents Stantec's responses to the EPA's Direction to Provide Additional Information on the 16 May 2023; green font represents Stantec's responses and/or clarifications to the EPA's questions following a meeting between Stantec, DIPL and EPA on 8 June 2023.

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1	**Extent of the proposed action** There is no succinct summary of the extent of proposed actions to be delivered in Stage 2, including construction of a fishing platform and extension of the access road and car parking established over Stage 1.	1. Provide a table summarising the maximum extent of each proposal element to be delivered in Stage 1 and Stage 2, and the total maximum extent of the whole proposed action. 2. Provide spatial files for proposed Stage 2 works in an appropriate format (such as, kml, kmz, shp)	The infrastructure footprint provided with the SER shows the extent of all developments proposed under this referral. This shapefile is contained in data folder: 20230224_mandorah_data_delivery provided to the EPA for inclusion with the SER. It was determined during the concept design phase that a fishing platform and additional car parking would not be included in this project and flagged that a second stage of the project is planned and may include: a) A fishing platform built on the breakwater including a pedestrian walkway from the land (to replace the existing Mandorah Jetty at the end of it's structural life); b) Extension of the access road to reach the pedestrian walkway and additional car parking, including car parking for ferry passengers and bays for the disabled; and c) The addition of a second lane to upgrade to a dual lane boat ramp, which may meet the roll on-roll off needs into the future. There is no exact extent for this and it would be completed under a separate referral. An approximate extent is provided in the attached concept site plan (Attachment 3).
2	**Modelling assessments** It is noted that the proponent has developed a suite of 2D models (Delft 3D and LITPACK) for impact assessment that predict changes to coastal processes (i.e., currents, waves, water levels) and associated coastal environment (i.e., sediment load transport and loads, sediments deposition and erosion). Uncertainty about the adequacy of the modelling approach remains, in particular, assumptions used, its parameterisation, calibration and results presented. Uncertainties in model design A number of inadequacies have been identified with the models parameterisation and assumptions used. It is not clear whether predictive models incorporate the combined effects of waves and currents (dry and wet season conditions) and climate change; the bathymetry change that may result from dredging and disposal actions; and representative grainsizes of sediments to be dredged or likely to be transported along the shoreline. Longshore sediment transport modelling (LITPACK) and plume modelling (Delft 3D) also present an uncertainty regarding modelling domain and simulation time. It is not clear whether these models have been run for sufficient time and extent, and are able to predict the full extent of environmental impacts (sediments erosion and deposition) in the vicinity of proposed work areas, such as potential damage to sacred sites located to the south (Restricted Work Area 2) and the north (250-300 m) of proposed work areas, and the fate of deposited and eroded sediments on the shoreline. The observed discrepancy between proposed on-ground activities and	To improve confidence in models outputs and impact predictions, and to assess the significance of potential impacts on the environment, provide additional information on the following aspects: 1. Provide details and sources of the baseline data that have been used in development and calibration of the models. Confirm that the timing of baseline data collection corresponds to the time of year that construction and maintenance works are proposed to occur. 2. Provide key inputs for all models in a table format, with the sources of input values including any data synthesis undertaken (as relevant). To address identified gaps in the models' design, describe and demonstrate how the following have been considered in the development of models and the prediction of impacts: • the model domain that should cover a wider potential impact area. Ensure that a finer grid is applied to the potential impact area and the model domain is the same for all modelling assessments. Display baseline conditions and predicted impacts for the impact area at an appropriate scale and a high resolution. • the combined effects of waves and tidal currents, cyclones, and sea level rise as a result of climate change. Ensure that the hydrodynamic model accounts for both dry and wet season conditions as this is critical for understanding inter-seasonal variations in sediment sources, transport rates and pathways. • the change in the sea floor profile created by dredging and dredge spoil disposal activities, and bedload transport that may affect waves and tide strength and sediment transport volumes.	1. For physical process modelling see Section 3 and 4 of the Metocean Report (Appendix K of SER). For Sediment transport modelling see Section 2 and 3 of the Sediment Transport Report (Appendix L of SER). It should be noted (as described in section 4 of the Sediment Transport report, that the '*hydrodynamic model applied should be reviewed to understand the conditions underpinning sediment transport…"* Also refer to additional field profiling/water sampling detailed in SER. Construction and maintenance timing is not yet confirmed, but datasets cover all seasons, and the modelling associated with environmental risk assessment considers all timing and/or worst-case scenarios (spring, neap, wet, dry etc.). It is not standard practice to include construction activities in modelling of long term movement of sediment / shoreline evolution. The construction activities and their impacts are more appropriately modelled using plume modelling. 2. Key model inputs are extensive. Therefore, two technical reports detailing these have been prepared (Appendices K & L), describing the inputs and how they've been incorporated. It is not clear what are considered the key inputs to be tabulated, however all of the water level, wave, current, climate, water quality and sediment property data used are explained in the Metocean and Sediment Transport reports, including how these data were used to calibrate and validate the model, a. Impact areas or areas of project interest do not extend beyond any of the model domains selected and applied for the various modelling applications. Model domains are the same for various scenarios (e.g. various dredge dispersion scenarios) but differ for different modelling applications as is standard practice. For example, its not appropriate to use the same model domain for dispersion modelling as for cyclone modelling, as the computation/run-time would be excessive and most of the area

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	modelling run times augments this concern, e.g. for backhoe operation requiring excavation of about 70,000 m3 at a rate of about 121.5 m3/hour over 8 working hours every day, the simulation time modelled should be at least 36 days under a scenario run consecutively for neap-spring tidal cycles. Moreover, the draft Dredging and Spoil Disposal Management Plan suggests that the estimated time to remove rock material may be approximately 2-3 months which is inconsistent with the modelling run times. Cumulative impact assessment of project The SER presents independent assessment of natural conditions of suspended sediments, long-shore sediment transport along the eastern coastline of Cox Peninsula and plume modelling from dredging, rock wall construction, piling and dredge spoil disposal activities that appear to be modelled in isolation but not cumulatively considering all risk pathways and sources that may affect sediments suspension and deposition. For example, longshore sediment transport does not consider suspended sediment dispersion caused by maintenance dredging and vice-versa. The proponent should consider undertaking an integrated modelling approach to predict the overall proposal effects with greater confidence. Most importantly, maritime infrastructure including various dredging and construction activities spanned to occur over 4-5 months, must be modelled consecutively and cumulatively. Model performance In light of the above issues, as specified in the NT EPA Direction to provide addition information in the SER, there is still uncertainty whether the modelling represents post development environmental conditions with sufficient confidence and are fit for predicting environmental impacts. A robust qualitative and quantitative assessment (such as Root-mean-square Error) of modelling predictions is missing from all predictive models. Of all predictive models, only the hydrodynamic model appears to be calibrated. The calibration and performance of this model appear to be primarily assessed based on the visual assessment of observed data and modelled predictions but not statistical evidence (such as Root-mean-square Error) to demonstrate that the model is predicting waves, tides and currents accurately and is fit for use in advanced assessments, i.e. sediment transport and plume modelling. Further, the lack of sensitivity analysis of models adds to the uncertainty around the predictions of currents and waves strength or direction, sediment transport volumes and dredge plume dispersion. Conclusion Overall, large uncertainties exist for sediment transport models. There is a high likelihood that these models are currently under-predicting the volume and composition of sediment deposition and suspended loads. Refer to submission on the SER from AAPA and DEPWS.	• the simulation time that would reasonably provide the full extent and magnitude of potential impacts (e.g. 50 years for longshore drift; 130 or more days for dredge plume dispersion) and define the time to reach equilibrium conditions (e.g., 2 weeks, 1 month, 5 years etc.). Revise the simulation time used in longshore sediment transport and plume dispersion modelling. • curved or non-linear areas along the coastline. For shoreline evolution assessment, consider using a number of shoreline locations and transects across the Mandorah beach, especially in the areas where there is a noticeable change in shoreline orientation. • grainsizes and settling rates of the sediments (both coarse and fine fractions) to be dredged and transported (post-development) across the Mandorah beach. Ensure that additional sediment samples are collected and analysed from the beach area to the north of the Mandorah facility, and model several representative grain sizes (rather than one D50 value) in sediment transport assessments. • the cumulative effects of coinciding marine processes that affect sediment deposition and suspension, e.g. suspended sediment transport from intertidal and dredged area, re-suspension and deposition of seabed and beach sediments etc. Ensure that the combined effects of all dredging and construction operations from where sediment plumes can occur, are also assessed, i.e. run a continuous simulation for the whole dredging campaign in a sequential manner as an additional scenario. If applicable, describe and include additional dredging method (e.g. blasting) that would be used to excavate high strength rock (possibly present) from the dredging footprint.	would not be of interest. Hydrodynamic model grids are described in Section 6.1.1 and become finer towards the area of interest, as is standard practice. b. All these effects/drivers have been considered where appropriate (including in combination) and detailed in the Metocean Report. The request suggests that the hydrodynamic model considers dry and wet season, but flows are known to be dominated by tidal forces, which aren't seasonal. It then talks about inter-seasonal variations in sediment sources, transport rates and pathways – these relate to sediment transport modelling rather than hydrodynamics. If the comment is suggesting that wet and dry season be considered in sediment transport modelling, this has already been achieved by separately assessing environmental risk for the two seasons. c. Physical processes modelling has been undertaken for both pre- and post-construction cases, as detailed in the Metocean Report. Post-construction layout/bathymetry is obviously not applied when modelling construction effects. The proposed disposal method is a dispersion technique that is not expected to significantly alter seabed bathymetry. d. The simulation times applied are appropriate to properly assess environmental risk associated with the project. Although the model run-time for marine construction activities is shorter than what may actually occur (130 or more days as suggested), all activities and full dredge and disposal volumes have been modelled. Therefore, this is a conservative approach in terms of environmental risk assessment i.e., more intense plume and sedimentation generation than reality, impact activities modelled in tandem that will probably not occur in tandem in reality. The shorter model timeframe is still well beyond the duration thresholds of sensitive receptors, so this element of environmental risk is not considered to be compromised. Although the design life of the facility is 50 years, it is not appropriate to model shoreline evolution over the full duration of the facilities life, for the following reasons: The considerable uncertainty in shoreline evolution modelling across such a long timeframe, compounded by the lack of a 50 year actual dataset to drive the model; and the fact that the project commits to monitoring and management (as required) at least every 5 years via the CMMP that was requested to be prepared to support the SER. The model has used a 10-year period of actual available data with associated shoreline change data to allow validation. The changes with respect to baseline across the 10-year period could be multiplied by 5 to assess 50 years (this is effectively what modelling would do) but intervention (bypassing) is expected to occur more regularly than this anyhow to prevent the environmental risk (e.g. facility induced erosion of sacred sites). Equilibrium conditions: - Not reached for plume dispersion due to constantly changing hydrodynamics (tides) so the conservative (highest concentrations/thresholds) modelling results for environmental risk assessment are extracted. - Reached ('dynamic equilibrium') rapidly for nearshore morphological changes (though these are minor) as described in Section 5.5 of the Sediment Transport Report. Putting a timeframe on these would be overstating the accuracy/reliability of such modelling but within the 1 month model timeframes. - Not expected to be reached for shoreline evolution as this is an ongoing process that will require bypassing to manage. e. Two primary shoreline orientation/sections are considered to exist within the extent of influence of the new facility on shoreline change. These have been accounted for by modelling two shoreline transects, as demonstrated in Section 7.4 of the Sediment Transport Report (Figure 7-6). Trying to account for changes in shoreline at a finer scale than this would likely confound the modelling application, not improving the estimates and possibly reducing accuracy. It is widely acknowledged in the industry that shoreline evolution modelling over long time periods is difficult/inaccurate, due the number and complexity of physical processes that cause it. This has been demonstrated by shoreline monitoring after installation of multiple structures throughout the world. The best available model systems/approaches have been applied but this shortfall has been acknowledged in the reporting and accounted for by preparing the CMMP to actively monitor and manage shoreline changes.

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			f. Sediment samples were collected from the littoral zone to the north of the proposed harbour, as mapped in Figure 3-1 of the Sediment Transport Report. Several samples were taken from the beach and littoral zone directly to the south of the proposed facility as this is the closest proximity of sediment availability to the project site (see same Figure). The reason sediment was not collected directly to the north of the project site is that there is no sediment there. It is rocky cliff and an intertidal zone. Note that in a longshore drift area it would only be important to test sediment north and south once the facility is in place. Beforehand, it is about assessing the most relevant sediment/shoreline, whether north or south, which is what has been done. The reason only two samples were collected well to the north is that the material will be less relevant to the sediment transport processes at the project site, due to distance and different exposure to coastal processes. A range of grain sizes have been observed and incorporated in the modelling. An average D50 is used in shoreline evolution modelling, which is a typical approach that assesses more gradual sediment transport of coarser fractions in the littoral zone, driven mainly by wave action. The finer fractions mentioned in the comments are more mobile and can be transported by tidal currents, which is represented by the Delft morphological modelling. One key purpose of applying the two modelling systems is the different processes, time scales and types of sediment transported. The application of the two model systems is a relatively comprehensive approach, given that the project commits to ongoing monitoring and management of its influence on sediment transport also. g. We assume this comment relates to natural sediment transport processes. The modelling assessment of construction impacts is limited to the construction related impacts (plume dispersion and sedimentation). I.e., all outputs are with respect to background conditions, not the total TSS or deposition given the challenges of predicting the actual TSS conditions at the time of construction (hence the need for baseline and construction monitoring). Background processes and conditions can be variable as described by the comment. The place to incorporate background conditions is when looking at project effects and assessing environmental risk. E.g. background conditions in the wet season usually lower environmental risk from sediment plumes as the severity of the added turbidity is relatively less. This appropriate environmental risk assessment has been carried out in the SER. No blasting will take place on the project so this has not been incorporated. Section 8.2 of the Sediment Transport Report discusses the comprehensive range of scenarios modelled that allow for full, proper marine environmental risk assessment associated with these activities. I.e., what the comment suggests should be run as an 'additional scenario' has already been run.
		3. Describe the calibration process including the suitability of baseline data and the sensitivity of the models' input values. Provide the outcomes of qualitative and quantitative assessment (e.g. RMSE) used in the calibration and sensitivity analysis of models. Ensure that the baseline data used for the models' development and the data used for the models' calibration are independent. Justify why the deviation of modelled predictions from observed measurements is acceptable.	3. This is described in Section 6.1.3 of the Metocean Report. Hydrodynamic modelling is validated against eight collected data sets throughout Darwin Harbour, including three at the project site. Wave modelling is validated against eight collected data sets throughout Darwin Harbour, including two at the project site. As described by the model setup input data and validation datasets are independent. RMSE statistics are provided in Attachment 2.
		4. Describe how the models' design is consistent with the requirements of the WAMSI Dredge Science Node Guideline on dredge plume modelling for environmental impact assessment.	4. Our studies have followed the process recommended in these guidelines, exactly as summarised in the foreword on page 7. Some key points about these guidelines: - The second paragraph of Section 1.4 states that the guidelines have been developed to focus on modelling practices for EIA of large capital dredging projects and acknowledges that there are projects that may not need fully detailed and extensive modelling, such as small capital dredging projects. For reference, the guidelines are based primarily on data collected, modelling applied, and learnings from Chevron's Wheatstone Capital Dredging Program in Western Australia, which was 26 million m^3. For further reference, the INPEX Nearshore Dredging Program in Darwin Harbour (which incurred no identified impacts to key environmental receptors) involved 16.1 million m^3 of material. These are the sort of large capital dredging programs for which these guidelines have been developed. This small capital dredging project (Mandorah) has, nevertheless, carried out plume dispersion

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			and sedimentation modelling at a similar scale and complexity to that of those projects. For example, neither of those projects modelled the full dredging program in the EIA stage (or at all) but rather portions of it that were perceived to carry higher environmental risk. The primary outcomes of modelling for those projects was ensuring monitoring and reactive management of the dredging actions once occurring. - The first sentence next to the foreword on page 7 describes the inherent uncertainties in sediment transport modelling associated with dredging. This was acknowledged very early on and discussed in (pro-active, pre-referral) meetings between DIPL/Cardno and DEPWS, where DEPWS emphasised that monitoring of the activities was the most important risk management measure for this project. Despite this, each review calls for more complexity of modelling, much of which is not technically feasible, that is very unlikely to be improving understanding of environmental risk because of the known limitations of such modelling.
		5. Report on the time duration, magnitude and full extent of modelled predictive impacts, e.g. impacts on sacred sites, marine water quality and benthic communities.	5. The duration, magnitude and full extent of modelled impacts, e.g. impacts on sacred sites, marine water quality and benthic communities, are described throughout the SER and its appendices. The duration of modelling is detailed in Table 8.2 of the SER, while the magnitude and extent of impacts are described in the technical chapters 8.1, 8.2 and 8.3.
		6. If necessary, review and update the Draft Dredging and Spoil Disposal Management Plan (DSDMP) and Draft Construction Environmental Management Plan (DCEMP) to reflect any changes arising from points 1-5 above. Ensure that survey and mitigation actions are planned appropriately at the rate of predicted impacts.	6. Based on our review, we don't believe changes are necessary at this point in time. It is highly likely the DSDMP will be refined once the dredging contract has been awarded. Modifications will be needed to ensure the management strategies are aligned with the final approach to dredging and dredge spoil disposal.
		7. Explain the extent to which the hydrodynamic, wave and sediment transport models were integrated for modelling the potential impacts of the dredging and spoil disposal activities. Did the calibration period include any storms?	7. The models were dynamically coupled for the purposes of simulating hydrodynamic processes and their effect on sediment movement, suspension and settlement. Modelling included the combined effects of hydrodynamics, waves, wind, and pressure for cyclones. This is described in Section 4 of the Sediment Transport Report. The calibration period included at least one severe storm event (see Figure 7-4 and 7-5 of the Metocean Report).
		8. To produce the RMSE values, what measured values were used against the modelled values? Were the measured values the same as used for calibration purposes?	8. The wave and hydrodynamic models applied to this project were based on previously calibrated models prepared for the Fort Hill Wharf Extension project (Cardno, 2019). For this project, the Fort Hill Warf model was refined via the addition of two new hydrodynamic grids and two new wave grids in the vicinity of Mandorah. The refined model was then validated using metocean data measured near Mandorah. Statistical performance metrics, including model skill, bias, RMSE, scatter index and correlation coefficients have been provided for the Mandorah site. The measured data was used to validate model performance and calibrate model. The outcomes of the calibration / validation process are discussed in Section 7 of the Metocean Report and show that the models successfully replicated water levels, currents and wave conditions.
		9. Does the coastal model account for sea level rise? And were the models subject to any sensitivity testing?	9. The models account for sea level rise effects (SLR) (and other climate change variables) but only with regard to the facilities design. Potential impacts to coastal processes were assessed against baseline conditions only. The effect of the facility following the onset of significant SLR was beyond the scope of the project. Sensitivity testing was undertaken during the plume dispersion modelling tasks. This included variations to the fines content, fraction of sediment released to water column, grain size, and dry density of dredged material, and the sequence/ aggregation of construction tasks.

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		10. What sediment size was used in the long shore modelling?	10. Sediment sizing for longshore sediment transport modelling was based on surficial sediment samples collected in the littoral zone. An average D50 (diameter 50^{th} percentile) of 1.2 mm was applied in the modelling.
		11. What is the estimated duration required to complete the proposed action, including dredging operation and the construction of maritime infrastructure (approx. or a range)	11. Please refer to Table 8.2 in Appendix L of the SER.
		12. Please indicate the maximum depth of the dredged area	12. 6.8 m AHD (at entrance to the channel)
		13. Considering the post-development conditions, the projected extent (dimensions) of the impact area that would undergo changes in terms of (a) tidal currents, (b) wave currents, (c) sediment deposition, and (d) sediment erosion	13. a) The Figures show the changes to the local currents over the wet season. Currents are predominantly tidally driven, hence not influenced by seasonality. The changes are confined to a 160,000 m^2 / 0.16 km^2 area, extending approximately 400 m north of the northern breakwater, 100 m south of the southern breakwater and 250 m offshore. b) Changes to wave fields pre- and post-construction are predominantly confined to the harbour footprint. Modelled typical wave conditions from the north-east to north-west lead to a changed wave field up to 60 m south of the proposed footprint and 10 m beyond the entrance of the proposed harbour. Typical wave conditions modelled from the south east lead to changes to the wave field up to 115 m to the north of the proposed footprint. Including the project footprint area, for the full range of potential wave conditions, modelling indicates that existing wave conditions will be altered for a 350 m alongshore stretch, and up to a maximum of 165m offshore of the shoreline (MHWS) (corresponding to the alignment of the harbour entrance). The total area of expected and potentially altered wave conditions is modelled to be 30,650 m2 / 0.03 km2. c) & d) Noting the limitations and assumptions associated with longshore sediment transport outlined in the report. Changes to shoreline accretion and erosion were modelled to extend up to 375 m to the south of the proposed facility (predominantly shoreline erosion) and up to 300 m to the north of the proposed facility (predominantly accretion). The total alongshore extent of modelled changes to shoreline sedimentation, including the footprint of the facility itself, was 950 m. The maximum cross-shore extent of erosion (translation of shoreline position) modelled to the south of the facility was 13 m for the ten year model period, with respect to the baseline shoreline modelled. The maximum cross-shore extent of accretion (translation of shoreline position) modelled to the north of the facility was 30m (up against the norther breakwater) for the ten year model period, with respect to the baseline shoreline modelled. This accretion distance was approximately 10 m at a distance of 50m north of the northern breakwater. These values assume no management intervention (monitoring and bypassing), which it must be noted has been proposed by the project.
		14. For each of the eight modelling scenarios conducted during the plume dispersion assessment, please define (a) the maximum predicted Total Suspended Solids (TSS) level, (b) the extent (dimensions) of turbidity plumes, and (c) the expected time for the projected TSS levels to return to original baseline levels	14. Of the eight modelling scenarios, the cutter suction and backhoe dredging phases (scenarios 1, 2, 5 and 6) are expected to mobile the highest volume of sediments, and therefore the highest in-water TSS concentrations and plumes of maximum dimension. For this reason, the SER focussed on these scenarios only. The modelling outcomes for these scenarios are presented in Figures 8.25, 8.26, 8.27 and 8.28 of the SER. As a rough estimate, we anticipate that a return to baseline would be reached in less than 3 days, due to the strong tidal currents in the harbour
		15. Describe the uncertainty in the model and how the uncertainty will be managed during the projects' construction.	
		16. The maximum thickness of sediment deposition predicted in the zones of high impact	

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		17. An indication of the particle size range considered ‘coarse’ for the purposes of the sediment dispersion modelling, and a justification for excluding coarse sediments from the plume dispersion assessment	15. As described above, the models were calibrated and validated using an extensive set of locally relevant data. Models are useful for comparing the predicted impacts of developments in the marine environment, under a range of construction scenarios (including engineering and the timing and duration of the construction phase). All models incorporate inherent uncertainty due to the stochastic nature of the calibration data, together with the unique and site-specific biology of receptors (i.e. corals). Standard practice in EIA is to manage the risks associated with model uncertainty through the development of a robust Dredge Spoil Disposal and Management Plant (DSDMP). The DSDMP provides a ‘safety net’ during the dredging program by assessing the real time concentrations of TSS and levels of light in the water column, relative to reference sites. The DSDMP developed for the Mandorah project includes a suite of conservative water quality triggers that if exceeded, will result in modifications to the dredging program where necessary to reduce the pressure on the environment and preserve the local environmental values.
		18. Confirm whether the dredge spoil disposal site is considered to be an area classified as a zone of moderate impact or high impact.	16. The Zone of High Impact (ZoHI) is the area where impacts on benthic communities or habitats are predicted to be irreversible. The thresholds utilised were based on coral which suffers irreversible damage at a lower level of sedimentation that the other communities found within the area. The maximum sediment thickness within the ZoHI is 1m within the project footprint and 50cm outside the footprint. However, note that the sedimentation thickness was generated as a worst case and cumulative overlay of all 4 activities (cutter suction, backhoe, Rockwall placement and maintenance). The estimate is therefore highly conservative.
		19. Additionally, there appears to be a noticeable disparity between the information presented in the SER and the subsequent information received on 7 June 2023 and then on 14 June 2023, especially with regard to trigger criteria and TSS zones. We recommend that the information across these documents is reviewed for consistency and that the final version of the additional information is updated to include corrected text, tables and figures where relevant.	17. Coarse particles were classified according to AS 1289.3.6.1-2009 as sands and gravels (D50 > 0.06 mm). Coarse sediments will be piped to the disposal site during the cutter-suction dredging phase. During the parametrisation of the model, the dry bed density was increased to account for the mixture of fines and coarser material in the dredge footprint. However, the settling velocity and grain size were not lowered to avoid under predicting TSS levels, in case higher levels of fines were encountered than predicted by bore samples. Modelling proceeded assuming 100% surface dispersal of the particles, with no physical or chemical clumping. Maintaining the physical qualities of the dredge spoil during the piping and disposal phase will be the responsibility of the dredging contractor. Adhering to this requirement is a key selection criterion and one of the main assumptions underpinning the draft DSDMP. Deviation from the assumptions will require modification of the DSDMP, prior to finalisation of the document and ultimate approval that is (a) based on the intended dredging approach and spoil disposal method and (b) ensures the disposal method does not compromise the NT EPA’s environmental objectives.
			18. Based on the modelling, the dredge spoil is predicted to disperse at the surface of the water column. There were no instances under which sedimentation at the disposal site resulted in moderate or high level impacts (Attachment 5); however given the biases in the model toward dispersion, the resulting TSS levels in the water column resulted in a small ZoHI impact at the disposal site (<0.087 ha) under dry season conditions (Figure 5-1, DSDMP). Under wet season conditions,

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			the ZoHI and ZoMI retracted, leaving just a large ZoI (i.e. there were no instances in which TSS concentrations exceeded the thresholds for the ZoMI and the ZoHI at the disposal site 19. As discussed under query 2 in Item 3 (see below), Table 8.3 of the SER erroneously refer to the PX of the 14-day moving average, due to a cut and paste error. The correct values, and the values used to derive the ZoI, ZoMI and ZoHI are based on the PX of the 7-day moving average (correct values are presented in Figures 8.25-8.28). The error did not affect the outcomes of the modelling. This omission explains the variance between the wet season threshold range and the TSS range. The correct Table values are included in Attachment 6 (below).
3	**Management Actions: Triggers and thresholds** Relationship between environmental variables As specified in the NT EPA Direction, the proponent has developed an algorithm for converting local turbidity (NTU) values to TSS concentrations, and depth averaged TSS concentrations to PAR using the water quality data from 15 sites collected over a 12-hour period (October 2022). Due to its importance in deriving triggers for management actions, an explanation of how these relationships were established is critical. It is also unclear whether collected data used in the assessment is representative of the conditions dominating the proposal area. Triggers and thresholds A revised suite of trigger criteria and thresholds also lacks a robust discussion on how these were derived and developed. It is not clear how triggers relate to thresholds, and the time duration and frequency of disturbance. Besides corals, these do not appear to consider impacts on other sensitive receptors (natural and dredge induced), such as mangroves, macroalgae and seagrass. This raises an uncertainty about whether established triggers and thresholds are the most conservative and suitable to be used for management actions. Zones of impact and influence The SER lacks an explanation of how the TSS zones of impact and influence were calculated and how they relate to zone thresholds. There appears to be disagreement between zone thresholds and TSS ranges of impact zones, e.g. wet season threshold range (20.61-55.39 mg/L) for moderate impact area is lower than the given TSS range for the respective zone (23.32-80.80 mg/L). This raises a concern about how thresholds would likely be met if predicted TSS concentrations are higher. The current boundaries of the impact area appear to be solely based on the sedimentation thresholds for corals. Like thresholds and triggers, the delineation of the impact area should consider other environmental variables, i.e., TSS and light availability at the seafloor. Conclusion Given the importance of the triggers and thresholds to implementing management responses, it is critical that this section is well documented and reasoned. Refer to submission on the SER from DEPWS.	1. a. Describe the methodology for established relationships between environmental variables and explain its application to management actions (triggers and thresholds). b. Discuss the suitability of monitoring sites including any data quality control undertaken to remove outliers (see DEPWS comment). c. Provide a locality map for monitoring sites overlying the predicted plume extent with this assessment, based on updated modelling. d. Ensure that PAR attenuation is also expressed as a percentage of sea surface light intensity. 2. Provide detailed analysis of data and the methodology for setting triggers and thresholds that should include discussion on:	1. a. **Method for establishing the relationship**: Data were correlated based on simultaneous measurements of TSS, NTU and PAR at a total of 25 sites (15 sites within the modelled dredge plume extent and 10 sites within the disposal site plume extent) over a 12 hr period, capturing high and low water conditions at the end of the dry season (see Appendix J and Table 8.3 of the SER). The data are considered fit for purpose for deriving an appropriate relationship. Both correlations yielded r^2 values >0.9 (Appendix J). **Application to management actions (triggers and thresholds)**: see responses under query 2a-d). b. Based on our review of the DEPWS responses, we assume the query is related to (i) the collection of the TSS, NTU and PAR data during the baseline phase or (ii) the proposed construction monitoring program. Regarding (i), data were collected from a total of 25 sites spread over an approximate 1.2-1.5 km^2 area, to the west of the proposed Mandorah facility: 15 sites within the modelled backhoe and cutter suction dredge plume footprint and 10 within the modelled disposal site plume footprint (see Attachment 1). The baseline data were collected over a 12 hr period, capturing high and low water conditions at the end of the dry season. The temporal and particularly the spatial extent of the sampling program was considered adequate for the purposes of establishing this relationship. Data were screened by an experienced coastal engineer prior to analysis. We don't believe the two points in A2 (Appendix J) as identified in the review represent outliers, especially given the observed variability in the system. Regarding (ii), the proposed construction monitoring sites were located based on the outputs of the modelling. Specifically, sites were placed based on the likely (P^{50}) and near worst case (P^{95}) extents of the TSS plumes during the backhoe and cutter suction dredging stages. c. Figures 5.1 and 5.2 in the Draft Dredging and Spoil Disposal Management Plan (Appendix B of the SER) depict the locations of the monitoring sites. As described above, the sites were positioned based on the modelled extent and concentration of the TSS plumes, as illustrated in Figures 8.17 and 8.18 of the SER. d. PAR is expressed as Daily Light Interval (DLI), which is the total PAR received by benthic communities over a single day (i.e. mol photons per m^2 per day). DLI is commonly encountered as the unit of measure when assessing impacts to corals, seagrasses and some sponges (WA EPA 2021) and is suitable for application at Mandorah. Expressing PAR attenuation as a percentage of surface light intensity is considered superfluous in this context. 2. See detailed responses below: a. **Thresholds** refer to the P^{99} and P^{80} statistics used to establish the zones of high and moderate impact, respectively. Thresholds were developed specifically for the EIA. The P^{80} and P^{99} values were developed using ~2.5 years of baseline TSS /

Item #	Context	Additional Information Required	Response
		a. The difference between the triggers and the thresholds; the frequency, duration, TSS/NTU, sediment deposition, light intensity at seafloor and species mortality; b. appropriate triggers and thresholds for managing potential impacts; c. association between triggers and thresholds; d. time duration linkage between disturbance and triggers/thresholds.	NTU data collected at Mandorah during the Inpex program. The Zones of Impact were determined by selecting the cells in the model where the P^{50} values during dredging exceeded the long-term baseline P^{80} and P^{99} values, as per Table 8.3. Note however that the values in Table 8.3 of the SER erroneously refer to the P^{X} of the 14-day moving average, due to a cut and paste error. The correct values, and the values used to derive the ZoI, ZoMI and ZoHI are based on the P^{X} of the 7-day moving average (correct values are presented in Figures 8.25-8.28). The error did not affect the outcomes of the modeling. This omission explains the variance between the wet season threshold range and the TSS range. The triggers are deliberately highly conservative i.e. well below the levels at which impacts are expected to occur based on the extensive research undertaken in offshore and relatively clearer waters under the WAMSI dredging node. Corals in waters adjacent to Mandorah are expected to be more resilient given the naturally turbid conditions experienced at the site. **Justification (how conservative are the thresholds?)**: Relative to sponges and seagrasses, corals exhibit heightened sensitivity to turbidity and sedimentation; hence, development of thresholds in this context was considered conservative. Fisher et al. (2019) determined the average NTU values at which probable adverse effects first manifested were greater than the P^{99} of the baseline data (as per Table 8-4 of the SER). The Zones of High (ZoHI) and Moderate Impact (ZoMI) were consequently established for the wet and dry season based on the P^{99} and P^{80} of the 7-day moving average for the respective seasons. The P^{80} was applied at the boundaries of the ZoMI / ZoI following ANZG (2018). Under ANZG (2018), an exceedance of the P^{80} represents an ‘environmental perturbation’ and a ‘cause’ for further investigation. The thresholds applied at the boundaries of ZoMI /ZoHI were equivalent to the P^{99} of the baseline data. Exceedance of the P^{99} may represent conditions severe enough to cause a change in the health to corals, and possibly mortality (based on the extensive research of Fisher et al (2019)). **Triggers**: The triggers presented in the DSDMP are unrelated to the Thresholds described in the SER. Triggers were established for the purposes of the operational monitoring under the DSDMP. Triggers were developed using the percentile approach advocated under ANZG (2018) and following Fisher et al (2018). Several triggers have been developed, from early warning to primary to secondary triggers. The triggers differ in magnitude (P^{80} – P^{95}) and the duration over which they are calculated (7 or 14 days). The triggers are also dynamic in that they are based on a comparison of median values at the impact sites, against the P^{80} and P^{95} at the reference sites over the course of the dredging period. **Species mortality**: see comments above under ‘justification (how conservative are the thresholds’. b. **Appropriateness of the triggers**: As described above, the triggers and thresholds are highly conservative. The approach is commensurate with the guidance in WAMSI and WA EPA (2021) which recommends the use of conservative triggers and thresholds in the absence of robust local data on coral biology and their tolerances. c. **Association**: Trigger and thresholds both draw on the work of Fisher et al. (2018) and the guidance provided in ANZG (2018). The thresholds are equivalent to the P^{80} and P^{99}s of the 7-day moving averages, derived from 2.5 years of baseline data. The P^{80} and P^{99} values are fixed values. The triggers for application during the dredging program are dynamic and will change depending on the background conditions at the time. The extent to which the triggers have or have not been met during the dredging campaign will be assessed by comparing the P^{50} value at the impact sites against the P^{80} and P^{95} values at the reference sites. d. **Choice of 7-day statistics**: 7-day statistics were applied given 14 and 28 day statistics counter-intuitively yielded higher (i.e. less conservative) thresholds. The higher 14 and 28 day values were an artifact of the multi-modal data distribution. Extending the time period captured more spring tide events than neap tide events; thus capturing greater number of elevated readings. Subsequent sensitivity testing using a range of thresholds within ~1 SD of the averages revealed no material changes in the predicted zones of impact, with each scenario resulted in small zones of high and moderate impact, irrespective of the values used.
		3. The discussion must cover all established triggers and thresholds for specific benthic communities including corals, seagrass, macro algae and filter feeders, confirmed during field survey. Interim triggers and thresholds for these benthic	3. The thresholds published in WAMSI are unsuitable for application at Mandorah. Area specific thresholds were developed using background water quality data in accordance with EPA (2016b) and following the Fisher et al. (2019).

Item #	Context	Additional Information Required	Response
		communities can be established with consideration of the WAMSI Dredge Science Node research reports at https://wamsi.org.au/research/programs/dredging/ until sufficient site-specific monitoring data is available.	
		4. Considering the combined effects of sediment deposition, TSS values and light availability on benthic biota, delineate the boundaries of zones of impact and influence. Describe the potential impact area for the combined various dredging and construction activities (see item 2).	4. In Section 8.3.3 of the SER the following figures are available based on the updated modelling and the revised thresholds these show it for the various dredging and construction activities including: • Figure 8.25: Predicted zones of impact during the cutter suction phase, based on dry season conditions. • Figure 8.6: Predicted zones of impact during the cutter suction phase, based on wet season conditions. • Figure 8.27: Predicted zones of impact during the back hoe phase, based on dry season conditions. • Figure 8.28: Predicted zones of impact during the back hoe phase, based on wet season conditions. • Figure 8.29: Predicted zone of impact due to sedimentation from the combined cutter suction and back hoe dredging phases. • Predicted zones of impact figures were not provided for the modeled break wall construction or maintenance dredging as there were no zones of impact outside the construction footprint. However raw outputs for all modelling are available for your reference in the **Sediment Transport Report - Appendix D.**
		5. Review and update the DSDMP to reflect any necessary changes arising from points 1-3 above. Ensure that survey and mitigation actions are planned appropriately at the rate of predicted impacts.	5. Based on our review, we don't believe changes are necessary. The DSDMP details the approaches to survey and mitigation actions, which are already considered fit for purpose.

Attachment 1 Baseline TSS, Turbidity and PAR monitoring sites (see black markers)


TSS Locations
Write a description for your map.
Legend
Untitled Placemark
Google Earth
Image © 2023 Airbus
Image © 2023 TerraMetrics
Image © 2023 Maxar Technologies
N
700 m

Attachment 2 Statistical Performance Metrics

The accuracy of the model is described by a range of quantitative validation metrics, specifically:

- Model Skill;
- Bias;
- RMS Error;
- Scatter Index; and
- Correlation.

These error statistics were applied to assess the calibration performance of the wave model system – generally the non-cyclonic model. The statistical error parameters and their equations are detailed below.

Model Skill

The model skill at simulating the measured conditions is given below. This produces 0 in cases of no agreement and 1 for perfect agreement between the modelled and measured data (Willmott et al, 1985).

$$ModelSkill = 1 - \frac{\sum_{i=1}^{N}[M_i - O_i]^2}{\sum_{i=1}^{N}([M_i - \bar{O}_i] + [O_i - \bar{O}_i])^2}$$

Where:

O_i observed, or measured data (m for waves)
M_i modelled data (m for waves)
$\bar{O}_i$ mean of observed data (m for waves)

Bias

The bias is a measure of the difference between the expected value and the true value of a parameter, and is calculated using the equation below. An unbiased model has a zero bias. Otherwise, the model is said to be positively or negatively biased, an indication as to whether the model is persistently over or under-predicting the physical conditions, respectively.

$$Bias = \frac{1}{N}\sum_{i=1}^{N}(M_i - O_i)$$

RMS Error

The RMS error is also a measure of the difference between the expected value and the true value of a parameter – see below. It provides a measure of the magnitude of the difference between the modelled and measured values.

$$RMS = \sqrt{\frac{1}{N}\sum_{i=1}^{N}[M_i - O_i]^2}$$

Scatter index

The scatter index is the RMS error normalised by the mean of the observations – see below. It provides an indication of the scatter of the data about the mean.

$$SI = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}([M_i - \bar{M}] - [O_i - \bar{O}])^2}}{\bar{O}}$$

Where:

$\bar{M}_i$ mean of modelled data (m for waves)

Correlation

The correlation is usually reported as the R^2 value. It is a measure of the strength of the linear relationship between two variables. Values of R^2 can be between 0 and 1, where 0 indicates no linear relationship, 1 indicates a perfect linear relationship and values greater than 0.5 indicate a strong linear relationship. The strength of the correlations between the modelled and measured water levels, current speeds and current deviations at Mandorah are depicted as R_2 values in Table 1. The correlations for wave height, peak wave period and peak wave direction are depicted as R^2 value in Table 2. Highlighted values represent R^2 value above 0.5.

$$R^2 = \frac{\sum_{i=1}^{N}[M_i - \bar{M}][O_i - \bar{O}]}{\sqrt{\sum_{i=1}^{N}[M_i - \bar{M}]^2 \sum_{i=1}^{N}[O_i - \bar{O}]^2}}$$

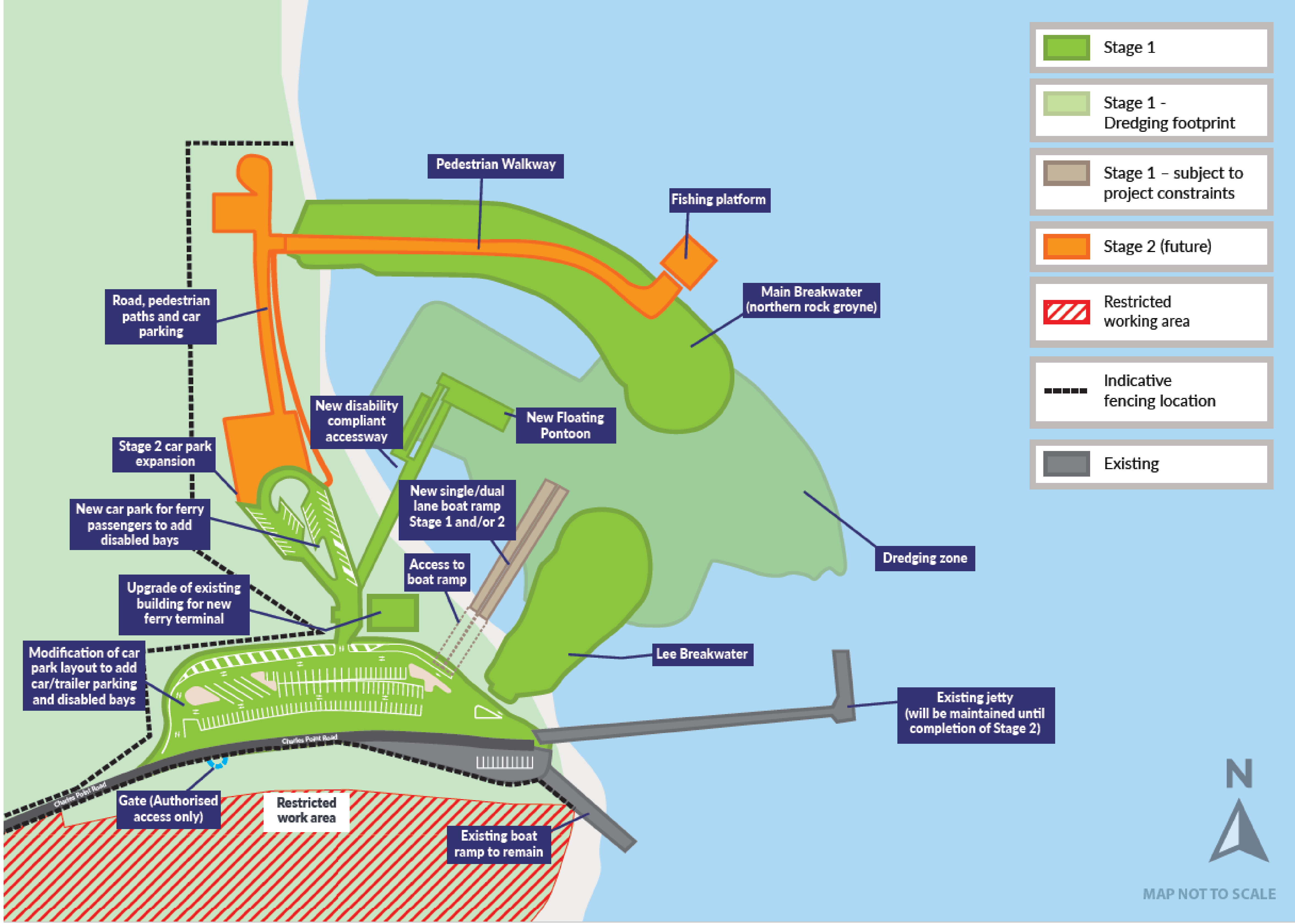
Table 1 Delft 3D Flow Model Performance Metrics for water Level, Current Speed, and Current Direction and at Mandorah

Parameter	Model Skill	Bias (measured-model)	RMSE	Scatter Index	Correlation Coefficient (R^2)
Water Level	0.998	0.057	0.136	0.033	**0.995**
Current Speed	0.870	0.053	0.163	0.680	**0.604**
Current Direction	0.637	-7.125	157.500	0.669	0.116
Current Speed U	0.758	0.018	0.056	0.014	0.474
Current Speed V	0.852	0.083	0.211	0.050	**0.576**

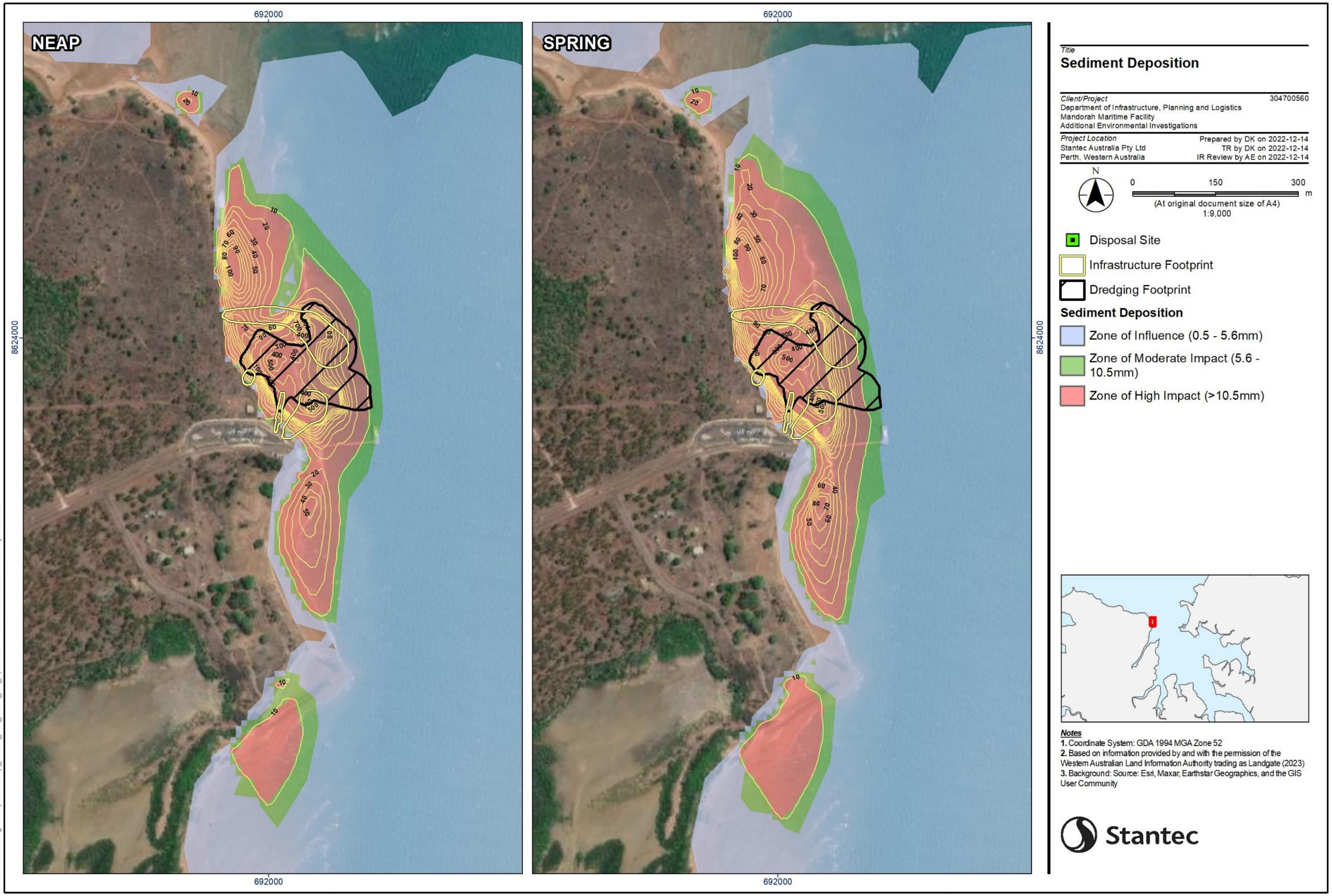
Table 2 Delft 3D Wave Model Performance Metrics for significant wave height, peak wave period, and peak wave direction at Mandorah

Parameter	Model Skill	Bias (measured-model)	RMSE	Scatter Index	Correlation Coefficient (R^2)
Significant Wave Height	0.388	0.124	0.432	7.782	0.051
Peak Wave Period	0.311	-0.036	4.762	1.322	0.004
Peak Wave Direction	0.452	52.316	156.425	1.720	0.018
Significant Wave Height U	0.685	0.011	0.1552	1.738	0.217
Significant Wave Height V	0.393	0.080	0.379	-13.059	0.094

Attachment 3 Proposed Site Plan



Attachment 4: Sedimentation Thickness



U:\300003584\gis\mapdocs\tmp_mand_ma_2022_02_dps.mxd Revised: 2023-06-20 By: fewalker

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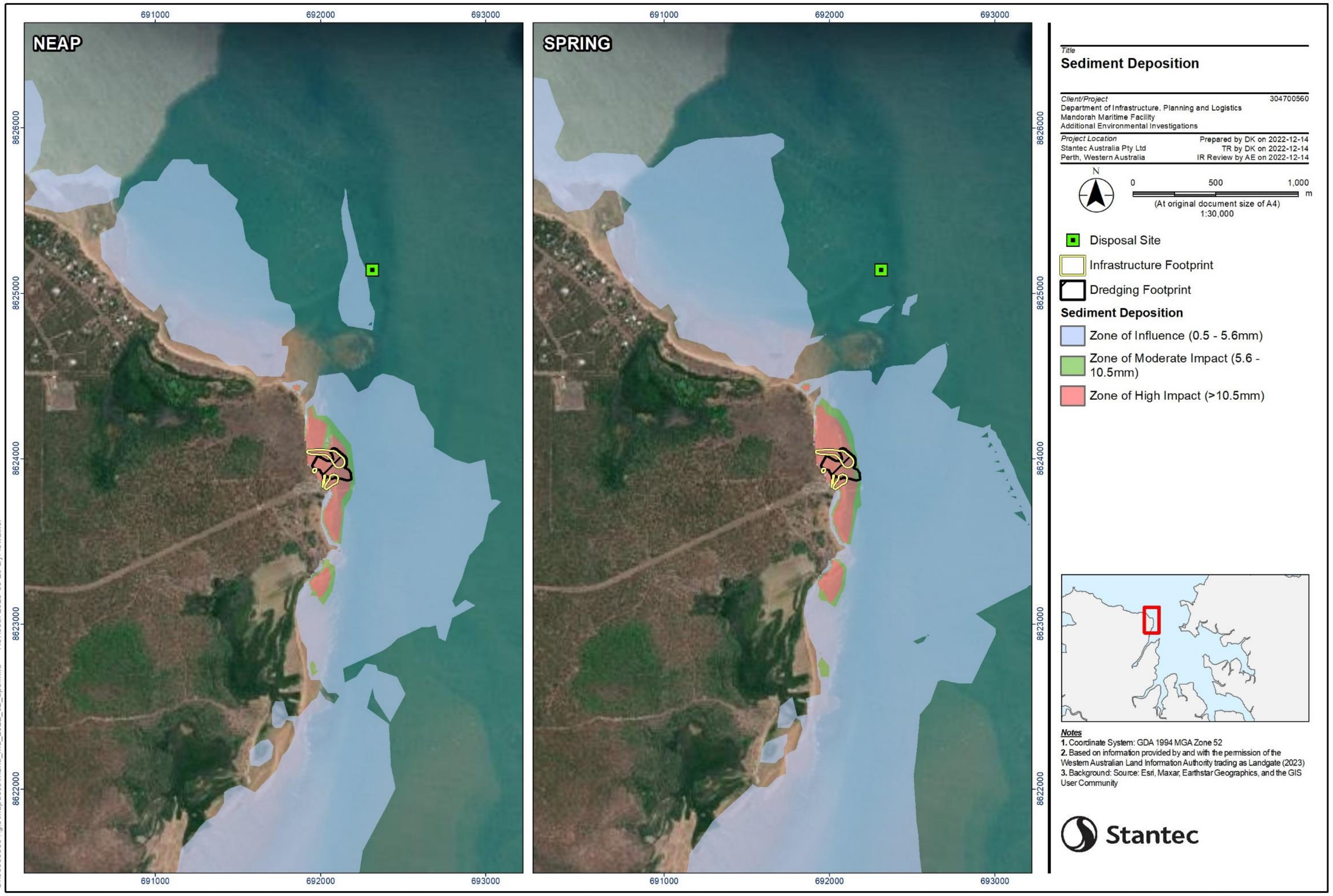
Attachment 5: Sedimentation Deposition Showing Disposal Site



Attachment 6: Corrected Table Values

*Table **Error! No text of specified style in document.**-1: Dry Season Thresholds for application to the Proposal Area.*

	NTU	TSS (mg/L)[d]	SD ($mg/cm^{-2}/ d^{-1}$)
ZOI	2.50[a]	>4.55[a]	>0.5mm
ZOMI	7.69[b]	13.98[b] -22.28[c]	>16[e] (5.6mm/14 days)[f]
ZOHI	12.26[c]	>22.28[c]	>30[e] (10.5 mm/14 days)[f]

(a) Based on the 20th percentile 7 day moving average TSS; (b) Based on the 80th percentile 7 day moving average TSS; (c) Based on the 99th percentile 7 day moving average TSS; (d) Local area NTU / TSS relationship used to derive TSS Values (TSS = NTU x 1.8167); (e) based on Pineda et al. (2017); (f) Converted $mg/cm^{-2}/ d^{-1}$ to mmm based on a 14 day period (DHI, 2010).

*Table **Error! No text of specified style in document.**-2: Wet Season Thresholds for application to the Proposal Area.*

	NTU	TSS (mg/L)[d]	SD ($mg/cm^{-2}/ d^{-1}$)
ZOI	3.62[a]	>6.58[a]	>0.5mm
ZOMI	12.83[b]	23.32[b] -80.80[c]	>16[e] (5.6mm/14 days)[f]
ZOHI	44.48[c]	>80.80[c]	>30[e] (10.5 mm/14 days)[f]

(a) Based on the 20th percentile 7 day moving average TSS; (b) Based on the 80th percentile 7 day moving average TSS; (c) Based on the 99th percentile 7 day moving average TSS; (d) Local area NTU / TSS relationship used to derive TSS Values (TSS = NTU x 1.8167); (e) based on Pineda et al. (2017); (f) Converted $mg/cm^{-2}/ d^{-1}$ to mm, based on a 14 day period (DHI, 2010).

Attachment 7: modelled zones of impact and influence during neap and spring tidal conditions (50th and 95th percentiles) as presented in Figures 4-3, 4-4, 4-5, 4-6 and 4-7 of Dredge Spoil and Disposal Management Plan (Appendix B).

	50th Percentile (SPRING)			95th Percentile (SPRING)		
Figure	ZoI (m2)	ZoMI (m2)	ZoHI (m2)	ZoI (m2)	ZoMI (m2)	ZoHI (m2)
Figure 4-3. Cutter suction dredging zones of impact – Dry season	26002056	11651	0	83649611	26826918	12333411
Figure 4-4. Cutter suction dredging zones of impact – Wet season.	11653700	400	0	84742800	11049900	188000
Figure 4-5. Backhoe dredging zones of impact – Dry season	36700	12100	14900	1164600	178100	195800
Figure 4-6. Backhoe dredging zones of impact – Wet season	37200	13800	0	895800	151600	36700

	50th Percentile (NEAP)			95th Percentile (NEAP)		
Figure	ZoI (m2)	ZoMI (m2)	ZoHI (m2)	ZoI (m2)	ZoMI (m2)	ZoHI (m2)
Figure 4-3. Cutter suction dredging zones of impact – Dry season	27967470	491215	865	79264754	32243266	21817421
Figure 4-4. Cutter suction dredging zones of impact – Wet season.	16308700	400	0	80343400	19190800	153700
Figure 4-5. Backhoe dredging zones of impact – Dry season	36800	8200	13300	1661777	374879	184313
Figure 4-6. Backhoe dredging zones of impact – Wet season	28400	12600	0	1028000	142000	36200

Figure	ZoI (m2)	ZoMI (m2)	ZoHI (m2)	
Figure 4-7. Cumulative sedimentation related zones of impact map (cutter suction dredging, backhoe dredging and rock wall placement)	17798554	99421	136955	(SPRING)
Figure 4-7. Cumulative sedimentation related zones of impact map (cutter suction dredging, backhoe dredging and rock wall placement)	16023736	101274	122545	(NEAP)

Attachment 8: Dredge Disposal Site