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Stage 2 Report

Dungeness Boating Safety Project – Detailed Morphological Modelling

Hinchinbrook Shire Council

9 October 2024

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Project Details

Project Name	Dungeness Boating Safety Project – Detailed Morphological Modelling
Client	Hinchinbrook Shire Council
Client Project Manager	James Stewart
Water Technology Project Manager	Ryan Dermek
Water Technology Project Director	Gildas Colleter
Authors	Ben Cowling, Ryan Dermek
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Level 5, 43 Peel Street
South Brisbane QLD 4101

Telephone	(07) 3105 1460
Fax	(07) 3846 5144
ACN	093 377 283
ABN	60 093 377 283

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ACKNOWLEDGEMENT OF COUNTRY

The Board and employees of Water Technology acknowledge and respect the Aboriginal and Torres Strait Islander Peoples as the Traditional Custodians of Country throughout Australia. We specifically acknowledge the Traditional Custodians of the land on which our offices reside and where we undertake our work.

We respect the knowledge, skills and lived experiences of Aboriginal and Torres Strait Islander Peoples, who we continue to learn from and collaborate with. We also extend our respect to all First Nations Peoples, their cultures and to their Elders, past and present.

Artwork by Maurice Goolagong 2023. This piece was commissioned by Water Technology and visualises the important connections we have to water, and the cultural significance of journeys taken by traditional custodians of our land to meeting places, where communities connect with each other around waterways.

The symbolism in the artwork includes:

- *Seven circles representing each of the States and Territories in Australia where we do our work*
- *Blue dots between each circle representing the waterways that connect us*
- *The animals that rely on healthy waterways for their home*
- *Black and white dots representing all the different communities that we visit in our work*
- *Hands that are for the people we help on our journey*

EXECUTIVE SUMMARY

The Dungeness Boating Safety Project aims to improve boating safety from Herbert's River Entreprise Channel to the Hindchinbrook Passage. The project involves dredging Enterprise Channel and the construction of a protective coastal structure, with the placement of the dredged material at the adjacent Dungeness Beach. This executive summary provides an overview of the project's objectives and key findings from the Water Technology's *Detailed Morphological Modelling Project – Stage 2*. Stage 1 involved reviewing historical information and collecting additional hydrographic data.

The project objective is to understand sediment transport patterns and assess the impact of the proposed dredged channel and coastal structure. An initial sediment transport analysis was developed during the project Stage 1, based on a literature and historical data analysis. Additional hydrographic data and detailed numerical modelling are detailed in this Stage 2 report. The modelling focuses on sediment transport rates at the study site and the broader geographical context of sediment transport pathways and seabed morphology at Dungeness, in the Entreprise Channel, and in the broader Hinchinbrook Passage.

The modelling report outlines the development of a series of individual hydrodynamic models to quantify sediment transport at the site, including:

- A regional spectral wave model to quantify wave processes at the site.
- A regional and local hydrodynamic model to quantify water level fluctuations and associated velocities and bed shear stress parameters.
- A local morphological sediment transport model to quantify expected sediment transport rates at the site.
- A local longshore transport model to provide additional specific information on longshore sediment transport potential.

The project utilised coupled hydrodynamic and spectral wave models to drive a detailed morphological model in combination with available data validation and literature to provide an understanding of sediment transport patterns at the site and the impact that a proposed dredged channel and coastal structure may have on these sediment transport patterns. The local site was split into zones to describe and report on the model results. These zones are shown below and referred to in this executive summary.

It should be noted at this point that morphological modeling is subject to certain limitations and uncertainties inherent in the modeling process. Efforts have been made to calibrate and validate the model against available data; however, the extent of calibration and validation is constrained by the availability and quality of such data. Consequently, the model may not be fully representative of all conditions or scenarios. The results of the morphological modeling presented in this report are intended to provide insights and support decision-making but should not be solely relied upon for critical decisions without consideration of the inherent uncertainties and potential need for further validation. In the sections below, the best estimate of erosion / accretion rates is presented, however should be viewed from the lens that morphological modelling can have a significant error margin.

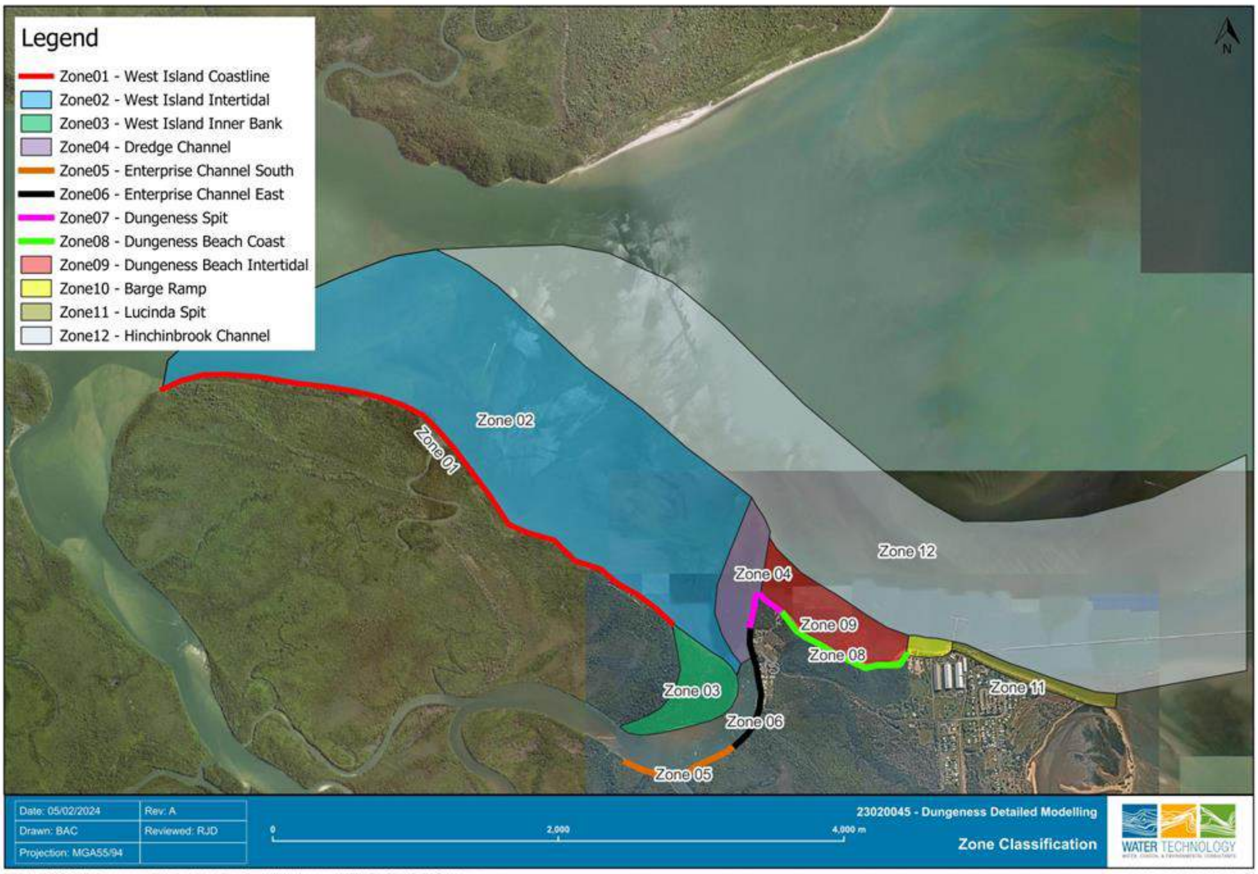

Figure 1-1 Zone classification for morphology results analysis

The base case numerical modelling suggests that:

- The Lucinda Spit and the Main Hinchinbrook Channel adjacent (Zones 11 and 12) are in an active coastal zone. There are relatively high rates of sediment transport and movement of shoals in these zones.
- Further west along Dungeness Beach (Zones 8, 9 and 10), the effects of wave action and subsequent sediment transport rates reduce. The morphology becomes more driven by tides rather than waves. Shoals offshore of Dungeness Beach (Zone 9) and the Western Island shoals (Zone 2) continue to grow, whilst the silty banks at the Dungeness Spit (Zone 7), Dungeness Beach (Zone 8) and the Western Island foreshore (Zone 1) are receding slowly.
- Enterprise Channel (Zone 4), where dredging is proposed, acts as a sediment sink between Dungeness Beach and the Western Island shoals (Zone 2 and 9), and is infilling at a rate of approximately 12,000 – 14,000m^3/year.
- The Western Island offshore shoals are more heavily influenced by the Herbert River sediment influx, with the modelling indicating the accumulation of sediment of approximately 20,000m^3/year on the Zone 02 Shoal.

Implementing a dredge channel scenario, with dredge material disposal on Dungeness Beach (Zone 8) - Works Option 1 - has an apparent (localised) effect on the sediment budget in adjacent zones. In summary:

- The dredged channel (Zone 4) infill rate has increased by approximately 20% (compared to the "no dredging" base case), to approximately 15,000 – 16,000m^3/year (from approximately 12,000 –

14,000m^3/year). This infill rate will result in a challenge to maintain a navigation channel. Regular maintenance dredging works would be required for safe navigation.

- There is a localised morphological impact to adjacent zones with decreasing deposition rates on the Western Island offshore shoals (Zone 2). This is thought to be due to shoals adjusting to the dredged channel, with sediment infill from the shoals into the dredged channel from the west, which is not observed in the base case scenario.
- Updrift, to the east of the coastal structure, there is minimal morphological impact with only a slight increase in deposition and slight reduction in erosion in the intertidal zone offshore of Dungeness Beach (Zone 9). The dredged channel partially fills with sediments associated with westerly sediment transport.
- The more efficient channel changes the tidal flow rates and subsequent shoal dynamics locally in Hinchinbrook Main Channel (Zone 12) adjacent to the Enterprise Channel. However, this effect is limited locally.
- Overall, impacts are limited to the immediate Western Island shoals (Zone 2), Dungeness Beach shoals (Zone 9) and Hinchinbrook Main Channel (Zone 12), without the effects propagating to the broader coastal zone.

Implementing a dredged channel and dredged material placement on Dungeness Beach with a coastal structure (i.e. training wall) - Works Option 2 - also has a localised effect on the sediment budget in adjacent zones.

- The dredge channel infill rate is reduced by approximately 45% - 50% (compared to the base case) and 55% (compared to Option 1). The coastal protection structure would significantly reduce the frequency of maintenance dredging.
- The net effect of the coastal structure is to increase deposition rates on the Western Island offshore shoals (Zone 2 predominately). This is related to reduced wave penetration to the Western Island due to the coastal structure and the narrowing of the spread of tidal currents across the broader Hinchinbrook Passage due to the coastal structure, with tidal flows focussed in the Hinchinbrook Passage rather than within the shoals.
- Updrift, to the east of the coastal structure, there is an apparent stabilising effect, with spit erosion reduced by 75% (Zone 7), and Dungeness Beach erosion reduced by up to 30% during La Nina scenario.
    - This decrease in erosion, especially in Zone 7 and 8, has been reviewed by SLR ecologists (See Appendix B), given the site has a significant mangrove forrest. The decreased erosion predicted in the modelling is thought to provide a net benefit for this mangrove forrest.
    - Dredged material placement is also included in the modelling. This dredged material placement was also reviewed by SLR ecologists, with a slight change to deposition patterns in the seagrass zone. This change was found to have minimal impact on adjacent seagrass beds given the low rate of deposition.
- Scour is introduced adjacent to the coastal structure, approximately eroding 700 – 1,600m^3/ year. This scour should be mitigateed in the design phase of the project by developing a structure with a toe at appropriate depth and adding a scour protection apron where required.
- The tidal prism that was previously spread across the Hinchinbrook Channel through to Dungeness Beach and the Western Island is constricted due to the coastal structure, which forces additional flow into the Main Hinchinbrook Channel (i.e. Hinchinbrook Passage). This causes a change to the shoaling of the Channel and scour in the Channel adjacent to the coastal structure. The scour extent and impact on shoals is restricted to a 500m radius from the structure.

Outside of these changes, no significant impacts were observed. It should also be noted that, in the context of the dredged material placement site:

- Dredged material should not be directly placed on marine plants, including areas with sparse mangroves or mangtove debris.
- The model does not show sensitivity to placement site on the foreshore – as such, prior to dredging, a new marine plant survey should be conducted and a new dredged material placement area selected. The rate of erosion of the foreshore in the baseline case means that the location of the marine plants is rapidly moving.
- Based on the most recent marine plant mapping (FRC Environmental, 2021), the available placement area for the dredge spoil is shown below in the context of the existing marine plants.
- However, it is recommended that re-survey is taken prior to each dredge campaign to avoid direct placement onto marine plants.

In terms of erosion protection, the coastal structure has a net stabilising effect on both Dungeness Beach and the Western Island shoals. Additional erosion protection is not recommended. The dredged material placement included in the modelling provides additional protection to Dungeness Beach which is eroding in the base case.

With appropriate monitoring and implementation processes, the dredged channel, coastal structure and dredged material placement could be designed to achieve a positive outcome in terms of stabilising coastal processes at the site. The modelling does not suggest any wide-ranging or long-term impacts on sediment budgets in the region. Further refinement of design of the channel and the coastal structure should be considered in the design process (length, width, alignment, volume) to manage boating safety and to optimise lifecycle costs (i.e., the spread of capital versus maintenance costs).

Furthermore, in the context of coastal environments, SLR Consulting (See Appendix B) has reviewed the modelling impacts to the major coastal environmental species at the site. Their review suggests that the modelling indicates that the dredging and coastal structure would:

- Significantly decrease the rate of deposition in Enterprise Channel, resulting in less frequent dredging, and less requirement to dispose of material.
- Significantly increase the stability of both mangrove and seagrass areas, decreasing the rate of mangrove loss, and likely resulting in an increase in the area of seagrass.

In terms of the important coastal environments adjacent to the site, the modelling suggests a net positive effect on the eroding mangrove forests, and minimal impact to seagrass beds.

To proactively monitor and de-risk the site and assist with design, construction and implementation, it is recommended that Council initiates a monitoring program as soon as possible, including:

- Localised high-resolution survey of Dungeness Beach, the adjacent spit and the western mangrove island every 6 months or post major storm event, taken during a Spring Low Tide. Aerial imagery should be captured concurrently with the beach survey.
- Annual hydrographic survey of Enterprise Channel and the adjacent Main Hinchinbrook Channel. This would likely require capture with a high-resolution multi-beam survey.
- Regional complete coverage survey via manned aircraft (for example, green LiDAR) or drone (drone photogrammetry or LiDAR) of the entire Hinchinbrook Coastline be undertaken at maximum 5-year intervals. Aerial imagery should be captured concurrently with the complete coverage survey.
- Regular (6-monthly) analysis and summary reporting of these datasets by a suitably qualified coastal engineer to review morphological changes and monitor maintenance dredging requirements. The model could be used to project maintenance dredging works.

These monitoring actions should be continued once the necessary boating safety infrastructure is installed to maintain safe navigation.

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1 INTRODUCTION

The Dungeness Boat Ramp is a vital piece of infrastructure to the Hinchinbrook region, with fishing participation as one of the highest percentage regions across Queensland at 34%. Dungeness also acts as a gateway to Hinchinbrook Island, the Great Barrier Reef and many of the islands off the coast of Australia, including Orpheus Island and the Palm Islands. Approximately 64% of the users who utilise the Dungeness boat ramp travel from Townsville and other non-local areas (HSC, 2021). Waterway access via the Dungeness boat ramp is of high importance to the community.

Enterprise Channel, which connects the boat ramp to deeper waters of Hinchinbrook Channel and beyond, is subject to excess sediment build-up, inhibiting waterway access at low and mid tides, particularly for vessels with deeper drafts. The Dungeness Boating Safety Project (DBSP) aims to address these issues and restore full-tide access from the Dungeness boat ramp to the Hinchinbrook Channel through a combination of periodic dredging and siltation reduction assisted by a coastal structure. It is also envisioned that the dredged material would be re-used for beach nourishment purposes on Dungeness Beach.

The scope of this detailed morphological modelling study, as part of the wider DBSP, aims to address the concerns raised by the State Assessment and Referral Agency (SARA) regarding sediment dynamics and the impacts of the proposed coastal structure and dredged channel. Water Technology has been commissioned to undertake a comprehensive study that includes data collection, detailed numerical modelling, and an impact assessment to provide a thorough understanding of sediment transport patterns and the potential coastal impacts of the proposed works. The first stage of the project focussed on literature and existing data review, and additional data collection – the reporting for this first stage is provided in Appendix A.

Stage 2 of the project is driven by the need to assess sediment transport rates, evaluate the impacts of the breakwater and channel on sediment dynamics and coastal erosion, and identify any potential long-term effects on the coastal environment west of Dungeness Spit. SARA has categorized these concerns into three key comments:

- *Comment 1: sediment transport rates or direction in this area westward past the spit end and onto the western face of the spit and sediment transport away from this area by tidal and riverine currents in Enterprise Channel within a broader geographical context (i.e. max 10kms surrounding the proposed breakwater and channel).*
- *Comment 2: the impact of the breakwater and channel on the current day sediment to the west and the consequent impact of the sand deficit to the updrift* coast including possible bed lowering and coastal erosion.*
- *Comment 3: the impact of the sand deficit created for the updrift* coast to the west of the breakwater on coastal processes in the area and whether there would be any adverse long term (10 years+) impacts on the coastal environment to the west of Dungeness Spit.*

* later clarified by DES as referring to the 'downdrift' rather than 'updrift' part of the coast.

This Stage 2 reporting focusses on the detailed numerical modelling of hydrodynamics, waves, and sediment transport to complement the data and literature review and collection undertaken in Stage 1 of the project (See Appendix A). The model results have been utilised to identify potential areas that may experience morphological changes due to the proposed works, and discussion is provided on risk profile, mitigation and monitoring of these impacts to reduce any long-term risks.

1.1 Study Area

The study area is shown in Figure 1-1 below, with key locations in the region highlighted. Dungeness is a small township located approximately halfway between Townsville and Cairns, near Lucinda, on the east coast of Australia in North Queensland.

The boat ramp and adjacent Enterprise Channel sit in a complex confluence of several waterways. Enterprise Channel is a tidal waterway that discharges into the far south-eastern end of Hinchinbrook Channel, immediately adjacent to Hinchinbrook Channel's connection to Halifax Bay and into the Coral Sea. Enterprise Channel delta is also directly connected to the Herbert River as a downstream tidal anabranch. The Herbert River and Seymour River also discharge into the Hinchinbrook Channel, upstream of the Enterprise Channel.

Figure 1-1 Site location

1.2 Project Objectives

The project objective can be summarised as utilising sediment transport modelling to understand sediment pathways and local morphological patterns, and the impact that the proposed coastal structure and dredged channel may have on sedimentation processes.

To expand on this, this will include the production of:

- A comprehensive sediment transport description – conducting detailed numerical modelling and data collection to analyse sediment transport rates and directions, focusing on the impact of the proposed coastal structure and channel within a broader geographical context.
- Erosion mitigation and remediation planning – Evaluating potential future erosion scenarios along the coast and assessing their impact on environmental values and built assets. Provision of recommendations for remediation options that can effectively mitigate erosion aspects.
- Shoreline Monitoring and Reporting – Develop a shoreline monitoring program and reporting arrangement to continuously assess and report on the evolving coastal processes, ensuring the long-term health of the coastal environment to the west of Dungeness Spit is maintained.

2 MODELLING APPROACH

Numerical models are developed through an iterative process that can significantly augment understanding of coastal processes across space and time. The numerical models simulate how waves and tides propagate over a large area. The Water Technology numerical modelling methodology will follow the steps outlined in Figure 2-1.

Stage 1 of the project (See Appendix A) focussed on data analysis and establishing a conceptual model. This Stage 2 report outlines the model setup, testing, and subsequent outputs.

This chapter details the development of the wave and hydrodynamic models. The philosophy of the modelling task was first to achieve a solid hydrodynamic and wave calibration and validation, which is the driver for the morphological modelling. The morphology modelling is detailed separately in Section 4 and follows the same modelling philosophy.

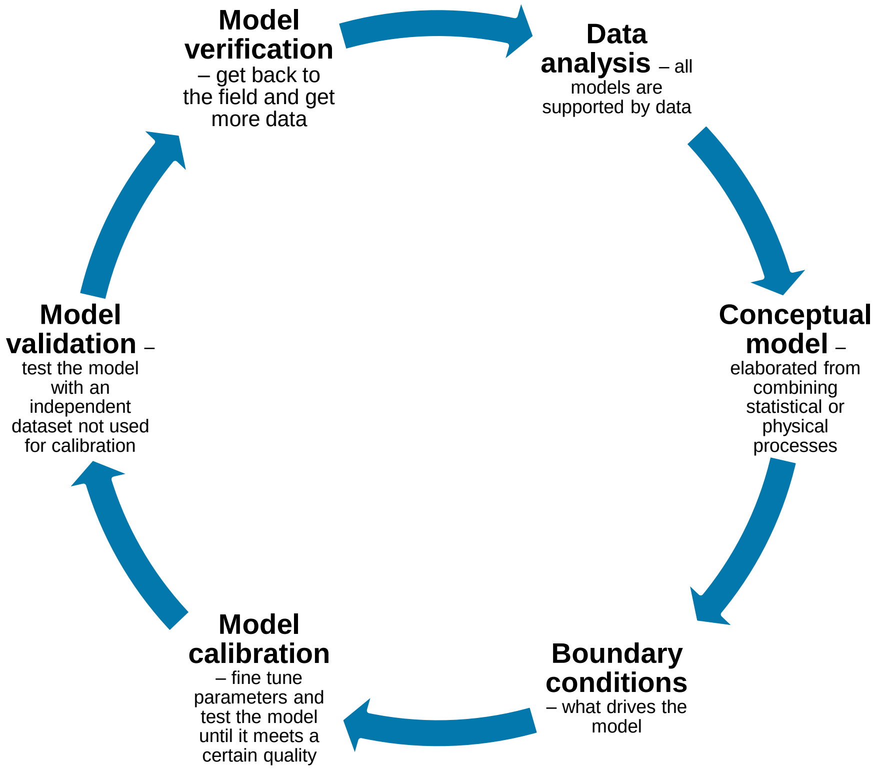


Figure 2-1 Numerical Modelling Methodology

2.1 MIKE Models

Numerical modelling was undertaken using the MIKE software suite developed by the Danish Hydraulics Institute (DHI). The MIKE suite includes the hydrodynamic (HD), spectral wave (SW) and sand transport (ST) modules, which were coupled together to ensure that the dominant physical processes are represented in the modelling in a physically realistic manner.

The flexible mesh (FM) version of MIKE was adopted due to its ability to adjust the spatial resolution of the model mesh resolution throughout the domain. This enables suitable mesh resolutions throughout the model domain (i.e. higher resolution in the areas of interest and lower resolution in the offshore areas away from any areas of interest) and also optimises model runtimes.

2.1.1 MIKE 21 FM Hydrodynamics

The MIKE 21 FM HD module has been developed for applications across oceanographic, coastal and estuarine environments. The module is the primary computational component of the remaining MIKE FM modelling systems, providing the two-dimensional hydrodynamic conditions for the other modules.

2.1.2 MIKE 21 FM Spectral Waves

MIKE 21 FM SW module has been developed for applications in offshore, coastal and port environments. The module simulates the growth, decay and transformation of wind-generated waves and swell in offshore and coastal areas. The model can include the following physical phenomena (DHI, 2023):

- wave growth by the action of wind;
- non-linear wave-wave interaction;
- dissipation due to white-capping;
- dissipation due to bottom friction;
- dissipation due to depth-induced wave breaking;
- refraction and shoaling due to depth variations;
- wave-current interaction, and
- the effect of time-varying water depth and flooding and drying.

2.1.3 MIKE 21 Sand Transport

The MIKE21 Sand Transport module allows for coupling with MIKE21 HD and MIKE21 SW to analyse sediment transport patterns around structures or near tidal inlets. The module calculates the sediment transport capacity and resulting bed level changes for non-cohesive sediment (sand) due to currents or combined waves-currents. The model includes both sediment bed load and suspended load but not sediment wash (particle smaller than 0.06mm). It uses a flexible mesh covering the area of interest based on the hydrodynamic data obtained from the HD module coupled with the SW module. (DHI, 2023).

2.2 Model Mesh

The spatial discretisation of the model domain was developed using a cell-centred finite volume method. The horizontal domain was discretised as triangular elements of varying resolution to represent the bathymetric variation and to provide computational stability in areas of flooding, drying and high hydraulic gradients.

The following key components were considered when defining the extent of the model mesh:

- The model boundaries must extend far enough offshore to enable the wave field to simulate the influence of Pelorus, Orpheus, Fantome and Palm Islands situated 17km east of the project site;
- The model mesh resolution should be sufficient to accurately represent the bathymetry around the proposed dredged zone, and natural changes in bathymetry throughout the domain; and
- The model mesh should, where possible, remain computationally efficient (that is, it shouldn't be excessively large to avoid lengthy model runtimes).

Having considered the above key aspects of mesh development and the long-term timeframes and large spatial area under consideration, it was deemed appropriate to adopt a regional and local mesh approach whereby the influence of winds and waves simulated by the regional mesh were subsequently fed into the local mesh model, along with tidal elevations, to replicate all hydrodynamic processes within the study area. The regional and local meshes are detailed in Section 2.2.1 and Section 2.2.2, respectively.

2.2.1 Regional Model

The regional model mesh extends approximately 750km offshore, 700km north and 900km south of the Dungeness Channel. The mesh resolution has been spatially varied to resolve the complex bathymetry, coastline and offshore islands, and the hydrodynamic processes in the Enterprise and Hinchinbrook Channels. The regional mesh resolution gradually varies from an average element arc length of ~200m (in the Dungeness and Hinchinbrook Channel regions) up to 8,500m (offshore area). The regional model mesh and composite bathymetry are illustrated in Figure 2-2.

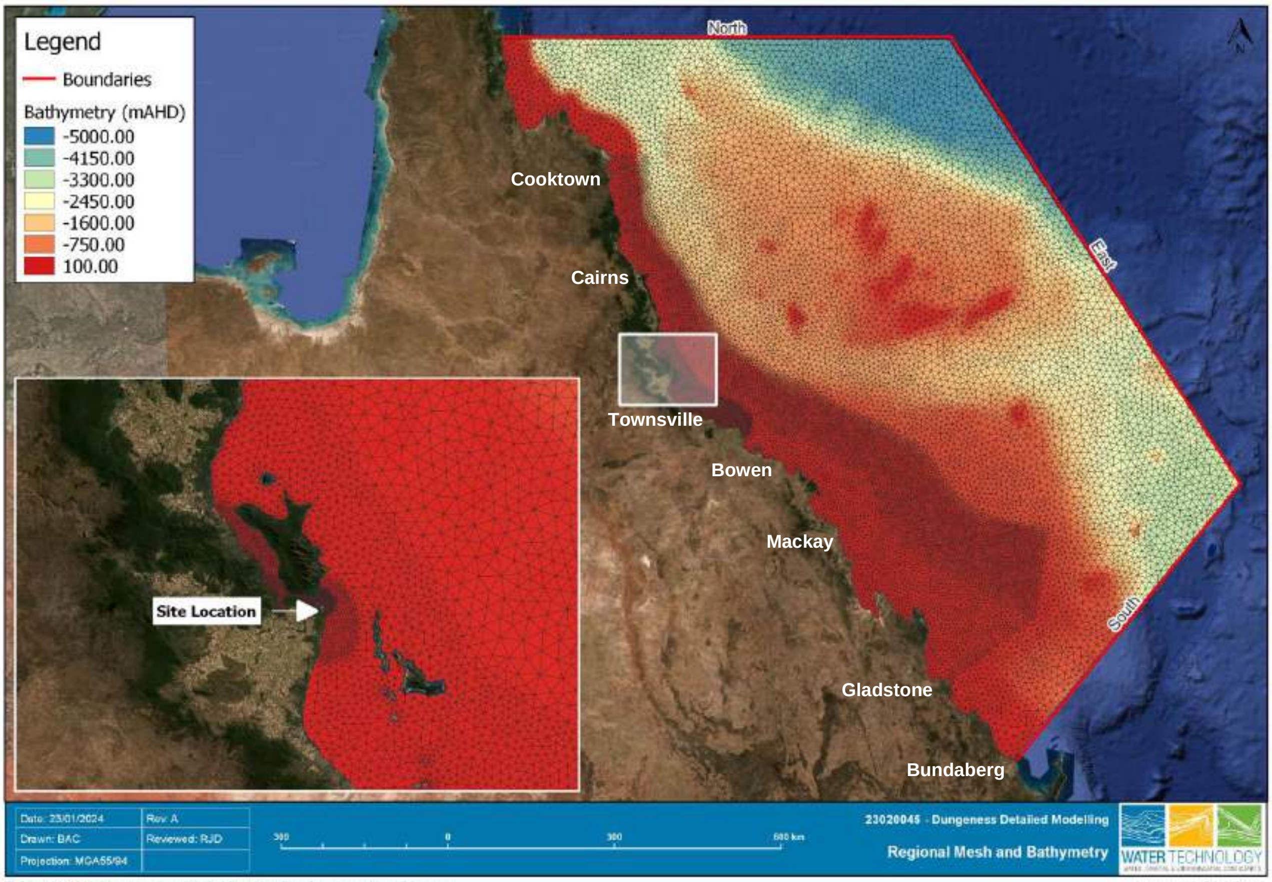


Figure 2-2 Regional model mesh and bathymetry

2.2.2 Local Model

The local model mesh extends approximately 30km offshore, 50km north and 80km south of the Dungeness Channel. The mesh resolution has been further increased around the location of interest to accurately resolve the proposed dredged channel and coastal structure in addition to the complex bathymetry and coastline. The local mesh resolution gradually varies from an average element arc length of 15m in the vicinity of the study site to 1000m in the offshore area. The local model mesh and composite bathymetry are illustrated in Figure 2-3.

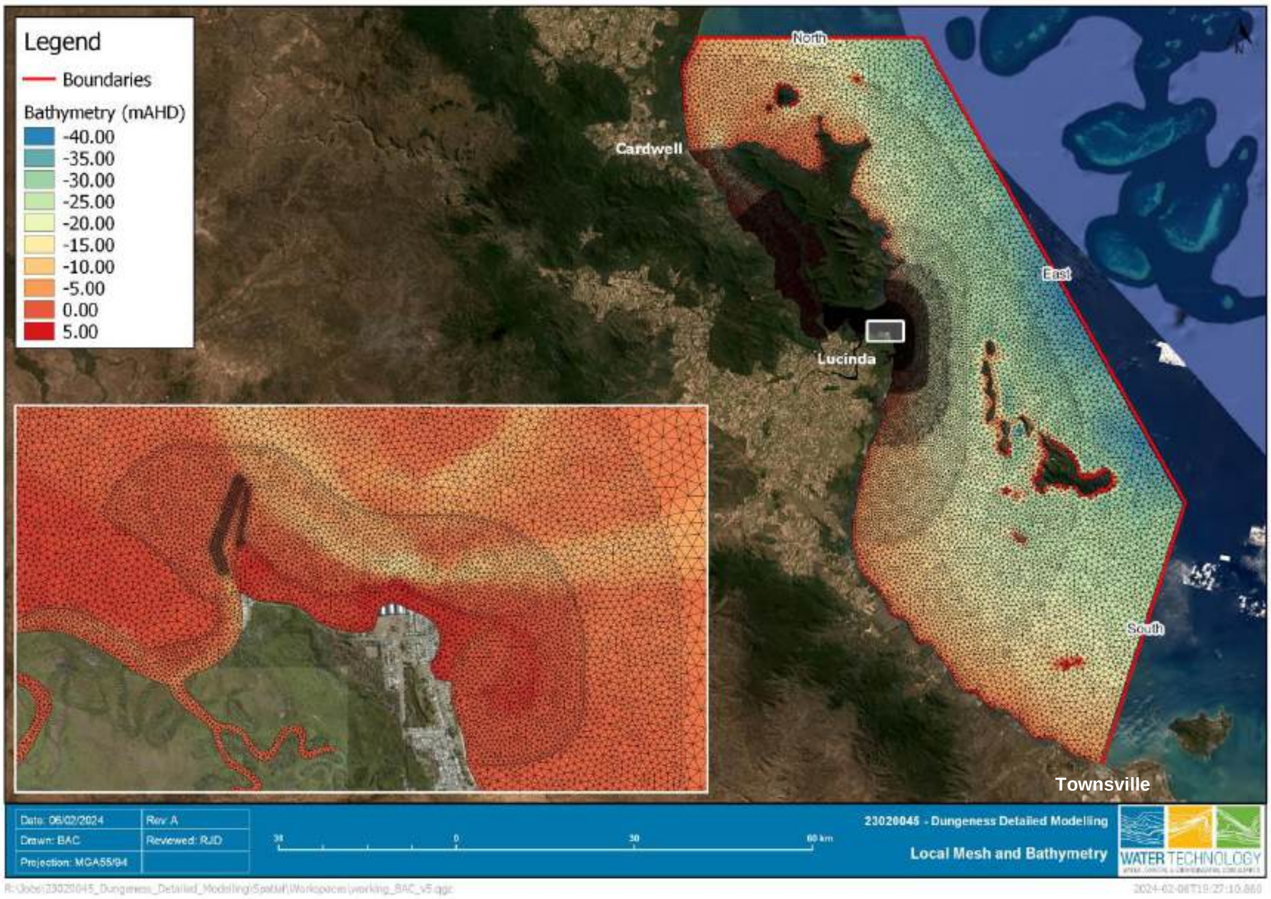


Figure 2-3 Local model mesh and bathymetry

2.3 Model Bathymetry

The regional and local model bathymetry utilised a combination of available datasets of various spatial extents, which are summarised in Table 2-1. The composite bathymetry dataset is also presented above in Figure 2-2 (regional model) and Figure 2-3 (local model).

Table 2-1 Bathymetric datasets relevant to model development

Dataset	Source	Spatial Extent	Date
High-Resolution Multi-Beam Survey	SANDMAP	Dungeness/Enterprise Channel/Hinchinbrook Channel	2023
Local Survey	HSC	Dungeness	Varies
CMAP – Digitised Navigational Charts	DHI in-built CMAP software	Regional	Varies
25m Intertidal	Geoscience Australia	Regional	2016
30m Great Barrier Reef	Geoscience Australia	Regional	2020
100m Great Barrier Reef	Geoscience Australia	Regional	2020

2.4 Bed Roughness

Sensitivity tests were performed on a range of Manning's M bed roughness coefficients using uniform and spatially varying values to obtain optimum calibration results. A Manning's M of 10 $m^{1/3}/s$ for intertidal mangrove areas in the Hinchinbrook Channel area and 32 $m^{1/3}/s$ in coastal and offshore waters were found to be the most representative of conditions during calibration. These values align with typical values utilised for roughness parameters in hydrodynamic models.

2.5 Boundary Conditions

2.5.1 Tidal Boundaries

Tidal offshore boundary conditions used to force the regional model were derived from the *MIKE21 Tidal Analysis and Prediction Module*. This global tide model derives its baseline altimetric data from satellite observations since 1992. The global tidal model information is primarily relevant for offshore tidal boundaries and is unlikely to be at a resolution capable of resolving local bathymetric influences – as such the global tidal model has been utilised for the offshore boundary in the regional model, which extends past the nearshore islands, Great Barrier Reef and onto the continental shelf. The regional model outputs force the local nested-model tidal boundary.

Tidal elevations varying in time and space were generated at 15-minute intervals for the northern and eastern boundaries, as shown in Figure 2-2.

The MIKE21 Global Tide Model for Heights is a 0.125°x0.125° resolution global model including the following 10 constituents: Semidiurnal: M2, S2, K2, N2 – Diurnal: S1, K1, O1, P1, Q1 – Shallow Water: M4.

2.5.2 Offshore Wave Boundary

The spectral wave model offshore boundary is forced with wave data extracted from the ERA5 (Fifth Generation of the European Centre for Medium-Range Weather Forecasts [ECMWF] Re-Analysis) model. The wave data from ERA5 includes information about ocean wave height, period, and direction, suitable for forcing the offshore boundary of the regional model. ERA5 model data is a widely used dataset in the scientific community due to its global coverage and high-quality data. The model outputs are at a high temporal resolution (one hourly), including a long-term re-analysis (1950 to present day) and are a consistent, quality-controlled product.

Due to the large extent of the regional model, the boundary conditions used to force the spectral wave model vary spatially along each boundary. The corresponding nodes were extracted from ERA5 and developed into the north, east and south boundary inputs.

2.5.3 Wind Boundary

The ERA5 global re-analysis model also produces a spatially varying wind and mean sea level pressure output that was used to force the model, with data extracted from the ERA5 global reanalysis model at 0.25°x0.25° grid resolution. This is applied across the full model domain to allow for local wind wave generation.

Local wind gauges were not of sufficient density or resolution to provide an improvement on the ERA5 boundary condition.

2.5.4 Atmospheric Pressure Boundary

The ERA5 global re-analysis model was used to gather spatially varying mean sea level pressure input to force the model. This data was extracted on a 0.25°x0.25° grid resolution and applied to all model simulations to model the effects of atmospheric pressure fluctuations on coastal processes.

3 MODEL CALIBRATION AND VALIDATION

Model calibration followed an iterative process of adjusting specific model parameters, typically the mesh resolution and roughness parameters, to obtain a quality-controlled agreement between observed data and model outputs. Model validation was then performed to review how the calibrated model can reproduce accurate predictions using the same model parameter settings as the calibrated model for a different period than that used for model calibration and at an alternate location. These steps are crucial to control the model performance and accuracy for various environmental conditions. Before investigating the sand transport, initial model calibration and validation focused on the hydrodynamic and wave conditions.

3.1 Calibration and Validation Standards

The model quality control was tested via calibration and validation to demonstrate how the model parameters can accurately replicate the natural processes characteristic of the region of interest. Model performance criteria applied to the hydrodynamic and spectral wave models were derived from Williams and Esteves (2017).

Hydrodynamic model performance guidelines are defined as follows:

- Water Levels:
  - Modelled water levels should be within 10% and 15% of the tidal range over a spring and neap tide cycle, respectively or within ± 0.1m; and
  - Timing of high water and low water should be within 15 minutes.
- Current speed and direction:
  - Modelled peak current speeds should be within 10 – 20% of measured speeds over a spring neap tidal cycle, or within ± 0.1 m/s; and
  - Absolute difference between the measured and modelled current direction should be ± 10°-15°.

The Spectral Wave model was qualitatively assessed to ensure that the range of Significant Wave Height (Hs) and Period (Tp) predicted by the model correlated with measurements.

The Index of Agreement (IOA) is also provided as an additional and more broadly recognised measure. The IOA ranges from 0 to 1, with larger values indicating a better agreement between the model and measured data.

It is important to note that although the above standards provide a basis for evaluating model performance, it is also necessary to undertake visual checks of model outputs to ensure sensible results are generated – not only at points of interest but across the model domain.

3.2 Hydrodynamic Model

The regional and local hydrodynamic models were calibrated with measured water level data available from MSQ at two locations (Lucinda 062006A and Cardwell 035012A gauges) and supplemented by field data collected using two water level loggers in the recent data collection campaign (2023) and ADCP data from the initial data collection campaign (2018). The local model was also calibrated to water elevations and measured volumetric discharges from ADCP profiles undertaken in 2023 to ensure the model replicated hydrodynamics within the study area as closely as possible to actual conditions.

The calibration and validation of the modelling framework was undertaken on a 2-Dimensional (2D) model scheme whereby model performance was compared with measured water levels and depth-averaged current speed and direction.

To supplement water elevation data collected in the field in both the 2018 and 2023 collection campaigns, historical data was sourced from Maritime Safety Queensland (MSQ) at Lucinda Offshore and Cardwell to guide the calibration and validation of the regional and local hydrodynamic models.

The elevation of the hydrodynamic model performance followed the recommendations outlined in Williams and Esteves (2017) summarised in Section 3.1. In addition, the Root Mean Square Error (RMSE), R^2, and Index of Agreement (IoA) between measured and modelled data have also been provided.

To control model performance across a range of tide conditions, the calibration phase extended over a 2-week spring tide cycle period in conjunction with logger deployment in September and October 2023. The validation period was 4 weeks in conjunction with the initial data collection campaign in December and January of 2018 and 2019, respectively. These periods are as follows:

- Model Calibration: 22/09/2023 – 06/10/2023
  - Lucinda 062006A – Tide Gauge
  - Cardwell 035012A – Tide Gauge
  - Logger deployment locations in the Enterprise Channel and Main Hinchinbrook Channel (Note this was only assessed in the local model due to mesh resolution in the regional model)
- Model Validation: 15/12/2018 – 15/01/2019
  - Lucinda 062006A – Tide Gauge
  - Cardwell 035012A – Tide Guage
  - ADCP deployment location in the main Hinchinbrook Channel (Note this was only assessed in the local model due to mesh resolution in the regional model)

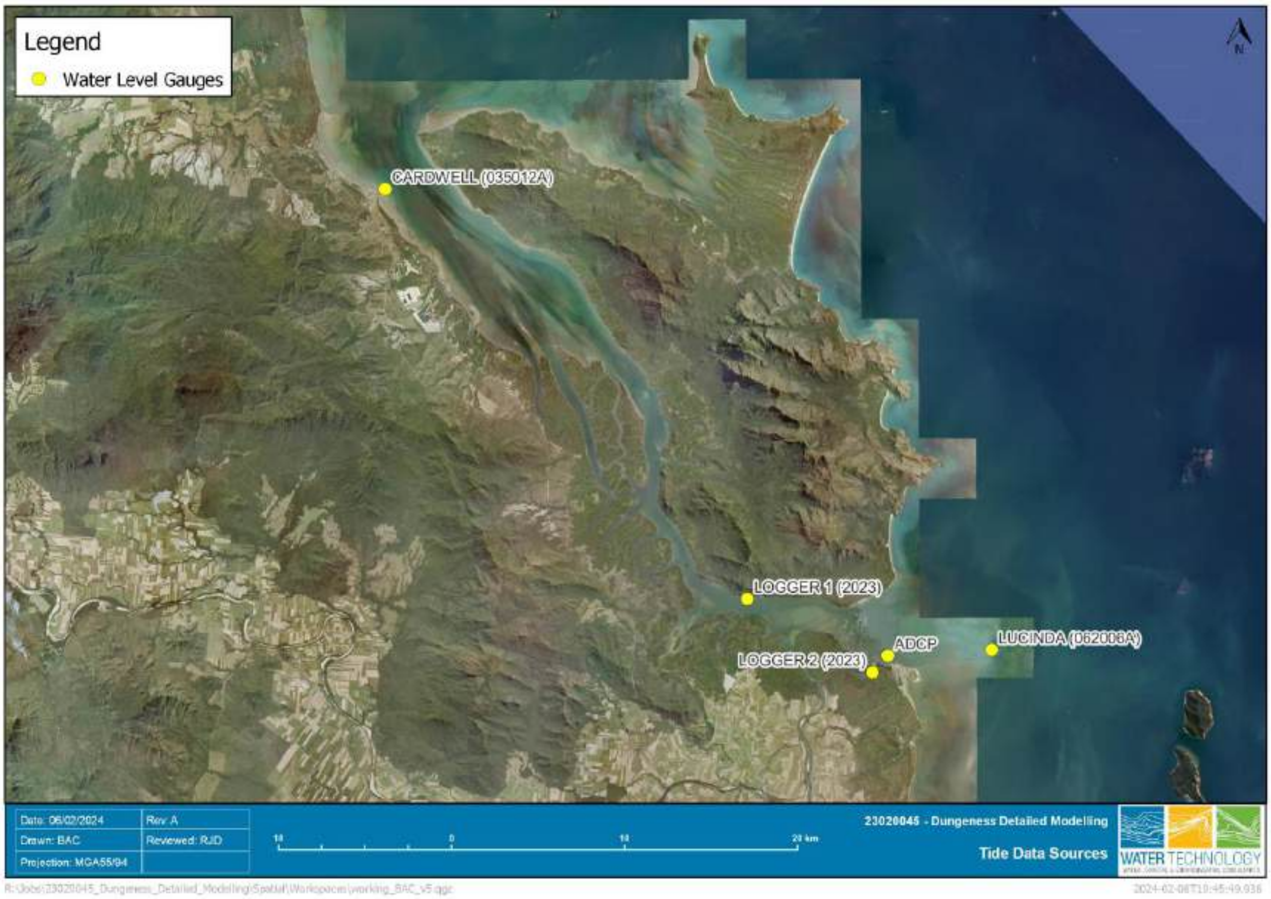


Figure 3-1 Tide gauge and data collection locations

3.2.1 Regional Water Level Calibration

The regional model calibration demonstrated sound agreement with predicted water level data at the Lucinda (062006A) gauge location. The modelled tidal amplitude for High Water (HW) and Low Water (LW) met the recommended standards. The tidal phasing was within calibration standards for both LW and HW, with a lag of ~8 and ~14 minutes, respectively. A plot of the calibration period and output calibration parameters are shown in Figure 3-2 and Table 3-1.

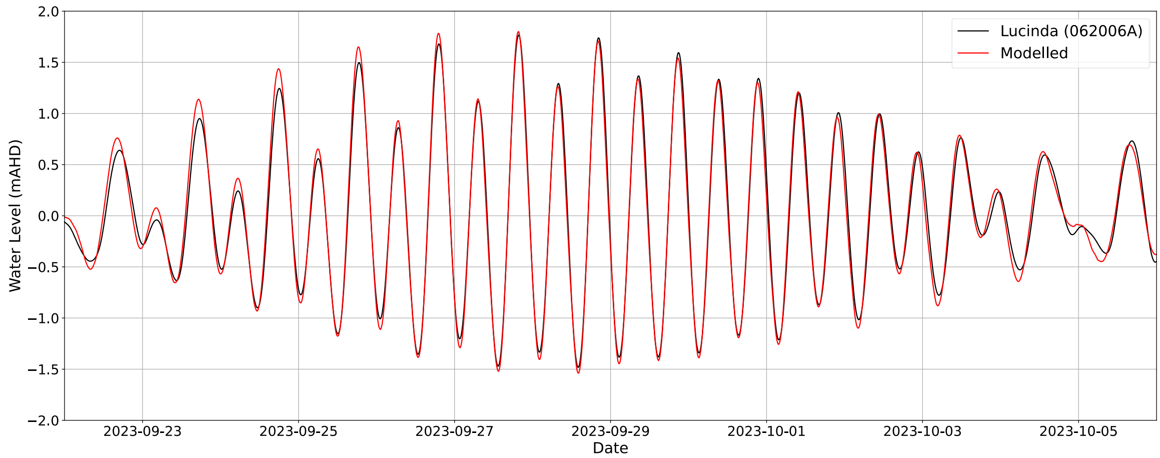


Figure 3-2 Regional Model Calibration – Lucinda Offshore Gauge 062006A

Table 3-1 Regional model performance measure for water levels – Model Calibration

Performance Measures	Lucinda Offshore Gauge (062006A)	Cardwell Tide Gauge (035012A)
Mean HW Difference (m)	0.04	0.08
Mean LW Difference (m)	-0.05	-0.06
Mean HW phase difference (min)	14.80	15.10
Mean LW phase difference (min)	8.48	-11.74
R^2	0.99	0.97
RMSE	0.09	0.13
Index of Agreement (IoA)	0.99	0.99

3.2.2 Regional Validation

The regional model validation also demonstrated a sound agreement with data at the Lucinda and Cardwell gauge locations. The modelled tidal amplitude for HW and LW met the recommended standards. The tidal phasing was marginally outside of calibration standards for HW and LW, with respective lags of ~21 and ~19 minutes at Lucinda.

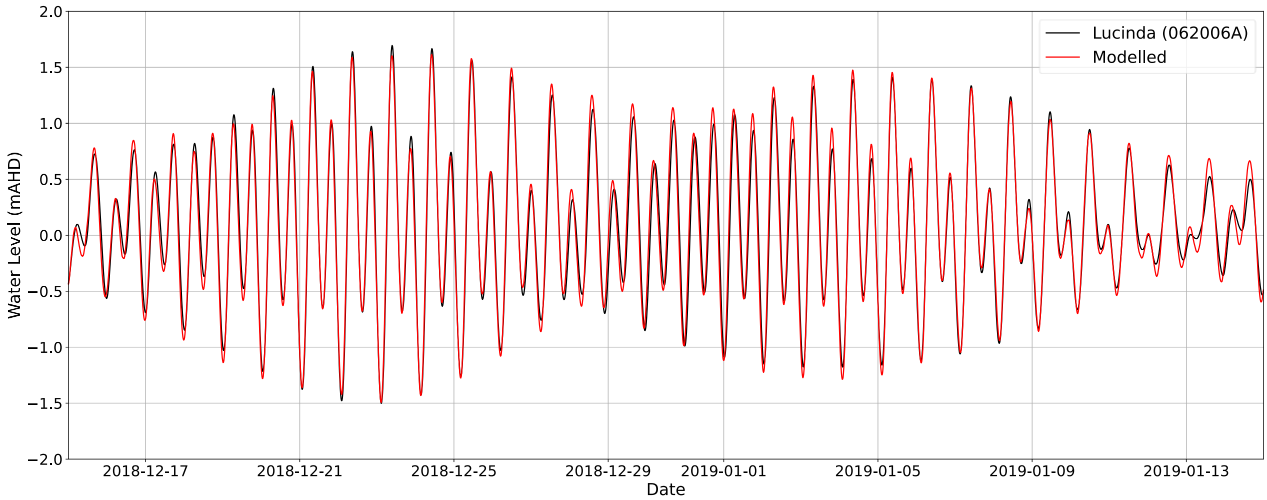


Figure 3-3 Regional Model Validation – Lucinda Offshore Gauge (062006A)

Table 3-2 Regional model performance measure for water levels – Model Validation

Performance Measures	Lucinda Offshore Gauge (062006A)	Cardwell Tide Gauge (035012A)
Mean HW Difference (m)	0.03	0.07
Mean LW Difference (m)	-0.04	-0.04
Mean HW phase difference (min)	21.50	26.5
Mean LW phase difference (min)	19.0	7.25
R^2	0.97	0.97

Performance Measures	Lucinda Offshore Gauge (062006A)	Cardwell Tide Gauge (035012A)
RMSE	0.11	0.11
Index of Agreement (IoA)	0.99	0.99

3.2.3 Local Calibration

The local model calibration demonstrated sound agreement with predicted water level data at the Lucinda (062006A) gauge location. The modelled tidal amplitude for High Water (HW) and Low Water (LW) met the recommended standards at all locations. The tidal phasing was within calibration standards for both LW and HW, with respective lags of ~4 and ~10 minutes at Lucinda.

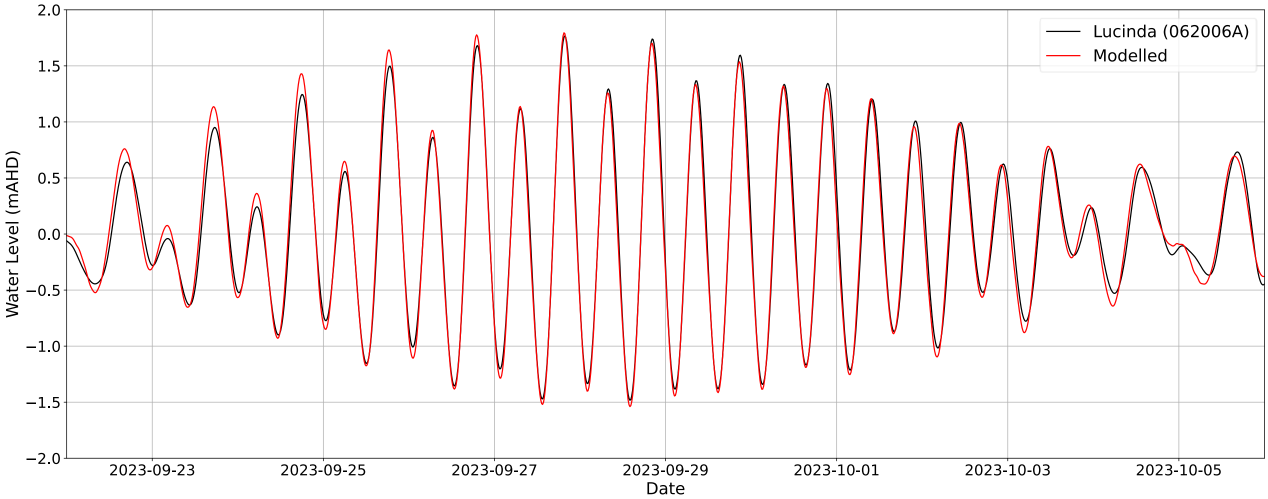


Figure 3-4 Local Model Calibration – Lucinda Offshore Gauge 062006A

Table 3-3 Local model performance measure for water levels – Model Calibration

Performance Measures	Lucinda Offshore (062006A)	Cardwell (035012A)	Logger 1 (Main Channel)	Logger 2 (Enterprise Channel)
Mean HW Difference (m)	0.04	0.06	0.09	0.02
Mean LW Difference (m)	-0.05	-0.03	0.01	0.09
Mean HW phase difference (min)	10.29	11.88	-10.83	13.33
Mean LW phase difference (min)	4.35	-20.87	-23.91	-9.13
R^2	0.99	0.96	0.94	0.96
RMSE	0.08	0.17	0.21	0.17
Index of Agreement (IoA)	0.99	0.99	0.97	0.98

3.2.4 Local Validation

The local model validation also demonstrated a sound agreement with data at the Lucinda and Cardwell gauge locations. The modelled tidal amplitude for HW and LW met the recommended standards. The tidal phasing was marginally outside of calibration standards for HW and LW, with respective lags of 22 and 20 minutes Lucinda, and a low water difference of 2 minutes at Cardwell.

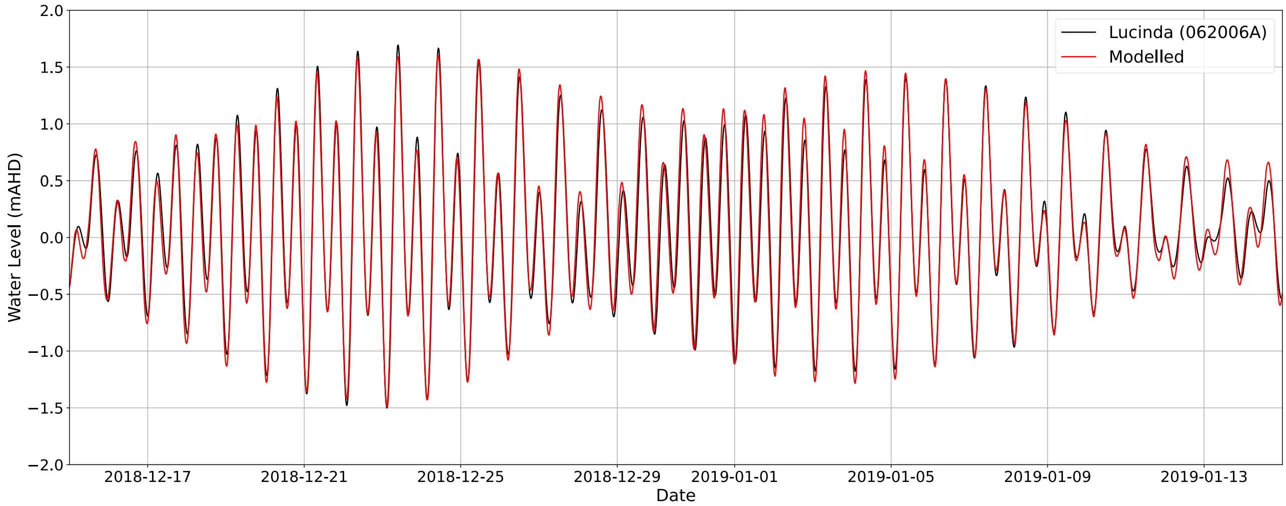


Figure 3-5 Local Model Validation – Lucinda Offshore Gauge 062006A

Table 3-4 Local model performance measure for water levels – Model Validation

Performance Measures	Lucinda Offshore (062006A)	Cardwell (035012A)	ADCP (Main Channel)
Mean HW Difference (m)	0.03	0.06	0.04
Mean LW Difference (m)	-0.03	-0.02	0.04
Mean HW phase difference (min)	22	23	21
Mean LW phase difference (min)	20	-2	1
R^2	0.97	0.97	0.92
RMSE	0.12	0.11	0.21
Index of Agreement (IoA)	0.99	0.99	0.94

3.2.4.1 ADCP Transect Discharges

As the Stage 1 reporting noted, a SonTek RiverSurveyor M9 ADCP mounted to a TB9s moving boat setup was used to measure current profiling data at four (4) of the key waterways. The M9 ADCP contains nine transducers with a profiling range of between 0.06m and 40m (distance) and +/- 20 m/s (velocity). The device's accuracy is up to +/- 0.2cm/s (distance) and +/- 0.25% of measured (velocity). Figure 3-6 illustrates the device rigging method and ADCP unit inserted into the board.

Transect discharge volumes and directions at four locations are shown below in Figure 3-7. The comparison of modelled results to the measured transects are discussed in the paragraphs below.

Figure 3-6 ADCP Setup attached to boat

Figure 3-7 Transect discharge locations

3.2.4.1.1 Transect 1

Discharge values at Transect 1 were measured on the 11th September 2023, from 6:30am for 12 hours until 6:30pm. This period covers a lower high and peak low tide through the Herbert River. The measured discharge volumes show a solid alignment for modelled flood and ebb tide volumes.

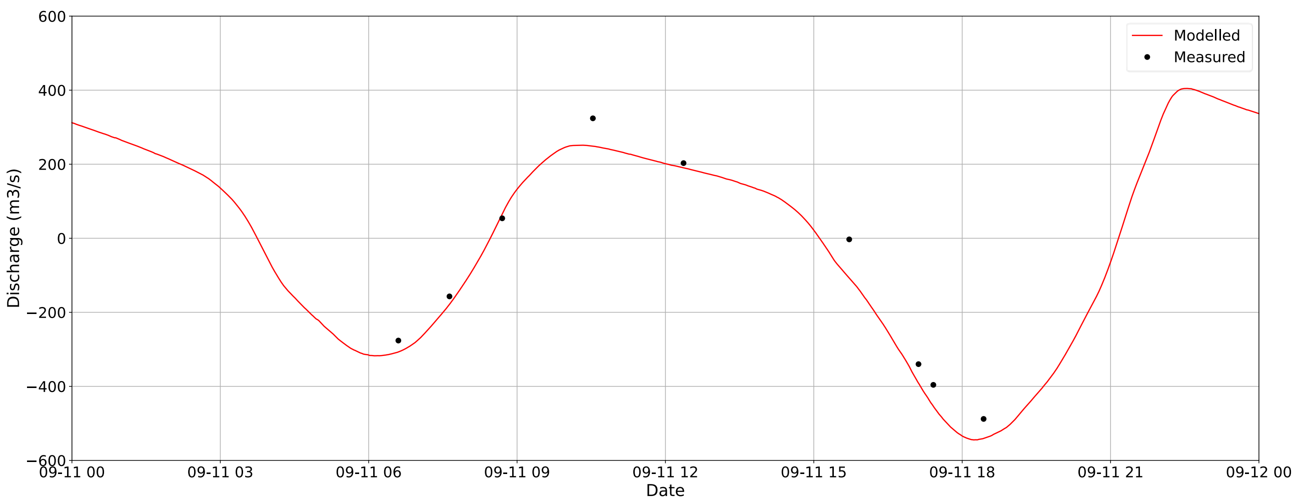


Figure 3-8 Transect discharge calibration – Transect 1 (Herbert River)

3.2.4.1.2 Transect 2

Discharge values at Transect 2 were measured on the 11th September 2023, from 7:00am for 12 hours until 7:00pm. This period covers a lower high and peak low tide through Enterprise Channel. The model also represents these flows well, with the asymmetrical ebb and flood tide captured in this key waterway.

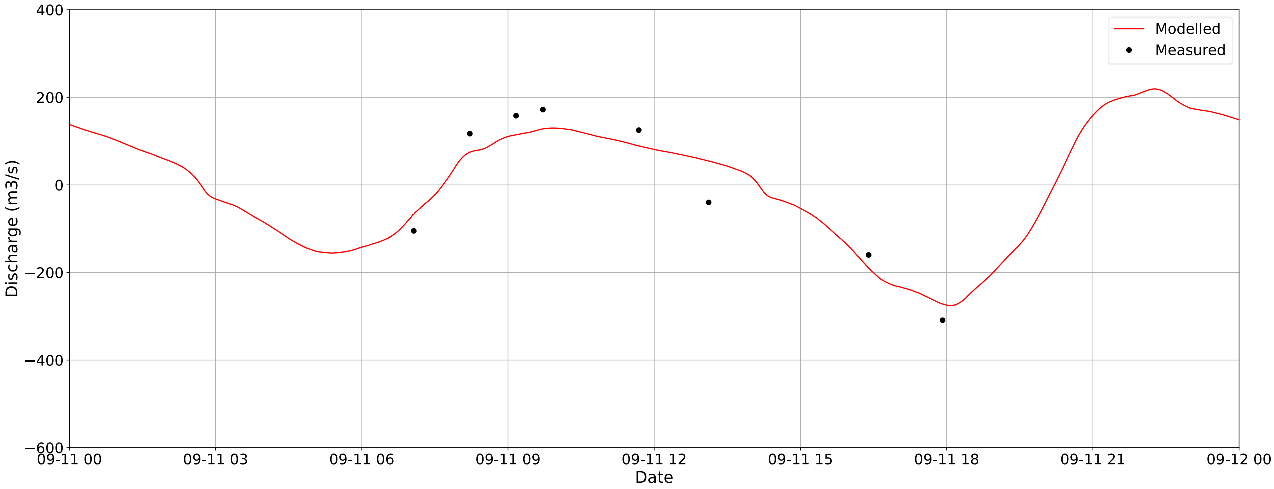


Figure 3-9 Transect discharge calibration – Transect 2 (Enterprise Channel)

3.2.4.1.3 Transect 3

Discharge values at Transect 3 were measured on the 13th September 2023, from 6:15 am for 12 hours until 6:15pm. This period covers a lower high and peak low tide through the Main Hinchinbrook Channel. Data collection within the Hinchinbrook Channel is much more complex than the smaller waterways, with a 2km wide collection zone, shoals and banks, and mild wave climate that propagates into the channel, making full capture difficult. Nevertheless, the model still shows a reasonable alignment with the flow rates captured by the ADCP.

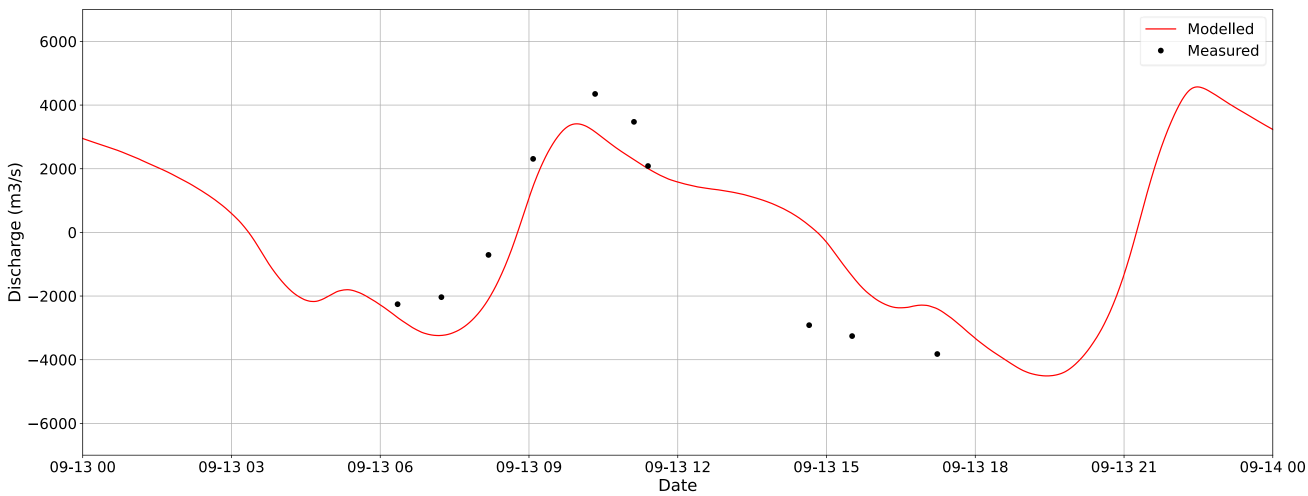


Figure 3-10 Transect discharge calibration – Transect 3 (Main Hinchinbrook Channel West)

3.2.4.1.4 Transect 4

Discharge values at Transect 4 were measured on the 14th September 2023, from 7:15 am for 11 hours until 6:15pm. This period covers a lower high and peak low tide through the Main Hinchinbrook Channel. The wave climate affected this part of the Hinchinbrook Channel on the day of data capture. The model underestimates flood and ebb tide flows at this site.

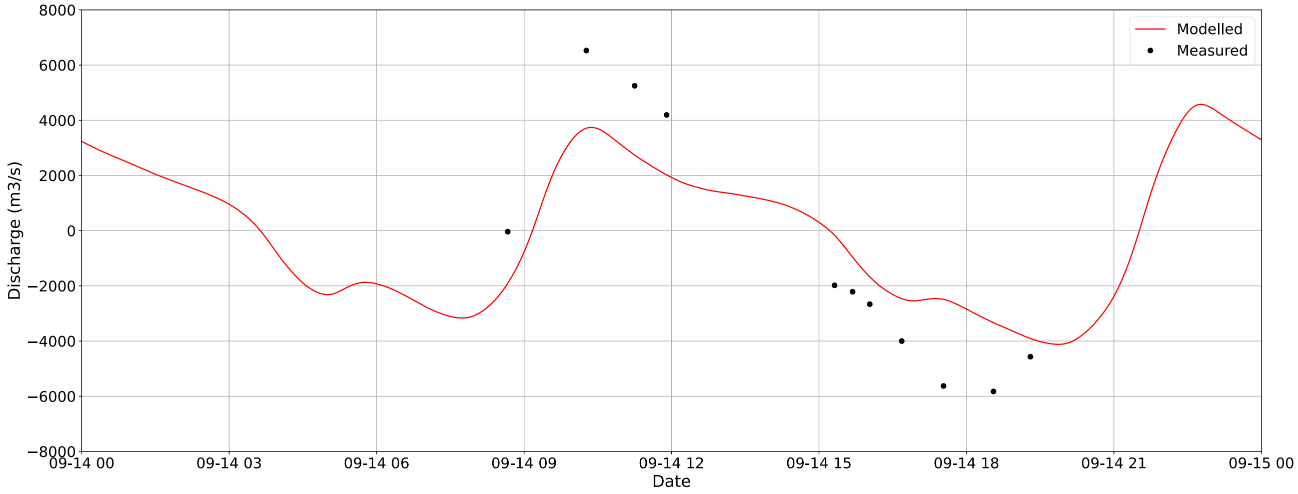


Figure 3-11 Transect discharge calibration – Transect 4 (Main Hinchinbrook Channel East)

3.2.4.2 Fixed ADCP Current Speed and Direction

Current speed and direction has also been compared to the fixed ADCP placement from 2018 in Figure 3-12, Figure 3-13 and Figure 3-14. There is a general alignment between the modelled and measured ADCP data. The model appears to underpredict the flood tide and over-predict the ebb tide velocities, however, the directional spread of the data is well correlated. This may be related to the model underlying description of friction, which is uniform and does not fully allow for the movement of bedforms (shoals, sandbars, channels) at the ADCP location.

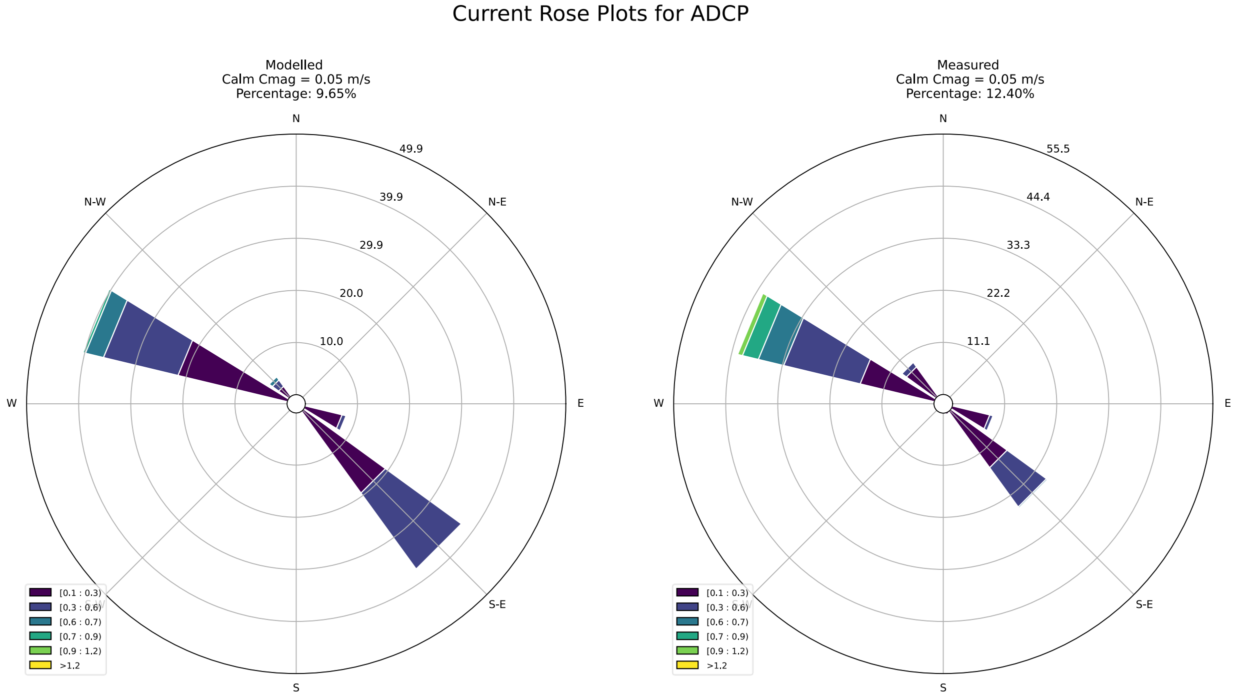


Figure 3-12 Current Speed Roses (Modelled (left) and Measured (Right) (2018 ADCP Collection Period)

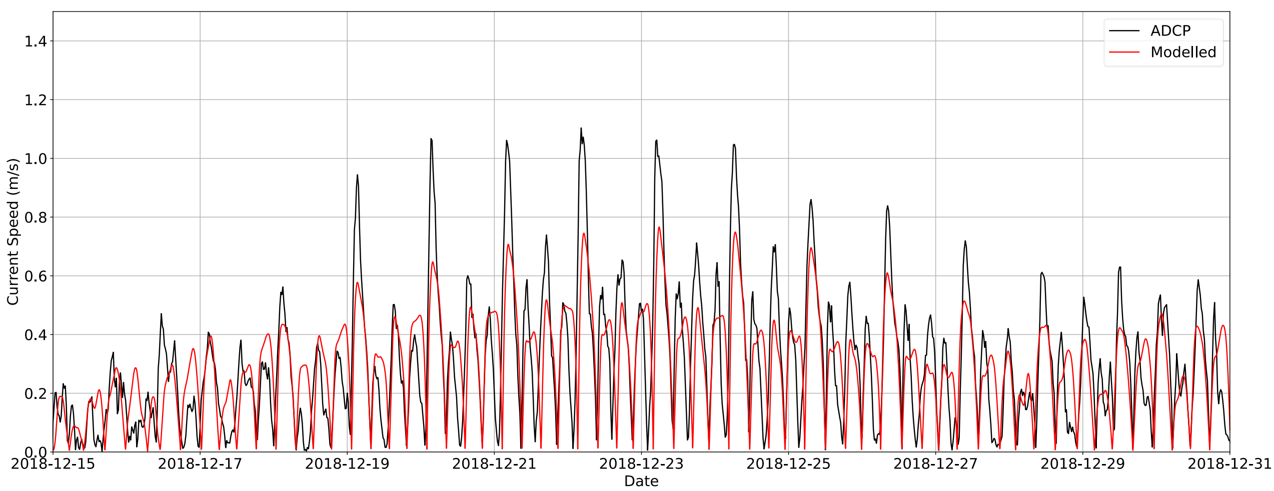


Figure 3-13 Current Speed calibration (2018 ADCP Collection Period)

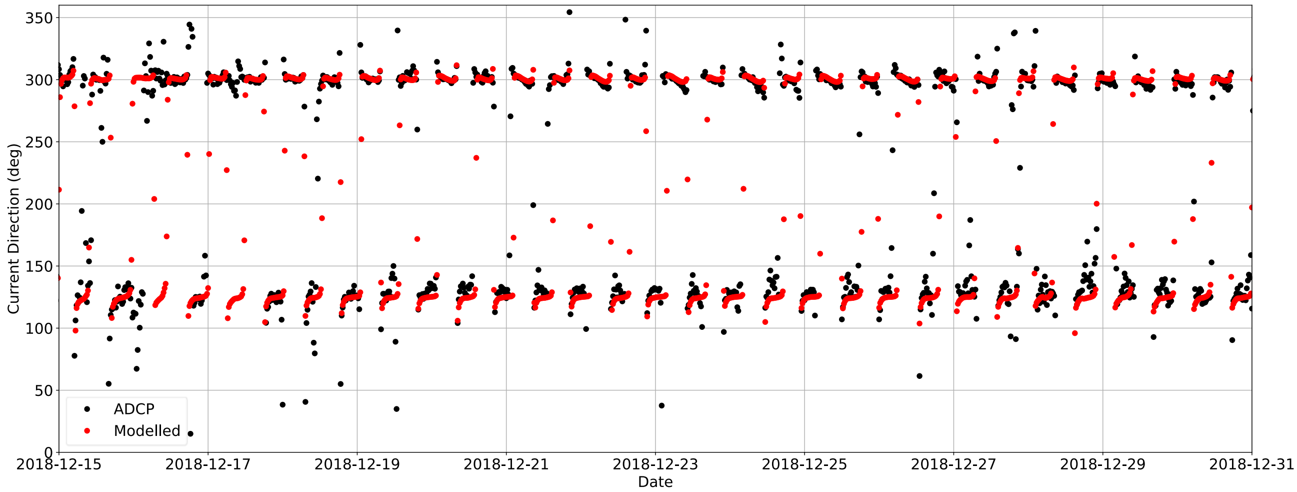


Figure 3-14 Current Direction calibration (2018 ADCP Collection Period)

3.3 Wave Model

The Spectral Wave (SW) model was developed using the regional mesh to replicate the attenuation of the wave field from offshore to nearshore regions. The spatially and temporally varying wave radiation stress was then applied directly to the local model domain and subsequently to the Sand Transport module.

Spectral Wave model calibration and validation was assessed quantitatively and qualitatively to ensure the significant wave heights, periods and directions predicted by the model correlated to measured data, both in magnitude and on a temporal scale.

It should be noted that calibration of a wave model with recorded wave data at a site with a mild to moderate wave climate is a complex undertaking. The local resolution of wind gauges is insufficient to accurately model wind in the region, which is why global wind model re-analysis data has been utilised. The local sea will be affected by local winds on a scale that is difficult to fully replicate in the model set-up.

3.3.1 Calibration

A comparison of modelled significant wave heights and peak spectral wave periods against measured data sourced from the Lucinda Wave Rider Buoy during its 1995-1996 deployment. The calibration period for wave height was 1st January 1996 through to 14th May 1996. This time period captured a number of relatively large peaks and various periods of relatively calm waters. This waverider buoy did not capture information on wave direction.

Typical Hs values are in the range of 0.25 – 1.10m, with associated peak wave periods ranging from 3 – 17.5s. The spectral wave model is considered to perform reasonably well for the chosen period given the small wave heights, and appears apparently capable of capturing peaks in the wave data, likely to be responsible for much of the wave energy capable of mobilising sand in the area of interest.

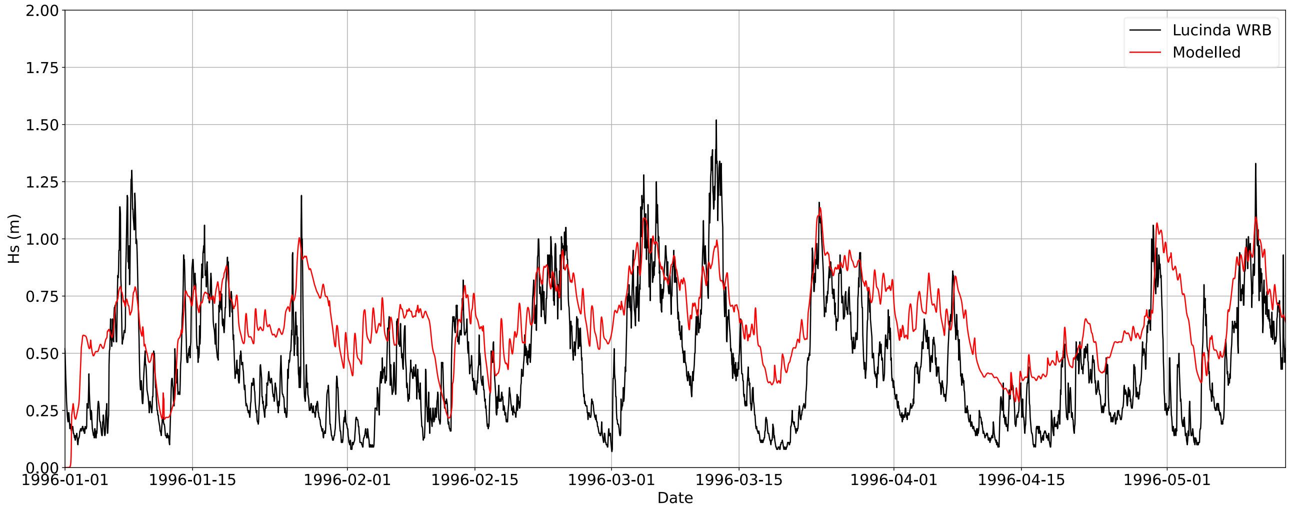


Figure 3-15 Significant Wave Height calibration (Lucinda Wave Rider Buoy)

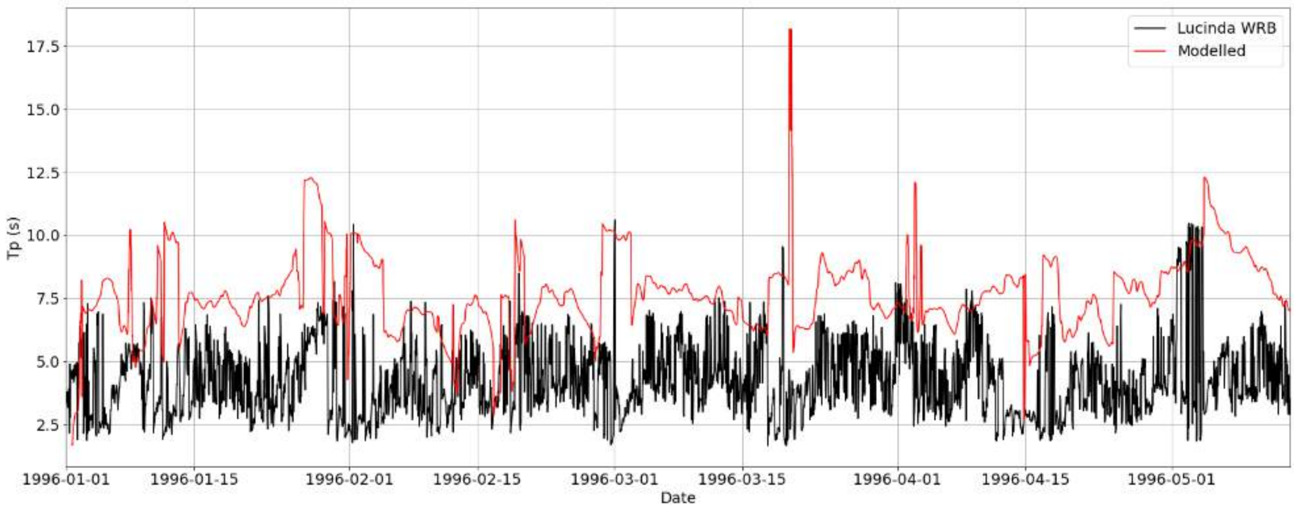


Figure 3-16 Peak period calibration (Lucinda Wave Rider Buoy)

3.3.2 Validation

A higher quality and longer time period dataset is available at the Townsville Waverider Buoy. This dataset is in open water (still protected by offshore islands and the Great Barrier Reef), however, it is more exposed to larger waves. The model shows an excellent correlation to the Townsville waverider buoy over the same calibration period, with modelled waves aligning well with measurements, as shown in s 3-17 and .

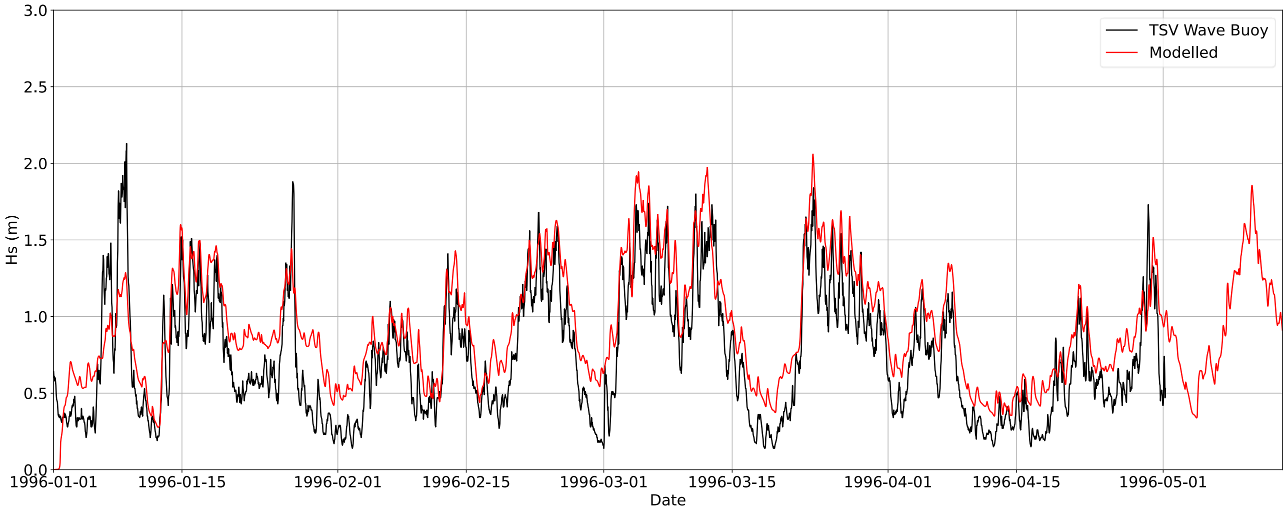


Figure 3-17 Significant Wave Height validation (Townsville Wave Buoy)

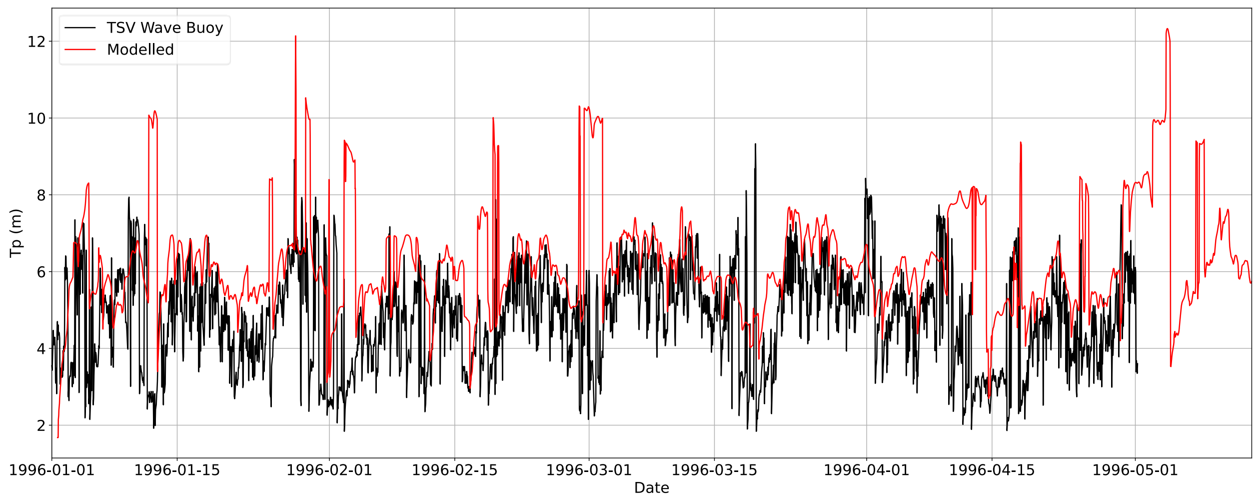


Figure 3-18 Peak Period validation (Townsville Wave Buoy)

4 MORPHOLOGICAL MODEL SETUP

The Sand Transport Module of MIKE 21 has been utilised to simulate the resulting transport of non-cohesive sediments on the seabed based on the mean horizontal flow conditions as coupled with the hydrodynamic module calculations. Additionally, the wave radiation stresses representing wave-driven currents are applied to the hydrodynamic module in conjunction with simulated Significant Wave Height (Hs), Peak Wave Period (Tp), and Peak Wave Direction taken from the regional wave model.

The setup and results of the baseline model are discussed in this section, with the impacts of the proposed dredged channel and coastal structure discussed in Section 5.

Figure 4-1 below shows the general arrangement of the model setup, with the mesh, sediment inflow boundaries and other input parameters noted. Figure 4-2 also shows the initial condition bathymetry for the model in the key area of interest, predominately based on the 2023 detailed bathymetric survey. Model bathymetry is a key input given that the modelling focuses on morphological changes.

This section of the report includes morphological modeling, which is subject to certain limitations and uncertainties inherent in the modeling process. While every effort has been made to ensure the accuracy and reliability of the results, it should be noted that even the highest quality morphological modelling is typically subject to variability of 50 – 100%, and results should be viewed taking this into account. Efforts have been made to calibrate and validate the model against available data; however, the extent of calibration and validation is constrained by the availability and quality of such data. Consequently, the model may not be fully representative of all conditions or scenarios. The results of the morphological modeling presented in this report should be used with caution. They are intended to provide insights and support decision-making but should not be solely relied upon for critical decisions without consideration of the inherent uncertainties and potential need for further validation.

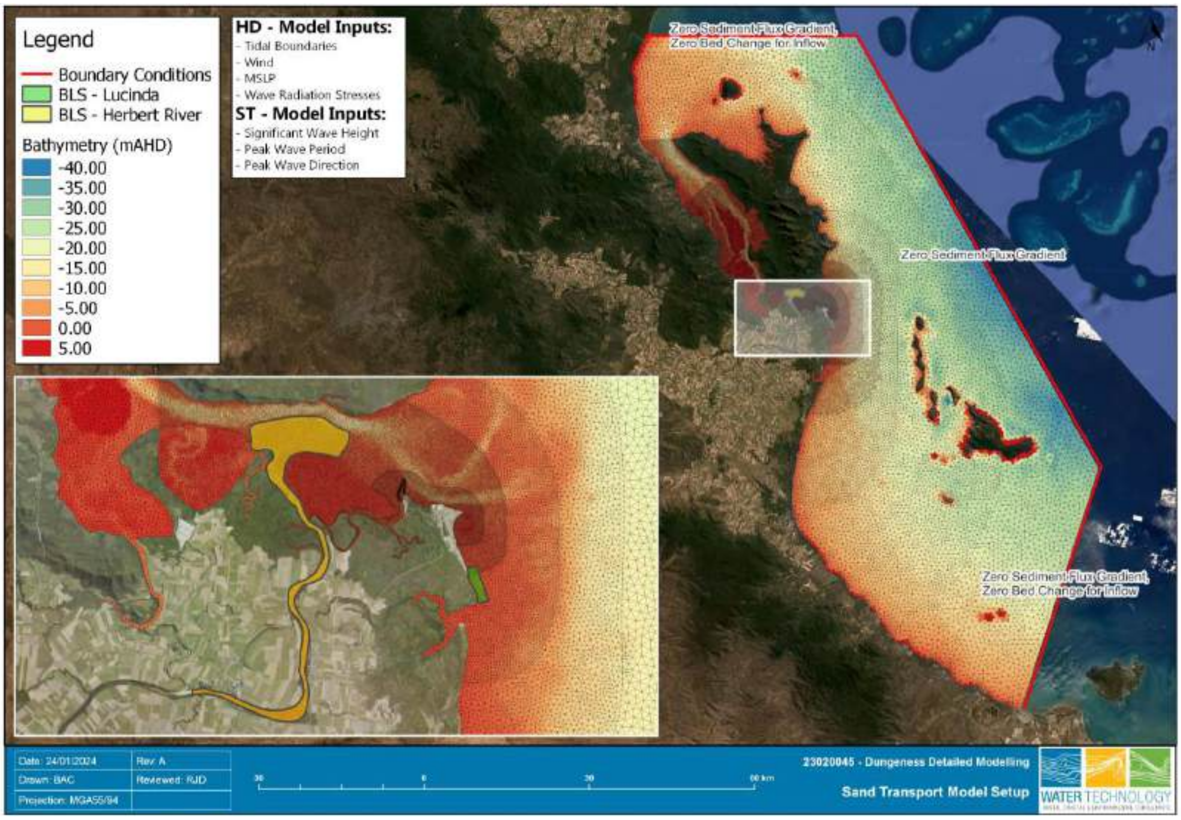


Figure 4-1 Sediment Transport Model Arrangement

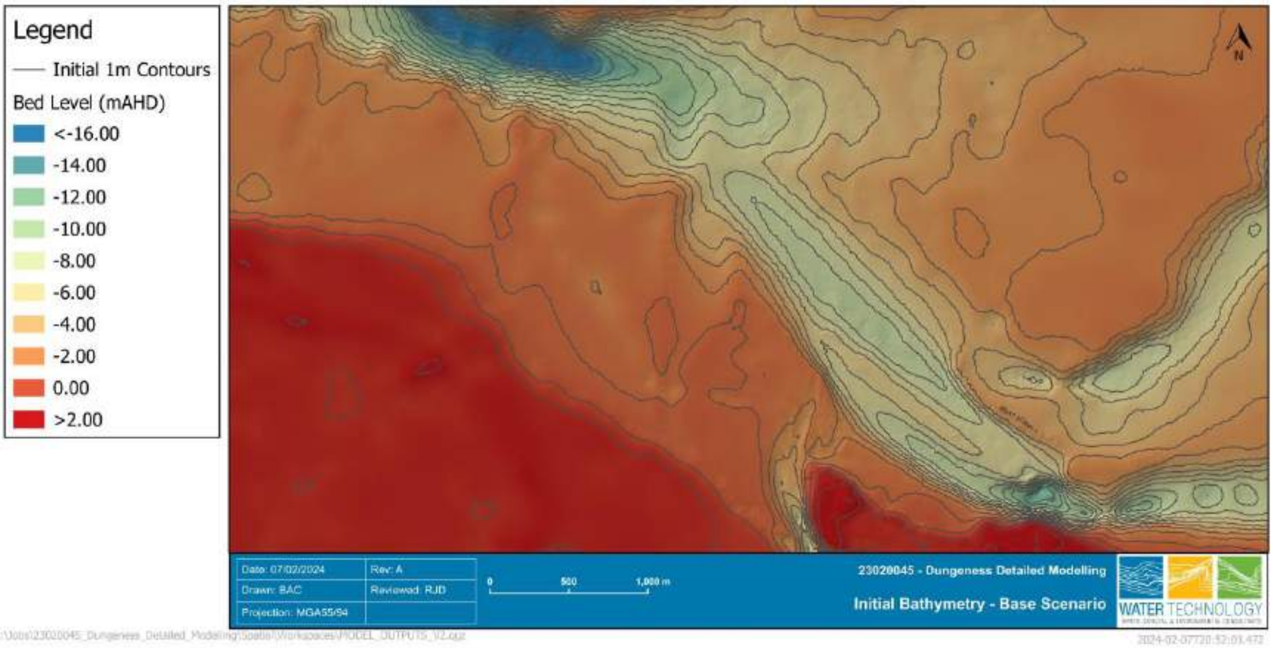


Figure 4-2 Model initial bathymetry in key area of interest

4.1 Scenario Period

An analysis of the Southern Oscillation Index (SOI) over the past 20 years was used to develop representative boundary and model input conditions to use in long-term morphological simulations. The monthly SOI from year 2004 to 2024 is shown below in Figure 4-3. Sustained SOI values greater than +7 (highlighted blue area) are indicative of a La Nina episode, while sustained SOI values lower than -7 (highlighted red area) are indicative of an El Nino episode.

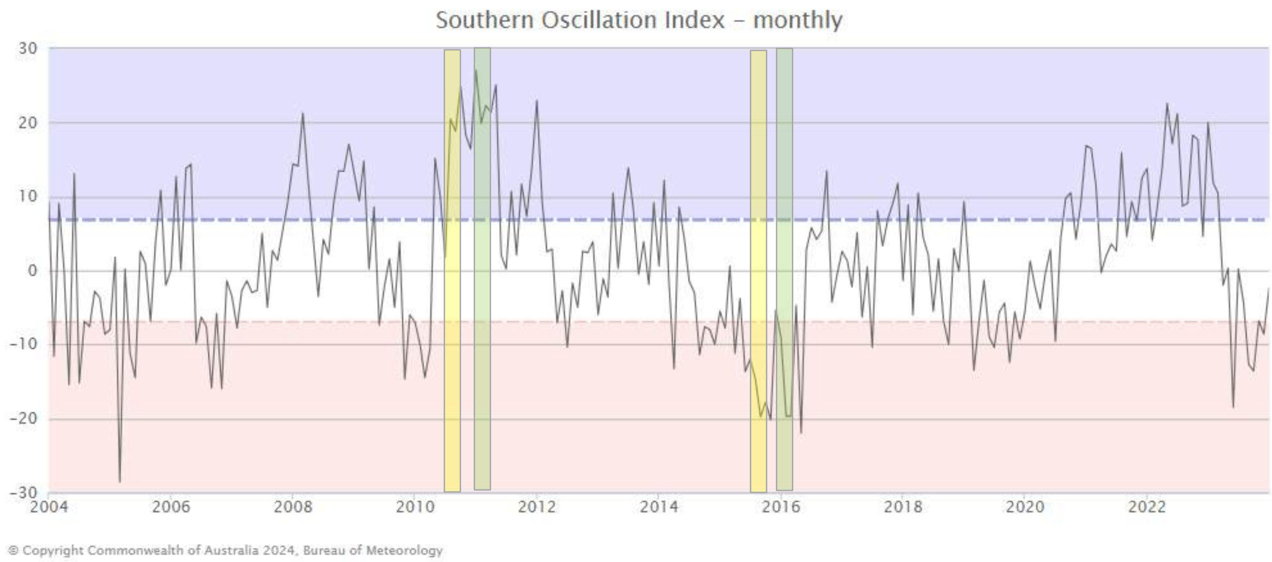


Figure 4-3 Monthly Southern Oscillation Index (SOI) (Bureau of Meteorology, 2024)

The Townsville Wave Buoy long term dataset was used to identify typical wet and dry season variations in wave conditions for the region. The regions highlighted in yellow, and green on Figure 4-3 have been determined as 'typical' La Nina (which is at peak condition between 2010-11) and 'typical' El Nino (which is at peak condition between 2015-2016) dry season and wet season conditions respectively. The periods are as follows:

- La Nina (2010-2011 period):
    - Dry Season: 01/06/2010 to 31/07/2010
    - Wet Season: 10/12/2010 to 10/02/20211
- El Nino (2015-2016 period):
    - Dry Season: 01/06/2015 to 31/07/2015
    - Wet Season: 10/12/2015 to 10/02/2016

Figure 4-4 below compares the significant wave heights at Townsville throughout the selected La Nina dry and wet season periods. While ambient conditions are generally comparable between the two datasets, notably larger storms are present during the La Nina wet season, with three storms producing larger sustained wave height periods, and Tropical Cyclone Yasi is the largest storm wave peak highlighted. These sustained peak wave periods typically last between 24 and 72 hours each. Peak wave directions correlating with larger wave action are typically from the north and east in the wet season, while larger waves typically arrive from the east in the dry season.

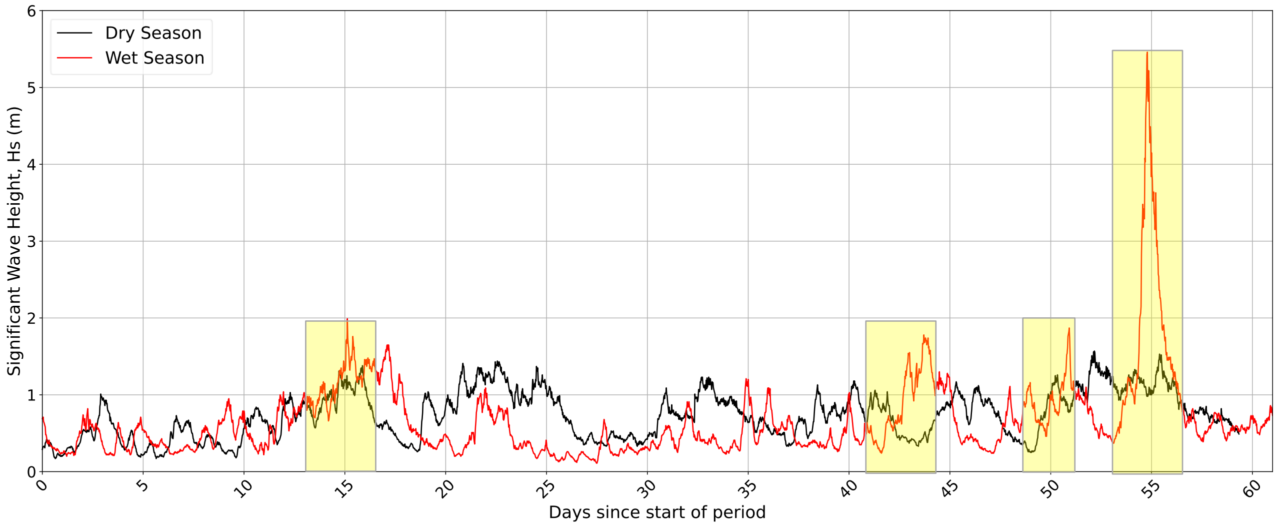


Figure 4-4 Significant wave height comparison during La Nina wet and dry seasons at Townsville Wave Buoy

Figure 4-5 below shows a comparison of the significant wave heights at Townsville throughout the selected El Nino dry and wet season periods. As this is a 'peak' El Nino condition period where conditions are typically mild, wave heights between the dry and wet seasons are generally comparable with only one large wave height peak in each dataset approaching 2 meters and storms lasting less than 48 hours.

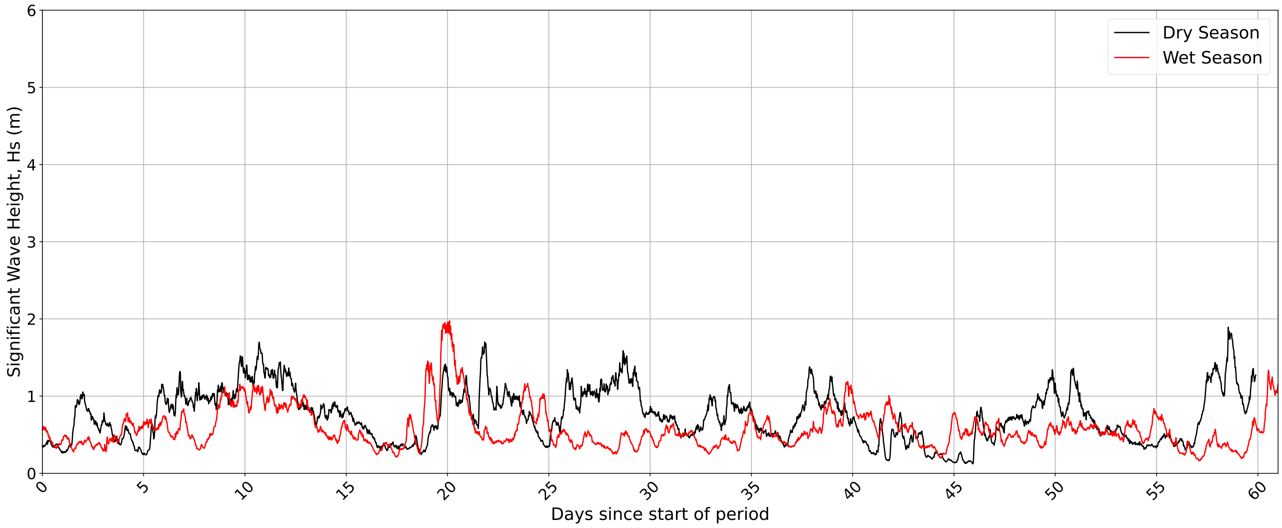


Figure 4-5 Significant wave height comparison during El Nino wet and dry seasons at Townsville Wave Buoy

Note that the data used in this analysis is taken from the Townsville wave buoy and used to indicate typical conditions in the region. Actual wave heights at the study site will likely vary from those shown above due to the sheltered nature of the site from the east and southeast by the Orpheus and Palm Island groups, inshore from the Great Barrier Reef.

The dry and wet season periods for each La Nina and El Nino condition were then repeated to generate a 5-year model run representative of a stormier La Nina period and a more benign El Nino period. In summary, the baseline scenarios run were:

- 01 – La Nina (2010-11 wet/dry input conditions), repeated for 5-year runtime
- 02 – El Nino (2015-16 wet/dry input conditions), repeated for 5-year runtime

A comparison of results between the La Nina and El Nino baseline runs is also provided in the sensitivity testing section 4.7.1.

4.2 Model Definition

The model utilises the 'Wave and Current' model definition. This method calculates sand transport rates by interpolating a user-generated specified sediment transport table. The table is generated so that any combination of bathymetry, current, wave and sediment conditions appearing in the simulation are within the range defined in the transport table (DHI, 2023). When using the 'Wave and Current' model definition, the sediment transport total load is used, including resolving wave-generated currents and tide-generated currents to resolve sediment transport calculations.

4.3 Sediment Properties

Analysis completed on the collected samples from the region in 2023 indicates a relatively consistent bed material as a medium grain sand with some silt content. The median grain diameter was identified as 0.57mm across all sites, which is considered representative of the region. The sample spread of grading suggests a grading coefficient of 2.48 to be used to capture grading of the material in the model.

4.4 Sediment Sources

As this model utilises the 'Wave and Current' model definition, the transport rates in the sediment transport table are calculated under the assumption that the concentration profile is fully developed. Therefore, it is not possible to directly add sediment transport from a source load into the system.

To capture the sediment entering the system from the Herbert River (totalling approximately 930,000 t per year (Bartley et al., 2004)), a bed level source representing the sediment is used to input into the domain. Here, the total sediment per year was applied to the Herbert River and Herbert River fan delta section in the model set to deposit an amount of sediment equalling 930,000t per year into the domain, in addition to the bed erosion calculated in the simulation.

Similarly, at the south-eastern boundary, it is apparent that there is a net northerly sediment transport driven by waves from the south-east. An average net longshore transport of 20,000m^3 has been estimated moving north each year at Lucinda, and this rate was applied to the southeast Lucinda beaches intertidal area in the model.

4.5 Morphology Validation

Validation of the morphologic model was undertaken against high-level processes that are known to occur. Validation opportunities are limited, given:

- Most of the morphological change that can be validated occurs underwater. The resolution, extent and accuracy of historic bathymetric surveys has typically been assessed as insufficient for quantitative model validation.
- The baseline bathymetry in the modelling is based on present-day (2023) hydrographic survey. Historic validation is difficult to achieve, given the initial bathymetry condition is unknown.

Therefore the morphology model was attempted to be validated against known ongoing processes, including:

- Spit erosion – multiple lines of evidence suggest erosion of the Dungeness Spit has been ongoing for many years and continues to contemporary times. Stage 1 reporting utilised aerial imagery to assess the spit erosion rate since 1956 as approximately 8m per year, with that value higher in recent times. A survey of some of the Spit is also available at a reasonable resolution.
    - The 5-year model runs for La Nina and El Nino scenarios clearly show erosion of the Spit at a location and similar magnitude to that which has been historically experienced and would be expected to continue.
    - Surveys are available of the Spit for 2014 and 2019. This has been compared to model results for the 5-year La Nina simulations. The amount of bed lowering in the intertidal zone (approximately 1m) aligns with the bed lowering experienced in the 5-year model simulations. An example section comparing these datasets is shown in Figure 4-6.
    - Historical satellite imagery is also available for the site through DEA Coastlines, as detailed in the Stage 1 Reporting. The estimated recent Spit erosion is in the order of 10m (between 2016 and 2021). The 5-year model simulations show erosion, at mean sea level, of approximately 12.1m over these 5 years. This comparison is shown in Figure 4-7, noting that the model bathymetry is starting from the 2023 'post-erosion' baseline.

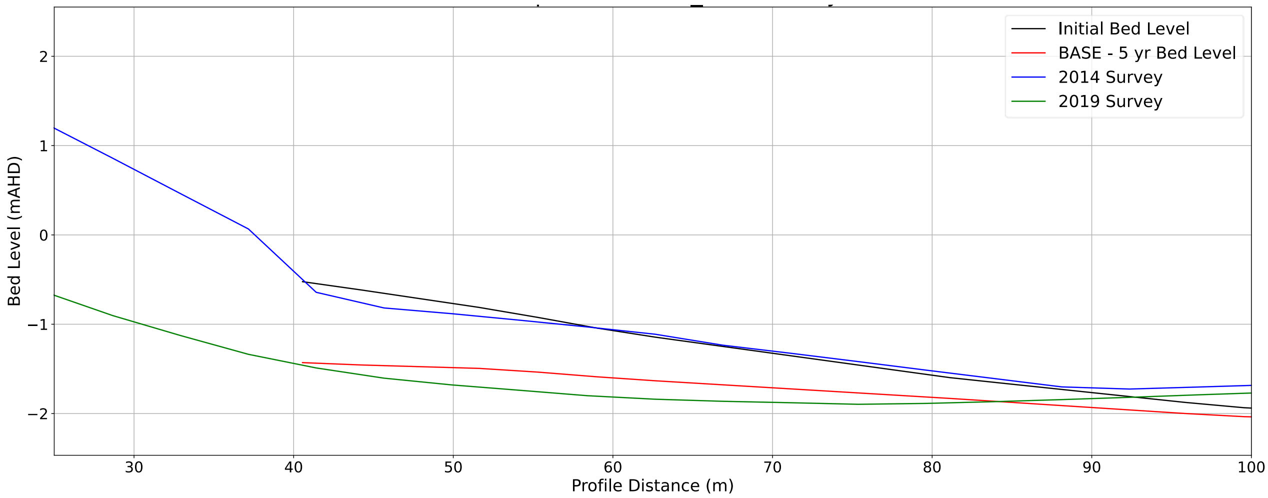


Figure 4-6 Model validation comparison to survey

Figure 4-7 Satellite imagery comparison to modelled results for validation

- Another validation pathway relates to the Enterprise Channel, given that there has been some historic survey in the channel. Surveys of the channel (2014, 2019 and 2023) have varying extents and quality control. 2014 – 2019 shows approximately 5,000m^3 of channel infill per year, whereas 2019 – 2023 shows approximately 7,300m^3 of channel infill per year. The distribution of the infill in Enterprise Channel is in a similar location and within a similar volumetric range of the modelling, which the model estimates to:

- A net infill of approximately 12,000m^3 / year during La Niña periods
- A net infill of approximately 14,000m^3 / year during El Niño periods

Comparisons to survey difference plots are shown in s 4-8, 4-9, and below. Note that the surveys' quality and resolution are variable and not carried out to hydrographic navigational survey standards across the study area.

Figure 4-8 Survey Difference plot 2014 to 2019

Figure 4-9 Survey Difference Plot 2014 to 2023

Figure 4-10 5-year model simulation difference plot - survey area clip in black outline for comparison to previous plots

Overall, while minimal quantitative validation data is available for the morphological model, the model does correlate to existing and expected key morphologic trends.

4.6 Baseline Morphology Model Results

The site is separated into 13 zones to summarise the baseline modelling outcomes:

- Zone 1 – Western Island bank, facing north to Hinchinbrook Channel
- Zone 2 – Western Island shoals and intertidal zone
- Zone 3 – Western Island bank, facing east to Enterprise Channel
- Zone 4 – Enterprise Channel entrance
- Zone 5 – Enterprise Channel East Bank, Upstream
- Zone 6 – Enterprise Channel East Bank, Dungeness
- Zone 7 – Dungeness Beach Spit
- Zone 8 – Dungeness Beach
- Zone 9 – Dungeness Beach shoals and intertidal zone
- Zone 10 – Lucinda Jetty to Dungeness Beach Seawall
- Zone 11 – Lucinda Jetty Beach
- Zone 12 – Hinchinbrook Main Channel

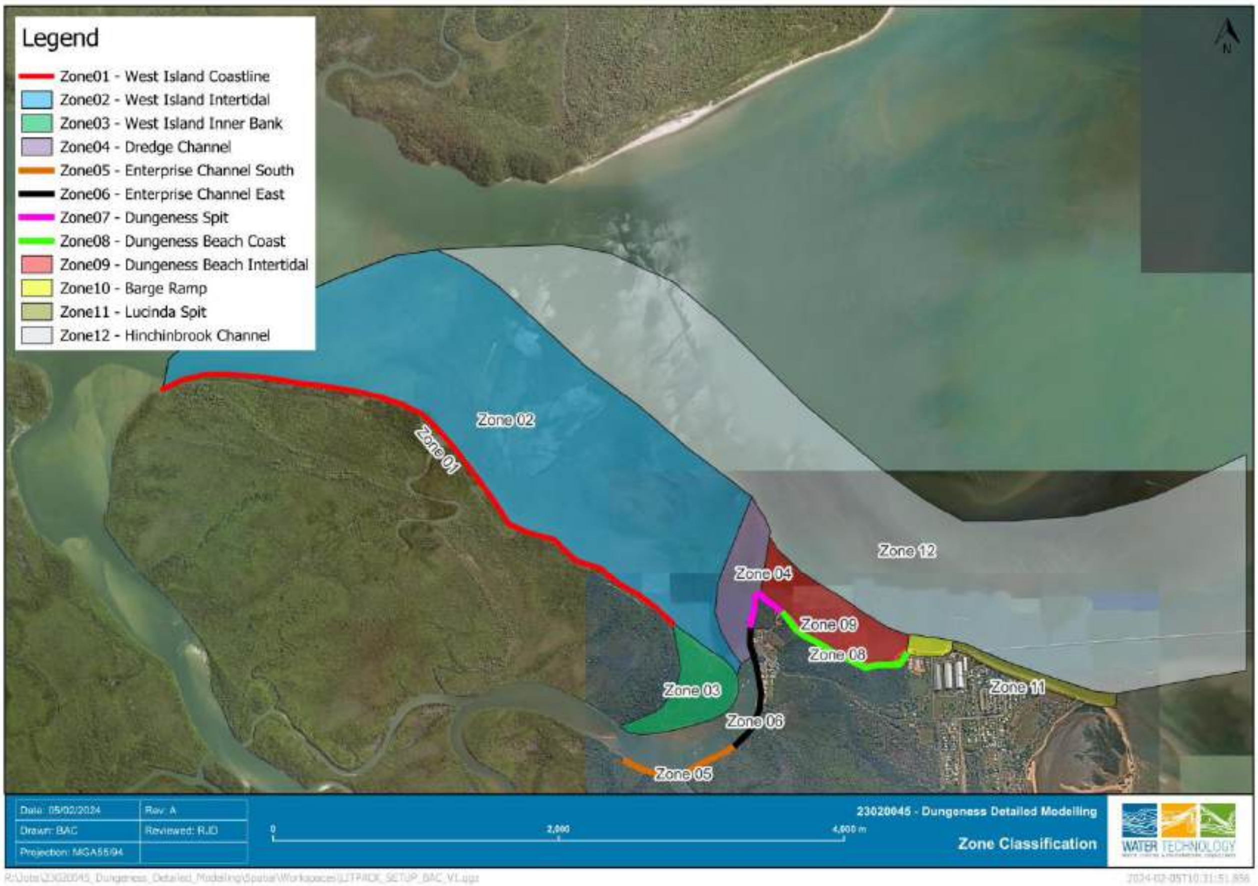


Figure 4-11 Zone classification for morphology analysis

The modelling suggests that the model domain outside these 12 primary zones of influence has minimal interaction with the focus areas of this project's scope. The ongoing dynamic nature of the waterways, mainland coastal fringe and Hinchinbrook Island hydrodynamics, waves and morphology are likely to remain in dynamic equilibrium unaffected by changes to Enterprise Channel.

4.6.1 Zone 1, 2 and 3 – Western Island

This section summarises the morphological baseline results for Zone 1, 2 and 3, all related to the island between the Herbert River and Enterprise Channel, which is dominated by mangrove forest and nearshore shoals. Access to this island is difficult by boat or on foot due to the wide fronting shoals and crocodile hazards.

In Zone 1, the contemporary history of the site (based on satellite imagery) suggests a general trend of the overall stability of the Western Island bank, with some minor bank erosion noted in historical imagery (0 – 0.6m of bank erosion/year). This mild erosive climate is also captured in the 5-year morphologic modelling scenario with:

- A net loss of approximately 600m^3 / year during stormier La Niña periods
- A small net gain of approximately 60m^3 / year during more mild El Niño periods

Wave energy is modelled to be typically from the ENE direction, with a wave height that rarely exceeds 20cm. These small values are likely within the margin of error of the morphological model.

Offshore of Zone 1, the model suggests that over the 5-year morphological model run, the Zone 2 Western Island shoals accrete with an estimated:

- A net accretion of approximately 20,000m^3 / year during La Niña periods (over a 410 Ha area, approximate average of 5mm/year bed level shift)
- A net accretion of approximately 15,000m^3 / year during El Niño periods (over a 410 Ha area, approximate average of 4mm/year bed level shift)

Zone 3 is on the Enterprise Channel side of the Western Island. This part of the Western Island has grown substantially from the 1950s to the early 2000s. Based on aerial imagery showing minimal growth, this area has stabilised in the last 10 – 15 years. The modelling suggests a zone of much lower tidal currents adjacent to zone 1 during peak flood and ebb tides where there is a flow split between Enterprise Channel and the Western Island, conducive to the deposition of mobilised sediment during flood tides. A similar process also occurs during an ebb tide, in reverse.

The model suggests that over the 5-year morphological model run, the bank slowly accretes with an estimated:

- Net accretion of approximately 400m^3 / year during La Niña periods
- Net accretion of approximately 100m^3 / year during El Niño periods

It is therefore expected that the bank of Zone 3 would continue to increase in size, however, this growth rate is very low, compared to the historical rapid growth. These small values are likely within the margin of error of the morphological model.

Overall, the Western Island appears to be in a state of dynamic equilibrium, which is also observed in the available historical datasets and replicated in the morphological modelling. In summary:

- Zone 1 faces minor net erosive pressures, however these are so small to be within the margin of error of the modelling.
- Zone 2 generally experiences the growth of shoals and acts as a sediment sink, thought to be predominately due to the excess sediment incoming from Herbert River.
- Zone 3 may also continue to experience deposition (however values are within the margin of error of the modelling), with excess sediment from Zone 2 being pushed into this zone given the favourable tidal flow conditions.

While there are some apparent trends with sediment volumes, these sediment transport rates are very minor and likely to vary from year to year. Tidal velocities are very slow due to the extent of shoals on the inner banks, and waves do not readily penetrate the site. In general, the western island is a low energy site unlikely to experience rapid changes.

Of note is that the modelling suggests that there is no strong sediment pathway from the Spit and Dungeness Beach (Zone 7, 8, and 9) towards this western mangrove island. This is not obvious from the baseline model results; however, it is clearly shown below in Section 5 impact assessment – implementing a breakwater at the Spit results in minimal change to erosion in Zone 1, and an increase in deposition in Zone 2. The breakwater also does not experience excessive sediment build-up on its updrift side. This suggests no strong net sediment pathway across the Enterprise Channel from east to west.

A summary of the sediment transport pathways for the Western Island, overlain on the morphological modelling results for the 5-year La Nina scenario, is shown in Figure 4-12 below.

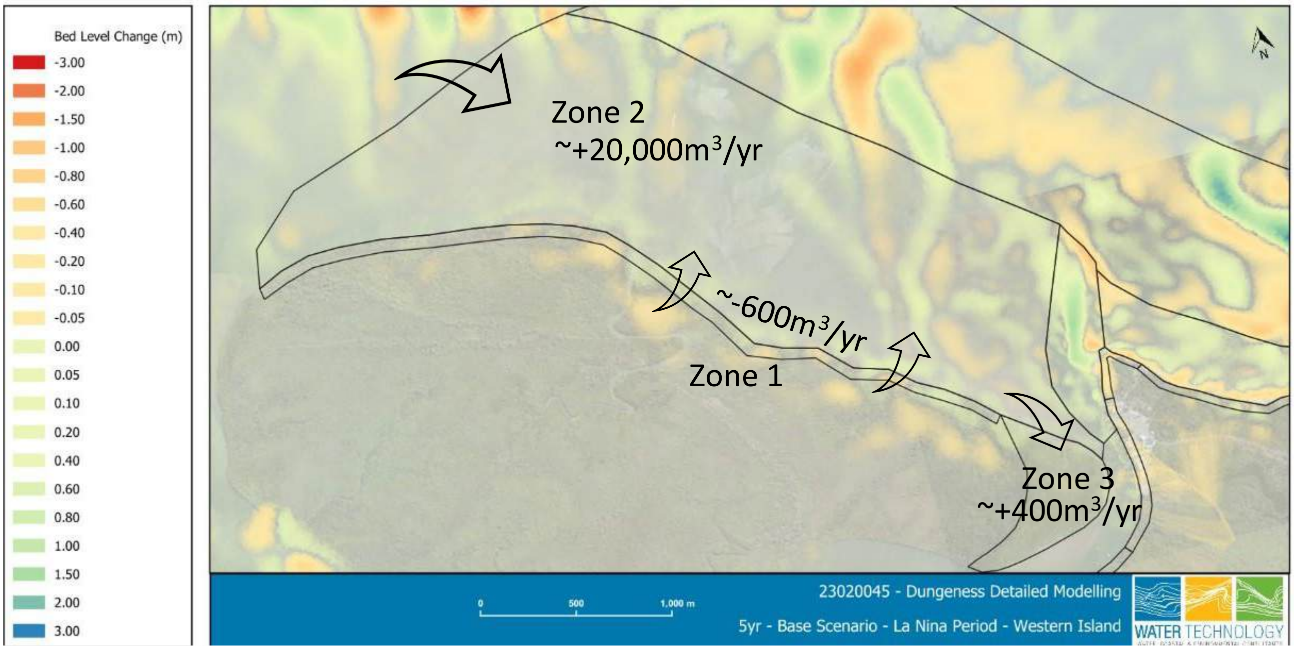


Figure 4-12 Estimated net sediment transport flows at the site during La Nina. The numbers are all lower during El Nino periods.

4.6.2 Zone 4 – Enterprise Channel

As emphasized in the stage 1 reporting, this project has arisen to improve boating safety in this key zone. Based on historical surveys and data captured during the morphology validation, the channel has been filled in recent years. The model captures this trend, predicting an infill rate of:

- A net infill of approximately 12,000m3 / year during La Niña periods (See Figure 4-13 for model results for this scenario and zone)
- A net infill of approximately 14,000m3 / year during El Niño periods

This infill is thought to be related to sand pushed from Dungeness Beach and the nearshore zone during flood tides driven by waves from the north-east.

When compared to the case that includes a ‘coastal structure’ (described in Section 5), it appears that most of the material filling the dredged channel is from Dungeness beach and nearshore zone (Zones 8 and 9), and eroded from the Spit (Zone 7).

Dungeness Channel effectively acts as a sediment ‘sink’ which is steadily filling over time, predominately driven by incoming sediment from the east. A summary of this transport pathway is depicted in Figure 4-13.

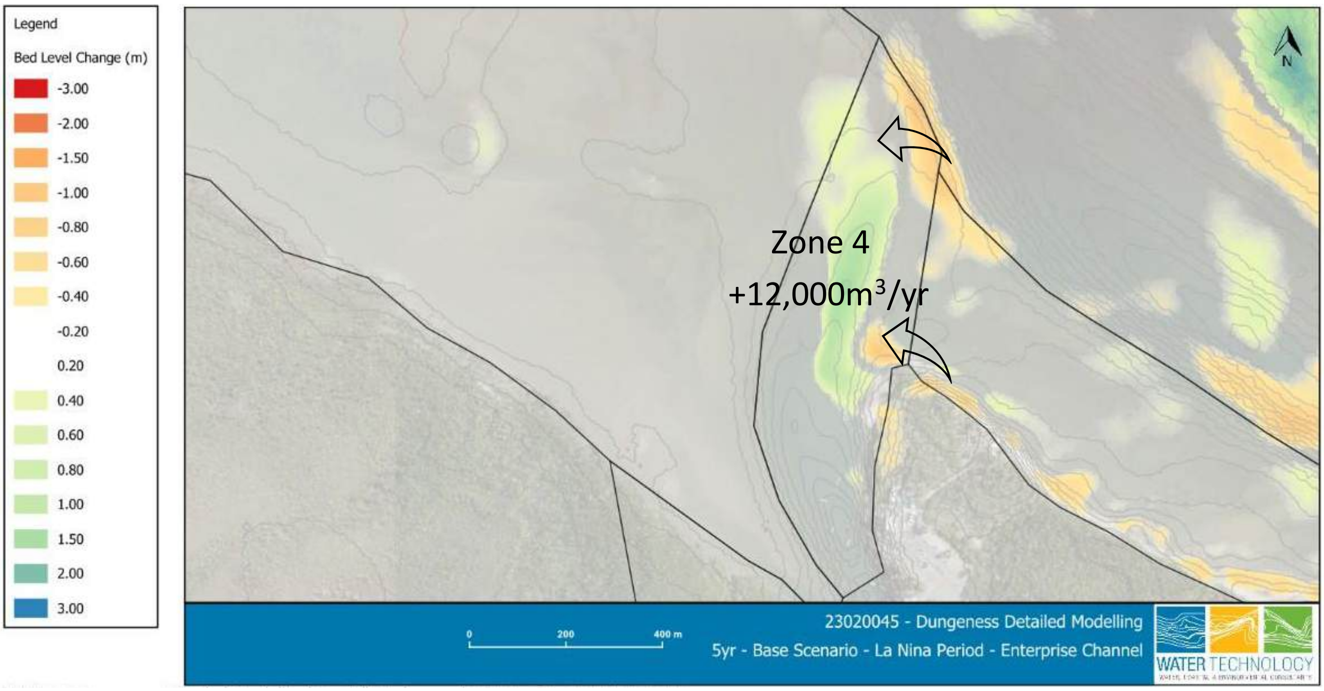


Figure 4-13 Sediment transport pathway, Zone 4

4.6.3 Zone 5 and 6 – Enterprise Channel East Bank

These zones were included in the assessment to review the Enterprise Channel eastern bank upstream of the Spit. A review of contemporary processes at this outer bend of the channel suggests that it remains relatively stable and is also partially armoured with a seawall. The model also implies this is the case, with no notable morphological changes recorded in all modelling scenarios.

4.6.4 Zone 7 – Dungeness Beach Spit

One of the most apparent visual morphological changes in the Dungeness area is that the spit has rapidly eroded over at least the last 70 years. This erosion was a key component of the model validation described in Section 4.5 above. Stage 1 reporting estimates erosion at an average rate of approximately 8m / year, estimated at approximately 2,500 m^3 / yr between 2014 and 2020.

This erosion is apparent in the modelled scenarios, with a modelled:

- Net erosion of approximately 1,400m^3 / year during La Niña periods
- Net erosion of approximately 1,000m^3 / year during El Niño periods

The decreased erosion during El Niño periods aligns with the expected milder wave conditions, minimising erosive pressures on the Spit. The Stage 1 reporting included a cause-and-effect analysis that suggested major cyclones likely have an impact on erosion rates of the Spit, which aligns with the modelling of increased erosion during a La Niña period.

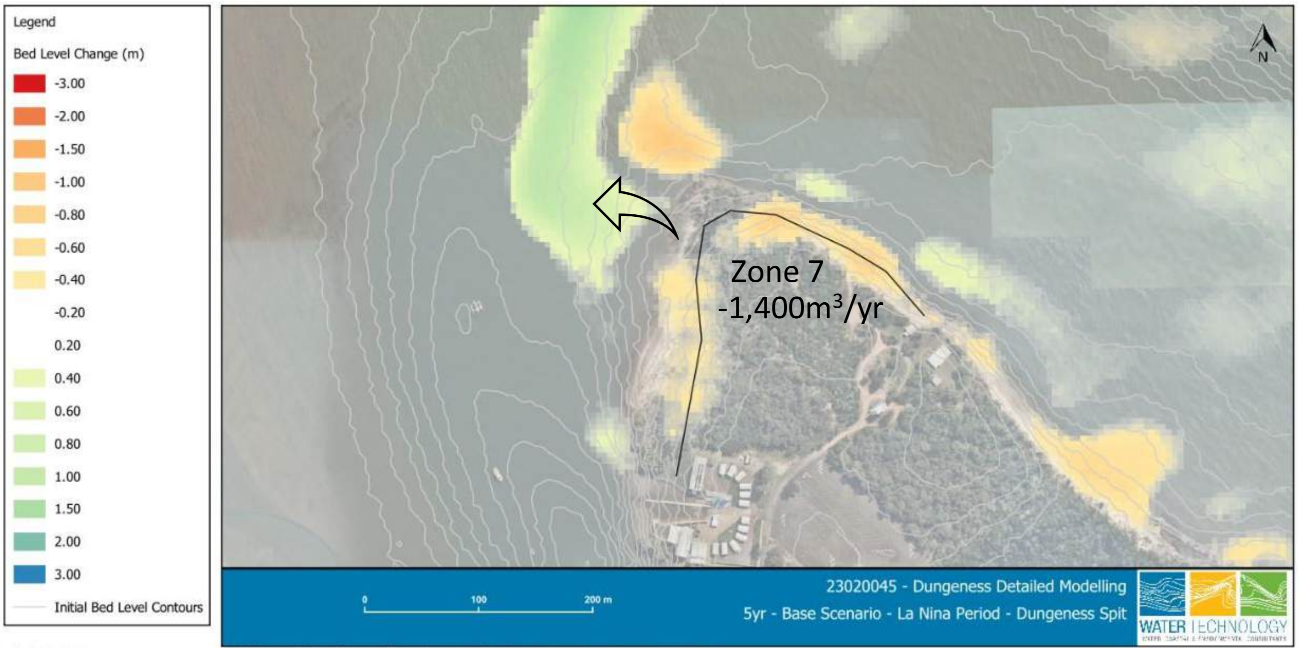


Figure 4-14 Zone 7 morphological model results and estimated approximate sediment transport rate

4.6.5 Zone 8, 9, 10, 11 – Dungeness Beach

The eastern beaches updrift of the Spit and dredge Channel are considered in this section. Similar to the Spit, the Zone 8 beach compartment that spans from the Spit (Zone 7) to the boat ramp and car park to the east has generally been eroded in contemporary times based on aerial imagery. This rate of erosion is up to 1.0m/year (based on aerial imagery), estimated in the Stage 1 reporting at approximately 4,000m^3/year. The modelling predicts slightly lower rates of erosion than the estimated volumes, with:

- Erosion of approximately 3,400m^3 / year during La Niña periods
- Erosion of approximately 2,700m^3 / year during El Niño periods

Figure 4-16 shows the morphological model outputs for this zone.

Offshore of Zone 8 sits another key compartment of the Dungeness Beach offshore shoals and intertidal zone, Zone 9. The modelling suggests this intertidal zone is accreting, with:

- Net accretion of approximately 6,600m^3 / year during La Niña periods
- Net accretion of approximately 6,200m^3 / year during El Niño periods

The accretion in this zone is thought to be explained by a net influx of sediment from the east. A LITPACK model was developed to supplement the morphological model results in this zone (and Zone 9, 10 and 11). LITPACK is an in-line longshore sediment transport module, part of the MIKE software. LITPACK enables a more detailed understanding of sediment transport fluxes across specific selected profiles. LITPACK inputs include waves, water levels and tidal currents (extracted directly from the existing spectral wave and hydrodynamic modelling) applies them to each profile to calculate longshore currents and subsequent sediment transport potential across the profiles. The LITPACK results are shown in Figure 4-15. This shows relatively high sediment transport potential from east to west in Zone 11. This potential transport is reduced in Zone 9 and 10 as the coastline bends to face a more northerly direction. With a more protected site and reduced longshore sediment transport potential, sediment is prone to be deposited in the nearshore zone. This deposition is visible in Zone 9 and 10, however is countered by the predicted foreshore erosion. In summary, Zone 10 is predicted to:

- Net erosion of approximately 500m^3 / year during the La Niña periods
- Net erosion of approximately 400m^3 / year during El Niño periods

These values align with the site observations, with Zone 10 partially armoured to counteract erosive processes.

Further east of Zone 10, Zone 11 is not as protected with high net sediment transport potential. This stretch of beach is a significant sediment source at the adjacent Lucinda Beach Spit, which constantly replenishes the beach from the south, even as sand is stripped from the beach due to high longshore sediment rates to the west. Hinchinbrook Channel also encroaches close to the foreshore in this zone, allowing larger waves to impact the shoreline. As such, it is apparent that this shoreline has been eroding, and a seawall has been built along part of its length. For this beach, the modelling suggests:

- Net erosion of approximately 16,000m^3 / year during La Niña periods
- Net erosion of approximately 13,000m^3 / year during El Niño periods

The estimated balance of sediment flows in this region is shown in Figure 4-16.

Figure 4-15 Net potential longshore drift rates along Dungeness Beach

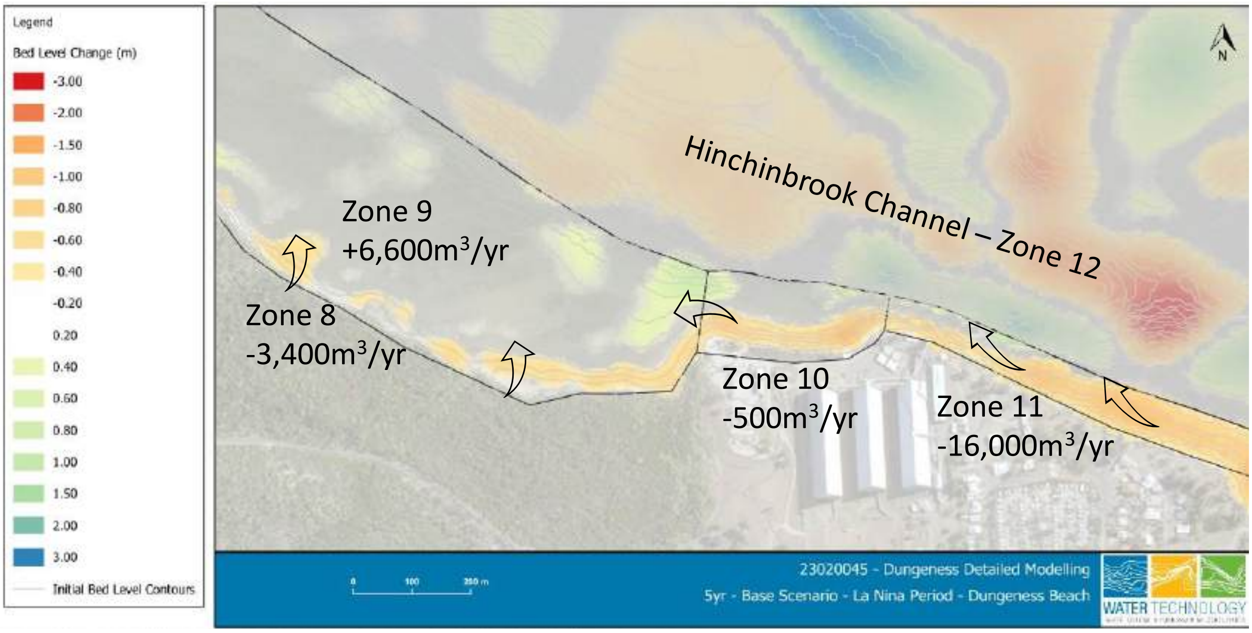


Figure 4-16 Zone 8, 9, 10 and 11 sediment transport pathways

4.6.6 Zone 12 – Hinchinbrook Channel

The broader Hinchinbrook Channel is subject to much more extreme variation in bed level, according to the modelling. The entrance to Hinchinbrook Channel between Lucinda and Hinchinbrook Island is subject to a higher level of wave energy than the rest of the site and also has a high volume tidal prism by a factor of 10 greater than that flowing through Enterprise Channel. As shown in Figure 4-17 below, the model predicts the ongoing movement of the shoals in the Hinchinbrook Channel, a highly dynamic environment.

This is in contrast to a key area of interest, the western mangrove island (Zones 1, 2 and 3), which are much less dynamic, given the protection from waves and currents afforded by the shoals.

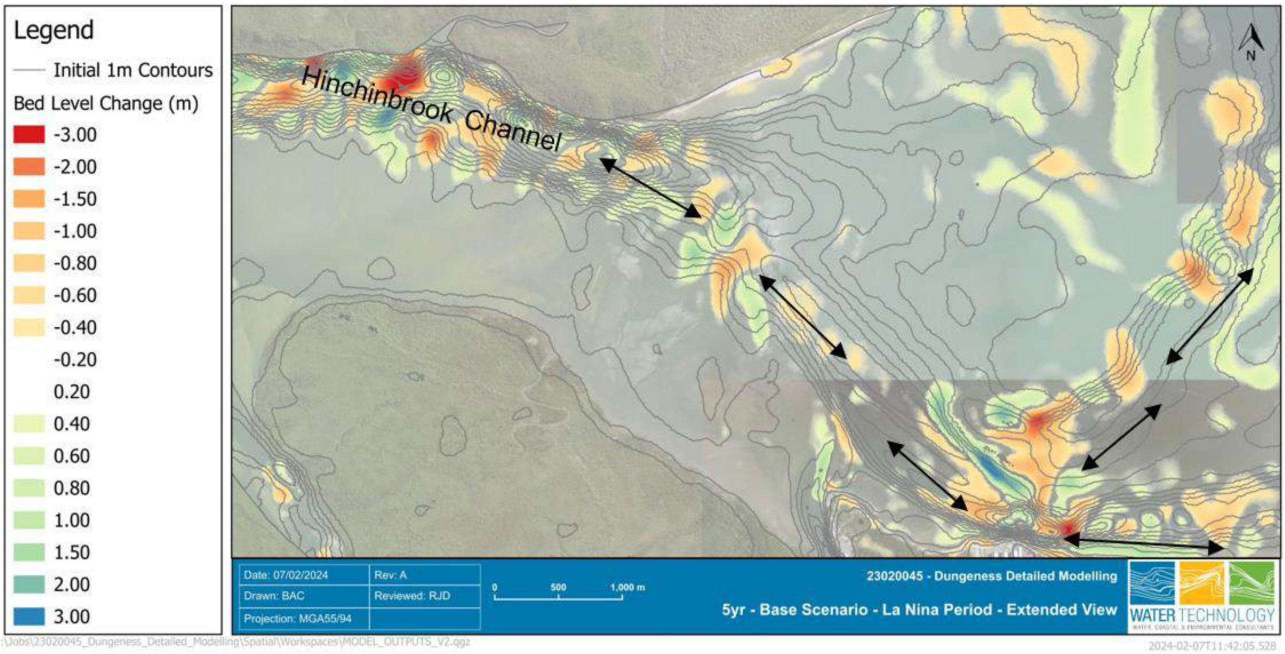


Figure 4-17 Modelled bed level changes in Hinchinbrook Main Channel(s), showing shoals propagating

4.6.7 Sediment Budget

The estimated sediment budget is summarised in Figure 4-18. The figure shows the estimated net sediment transport between compartments. In summary, the modelling suggests:

- The Lucinda Spit and the main Hinchinbrook Channel adjacent (Zones 11 and 12) are in the active coastal zone. There are relatively high rates of sediment transport and movement of shoals in these compartments.
- Further west along Dungeness Beach, longshore transport rates reduce, and sediment transport becomes driven by tides rather than waves. Large shoals offshore of Dungeness Beach (Zone 9) and the Western Island (Zone 2) continue to grow, whilst the silty banks at the Dungeness Spit (Zone 7) and beach (Zone 8) and Western Island (Zone 1) recede slowly.
- Enterprise Channel (Zone 4), where dredging is proposed, acts as a sediment sink between Dungeness Beach and the Western Island shoals (Zone 2 and 9), infilling at a rate of approximately 12,000m^3/year.
- The Western Island offshore shoals are more heavily influenced by the Herbert River sediment influx (rather than incoming sediment from Enterprise Channel or Dungeness Beach), with the shoals estimated to be accumulating sediment at a rate of approximately 20,000m^3/year.

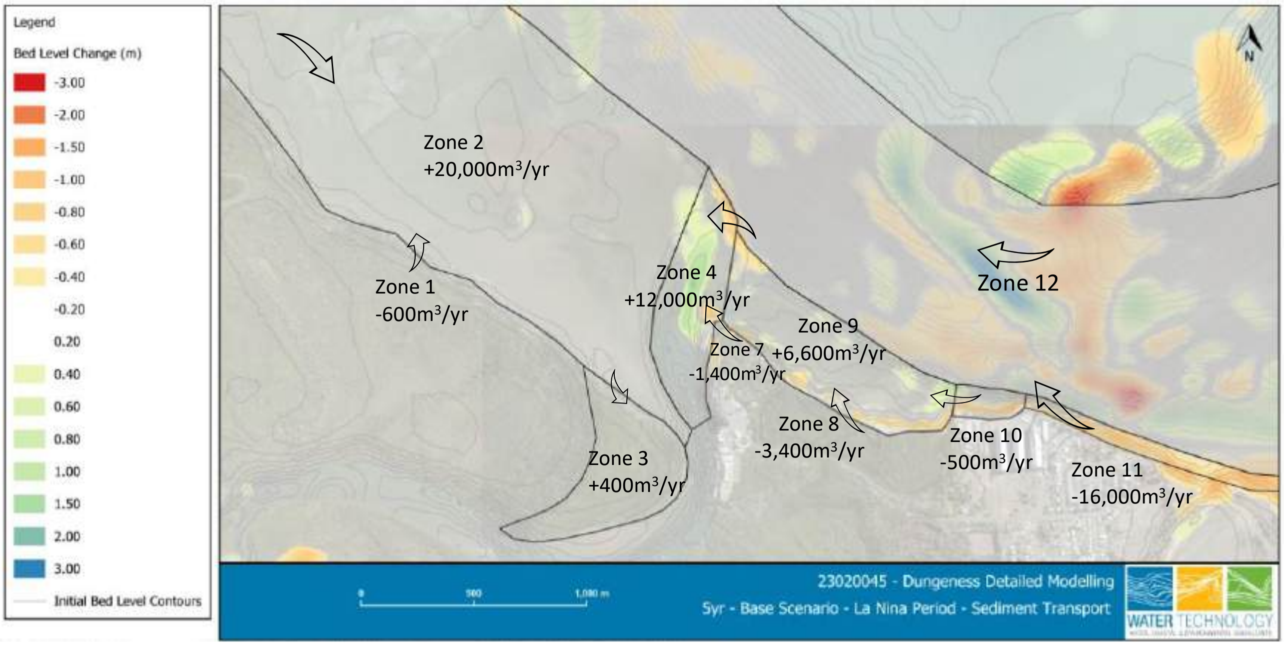


Figure 4-18 Estimated sediment budget based on model outputs

4.7 Sensitivity Tests

4.7.1 El Nino and La Nina comparison

A comparison was made between the more stormy La Nina and the more benign El Nino periods. On a local scale, some impacts were noted with differences between erosion or accretion rates in specific zones, as noted above in Section 4.6.

Typically, there is a notable decrease in erosion rates during El Nino period on Dungeness Beaches, likely due to the mild wave climate establishing slightly less favourable conditions for material mobilisation. Similarly, there appears to be less shoal movement in the Hinchinbrook Channel, especially closer to the entrance, also indicative of fewer storms impacting the shoals.

However, in general, there is not a major difference between the two scenarios. This lack of difference is because the site morphology remains heavily tidally influenced, with tides almost identical between El Nino and La Nina scenarios. Day-to-day wave conditions also remain similar, which act on sands on the shoals and coastline.

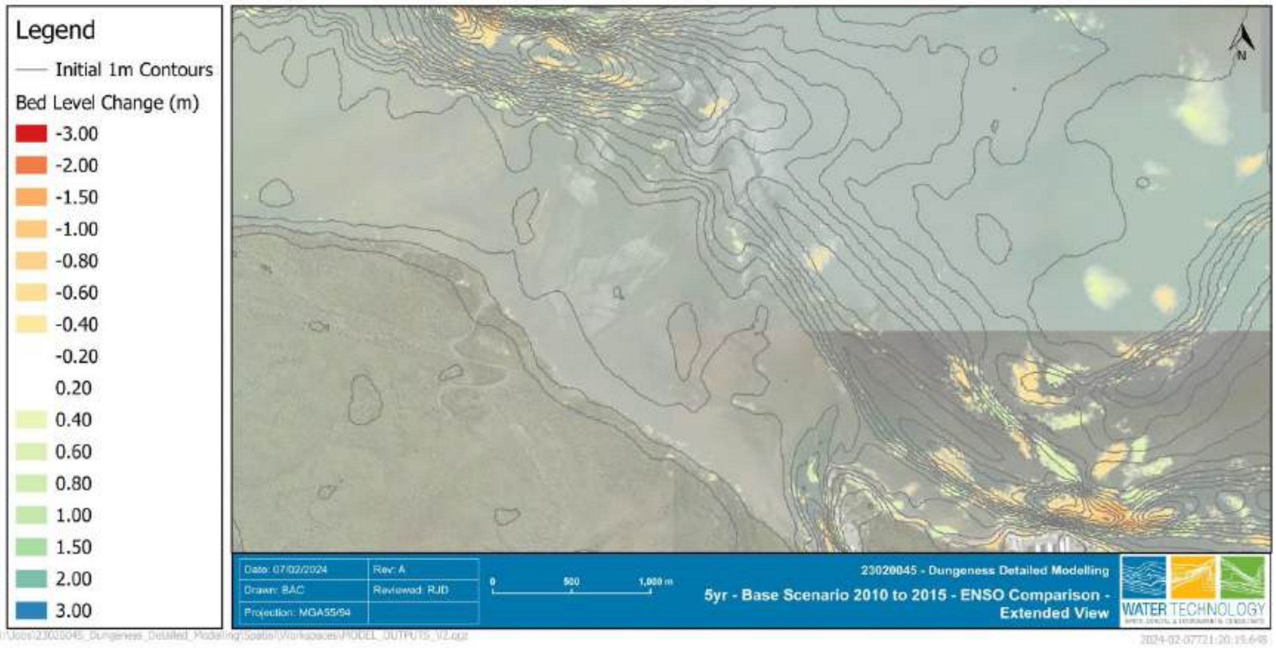


Figure 4-19 Comparison El Nino to La Nina scenario run

4.7.2 Dredge material placement zone

The dredged material placement zone is constrained by marine plants offshore (seagrass) and onshore (mangrove, including mangrove debris from dead mangroves). Due to the rapid erosion of Dungeness Beach, the available placement zone is changing, and has likely moved landward since the previous mapping of marine plants by FRC Environmental (2021). As such, one of the recommendations of the reporting is to ensure marine plant mapping is updated prior to undertaking each dredge campaign. A sensitivity test was also conducted to test the sensitivity of the modelling to the movement of the dredge material placement zone, specifically for the Works Option 2 Scenario with a dredged channel and coastal structure. Figure 4-20 below shows a comparison of two different dredge placement zones, one setback from the existing mapped marine plant area (red polygon) and one outside of the existing mapped marine plants (green polygon).

The modelling is not sensitive to modifications to the dredge material placement area in the intertidal zone. The modelling suggests that the incorporation of the breakwater stabilises the spit, such that changes to the placement of the dredged material placement within the intertidal zone does not have wider impacts outside of the immediate placement zone. The figure shows additional erosion in the eastern edge of the placement zone, where more material has been placed, that is deposited in the nearshore zone. In terms of coastal processes, this impact is minimal. This has also been assessed from an ecological perspective (See SLR reporting In Appendix B).

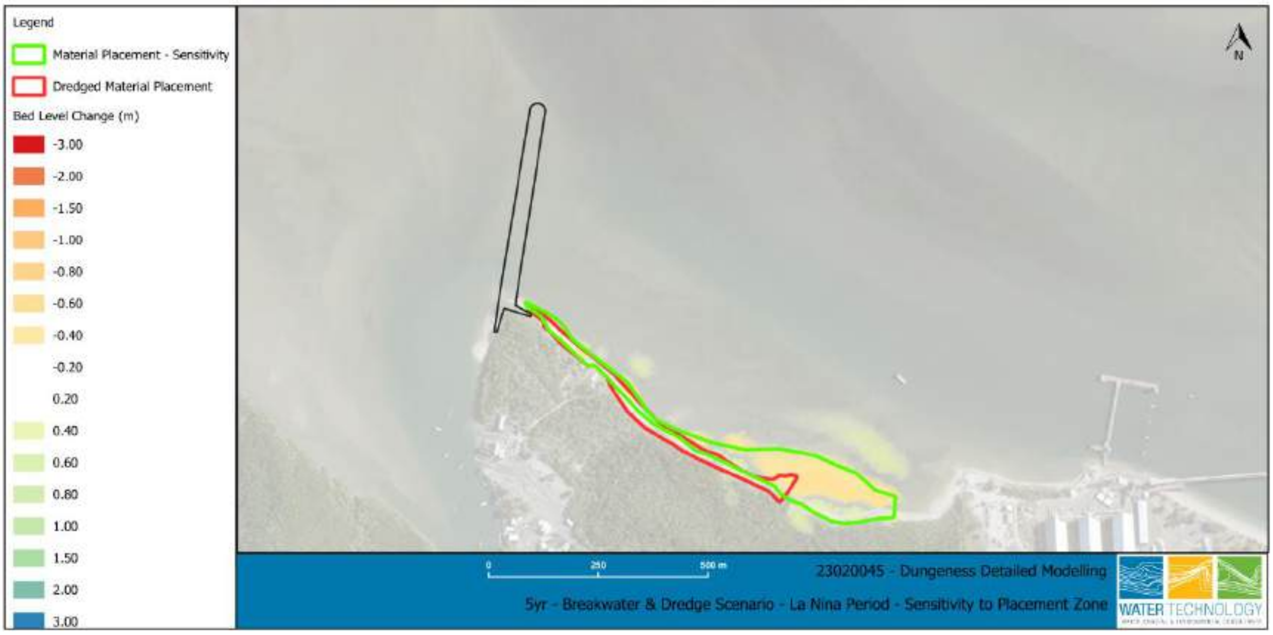


Figure 4-20 Sensitivity to dredge material placement

4.7.3 Hydrodynamics only

A La Nina scenario was also run with no wave inputs as a sensitivity test. The effects of this scenario show that there is some significant wave effects along Dungeness Beach, and waves drive some of the erosion of the Spit and infill of the Channel.

However, it is apparent that there are minimal effects further upstream; for example, the Western Island shows no change with or without wave impacts. Therefore, it is apparent that these sites' morphology is more tidal and riverine-driven than wave-driven.

Figure 4-21 Hydrodynamics only sensitivity test

4.7.4 Sea Level Rise Sensitivity

The model assumes present-day sea level for the 5-year scenarios. Given that any coastal structures installed in the near future will likely still be in place as sea levels rise in coming years, a sensitivity test was added. The offshore water level boundary was raised by 0.8m for this scenario. This sea level rise allowance is compatible with the Department of Environment and Science recommendations for 2100.

The primary change is apparent along Hinchinbrook Channel mouth and Dungeness Beach, where sediment transport volumes have changed in response to changing sea levels and wave climate. Sand bars in the Hindchinbrook Passage Entrance seem to shoal and adjust to the rising sea level while the main channel migrates offshore, reversing the current trend. Much of the nearshore coast is armoured along Lucinda, apart from Dungeness Beach and The Spit. The southern coast of Hindchinbrook Island becomes more dynamic than the current sea level rise scenario, indicating a likelihood of ongoing erosion in this area. Impacts related to coastal flooding due to rising sea levels are likely to be high, and changes to the sediment transport regime are likely to occur.

Figure 4-22 Sea level rise sensitivity

5 BOATING SAFETY WORKS IMPACT ASSESSMENT

This project aims to investigate morphological processes and impacts on the morphology from potential works to improve boating safety. Three options have been tested in the model for the La Nina and El Nino scenarios:

- Works option 1 - a dredged channel, with dredged material placement on Dungeness Beach.
- Works option 2 - dredged channel with material placement on Dungeness Beach and a coastal structure

5.1 Works Option 1 – Dredged Channel

The siting and bathymetry of the dredged channel scenario is shown below. The model bathymetry was excavated along the dredge channel footprint shown in Figure 5-1 to -2.9m AHD with an approximate 50m channel width. This is thought to allow a suitable draft for boating activities. Material was also added to the material placement footprint on Dungeness Beach, assuming a direct 1:1 ratio between material extracted for the dredged channel and that placed on the beach, with 32,500m^3 placed in the footprint shown in Figure 5-1.

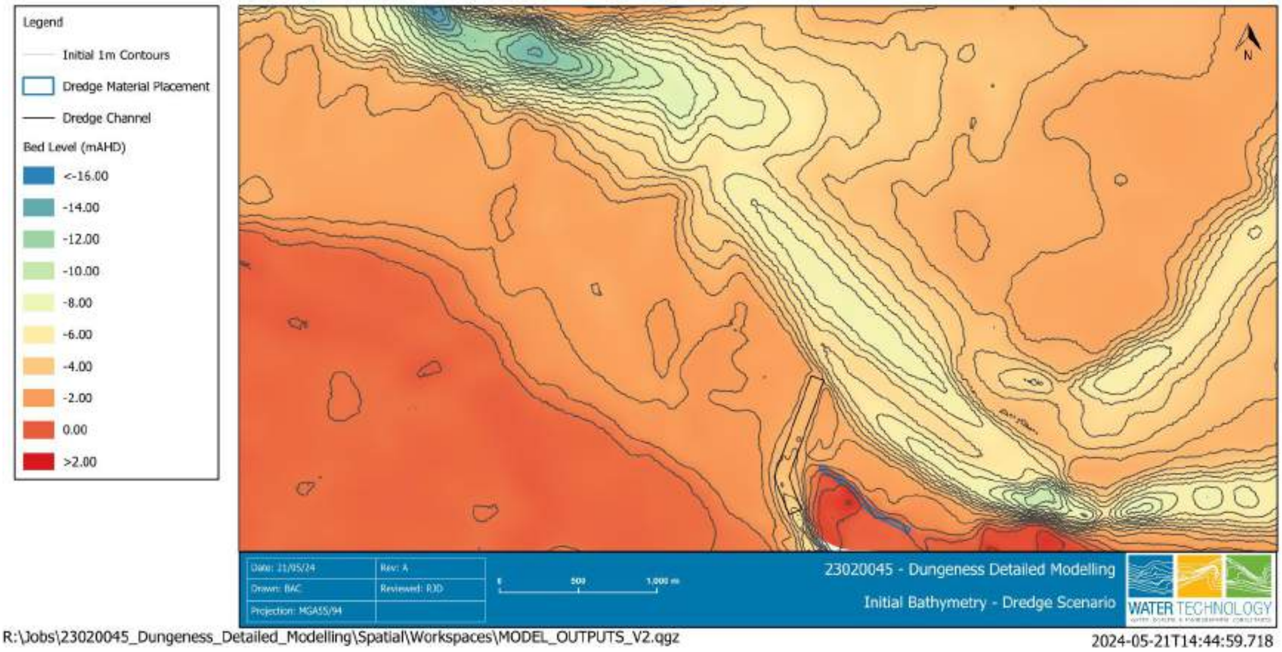


Figure 5-1 Dredged channel scenario bathymetry

5.2 Works Option 1 Results

5.2.1 Zone 1, 2 and 3 – Western Island

This section summarises and compares the morphological results for Works Option 1 at Zone 1, 2 and 3. In Zone 1, the contemporary history of the site and baseline morphology suggested net mild erosion of approximately 600m^3/year during La Niña, with some minor accretion during mild El Niño (100m^3). With the dredge channel included, the changes are as follows:

- A net erosion of approximately 900m^3 / year during stormier La Niña periods (baseline loss of 600m^3)
- A net gain of approximately 100m^3 / year during more mild El Niño periods (baseline gain of 100m^3)

Offshore of Zone 1, the model suggests that over the 5-year morphological model run, the Zone 2 Herbert River Tidal Delta accretes.:

- A net accretion of approximately 19,000m^3 / year during La Niña periods (baseline 20,000m^3/year)
- A net accretion of approximately 13,000m^3 / year during El Niño periods (baseline 15,000m^3/year)

Zone 3 is on the Enterprise Channel side of the western mangrove island. The baseline modelling suggests continued deposition at a slow rate, which the dredged channel option also replicates. The model suggests that over the 5-year morphological model run, the bank accretes with an estimated:

- A net accretion of approximately 400m^3 / year during La Niña periods (baseline accretion of 400m^3)
- A net accretion of approximately 100m^3 / year during El Niño periods (baseline accretion of 100m^3)

Overall, including the dredged channel does not impact Zone 3.

For the Western Island, there does not appear to be a major impact on the sediment transport rates due to the dredged channel. Between the Zones 1 and 2, there is an overall trend of the net decrease in deposition (and a slight increase in erosion in Zone 1 for the El Nino scenario). This is expected partially due to the adjacent Enterprise Channel (Zone 4) experiencing increased deposition rates, with this absorption of excess material in the channel resulting in lowered deposition rates on the adjacent banks. It can also be seen in the results (See Figure 5-2) that there is some erosion from Zone 2 into the dredged channel from west to east, which is not experienced in the base case scenario. This is likely an adjustment of the adjacent shoals to the deeper dredge channel.

Although there are changes noted, it is expected these will not significantly accumulate beyond the local area of impact over time, given that the results suggest (except for the El Nino scenario for Zone 1) a minor reduced deposition rate (rather than erosion). The Western Island will continue to have a net surplus of incoming material.

5.2.2 Zone 4 – Enterprise Channel

As emphasised in the stage 1 reporting, this project has arisen to improve boating safety in this key zone. The channel has been infilling in recent years, and this is replicated in the base case model. The dredged channel also shows infilling of the channel, however, at an increased rate with:

- A gross infill of approximately 15,000m^3 / year during La Niña periods (Increased from 12,000m^3/year in the baseline)
- A gross infill of approximately 16,000m^3 / year during El Niño periods (Increased from 14,000m^3/year in the baseline)

The net increase in the infill of the channel is expected, given that the deeper and broader channel allows more opportunity for deposition. Figure 5-2 shows the model results in this area, with additional sediment infilling the channel from the east and west compared to the base case scenario.

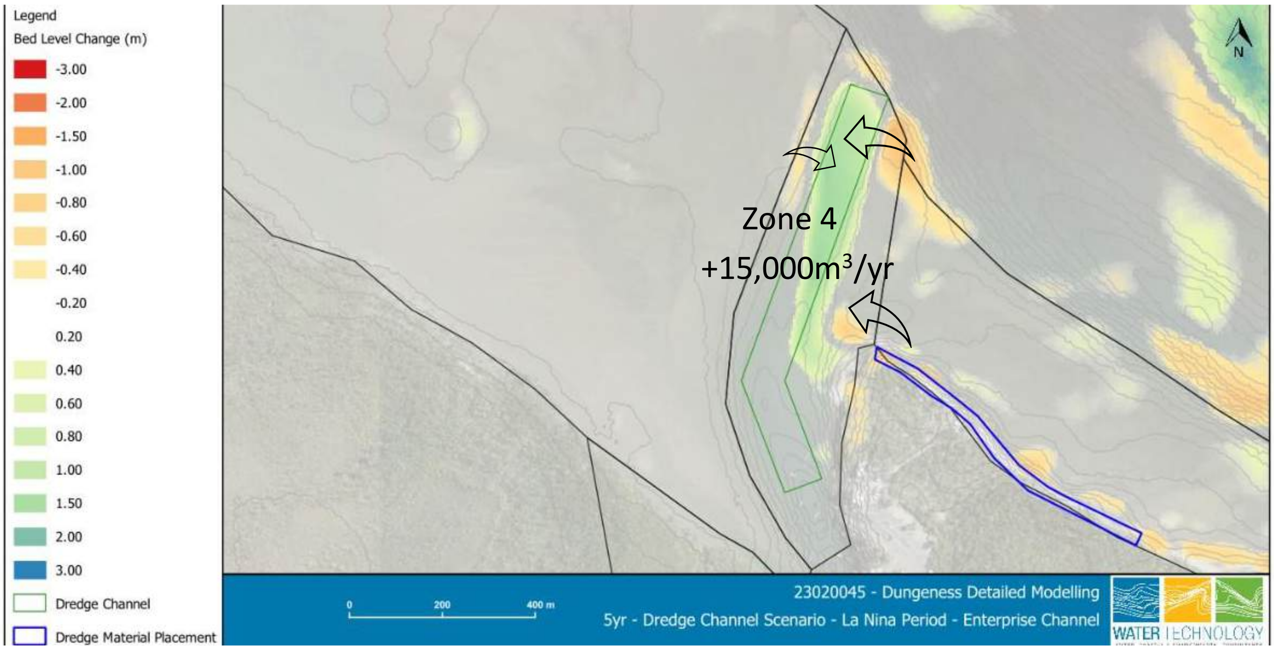


Figure 5-2 Sediment transport pathway, Zone 4, dredge channel option

5.2.3 Zone 5 and 6 – Enterprise Channel East Bank

These zones have no change compared to the baseline scenario, which shows minimal morphological impacts.

5.2.4 Zone 7 – Dungeness Beach Spit

A review of this zone did not shows minimal impacts due to the dredged channel. Erosion rates at Dungeness Beach Spit are maintained at approximately:

- Net erosion of approximately 1,300m^3 / year during La Niña periods (baseline 1,400m^3/year)
- Net erosion of approximately 900m^3 / year during El Niño periods (baseline 1,100m^3/year)

5.2.5 Zone 8, 9, 10, 11 – Dungeness Beach

The northern beaches updrift of the Spit and Dredge Channel are considered in these zones. The modelling predicts similar rates of erosion than the base case scenarios with:

- Erosion of approximately 3,500m^3 / year during La Niña periods (3,400m^3 / year in base case)
- Erosion of approximately 2,700m^3 / year during El Niño periods (2,700m^3 / year in base case)

Offshore of Zone 8 sits another key compartment of the Dungeness Beach offshore shoals and intertidal zone, Zone 9. The modelling suggests similar, but slightly lower, deposition rates in this intertidal zone compared to the base case, with:

- Net accretion of approximately 6,500m^3 / year during La Niña periods (6,600m^3 / year in base case)
- Net accretion of approximately 6,100m^3 / year during El Niño periods (6,200m^3 / year in base case)

As we move away from the dredged channel, the impacts of the channel are minimised. Zone 10 shows almost identical results compared to the base case.

5.2.6 Zone 12 – Hinchinbrook Channel

A review of this zone does show some impacts in the main channel. This is a highly dynamic zone with shoals regularly moving along the channel.

5.2.7 Impact on the sediment budget

Overall, the dredge works option has a localised impact on the sediment budget in adjacent zones.

- The dredge channel (Zone 4) infill rate is increased by approximately 20% (compared to the base case).
  - With this infill rate, parts of the channel are shoaling at up to approximately 300mm/year. Assuming a trigger depth of 0.5m LAT for the shoal, we would expect maintenance dredging triggers would be reached after approximately 1.5 – 2 years. This maintenance dredging volume would be 20,000 – 30,000m^3 of material.
- The net effect of the dredged channel is to decrease deposition rates on the Western Island and its offshore shoals (in particular, Zone 2). This is thought to be due to shoals adjusting to the wider and deeper channel, with material shown to infill from the shoals into the dredged channel from the west, which is not observed in the baseline scenario.
- Updrift, to the east of the coastal structure, there is minimal morphological impact with only a slight increase in deposition and a slight reduction in erosion in the intertidal zone offshore of Dungeness Beach (Zone 9). The dredged channel shows some minor additional infill from sediments associated with westerly sediment transport.
- The more efficient channel changes the tidal flow rates and subsequent shoal dynamics locally in the Hinchinbrook main channel (Zone 12) adjacent to the Enterprise Channel. This effect is limited to the local site.

A difference plot between the bed level changes experienced in the baseline versus dredged scenario is shown below in Figure 5-3. It can be seen that impacts are limited to the immediate Western Island shoals (Zone 2), Dungeness Beach shoals (Zone 9) and Hinchinbrook Main Channel (Zone 12), without the effects propagating to the broader coastal zone.

Figure 5-3 Difference in bed level change (Dredge scenario compared to baseline scenario)

5.3 Works Option 2 – Dredged Channel and Coastal Structure

The siting and bathymetry of the dredged channel and coastal structure scenario is shown below. The model bathymetry for the dredged channel was excavated along Figure 5-1 to a depth suitable for boating, as per the dredge-only option 1 (-2.9m AHD bed level, approximately 50m wide channel). The coastal structure was included along the footprint shown in the figure above as a raised 'non-erodible' layer to replicate the armoured coastal structure performance. Material was also added to the material placement footprint on Dungeness Beach, with 13,500m^3 placed in the footprint shown in Figure 5-4.

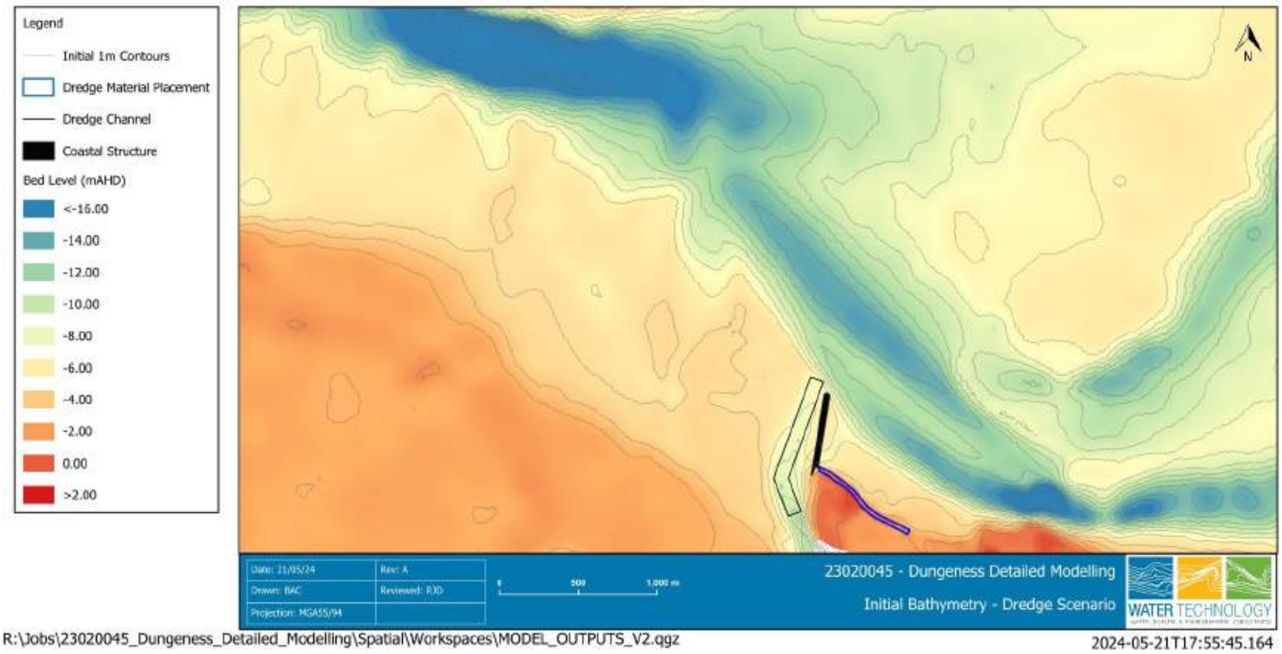


Figure 5-4 Dredged channel and coastal structure option bathymetry

5.4 Works Option 2 Results

5.4.1 Zone 1, 2 and 3 – Western Island

This section summarises the Works Option 2 morphological results for Zone 1, 2 and 3, all related to the island between the Herbert River and Enterprise Channel, which is dominated by mangrove forest and nearshore shoals.

In Zone 1, the contemporary history of the site and baseline morphology suggested net mild erosion of approximately 600m^3/year during stormier La Niña periods, and 100m^3 of accretion during El Niño. The coastal structure in place shows similar results compared to the dredge only works option, with:

- A net loss of approximately 900m^3 / year during stormier La Niña periods (baseline loss of 600m^3)
- A net gain of approximately 300m^3 / year during more mild El Niño periods (baseline gain of 100m^3)

Offshore of Zone 1, the model suggests that over the 5-year morphological model run, the Zone 2 Western Island shoals accrete at a higher rate with coastal structure inclusion, with:

- A net accretion of approximately 27,000m^3 / year during La Niña periods (baseline 20,000m^3/year)
- A net accretion of approximately 25,000m^3 / year during El Niño periods (baseline 15,000m^3/year)

Zone 3 is on the Enterprise Channel side of the western mangrove island. The baseline modelling suggests continued deposition, however, at a slow rate. The model suggests that over the 5-year morphological model run with coastal structure, this zone accretes with an estimated:

- A net accretion of approximately 30m^3 / year during La Niña periods (baseline accretion of 400m^3)
- A net accretion of approximately 10m^3 / year during El Niño periods (baseline accretion of 100m^3)

Overall, the inclusion of the coastal structure suggests trends remain similar to the base case scenario, however, there is a general increase in sediment deposition on the Western Island shoals.This is thought to be due to the coastal structure significantly reducing tidal and wave forcing in this zone, resulting in lower sediment transport potential. Flows are re-directed further offshore, resulting in less opportunity for sediment mobilisation and increased opportunity for deposition on the Western Island's banks and nearshore shoals.

5.4.2 Zone 4 – Enterprise Channel

The modelling suggests an infilling channel in the baseline morphology scenario and dredged channel scenario. The model captures this trend, predicting an infill rate of:

- A gross infill of approximately 7,000m^3 / year during La Niña periods (decreased from 12,000m^3/year in the baseline, approximate 45% decrease in infill rate. Also a 55% decrease in infill rate compared to the dredged channel only option)
- A gross infill of approximately 7,000m^3 / year during El Niño periods (decreased from 14,000m^3/year in the baseline, approximate 50% decrease in infill rate. Also a 55% decrease in infill rate compared to the dredged channel only option)

In addition to the reduced channel infill rates, the coastal structure option also shows a scour pocket adjacent to the breakwater, including:

- An increase in scour of approximately 700m^3 / year during La Niña periods compared to the baseline scenario
- An increase in scour of approximately 1,600m^3 / year during El Niño periods compared to the baseline scenario

The net decreased infill rate of the channel is expected, given the protection afforded by the coastal structure to the dominant flood tide and wave action. The tidal flow regime is compressed along the inside of the breakwater, initiating scour and removing opportunities for deposition.

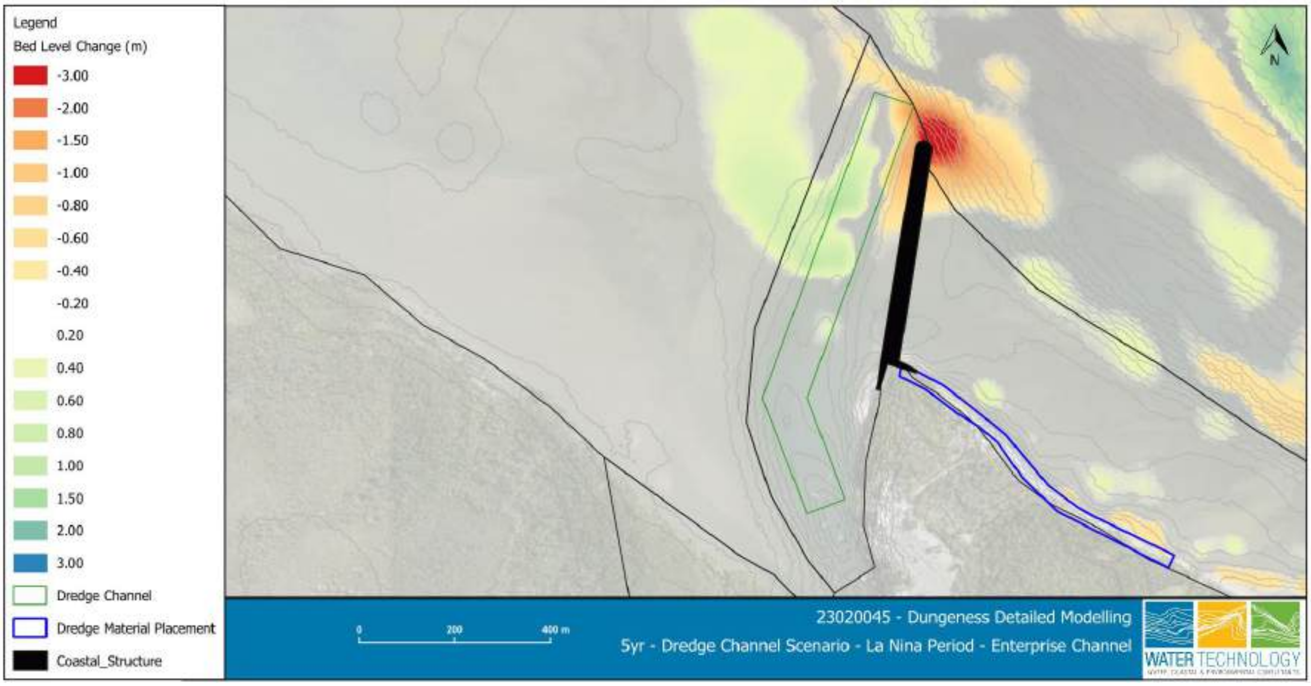


Figure 5-5 Erosion and scour in the vicinity of dredge channel and coastal structure

5.4.3 Zone 5 and 6 – Enterprise Channel East Bank

These zones have no change compared to the baseline scenario, which shows minimal morphological impacts.

5.4.4 Zone 7 – Dungeness Beach Spit

This known ongoing erosion of the spit (baseline modelling predicts approximately 1,000m^3/year of erosion) is reduced with the coastal structure scenarios, with:

- A net erosion of approximately 200m^3 / year during La Niña periods (decreased from 1,400m^3/year in the baseline, approximate 90% decrease in erosion rate.)
- A net erosion of approximately 100m^3 / year during El Niño periods (decreased from 1,100m^3/year in the baseline, approximate 90% decrease in erosion rate.)

The coastal structure stabilises the Spit. As can be seen in Figure 5-5, there is not an excessive build-up of material on the inside of the coastal structure; the stabilisation of the spit is thought to be predominately due to a reduction in the flood tide velocities and subsequent capacity for transport of material from the Spit zone; rather than blocking of longshore sediment transport capacity.

5.4.5 Zone 8, 9, 10, 11 – Dungeness Beach

The northern beaches updrift of the Spit and dredge Channel are considered in these zones. The modelling predicts overall reduced rates of erosion than the base case scenario, with:

- Erosion of approximately 2,300m^3 / year during La Niña periods (3,500m^3 / year in base case). In addition to the reduced erosion on the beach, the La Niña scenario also shows less erosion by 1,200m^3/year compared to the base case.
- Erosion of approximately 2,800m^3 / year during El Niño periods (2,700m^3 / year in base case). This scenario shows similar erosion to the base case.

Offshore of Zone 8 sits another key compartment of the Dungeness Beach offshore shoals and intertidal zone, Zone 9. The modelling suggests similar rates of deposition rates in this intertidal zone compared to the base case, with:

- Net accretion of approximately 6,400m^3 / year during La Niña periods (6,600m^3 / year in base case)
- Net accretion of approximately 6,400m^3 / year during El Niño periods (6,200m^3 / year in base case)

As we move away from the coastal structure, the impacts are minimised. Zone 10 and 11 show very similar results compared to the base case. Inclusion of the coastal structure results in a reduced sediment transport capacity along Dungeness beach and shoals, reducing erosion and increasing deposition potential.

5.4.6 Zone 12 – Hinchinbrook Channel

A review of this zone does show some impacts in the immediate vicinity due to the initiation of scour and increased tidal flow capacity being forced into Hinchinbrook Main Channel. This scour effect is relatively localised, and impacts are not seen to propagate down or upstream, with similar shoaling effects in the coastal structure scenario compared to the baseline scenario.

5.4.7 Impact on the sediment budget

Overall, the coastal structure does have a limited, localised impact on the sediment budget in adjacent zones.

- The dredge channel infill rate is reduced by approximately 50% (compared to the base case) and 55% (compared to the dredge-only option).
  - With this infill rate, parts of the channel are shoaling at up to approximately 170mm/year. Assuming a trigger depth of 0.5m LAT for the shoal, we would expect maintenance dredging triggers would be reached after approximately 3 years. This maintenance dredging volume would be approximately 20,000m^3 of material.
  - This effectively halves the frequency of dredging. It is also noted, given the relatively low rates of deposition and uneven distribution of shoaling in the channel, minor bed levelling campaigns may be conducted to remove higher shoals and further reduce frequency of maintenance dredging. It is proposed that, given the shoaling rates, it would be likely achievable to have an approximate 5 year frequency of maintenance dredging campaigns with the coastal structure incorporated, and intermittent levelling of higher shoals within the channel.
- The net effect of the coastal structure is to increase deposition rates on the Western Island offshore shoals (Zone 2 predominately). This is thought to be due to reduced wave penetration and tidal forcing with flows directed away from the shoals into the main Hinchinbrook Channel.
- Updrift, to the east of the coastal structure, there is an apparent stabilising effect, with spit erosion reduced by 90% (Zone 7), and Dungeness Beach erosion reduced by up to 30% during La Nina scenario. This is thought to be primarily due to the dredged material placement on the Dungeness intertidal zone being worked offshore, and due to reduced tidal forcing, with flows away from the shoals into the main Hinchinbrook Channel by the coastal structure.
- A scour pocket develops adjacent to the breakwater on the Enterprise Channel and Hinchinbrook Channel side at a rate of 700 – 1,600m^3 of scour per year.
- The tidal flows that were previously spread across the Hinchinbrook Channel through to Dungeness Beach and the Western Island are constricted and forced into the main Hinchinbrook Channel. This causes a change to the shoaling and scour in the Channel adjacent to the breakwater. The propagation of this scour and subsequent impacts to shoaling are restricted to the immediate approximate 500m radius from the breakwater.

- The model shows that the channel alignment should be moved slightly to the east, closer to the coastal structure, to benefit from local scour.
- Outside of these key zones, the impact of the coastal structure is expected to be negligible.

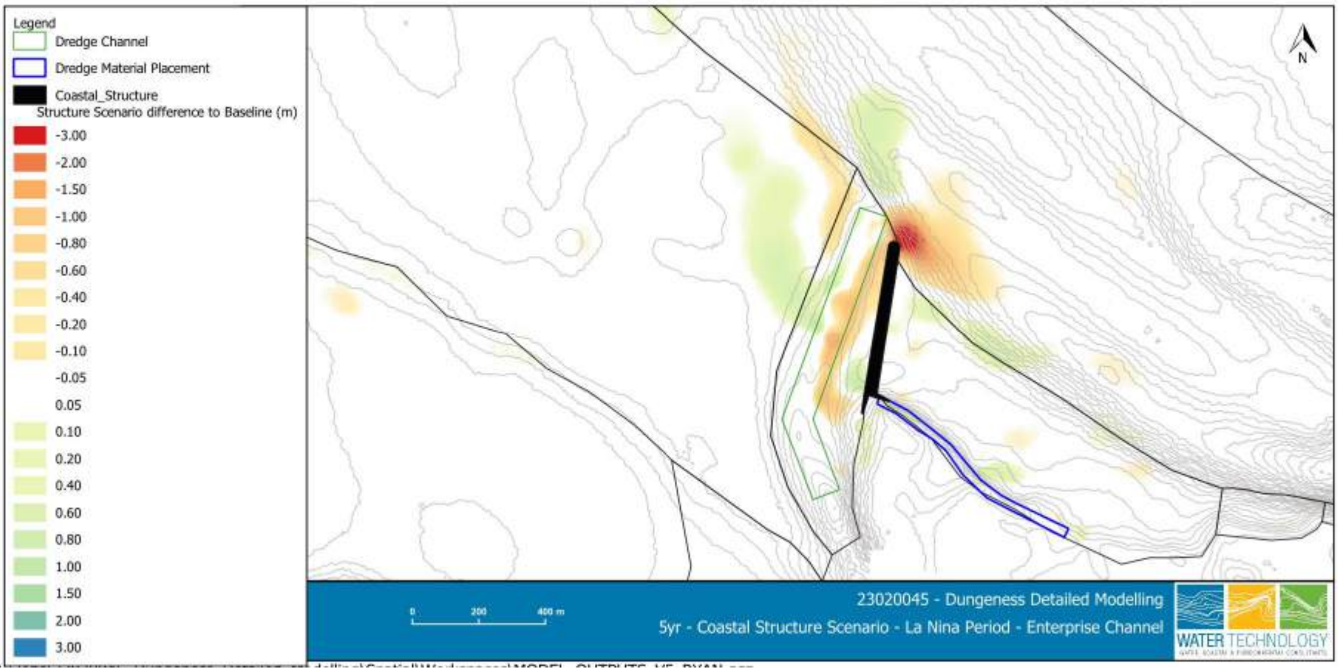


Figure 5-6 Difference in bed level change (Coastal structure works option compared to baseline scenario)

5.4.8 Commentary on Impact to Coastal Environments

While this study is focussed on sediment budgets and shoreline morphology, the SARA information request that is the driver for this project also mentions the potential impact to coastal environments, and as such, this is addressed. FRC Environmental (2019 and 2021) have previously undertaken ecological survey and environmental impact assessment at the site based on previous design iterations of the dredge channel and coastal structure. The key ecological features at the site relevant to this assessment are:

- Seagrass meadows, predominately in Zone 9 and 2.
- Mangrove forests on Western Island, Zone 1 and at Dungeness Beach, Zone 7 and 8. Of particular note is the ongoing erosion of mangrove forrest at Dungeness Beach.

SLR Consulting (previously FRC Environmental) was engaged as part fo this commission to review the model results in the context of the effect on coastal environments. Their report is attached in Appendix B. A summary of their reporting indicates that the dredging and coastal structure would:

- Result in less erosion of the mangroves along the western foreshore of West Island.
- Result in some accretion in the sparse seagrass beds offshore of West Island (Zone 2), however this accretion is well within the capacity of the seagrass to continue to grow, and the depth will remain appropriate for seagrass.
- The coastal structure would significantly decrease the rate of deposition in the Enterprise Channel, resulting in less frequent dredging, and less requirement to dispose of the dredge material.
- Significantly decrease erosion of the Spit and along Dungeness Beach, significantly reducing erosion impacts to mangroves, and

- Stabilisation of the sediment in the seagrass offshore of Dungeness Beach, resulting in a more stable area of seagrass.

Overall the model results do not suggest any long-term or wide-ranging effects on coastal environments.

6 COASTAL MONITORING PROGRAM

The purpose of this chapter is to present a monitoring methodology for the coastal zone in the vicinity of the potential Dungeness boating safety project area. The discussion in this chapter includes an evaluation of monitoring relevant to the site and recommendations for implementation. A combination of land and marine observations is required to understand trends and changes to help further understand the impact of the implementation of boating safety works.

This chapter provides a foundation for the future monitoring program by identifying monitoring gaps and recommending where future monitoring is required.

6.1 Philosophy

Recent advances in drone technology and remote sensing have allowed for increased coverage of monitoring data in recent years, which can be collected at a cost-effective rate – even at remote sites such as that in the vicinity of Dungeness and Hinchinbrook Channel. Coupled with the availability of technology, there is a need for assessment and prioritisation of monitoring activities to develop a cohesive coastal monitoring program for the site.

The recommended coastal monitoring framework includes:

- Utilising existing monitoring activities undertaken across national, state, regional and local contexts.
- A schedule of additional localised monitoring, with the frequency, timing and purposes of monitoring activities nominated.

The Coastal Monitoring Program uses an approach to establishing critical monitoring activity and building long-term repeatable datasets that can inform the Council's effective coastal and boating safety management, such as providing thresholds of change or trigger points for additional dredging and tracking and reporting trends. The monitoring will also be used to ensure the project is achieving the environmental and coastal process objectives embedded into the Council's policies and environmental responsibility, as well as regulatory requirements embedded into the development approvals process to ensure impacts are minimised to coastal processes and key environmental areas.

This approach allows the Council to monitor macro-scale and local-scale trends and impacts upon the coastal environment to inform coastal management decision-making for adaptation, conservation, resource management and sustainable development outcomes.

It is envisioned that the data and results collated in a regular monitoring report will seek to establish a baseline to track trends in key physical indicators across a range of temporal and spatial scales, including prior to coastal works being undertaken and after the works.

6.2 Coastal physical processes

The program aims to capture data related to physical processes shaping the coastal environment, rendering insights into the dynamic interplay of waves, tides, currents, sediment movement, and shoreline erosion. The monitoring program considers:

- Beach survey (terrestrial and hydrographic)
- Coastal imaging
- Aerial photography
- Water Level and wave monitoring
- Weather stations.

These are further described in the sections below.

6.2.1 Beach survey (terrestrial and hydrographic)

There is minimal record of beach surveys along the coastline of interest for this site. This type of monitoring would focus on understanding morphological changes to the coastline while also tracking the underwater bathymetric changes that affect boating safety and underwater ecosystems. It is recommended that this monitoring be initiated as soon as possible with:

- Ideally, the whole of coast LiDAR or photogrammetry dataset would be flown along the Hinchinbrook LGA coastline at regular intervals. Hinchinbrook has a long coastline for a relatively small Council, so it is likely that a program like this would be challenging to fund at regular intervals. It is therefore proposed that the whole of coast LiDAR/photogrammetry be supplemented with local (covering Dungeness Beach and Western Island):
  - Drone LiDAR or photogrammetry covering Dungeness Beach and the western mangrove island at 6 month intervals OR;
  - Regular beach profile survey at approximately 200m spacing, also at 6-month intervals. This may be possible at Dungeness Beach; however, accessing the Western Island would likely be difficult due to the offshore shoals and densely vegetated bank. Terrestrial RTK survey has an added safety risk compared to remote sensing, as the site is known to be a zone where crocodiles are present.
- Regular hydrographic surveys will also be required to supplement the terrestrial data acquisition. It is recommended that Enterprise Channel's regular multi-beam survey be captured to track the channel's infill and immediate Hinchinbrook Channel connection point.

6.2.2 Coastal imaging

Installing a coastal imaging system is another option available for tracking physical processes and may reduce the frequency of above-ground survey requirements. Options available include:

- Establishing a CCTV camera at the Spit. This could be supplemented with additional cameras embedded into the breakwater if this is constructed. This imaging camera could be used to track:
  - Beach width at Dungeness Beach
  - Use of cameras will be difficult on the Western mangrove island, given the site's remote location and likely obstructed view due to dense vegetation.
- Establishing a CCTV camera at the boat ramp could also be a valuable tool to understand boating numbers and habits, optimise the boat ramp and surrounding parking, and justify the capital spent on dredging and coastal structure construction.
- Council could also consider establishing *CoastSnap* stations at key sandy beach locations. These stations allow visitors to the coastal area to set up their smartphones in a fixed cradle, take a photo, and upload it to an application on their phone. The areas of interest are unlikely to have enough foot traffic to implement this option.

6.2.3 Aerial photography

A database of aerial photography, dating as far back as the 1960s, is available on the Queensland Government Qimagery Database. Imagery should continue to be captured through the use of:

- Regional imagery has been captured with manned aircraft, and will likely continue to be done via Council-wide imagery capture and/or private entities such as Nearmap.

- Satellite imagery has been available since the late 1980s and has also been heavily processed and released for use in shoreline mapping through Geoscience Australia's DEA (Digital Earth Australia) Coastlines product (www.dea.ga.gov.au/products/dea-coastlines).
- Imagery remains an important dataset for monitoring the Hinchinbrook coastal areas due to its typical high spatial coverage and captured at regular, high-frequency intervals. It is recommended that high-resolution imagery be captured when Council does a drone survey in the area.

6.2.4 Wave and water level monitoring

A broader network of metocean monitoring is available to Council, typically managed by other authorities such as the State Government.

The area is serviced by a reasonable number of water level stations, which are critical at the site, and have been suitable for use in this modelling exercise. These include at Lucinda and Cardwell.

The Hinchinbrook Region is less well-served with wave data. The only wave gauge available in the vicinity is at Townsville. Historic data from 1995/1996 is available at Lucinda. It is not apparent that additional wave monitoring would significantly benefit the monitoring at the site.

Overall, it is considered that the site is reasonably well served by water level and wave monitoring, and it is not recommended that Council focus on this type of monitoring.

6.2.5 Weather Stations

Typically operated by the Bureau of Meteorology, weather stations capture wind data relevant to the site, including directional wind measurements, at locations in the general vicinity. Relevant to coastal and physical processes near the site, wind gauges are located at:

- Lucinda Point (Station 032141) – 3 Hourly Synoptic (1980-Present) and 1 min (June 2013 – Present)
- Cardwell (Station 032004) – 24 Hourly
- Cowley Beach (Station 032194) – 3 Hourly

For this study, this was generally found to be a low-resolution of wind data. It is recommended that an additional wind gauge could be established locally however this is unlikely to impact project outcomes significantly. As such, this is not considered as a high priority.

6.2.6 Summary – Physical processes monitoring

Overall, while some relevant monitoring activities capture data relevant to coastal physical processes at the site, it is recommended that the monitoring is enhanced. Council should also attempt to consolidate these datasets into a common database with regular reporting for easy access and understanding of the data. Potential additional physical coastal monitoring options are further discussed below.

6.3 Infrastructure

Council should also undertake periodic monitoring of its physical coastal assets. This is critical to the prioritisation and risk-based approach of Council's operational and capital works programs. Coastal assets are inspected regularly, in some instances more than other (non-coastal) assets, due to their additional exposure to deterioration. Coastal assets often also have additional inspection requirements after storm events, where erosion or coastal inundation may have altered the asset's condition.

Apart from coastal structures, a range of other built council assets on the coast are regularly monitored for usage, condition, and adequacy. These include public amenities blocks, community centres, roads and transport infrastructure, and parks and recreational facilities.

It is understood that Council undertakes a range of inspections by day-to-day operational staff undertaking simple visual inspections, trained staff undertaking asset-specific monitoring inspections and hiring specialists to undertake specific condition inspections of degraded assets.

Council has a strong asset monitoring program, and in general, this should be maintained and followed in line with best practice guidelines and existing individual asset management frameworks for any new infrastructure that is implemented at the site.

6.4 Monitoring Reporting

It is envisioned that one of the key outcomes of the coastal monitoring program would be to establish a *'Dungeness Boating Safety Monitoring'* Report at yearly intervals. This reporting should be undertaken by a suitably qualified coastal engineer or similar and would produce a snapshot of the state of the Dungeness coastline and adjacent coasts and Enterprise Channel. After the baseline assessment in the first report, consideration can be given to the general direction and behaviour of the data over an extended period, i.e identification of trends in data points to determine the required rate of dredging and erosion or deposition rates at the key beach locations. The Dungeness Boating Safety monitoring may focus on three aspects:

- **Boating safety assessment** – considering the apparent amenity of Enterprise Channel through bathymetric survey, imagery and boating incident reporting.
- **Foreshore condition** – considering the width of beaches, sand availability, coastal resilience and amenity of the beaches and foreshore through several key parameters.
- **Mangrove bank stability** – specifically for the West Island, tracking of the long-term stability of the mangrove forests is of high environmental importance.

This document aims to provide context for Council to develop key indicators further, and monitor the success of the Dungeness Boating Safety Project.

6.5 Recommended Monitoring Summary

In summary, it is recommended that, prior to the installation of the Dungeness boating safety works, Council initiate a monitoring program that includes:

- Localised high-resolution survey of Dungeness Beach, the adjacent spit and the western mangrove island every 6 months or post major storm event, taken during a Spring Low Tide. Aerial imagery should be captured concurrently with the beach survey.
  - Concurrently, Council may consider regional complete coverage surveys via manned aircraft (for example, green LiDAR) or drone (drone photogrammetry or LiDAR) of the Hinchinbrook Coastline at regular intervals that may reduce the need for localised surveys. Aerial imagery should be captured concurrently with the full coverage survey.
- Annual hydrographic survey of Enterprise Channel and the adjacent primary Hinchinbrook channel. This would likely require capture with a high-resolution multi-beam survey. The turbid waters are typically unsuitable for other remote sensing methods of data capture.

These monitoring actions should be continued once boating safety infrastructure is installed to assist with assessing the impacts to be in line with those predicted.

7 DISCUSSION AND SUMMARY

The project utilised coupled hydrodynamic and spectral wave models to drive a detailed morphological model. The modelling, in combination with available data validation and literature, provides an understanding of sediment transport patterns at the site and the impact that a proposed coastal structure and dredged channel will have on these sediment transport patterns.

The numerical modelling of the base case (without dredged channel or coastal structure) suggests that:

- The Lucinda Spit and main Hinchinbrook Channel adjacent (Zones 11 and 12) are in an active coastal zone. There are relatively high rates of sediment transport and movement of shoals in these zones, driven by wave energy and tidal fluctuations.
- Further west along Dungeness Beach, the effects of wave action and subsequent sediment transport rates reduce. The morphology becomes more dominated by tides rather than waves. Large shoals offshore of Dungeness Beach (Zone 9) and the Western Island (Zone 2) continue to grow, whilst the silty banks at the Dungeness Spit (Zone 7) and beach (Zone 8) and Western Island (Zone 1) continue to recede slowly, typical of mild wave climate coast with a silty coastline.
  - Notably, this suggests that the mangrove forests in these zones will be impacted by erosion in the baseline scenario.
- Enterprise Channel (Zone 4), where dredging is proposed, acts as a sediment sink between Dungeness Beach and the Western Island shoals (Zone 2 and 9), infilling at a rate of approximately 12,000 – 14,000m^3/year.
- The Western Island offshore shoals are more heavily influenced by the Herbert River sediment influx, with the shoals estimated to accumulate sediment at approximately 20,000m^3/year.

Implementing Works Option 1 (dredge channel only, with dredge spoil placed on Dungeness Beach) has an apparent (localised) effect on the sediment budget in adjacent zones as follow:

- The dredged channel (Zone 4) infill rate is increased by approximately 20% (compared to the base case), to approximately 15,000m – 16,000m^3/year (from approximately 12,000 – 14,000m^3/year).
  - With this infill rate, parts of the channel are shoaling at up to approximately 300mm/year. Assuming a trigger depth of 0.5m LAT for the shoal, we would expect maintenance dredging triggers would be reached after approximately 1.5 – 2 years. This maintenance dredging volume would be 20,000 – 30,000m^3 of material.
- There is a localised impact to decrease deposition rates on the Western Island offshore shoals (Zone 2). This is likely due to shoals adjusting to the broader and deeper channel, with material shown to infill from the shoals into the dredged channel from the west, which is not observed in the baseline scenario.
- Updrift, to the east of the coastal structure, there is minimal impact.
- The more efficient channel changes the tidal flow rates and subsequent shoal dynamics locally in the Hinchinbrook main channel (Zone 12) adjacent to the Enterprise Channel. This effect is limited locally.
- Impacts are limited to the immediate Western Island shoals (Zone 2), and Hinchinbrook Main Channel (Zone 12), without the effects propagating to the wider coastal zone.

Implementing Works Option 2 (a dredged channel with dredged material placed on Dungeness Beach and an adjacent coastal structure) also has a localised effect on the sediment budget in adjacent zones as follow:

- The dredge channel infill rate is reduced by approximately 45% - 50% (compared to the base case) and 55% (compared to the dredge-only option). This would significantly reduce the frequency of maintenance dredging requirements.

- With this infill rate, parts of the channel are shoaling at up to approximately 170mm/year. Assuming a trigger depth of 0.5m LAT for the shoal, we would expect maintenance dredging triggers would be reached after approximately 3 years. This maintenance dredging volume would be approximately 20,000m^3 of material.
- This effectively halves the frequency of dredging. It is also noted, given the relatively low rates of deposition and uneven distribution of shoaling in the channel, minor bed levelling campaigns may be conducted to remove higher shoals and further reduce frequency of maintenance dredging. It is proposed that, given the shoaling rates, it would be likely achievable to have an approximate 5 year frequency of maintenance dredging campaigns with the coastal structure incorporated, and intermittent levelling of higher shoals within the channel.

- The net effect of the coastal structure is to increase deposition rates on the Western Island offshore shoals (Zone 2 predominately). This is likely due to reduced wave penetration due to the coastal structure and narrowing of the spread of tidal currents across the broader Hinchinbrook Channel due to the coastal structure, with tidal flows focussed in the Hinchinbrook Channel rather than within the shoals.
  - Note that this increased shoaling has been reviewed by marine ecologists, See Appendix B, with the rate of shoaling suggesting negligible effects on the offshore seagrass beds.
- Updrift, to the east of the coastal structure, there is an apparent stabilising effect, with spit erosion reduced by 75% (Zone 7), and Dungeness Beach erosion reduced by up to 30% during La Nina scenario. Deposition in the intertidal zone offshore of Dungeness Beach is approximately doubled (Zone 9). The dredged material is effectively retained within the compartment. Noting that, as per Appendix B report from SLR, dredged material that is washed into the intertidal zone is done so at a rate that does note affect the seagrass.
  - Note that this stabilisation has been reviewed by marine ecologists, See Appendix B, with the stabilisation suggesting environmental benefits, with the Spit and beach stabilisation resulting in a reduction in erosion to the mangrove forrest. The increased deposition will also likely increase the area available for seagrass beds.
- Scour is introduced adjacent to the coastal structure at a rate of 700 – 1,600m^3 of scour erosion per year. This scour will need to be mitigated through the coastal structure design process, by having a sufficiently embedded toe and scour apron where required.
- The tidal flows that were previously spread across the Hinchinbrook Channel through to Dungeness Beach and the Western Island are constricted and forced into the main Hinchinbrook Channel. This causes a change to the shoaling of the Channel and scour in the Channel adjacent to the breakwater. The propagation of this scour and subsequent impacts to shoaling are restricted to the immediate approximate 500m radius from the breakwater.

Outside of these key zones, the impact of the coastal structure is expected to be negligible, and there does not appear to be larger and widespread impacts than those noted above.

In terms of additional erosion protection measures, the breakwater has a net stabilising effect on both Dungeness Beach and the Western Island shoals. Additional erosion protection is not recommended.

In terms of the dredge spoil placement, included in the model to be placed on Dungeness Beach;

- Material should not be placed on marine plants. Updated marine plant survey, given ongoing relatively rapid erosion of the Spit, should be undertaken to refine the dredge spoil placement area as the project progresses to design stage.
- The model is not sensitive to the placement location of the dredge spoil. Material is retained within the immediate Dungeness Beach system, as the beach is stabilised by the coastal structure.

- Review of the performance of this material by ecologists, SLR Consulting Pty Ltd (See Appendix B), suggests that this rate of spread of material within the compartment is negligible in terms of affect on seagrasses and other marine plants.

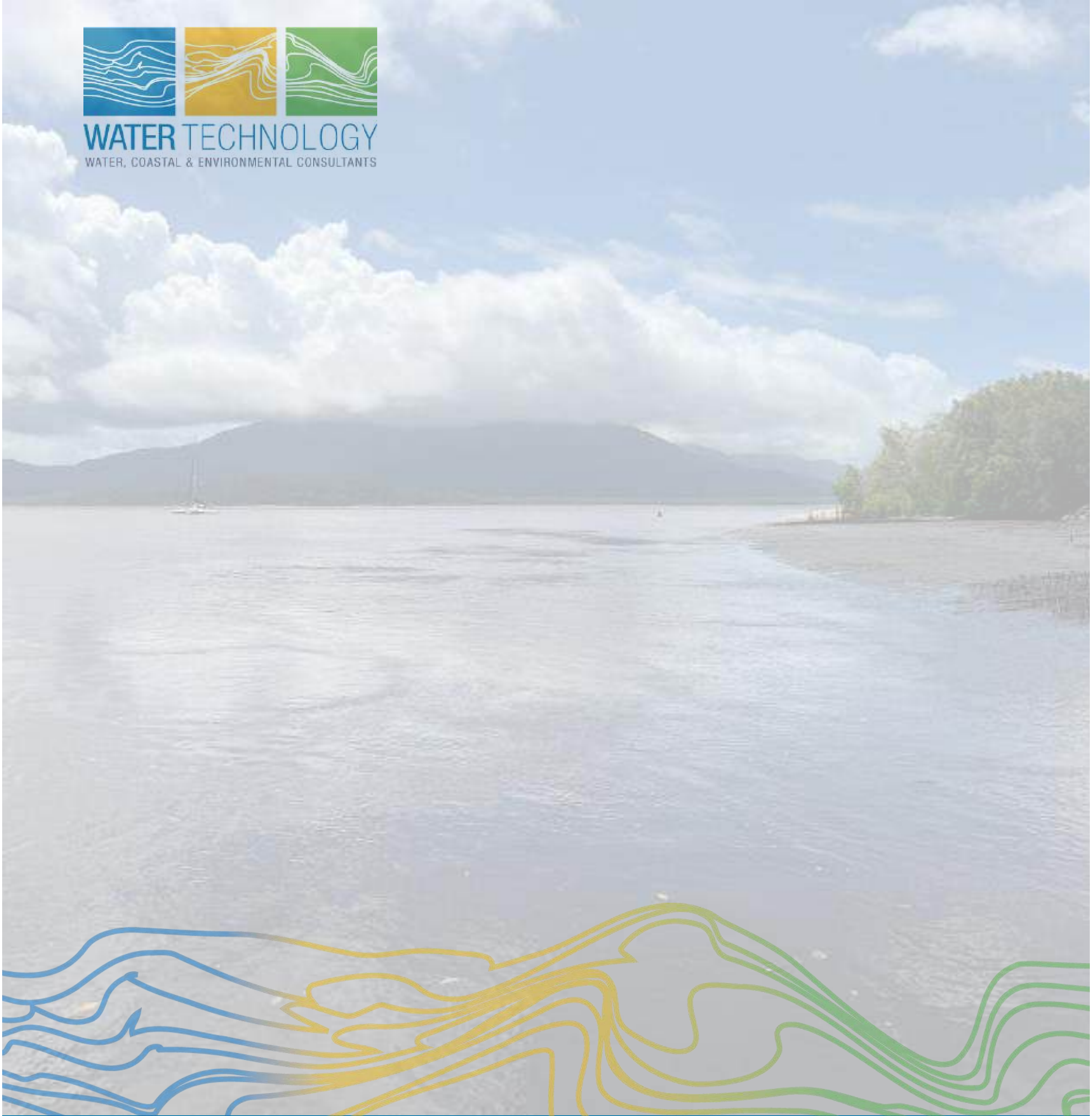
To proactively monitor and de-risk the site and assist with model validation and future studies, it is recommended that, before installation of the Dungeness boating safety works, Council initiate a monitoring program that includes:

- Localised high-resolution survey of Dungeness Beach, the adjacent spit and the western mangrove island every 6 months or post major storm event, taken during a Spring Low Tide. Aerial imagery should be captured concurrently with the beach survey.
- Annual hydrographic survey of Enterprise Channel and the adjacent primary Hinchinbrook channel. This would likely require capture with a high-resolution multi-beam survey.
- Regular (6-monthly) analysis and summary reporting of these datasets by a suitably qualified coastal engineer to review morphological changes and monitor maintenance dredging requirements. The model could be used to project maintenance dredging works.

These monitoring actions should be continued once boating safety infrastructure is installed to assist with de-risking the project.

APPENDIX A
DUNGENESS BOATING SAFETY PROJECT – STAGE 1 REPORTING

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS



Stage 1 Report

Dungeness Boating Safety Project – Detailed Morphological Modelling

Hinchinbrook Shire Council

26 February 2024

Document Status

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V01	Draft for expert review	RJD	RJD	15/12/2023
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Project Details

Project Name	Dungeness Boating Safety Project – Detailed Morphological Modelling
Client	Hinchinbrook Shire Council
Client Project Manager	James Stewart
Water Technology Project Manager	Ryan Dermek
Water Technology Project Director	Gildas Colleter
Authors	Ben Cowling
Document Number	23020045_R01v02_Stage_1.docx

Level 5, 43 Peel Street
South Brisbane QLD 4101
Telephone (07) 3105 1460
Fax (07) 3846 5144
ACN 093 377 283
ABN 60 093 377 283

Quality ISO 9001 SAI GLOBAL | Environment ISO 14001 SAI GLOBAL | OHS ISO 45001 SAI GLOBAL

EXECUTIVE SUMMARY

The Dungeness Boating Safety Project aims to improve boating safety in the Dungeness area. It has been proposed that the project involves the construction of a coastal structure and dredging of Enterprise Channel, with placement of the dredged material at the adjacent Dungeness Beach. This executive summary provides an overview of the project's objectives and key findings from the literature review and data collection stage (Stage 1) of Water Technology's *Detailed Morphological Modelling Project*, prior to undertaking the modelling in Stage 2.

The overall project's main objective is to understand sediment transport patterns and assess the impact of the proposed coastal structure and dredged channel. An initial sediment transport description has been developed through detailed data collection and literature review phase, attempting to extract as much information as possible from historic studies and modelling in the area prior to engaging in the new modelling. This analysis focuses on sediment transport rates and the broader geographical context. This Stage 1 reporting also focusses on the planning and implementation of additional data collection that will inform the morphological modelling in Stage 2.

The literature review highlights the importance of quantifying sediment contributions from the Herbert River and Hinchinbrook Channel. Previous studies have provided insights into regional sediment transport, flood and tidal actions, and the ecological impact of the proposed development. A conceptual model has been developed to showcase the current understanding of sediment transport budgets in the study area.

The project also addresses the historic erosion mitigation and remediation planning in the area. Potential future erosion scenarios have previously been evaluated, considering their impact on environmental values and built assets. Recommendations for effective remediation options to mitigate erosion aspects have been provided.

A major data collection campaign is also detailed, with the collected data giving additional detail on key inputs to the morphological modelling, including:

- High Resolution Muti-beam survey over Enterprise Channel and an area that extends into Hinchinbrook Channel and offshore.
- Sediment sampling and testing at 34 sites within Enterprise Channel, Hinchinbrook Channel and adjacent waterways.
- Acoustic Doppler Current Profiles (ADCP) of Hinchinbrook Channel, Enterprise Channel and lower Herbert River over a Spring Tide cycle.
- Fixed water level monitoring in Enterprise Channel over a several month period.

The Dungeness Boating Safety Project aims to address coastal erosion and enhance safety through the construction of a breakwater and channel dredging. By understanding sediment transport patterns, evaluating erosion scenarios, and implementing a shoreline monitoring program, the project aims to mitigate erosion risks and maintain the coastal environment's long-term health.

Stage 1 of the project has resulted in a detailed understanding of the site and successful collection of additional high quality data that can be utilised in the Stage 2 morphological modelling assessment.

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1 INTRODUCTION

The Dungeness Boat Ramp is a vital piece of infrastructure to the Hinchinbrook region, with fishing participation as one of the highest percentage regions across Queensland at 34%. Dungeness also acts as a gateway to Hinchinbrook Island, the Great Barrier Reef and many of the islands off the coast of Australia including Orpheus Island and the Palm Islands. Approximately 64% of the users who utilise the Dungeness boat ramp travel from Townsville and other non-local areas (HSC, 2021). Waterway access via the Dungeness boat ramp is of high importance to the community.

Currently, Enterprise Channel, which connects the boat ramp to deeper waters of Hinchinbrook channel and beyond, is subject to excess sediment build-up which inhibits waterway access at low and mid tides, particularly for vessels with larger drafts. The Dungeness Boating Safety Project (DBSP) aims to address these issues and restore full-tide access from the boat ramp to Hinchinbrook Channel through a combination of dredging and siltation reduction assisted by a coastal structure.

The scope of this detailed morphological modelling study, as part of the wider DBSP, aims to address the concerns raised by the State Assessment and Referral Agency (SARA) regarding sediment dynamics and the impacts of the proposed coastal structure and dredged channel. Water Technology has been commissioned to undertake a comprehensive study that includes data collection, detailed numerical modelling, and an impact assessment to provide a thorough understanding of sediment transport patterns and the potential coastal impacts of the proposed works.

The project is driven by the need to assess sediment transport rates, evaluate the impacts of the breakwater and channel on sediment dynamics and coastal erosion, and identify any potential long-term effects on the coastal environment west of Dungeness Spit. These concerns have been categorized by SARA into three key comments:

- *Comment 1: sediment transport rates or direction in this area westward past the spit end and onto the western face of the spit and sediment transport away from this area by tidal and riverine currents in Enterprise Channel within a broader geographical context (i.e. max 10kms surrounding the proposed breakwater and channel).*
- *Comment 2: the impact of the breakwater and channel on the current day sediment to the west and the consequent impact of the sand deficit to the updrift* coast including possible bed lowering and coastal erosion.*
- *Comment 3: the impact of the sand deficit created for the updrift* coast to the west of the breakwater on coastal processes in the area and whether there would be any adverse long term (10 years+) impacts on the coastal environment to the west of Dungeness Spit.*

* later clarified by DES as referring to the ‘downdrift’ rather than ‘updrift’ part of the coast.

To address these concerns, Water Technology has designed a methodology consisting of several stages. The project follows a staged approach, beginning with a scope review and literature review to establish a solid foundation of knowledge. This is followed by a targeted data collection program, including sediment sampling, water level logging, Acoustic Doppler Current Profiler (ADCP) transects, water quality testing and bathymetric survey, aimed at reducing uncertainties in sediment transport pathways.

The collected data will inform the refinement of an existing numerical model, allowing for increased resolution, improved validation, and better representation of the complex morphological processes in the study area. Sensitivity testing and calibration will be conducted to ensure the model's accuracy and reliability. Long-term scenarios will be simulated to assess the impacts of the coastal structure and dredged channel development over seasonal and interannual timescales.

The morphological model results will be utilised to identify potential areas that may experience morphological changes due to the proposed works. This assessment will be overlaid with built asset databases and ecological mapping to evaluate impacts on infrastructure and environmental values. Mitigation measures and feasible remediation options will be proposed to minimise any adverse effects and ensure the long-term sustainability of the coastal environment.

1.1 Study Area

The study area is shown in Figure 1-1 below, with key locations in the region highlighted. Dungeness is a small township located approximately halfway between Townsville and Cairns, near Lucinda, on the east coast of Australia in North Queensland.

The boat ramp and adjacent Enterprise Channel sit in a complex confluence of several waterways. Enterprise Channel is a tidal waterway that discharges into the far south-eastern end of Hinchinbrook Channel, immediately adjacent to Hinchinbrook Channel's connection to Halifax Bay and the wider Coral Sea. Enterprise channel is also directly connected to the Herbert River, as a downstream tidal anabranch. The Herbert River and Seymour River also discharge into Hinchinbrook Channel, upstream of Enterprise Channel.

Figure 1-1 Site location

1.2 Project Objectives

The project objective can be summarised as utilising morphological modelling to provide an understanding of sediment transport patterns at the site, and the impact that the proposed coastal structure and dredged channel will have on this sediment transport.

To expand on this, this will include production of:

- A comprehensive sediment transport description - conducting detailed numerical modelling and data collection to analyse sediment transport rates and directions, with a focus on the impact of the proposed breakwater and channel within a broader geographical context.
- Erosion mitigation and remediation planning – evaluation of potential future erosion scenarios along the coast and assess their impact on environmental values and built assets. Provision of recommendations for remediation options that can effectively mitigate erosion aspects.
- Shoreline Monitoring and Reporting - development a shoreline monitoring program and reporting arrangement to continuously assess and report on the evolving coastal processes, ensuring the long-term health of the coastal environment to the west of Dungeness Spit is maintained.

2 LITERATURE REVIEW

The project's first phase is to undertake a literature review of previous studies to date related to regional sediment transport to develop a preliminary sediment budget for the surrounding coastal zone.

This review aims to quantify known sediment contributions from the Herbert River via flooding and tidal actions and fluxes through Hinchinbrook Channel via tidal actions.

This information is also incorporated into a conceptual model that displays the current understanding of sediment transport budgets across key sediment compartments in the study area. The conceptual model has been developed utilising existing numerical model results, literature review, mass balance calculations and estimating changes in compartment volume. The conceptual model will be further refined with the updated numerical model developed as part of this project.

2.1 Recent studies

Water Technology and others have completed a series of previous investigations in the Dungeness and Hinchinbrook Shire region. A brief summary of these investigations is provided below with further detail provided in section 2.1.1 - 2.1.6 below:

- ***Dungeness Enterprise Channel Dredging Study (DECD) (Initial Commission) – One-Month Simulation:*** Water Technology was commissioned by HSC in 2018 to investigate the extent, intensity, and persistence of dredge-generated suspended sediment plumes associated with a proposed dredging exercise at Dungeness. A dredge channel and breakwater layout had been provided to Water Technology by Hinchinbrook Shire Council (designed by others).
- ***DECD (Variation 1) – One-Year Simulation:*** In February 2019, HSC commissioned Water Technology to carry undertake a variation (1) on the initial works – to undertake further investigation of the sediment transport in the study area, and to assess the likely sedimentation rate of the channel with and without a breakwater over the course of one year– thereby evaluating its efficacy in maintaining a navigable channel from Dungeness boat ramp to the main Hinchinbrook Channel. The modelling works conducted for this assessment are built upon the modelling undertaken for the initial commission, including the same dredge channel and breakwater alignment.
- ***DECD (Variation 2) – Three-Year Simulation:*** In August 2019, HSC commissioned Water Technology to undertake an additional sediment transport investigation (variation 2) – in order to assess longer term sedimentation within the channel (over a three-year period) including a coastal processes study, beach nourishment recommendation, breakwater optimisation, and costing. This was then utilised to assist approvals submission (approvals documentation submitted by others).
- ***Approval for dredging and placement of capital dredge material achieved (by others). Breakwater not approved.***
- ***DECD RFI Response 1 -*** In January 2021, HSC commissioned Water Technology to undertake an assessment and provide reporting to support a response to an Information Request received from the State Assessment and Referral Agency (SARA) following lodgement of a development application for operational work. This commission also included a Dredge Management Plan (DMP) to discuss dredging and beach nourishment operations in more detail.
- ***DECD RFI Response 2 -*** In 2022, Water Technology completed a re-analysis to review the assumption that coastal transport processes, such as erosion and accretion, will be adversely affected by the implemented breakwater. The study focused on three scenarios: existing conditions, approved dredging and beach nourishment, and rejected breakwater, dredging, and beach nourishment.
- **Dungeness Boating Safety Project (DBSP) (this project) –** In 2023, HSC commissioned Water Technology to undertake data collection and detailed numerical modelling, specifically sediment transport

modelling, to a level of detail that addresses the requirements outlined by SARA in the Request for Information (RFI), 2008-18147 SRA. An overview of the overall project is shown in Figure 2-1 and how the scope of this morphological modelling study is aimed at providing a technical response to the RFI.

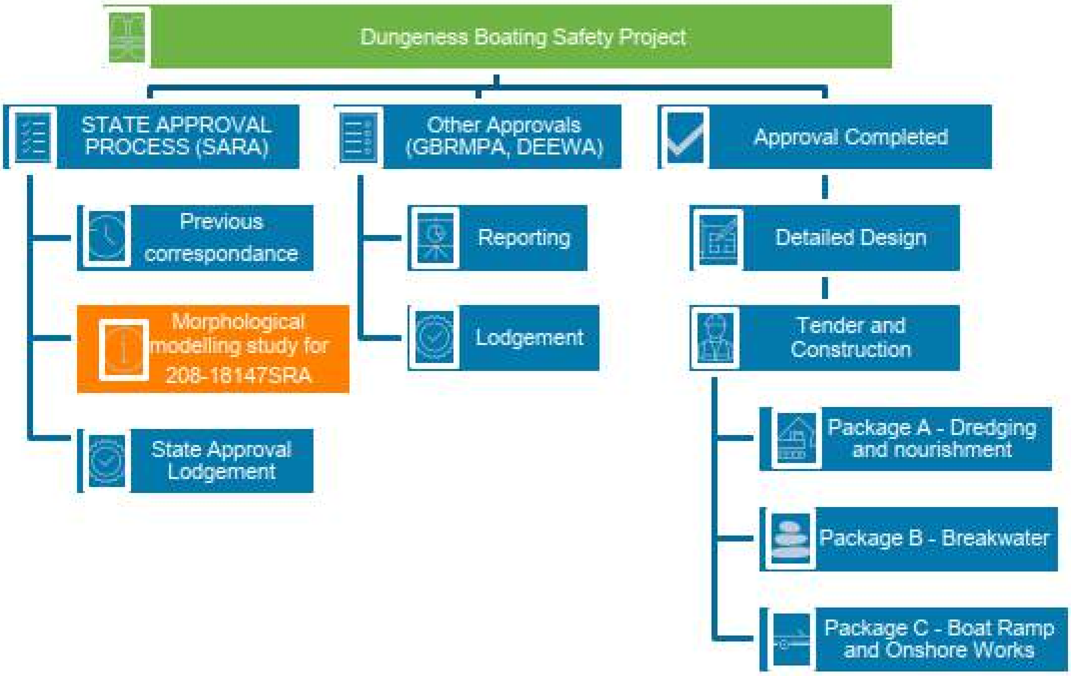


Figure 2-1 Dungeness Boating Safety Project overview

2.1.1 *DECD – Initial Commission* (Water Technology, February 2019)

HSC commissioned Water Technology to undertake hydrodynamic and sediment transport modelling investigations related to the proposed Dungeness Enterprise Channel dredging, breakwater and beach replenishment works proposed by Council.

A field monitoring campaign was conducted in the Lucinda region to assist the development of a suite of numerical models to undertake hydrodynamic and sediment transport modelling investigations related to the proposed Dungeness Enterprise Channel dredging, breakwater and beach replenishment works.

Following an extensive calibration process, hydrodynamic and spectral wave models were developed in accordance with the GBRMPA Hydrodynamic Modelling Guidelines (August 2012) to ensure an adequate representation of hydrodynamic conditions in the Lucinda region.

An evaluation of historical long-term environmental conditions identified May 2015 as the month most representative of ambient dry season conditions, during which the dredging campaign is proposed.

The proposed dredging operation was expected to utilise a Cutter Suction Dredger (CSD). The CSD was assumed to operate Monday to Friday from 9am to 5pm for a 19-day period at a dredge rate of 125m^3/hr to excavate a total volume of 13,615 m^3. The dredge conceptualisation was incorporated into the model via a dredge timeseries that represents the fines lost to the water column at the seabed. Modelling results demonstrated marginal differences in terms of sediment plume extent, intensity and duration between the existing and developed case (post-construction of the breakwater) and hence a summary of key observations applicable to both cases is presented as follows:

- Highly energetic local hydrodynamics characterised by strong current velocities during both flood and ebb tides and a near-uniform vertical velocity profile near the dredge zone resulted in a relatively rapid advection and dispersion of sediment plumes from the site of dredging and very limited opportunities for such material to settle;

- The spatial extent of the dredge-generated sediment surface plume above 10mg/L was less than 4.6 km2 in area, never extending more than 4.3 km northwest and 3.5 km east from the dredger and not affecting any sensitive habitats. Compared to the naturally variable TSS concentration in the region (measured median of approximately 40mg/L), this level of SSC would practically be not visible;
- Suspended sediment plume concentrations above 100mg/L extended a maximum distance of 600m from the dredged zone;
- The duration of maximum suspended sediment values generally lasted less than 6 hours; and
- A low magnitude of sediment deposition due to high shear stresses and strong current velocities.

2.1.2 *DECD – Variation 1* (Water Technology, May 2019)

In February 2019, HSC commissioned Water Technology to carry undertake a variation (1) on the initial works to undertake further investigation of the sediment transport in the study area, and to assess the likely sedimentation rate of the channel with and without a breakwater over the course of one year– thereby evaluating its efficacy in maintaining a navigable channel from Dungeness boat ramp to the main Hinchinbrook Channel. The modelling works conducted for this assessment are built upon the works conducted for the initial commission, including the same dredge channel and breakwater alignment design provided to Water Technology. The study revealed several key findings.

A sediment transport model was developed for base and developed cases, with the developed model incorporating the proposed breakwater. In both the developed and base case scenarios for one year of modelling, significant alterations in bed levels occurred both nearshore and offshore. These changes encompassed both increases and decreases in bed levels, notably within the maintenance and excavation zones.

Under the base case, the one-year simulation highlighted substantial potential for nearshore erosion along the beach east of the river mouth. This eroded sediment was projected to move westward offshore, forming a sand bank near the eastern boundary of the Dungeness Enterprise Channel. Bed level fluctuations in the channel's maintenance and excavation sections ranged from around +1.0m of deposition to approximately -0.6m of erosion.

In contrast, the developed case indicated a reduction in nearshore erosion potential near the breakwater, causing sedimentation to be concentrated to the west of it. The shoreline parallel bar also expanded. While bed level changes within the maintenance and excavation regions matched those of the base case in magnitude (+1.0m), their spatial extent was reduced by around 40% due to the breakwater construction. Similarly, bed level decreases in the northern part of these areas were less extensive and remained at a comparable magnitude (-0.6m). A scour hole formation was projected at the breakwater's end.

Simulating Cyclone Yasi revealed reduced sediment movement on the lee side of the breakwater in the developed case, with the base case showcasing a more extended shoreline parallel bar to the west.

Deposition within the maintenance and excavation zones varied between scenarios: the base case showed approximately 9,800 m3 and 6,500 m3 for one year simulation, and 600 m3 and 200 m3 for Cyclone Yasi. Under the developed case, the numbers were 5,900 m3 and 4,400 m3 for one year simulation, and 500 m3 and 200 m3 for Cyclone Yasi.

The introduction of the breakwater led to deposition reductions of 40% and 32% respectively in the maintenance and excavation zones for the one-year simulation, and 17% in the maintenance area during Cyclone Yasi. Sediment loss increased by 33% and 125% for the maintenance and excavation areas respectively under the developed case.

The breakwater primarily hindered longshore sediment transport along the beach east of the Dungeness Enterprise Channel. Additional influences, like wave and current manipulation, also contributed to sedimentation. Overall, the breakwater's presence resulted in sediment accumulation on its eastern side, anticipated to persist over time, potentially inducing significant changes in beach morphology, including alterations in orientation and width.

2.1.3 *DECD – Variation 2* (Water Technology, November 2019)

In August 2019, HSC commissioned Water Technology to conduct a sediment transport investigation over a three-year period to assess sedimentation and erosion in the channel with an updated breakwater alignment. The study also included a coastal processes analysis, beach nourishment recommendation, breakwater optimisation, and cost assessment. The following conclusions were drawn from the results:

- All modelling to date highlights the north-west migration of sand bars and sediments in the study area due to the net north-westerly flood tide currents;
- All modelling indicates the intertidal sediment along Dungeness Beach undergoes significant erosion due to the strong flood current speeds bed shear stress. This creates the net northwest longshore drift which continually erodes away the spit;
- Intertidal sediment also moves perpendicular to the beach (cross shore drift), which is shown as areas of scour and deposition parallel to Dungeness Beach in all modelled scenarios;
- The modelling predicts the beach nourished sediment undergoes significant erosion in the first twelve months. Both nourishment scenarios have a large intertidal area persisting after 3 years, indicating it is effective. A larger intertidal area is retained under the breakwater scenarios due to the reduced longshore drift;
- The modelling did not predict the beach nourishment to increase sediment deposition in the navigation channel;
- The realigned breakwater is much more effective at preventing siltation in the dredge channel, compared with the initial design;
- The shortened breakwater (scenario 5) also prevented siltation but was slightly less effective compared to the realigned design (scenario 3 and 4).
- The realigned breakwater resulted in a significant area of erosion at the tip of the breakwater which continually deepens throughout the three year simulation. This is due to natural morphological changes in the channel as it deepens and shifts northwest as well as an increase in bed shear stress due to the breakwater structure;
- Based on the modelling results it is estimated that with no breakwater, dredging would likely be required within 12 months, with the realigned breakwater dredging would be required within 5-10 years and with the shortened breakwater dredging would likely be required within 3-5 years;
- There are additional processes, such as swash zone action and extreme events, that contribute to erosion but are not captured within the long term modelling, therefore sedimentation in the navigation channel could be underestimated which would reduce the estimated return dredge period;
- The BW modelling predicted the realigned breakwater would reduce significant wave heights in the marina area to approximately 20 cm based on a 1 year ARI significant wave height of 0.8 m from north-northeast and east;
- A breakwater that was 75 m shorter was also simulated in the BW modelling. It was predicted to be just as effective as the longer breakwater at increasing safe harbourage;
- Beach nourishment would be beneficial re-use of the dredge material and is expected to be a cheaper disposal option compared to ocean dumping or landfill;

- Beach nourishment will impact on the amenity of the beach due to the dark colour of the dredge material;
- Annual maintenance dredging is required without the breakwater, less frequent maintenance dredging is required with the breakwater to remove sedimentation from cyclonic or fluvial events;
- While the initial capital cost to construct the breakwater are high ongoing maintenance cost would be reduced. Due to similar lifetime costs, the shortened breakwater (scenario 5) is the preferred option due to better environmental outcomes and potential scour protection;
- Sea level rise can be beneficial to the dredge area by potentially providing a greater water depth;
- The presented analysis is valid for average years only and conclusions and recommendations might vary due to cyclonic conditions or other storm events; and
- A breakwater is beneficial in reducing the maintenance dredging requirements and providing a degree of erosion protection to the northern beach. However, downdrift erosion (west and south of the breakwater) will need to be considered further as this could result in detrimental impacts in other areas such as around the boat ramp.

Along with the following recommendations for future work:

- Dredge material disposal options and costs will need to be investigated further;
- Approvals are required for all options and might not be provided for some of the options (e.g. breakwater within Marine Park). Discussions should be held with the relevant State departments to ensure that all options are feasible from an approval point of view;
- Dredge depth requirements for all tide access should be reviewed;
- Alternative options such as bed levelling should be considered due to the short lifespan of the capital dredging (annual maintenance dredging required);
- It is recommended that the shortened breakwater be considered for detailed design as the lifetime cost is similar to the longer breakwater, however it will potentially have better environmental outcomes, reduce downdrift erosion and provide some scour protection at the end of the breakwater.

2.1.4 *DECD RFI Response 1* - (Water Technology, 2021)

In January 2021, HSC commissioned Water Technology to undertake an assessment and provide reporting to support a response to an Information Request received from the State Assessment and Referral Agency (SARA) following lodgement of a development application for operational work. This commission also included a Dredge Management Plan to discuss dredging and beach nourishment operations in more detail.

The response included discussion around optimisation of the breakwater design to strike a reasonable balance between cost and functional performance, and further description on the ‘low crested’ nature of the structure. Low crested breakwaters are most prone to damage at the crest and the backslope from overtopping waves. The roundhead is also most prone to damage due to its exposure to waves and scour. This has been considered and addressed in the concept design.

The design was further discussed in the context of the surrounding environmental values, specifically the mangroves at the breakwater landing area. The seawall that is merging the breakwater to the land has been designed with a reduced crest width. Impacts on mangroves are still to be expected from construction activities, however, should the breakwater not be constructed, ongoing erosion of the spit might be experienced, resulting in ongoing mangrove decline. Historical erosion rates averaged 6.6 m/year from 1956 to 2017, with a range of 2 to 16 m/year observed over that time (Water Technology, 2019). The planned beach nourishment activities are likely to reduce the amount of ongoing erosion, however, erosion is still expected to continue despite the beach nourishment activities due to the natural sediment movement.

One consideration for the seawall components of structure are the possibility of end effects, which are often experienced at seawall and breakwater structures. While the breakwater structure is expected to capture sand and hold it on the beach (thereby reducing the potential for end effects at the north-eastern seawall), it is possible that the interception of sand supply into the channel may result in some localised erosion of the shoreline at the end of the north-western seawall. Additionally, previous studies (Water Technology, 2019b) have shown that the Dungeness foreshore is shifting towards the east. The existing foreshore consists of hard infrastructure (seawalls) which will halter the ongoing erosion. However, erosion might still be experienced up- and downstream of the existing hard infrastructure, namely north of the Hinchinbrook Marine Cove and south of Denny Street. Therefore, after construction is completed, it is strongly recommended that Council undertake a program of shoreline monitoring in order to identify and mitigate any potential localised erosion impacts.

The following assumptions have been applied in the concept design and should be refined during detailed design stages:

- No geotechnical analysis was undertaken as part of the concept design. Specifically, settlement of the breakwater has not been considered and might impact on the performance. The minimum crest level of 3 m AHD should apply to the breakwater after settlement occurred.
- The breakwater transition onto land is based on 2020 bathymetric and 2021 topographic surveys undertaken by Council. Ongoing erosion of the spit is expected (in between the time of these survey and the eventual commencement of construction), and therefore the merging of the breakwater into the land contours will need to be revised during detailed design and possibly again prior to construction, depending on the anticipated timeframes and the occurrence of erosive events.
- One design wave height has been applied to the whole breakwater for consistency and to limit transition areas. Varying wave heights along the structure can be considered during detailed design so as to potentially reduce rock sizing in some areas. However, consultation with the local quarries revealed that there is not much (if any) cost saving in adopting smaller rock armour.
- Early quarry involvement should be considered to ensure that rock of suitable sizing and qualities can be secured for construction. Purposeful early quarrying might have to be considered due to the expected quantities.
- Ongoing contractor involvement is recommended to ensure that the breakwater remains uncomplicated to construct and that sufficient site access is provided.
- Physical modelling should be undertaken as part of the detailed design phase in order to generate a cost effective design. Low crested structures are studied less than conventional breakwater structures and physical modelling is expected to result in savings on the final design. Savings can be in the form of potentially reducing the geometry of the roundhead as well as potentially reducing the armour sizing.
- Design of navigational aids as part of detailed design phases.

The following can be concluded from the additional modelling work and breakwater concept design:

- There are minimal impacts to water quality associated with dredging and dewatering. Changes to suspended sediment are short-term (in the order of 1-3 hours) due to the rapid and advection and dispersion of the plume;
- The morphological reanalysis highlighted how effective the breakwater is at stabilising the sediment transport dynamics along Dungeness Beach, and preventing further erosion of the mangroves;
- The breakwater can be designed as a low crested structure to reduce capital cost while providing a barrier to reduce dredge channel infill rates;
- The cost for dredging, beach nourishment and breakwater construction is estimated to be around $5.4 million;

- Geotechnical assessment, detailed design and physical modelling are recommended as future design stages.

Breakwater Design (Water Technology, 2021)

As part of this DECD RFI Response 1, Water Technology revised the breakwater initially provided as a reference design by Council. The position, length and alignment of the structure has been optimised based on analysis undertaken during preceding studies (Water Technology, 2019a; and Water Technology, 2019b).

The optimisation process recommended breakwater length be around 370 m from base to trunk, which is approximately 87 m less than what is shown in the initial reference design. The length of the structure was determined based on the need to limit the potential seabed scour at the head of the breakwater, while still ensuring that the breakwater fulfills its primary function of reducing siltation rates within the dredge channel.

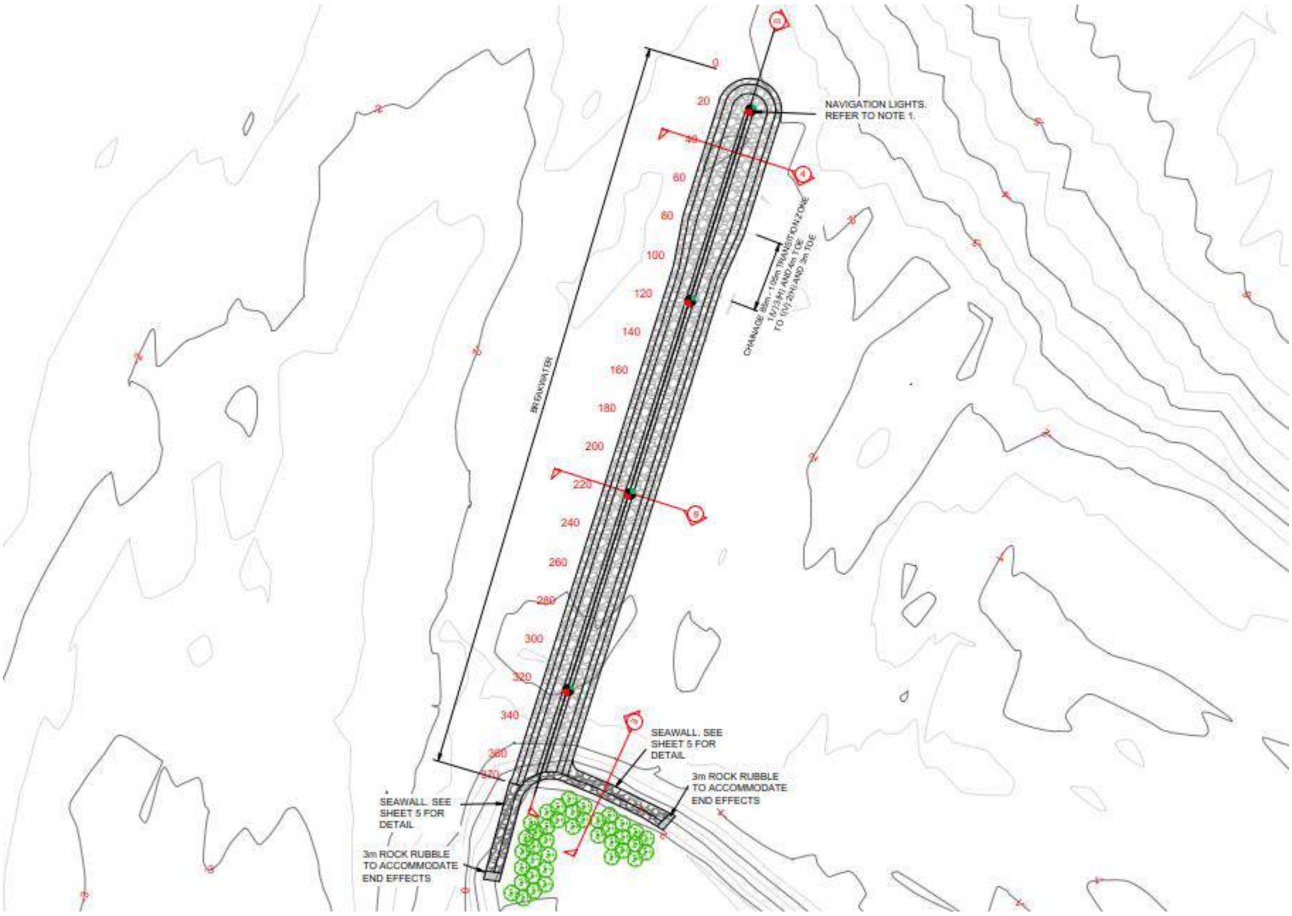


Figure 2-2 Plan view of concept breakwater design (Water Technology, 2021)

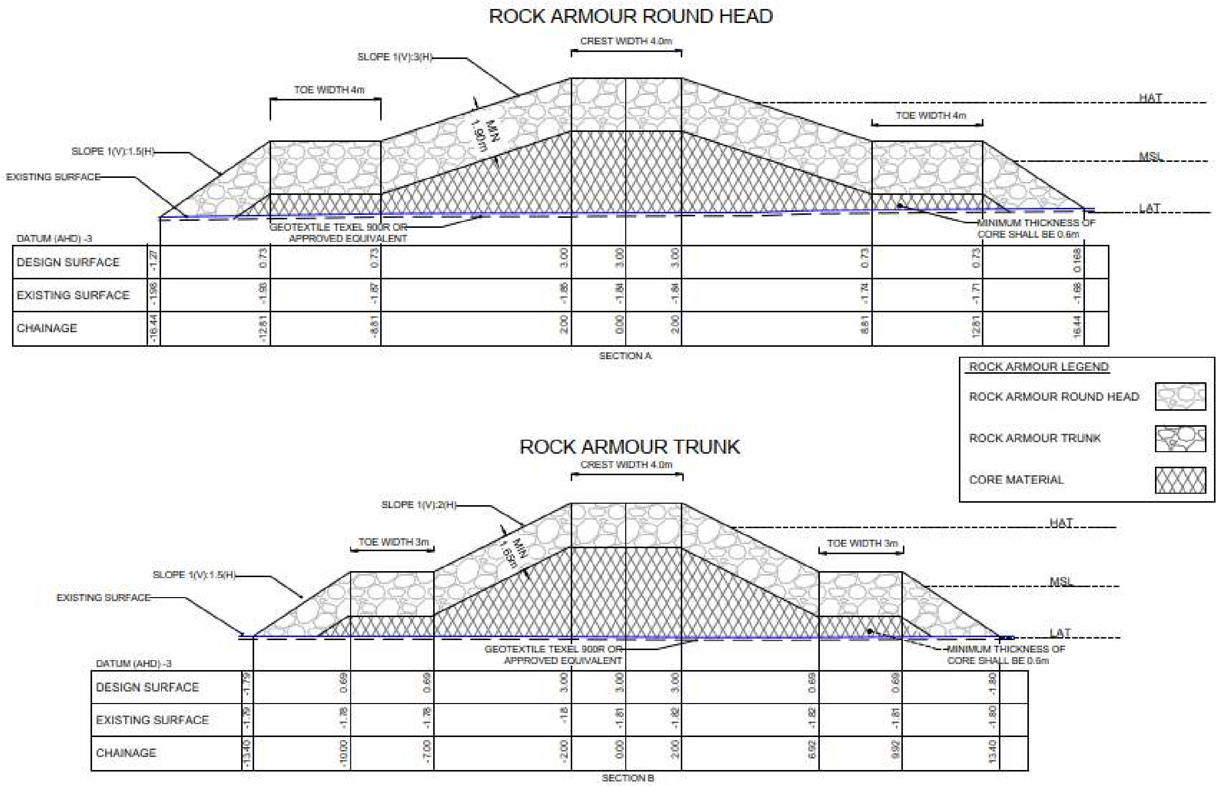


Figure 2-3 Cross sections of concept breakwater design (Water Technology, 2021)

A cost estimate was also developed for the breakwater concept design and is summarised in Table 2-1 below.

Table 2-1 Cost estimate for proposed concept design (Water Technology, 2021)

Reference	Cost
Direct Cost Total	$3,230,060.38
Indirect Cost Total	$1,148,006.04
Risk Cost Total	TBD
Contingency Cost Total	$969,018.11
Total	**$5,347,084.53**

Morphological Re-analysis (Water Technology, 2021)

The following data was extracted from the previous modelling and coastal processes study (Water Technology, 2019b). In this study the bed morphology was simulated under a range of scenarios including:

- Dredging only
- Dredging and beach nourishment
- Dredging, beach nourishment and breakwater

Time series results are presented in Figure 2-4 to Figure 2-6. The plots highlight sedimentation rate and cumulative deposition over a one-year period for each of the above scenarios.

The results show significant sediment transport for the dredge only scenario, with erosion and accretion occurring at all sites. With significant erosion occurring at site 2, which is closest to the spit.

For the scenario that included beach nourishment, as expected, there was also significant sediment movement due to the availability of extra erodible sand in the dynamic environment. Erosion was also greatest at location 2, which is closest to the spit, however sediment deposition (or accretion) appeared to be more stable.

When implementing the breakwater into the model, there was a significant reduction in erosion as sediment transport processes at Dungeness Beach stabilised, with accretion observed. The model results highlight how effective the breakwater is at stabilising the system and preventing erosion of the beach and mangrove habitat.

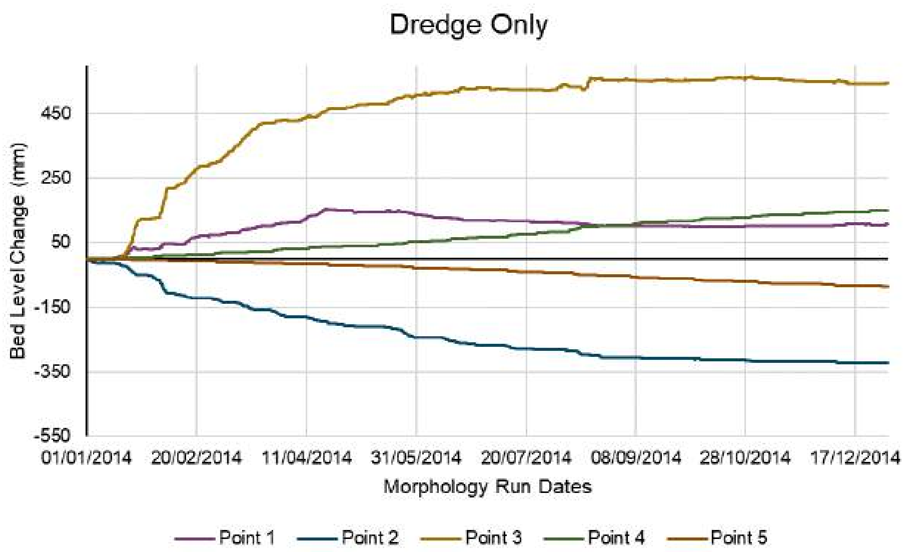


Figure 2-4 Bed Level change simulation for dredging

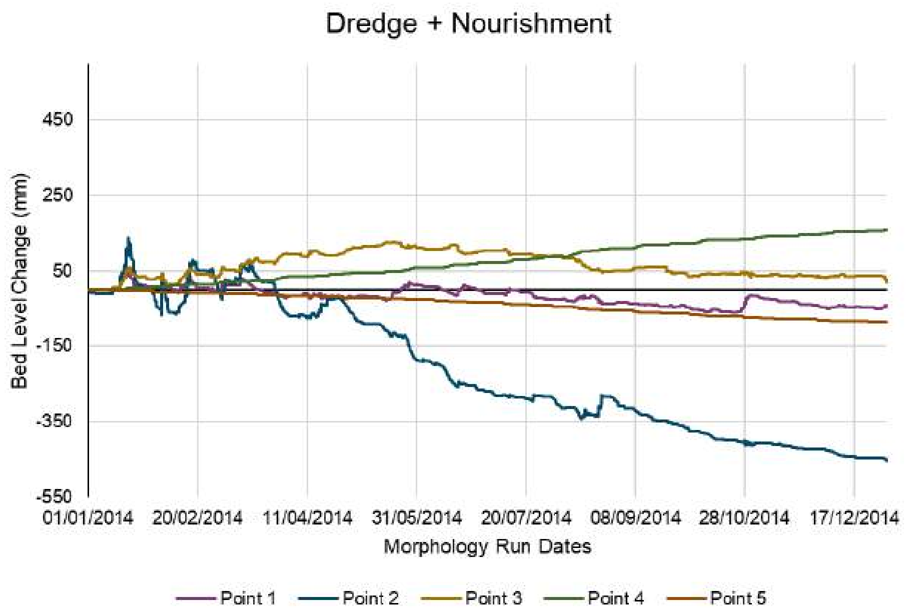


Figure 2-5 Bed level change simulation for dredging and beach nourishment

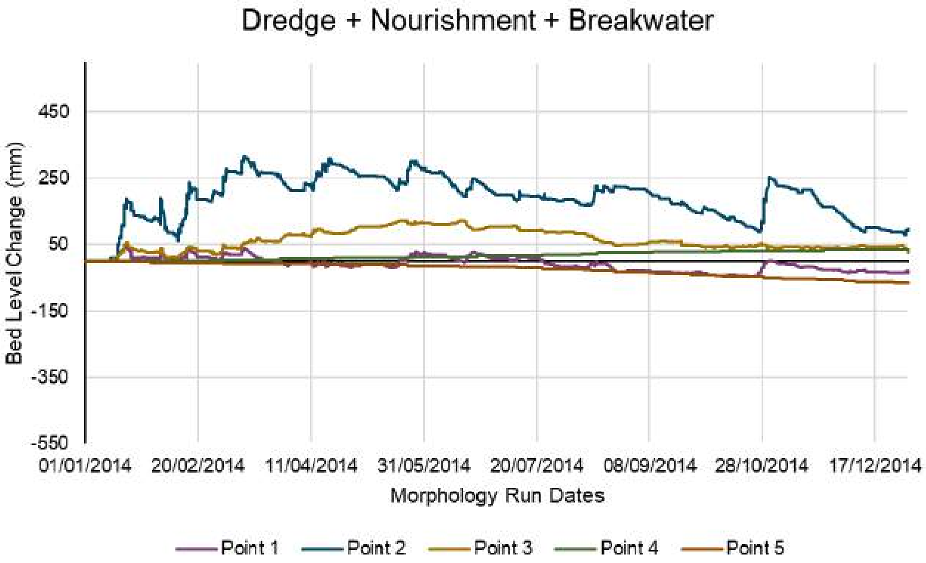


Figure 2-6 Bed level change simulation dredging, beach nourishment and breakwater application

Dredge Management Plan (Water Technology, 2021)

The Dredge Management Plan for the Dungeness Breakwater and Dredging project was prepared by Water Technology Pty Ltd for the Hinchinbrook Shire Council. The main objectives of the plan are to ensure near-total tide access in the dredge area, incorporate a long-term maintenance dredging system, and manage environmental impacts.

Specific management actions are in place to mitigate impacts to marine water quality and benthic ecology. These include the use of turbidity curtains around the dredge area, placement of dredged materials in the beach nourishment area, and implementation of a reactive turbidity monitoring program. The plan also addresses key environmental issues such as marine megafauna management, navigation and maritime safety, and noise and air quality. The contamination assessment concludes that the clean dredged sand is highly suitable for beneficial reuse as beach nourishment.

The implementation strategy for the project includes the use of a dedicated Cutter Suction Dredge (CSD), hydrographic survey(s), and a monitoring program. Compliance with international dredging standards and company standards on quality, occupational health and safety, and environment management systems are also important.

2.1.5 *DECD RFI Response 2 -* (Water Technology, 2022)

A submission was made to SARA whereby the proposed dredging and first round of beach nourishment work was approved, but the breakwater was not. The response from SARA stated that the breakwater was not approved ‘due to the structure having adverse impacts on coastal processes, including blocking sediment transport and changes to the natural fluctuations of sand and resulting erosion and sedimentation.’

The memo highlights the findings of a reanalysis conducted to challenge the assumption that coastal transport processes, such as erosion and accretion, will be adversely affected by the implemented breakwater. The study focused on three scenarios: existing conditions, approved dredging and beach nourishment, and rejected breakwater, dredging, and beach nourishment. During peak ebb and flood periods of a spring tide, the analysis examined changes in current speeds and bed shear stress. The results indicate that the breakwater has more significant effects during the flood tide, with notable reductions in current speeds on either side of the structure. However, the main channel's sediment transport processes remain largely unaffected by the breakwater.

The memo also provides a summary of the sediment transport conceptual model. The model was developed based on site visits, data collection, coastal process assessments, and modelling. Key takeaways from the conceptual model include the presence of tidal asymmetry, with a strong flood tide and weaker ebb tide driving sediment transport. The erosion of the western mangrove bank is attributed to the loss of protection from the eroded Spit, which occurred due to exposure to strong tidal currents and waves. The breakwater's introduction is not expected to significantly reduce major sediment transport in the main channel but will reduce cross-shore transport at Dungeness Beach adjacent to the structure. The breakwater will provide protection from tide and storm events, stabilizing the shoreline and preventing erosion on the western bank.

In contradiction to SARA's assessment, the conducted modelling and analysis indicate that the breakwater will not result in major upstream erosion or adverse impacts on sediment transport and coastal processes. The findings suggest that while localised changes occur around the breakwater, the main channel's sediment transport processes will remain minimally affected. The breakwater is expected to stabilise eroding areas, reduce cross-shore transport at Dungeness Beach, and limit sediment supply from the Spit, resulting in a slightly reduced sediment budget in the main channel.

2.1.6 Hinchinbrook Shire Council Shoreline Erosion Management Plan (Water Technology, 2023)

The Shoreline Erosion Management Plan (SEMP) for the Hinchinbrook Shire Council covers several coastal precincts, including Dungeness and the Enterprise Channel. One of the main issues arising at the Dungeness and Enterprise Channel area is the shoreline's historical changes, such as a reduction in the westerly extension of the Enterprise Channel spit and the growth and vegetation of the shoreline opposite Dungeness. To manage this issue, a section of an existing rock wall along the eastern bank of the channel has been built to stabilize the historical channel migration. The study shows that this section of the existing rock wall, located on Council land, is currently in good condition and, apart from ongoing inspections/maintenance and damage repair after flood events, no specific action is required for this section of the shoreline.

The plan proposes that dredging and the installation of a breakwater could help manage the sediment transport. However, it also highlights limitations to these options such as storm erosion loss. The document emphasizes the importance of managing sediment transport taking social, environmental, and economic values into account.

The SEMPs aim is to provide a long-term framework for the protection, sustainable use, and enjoyment of coastal public lands and assets. One of the key objectives of the plan is to address the sediment transport along the HSC coast driven primarily by waves. The document emphasizes that while dominant south-easterly ambient waves drive a net northerly longshore sediment transport along the HSC coast, the sediment transport is affected by all wave directions and storm events.

The SEMP reports that tropical cyclone activity can generate highly energetic northerly winds and waves, which can confuse boating activity. The study suggests that actions such as dredging and the installation of a breakwater would assist in maintaining safe navigational depth within the Enterprise Channel and managing the erosion and morphological changes of the Dungeness spit, which is located at the northern end of Dungeness beach. However, the study also highlights that a breakwater would likely not reduce storm erosion loss. Under such conditions, sand would be eroded along Dungeness beach by storm waves and deposited in a nearshore bar that would bypass the breakwater.

In summary, the SEMP highlights the importance of managing sediment transport through the installation of structures such as the breakwater while considering social, environmental, and economic values.

2.2 Other literature

2.2.1 Dynamics, Flushing and Trapping in Hinchinbrook Channel, A Giant Mangrove Swamp, Australia (Wolanksi et al., 1990)

This study investigated the tidal dynamics, flushing and trapping in Hinchinbrook Channel through a series of three field measurement programmes in 1989. The study found that the tidal dynamics in the channel are controlled by two nearly identical tidal waves entering the channel at each of the southern and northern openings. It notes that the mangrove swamps are important dynamically in impacting the tidal prism. The dispersion of nutrients, brackish water and any water-borne contaminants is through tidal diffusion only. The process of dispersion is controlled by lateral trapping in mangrove swamps and is very slow, indicating a residence time of approximately 50 days. The northern extent of Hinchinbrook Channel experiences additional coastal trapping of water in the shallow, mangrove fringed coastal waters. Under certain conditions, mangrove creek water is trapped in this area for at least two weeks in a coastal boundary layer along the mangrove fringed western bank. This concludes that brackish water, outwelled nutrients, and any contaminants are only very slowly flushed out of the mangrove creeks and, once flushed into the channel, remain trapped in the coastal zone when winds are light. The contaminants are appreciably diluted at spring tides by the tidal trapping effect in mangrove swamps. Coastal waters are constantly exchanged between the coastal boundary layer and the mangrove swamp, ensuring a strong dynamic link between mangrove and coastal waters.

Some key observations related to tidal currents include:

- Strong tidal currents up to 0.9 m/s;
- In the southern region, the flood tidal currents are northward (dominated by a tidal wave entering from the southern region);
- In the northern region, the flood tidal currents are southward (dominated by a tidal wave entering from the northern opening);
- Ebb tidal currents stronger than flood tidal currents;
- Tidal asymmetry is partially due to the presence of mangrove swamps and is responsible for maintaining a deep, self-scouring tidal channel.

Some key observations related to stratification include:

- Following the flooding of the Herbert River on the 1st February 1989, measurements showed that river runoff into Hinchinbrook Channel was short-lived and freshwater was injected into Hinchinbrook Channel as a pulse;
- Following the end of the flood, the freshwater that had been injected into the estuary became rapidly vertically well-mixed by tidal motions.
- The waters were vertically stratified in salinity and the isohalines surfaced at both the southern and northern openings.
- On 20th February, in the absence of any significant additional freshwater inflow, the brackish water found in the channel a week earlier was still there but this time the isohalines were nearly vertical, as a result of the mixing by the spring tides that occurred during the period.
- The persistence of the brackish water implies trapping in the channel.

2.2.2 Dungeness Enterprise Channel Feasibility Study (Central Queensland University, 1998)

The report presents a feasibility study commissioned by the Hinchinbrook Shire Council on the Dungeness - Enterprise Channel project. The study examines natural processes in the area and recommends stabilising the estuary and beach region. The report analyses the sediment transport, wave action, and wind patterns in the region to understand the erosion processes and suggests constructing a ‘jetty’ using geobags filled with sand to stabilise the channel entrance.

The study finds that the erosion of the peninsula at the entrance to Enterprise Channel has been ongoing for the past century. It identifies the long-term dominant wind direction for 1981 to 1997 for the sea sector as northeast and analyses wave data to determine that local waves from the sector of 60° to 120° affect the region. The report reveals that the channel has been silted up due to the confluence with the Herbert River, resulting in tidal flow becoming the dominant flow. Sedimentation occurs along the western bank of Enterprise Channel, likely influenced by the outflow from Dungeness Creek. The erosion of the beach is mainly directed westwards and is attributed to wave and tidal current action.

To stabilize the channel entrance, the report recommends constructing a jetty using geobags filled with sand obtained from dredging the approach channel. The suggested jetty should have a length of 60 meters, bearing 0°, and a height of 2.2 meters above the Australian Height Datum (AHD). The geobags should be laid on a geofilter extended 4.5 meters on each side of the jetty. The report suggests consulting with Soil Filters Australia Pty Ltd for the detailed technology of working with geobags. The protection of the eastern bank of the channel upstream from the estuary is also recommended, using a terrafix geotextile to prevent erosion.

Overall, the study concludes that the erosion of the peninsula has been a long-term process which might be influenced by significantly low wave conditions and accelerated by floods or cyclonic events. It should be noted that at the time of the study, no documented evidence relating to flood or cyclonic erosion had been found. It proposes the construction of a jetty using geobags and the protection of the eastern bank as feasible measures to stabilize the entrance to Enterprise Channel and prevent further erosion. Continuous monitoring of the beach changes is recommended to evaluate the effectiveness of the jetty solution and inform future decisions.

2.2.3 Environment Management of a Proposed Groyne at Dungeness (SKM, 2000)

The report details the investigation of implementing a sandbag groyne (60m long, 3 metres high and 6m wide) adjacent to a dredged channel (20 metres wide and 200 meters long). The aim to allow all-tide access into Hinchinbrook Channel and overcome the safety problem presented by tidal restrictions on access to the channel, importantly for the local Coast Guard.

The study looked at potential impacts in Water Quality, Potential Acid Sulfate Soils (PASS), Construction, Flora, Fauna and World Heritage Values/Fish Habitat Areas. Noting that the greatest potential for the development to impact on the physico-chemical environment is during the dredging phase in relation to impacts on hydrology and from the disturbance of sediments. A number of environmental management plans were presented for each of the above listed potential impacts with mitigation measures for each individual issue.

2.2.4 Evolution and dynamics of tropical river plumes in the Great Barrier Reef: An integrated remote sensing and in situ study (Burrage et al., 2002)

This journal article presents an integrated study of the Herbert River plume's dynamics and evolution using both in-situ data and remote sensing techniques. The study focused on the river's short-lived but intense freshwater discharge, which is critical to marine research and management in the Great Barrier Reef (GBR) World Heritage Area. Salinity was used as a tracer to identify the origin of river-borne contaminants and distinguish the effects of storm-induced resuspension and river discharge on turbidity. The study found that the plume's location and structure evolved in response to changing river flows, tidal and subtidal circulation, and wind.

Further analysis of the Herbert River plume over a 10-day period revealed that the size, location, and visibility of the plume significantly varied due to changes in tidal, wind, wave, and ambient current forcing. The plume's width and dispersal were affected by wind stress and along-shelf flow, indicating that all terms in the momentum balance must be considered in analysing the plume response to atmospheric and hydrodynamic forcing.

The plume was classified dynamically into an intermediate Kelvin number class, indicating that the momentum balance must be considered when analysing the plume response to atmospheric and hydrodynamic forcing. Although progress has been made in modelling plume behaviour, further research is required to understand the dynamics of plume evolution under different circumstances likely to be encountered in the GBR. Overall, this study demonstrates the need for a multidisciplinary approach that includes remote sensing techniques, in-situ data, and numerical models to develop a comprehensive understanding of the GBR's river plumes' evolution and dynamics.

2.2.5 Patterns of Erosion and Sediment and Nutrient Transport in the Herbert River Catchment, Queensland (CSIRO, 2003)

This aim of this project was to identify the major processes involved in the delivery of sediment and nutrients to rivers within the Herbert River Catchment. The study noted that various investigations exist into the movement of sediment and nutrients in the Herbert River Catchment, however few studies look at this from a 'whole of catchment' perspective. The study used spatial modelling of the erosion, deposition, and transport processes that move sediment and nutrients within landscapes and streams to produce regional budgets for the Herbert River Catchment.

It is noted that the model outputs are averages only and are considered to be representative of the range of conditions experienced over a 100-year climate record. The use of averages constrains the relevance of the modelling to larger spatial scales (sub-catchments) and means that the results should not be used to extrapolate to sediment and nutrient loads at the individual property or farm scale.

The study reveals that the dominate source of sediment in the Herbert River Catchment is hillslope erosion, contributing 52% of the total sediment load at the river mouth. Gully and streambank erosion contribute equally approximately 24% to make up the remaining sediment load. The quantified sediment budgets are listed below in Figure 2-7.

Sediment budget item	Predicted mean annual rate (t y^{-1})	
	This survey	NLWRA
Hillslope delivery	430,000	840,000
Gully erosion rate	210,000	170,000
Riverbank erosion rate	220,000	100,000
Total sediment supply	860,000	1,110,000
Total suspended sediment stored	30,000	430,000
Total bed sediment stored	200,000	120,000
Sediment delivery to estuary	***620,000***	***560,000***
Total losses	860,000	1,110,000

Figure 2-7 Comparison of the sediment budget between this project and the NLWRA for the Herbert River Catchment (CSIRO, 2003 – Table 7)

This study also suggests that further research is needed to integrate the total sediment load (bedload and suspended sediment) so that it is possible to accurately estimate exports from the Herbert River mouth. The results from the pre-1850 scenario suggest that there has been a 6-fold increase in the amount of sediment exported from the Herbert River Catchment.

2.2.6 A sediment budget for the Herbert River catchment, North Queensland, Australia (Bartley et. al, 2004)

The paper presents the findings of a study that aimed to determine the major sediment sources and sinks within a large tropical catchment using GIS-based models, particularly the SedNet model. The research focused on the Herbert River catchment in North Queensland, Australia.

The study revealed that hillslope erosion was the dominant source of sediment, contributing 52% (~490,000 t/year) of the total sediment load at the river mouth. Gully erosion and stream bank erosion each contributed approximately 24% (~220,000 t/year) of the sediment load. Hillslope erosion was particularly significant in grazing lands and forested areas, especially in steep eucalypt-dominated woodland areas in the Herbert River gorge. Forested sites, despite covering a smaller portion of the catchment, generated almost the same amount of sediment as grazing lands due to their high rainfall and steep slopes.

Gully erosion exhibited significant variability across the catchment, with the most severe erosion observed around mine sites in the Upper Herbert and steeper grazing areas upstream of the Herbert River gorge. Riverbank erosion contributed an equal amount of sediment as gully erosion, with no discernible pattern observed in the catchment. Higher rates of bank erosion were noted in upper catchment areas and specific sections of the main Herbert River channel, particularly where riparian zones were lacking and stream power was highest.

The SedNet model predicted that approximately 40,000 t/year of fine sediment was stored on the flood plain. The study also utilized radioactive isotope tracer concentrations as a tracer for sediment sources, finding that concentrations generally increased towards the coast, indicating a higher contribution from hillslope erosion along the river.

Overall, the results highlight the effectiveness of GIS-based models in predicting sediment sources and sinks within the Herbert River catchment. The findings provide valuable insights for implementing targeted catchment management practices to mitigate soil erosion. Understanding the relative contributions of different land uses and erosion processes can help inform conservation strategies and enhance sustainable land management practices in the region.

Sediment budget item	Predicted mean annual rate (t $year^{-1}$)
Hillslope Delivery	490 000
Gully erosion rate	220 000
Riverbank erosion rate	220 000
Total sediment supply	930 000
Total suspended sediment stored	40 000
Total bed sediment stored	210 000
Sediment delivery to the estuary	680 000
Total losses	930 000

Figure 2-8 Summary of sediment budget for the Herbert River catchment (Bartley, 2004)

Land use	Area (km²)	Proportion of total area (%)	Predicted total soil loss (t year⁻¹)	Average erosion rate (t ha⁻¹ year⁻¹)
Native pastures	5840	60	200 000	0.34
Improved pastures	48	0.5	1000	0.10
Forest and other reserves(1)	2881	30	200 000	0.69
Sugar cane	690	7	35 000	0.51
Other agriculture	79	0.8	5000	0.64
Residential or industrial	22	0.2	0	0.01
Mining	52	0.5	40 000	7.76
Other (e.g. quarries)	135	1.4	10 000	0.74

(1)The forest and other reserves category contains a range of forest types from open eucalypt woodland to rainforest and melaleuca species.

Figure 2-9 Contribution of Hillslope erosion from each of the major land use areas with the Herbert River Catchment (Bartley, 2004)

2.2.7 Wet Tropics Water Quality Statistics for High and Base Flow (DES, 2014)

The Great Barrier Reef Catchment Loads Monitoring Program (GBRCLMP) collects water quality data at 25 sites along the east coast of Queensland, including the Herbert River. The program measures concentrations and calculates annual loads of various substances in the water. The results indicate that the Herbert River at Ingham had the highest values for the 80th percentile of oxidized nitrogen and ammonia nitrogen under base flow conditions, as well as dissolved organic phosphorus during high flow periods. However, these results should be interpreted cautiously due to the limitations of the data.

Comparing base flow and high flow conditions, the percentile values generally showed higher concentrations during high flow periods. Soluble parameters had percentiles 1.24 times larger under high flow conditions, while total parameters had percentiles more than seven times larger. The results varied across different sites due to differences in rainfall and catchment characteristics. These percentile values can be used to inform water quality guidelines in Queensland.

The report suggests that similar reports for other regions and annual updates for the Wet Tropics could be generated if requested. The data collected by the GBRCLMP, and the Herbert Water Quality Monitoring Program provide valuable information for assessing water quality in the Herbert River catchment and can contribute to the development of effective environmental management strategies.

2.2.8 Sediment Sources to the Great Barrier Reef – What if the coastal zone is a major sediment source rather than a sink? (Spencer et. Al, 2014)

A study conducted in the Princess Charlotte Bay (PCB) area of the northern Great Barrier Reef (GBR) challenges the commonly held assumption that coastal plains act as sediment sinks. Instead, it suggests that the extensive coastal plain through which the major rivers of the Normanby Basin flow is a significant sediment source. Geochemical tracing data indicates that the coastal plain is responsible for delivering up to four times more sediment to PCB than the entire catchment itself. The study calls for further research to understand the processes behind this erosion and the mechanisms by which sediment is transferred from the coastal plain to the bay.

The findings of the study have broader implications, suggesting that other coastal plains along the Queensland coast may also be significant sediment sources to the Great Barrier Reef. To accurately estimate sediment loads and effectively manage catchments draining into the GBR, sediment budget models need to incorporate coastal erosion and variable source/sink floodplains. Neglecting these components in modelling could lead to underestimating sediment input and misdirecting resources for sediment pollution mitigation.

The study emphasizes the need for tailored sediment budget models that consider the specific characteristics of each catchment. It highlights the importance of including coastal processes and floodplains as either erosional or depositional zones in order to inform management decisions regarding sediment loads entering PCB and the northern GBR. Failing to account for these factors could result in inaccurate estimations and ineffective allocation of resources. Therefore, a greater focus should be placed on understanding the processes within the coastal zone interface between Reef Catchments and the GBR lagoon.

2.2.9 Dungeness Dredge Channel and Boat Ramp (Jacobs, 2018)

This geotechnical investigation report was conducted for the Hinchinbrook Shire Council in March 2018 by Jacobs Group (Australia) Pty Limited. The investigation aimed at providing geotechnical information and preliminary advice for the proposed dredge pocket in the Dungeness Enterprise Channel and maintenance and upgrade works to the area adjacent to the boat ramp at Dungeness. The investigation involved a limited number of vibrocore samples and Flat Plate Dilatometer Testing at the site, with subsurface conditions inferred from these. The test pit site locations are shown below in Figure 2-10.

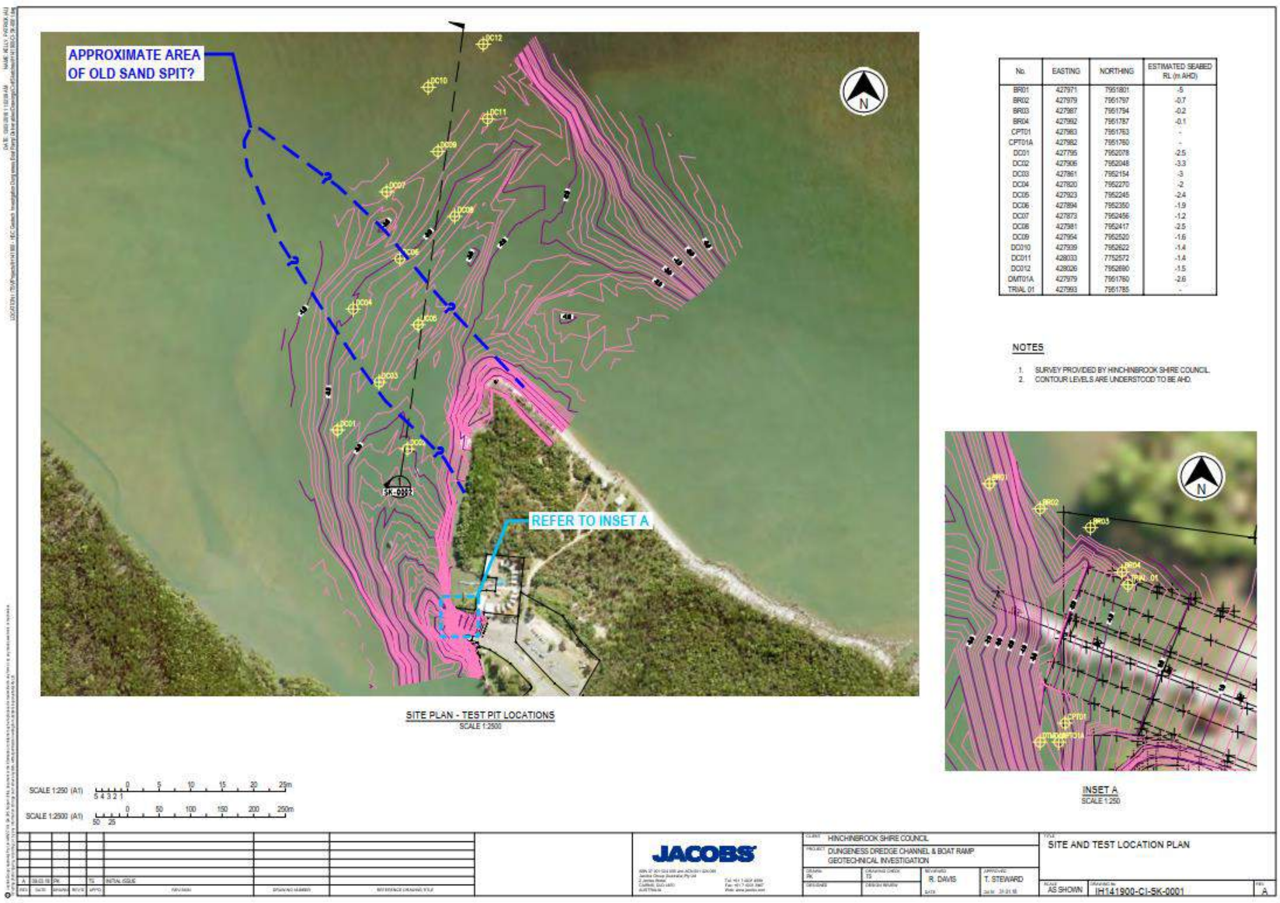


Figure 2-10 Site plan and test pit locations (Jacobs, 2018)

The soil and classification test results indicate a mixture of sand, clay, silty sand and clayey sand at BR01-BR04 and DC01-DC12.

Subsurface conditions within the proposed dredge pocket of the main channel are predominantly very loose to loose sand (occasionally silty or clayey sand) with only minor intermittent layers of fine grained soil (very soft to soft silt and clay). Conditions adjacent to the boat ramp on the northern side are predominantly soft high plasticity clay with some minor intermittent layers of sand. The vibrocore test locations BR01, 03 and 04 all refused prior to target depth on what appeared to be a layer of gravel. This may also be old rockfill from previous construction activities.

The investigation also looked at Acid Sulfate Soil (ASS) testing, with results indicating most of the soils encountered could be ASS with factors indicating Potential Acid Sulfate Soil (PASS). All testing suggested that none of the test factors were high enough to suggest any of the samples were Actual Acid Sulfate Soil (AASS).

2.2.10 Near-reef and nearshore tropical cyclone wave climate in the Great Barrier Reef with and without reef structure (Callaghan et al., 2020)

This study was completed in 2020 and investigated the effect of the Great Barrier Reef (GBR) structure on the nearshore wave climate along the coast. The study developed tropical cyclone wave climates for the entire GBR by simulating several thousand synthetic cyclones derived from the HadGEM general circulation model with RCP8.5 climate change scenario. The study concludes that the existing GBR structures reduce nearshore wave or runup height by between 1.5 and 2 times compared to the no reef case. The reduction in wave or runup height was found to be minimal for 1m Sea Level Rise (SLR). These findings indicate that there is more flooding potential from coral removal than SLR within the GBR lagoon.

2.3 SARA Responses

Water Technology's scope of services is to undertake data collection and detailed numerical modelling, specifically sediment transport modelling, to a level of detail that addresses the requirements outlined by SARA in the Request for Information (RFI), 2008-18147 SRA. The State has provided a series of historic requests for information since the DA was lodged on 31/08/2020, and these are summarised below.

2.3.1 2008-18147 SRA Advice Notice – 31/08/2021

This SARA information request related to a number of issues listed in summary below:

- Environmentally relevant activity (ERA): ERA 16 – Dredging
  - The application material does not address the requirement to provide analysis of the impacts to all environmental values at the location – specifically water and land.
  - Dredging of this threshold requires a whole of life Dredge Management Plan (DMP) to manage and mitigate the risk to the Great Barrier Reef Marine Park and associated water environmental values. Information regarding the land-based dredge material placement area should be included in this document.
- Removal, destruction or damage of marine plants
  - The application material does not include plans of sufficient detail to undertake an assessment of the development's impact on marine plants.
- Maritime Safety
  - The development application has not provided information about the proposed measures to prevent vessels from entering or transiting through the construction zone during construction.
  - The development application has not provided information about the proposed location and type of lighting to be installed on the completed breakwater structure.

2.3.2 2008-18147 SRS Information Request - 01/09/2021

This SARA information request related to a number of issues in conjunction with the previous advice notice. Following a review from SARA, the following issues were identified with the proposed development:

- Removal, destruction or damage of marine plants:

- The proposal, in its current form and with the information provided, is unlikely to achieve compliance with Performance Outcome (PO) PO2, PO8, PO10 - PO12, PO17, PO20, PO22, PO24 and PO25 of State code 11 of SDAP with reasons listed within the document.
- The application material does not adequately demonstrate there is a need for the development, and alternatives (locations and designs) which do not involve removal, destruction or damage of marine plants and impacts to fisheries resources and fish habitats are not viable.
- It has not been demonstrated that the spatial extent of marine plant disturbance has been minimised to the greatest extent possible. The ecological report appears to be based on a 400m rather than an 830m long breakwater, suggesting that the full impact of the proposed option has not been accurately identified.
- It has not been demonstrated that the timing of the works avoids marine plant flowering, fish spawning and fish migration periods.
- The proposed breakwater will modify marine coastal processes including:
  - sediment transport and deposition
  - erosion/accretion rates and locations
  - the velocity and direction of tidal, long-shore and estuarine currents and flows
  - sub-tidal and intertidal habitat elevations and inundation patterns

  The beach nourishment program will degrade seagrass beds. Seagrass serves as prime fish habitat for recreation and commercial fish species and supports a diverse array of other marine fauna that contributes to fisheries productivity and the region's economy. No information has been provided regarding the proposed works potential to impact on marine plants through the modification of coastal processes and inundation patterns. These broadscale impacts will affect adjacent near-shore, offshore and estuarine environments, onshore tidal wetlands, declared fish habitat areas and world heritage foreshores.
- The works have been proposed without any obvious threat of erosion on infrastructure and land use, and without any due consideration of the effects surrounding coastal processes (which in turn affect marine plants).
- It has not been demonstrated that the proposed beach replenishment works will comply with a minimum replenishment cycle of two years. The application material is unclear about sand retention replenishment times. Moreover, it is unclear whether dredge spoil is available to service the replenishment cycle or that the dredge spoil material has the characteristics required of beach replenishment material. No other source of replenishment material has been discussed.
- The proposed works do not provide details of restoration works except in terms of restoring sand to the northern beaches. There are concerns the proposed works will:
  - degrade and fragment mangrove habitat at the start of the breakwater
  - prevent tidal inundation of marine plant communities growing at the upper extent of tidal reaches
  - smother seagrass in or adjacent to beach nourishment zones
  - smother or undermine marine plants due to changes to sediment transport, erosion and accretion processes and sub-tidal elevations

  These changes will be difficult to predict and rectify. However, it is likely restoration or remediation works will be required in at least some the marine communities adjacent to the permanent works.
- A minimum 20,187m^2 of marine plants will be lost or severely impacted by the proposed works. Given the discrepancies in breakwall length within the documentation, it is likely the impact has been

underestimated. The ecological report based its estimations on a 400m instead of an 830m long breakwater and did not sufficiently account for the spatial and temporal impacts of the breakwater and beach nourishment on physical processes.

The modelling suggests there will be changes in sub tidal topography and changes to the rate and distribution of erosion and accretion processes. The increase in suspended sediment from the dredging works and the placement of spoil will exacerbate these impacts. The impacts will present as changes in marine plant extent, distribution, diversity, and abundance and need to be accounted for when it comes to 'avoiding, minimising mitigating' impacts and calculating a significant residual impact.

The application material refers to some mitigation actions regarding dredging and beach nourishment but not the extended impacts arising from changes to coastal processes. The application does not provide or commit to site specific work methods, plans or actions that 'avoid, minimise, mitigate' impacts to marine plants and other fisheries habitats.

2.3.3 2008-18147 SARA Response – Dungeness Road, Lucinda

This SARA response involves the approval of the dredging for all tides access to Dungeness Boat Ramp with the following conditions as specified in the response document:

- The rock breakwater conflicts with State Development Assessment Provisions (SDAP), specifically State Code 8: Coastal Development and tidal works and State Code 11: Removal, destruction or damage of marine plants. This is due to the structure having adverse impacts on coastal processes, including blocking sediment transport and changes to the natural fluctuations of sand and resulting erosion and sedimentation. Significant impacts to marine plants communities will also occur within surrounding waters, including the Hinchinbrook Channel declared Fish Habitat Area. Given this, the response does not include approval of the rock breakwater.
- To enable all tides access this response approves dredging of the boat access channel and a once only disposal of capital dredge spoil on Dungeness Beach. Future maintenance dredging of the boat channel is also approved, providing spoil disposal occurs off site. A condition, requires monitoring of the capital dredge spoil disposal impacts on the seagrass bank adjacent to Dungeness Beach.

3 DATA REVIEW

A range of datasets were obtained and reviewed to guide the development and calibration of hydrodynamic and spectral wave models. This section provides an overview of the data followed by a description of the data obtained for the purposes of this assessment.

3.1 2018 Data Collection Campaign

A data collection program was designed to collect quantitative and qualitative data with which to develop and calibrate hydrodynamic and spectral wave numerical models of the first project commission. This field monitoring program spanned from the 14th of December 2018 to the 16th of January 2019, and aimed to capture the following datasets:

- *In situ* water elevation measurements at three (3) locations;
- *In situ* current profile measurements at a single location using a bottom-mounted Acoustic Doppler Current Profiler (ADCP);
- *In situ* turbidity measurements using a nephelometer (mounted on the ADCP frame);
- *In situ* wave measurements using a wave recorder (mounted on the ADCP frame); and
- Current circulation patterns using drifter tracks.

Table 3-1 and Figure 3-1 illustrate instrument deployment locations.

Table 3-1 Instrument deployment locations

Instrument	Lat/Lon (WGS84)
Bottom-mounted frame: - ADCP - Nephelometer - Water Level Logger - Wave Logger	18.51995°S, 146.32581°E
Offshore Water Level Logger	18.53027°S,146.37908°E
Hinchinbrook Channel Water Level Logger	18.49314°S,146.25316°E

Figure 3-1 Data collection locations from previous campaign

3.1.1 Currents

The current measurements are representative of a typical estuarine/coastal environment. Table 3-2 contains depth averaged current statistics for the ebb, flood and total tides. Over the measurement period, peak spring tide current speeds range from 1m/s at the near seabed to 1.2m/s at the near surface, and during the measured neap tide, range from 0.5m/s (bottom) to 0.7m/s (surface).

Figure 3-2 and Figure 3-3 illustrate the current velocity profile as timeseries plots and a depth-averaged current rose which enable us to draw the following observations:

- Currents are dominated by tidal forcing and flow along a northwest-southeast axis parallel to the shoreline;
- Peak currents speeds are greater during the flood tide than during the ebb tide; and
- Current speeds at the seabed are marginally weaker than in the upper water column (surface layer), which indicates a well-mixed water column and a strong potential for seabed erosion and resuspension of dredge material.

Figure 3-4 and Figure 3-5 display vector plots of velocity profiles for spring ebb tide, spring flood tide and during a period of low current speeds and strong winds. The plots demonstrate how the magnitude of current speeds is greater during the flood tide. Figure 3-5 demonstrates the greater vertical stratification of the current scheme that can occur during periods close to slack water.

Table 3-2 Depth-averaged ADCP current statistics

Parameter		Flood	Ebb	Total
Current Speed (m/s)	Mean	0.31	0.21	0.28
	20th percentile	0.09	0.07	0.10
	90th percentile	0.63	0.41	0.55
	Maximum	1.10	0.63	1.10
Net current direction (°)		304	128	300

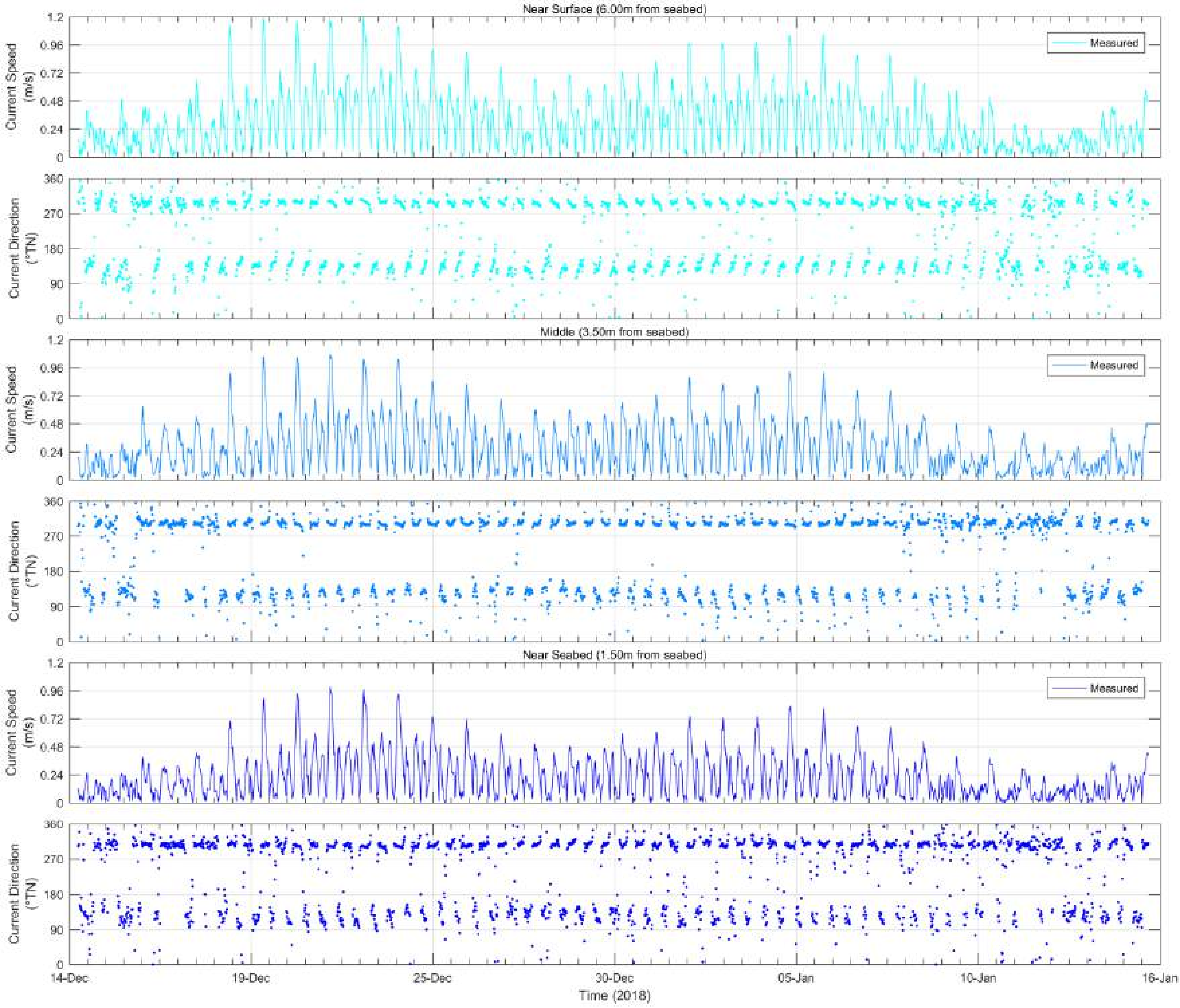


Figure 3-2 Measured current speed and direction at the surface, mid-depth and bottom

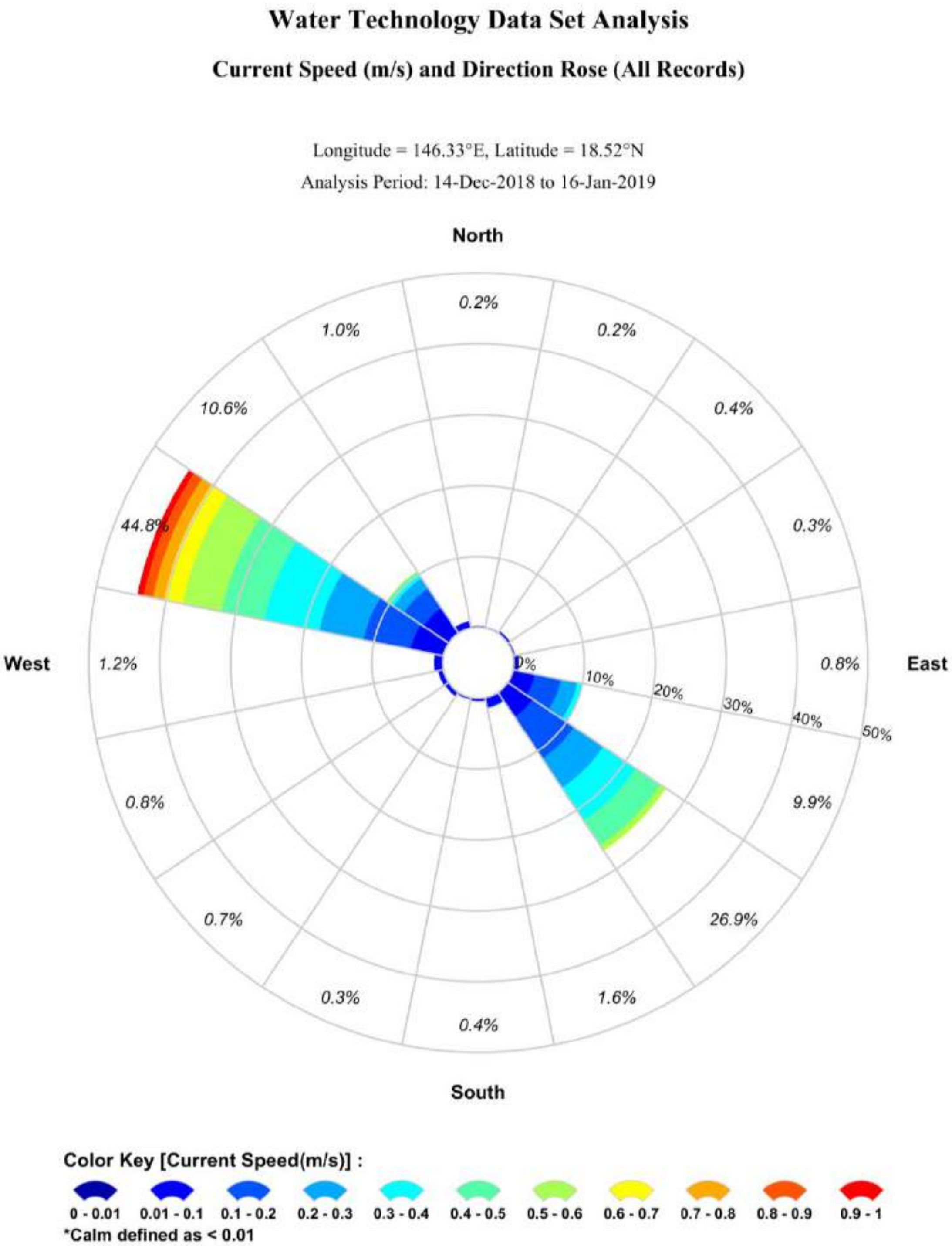
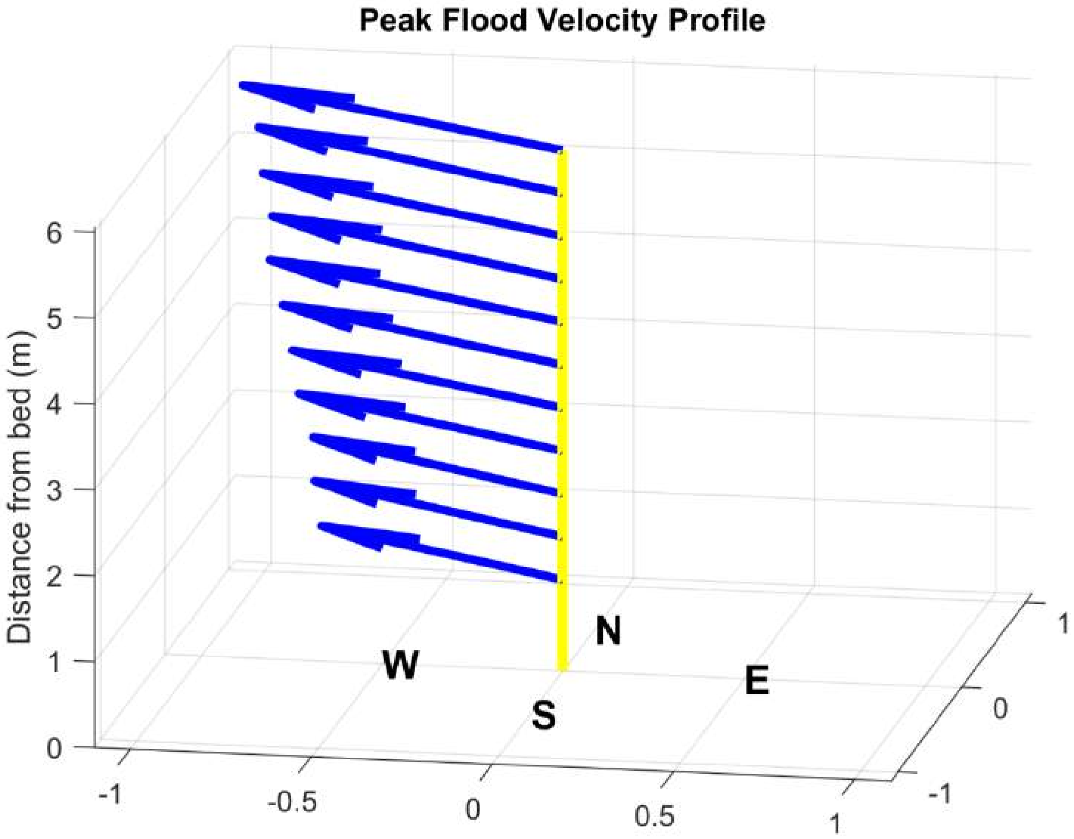


Figure 3-3 Depth averaged current rose of speed and direction. Note, the current rose indicates the direction going towards.



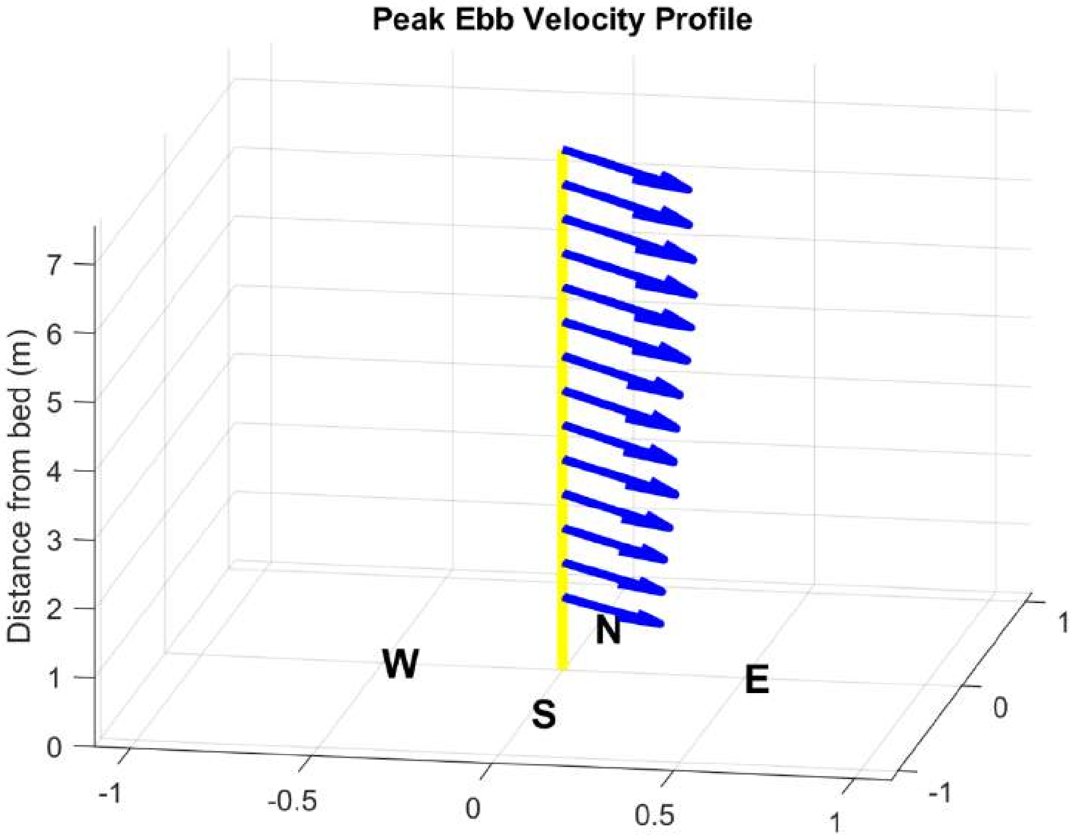


Figure 3-4 Velocity profile for a spring tide during the peak ebb and flood

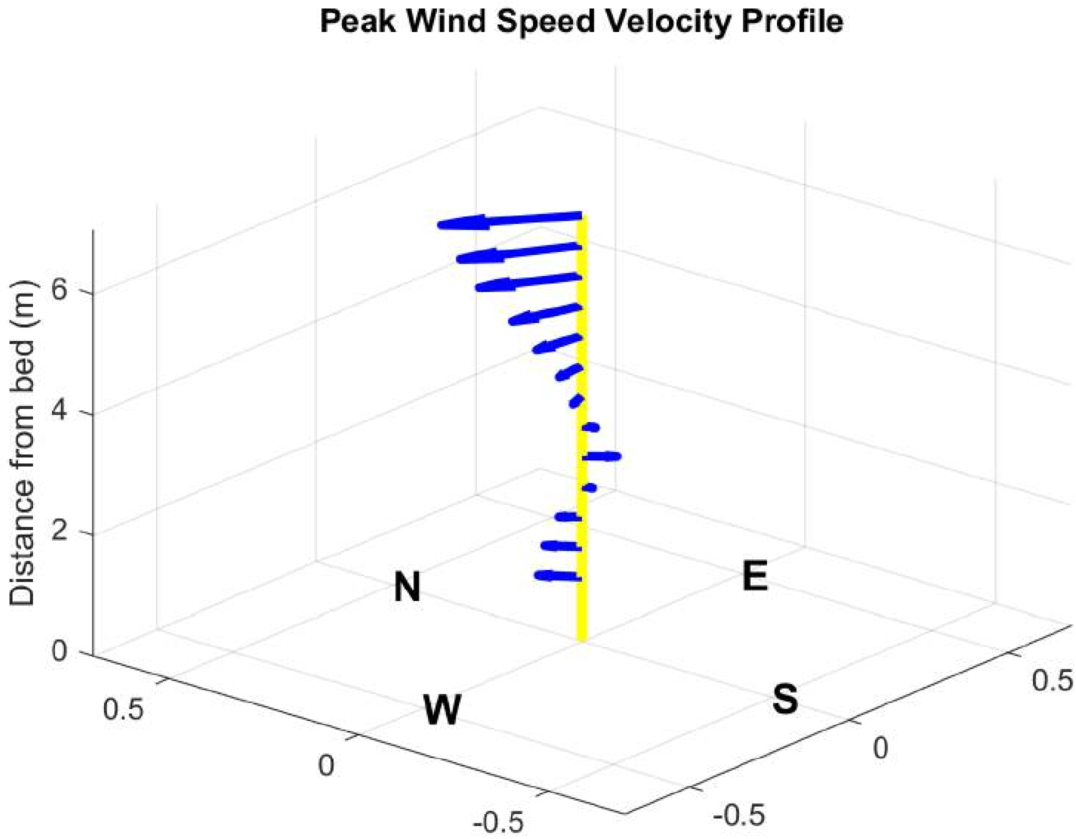


Figure 3-5 Velocity profile during a period of weak current speeds and peak wind speed

3.1.2 Water Elevations

Two (2) out of the three (3) water level loggers that were deployed could not be retrieved and as a result all data recorded by these two (2) devices was lost. The third logger mounted on the ADCP frame was successfully collected and all data analysed and processed to guide hydrodynamic model calibration/validation.

The post-processing phase consisted of running the raw data through a low pass filter with a cut-off frequency of 0.041 Hz in order to eliminate any low frequency signals, or residuals resulting from fouling, partial obstruction of the pressure sensors over time, gradual atmospheric pressure changes or storm surge as a result of the cyclonic activity in the area. The high lowpass filtered data was then subtracted from the original data to obtain corrected water surface elevations.

Timeseries graphs of the filtered measured water elevations are presented in Figure 3-6.

Additional measured water elevation data available from MSQ at Cardwell and Lucinda Offshore was sourced for the period of deployment to provide further points of comparison for model calibration/validation.

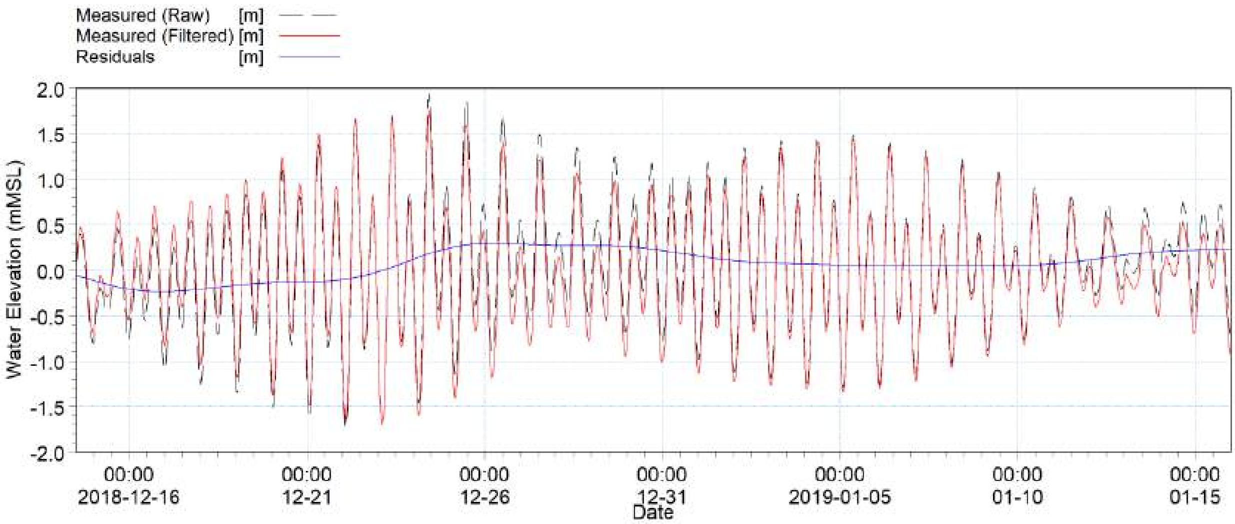


Figure 3-6 Measured raw and filtered water elevation at the ADCP location

3.1.3 Turbidity

Turbidity was measured *in situ* continuously throughout the monitoring campaign as well as via laboratory testing of collected water samples. Water samples were taken from the mid-water column at the ADCP location during instrument deployment and sent to the laboratory for analysis. The water samples were analysed for turbidity (NTU) and total suspended solids (TSS) concentration (mg/L), which allowed for the conversion of NTU to mg/L using a factor of 1.89 (see Table 3-3).

Table 3-3 presents percentile statistics for the *in-situ* turbidity measurements as well as for converted TSS values. The statistics indicate that the median, which is indicative of background levels during monitoring, is 20.7 NTU or 39.2 mg/L.

The *in-situ* measurements are presented as a box plot and time series in Figure 3-7 and Figure 3-8, respectively.

Table 3-3 Laboratory results for turbidity, TSS and conversion factor.

Date/Time	TSS (mg/L)*	Turbidity (NTU)	Conversion factor (NTU to TSS)
4/12/2018 8:03	8	3.5	2.28
4/12/2018 11:05	6	4.0	1.50
		Average	1.89

Table 3-4 Turbidity and converted TSS statistics

Percentiles	Turbidity (NTU)	Converted TSS (mg/L)
5^{th}	4.9	9.3
25^{th}	10.6	20.0
50^{th}	20.7	39.2
75^{th}	52.1	98.5
95^{th}	143.5	271.3

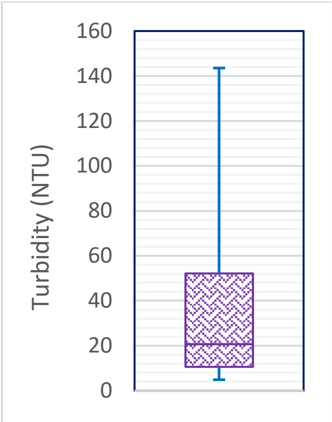


Figure 3-7 Box plot of *in situ* turbidity measurements

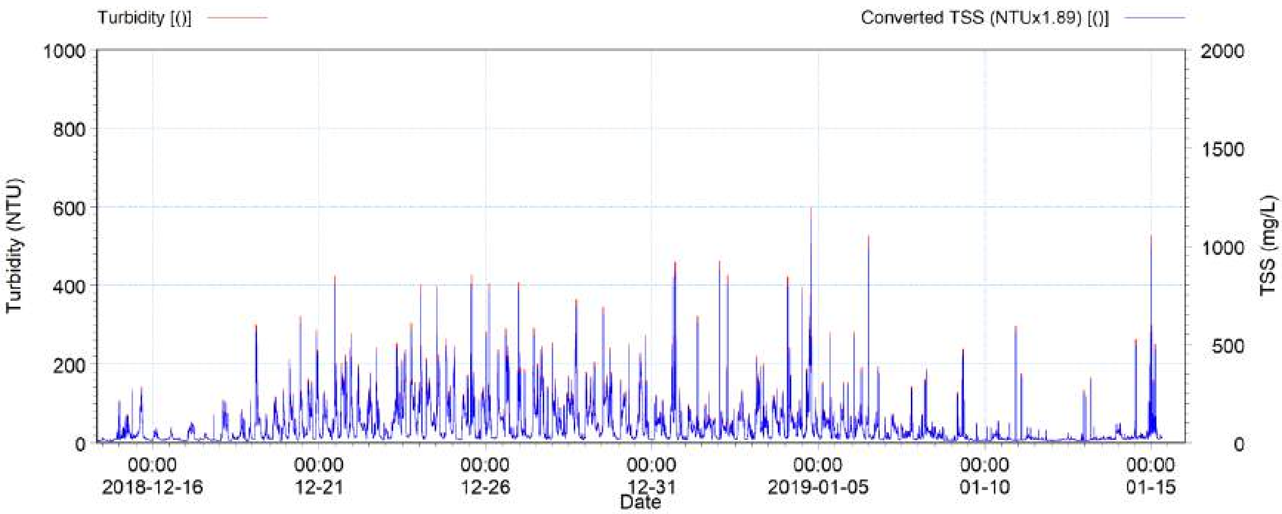


Figure 3-8 Measured *in situ* turbidity (left axis) and derived TSS concentration (right axis) using a ratio of TSS=1.89xNTU

3.1.4 Waves

The measured wave data is presented in Table 3-5 and Figure 3-9. During the monitoring period, the deployment location was dominated by local seas, as recorded waves had periods less than 8 seconds for 97% of the time. The significant wave height peaked at 0.4 m.

Table 3-5 Wave statistics from measured wave data

Parameter		Value
H_s (m)	5th percentile	0.05
	25th percentile	0.09
	50th percentile	0.13
	75th percentile	0.16
	95th percentile	0.22
T_p (s)	5th percentile	4.6
	25th percentile	5.0

Parameter		Value
	50th percentile	5.5
	75th percentile	6.0
	95th percentile	7.6
Percentage of time T_p <8 s		97
Percentage of time T_p >8 s		3

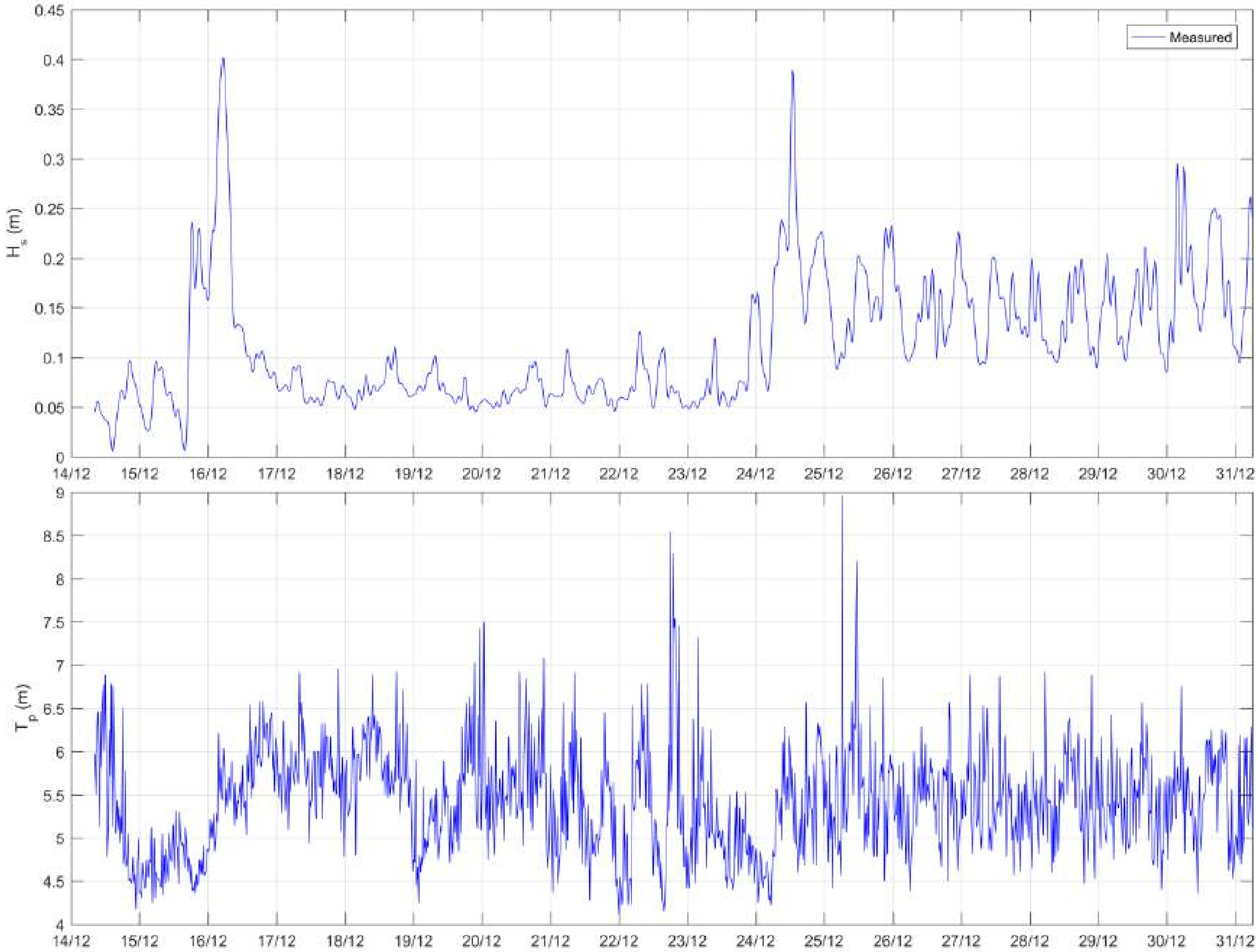


Figure 3-9 Measured H_s and T_p at the ADCP location

3.1.5 Drogue Tracking

Surface current circulation patterns in the vicinity of the ADCP location and the proposed dredge zone were recorded by way of surface drifter buoy releases performed on the 14th December 2018. Another attempt at capturing additional drifter tracks on the 16th of January 2019 (instrument retrieval date) was hindered due to strong winds, rainfall and limited visibility. Table 3-6 presents a summary of drifter track logs recorded by the mounted GPS unit and Figure 3-10 illustrates drifter trajectories.

Average current velocities measured by the drifter releases demonstrated satisfactory correlations with measured current velocities which fell within the 20th percentile and mean measured current speed. This data provides a good indication of where the dredge plume might go under flood and ebb tides.

Table 3-6 Summary of Drifter Tracks Recorded on the 14th of December 2018

Drifter ID	Time of Deployment	Time of Retrieval	Time Deployed	Distance Travelled (m)	Average Speed (m/s)
1	14/12/2018 07:43	14/12/2018 10:51	3h08min	1,030	0.09
2	14/12/2018 10:55	14/12/2018 13:15	2h20min	1,340	0.16

Figure 3-10 Drifter tracks from the initial data collection campaign

3.2 Other Data

3.2.1 Water Level Gauges

Lucinda (offshore) is a Maritime Safety Queensland (MSQ) Standard Reference Port for tidal planes and storm tide monitoring station, represents a nearby and highly relevant tidal gauging site, approximately 7km to the west and offshore of the site. Table 3-7 shows the Lucinda tide gauge tidal planes.

Table 3-7 2023 Tidal Planes – Lucinda (Offshore) (Queensland Tide Tables (MSQ), 2023)

Tidal Plane	Present Day (m AHD)
Highest Astronomical Tide (HAT)	2.16
Mean High Water Springs (MHWS)	1.14

Tidal Plane	Present Day (m AHD)
Mean High Water Neaps (MHWN)	0.33
Mean Sea Level (MSL)	0.04
Mean Low Water Neaps (MLWN)	-0.25
Mean Low Water Springs (MLWS)	-1.05
Lowest Astronomical Tide (LAT)	-1.90

Within the wider study area, there is also an MSQ secondary port reporting station and storm tide monitoring station at Cardwell. Data was also able to be retrieved from a temporary station that was setup on the Old Sugar Wharf (approximately 1.8km west of Enterprise Channel) to replace Lucinda Offshore when it was destroyed by YC Yasi in 2011, and was kept active once Lucinda (offshore) gauge was re-established.

Figure 3-11 shows a snapshot from the Lucinda (offshore) Storm Tide Monitoring Station that highlights a neap tide, a spring tide, and a storm surge event that occurred during Cyclone Larry at the Lucinda storm tide station in 2006.

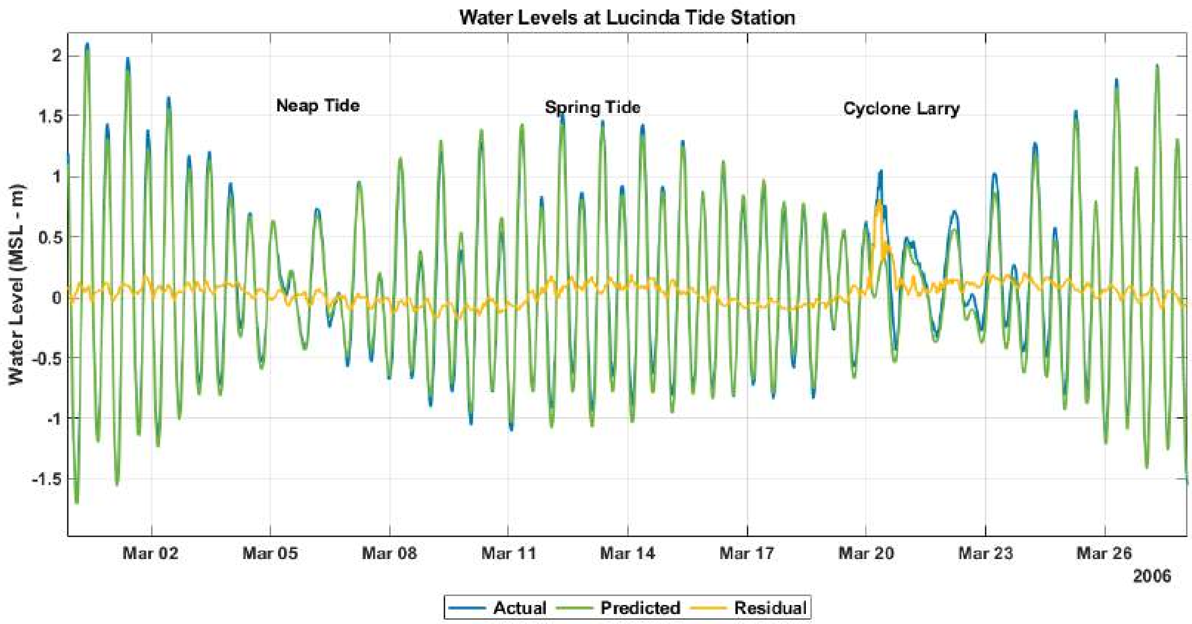


Figure 3-11 Water levels at Lucinda Tide Station

The predicted astronomical water level is shown as green, the actual measured water level is shown by the blue line and the residual, which is the difference between the measured sea level and predicted astronomical tide level, is the yellow line. This timeseries highlights the short-term impact of Cyclone Larry on water levels, which created a storm surge of approximately 0.75 m at Lucinda. For this event, the storm surge occurred during a neap tide, so despite the storm surge, water levels remained within the 'day-to-day' range at Lucinda.

A detailed storm tide study has previously been undertaken in 2004 for the Hinchinbrook region (Connell Wagner, 2004). The storm tide levels for various Annual Exceedance Probability's (AEP) are shown in Table 3-8 including and excluding wave setup.

Table 3-8 Dungeness Storm Tide levels inclusive of greenhouse related central pressure change

Average Recurrence Interval	Storm Tide Level (m AHD) excl wave setup	Wave Setup Height (m)	Design Storm Tide Level (m AHD) incl wave setup	Design Storm Tide Level (m LAT) incl wave setup
2% AEP (50 YR)	2.25	0.20	2.45	4.29
1% AEP (100 YR)	2.51	0.35	2.86	4.7
0.2% AEP (500YR)	3.04	0.45	3.49	5.33
0.1% (1000YR)	3.26	0.45	3.71	5.55

3.2.2 Wind Climate

Regional and local winds can influence the speed and direction of currents, waves, and sediment transport. The wind climate is measured by the Bureau of Meteorology (BoM) at several weather stations near Lucinda, which include:

- Lucinda Point (Station 032141) – 3 Hourly Synoptic (1980-Present) and 1 min (June 2013 – Present)
- Cardwell (Station 032004) – 24 Hourly
- Cowley Beach (Station 032194) – 3 Hourly

The annual wind climate of Lucinda is summarised within a wind rose presented in Figure 3-12. Lucinda is situated in the trade wind belt. As a result, the area's wind is dominated for most of the year by the south-to-south-east trade winds. There is, however, a pronounced seasonality in the local wind climate. For example, during the dry season from May to September, winds tend to arrive consistently from a more south-easterly direction. Conversely, during the wet season months of October to April, winds are more easterly and interspersed with afternoon northerlies (and occasionally tropical cyclone activity) – see Figure 3-13.

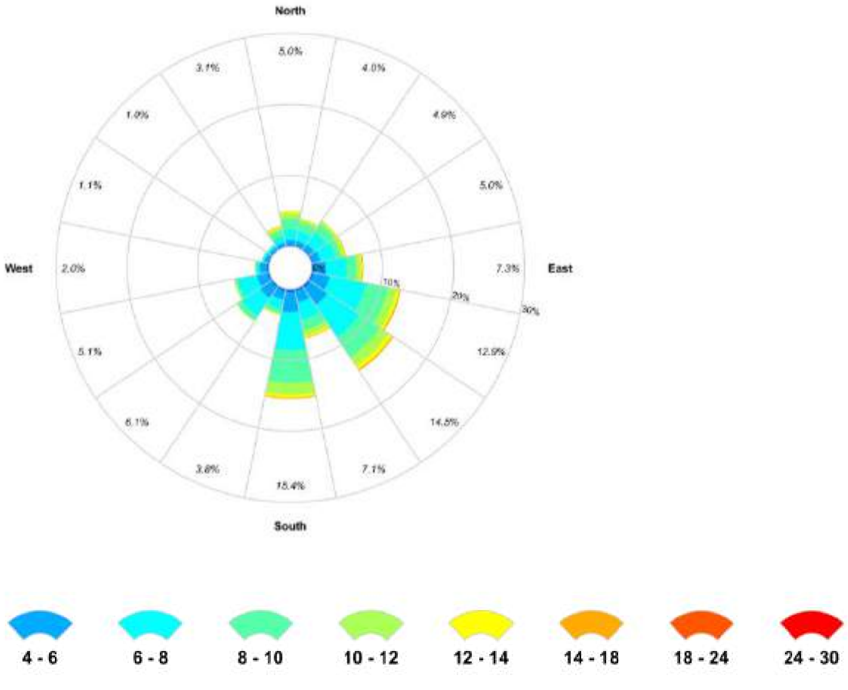


Figure 3-12 Wind rose of Lucinda (1990 to 2022)

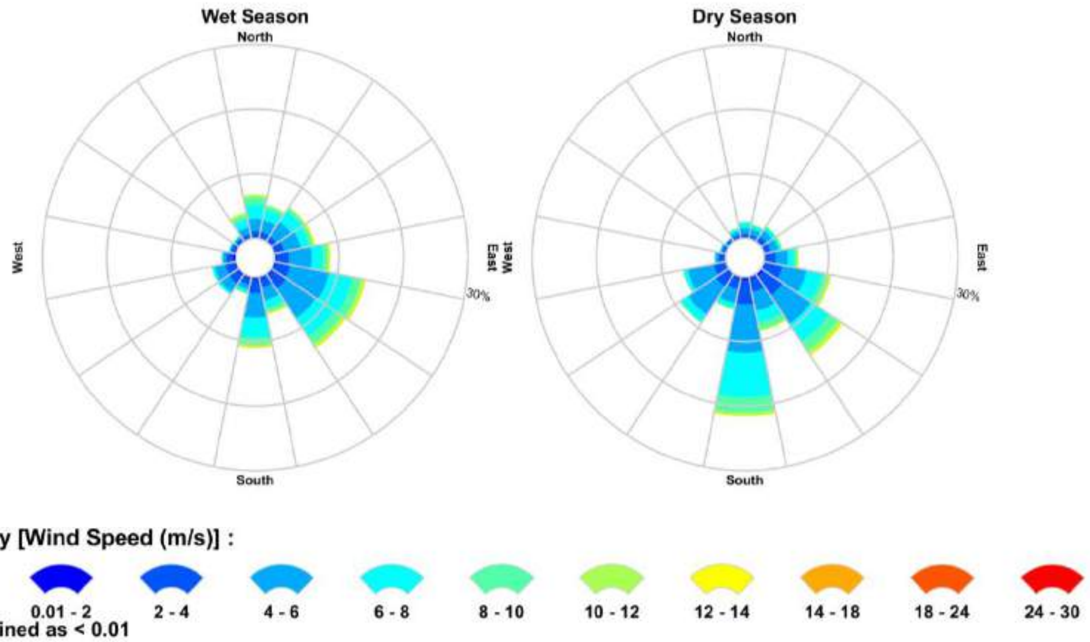


Figure 3-13 Seasonal Wind Roses of Lucinda Point (1990-2022)

3.2.3 Wave Climate

Swell Waves

Weather systems generate swell waves out in the Coral Sea, beyond the Great Barrier Reef. In order to reach the Hinchinbrook coast, these waves must pass through and over the extensive reefs and shallow shoals that constitute the Great Barrier Reef. Consequently, there is considerable attenuation of wave energy during this propagation process, and very little offshore swell wave energy reaches Hinchinbrook.

Local Sea Waves

Local sea waves are generated by winds blowing across the open water fetches between the mainland and the outer Great Barrier Reef system. The significant distances between the mainland and the Great Barrier Reef generate large waves. Waves growth is further increased during cyclones, which are relatively common in North Queensland.

The south-easterly trade winds dominate the direction of ambient waves (i.e., the “day-to-day”). Therefore, the majority of local sea wave energy arrives from the southeast. The study area coastline is relatively well protected from easterly and south-easterly waves by the Palm Islands archipelago. However, to the north of the study area, there are very long open water fetches across which winds can generate significant wave energy. It is from this sector that the largest waves approach the study area. These northerly waves generally occur during the wet season, particularly in the afternoon. Additionally, tropical cyclone activity can generate highly energetic northerly winds and waves. Waves from these sources can coincide, generating a cross-sea, which can confuse boating activity.

Waves primarily drive sand transport processes. However, while the dominant south-easterly ambient waves drive a net northerly longshore sediment transport along the HSC coast, the sediment transport is affected by all wave directions and storm events.

Available Wave Data

The Queensland Government installed a wave rider buoy (WRB) at Lucinda and recorded hourly, non-directional wave parameters. The deployment period spanned 1995 and 1996 and covered approximately 1 year and 2 months, as detailed in Table 3-9.

Table 3-9 Lucinda WRB History

Site	Latitude	Longitude	Time Period (43pprox..)	Recording Frequency	Directionality
Lucinda WRB	-18.5157	146.3833	1995 March – 1996 May	hourly	Non-directional

Figure 3-14 shows a timeseries of significant wave height (H_s) and peak wave period (T_p) and indicates that the significant wave height ranged between approximately 0.1 m to 1.5 m and had an average Hs of 0.45 m. The peak wave periods were generally less than 8 seconds, indicating the area is dominated by local sea waves, with some moderate local swells occurring during storms or cyclonic events.

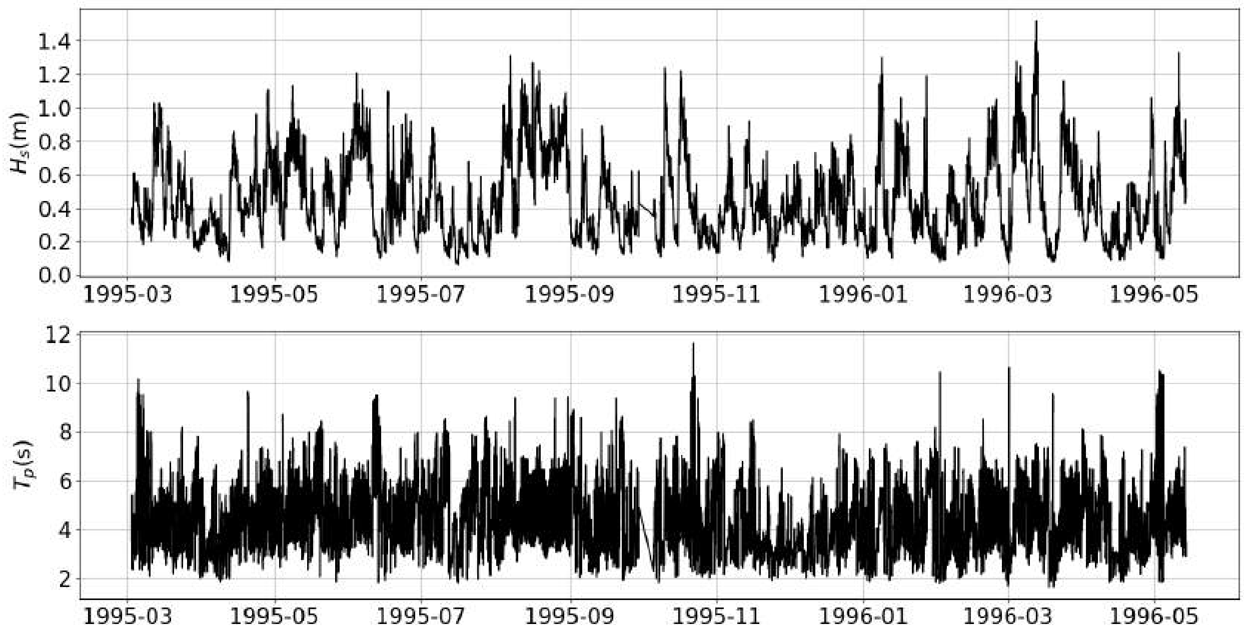


Figure 3-14 Time Series of Recorded Wave Data at Lucinda WRB: 1995-1996

Figure 3-15 shows the joint occurrence of H_s against T_p. This plot allows the identification of potential swell occurrence in Hinchinbrook channel coastal waters. It indicated that ambient significant wave heights were typically less than 1m with associated T_p less than 5s. A high percentage of waves are locally generated waves (wind waves), with negligible long wave energy (T_P > 9s).

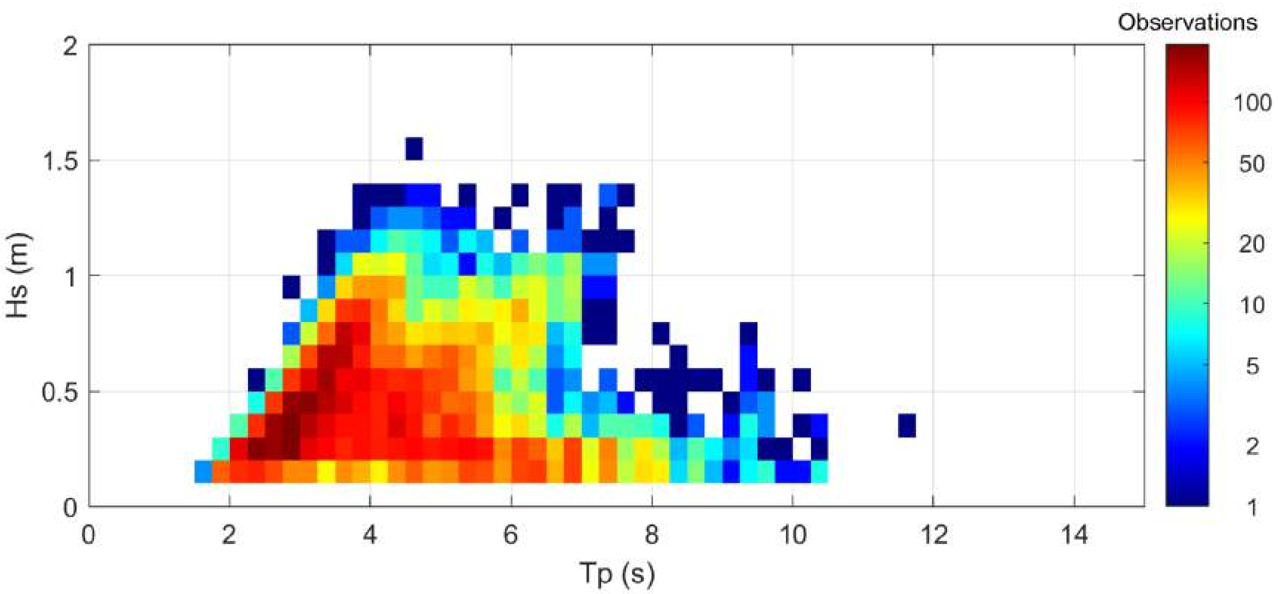


Figure 3-15 Joint Occurrence of Hs v Tp at Lucinda offshore WRB: 1995-1996

3.3 Survey Data

3.3.1 Existing Bathymetric Data

A number of pre-existing survey datasets are available in the region of varying extents and resolutions. These are listed below in Table 3-10.

Table 3-10 Existing LiDAR and survey datasets

Dataset	Source	Extent	Resolution
GBR Bathymetry	Geosciences Australia	Regional	30m
C-MAP	C-MAP Nautical Charts	Regional (Land and Water)	Varying
Intertidal	Digital Earth Australia	Intertidal/Regional	25m
Dungeness Surveys	HSC	Dungeness Beach – Boat ramp	5 – 50m in channel

3.3.2 SANDMAP Bathymetric Survey

As part of this project, an additional survey was completed for a large portion of the Hinchinbrook Channel, Enterprise Channel and where possible, the Herbert River mouth. The extent of this survey is shown below in Figure 3-16.

A number of features were identified in a review of the dataset including:

- Large (potentially) rocky outcrops in the main channel of varying sizes, ranging from 20m in diameter through to 100+ metres in length.
- Sand waves on the seabed of varying orientations and wavelengths/amplitudes.
- Natural scour channels formed at the mouth of the Enterprise Channel.
- Large delta formations at most of the river confluences with the Hinchinbrook Channel.

Figure 3-16 Extent of bathymetric survey completed by SANDMAP

3.4 Imagery

The Hinchinbrook region has a limited number of imagery sources available:

- The most recent imagery is available on Nearmap however the extent is limited to as far north as 1km north of Dungeness into the channel, the Enterprise Channel and most of the land south of that point.
- Queensland Globe imagery provides a similar extent of recent imagery as Nearmap with older imagery supplementing the remaining parts of the study region.
- Historical imagery is discussed in subsequent sections of this report and is mostly taken from QGlobe or imagery provided by HSC.
- Digital Earth Australia (DEA) coastlines has recently been updated to include 2022 coastlines in the dataset.

3.5 Sediment Data

3.5.1 Geological History

The coastal geology and geomorphology of the Hinchinbrook Coast region has been investigated and documented in the Herbert River Coastal Sector report, Marine & Coastal Geology Unit Project Report MA50/3, prepared by the Department of Minerals and Energy for the (then) Beach Protection Authority (BPA) in June 1993 (Holmes, BPA, 1993). The remainder of this section summarises the BPA findings for the study area and is complemented and supported by contemporary studies, aerial imagery, and site visits.

Historically, the Hinchinbrook coastline has experienced significant dynamic change. Two dominating factors have influenced the Hinchinbrook coastline over the past 18,000 years. As per (BMT, 2009), these include:

- Major sea level change between 18,000 and 6,500 years ago, rising by approximately 120 metres to the present sea level. As the sea rose, the shoreline moved landward, submerging the former coastal plain. During this transgression, the existing older Pleistocene alluvial and coastal sediments were reworked at the shoreface and, in part, transported onshore. In addition, fluvial sediments from the Herbert and other coastal rivers continued to supply fine and sandy sediments to the coast.
- The evolution of the Herbert River entrance since the "stillstand," 6500 years ago, has seen it move progressively north. It is estimated that the annual supply of sediment to the Hinchinbrook coastline is in the order of 130,000 m^3/year. This sediment surplus has resulted in the accretion of the shoreline adjacent to the Herbert River entrance as it has progressively migrated north. Holmes (1993) hypothesised that as the Herbert River has migrated north, this may have resulted in a sediment supply deficit.

The Burdekin catchment, and to a lesser extent the Ross River catchment, supplies the coastal and shelf areas to the south of Hinchinbrook with annual sediment loads that can be resuspended and distributed north toward the coastal region in Hinchinbrook. A study by BMT (2018) of sedimentation in ports of the Great Barrier Reef found that major catchment loads are not contributing directly to sediment deposited in navigational channels (including Townsville and Cairns). This lack of connectivity is due to the vast quantities of sediment accumulated in coastal waters at geological timeframes. This study suggests that the dominant sediment supply to coastal areas would be existing sediment deposits on the GBR shelf and is not directly related to catchment inputs. As such, the movement of the Herbert River to the north is not likely to result in a significant sediment supply deficit in coastal waters.

The coast is highly dynamic even at human timescales, where modern processes such as floods, distributary channel switching, channel and estuary meandering and coastal realignment affect coastal stability. As a result, the Hinchinbrook coast generally has a moderate to high erosion potential, with some areas more vulnerable to erosion than others.

3.5.2 Local Sediment Characteristics (Dungeness)

Several studies have looked at the sediment characterises in the proposed dredge area. An initial geotechnical study investigated acid sulphate soils in the dredge area (Jacobs, 2018). The study found that sediment in the dredge area was predominantly very loose to loose SAND (occasionally SILTY or CLAYEY SAND) with only minor intermittent layers of fine grained soil (very soft to soft SILT and CLAY).

Discussion of sediment characteristics herein are provided in relation to the proposed capital dredge area and maintenance dredge area as defined in the Dredge Management Plan (Water Technology, 2021).

An Acid Sulphate Soil Assessment was also undertaken at sampling sites in the capital dredge area. The assessment found the following:

- Clays in the capital dredge area are Acid Sulphate Soils with insufficient Acid Neutralising Capacity (ANC) to buffer any acidity generated on exposure to oxygen. These clays are mostly present adjacent to the boat ramp and appear only as minor intermittent layers in the main dredge channel; and
- Sands in the capital dredge area have appreciable amounts of potential acidity, but also contain sufficient ANC to neutralise any acidity formed on oxidation. The material in the main dredge channel is mostly sand.

It was consequently recommended that all clay materials are treated with 50kg/m^3 of fine agricultural lime which equates to approximately 90kg of $CaCO_3$ per tonne of soil (assuming a bulk unit weight of 1.8t/m^3) if they are exposed to oxygen by placement on the foreshore (Jacobs, 2019).

Another study by FRC environmental was undertaken in 2019 which developed a Sampling and Analysis plan (SAP) to:

- Support consideration of the dredge material disposal options, and to
- Provide information for the environmental management of the dredging and disposal works.

In the most recent study, all sampling was assessed according to NAGD guidelines with potential contaminants assessed against the sediment quality guidelines presented in the NAGD (frc environmental, 2019). Samples were collected from seven locations in the capital dredge area, and three sites in the maintenance area, as shown in Figure 3-17.

Additional sampling was also undertaken in 2021 by FRC environmental, to assess the particle sizes of sand on Dungeness Beach. The three sampling locations are shown in Figure 3-17.

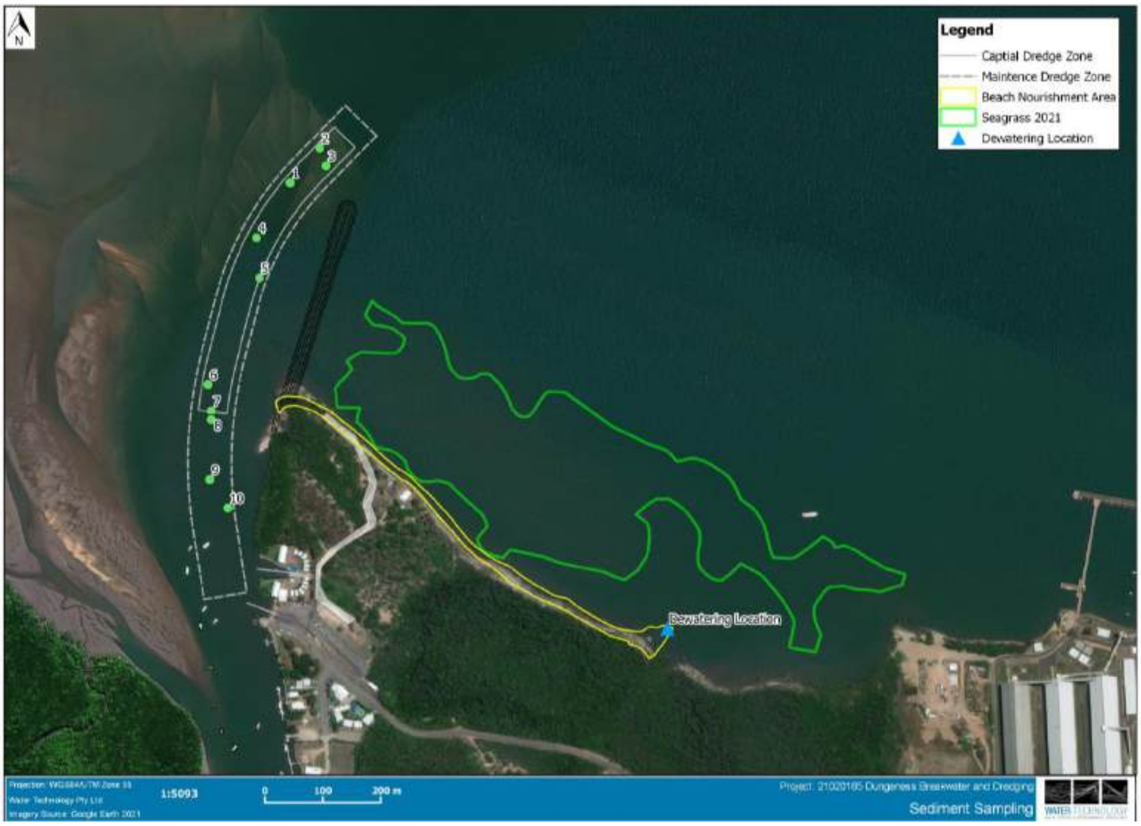


Figure 3-17 frc sediment Sampling sites

Each core sample was split into surface and lower subsamples, as shown in Figure 3-18. Particle size distribution analysis was performed on surface and lower subsamples. With regard to contaminants a ‘Comprehensive’ suite was performed on the surface sub-sample and a ‘Basic’ containment suite was assessed for the lower sub-samples, and only a basic suite of contaminants was assessed in the basic (lower) core portions. The ‘Comprehensive’ set comprises all the parameters listed in the NAGD except dioxins, furans and radionuclides, and this was used to analyse samples representative of areas with the highest risk of contamination. The ‘Basic’ set aims to determine the intrinsic physical and chemical properties of the dredge material in areas of lower risk (refer to frc environmental, 2019 for further details).

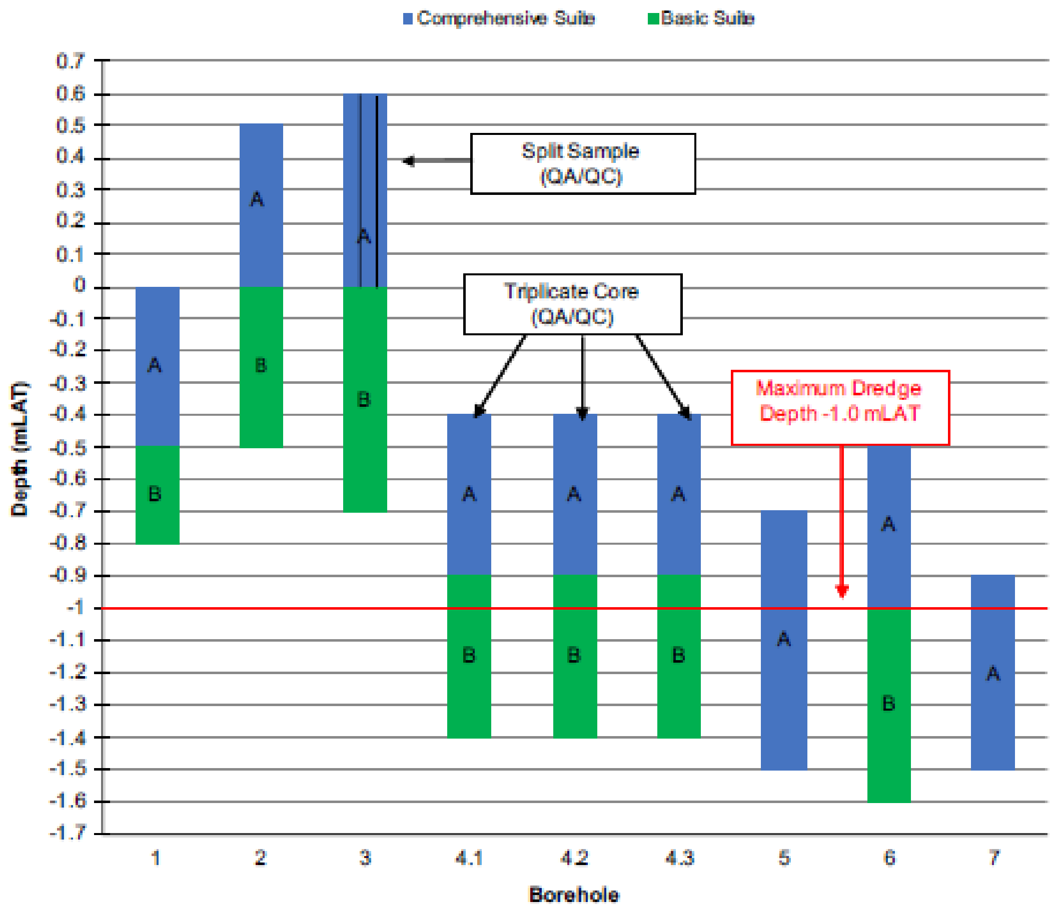


Figure 3-18 Borehole partiTons (frc environmental 2019)

This study found that surface sediment was generally dominated by sand at each site, with the highest concentrations of clay at sites three and four (located towards the seawards end of the dredge channel). Similarly, deeper sediments were dominated by sand with the highest concentrations of clay at site four. The median particle size of sand within proposed dredge area is 385 µm and has an average clay portion of 6%, which is similar physical to the sand characteristics Dungeness Beach (which has median grain size of 460 µm and 7% clay). In Figure 3-19 the average particle size distribution (PSD) from within the dredge area is plotted against the PSD from the three sampling sites at Dungeness Beach. The particle size analysis of sediment highlights the similarity and compatibility of dredge material and sand within the nourishment area.

Of the sites assessed, only one site had had clay portion great than 10%, which was the lower portion of borehole 4 (the upper portion borehole had a mean clay content less of 4%). As shown on Figure 3-18 the lower portion of borehole 4 is predominantly below the maximum dredge depth. This indicates that small pockets of sediment with high content clay could be encountered if the maximum dredge depth is exceeded, however the majority of sediment in the dredge area in considered to be clean sand.

The contamination assessment found:

- Within the dredge site there is no evidence of the presence of contaminated material when tested to National Assessment Guidelines on Dredging (NAGD) (2009); and
- None of the sediment samples were Actual Acid Sulphate Soils (AASS), but the clay portions could be Potential Acid Sulphate Soils (PASS) which could be treated with lime.

This analysis provides confidence that the clean dredged sand is highly suitable for beneficial reuse as beach nourishment.

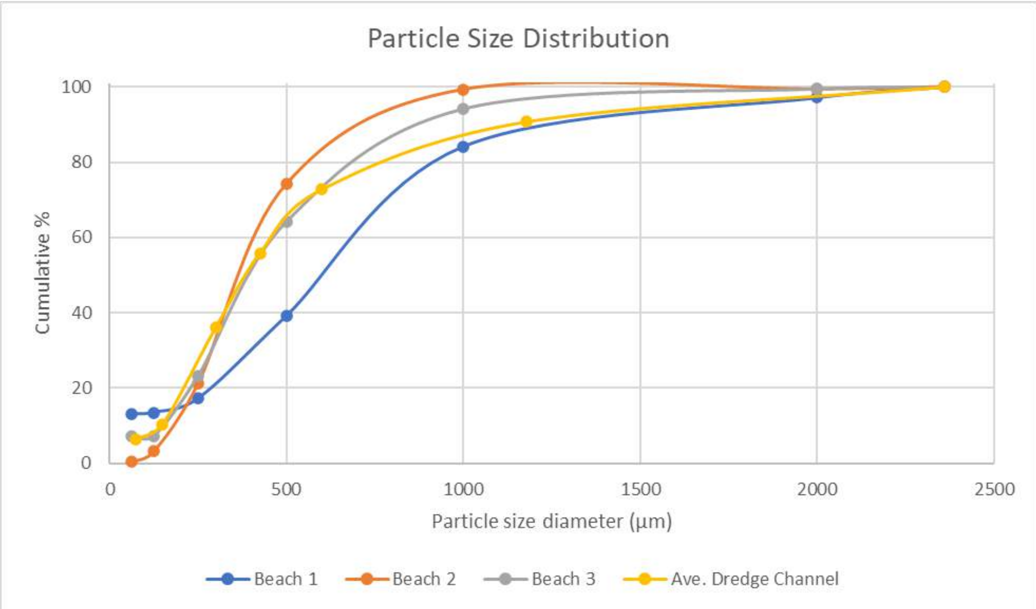


Figure 3-19 Particle size distribution

3.5.3 Regional Sediment Composition

Sediment sampling was undertaken at the locations shown in Figure 3-20. The median particle size (D50) at each site is tabulated in Table 3-11.

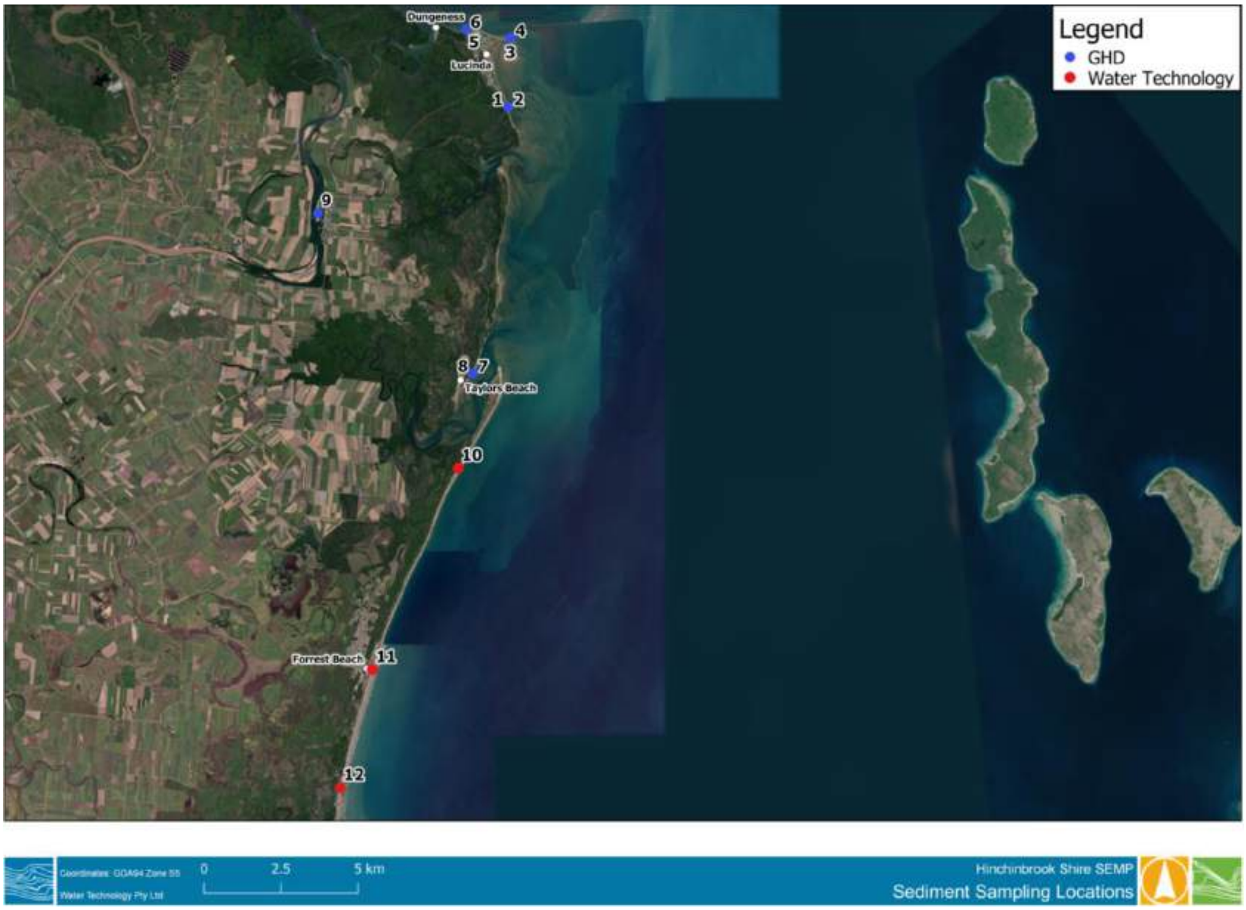


Figure 3-20 Sediment Sampling Locations

Table 3-11 Particle Size Distribution Results (ALS Environmental, 2019)

Sample ID	Collected when/by	Location	Description	Median size – D50 (mm)
1	2019/GHD	Lucinda Foreshore	Intertidal	0.425
2	2019/GHD	Lucinda Foreshore	Above high tide line	0.26
3	2019/GHD	Lucinda – the Spit	Intertidal	0.21
4	2019/GHD	Lucinda – the Spit	Above high tide line	0.225
5	2019/GHD	Lucinda/Dungeness	Intertidal	0.25
6	2019/GHD	Lucinda/Dungeness	Above high tide line	0.25
7	2019/GHD	Taylors Beach	Intertidal	0.4
8	2019/GHD	Taylors Beach	Above high tide line	0.26
9	2019/GHD	Halifax	River bank	0.4
10	2022/Water Tech	Mandam Creek/Taylors Spit	Above high tide line	0.4
11	2022/Water Tech	Forrest Beach	Above high tide line	0.38
12	2022/Water Tech	Cassady Beach	Above high tide line	0.6

3.6 Sediment Sampling (FRC, 2023)

A sediment sampling and analysis plan was developed based on the literature review, preliminary conceptual model and informed by the bathymetric survey. The sampling locations are shown in Figure 3-21. Higher priority sites were specified around the Enterprise Channel and Dungeness area, including core sampling sites at 1-10, 12, 14, 20 and 21. The remaining sites were grab samples. Core samples collected were analysed as the first 0.5m of the core as part A and the lower 0.5m of the core as part B. It should be noted that sites 33 and 34 were not collected by frc due to rocky substrate >100mm.

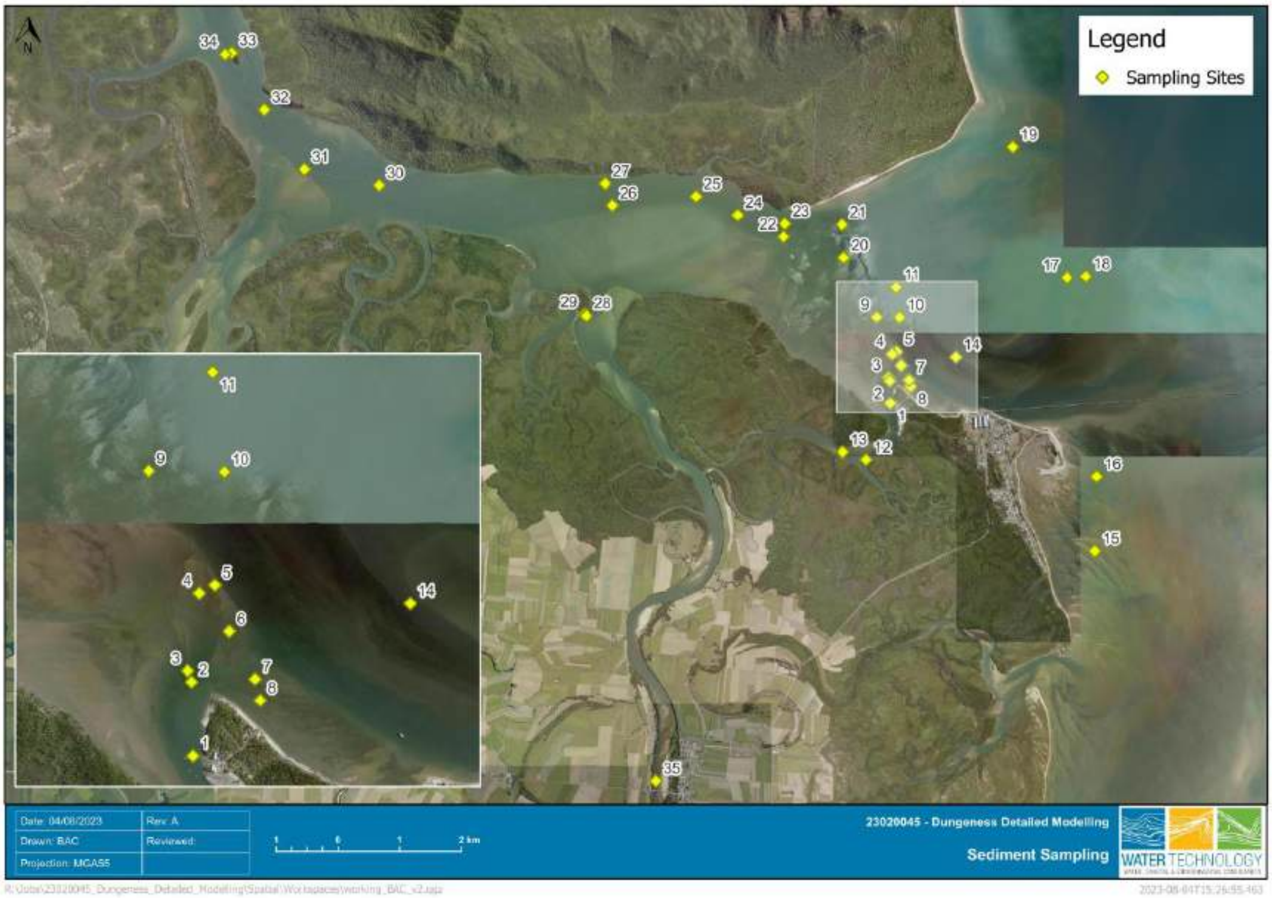


Figure 3-21 2023 Sediment sampling site locations

The results from the sediment sampling indicate a number of key features of the soil which will be used to inform the modelling. These include:

- Soil Bulk Density (1090 kg/m^3 to 1750 kg/m^3)
- Moisture Content (7 %w/w to 64 %w/w)
- Particle Sizing of Soils by Sieving down to 63µm
- Particle Sizing of Soils <75µm by Hydrometer (0.0011 mm to 0.0612 mm)

A Gradistat Analysis (Blott, 2020) was completed on the analysed sample data. This method uses the grading of each sample to determine various parameters, which then allow the sample to be classified into a textural group. The vast majority of samples indicated SAND (sites 1, 2, 4-9, 11, 12 and 14-30), three indicate SANDY MUD (13, 31 and 32), and three indicate MUDDY SAND (sites 2, 3 and 10). This is presented in Figure 3-22.

Figure 3-22 Soil Classification Map

3.7 Marine Plant Mapping

A marine plant survey was conducted in 2018 by frc environmental, with results shown below in Figure 3-23. The majority of the western bank focus area is sparsely covered with seagrass, with patches of dense and moderate seagrass coverage in some areas. Dungeness Beach has a higher concentration of moderate seagrass with small regions of dense seagrass and rocky/shellfish reef and the area further offshore having sparse coverage of seagrass.

Figure 3-23 2018 marine plant mapping

4 SUMMARY OF PHYSICAL PROCESSES

The coastal environment responds continually to the ever-changing influences of waves, tides, ocean currents, winds, and the supply of littoral sediments. Collectively these complex and dynamic coastal processes shape the physical environment of the Dungeness region.

4.1 Overview Local Area

Enterprise Channel, which runs past Dungeness, is a downstream anabranch from the Herbert River, see Figure 4-1. Most of the discharge from Herbert River catchment will flow out at the river mouth located to the west from Enterprise Channel. Piorewicz (1998) stated that the Herbert River is subject to frequent flooding which causes the junction (yellow arrows, Figure 4-1) with Enterprise Channel to silt up. Aerial imagery has indicated that at times the upstream part of Enterprise Channel is dry during ebb tide. The result is that Enterprise Channel is tidally dominated, which means that the currents within the channel are mainly driven by the tide.

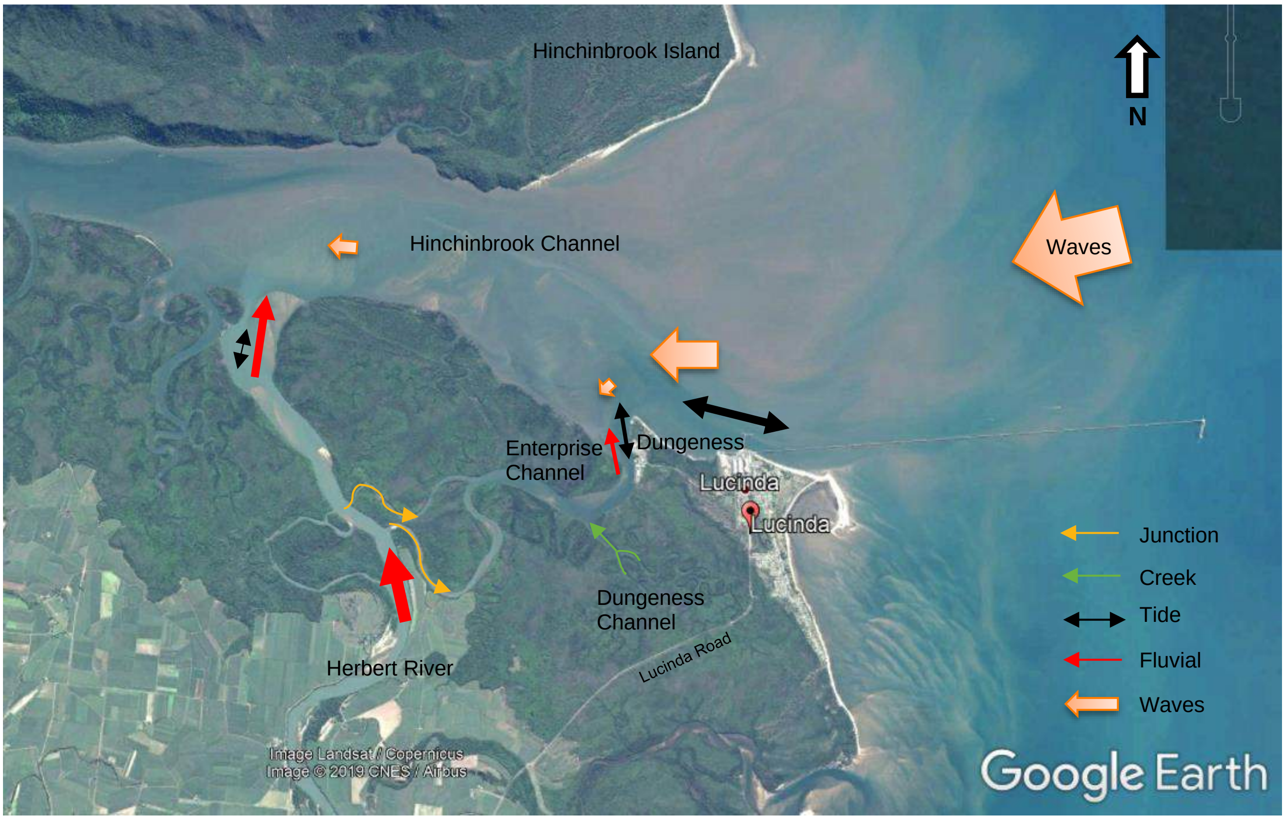


Figure 4-1 Overview Fluvial and Oceanic Influence Dungeness creek, Enterprise Channel and Herbert River, source: Aerial Image from 2014, Google Earth

Dungeness creek (green arrows, Figure 4-1) is a small creek, which runs down from Lucinda Road into Enterprise Channel. Piorewicz (1998) suggests that outflow from Dungeness creek combined with the currents of Enterprise Channel causes sedimentation at the western bank of Enterprise Channel. The layout of Dungeness Creek hasn't changed much in the past 60+ years, however the width of the creek has slightly decreased over this time.

The influence of waves and tides are also shown on Figure 4-1, where waves are displayed as orange arrows and the tide as black double arrows. The waves are predominately arriving from the east at Hinchinbrook channel entrance. The bigger waves will be broken at the entrance due to the shallow sand banks. The influence of the smaller and the broken waves decreases once they travel further up the Hinchinbrook channel.

All rivers and channels are subject to tidal influence. The Herbert River records tidal influence until Ingham which is about 26km upstream. The upstream part of Enterprise Channel, at the junction with the Herbert River is observed to be dry during ebb tide. Dungeness creek is also tidally influenced.

4.2 Morphological Processes

Coastal geomorphology is the morphological development and evolution of the coast as it acts under the influences of rain, wind, waves, currents, and sea level rise. Two key geomorphological forcings influence the coastline morphology:

- Riverine processes related to the Herbert River and
- Offshore coastal processes (tides, waves, currents).

The Lucinda coastal plain consists of a complex sequence of estuarine mangroves, beach ridges and barrier spits. The analysis of historical aerial photography demonstrates that the shoreline adjacent to the Enterprise Channel extending to the Lucinda Jetty has historically experienced significant variations in position (BMT, 2009).

Dungeness is located west of Lucinda and has a north-facing beach adjacent to the mouth of Enterprise Channel. The Enterprise Channel is the main distributary channel of the Herbert River. Since 1943 the alignment of the Enterprise Channel has progressively shifted eastward adjacent to Dungeness, evidenced by a reduction in the westerly extension of the Enterprise Channel spit (Dungeness Spit) and the growth and vegetation of the shoreline opposite Dungeness.

Meanwhile, the Hinchinbrook Channel has progressively narrowed due to the accumulation of sediments from the Herbert River ebb tide delta. This area is surrounded by extensive mangrove forests and is protected from wave action by Hinchinbrook Island, with the dominant processes being tides and currents. This area is dominated by delta sand, which is poorly sorted grey-brown, medium to very coarse gravelly sand with varying mud content.

This section subsequently summarises an analysis of aerial imagery with reference to coastal morphology, focusing on three compartments of the Hinchinbrook region – Lucinda and Dungeness, the Enterprise Channel, and the Dungeness Spit and Hinchinbrook Channel. The aerial images have been obtained from QImagery and cover a period between 1956 and 2023 at various intervals. The images have been georeferenced, scaled and rotated for comparison purposes. A graphic of the various compartments and relative eroded areas are shown in Figure 4-2, with the 1956 imagery in the background overlaid with the 2017 shoreline (black dotted line).

Figure 4-2 Aerial Imagery of 1956 with 2017 (dotted outline) overlay (source: QImagery)

4.2.1 Lucinda and Dungeness Northern Beaches (Wave Dominated):

The first compartment in the analysis investigates the Lucinda and Dungeness Northern Beach area. The shoreline at Dungeness Beach has retreated around 30 to 65 m (equivalent to erosion rates of around 1-2 metres per year, with the rate recently slowing over the past decade). This reduction in erosion rate is likely due to a combination of the following factors:

- Dungeness Beach is gradually reaching a new equilibrium alignment to the surrounding coastal infrastructure (such as the Port of Lucinda seawalls) and to the progression of the Lucinda Spit.
- The gradual shoreline recession is slowing down due to the small-scale beach nourishment activities at the Port of Lucinda.

The likely cause of erosion seen in these areas can be attributed to predominantly wave exposure from the east and north. As seen in Figure 4-2, the compartment labelled 'Eastern Beaches' has accreted significantly over this time period. Longshore sediment transport travelling in a net northerly direction along the coastline meet outflows from the Hinchinbrook Channel, forming a 'hook' shape. The Lucinda Northern Beaches have been relatively stable over this time, mostly due to coastal protection works along the foreshore.

The growth of the Lucinda spit has had two major impacts:

- The extension of the sand spit acts similar to a groyne structure, trapping the northwards-directed longshore sediment transport that travels along the open coastline. This has resulted in significant shoreline accretion between the Lucinda spit and the Lucinda groyne field. From 1943 the shoreline in this location has accreted by approximately 230m. From 1988 to 2020, the rate of shoreline accretion behind the spit was between 0.5 m to 2 metres per year.

- The growth of the Lucinda spit has deprived the Dungeness beach of marine sediments transported by coastal waves alongshore. This has contributed to the recession of the Dungeness spit and the thinning of Dungeness beach.

The erosion of Dungeness Northern Beach is also the result of wave action from the critical north-easterly direction, directly impacting the beach. Waves attacking the beach disturb sediment in the nearshore, suspending the sediment in the water column. This suspended sediment is then transported through the flood and ebb tidal currents flowing through the Hinchinbrook Channel, creating a deficit in the sediment balance and ultimately causing long term recession of the beach.

4.2.2 Enterprise Channel (Fluvial Dominated):

The Enterprise Channel has undergone significant changes over the analysed period, with notable changes to the western 'inner' bank having significant accretion, and the eastern 'outer' bank experiencing some erosion. This erosion has since halted in areas of coastal protection close to the southern extent of Dungeness, with some accretion experienced at the northern extent of Dungeness closer to the spit.

The western bank accretion can be attributed to a combination of sediment inflows from the Herbert River along with marginal inflows from Dungeness Creek to the south and longshore transport entering from the east. As this is a low energy environment, protected from wave action by the Dungeness Spit, the sediment settles in this western region. The sediment build-up then creates conditions conducive to mangrove growth which then subsequently stabilises the area from erosion during flooding events.

The eastern bank southern extent erosion is typical of a riverine outer bend, however as mentioned has been stabilised due to the construction of coastal protection. The eastern bank northern extent accretion can be attributed to wave action to the north and east carrying sediment into the Hinchinbrook Channel and 'sweeping' it around the Dungeness Spit, notably on stronger flood tides.

4.2.3 Dungeness Spit and Hinchinbrook Channel (Wave and Fluvial Combination):

The Dungeness Spit and Hinchinbrook Channel represent a complex coastal environment shaped by a combination of wave and fluvial influences. Over time, this region has witnessed significant changes in shoreline morphology, with erosion and accretion dynamics influenced by various factors.

The Dungeness Spit has experienced substantial erosion towards the southeast, resulting in a reduction in length of approximately 400 meters. Erosion rates have varied over this period, however, consistently indicate erosion of the spit. Cyclonic events, such as Cyclone Ingrid and Cyclone Yasi, have likely played significant roles in the high erosion events.

A sediment pulse has been observed, moving down the western side of the spit, primarily driven by wave action and strong flood tides into the Enterprise Channel. Additionally, the northern banks of the island to the west of Dungeness have faced erosion, which has been exacerbated by the erosion of the spit itself, as the spit previously provided protection from waves and currents.

The western bank of Enterprise Channel (opposite Dungeness boat ramp) has accumulated sediment and experienced mangrove growth, influenced by sediment inflows from the Herbert River and Dungeness Creek, as well as the protection provided by the Dungeness Spit. In contrast, the eastern bank of Enterprise Channel has eroded due to wave action, with coastal protection measures now in place to stabilize this area.

As previously discussed, the expansion of the Lucinda Spit has also impacted the coastline in this region. It traps sediment from northward-directed longshore sediment transport, leading to significant shoreline accretion between the Lucinda Spit and the Lucinda groyne field.

4.2.4 Dungeness Spit – Erosion Rates

A visual representation of the erosion of the Dungeness Spit is shown in Figure 4-3 with calculated erosion rates through aerial imagery analysis presented in Figure 4-4. Erosion rates vary over the period, ranging from 2-16 m/year with a long-term erosion rate of the spit of approximately 6.06 m/year. As the images are sometimes at greater intervals, it is difficult to correlate higher erosion events with a potential cyclone event that may have caused it. However, it is noted that some of the high erosion rates suggest an influence from cyclonic events. An example of such events include:

- A sudden increase in erosion has been observed between 2004 - 2005. Cyclone Ingrid occurred during March 2005, which reached category 5 offshore of Cooktown. Large waves have travelled down the coast and likely effected the spit at Dungeness.
- Another example is the erosion between 1983-1984, where category 5 tropical cyclone Elinor established during the end of February 1983.
- The spike during 1992-1993 may have been caused by category 4 tropical cyclone Oliver (February 1993).
- It is high likely that Cyclone Yasi would have had a significant effect on the spit as well, but the imagery interval between 2005 and 2017 was not frequent enough to identify this.

Figure 4-3 Eroding spit 1956 (left) and 2023 (right)

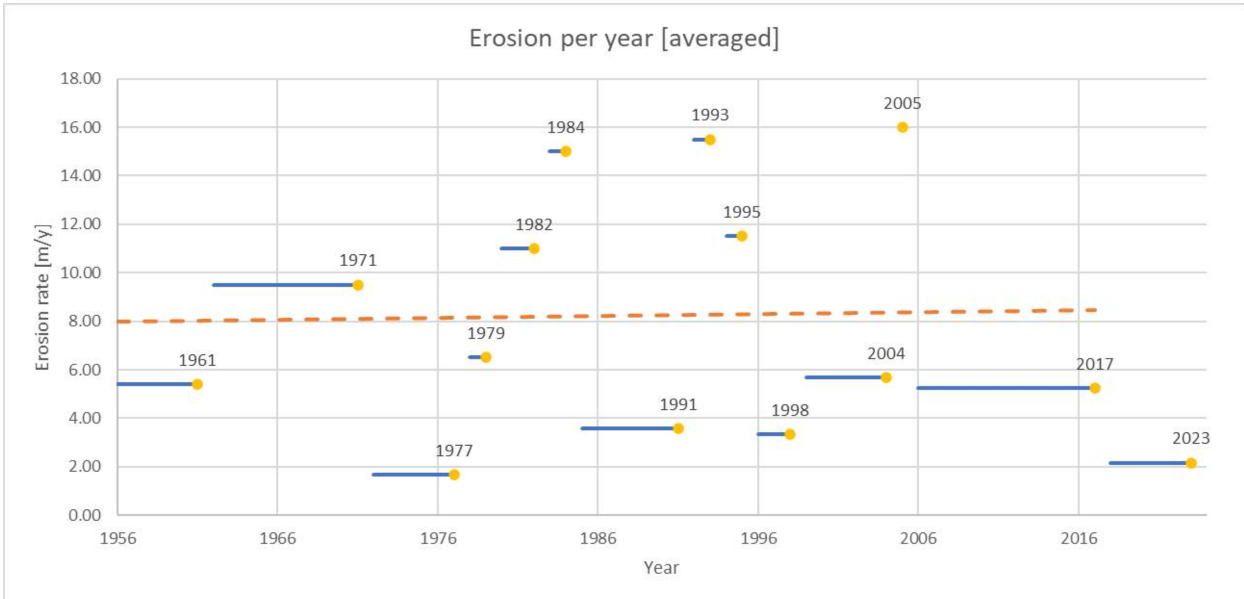


Figure 4-4 Erosion Rate per year of Dungeness Spit

4.2.5 Satellite Imagery Review

Using the Digital Earth Australia Coastlines tool, the evolution of the Lucinda Spit from 1988 to 2022 is displayed in Figure 4-5. This figure shows that:

- From 1988 to 1998, the Lucinda spit had an east-west (shore-perpendicular) orientation. During this 10-year period, the spit accreted approximately 530 m out in an easterly direction.
- From 1998 to 2002, the spit developed a pronounced clockwise curvature (or hook), with an arm extending southward around 400 m. This shape of the spit curvature strongly suggests that it is shaped by a combination of Herbert River ebb tide flows (fanning out from the outgoing tide), coastal tidal flow, and the south-easterly local sea waves.
- From 2002-2022, the spit has developed a second hook that runs back from west to east - giving it a circular shape. During this period, the spit has been migrating back towards the shore. As a result, the spit is reattaching to the subaerial beach at Lucinda. The alongshore sediment transport will be restored (to a certain degree) towards the Dungeness beach when this occurs.

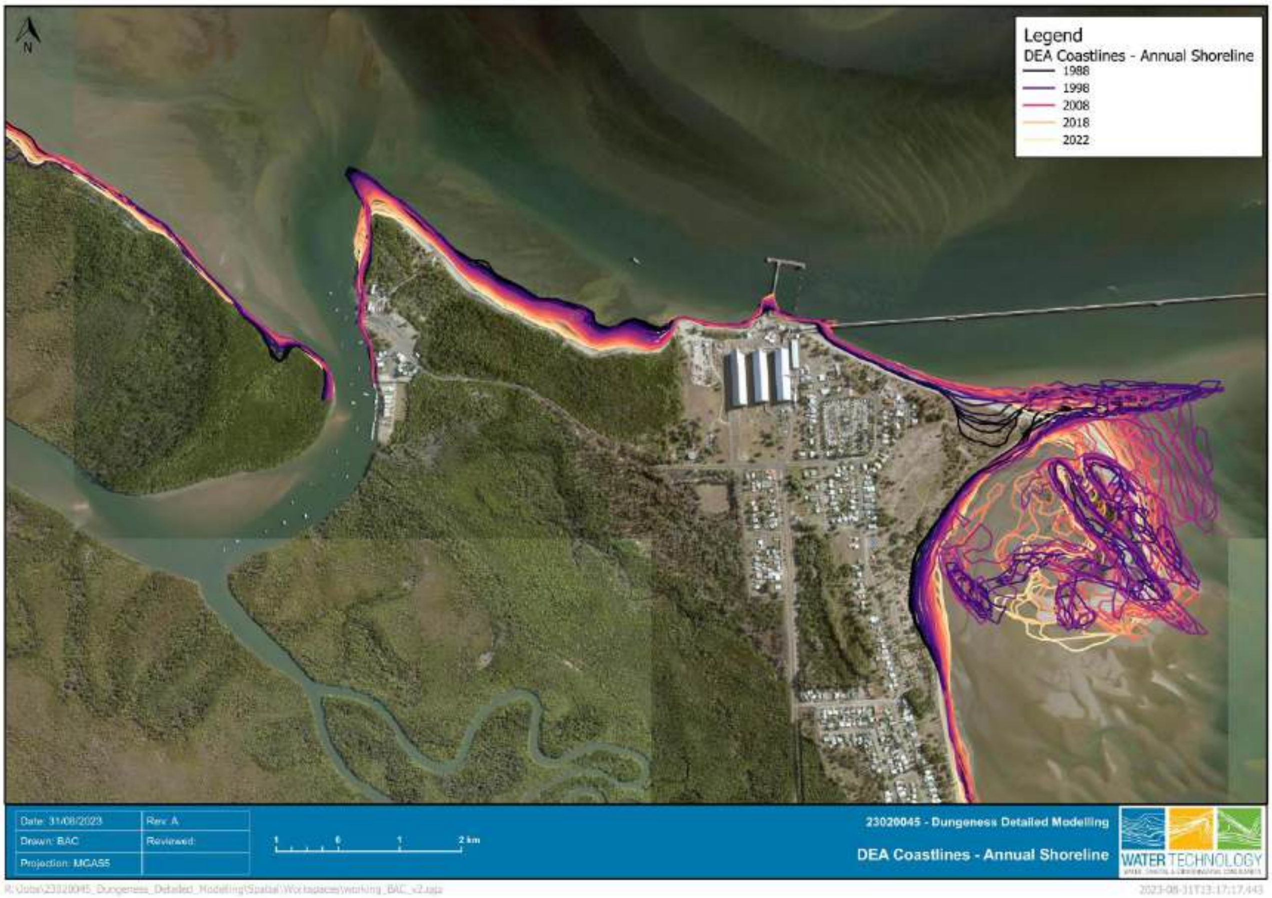


Figure 4-5 Shoreline Change at the Lucinda and Dungeness Spits from 1988 – 2022

4.2.6 Erosion Volumes

An erosion volume calculation was completed for a number of transect profiles around the study area. These volumes utilised historical surveys of the area dating back to 2014 ranging through to 2020, the most recent 2023 survey and various available bathymetry datasets. The compartments analysed are shown in Figure 4-9, where green compartments are accreting shorelines and red compartments are eroding.

Figure 4-6 Erosion volume compartments

The estimated volume calculated for each compartment are presented below in Table 4-1. These volumes provided an insight into the approximate amount of sediment lost or gained from each compartment per year.

Table 4-1 Estimated Erosion Volumes

Compartment	Length (m)	Time Period	Total Volume (m3)	Volume per Year (m3/year)
DB_01	150	2016-2019	-1636	-409
DB_02	347	2016-2020	-7977	-1595
DB_03	180	2016-2023	-10974	-1371
DB_04	162	2014-2020	-10696	-1528
DS_01	95	2014-2020	-17917	-2559
DS_02	107	2014-2020	+7986	+1140

Compartment	Length (m)	Time Period	Total Volume (m3)	Volume per Year (m3/year)
DS_03	135	2014-2020	+4402	+628
WI_01 (volume above -1.0mAHD)	25 ha	1956-2023	+411,594	+6143

4.3 Potential Longshore Sediment Transport Modelling

Water Technology developed a longshore sand transport model to estimate the potential sediment transport at two locations, along Dungeness Beach and the open Lucinda coastline. The model uses the Queens Formulation for longshore sediment transport, which was initially developed by Kamphuis (1991). The model does not take into account the effect of the nearshore reefs, local groyne structures and wave refraction, wave breaking on reefs or the lack of sediment supply along the coast.

The median grain size (d50%) of sand has been assumed to be 0.50mm, noting that significant variation, typically +-0.5mm occurring across the collected samples.

The numerical model was setup to estimate the hourly longshore sediment transport rates using wind-wave hindcast at Lucinda, astronomical tide levels from 2013 to 2022 and corrections for nearshore wind and wave setup. The model uses Bureau of meteorology wind measurement for Lucinda Point, which was adjusted to hindcast wave parameters at the site. Figure 4-7 shows the modelled potential net longshore sediment transport accumulating from 2013 to 2022 along Lucinda. The direction of the transport is positive north and negative south.

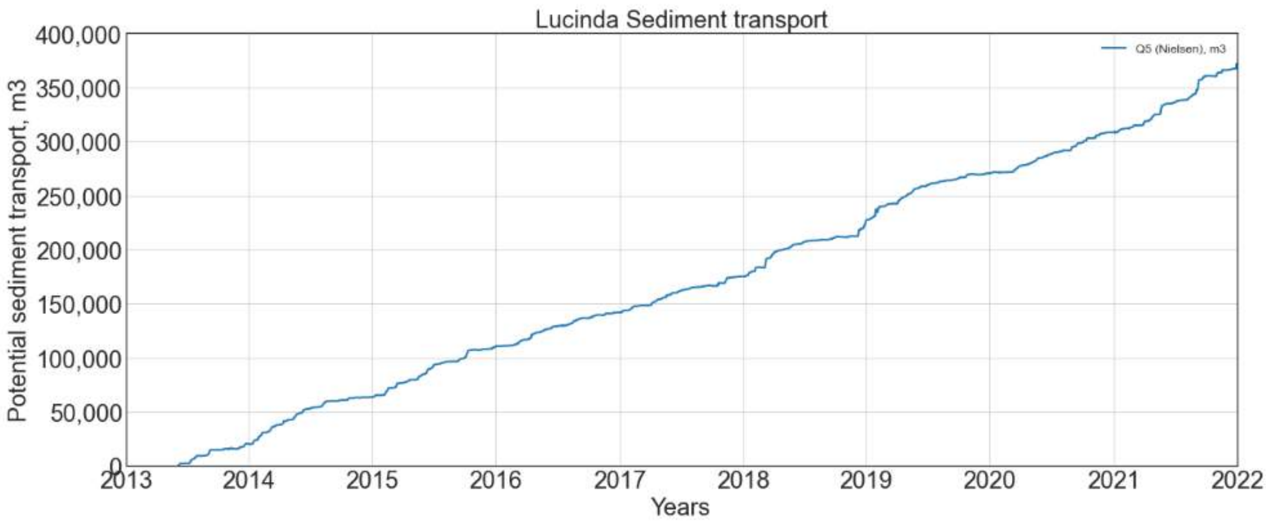


Figure 4-7 Potential longshore sediment transport at Lucinda (2013 – 2022)

The trend shown indicates a strong northerly transport occurring year-round, with occasional sharp increases likely the result of storm or cyclone wave action.

The potential longshore sediment transport at Dungeness Beach is significantly lower than on the open coast, as shown in Figure 4-8. The sheltered nature of Dungeness Beach shows on average approximately 10-15,000 m^3/year moving west along Dungeness Beach.

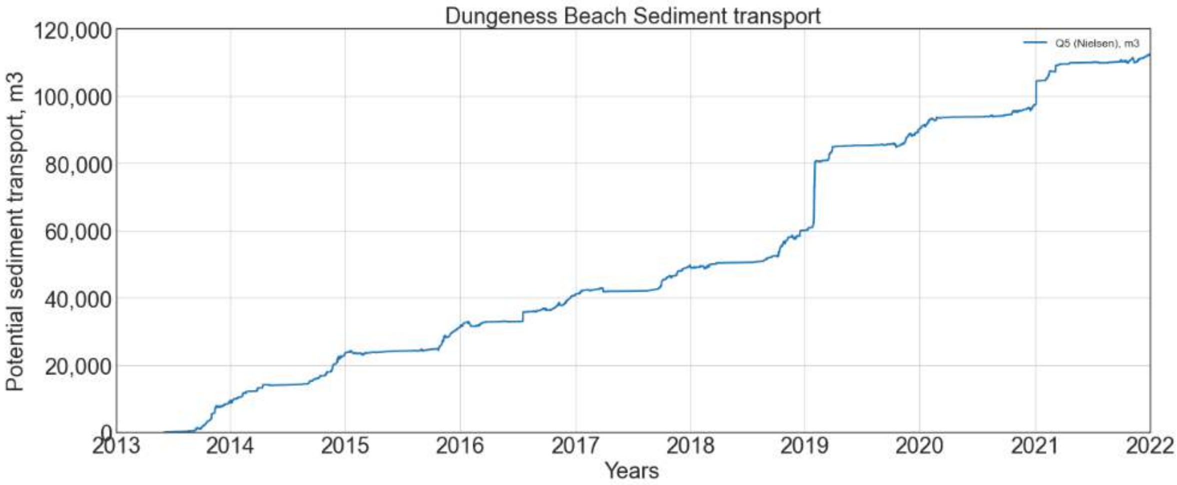


Figure 4-8 Potential longshore sediment transport at Dungeness Beach (2013-2022)

Considering the simplified nature of this sediment transport model, the actual bulk sediment transport is likely to be within ±100% of the calculation and the net sediment transport is even less accurate.

4.4 Existing Coastal Protection Works

4.4.1 Dungeness

Figure 4-9 Coastal Protection Structures at Lucinda and Dungeness

In order to manage the historical migration of the Enterprise Channel, several ad hoc rock seawalls have been built along the eastern bank of the channel to stabilise it. The section of the existing rock wall along Enterprise Channel that is located on Council land is in good condition and effectively maintains the channel alignment. However, it should be noted that the upstream (western) end of the seawall (which is located within the Strategic Portland Boundary) is currently experiencing some end erosion effects that are presently being managed through beach nourishment.

The north-facing shore of Lucinda is vulnerable to the channel movement of the Herbert River. Erosion along this shoreline can potentially threaten the assets associated with the Lucinda Jetty. Significant seawalls have been constructed adjacent to the Jetty structure to protect these assets. East towards the Lucinda spit this seawall transitions to a smaller seawall structure, covered mainly by the frontal dune and vegetation (BMT, 2009).

4.4.2 Dungeness Beach Nourishment

Sediment maintenance of the Lucinda Barge ramp is currently undertaken. Excavation works to remove sediment build up on the ramp is undertaken up to three times a week, and total just under 5,000t per year (pers comm. Port of Townsville Limited, November 2022). This equates to a volume of around 2,500m3 a year.

The sand is stockpiled adjacent to the ramp and then returned to the system upstream, at Dungeness Beach, at the Western end of the Port boundary.

Figure 4-10 Dredge sand stockpiling at Lucinda Barge Ramp

5 DATA COLLECTION

5.1 Introduction

A data collection was designed to collect quantitative and qualitative data with which to further develop and calibrate the hydrodynamic and spectral wave numerical models of the Lucinda – Hinchinbrook Channel Region. This field monitoring program spanned from 9th September 2023 through to 15th September 2023, and aimed to capture the following datasets:

- *In Situ* water elevation measurements at two (2) locations;
- *Acoustic Doppler Current Profiler (ADCP)* transects at four (4) locations;
- *In Situ* Total Suspended Sediment (TSS) measurements at three (3) locations corresponding to the transect locations at T1, T2, and T3.

Figure 5-1 Data collection instrumentation locations

5.2 Instrumentation

5.2.1 Water Elevation

In-Situ Rugged Troll water level loggers were deployed on the seabed at two (2) locations to capture water level amplitude and phase at a 10-minute interval. These devices are pictured attached to deployment mount below in Figure 5-2.

Figure 5-2 Water level logger and deployment mount

5.2.2 ADCP

The SonTek RiverSurveyor M9 ADCP mounted to a TB9s moving boat setup was used to measure current profiling data at four (4) locations in the area of interest. The M9 ADCP contains nine transducers with a profiling range of between 0.06m and 40m (distance) and +/- 20 m/s (velocity). The accuracy of the device is up to +/- 0.2cm/s (distance) and +/- 0.25% of measured (velocity). Figure 5-3 illustrates the device rigging method and ADCP unit inserted into the board.

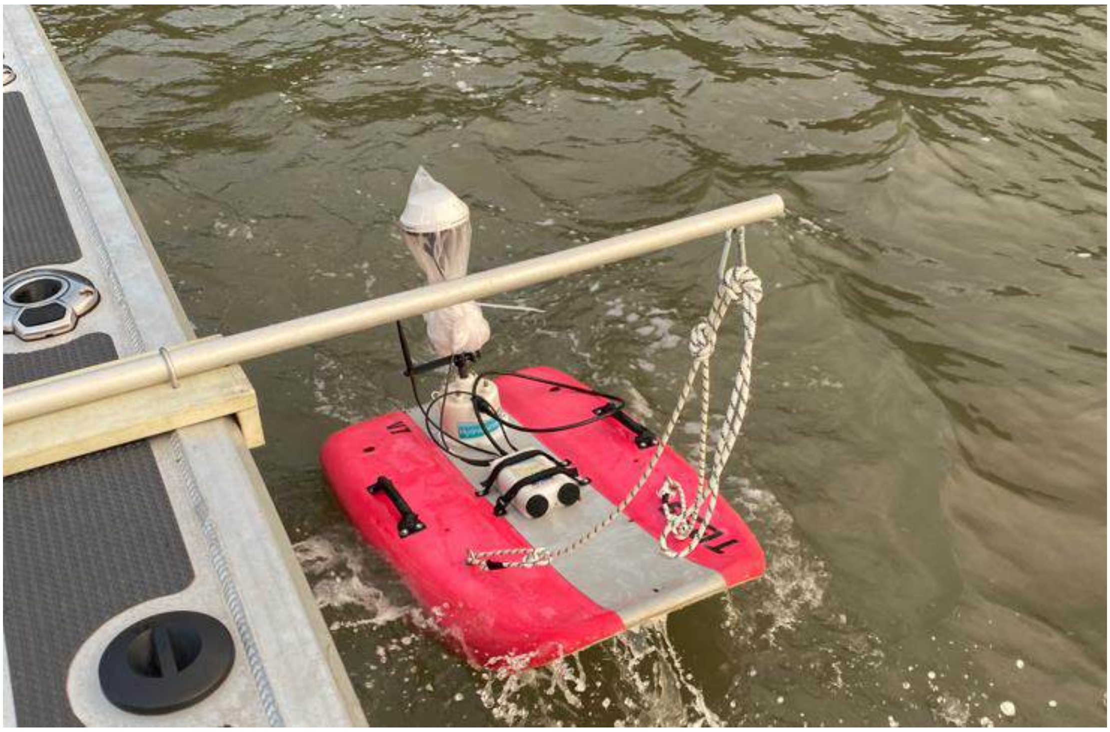


Figure 5-3 ADCP Setup attached to boat

5.3 Measurements

5.3.1 ADCP Transects

The measured discharge at each of the four transects are presented below in Figure 5-4 to Figure 5-7.

Transect 1

Discharge values at Transect 1 were measured on the 11th September 2023 starting at approximately 6:30 am for a 12 hour period through to 6:30pm. This period covers a lower high tide and a peak low tide through the Herbert River.

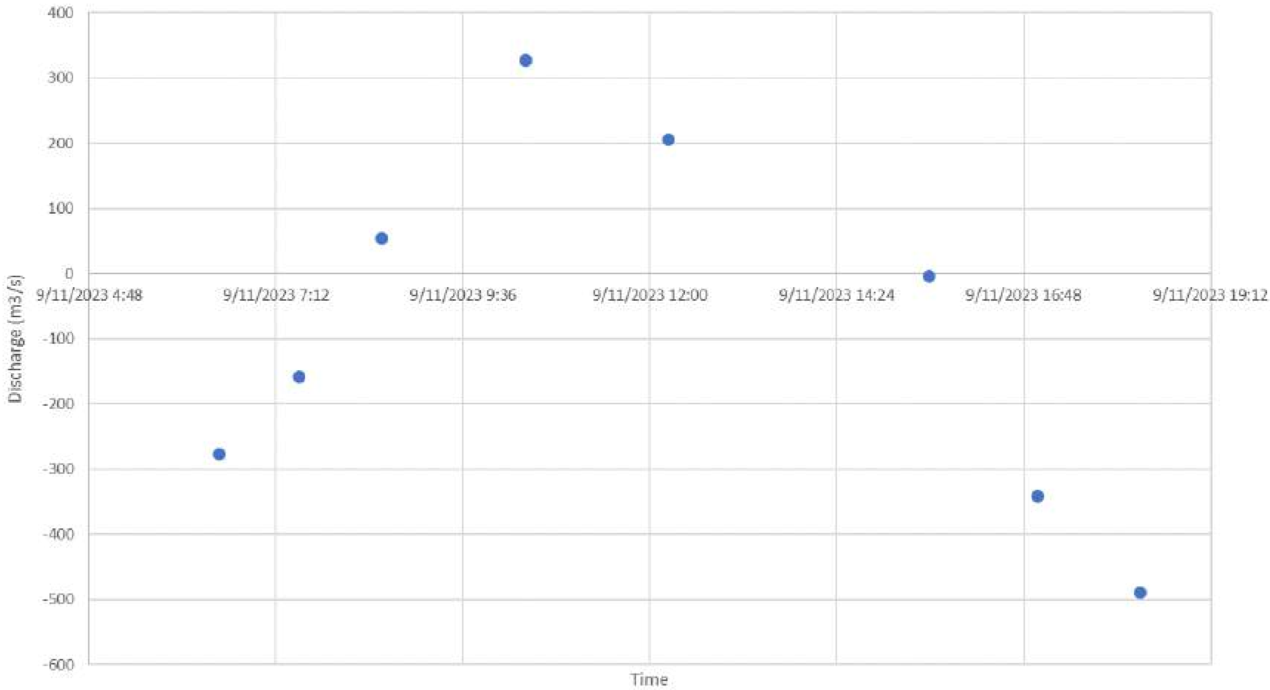


Figure 5-4 Measured discharge through Transect 1

Transect 2

Discharge values at Transect 2 were measured on the 11th September 2023 starting at approximately 7:00 am for a 12 hour period through to 7:00pm. This period covers a lower high tide and a peak low tide through the Enterprise Channel. Measurements were taken intermittently between Transect 1 and Transect 2.

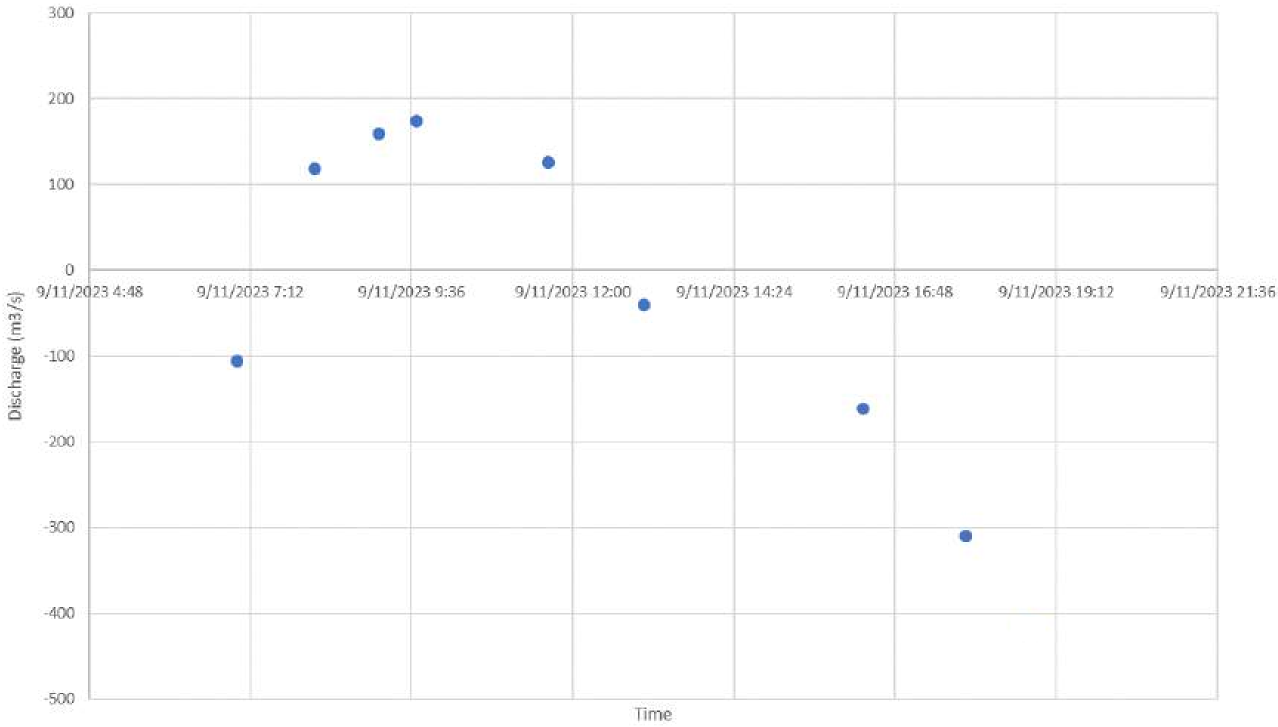


Figure 5-5 Measured discharge through Transect 2

Transect 3

Discharge values at Transect 3 were measured on the 13th September 2023 starting at approximately 6:15 am for a 12 hour period through to 6:15pm. This period covers a lower high tide and a peak low tide through the main Hinchinbrook Channel.

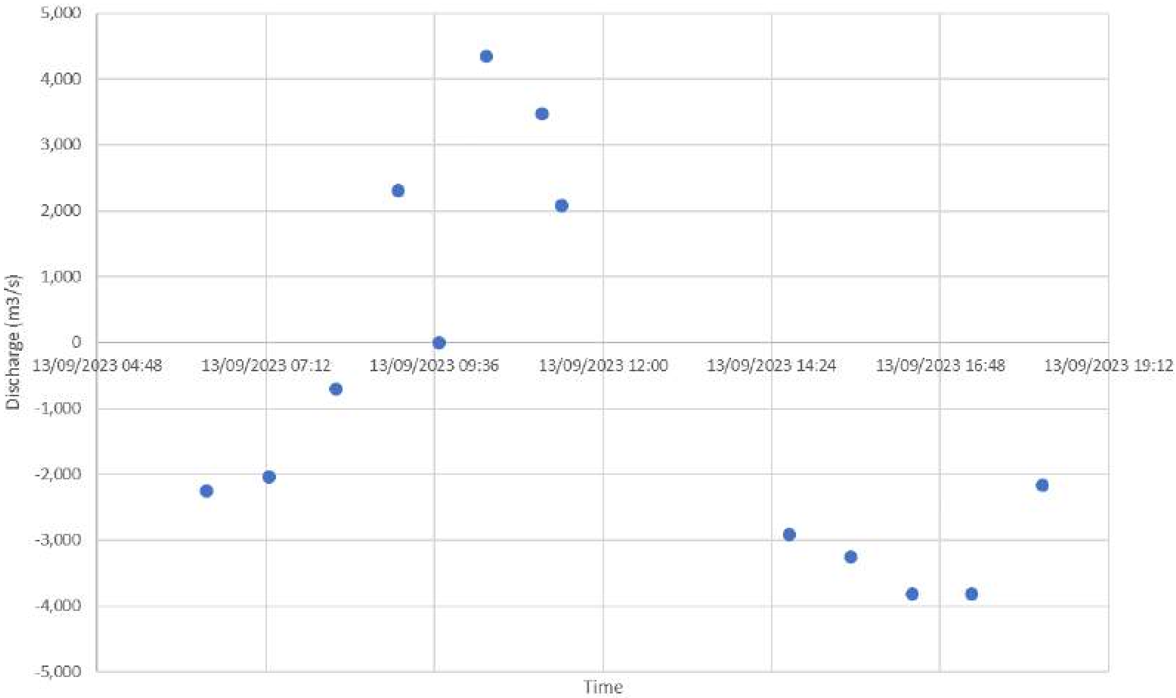


Figure 5-6 Measured discharge through Transect 3

Transect 4

Discharge values at Transect 4 were measured on the 14th September 2023 starting at approximately 7:15 am for a 11 hour period through to 6:15pm. This period covers a lower high tide and a peak low tide through the main Hinchinbrook Channel.

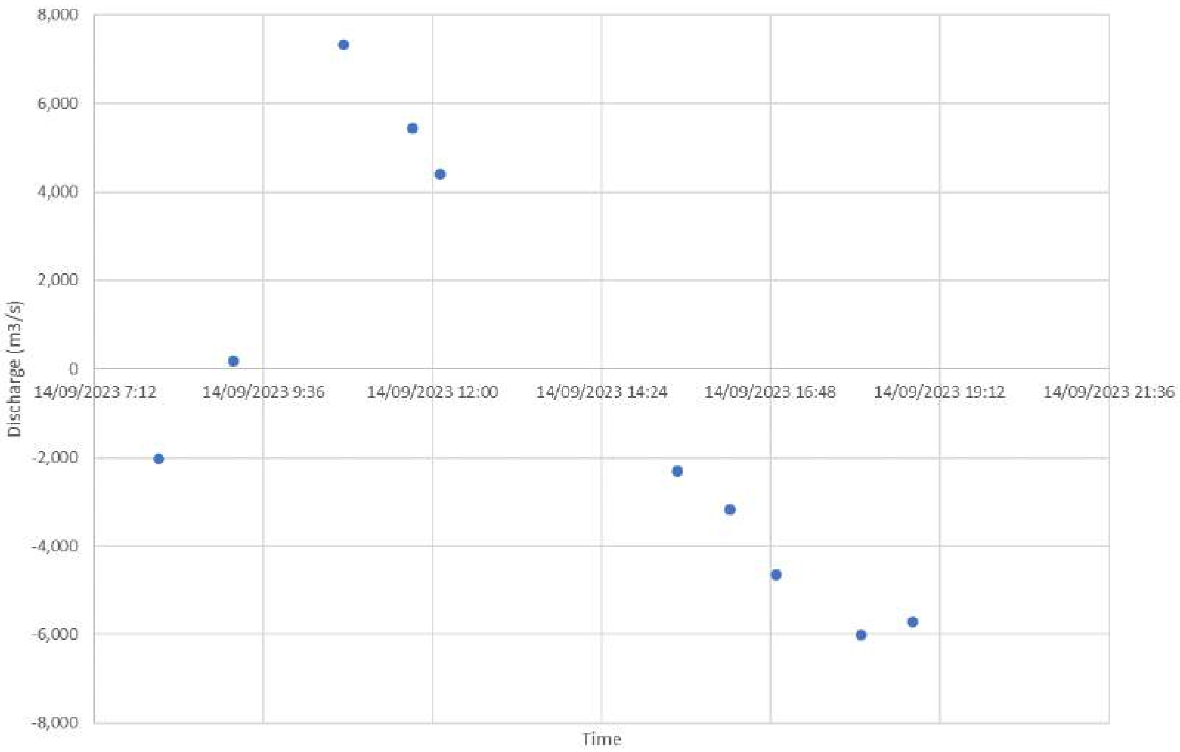


Figure 5-7 Measured discharge through Transect 4

5.3.2 Water Elevations

5.3.3 Total Suspended Solids (TSS)

Turbidity was measured through sample bottle collection at three of the four transects. Water samples were taken from the mid-water column at each location and sent to the laboratory for analysis. The water samples were analysed for Total Suspended Solids (TSS) concentration (mg/L).

Table 5-1 presents a summary of the analysed samples TSS, with the reporting limit set at 5 mg/L and samples dried at 104 ± 2°C.

Table 5-1 Summary of TSS sample testing results

Location	Number of Samples	Minimum TSS (mg/L)	Maximum TSS (mg/L)	Average TSS (mg/L)
Transect 1	7	<5	15	9
Transect 2	6	<5	43	21
Transect 3	10	8	60	27.8

6 CONCEPTUAL MODEL

This section describes the revised conceptual model built on knowledge from previous investigations and newly gathered observations and data collection. Comments related to hydrodynamic properties of the region reference the Memorandum previously provided by Water Technology (Coastal Processes and sediment transport conceptual model, 2022).

The updated conceptual model of existing conditions can be seen in Figure 6-1. The area has a tidal asymmetry with a very strong flood tide and a weaker ebb tide, which drives sediment transport processes in the area. The strong flood tide results in high current speeds in the main channel and is associated with significant longshore transport and bedload movement in these high energy areas. The western mangrove bank is a lower energy environment (green hatch) and has experienced erosion in some areas due to the loss of protection previously provided by the (now eroded) Spit.

The spit has undergone significant erosion due to exposure to strong tidal currents and waves which create a cross-shore transport mechanism at Dungeness Beach. Some of the sediment that is eroding from the spit and beach is being deposited in the navigation channel (red hatch), causing siltation and preventing all tide access.

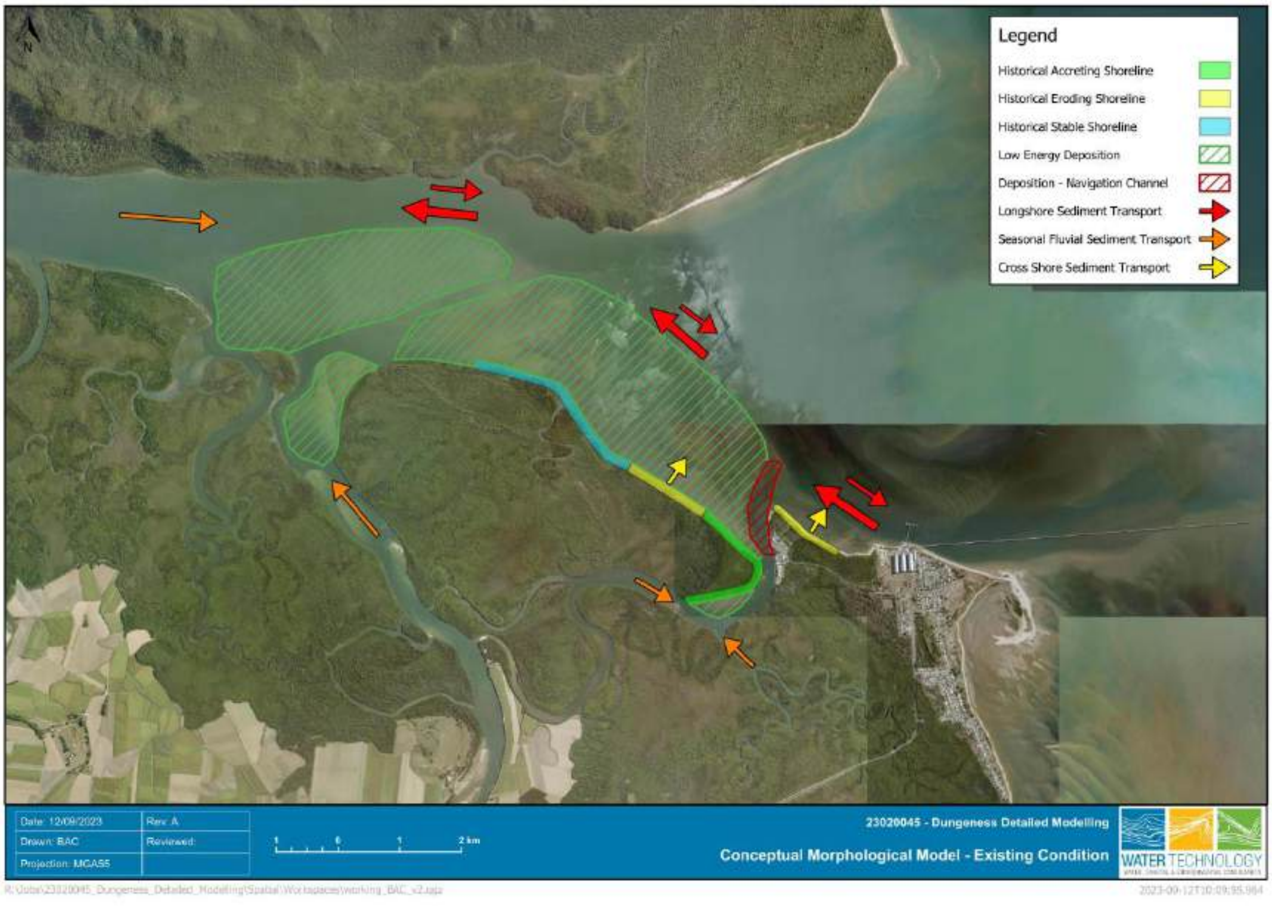


Figure 6-1 Conceptual model of existing sediment transport processes at Dungeness

The conceptual model of sediment transport processes with the newly proposed breakwater configuration is shown in Figure 6-2. Based on our understanding of the area, the breakwater is not expected to reduce the high bedload movement and major sediment transport processes in the main channel. As shown, it will reduce the current rate of cross-shore transport at Dungeness Beach, but only in areas directly adjacent to the breakwater due to decreased flood tide current speeds and bed shear stresses. It is not expected that the breakwater will cause all cross-shore transport on Dungeness Beach to cease in its entirety, and on the eastern portion of the beach it is expected that this transport mechanism will remain, but at a slightly reduced capacity. The longshore transport mechanisms in the main channel will remain and whilst there will be a slightly reduced sediment budget due to reductions in cross-shore transport at Dungeness Bach, we believe this will not cause downstream erosion as the majority of this sediment was previously settling in the navigation channel and on the inside bend of the western bank. The alignment extending north-east for some distance followed by a north-western extension will allow sediment deposition on the western side of the breakwater, historically where the spit extended prior to it's erosion.

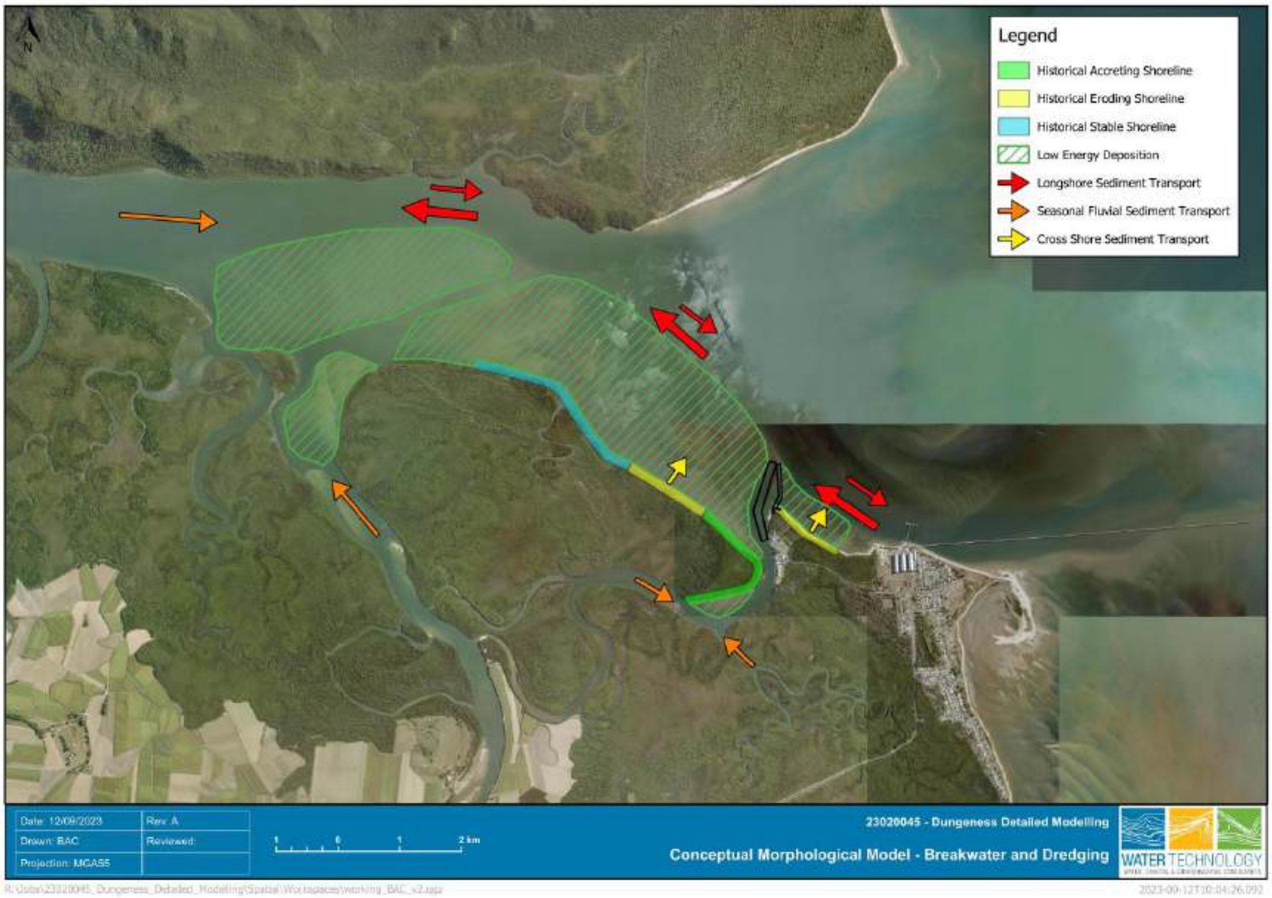


Figure 6-2 Conceptual model of sediment transport processes at Dungeness with a breakwater

The current erosion of the western bank is expected to cease, as the breakwater will provide protection from the incoming tide and storm events. This shoreline area is expected to stabilise and, due to reduced sediment supply from the Spit/Dungeness Beach, the accretion on the inside bend is predicted to cease. Although the sediment supply to this area is somewhat decreased by the breakwater, no additional erosion is expected as bed shear stresses decrease in this area.

The conceptual models, which are supported by the historical shoreline analysis, data collection and previous modelling, show that we have a thorough understanding of coastal processes and have reviewed and refined the breakwater alignment in a manner such that impacts on major sediment transport processes are limited, whilst managing to stabilise currently eroding areas.

7 REFERENCES

Bartley, R., Henderson, A., Prosser, I.P., Hughes, A.O., McKergow, L., Lu, H., Brodie, J., Bainbridge, Z., and Roth, C.H. (2003). *Patterns of Erosion and Sediment and Nutrient Transport in the Herbert River Catchment. CSIRO and the Herbert River Catchment Group.*

Bartley et. al (2004). *A Sediment Budget for the Herbert River Catchment, North Queensland, Australia.*

BMT (2009). *Hinchinbrook Shoreline Erosion Management Plan.*

BMT (2018). *GBR Quantitative Sediment Budget Assessment*.

Burrage, Heron, Hacker, Stieglitz, Steinberg, and Prytz (2002). *Evolution and Dynamics of Tropical River Plumes in the Great Barrier Reef: An Integrated Remote Sensing and In-Situ Study.*

Callaghan et al. (2020). *Near-reef and nearshore tropical cyclone wave climate in the Great Barrier Reef with and without reef structure.*

Central Queensland University (1998). *Dungeness Enterprise Channel Feasibility Study.*

Connell Wagner (2004). *Hinchinbrook Storm Surge Study.*

CSIRO (2003). *Patterns of Erosion and Sediment and Nutrient Transport in the Herbert River Catchment, Queensland.*

DES (2014). *Wet Tropics Water Quality Statistics for High and Base Flow.*

Department of Minerals and Energy (1993). *Marine and Coastal Geology Unit Project Report MA50/3*.

frc (2019). *Dungeness Enterprise Channel Dredging and Beach Replenishment Sediment Sampling and Analysis.*

Hinchinbrook Shire Council (HSC) (2021). *Priority Projects 2021 – 2022.*

Horsfield, R. (2005). *Erosion Protection Works for Dungeness Spit. Email with handouts PowerPoint Presentation. Received from Hinchinbrook Shire Council.*

Jacobs (2018). *Dungeness Dredge Channel and Boat Ramp.*

MSQ (2023). *Queensland Tide Tables 2023.*

Pietsch et. al. (2015). *Age, distribution and significance within a sediment budget, of in-channel depositional surfaces in the Normanby River, Queensland, Australia*.

Piorewicz, J. (1998). *Dungeness Enterprise Channel Feasibility Study. Central Queensland University, James Goldston Faculty of Engineering and Physical Systems. Rockhampton. Edited by Joan Millar. Prepared for Hinchinbrook Shire Council.*

Sinclair Knight Merz (SKM) (2000). *Environmental Management of a Proposed Groyne at Dungeness.*

Spencer et. al (2014). *Sediment Sources to the Great Barrier Reef – What if the Coastal Zone is a Major Sediment Source Rather than a Sink.*

SARA (Aug 2020). *2008-18147 SRA OPW20/0004 – Information Request.*

SARA (Sep 2020). *2008-18147 SRA OPW20/0004 – Advice Notice.*

SARA (Nov 2021). *2008-18147 SRA OPW20/0004 – SARA Response.*

Water Technology (May, 2019). *Dungeness Enterprise Channel Sediment Transport Study.*

Water Technology (February, 2019). *Hydrodynamic and Sediment Transport Modelling Study.*

Water Technology (November, 2019). *Dungeness Enterprise Channel Modelling and Coastal Processes Study.*

Water Technology (July, 2021). *Dungeness Breakwater and Dredging – Dredge Management Plan.*

Water Technology (August, 2021). *Dungeness Breakwater and Dredging – Modelling and Breakwater Design.*

Water Technology (February, 2022). *Coastal Processes and Sediment Transport Conceptual Model.*

Water Technology (2023). *Hinchinbrook Shire Council Shoreline Erosion Management Plan.*

Wolanski, Mazda, King, and Gay (1990). *Dynamics, Flushing and Trapping in Hinchinbrook Channel, a Giant Mangrove Swamp, Australia.*

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Melbourne
15 Business Park Drive
Notting Hill VIC 3168
Telephone (03) 8526 0800

Sydney
Suite 3, Level 1, 20 Wentworth Street
Parramatta NSW 2150
Telephone (02) 9354 0300

Brisbane
Level 5, 43 Peel Street
South Brisbane QLD 4101
Telephone (07) 3105 1460

Adelaide
1/198 Greenhill Road
Eastwood SA 5063
Telephone (08) 8378 8000

Perth
Ground Floor, 430 Roberts Road
Subiaco WA 6008
Telephone (08) 6555 0105

New Zealand
7/3 Empire Street
Cambridge New Zealand 3434
Telephone +64 27 777 0989

Wangaratta
First Floor, 40 Rowan Street
Wangaratta VIC 3677
Telephone (03) 5721 2650

Geelong
51 Little Fyans Street
Geelong VIC 3220
Telephone (03) 8526 0800

Wimmera
597 Joel South Road
Stawell VIC 3380
Telephone 0438 510 240

Gold Coast
Suite 37, Level 4, 194 Varsity Parade
Varsity Lakes QLD 4227
Telephone (07) 5676 7602

watertech.com.au

APPENDIX B
REVIEW OF MARINE PLANT IMPACTS

frc environmental
deep thinking. science.
PART OF SLR

ACN 002 895 007
ABN 72 002 895 007

Unit 1/7 Grant Street
Cleveland Q 4163
Australia

PO Box 2363
Wellington Point Q 4160
Australia

P 07 3286 3850
F 07 3821 7936
E info@frcenv.com.au
www.frcenv.com.au

Memorandum

Our Reference: 240308ii

To	Ryan Dermek, Water Technology
From	Carol Conacher
Date	04 October 2024

Dungeness Boating Safety Project: Assessment of Potential Impacts to Marine Plants

1 Introduction

The Dungeness Boating Safety Project aims to improve boating safety from Enterprise Channel in the Herbert River to the Hinchinbrook Passage. The project involves dredging Enterprise Channel and the construction of a protective coastal structure, with the placement of the dredged material at the adjacent Dungeness Beach.

Enterprise Channel, which connects the boat ramp to deeper waters of Hinchinbrook Channel and beyond, is subject to excess sediment build-up, inhibiting waterway access at low and mid tides, particularly for vessels with deeper drafts. The Dungeness Boating Safety Project (DBSP) aims to address these issues and restore full-tide access from the Dungeness boat ramp to the Hinchinbrook Channel through a combination of periodic dredging and siltation reduction assisted by a coastal structure. It is also envisioned that the dredged material would be re-used for beach nourishment on Dungeness Beach.

The distribution of marine habitats in the region and near the proposed developments; likely direct and indirect impacts; recommendations for avoidance, minimisation and mitigation of impacts, and recommendations for monitoring are presented in the report "Dungeness Enterprise Proposed Channel Works: Assessment of Potential Impacts to Marine Plants (frc environmental 2021). Following the issuing this report in August 2021 there have been slight changes to the design of the breakwater and detailed morphological modelling of likely impacts ('Stage 2 Modelling'; Water Technology 2024b).

The purpose of this report is to interpret this updated modelling, and assess likely impacts to marine plants. The updated modelling includes time series plots of sediment bed level (Appendix A), and GIS layers of erosion and sedimentation.

2 Summary of the Distribution of Marine Plants

The distribution of marine plants in the vicinity of the proposed works was mapped in 2019 and 2021, via field surveys and interpretation of aerial photography (frc environmental 2019 and frc environmental 2021; Maps 2 and 3 Appendix B). This mapping was supplemented in 2024 by interpretation of aerial photography to determine the current distribution of mangroves (Map 4 Appendix B).

The foreshore is dominated by mangrove forests, with a band of dead mangroves and mangrove debris in the intertidal zone, and with small patches of saltmarsh to landward.

Recent tropical cyclones have damaged the mangroves, and in recent years extensive mangrove habitat on Dungeness Spit was lost due to severe erosion. Shoreline erosion and mangrove loss between 2023 and 2024 is illustrated in Figure 2.1, and is indicative of ongoing erosion in this area.

Figure 2.1 Shoreline erosion and mangrove loss along the foreshore.

The lower intertidal and shallow subtidal area offshore of the mangroves consists of shoaling sand and mud flats, bisected by the Enterprise Channel. Large areas of these intertidal and shallow subtidal flats are covered with seagrass. In the most recent survey in 2021 *Halodule uninervis* was the dominant species, with other species including *Nanozostera muelleri* (previously known as *Zostera muelleri*) *Halophila ovalis*, and *Halophila decipiens* (frc environmental 2019 and 2021).

The distribution of seagrass in this area is likely to vary as the shoals move, with storm conditions that may disturb the seagrass, sedimentation associated with heavy rainfall, and with changes to turbidity (and light penetration) caused by strong winds and/or heavy rainfall. Highly turbid water in particular has been implicated in limiting the distribution of seagrass in this area, with mean depths for all seagrass species in the southern Hinchinbrook Channel (i.e. near the study area) less than 2.9 below MSL (Lee Long et al. 1998).

Halophila ovalis and *decipiens* are colonising species. While they commonly die back when conditions are not favourable, they seed prolifically and rapidly colonise after a disturbance (Kilminster et al. 2015). *Halodule uninervis* and *Nanozostera muelleri* are more opportunistic, but are still rapid colonisers. They are able to better withstand unstable and depositional environments, but also seed prolifically and can recolonise relatively rapidly from seed (Kilminster et al. 2015). In a recent study *Nanozostera* and *Halophila* continued to grow when they were buried in shallow sediment (1 – 5 mm), with growth rates higher when buried in 2.55 mm of sediment than when not buried (Benham et al. 2019). That is, these species are adapted to growing in areas of unstable sediment where a shoal may slowly accrete or move across them.

Analysis of historical aerial images indicates there has been considerable changes in the spit, channel and foreshore (Water Technology 2019). In summary (Figure 2.2):

- there has been significant erosion of the spit, such that the spit no longer protects the entrance to the channel
- the western bank of Enterprise Channel has significantly accreted
- the northern mangrove lined beach of Dungeness has significantly eroded (approximately 125 m between 1956 and 2017, or on average 2 m per year)
- there has been some accretion on the western side of the spit, inside the channel, and
- the northern beaches of Lucinda have been protected with coastal protection works and are relatively stable.

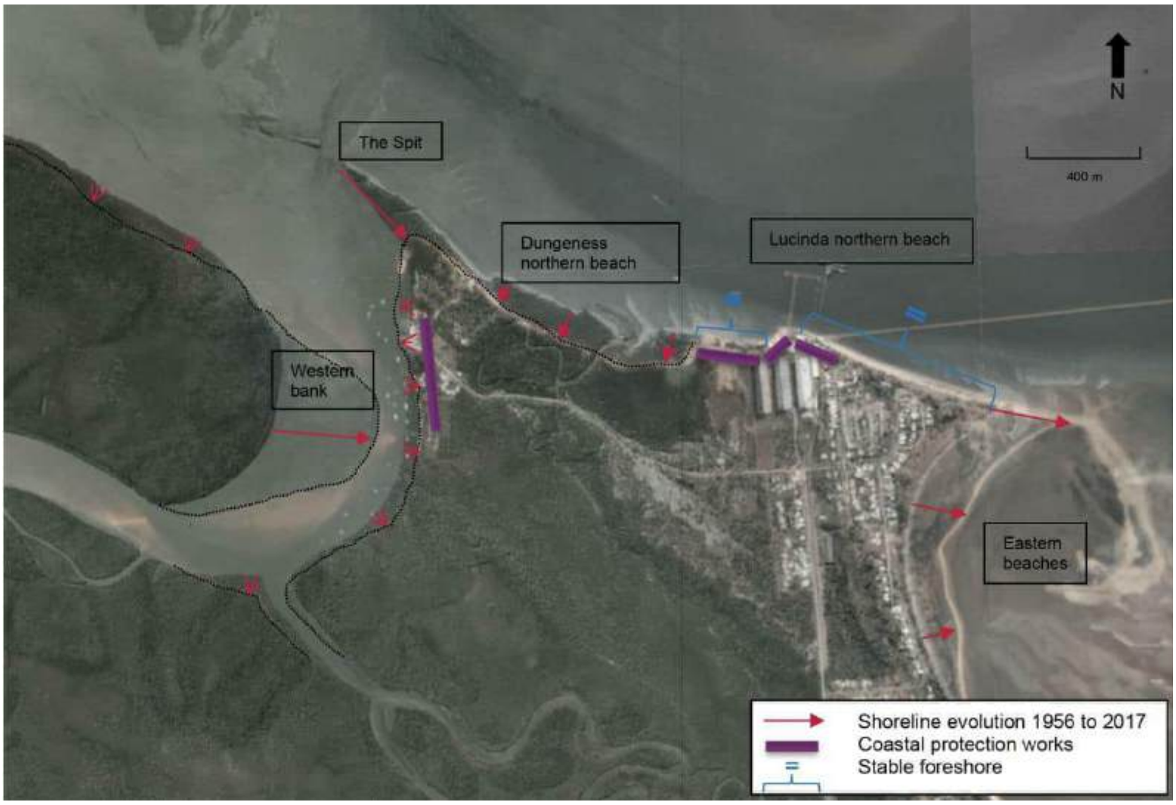


Figure 2.2 Aerial imagery from 1956 and 2017 (dotted outline) showing significant erosion of the spit and the northern foreshore of Dungeness (Water Technology 2019).

3 Conceptual Models of Sediment Transport Processes

Updated conceptual models of sediment transport processes with and without a breakwater are presented in the Stage 1 Modelling Report (Water Technology 2024a).

The conceptual model for the existing condition (Figure 3.1) indicates that:

- There is a tidal asymmetry, with a very strong flood tide and weaker ebb tide, which drives sediment transport processes in the area
- The strong flood tide results in high current speeds in the main channel
- The strong flood tide is associated with significant longshore transport and bedload movement in these areas.
- The Spit has significantly eroded due to exposure to strong tidal currents and waves.
- Some of this eroded material is deposited in the navigation channel, preventing access in all tide conditions.

- The south-western end of West Island is a lower energy environment and has experienced some erosion, due to the loss of the protection provided by the (now eroded) Spit.

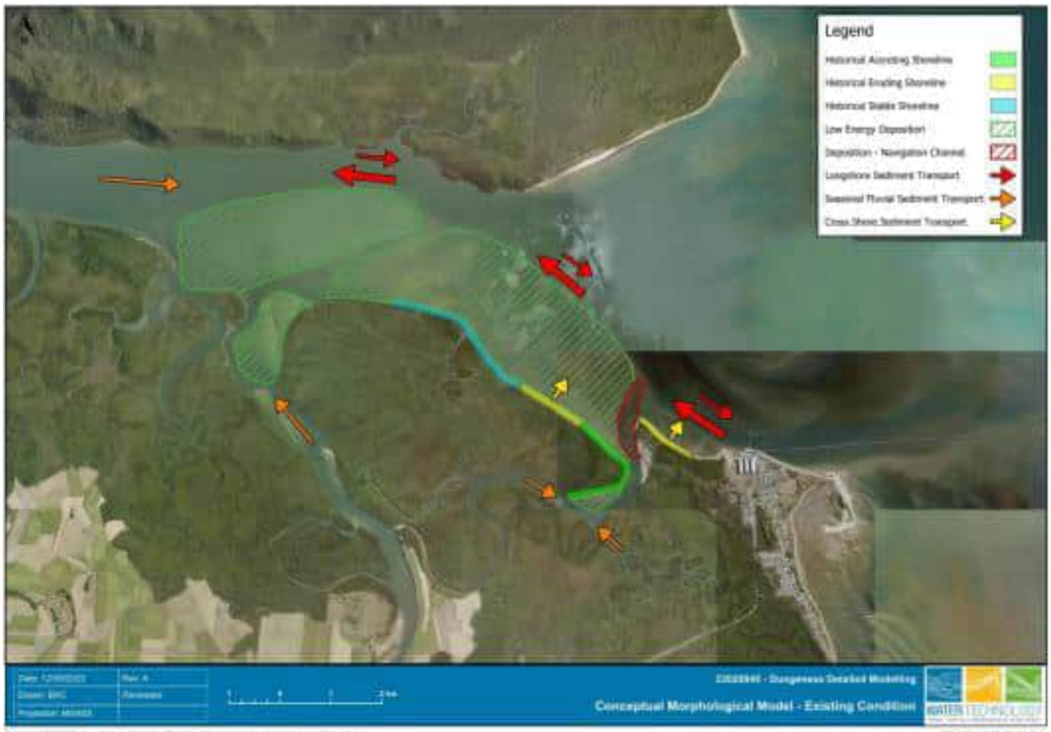


Figure 3.1 Conceptual model of existing sediment transport processes (Water Technology 2024a).

The conceptual model of sediment transport processes with a breakwater (Figure 3.2) indicates that:

- There is no reduction in the high bedload movement and major sediment transport processes in the main channel.
- The current rate of cross-shore transport at Dungeness Beach will be reduced, but will not cease.
- Cross shore transport at Dungeness Beach will only be reduced in areas directly adjacent to the breakwater.
- On the eastern portion of the beach cross shore transport will be slightly reduced.
- The longshore transport in the main channel will remain, and while there will be a slightly reduced sediment budget due to reductions in cross-shore transport at Dungeness Beach, this will not cause downstream erosion as most of this sediment

previously settled in the navigation channel and on the inside bend of the western bank.

- The proposed alignment will allow sediment deposition on the western side of the breakwater, historically where the spit extended prior to its erosion.

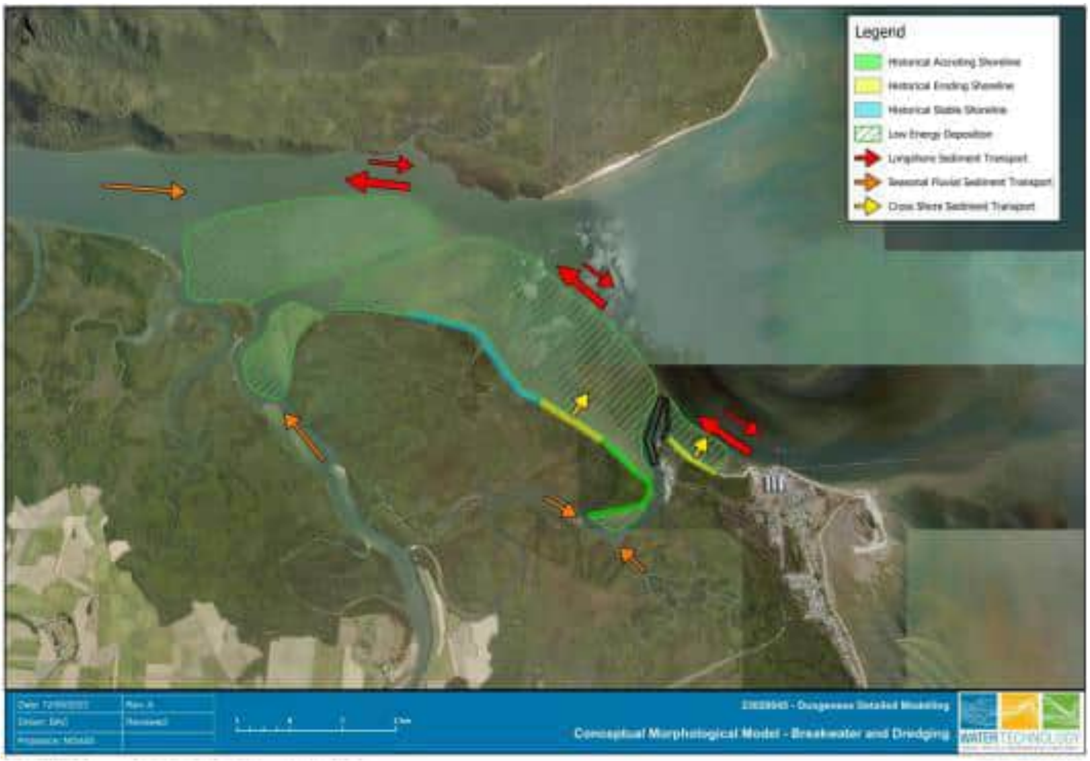


Figure 3.2 Conceptual model of sediment transport processes with a breakwater (Water Technology 2024a).

3.1 Stage 2 Morphological Modelling

The Stage 2 Modelling Report (Water Technology 2024b) focuses on sediment transport rates in the local area, and the broader geographical context of sediment transport pathways and seabed morphology at Dungeness, in the Enterprise Channel, and in the broader Hinchinbrook Passage. The local area was split into zones to describe and report on the model results (Figure 3.3; Map 1 Appendix B).

Figure 3.3 Zones used in the Stage 2 modelling (Water Technology 2024b).

Three scenarios were modelled:

- the base case
- works option 1 - dredged channel, and
- works option 2 - dredged channel and coastal structure.

Each of these scenarios were modelled for both La Nina and El Nino years, with results reported as cubic metres of sediment eroded or deposited per annum.

Time series plots of bed level at 9 sites were produced by Water Technology to assist in the interpretation of potential impacts to marine plants (Figure 3.4; Appendix A).

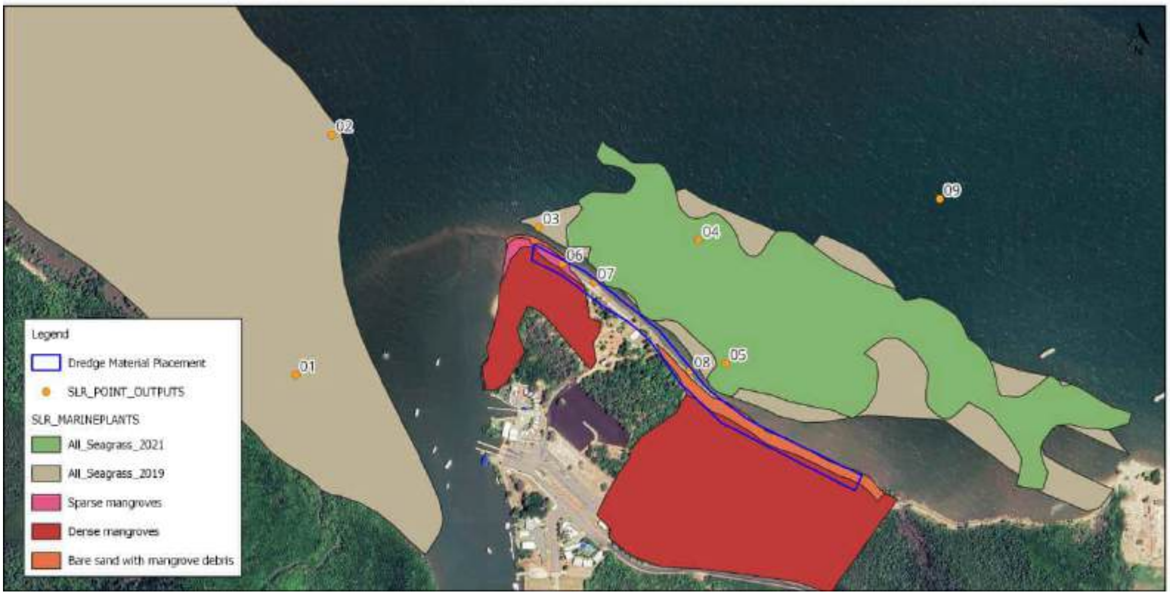


Figure 3.4 Sites where changes in bed level were modelled over time.

Water Technology also provided sediment and erosion overlays for each of the three scenarios in La Nina and El Nino years. The overlays show areas where modelling indicates there may be an indirect impact of a decrease in sediment height of over 20 mm per annum and the increase in sediment height of over 50 mm per annum. These thresholds were based on the known growth rates of the seagrass species occurring in the area, and their likely resilience to erosion and sedimentation. The thresholds are conservative and are used to indicate possible indirect impacts to seagrass distribution where the sediment erodes more than 20 mm per year, or where there is sedimentation of more than 50 mm per year (Appendix B: Maps 5 to 8). These thresholds were also applied to the mangrove forests, and are considered to be very conservative. In each of these maps, the modelled areas of deposition and erosion are overlain with the predicted areas of deposition and erosion, in each zone, for each scenario in La Nina and El Nino conditions.

3.2 Dredge Sand Placement Sensitivity

The dredged material placement zone is constrained by marine plants offshore (seagrass) and onshore (mangrove, including mangrove debris from dead mangroves). Due to the rapid erosion of Dungeness Beach, the available placement zone is changing, and has likely moved landward since the previous mapping of marine plants (frc environmental 2021). The sensitivity of the modelling to changes in the position of the dredge material placement zone was tested, and it was determined that the modelling is not sensitive to these changes (Water Technology 2024b). Further, once placed the dredge spoil is relatively stable and will not spread out to other areas (Water Technology 2024 pers.

comm.). To ensure that dredge material is not placed on any marine plants it is recommended that the distribution of marine plants is mapped immediately prior to any works (Water Technology 2024b).

3.3 Sea Level Rise Sensitivity.

The model assumes present-day sea level for the 5-year scenarios. However, there was also a sensitivity test for 0.8 m sea level rise. The primary change was along Hinchinbrook Channel mouth and Dungeness Beach, where sediment transport volumes changed in response to changing sea levels and wave climate. Sand bars in the Hinchinbrook Passage Entrance shoaled and adjusted to the rising sea level, while the main channel migrates offshore, reversing the current trend.

Much of the nearshore coast is armoured along Lucinda, apart from Dungeness Beach and The Spit. The southern coast of Hinchinbrook Island becomes more dynamic than in the baseline scenario, indicating a likelihood of ongoing erosion in this area.

Impacts related to coastal flooding due to rising sea levels are likely to be high, and changes to the sediment transport regime are likely to occur.

4 Assessment of Direct Impacts

The proposed works will result in permanent and temporary direct impacts to marine plants (Table 4.1; Appendix B: Map 4).

Table 4.1 Direct impacts to marine plants

Proposed Works	Seagrass (ha)	Mangrove (ha)	Permanent/ Temporary
Channel Dredging	0	0	NA
Placement of Dredge Spoil[1]	0	0	NA
Coastal Structure	0.0260	0.1469	Permanent
Dredge Pipeline[2]	0.0059	0	Temporary
Access Track[3]	0	0.0422	Temporary

[1] The distribution of marine plants will be mapped prior to the placement of dredge spoil, and no spoil will be placed on marine plants.

[2] The pipeline will be placed to avoid seagrass; however it may need to cross the seagrass bed from north to south.

[3] Following completion of the works, where the access track resulted in damage to mangroves, the sediment will be reprofiled to match pre-disturbance levels, with sediment of similar texture and composition, and planted with mangroves.

The Proposed works will also result in the creation of approximately 1.8505 ha of intertidal and shallow subtidal rocky reef habitat.

5 Assessment of Potential Indirect Impacts

The proposed works may also result in indirect impacts to marine plants as a result of changes to erosion and accretion rates. The assessment of these impacts is based on the results of modelling of three scenarios: baseline; dredging; dredging and coastal infrastructure (Water Technology 2024b).

Critically, due to ongoing coastal processes, the baseline scenario predicts changes to the existing state, including erosion of the shoreline. Construction of the coastal structure decreases the rate of erosion (Water Technology 2024b). Potential indirect impacts of erosion and sedimentation baseline (no dredging or coastal structure), dredging and coastal structure scenarios are summarised in Table 5.1 to Table 5.4; illustrated in Maps 5 to 8 in Appendix B, and summarised in the text below. As discussed in Section 3.1, the thresholds used were a decrease in sediment height of over 20 mm per annum and an increase in sediment height of over 50 mm per annum.

Table 5.1 Potential indirect impacts to marine plants in La Nina conditions, due to sediment deposition and erosion above the thresholds (hectares).

		Base		Dredge		Coastal Structure	
Zone	***Marine Plant***	***Deposition***	***Erosion***	***Deposition***	***Erosion***	***Deposition***	***Erosion***
1	Mangrove	0.000	1.782	0.000	1.721	0.022	0.768
2	Mangrove	0.000	0.049	0.000	0.044	0.002	0.110
2	Seagrass	0.621	4.037	0.608	4.128	0.000	0.000
4	Mangrove	0.006	0.183	0.006	0.166	0.000	0.000
4	Seagrass	0.000	0.025	0.000	0.025	0.000	0.000
7	Mangrove	0.000	0.968	0.000	0.963	0.000	0.000
8	Mangrove	0.000	0.135	0.000	0.072	0.079	0.146
9	Mangrove	0.000	0.462	0.000	0.403	0.000	0.296
9	Seagrass	4.175	2.142	3.870	2.383	3.093	1.067
10	Seagrass	0.013	0.005	0.013	0.005	0.013	0.005
12	Seagrass	0.000	0.079	0.000	0.079	0.007	0.024

Table 5.2 Difference in areas of potential erosion and deposition above the thresholds of dredge and coastal structure scenarios compared to the baseline scenario in La Nina Condition (hectares).

		Dredge			Coastal Structure		
Zone	***Marine Plant***	***Deposition***	***Erosion***	***Overall Improvement in Stability***	***Deposition***	***Erosion***	***Overall Improvement in Stability***
1	Mangrove	0	-0.061	0.061	0.022	-1.014	0.992
2	Mangrove	0	-0.005	0.005	0.002	0.061	-0.063
2	Seagrass	-0.013	0.091	-0.078	-0.621	-4.037	4.658
4	Mangrove	0	-0.017	0.017	-0.006	-0.183	0.189
4	Seagrass	0	0	0	0	-0.025	0.025
7	Mangrove	0	-0.005	0.005	0	-0.968	0.968
8	Mangrove	0	-0.063	0.063	0.079	0.011	-0.09
9	Mangrove	0	-0.059	0.059	0	-0.166	0.166
9	Seagrass	-0.305	0.241	0.064	-1.082	-1.075	2.157
10	Seagrass	0	0	0	0	0	0
12	Seagrass	0	0	0	0.007	-0.055	0.048
Potential Total Area of Improved Condition							
Seagrass				**-0.014**			**6.888**
Mangroves				**0.21**			**2.162**

Table 5.3 Potential indirect impacts to marine plants in El Nino conditions, due to sediment deposition and erosion (hectares).

		Base		Dredge		Coastal Structure	
Zone	***Marine Plant***	***Deposition***	***Erosion***	***Deposition***	***Erosion***	***Deposition***	***Erosion***
1	Mangrove	0.000	0.781	0.000	0.791	0.000	0.795
2	Mangrove	0.000	0.092	0.000	0.097	0.000	0.111
2	Seagrass	0.382	0.005	0.430	0.012	0.000	0.000
3	Mangrove	0.000	0.002	0.000	0.005	0.000	0.000
4	Mangrove	0.000	0.104	0.000	0.089	0.000	0.000
4	Seagrass	0.000	0.042	0.000	0.036	0.000	0.000
7	Mangrove	0.000	0.916	0.000	0.883	0.000	0.000
8	Mangrove	0.025	0.126	0.012	0.034	0.000	0.036
9	Mangrove	0.002	0.416	0.000	0.399	0.000	0.280
9	Seagrass	2.852	1.953	2.697	2.025	3.372	1.072
10	Seagrass	0.013	0.005	0.013	0.005	0.013	0.005
12	Seagrass	0.000	0.068	0.000	0.066	0.007	0.018

Table 5.4 Difference in areas of potential erosion and deposition above the thresholds of dredge and coastal structure scenarios compared to the baseline scenario in El Nino conditions (hectares).

		Dredge			Coastal Structure		
Zone	***Marine Plant***	***Deposition***	***Erosion***	***Overall Improvement in Stability***	***Deposition***	***Erosion***	***Overall Improvement in Stability***
1	Mangrove	0	0.01	-0.01	0	0.014	-0.014
2	Mangrove	0	0.005	-0.005	0	0.019	-0.019
2	Seagrass	0.048	0.007	-0.055	-0.382	-0.005	0.387
3	Mangrove	0	0.003	-0.003	0	-0.002	0.002
4	Mangrove	0	-0.015	0.015	0	-0.104	0.104
4	Seagrass	0	-0.006	0.006	0	-0.042	0.042
7	Mangrove	0	-0.033	0.033	0	-0.916	0.916
8	Mangrove	-0.013	-0.092	0.105	-0.025	-0.09	0.115
9	Mangrove	-0.002	-0.017	0.019	-0.002	-0.136	0.138
9	Seagrass	-0.155	0.072	0.083	0.52	-0.881	0.361
10	Seagrass	0	0	0	0	0	0
12	Seagrass	0	-0.002	0.002	0.007	-0.05	0.043
Potential Total Area of Improved Condition							
Seagrass				**0.036**			**0.833**
Mangroves				**0.102**			**1.627**

Zone 1, Along the Western Foreshore of West Island.

- This Zone is a mangrove forest, with spare seagrass offshore in Zone 2 (frc environmental 2019).
- This Zone is currently relatively stable, with some minor bank erosion, particularly in La Niña periods, with erosion likely to continue at a slow rate (Table 5.5).
- With dredging the channel, modelling indicates this Zone would become more stable in La Niña periods, and erode more in El Niño periods (Table 5.5).
- In the dredging and the coastal structure scenario the modelling indicates there would be a reduction in erosion compared to the baseline scenario (Table 5.5).
- Modelling of erosion and deposition thresholds indicates that with dredging the Channel (Appendix B: Maps 5 & 7; Table 5.2 to Table 5.6)
  - in La Nina and El Nino conditions the area of mangroves over the erosion threshold would slightly decrease
- Modelling of erosion and deposition thresholds indicates that with dredging the Channel and the Coastal Infrastructure (Appendix B: Maps 6 & 8;
- Table 5.2 Difference in areas of potential erosion and deposition above the thresholds of dredge and coastal structure scenarios compared to the baseline scenario in La Nina Condition (hectares).
- to Table 5.6)
  - in La Nina conditions there would be less erosion in the mangroves, with an increase in deposition in some small areas – overall an improvement in stability (0.992 ha)
  - in El Nino conditions there would be a small increase in the area over the erosion threshold (0.014 ha).

That is, with dredging only, there would be less erosion of the mangrove lined foreshore. With dredging and coastal infrastructure this foreshore would become much more stable in La Nina conditions. While there may be some slight erosion in El Nino conditions, overall the area would be more stable, and there would be a slight net benefit to the mangrove forest.

Table 5.5 Zone 1: Modelled deposition (-ve) / accretion (+ve) of sediment in each scenario (m^3).

	Baseline	Dredging Only	Dredging & Coastal Structure
La Niña	-600	-900	-900
El Niño	+60	+100	+300

Zone 2, the broad intertidal area extending seaward of Zone 1.

- This Zone is dominated by sparse seagrass beds (<5% cover) in the west and bare sand near the channel (frc environmental 2019), with mangroves along the foreshore (extending out from Zone 1).
- This Zone generally acts as a sediment sink, with shoals increasing in size. This is likely to be due to sediment input from the Herbert River, with the modelling indicating the accumulation of sediment of approximately 20,000 m^3 / year on the shoals in this Zone.
- With dredging the channel, modelling indicates that there would be slightly less accretion in this Zone (Table 5.6).
- With dredging and the coastal structure, the modelling indicates there would be a higher rate of accretion in this Zone than in the baseline (Table 5.6).
- Time series sites 1 and 2 are in this Zone (Appendix A). These sites are over a sparse seagrass bed.
- At site 1 there is less change in the bed level in the dredge and coastal structure scenario than in the other two scenarios.
- At site 2, on the outer edge of the seagrass bed, in a El Niño period there is likely to be more sediment accretion in the dredge and coastal structure scenario than in the other two scenarios, with bed level changing from approximately -1.18 m AHD to approximately -1.14 m AHD over a 5-year period, i.e. 8 mm per year. Seagrasses are likely to be able to withstand this gradual accretion, and it is likely to promote lateral growth (Benham et al. 2019).
- At site 2 in a La Niña period, after 5 years there is similar sediment accretion in all three scenarios, however the accretion in the dredge and coastal structure scenario is more gradual. The seagrass is unlikely to be negatively impacted by this gradual accretion, with growth promoted by burial of 2.5 mm (Benham et al. 2019). While the rapid accretion modelled for the baseline and dredge only scenarios in the final

year of the La Niña period at this site may negatively impact seagrass growth, these species are likely to rapidly recolonise.

- Modelling of erosion and deposition thresholds indicates that with dredging the Channel (Appendix B: Maps 5 & 7):
  - in La Nina conditions there would be a smaller area of mangroves, and a slightly larger area of seagrass potentially impacted by erosion and a slightly smaller area potentially impacted by deposition (Table 5.2) and in
  - El Nino conditions there would be slightly larger areas of seagrass potentially impacted by both deposition and erosion (Table 5.4)
- Modelling of erosion and deposition thresholds indicates that with dredging the Channel and the Coastal Infrastructure (Appendix B: Maps 6 & 8;
- Table 5.2 Difference in areas of potential erosion and deposition above the thresholds of dredge and coastal structure scenarios compared to the baseline scenario in La Nina Condition (hectares).
- to Table 5.6) in both La Nina and El Nino conditions there would be less erosion and deposition potentially impacting the seagrass than in baseline conditions, however there may be slightly more erosion of the mangroves (Table 5.2 and Table 5.4).
- While the distribution of seagrass was not mapped in the western part of this zone, the areas of change above the sediment and erosion thresholds in the unmapped area do not change.
- That is, in the dredging only scenario this sparse seagrass bed is likely to become slightly more stable. In the dredging and coastal structure scenario, there are unlikely to be any negative impacts to the seagrass, as the area will become more stable.

Table 5.6 Zone 2: Modelled deposition (-ve) / accretion (+ve) of sediment in each scenario (m^3).

	Baseline	Dredging Only	Dredging & Coastal Structure
La Niña	+20,000	+19,000	+27,000
El Niño	+15,000	+13,000	+25,000

Zone 3, the south-western peninsula of West Island.

- This Zone is a mangrove forest (frc environmental 2019), and is an area of deposition, with excess sediment from Zone 2 pushed into this area by tidal flows.
- This part of the Western Island has grown substantially from the 1950s to the early 2000s. Based on aerial imagery showing minimal growth, this area has stabilised in the last 10 – 15 years.
- The model suggests that over the 5-year morphological model run, the bank slowly accretes with more accretion in La Niña than El Niño periods (Table 5.7).
- Of note, there is no strong sediment pathway from the Spit and Dungeness Beach (Zones 7, 8 and 9) to the West Island area (Zones 1, 2 and 3).
- With dredging the channel, modelling indicate there would not be a significant impact to Zone 3 (Table 5.7).
- In the dredging and the coastal structure scenario, the modelling indicates there would be less deposition in this area (Table 5.7).
- Modelling of erosion and deposition thresholds indicates that in both development scenarios and in both La Nina or El Nino conditions there will be no impact to marine plants (Appendix B: Maps 5 to 8, Table 5.2 to Table 5.6).

Table 5.7 Zone 3: Modelled deposition (-ve) / accretion (+ve) of sediment in each scenario (m^3).

	Baseline	**Dredging Only**	**Dredging & Coastal Structure**
La Niña	+400	+400	+30
El Niño	+100	+100	+10

That is, neither of the proposed development scenarios are likely to have a significant impact on the mangroves in this Zone.

Zone 4, Enterprise Channel.

- The Enterprise Channel, where dredging is proposed, acts as a sediment sink between Dungeness Beach and the Western Island shoals (Zone 2 and 9). It is infilling at a rate of approximately 12,000 m^3 /year, predominantly driven by sediment coming from the east (the near shore Zone of Dungeness Beach).

- This Zone is predominantly bare sand, with a small area of mangroves associated with Zone 7, and a small area of seagrass associated with Zone 9 extending into this Zone.
- In both La Nina and El Nino conditions the area will be more stable with both proposed development scenarios, and the mangrove shoreline less likely to erode (Table 5.2 to Table 5.4; Appendix B Maps 5 to 8).

That is, there are unlikely to be any negative impacts to marine plants in this Zone, and there is likely to be positive impacts to mangroves.

Zones 5 and 6 on the eastern bank of the Enterprise Channel upstream of the spit.

- These Zones are relatively stable and partially armoured with a seawall.
- There is a large mangrove forest here, with mangroves lining the channel where there is no seawall.
- With dredging the channel, and with dredging the channel and installing a coastal structure there is no change compared to the baseline scenario for these Zones.

That is there are unlikely to be any impacts to marine plants in this Zone in either of the developed scenarios.

Zone 7, Dungeness Beach Spit.

- The Spit has rapidly eroded over the past 70 years, with major cyclones a major contribution to this erosion.
- The mangroves in this Zone are eroding, with a band of bare sand with mangrove debris along the foreshore, and sparse mangroves behind.
- In both development scenarios, and in La Nina and El Nino conditions, the area above the erosion threshold in will decrease (Table 5.2 and Table 5.4).

That is, the dredge and coastal structure scenario would result in less erosion of the mangroves, a positive outcome.

Zone 8, Dungeness Beach foreshore from the spit to the ramp and carpark.

- The shoreline along the Dungeness foreshore predominately consists of bare sand leading up to a band of dead mangroves and mangrove debris in the intertidal Zone that is up to 10 m wide. To landward of this band of dead mangroves there are some sparse mangroves for approximately 10 m, with density increasing to landward.
- Along Dungeness Beach (Zones 8, 9 and 10) the morphology is more driven by tides rather than waves.
- The Dungeness beach foreshore is eroding, despite beach nourishment from the boat ramp.
- The modelling indicates that with dredging there would be slightly higher rates of erosion in this Zone (Table 5.8).
- Modelling indicates erosion is reduced in this Zone in the dredging and coastal infrastructure scenario (Table 5.8).
- Modelling of erosion and deposition thresholds indicates that in La Nina and El Nino conditions in the dredge scenario the mangroves become more stable, and also in El Nino conditions with the Coastal Structure. However there would be a slight increase in deposition in La Nina conditions with the Coastal Structure (Appendix B: Maps 5 to 7; Table 5.2 to Table 5.6)

That is, there would be less erosion of the mangrove lined foreshore, and consequent loss of mangroves:- a positive impact to marine plants.

Table 5.8 Zone 8: Modelled deposition (-ve) / accretion (+ve) of sediment in each scenario (m^3).

	Baseline	**Dredging Only**	**Dredging & Coastal Structure**
La Niña	-3,400	-3,500	-2,300
El Niño	-2,700	-2,700	-2,800

Zone 9

- Zones 9 and 10, and the intertidal area to the east of Zone 8, have net accretion, likely a result of the influx of sediment from the east, with sand regularly building up on the boat ramp in Zone 10. Approximately 5000 t per year are removed from the ramp, with excavation up to 3 times per week. The sand is stockpiled next to the ramp and returned to the system upstream at Dungeness Beach (Water Technology 2024a).

- Shoals in this area continue to grow.
- In 2021, *Halodule uninervis* was the dominant species in Zone 9, in both monospecific and mixed species communities. Other seagrass species included *Nanozostera muelleri* and *Halophila decipiens*.
- In the previous survey in 2019 there was a slightly greater area of seagrass, in this Zone. However, fluctuations in the cover of seagrass cover in this area are expected due to the location of these beds on the mouth of the Dungeness Enterprise Channel, where there is sediment movement and significant fluctuations in turbidity.
- There is a small area of mangroves in zone 9, extending in from the mangrove lined shore in Zones 7 and 8.
- Modelling indicates there is a slight increase in deposition in the dredge only scenario, and a more significant increase in the dredge and coastal infrastructure scenario (Table 5.9).

Table 5.9 Zone 9: Modelled deposition (-ve) / accretion (+ve) of sediment in each scenario (m^3).

	Baseline	**Dredging Only**	**Dredging & Coastal Structure**
La Niña	+6,600	+6,500	+6,400
El Niño	+6,200	+6,100	+6,400

Time series sites 3, 4, 5, 6, 7 and 8 are in this Zone (Appendix A). Sites 4 and 5 were in sparse seagrass. Site 3 was in sparse seagrass in 2019, but this area was bare in 2021 (Map 3 Appendix B). Sites 6, 7 and 8 were on bare substrate.

At sites 3 and 4, the time series graphs indicate there is little difference between the base and dredge only scenarios.

The time series graphs indicate that at site 3 the sediment bed level is far more stable in the dredge plus coastal structure scenario, than the other two scenarios and consequently seagrass is more likely to form a stable habitat in this scenario. Similarly at sites 4 and 5 the bed level is more stable in this scenario, and consequently provides a more stable habitat for seagrass growth.

That is, the proposed dredging and coastal structure will stabilise sediment in this Zone, and consequently the seagrass beds are likely to become more stable. Although there is some accretion, the shoals remain within the appropriate depth range for seagrass growth. No negative impacts to seagrass are anticipated based on tis modelling.

Time series sites 6, 7 and 8 are in the area where dredge sediment is modelled as being deposited, and consequently there is an increase bed level here. The area of marine plants in this area will be remapped prior to dredging, and no dredge spoil will be placed on marine plants. Modelling indicates that the dredge spoil material is stable, and moves very little, and consequently it will not pose a risk to marine plants.

- Modelling of erosion and deposition thresholds indicates that with dredging the Channel and with the Coastal Infrastructure there would be an overall improvement in the stability of the seagrass beds (Appendix B: Maps 5 & 7, Table 5.2 to Table 5.6).

Zone 10

- A small area of seagrass extends into Zone 10 from Zone 9. The foreshore of Zone 10 appears to be a rock wall, with no mangroves.
- The modelling indicates that with dredging there would be slightly higher rates of erosion in Zone 10, with this erosion decreasing with distance from the dredge channel, with very little change in Zone 10 compared to the baseline.
- In Zone 10 there is little difference to the base scenario, however the coastal structure reduces sediment transport along Dungeness beach, reducing erosion and increasing accretion.
- In La Nina conditions in both scenarios, there is no change in the area above the erosion or deposition thresholds in the seagrass area. In El Nino conditions there is an improvement in the stability of the beds (Table 5.2 &Table 5.6; Appendix B Map 6).

Zone 11, inshore intertidal area further to the east.

- This Zone is not as protected as Zones 9 and 10. It has high sediment transport from east to west, with net erosion. The shoreline in this area has been eroding, with a seawall built along part of its length. There are no mangroves along this shoreline.
- This Zone is in the active coastal Zone and the morphology is driven by wave action.
- There do not appear to be any mangroves along the foreshore of this zone.

- The modelling indicates that with dredging there would be very little change compared to the baseline.
- Modelling indicates erosion is reduced in this Zone in the dredging and coastal infrastructure scenario. If there is any seagrass in this area, this more stable substrate would be beneficial to it.

Zone 12, the Hinchinbrook Channel.

- The Hinchinbrook Channel is subject to extreme variation in bed level. The area between Lucinda and Hinchinbrook Island is subject to higher wave energy than the rest of the area, and has a significantly higher tidal prism than that flowing through the Enterprise Channel. This results in ongoing movement of the shoals.
- There is a very small area of seagrass in this Zone, extending out from Zone 9.
- This Zone is in the active coastal Zone and the morphology driven by wave action.
- Modelling indicates there would be some impact in the channel with dredging, and some impact in the immediate vicinity of the coastal infrastructure in the dredging and coastal infrastructure scenario.
- Time series site 9 is in this Zone. There is very little difference in deposition and accretion rates for each scenario in this Zone in El Niño periods (Appendix A). In La Niña periods, there is less accretion in the dredging and coastal structure scenario than in the two other scenarios.

Modelling of the thresholds indicate that overall the area of seagrass would become more stable (Table 5.2 & Table 5.4).

6 Summary and Conclusions

6.1 Direct Impacts

No marine plants would be permanently directly impacted by the dredging, with a small area of seagrass potentially temporarily disturbed by the placement of the pipeline (Table 4.1. Any damage to the seagrass is anticipated to naturally recover once the pipeline is removed.

A small area of mangroves would be directly impacted by the construction of the coastal structure, and a small area temporarily impacted by construction and use of the access track (Table 4.1). This area of temporary disturbance will be reprofiled to the original conditions, and the sediment returned to its original condition. Where mangrove seedlings do not colonise this area within 18 months, propagules will be collected and planted in this area. These seedlings will be monitored and maintained, to ensure they reach maturity.

6.2 Indirect Impacts

In summary, the modelling indicates that dredging only would lead to:

- A slight decrease in the stability of sediment in seagrass beds over threshold levels that may result in a slight loss of seagrass.
- An increase in the stability of mangrove sediment, and less erosion of the mangroves.

In summary, the modelling indicates that the dredging and coastal structure would:

- significantly decrease the rate of deposition in the Enterprise Channel, resulting in less frequent dredging, and less requirement to dispose of the dredge material
- significantly increase the stability of both mangrove and seagrass sediments, decreasing the rate of mangrove loss, and likely resulting in increase in the area of seagrass.

7 References

Benham, CF, Beavis, SG & Jackson, EL 2019. 'Tolerance of tropical seagrasses *Zostera muelleri* and *Halophila ovalis* to burial: Toward an understanding of threshold effects', *Estuarine Coastal and Shelf Science*, vol. 218, pp. 131-138.

frc environmental 2019. *Dungeness Enterprise Channel Dredging, Rock Wall & Beach Replenishment: Ecological Survey and Environmental Impact Assessment 2019*. Unpublished report submitted to Hinchinbrook Shire Council.

frc environmental 2021. Dungeness Enterprise Channel proposed works: assessment of potential impacts to marine plants. Project 210202. Unpublished report submitted to Hinchinbrook Shire Council.

Kilminster, K, McMahon, K, Waycott, M, Kendrick, GA, Scanes, P, McKenzie, L, O'Brien, KR, Lyons, M, Ferguson, A, Maxwell, P, Glasby, T & Udy, J 2015. 'Unravelling complexity in seagrass systems for management: Australia as a microcosm', *Science of theTotal Environment*, vol. 534, pp. 97-109.

Lee Long, WJ, McKenzie, LJ, Roelofs, AJ, Makey, LJ, Coles, RG & Roder, CA 1998. *Baseline Survey of Hinchinbrook Region Seagrass - October (Spring) 1996*, report prepared for Great Barrier Reef Marine Park Authority.

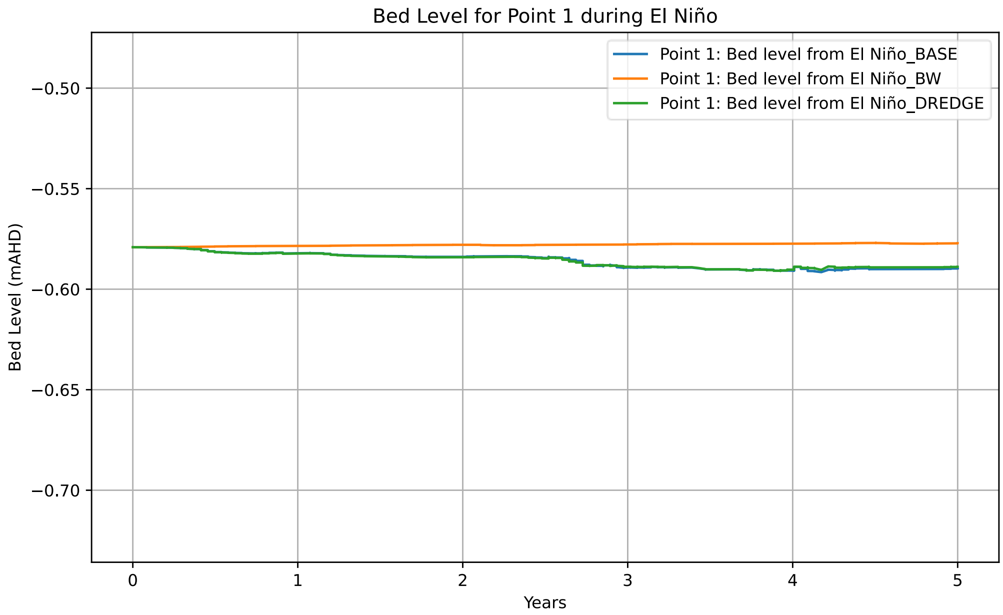
Water Technology 2019. Dungeness Enterprise Channel Modelling and Coastal Processes Study. Report for Hinchinbrook Shire Council.

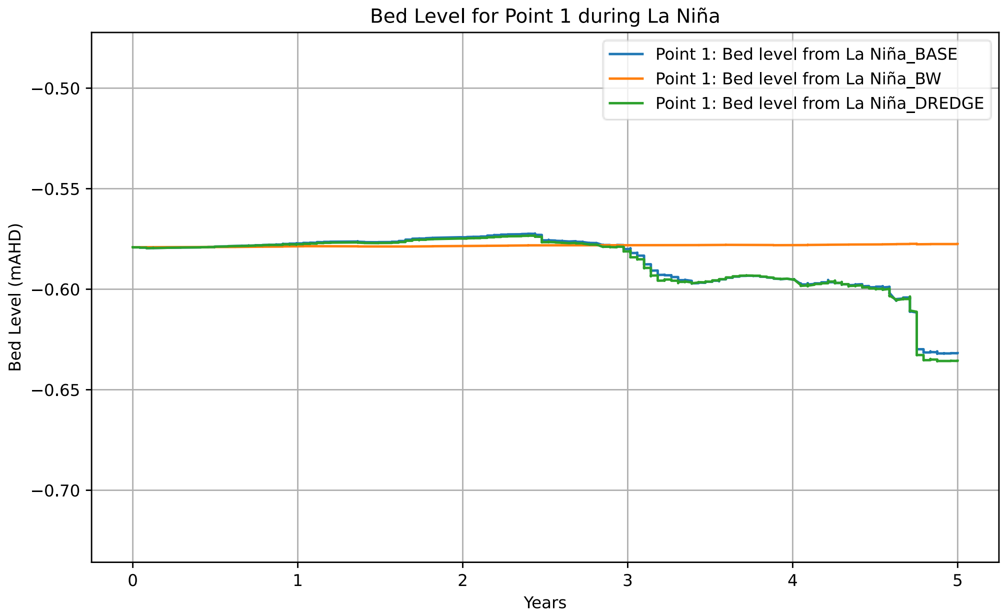
Water Technology 2024a. Stage 1 Report. Dungeness Boating Safety Project – Detailed Morphological Modelling. Report prepared for Hinchinbrook Shire Council. February 2024.

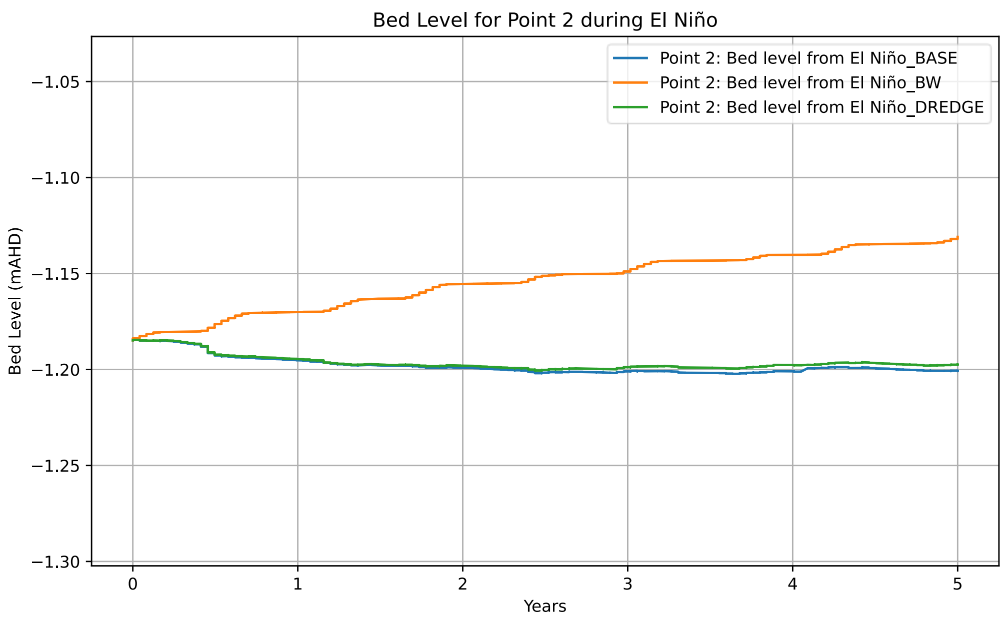
Water Technology 2024b. Stage 2 Report. Dungeness Boating Safety Project – Detailed Morphological Modelling. Report prepared for Hinchinbrook Shire Council. 06 September 2024.

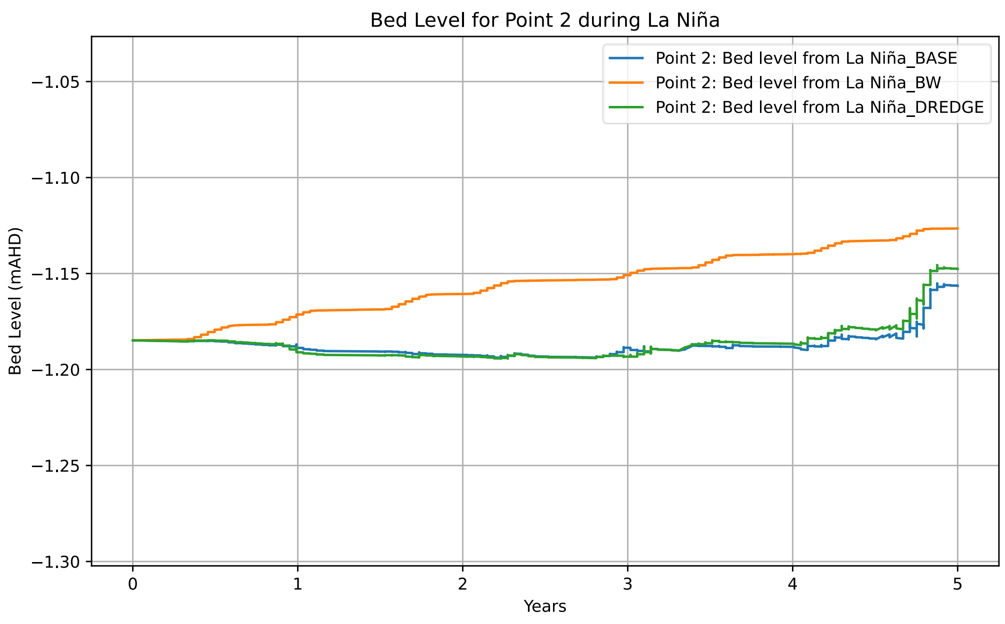
Appendix A: Time Series Plots of Sediment Bed Level

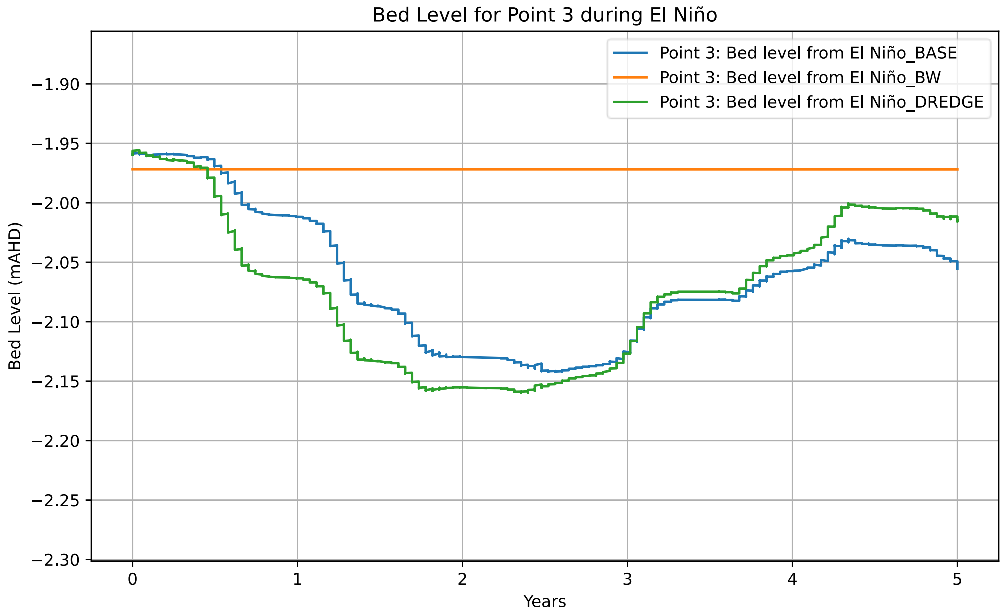
Appendix A Time Series Plots of Sediment Bed Level

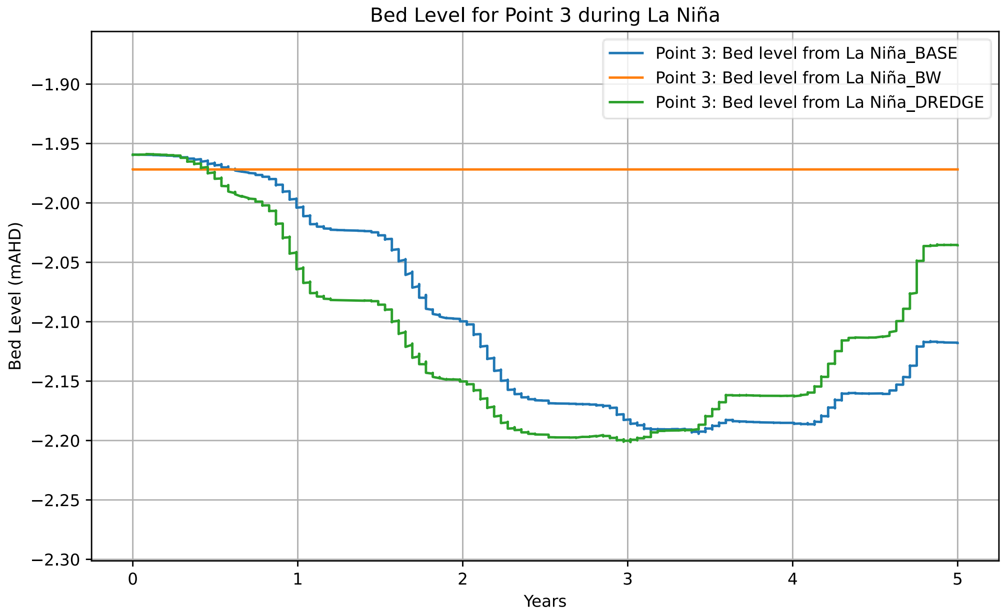


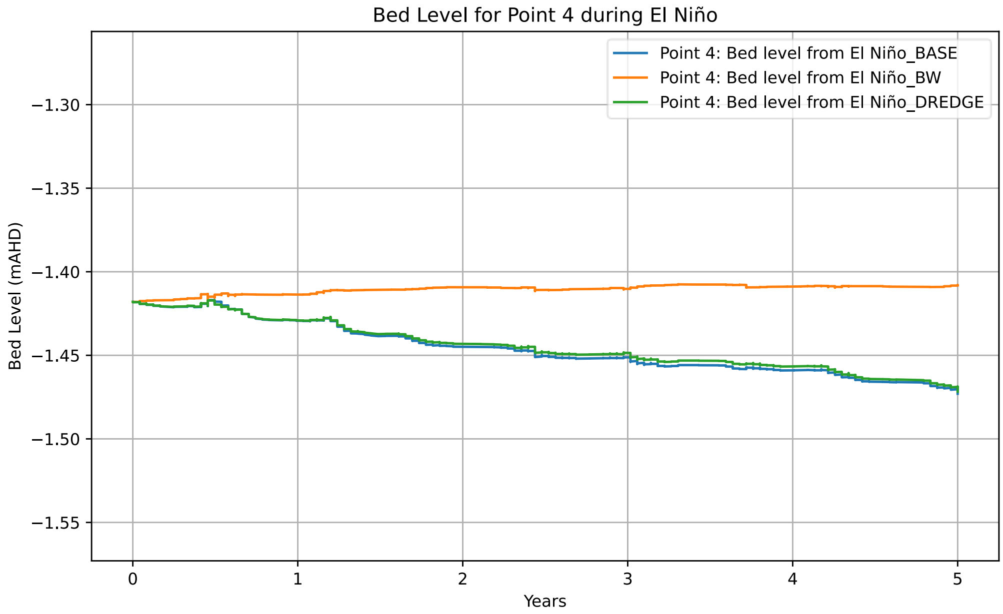


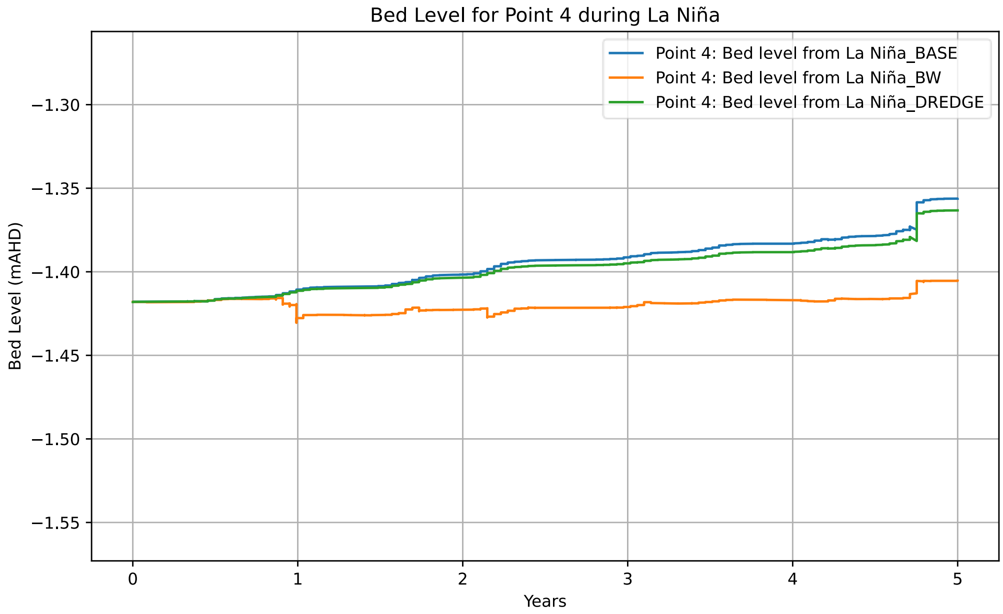

Bed Level for Point 2 during El Niño
Point 2: Bed level from El Niño_BASE
Point 2: Bed level from El Niño_BW
Point 2: Bed level from El Niño_DREDGE
Bed Level (mAHD)
−1.05
−1.10
−1.15
−1.20
−1.25
−1.30
0
1
2
3
4
5
Years

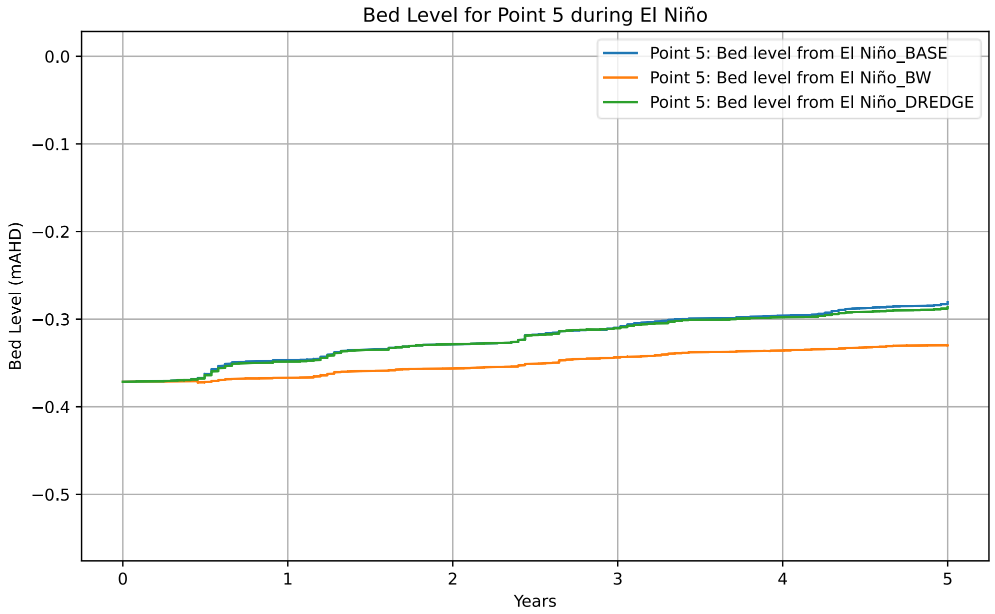

Bed Level for Point 2 during La Niña
Point 2: Bed level from La Niña_BASE
Point 2: Bed level from La Niña_BW
Point 2: Bed level from La Niña_DREDGE
Bed Level (mAHD)
−1.05
−1.10
−1.15
−1.20
−1.25
−1.30
0
1
2
3
4
5
Years

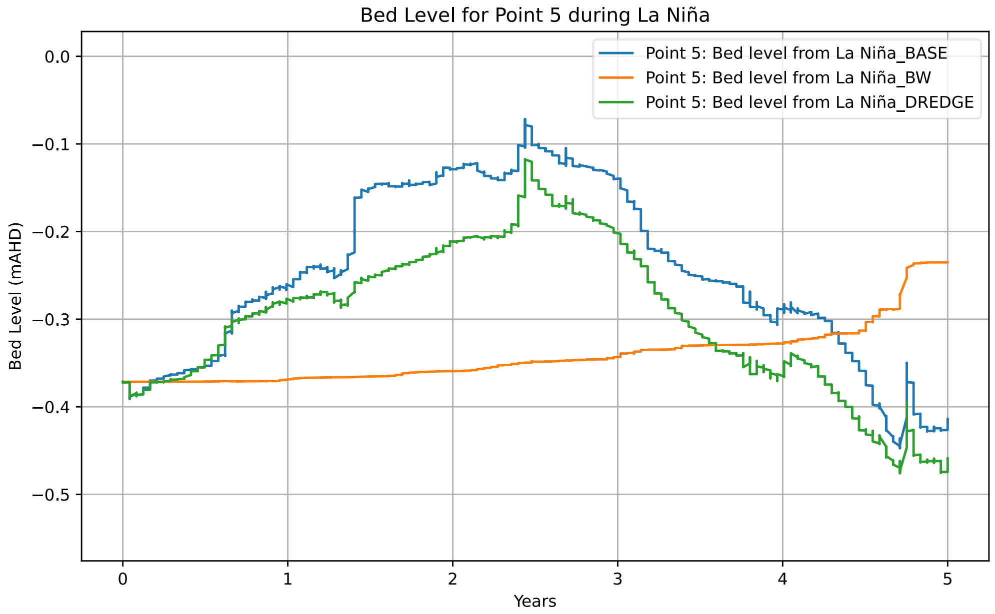

Bed Level for Point 3 during El Niño
Point 3: Bed level from El Niño_BASE
Point 3: Bed level from El Niño_BW
Point 3: Bed level from El Niño_DREDGE
Bed Level (mAHD)
−1.90
−1.95
−2.00
−2.05
−2.10
−2.15
−2.20
−2.25
−2.30
0
1
2
3
4
5
Years

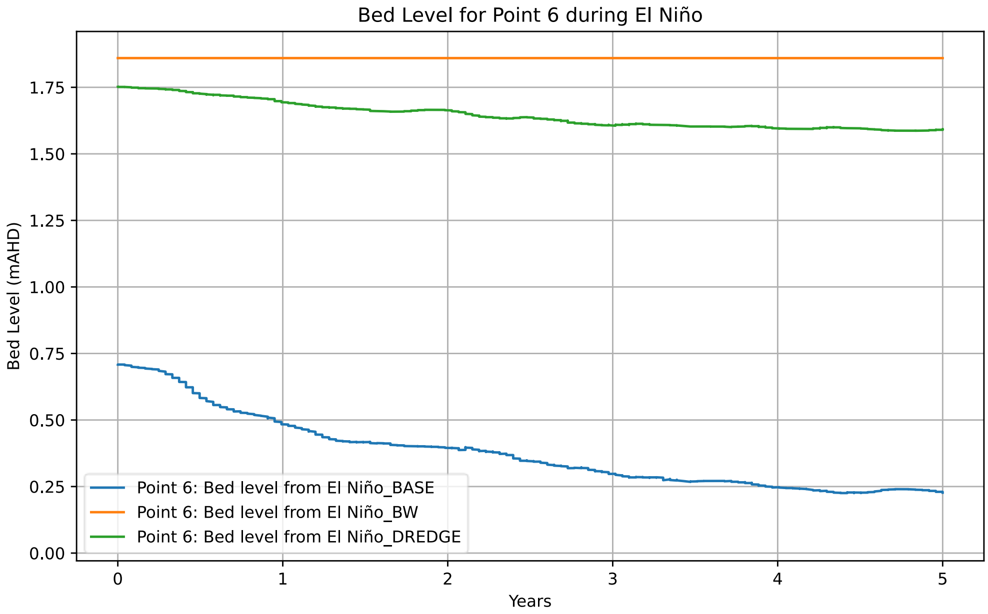

Bed Level for Point 3 during La Niña
Point 3: Bed level from La Niña_BASE
Point 3: Bed level from La Niña_BW
Point 3: Bed level from La Niña_DREDGE
Bed Level (mAHD)
−1.90
−1.95
−2.00
−2.05
−2.10
−2.15
−2.20
−2.25
−2.30
0
1
2
3
4
5
Years

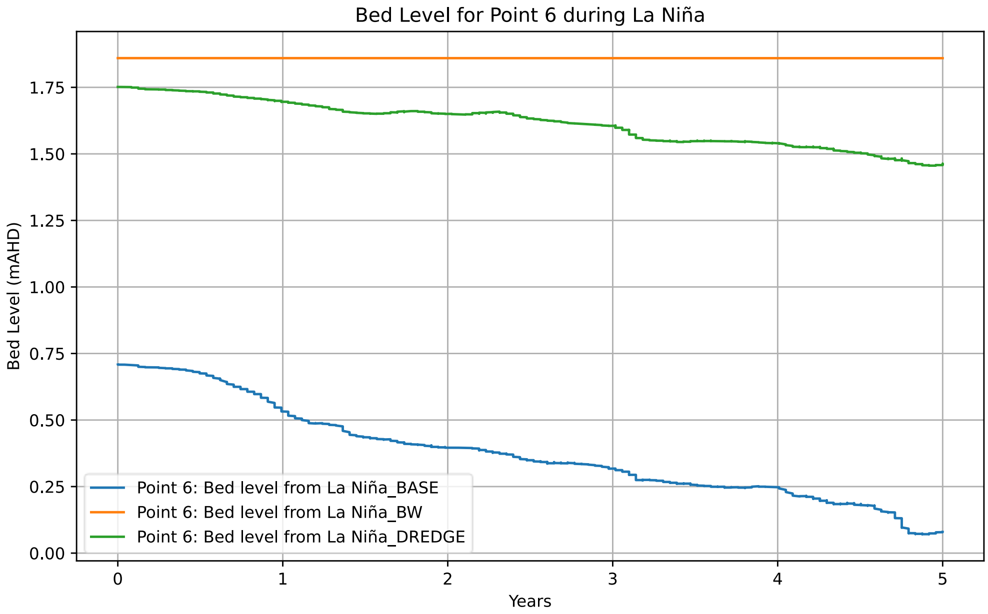

Bed Level for Point 4 during El Niño
Point 4: Bed level from El Niño_BASE
Point 4: Bed level from El Niño_BW
Point 4: Bed level from El Niño_DREDGE
Bed Level (mAHD)
−1.30
−1.35
−1.40
−1.45
−1.50
−1.55
0
1
2
3
4
5
Years

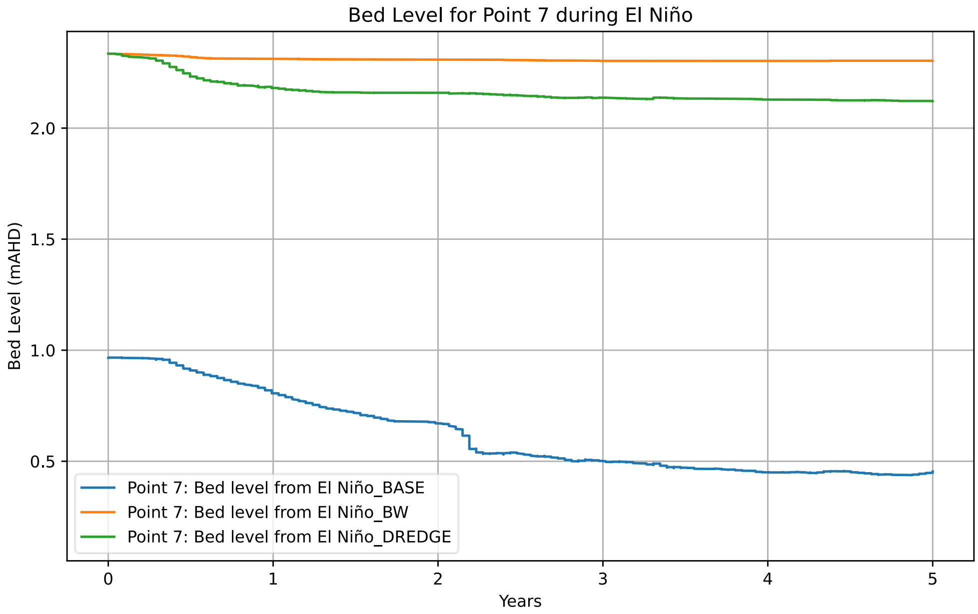

Bed Level for Point 4 during La Niña
Point 4: Bed level from La Niña_BASE
Point 4: Bed level from La Niña_BW
Point 4: Bed level from La Niña_DREDGE
Bed Level (mAHD)
−1.30
−1.35
−1.40
−1.45
−1.50
−1.55
0
1
2
3
4
5
Years

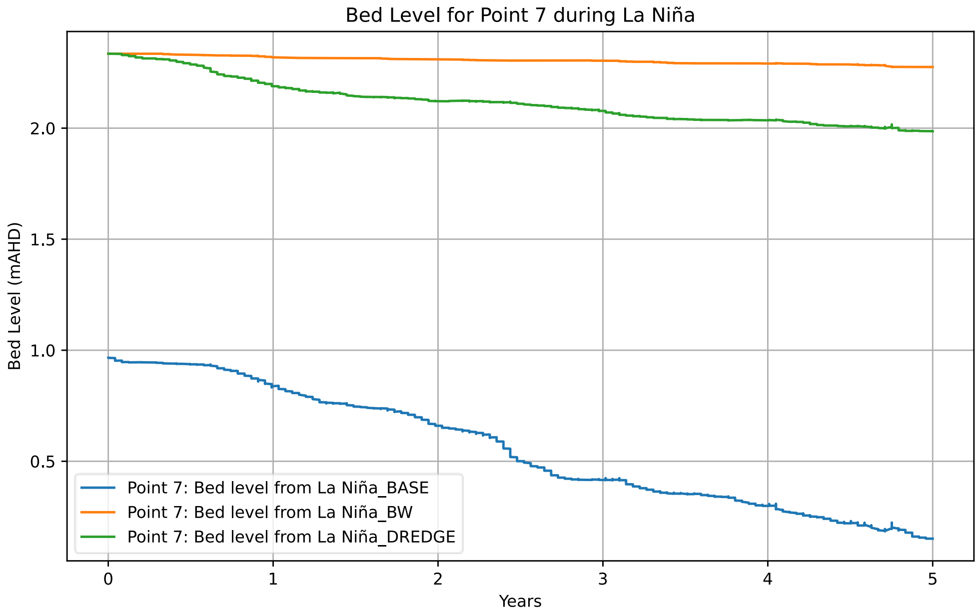

Bed Level for Point 5 during El Niño
Point 5: Bed level from El Niño_BASE
Point 5: Bed level from El Niño_BW
Point 5: Bed level from El Niño_DREDGE
Bed Level (mAHD)
Years
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
0
1
2
3
4
5

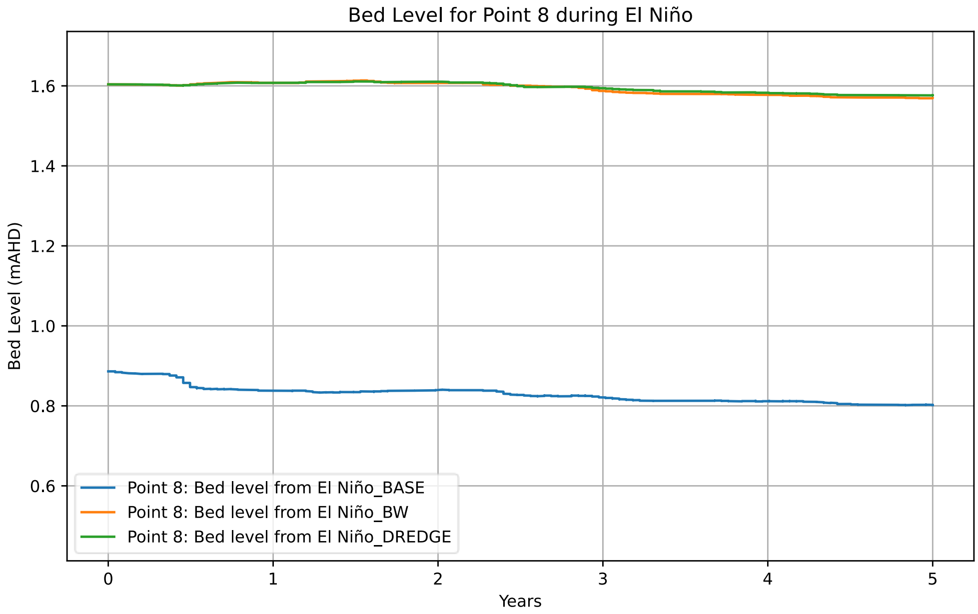

Bed Level for Point 5 during La Niña
Point 5: Bed level from La Niña_BASE
Point 5: Bed level from La Niña_BW
Point 5: Bed level from La Niña_DREDGE
Bed Level (mAHD)
Years
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
0
1
2
3
4
5

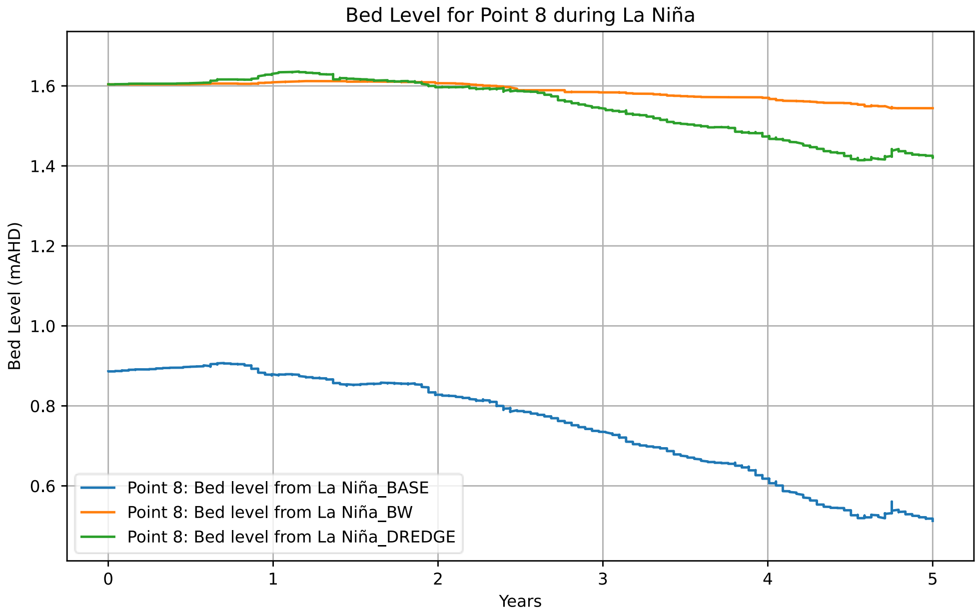

Bed Level for Point 6 during El Niño
Bed Level (mAHD)
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
0
1
2
3
4
5
Years
Point 6: Bed level from El Niño_BASE
Point 6: Bed level from El Niño_BW
Point 6: Bed level from El Niño_DREDGE

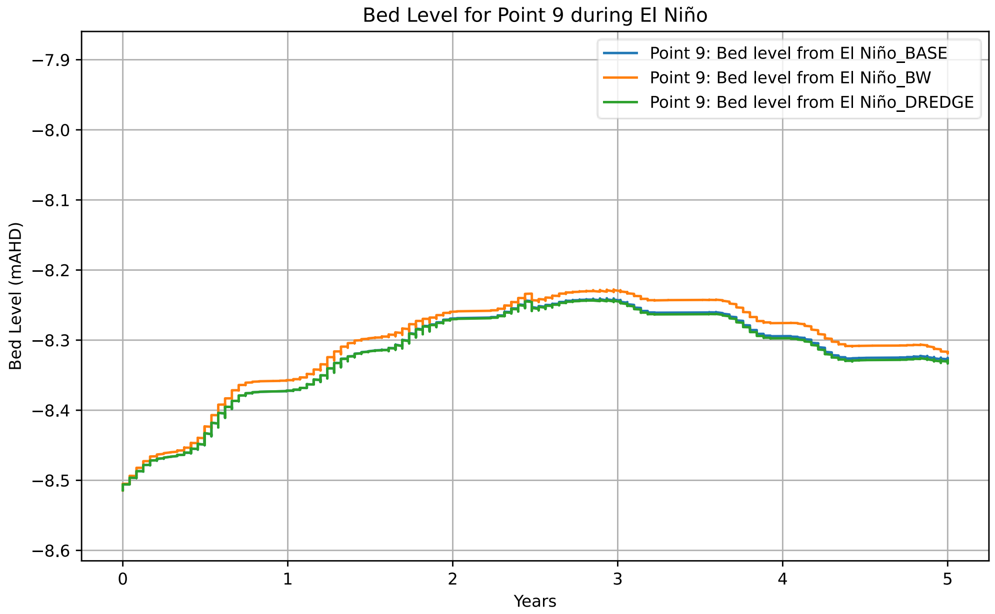

Bed Level for Point 6 during La Niña
Bed Level (mAHD)
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
0
1
2
3
4
5
Years
Point 6: Bed level from La Niña_BASE
Point 6: Bed level from La Niña_BW
Point 6: Bed level from La Niña_DREDGE

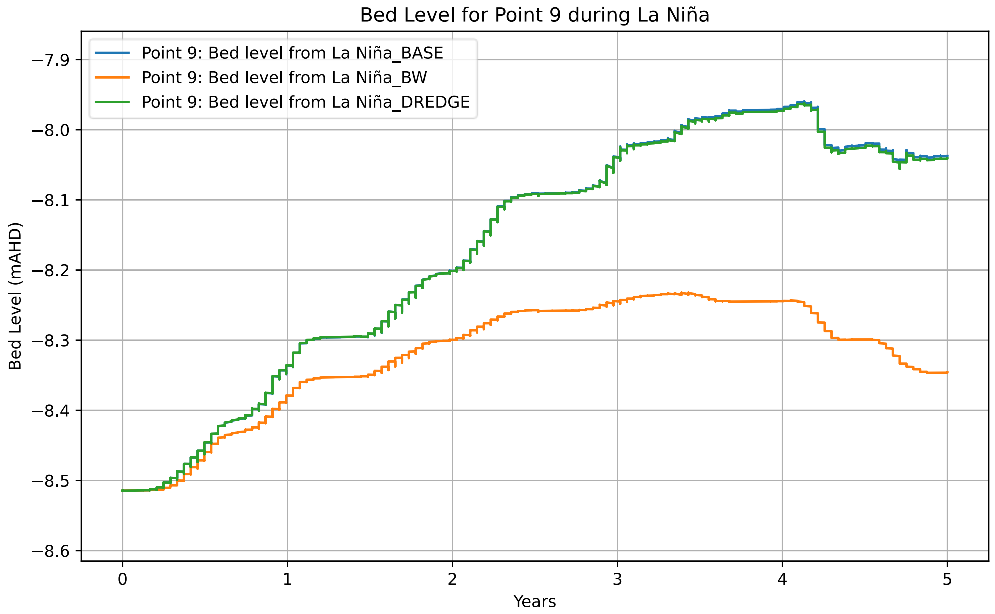

Bed Level for Point 7 during El Niño
Bed Level (mAHD)
2.0
1.5
1.0
0.5
0
1
2
3
4
5
Years
Point 7: Bed level from El Niño_BASE
Point 7: Bed level from El Niño_BW
Point 7: Bed level from El Niño_DREDGE


Bed Level for Point 7 during La Niña
Bed Level (mAHD)
2.0
1.5
1.0
0.5
0
1
2
3
4
5
Years
Point 7: Bed level from La Niña_BASE
Point 7: Bed level from La Niña_BW
Point 7: Bed level from La Niña_DREDGE


Bed Level for Point 8 during El Niño
Bed Level (mAHD)
1.6
1.4
1.2
1.0
0.8
0.6
0
1
2
3
4
5
Years
Point 8: Bed level from El Niño_BASE
Point 8: Bed level from El Niño_BW
Point 8: Bed level from El Niño_DREDGE


Bed Level for Point 8 during La Niña
Bed Level (mAHD)
1.6
1.4
1.2
1.0
0.8
0.6
0
1
2
3
4
5
Years
Point 8: Bed level from La Niña_BASE
Point 8: Bed level from La Niña_BW
Point 8: Bed level from La Niña_DREDGE


Bed Level for Point 9 during El Niño
Point 9: Bed level from El Niño_BASE
Point 9: Bed level from El Niño_BW
Point 9: Bed level from El Niño_DREDGE
Bed Level (mAHD)
−7.9
−8.0
−8.1
−8.2
−8.3
−8.4
−8.5
−8.6
0
1
2
3
4
5
Years


Bed Level for Point 9 during La Niña
Point 9: Bed level from La Niña_BASE
Point 9: Bed level from La Niña_BW
Point 9: Bed level from La Niña_DREDGE
Bed Level (mAHD)
−7.9
−8.0
−8.1
−8.2
−8.3
−8.4
−8.5
−8.6
0
1
2
3
4
5
Years

Appendix B: Maps

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Q 4160 Australia

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Dungeness Enterprise Proposed Dredge and Rock Wall

Map 1: Zone Classification for Morphology Results Analysis

SOURCES

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Hinchinbrook Shire Council proposed works

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LEGEND

Zone Classification

- Zone 01
- Zone 02
- Zone 03
- Zone 04
- Zone 05
- Zone 06
- Zone 07
- Zone 08
- Zone 09
- Zone 10
- Zone 11
- Zone 12

- Coastal Structure
- Dredge Channel
- Beach Nourishment Area

N

SCALE

0 0.5 1
Kilometres

Scale: 1:25,000 @ A3

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Units: Degree

DATE
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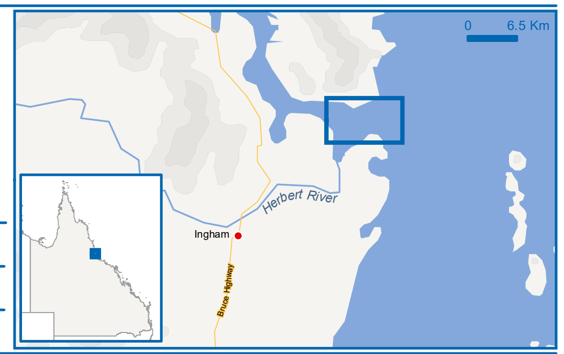

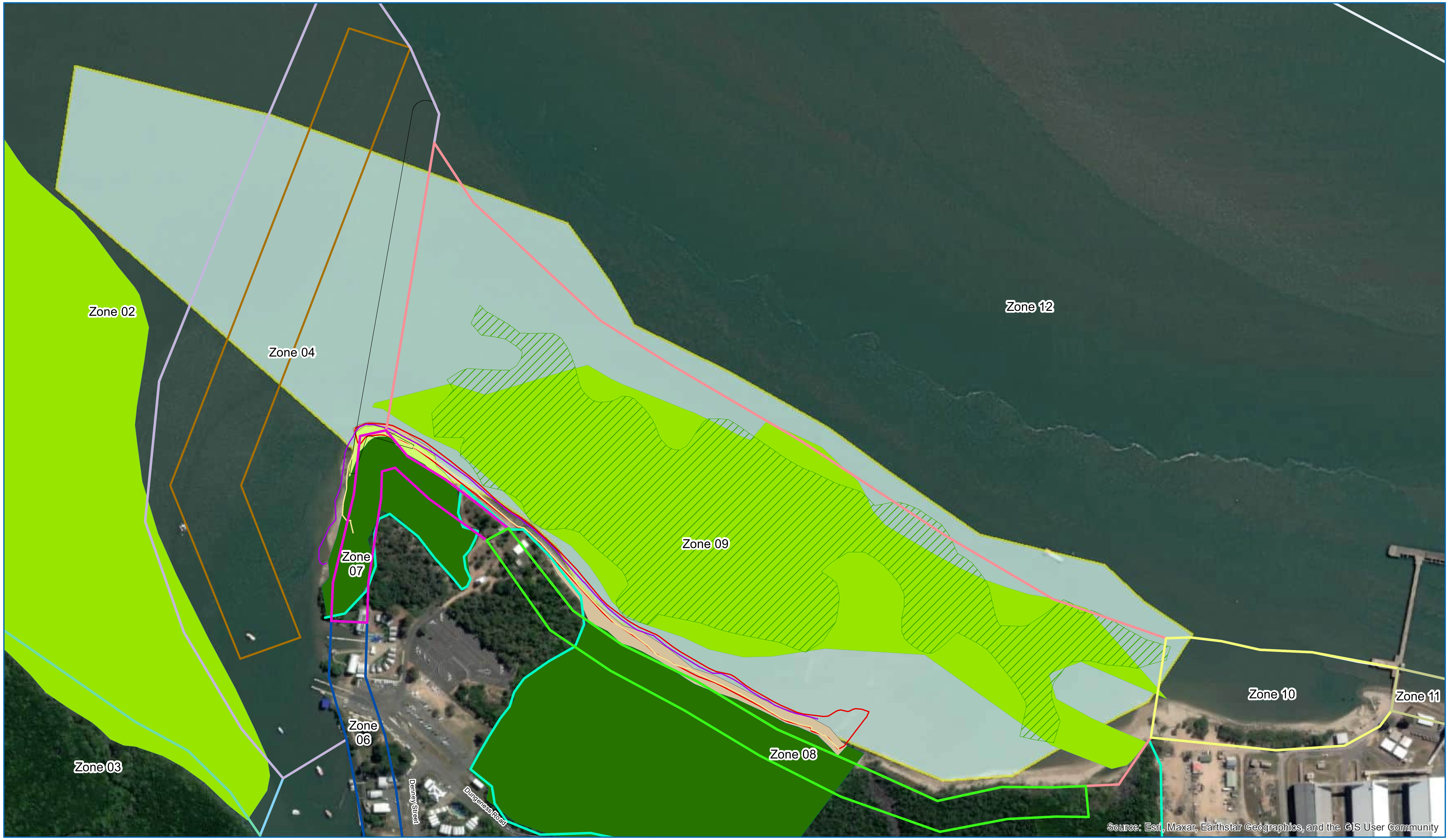

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Dungeness Enterprise Proposed Dredge and Rock Wall Works

Map 2:
Marine Plants

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frc environmental marine plant surveys 2019 and 2021
Hinchinbrook Shire Council propose works

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LEGEND

Zone Classification
- Zone 02
- Zone 03
- Zone 04
- Zone 06
- Zone 07
- Zone 08
- Zone 09
- Zone 10
- Zone 11
- Zone 12

- HAT
- MHWS
- MSL
- Coastal Structure
- Dredge Channel
- Beach Nourishment Area
- Investigation area 2021

- Bare sand with mangrove debris
- Sparse mangroves
- Dense mangroves
- All seagrass 2019
- All seagrass 2021

N

SCALE

0 0.125 0.25
Kilometres

Scale: 1:5,000 @ A3

PROJECTION
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Units: Degree

DATE
2024-05-07

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VERSION
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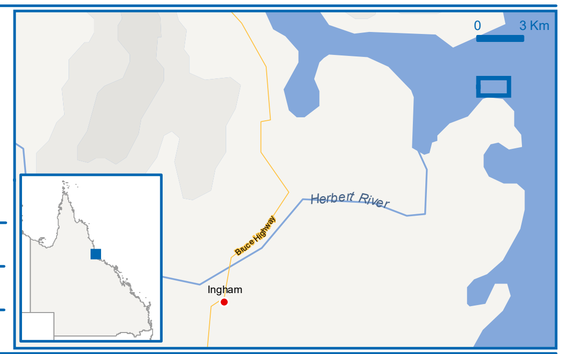

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Dungeness Enterprise Proposed Dredge and Rock Wall

Map 3: 2021 Seagrass species

SOURCES

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© The State of Queensland (Department of Natural Resources, Mines and Energy) 2018
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frc environmental marine plant survey 2021
Hinchinbrook Shire Council proposed works

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LEGEND

Zone Classification
Zone 02
Zone 03
Zone 04
Zone 06
Zone 07
Zone 08
Zone 09
Zone 10
Zone 11
Zone 12

HAT
Coastal Structure
Dredge Channel
Beach Nourishment Area

Moderate *Halodule uninervis* and Sparse *Halophila decipiens*
Moderate *Zostera muelleri*
Sparse *Zostera muelleri*
Sparse *Halodule uninervis* and *Halophila decipiens*
Moderate *Halodule uninervis*
Sparse *Halodule uninervis*

N

SCALE

0 0.125 0.25
Kilometres

Scale: 1:5,000 @ A3

PROJECTION
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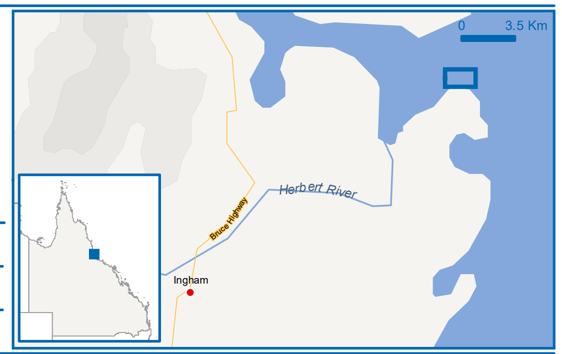

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Dungeness Enterprise Proposed Dredge and Coastal Structure Works

Map 4: Proposed Direct Impacts

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LEGEND

- Modelling zones
- Proposed works
  - Channel
  - Placement of dredge spoil
  - Coastal structure
  - Indicative access track
- Indicative dredge pipeline
- Distribution of marine plants (frc environmental 2018, 2021 & 2024)
  - Mangrove 2018 & 2021
  - Seagrass 2018 & 2021
  - Mangroves 2024
  - Limit of seagrass mapping

N

SCALE

0 40 80 160 240 320 400
Meters

Scale: 1:10,000 @ A3

PROJECTION
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Projection: Transverse Mercator
Datum: GDA2020

DATE
2024-10-02

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VERSION
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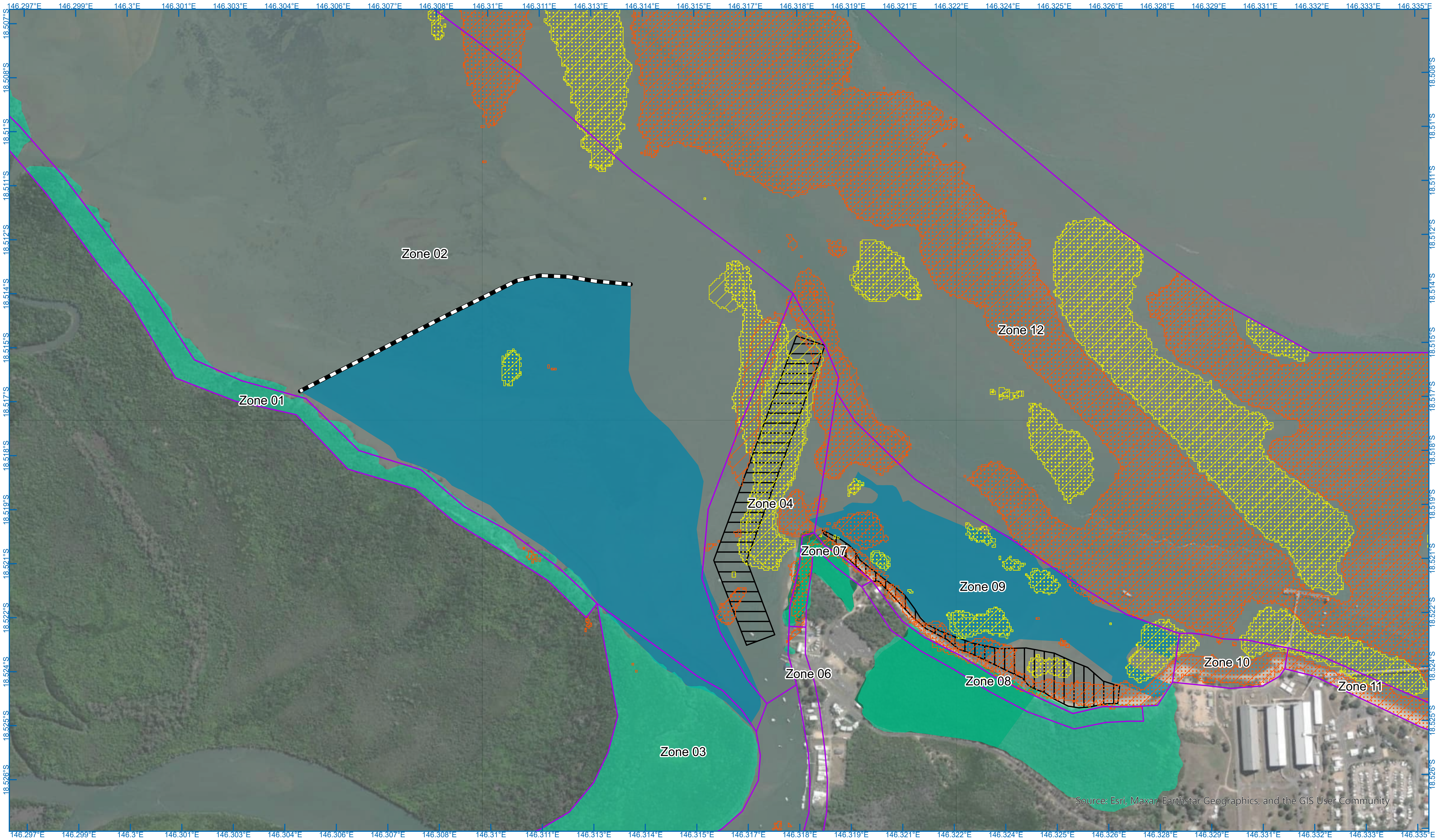

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Dungeness Enterprise Proposed Dredge and Coastal Structure Works

Map 5: Modelled Deposition and Erosion for Dredge Scenario During El Niño

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LEGEND

Modelling zones

Modelling results (WaterTech 2024)

Dredge scenario
- Deposition area
- Erosion area

Base scenario
- Deposition area
- Erosion area

Proposed works
- Channel
- Placement of dredge spoil

Distribution of marine plants (frc environmental 2018, 2021 & 2024)
- Mangrove 2018 & 2021
- Seagrass 2018 & 2021
- Mangroves 2024
- Limit of seagrass mapping

N

SCALE

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Meters

Scale: 1:10,000 @ A3

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Projection: Transverse Mercator
Datum: GDA2020

DATE
2024-10-02

DRAWN BY
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VERSION
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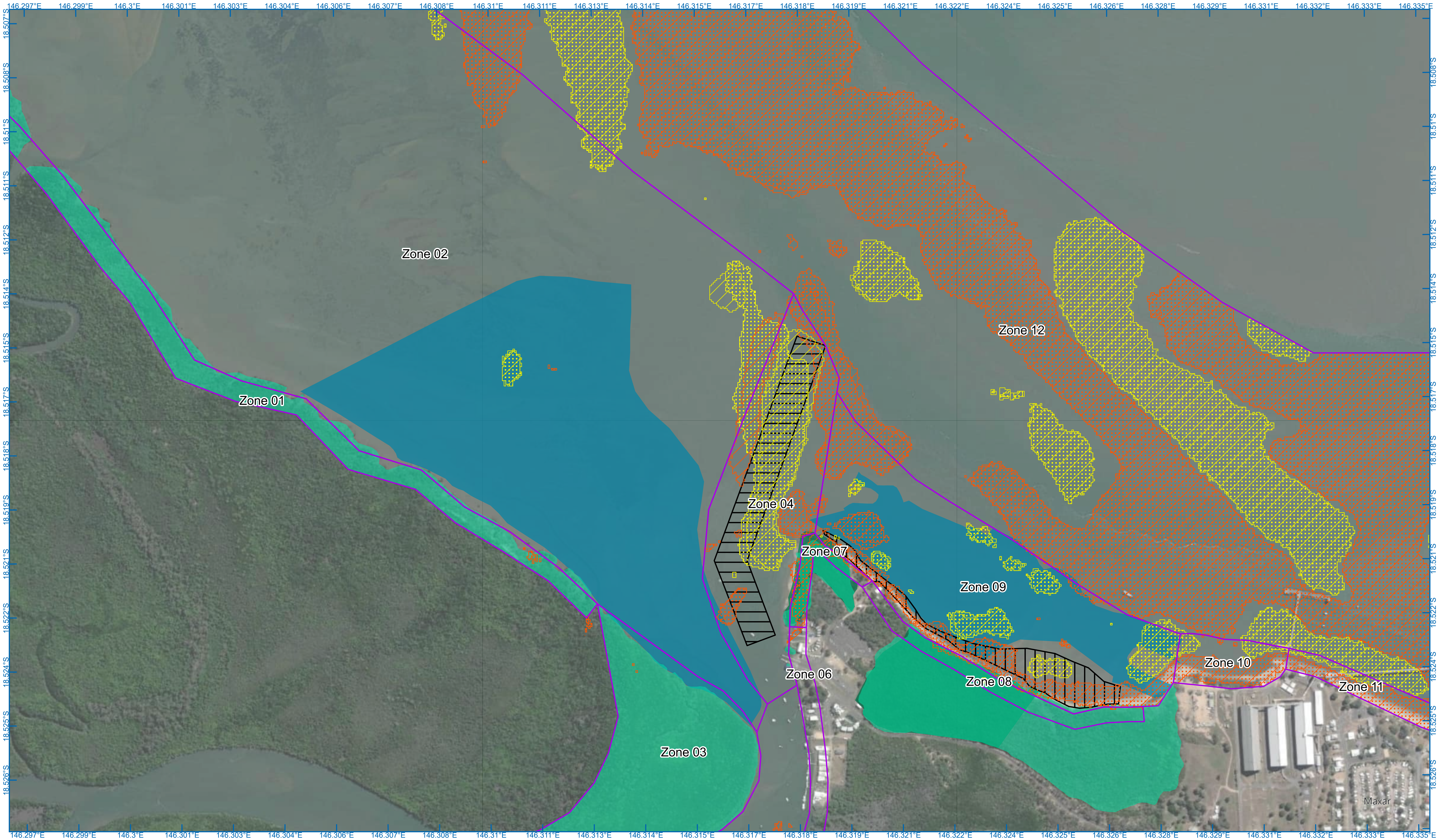

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Dungeness Enterprise Proposed Dredge and Coastal Structure Works

Map 5: Modelled Deposition and Erosion for Dredge Scenario During El Niño

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LEGEND

Modelling zones

Modelling results (WaterTech 2024)

Dredge scenario
- Deposition area
- Erosion area

Base scenario
- Deposition area
- Erosion area

Proposed works
- Channel
- Dredge placement

Marine plant mapping (frc environmental 2018 & 2021)
- Mangrove
- Seagrass
- Indicative mangroves 2024

N

SCALE

0 40 80 160 240 320 400
Meters

Scale: 1:10,000 @ A3

PROJECTION
Coordinate System: GDA2020 MGA Zone 55
Projection: Transverse Mercator
Datum: GDA2020

DATE
2024-09-26

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VERSION
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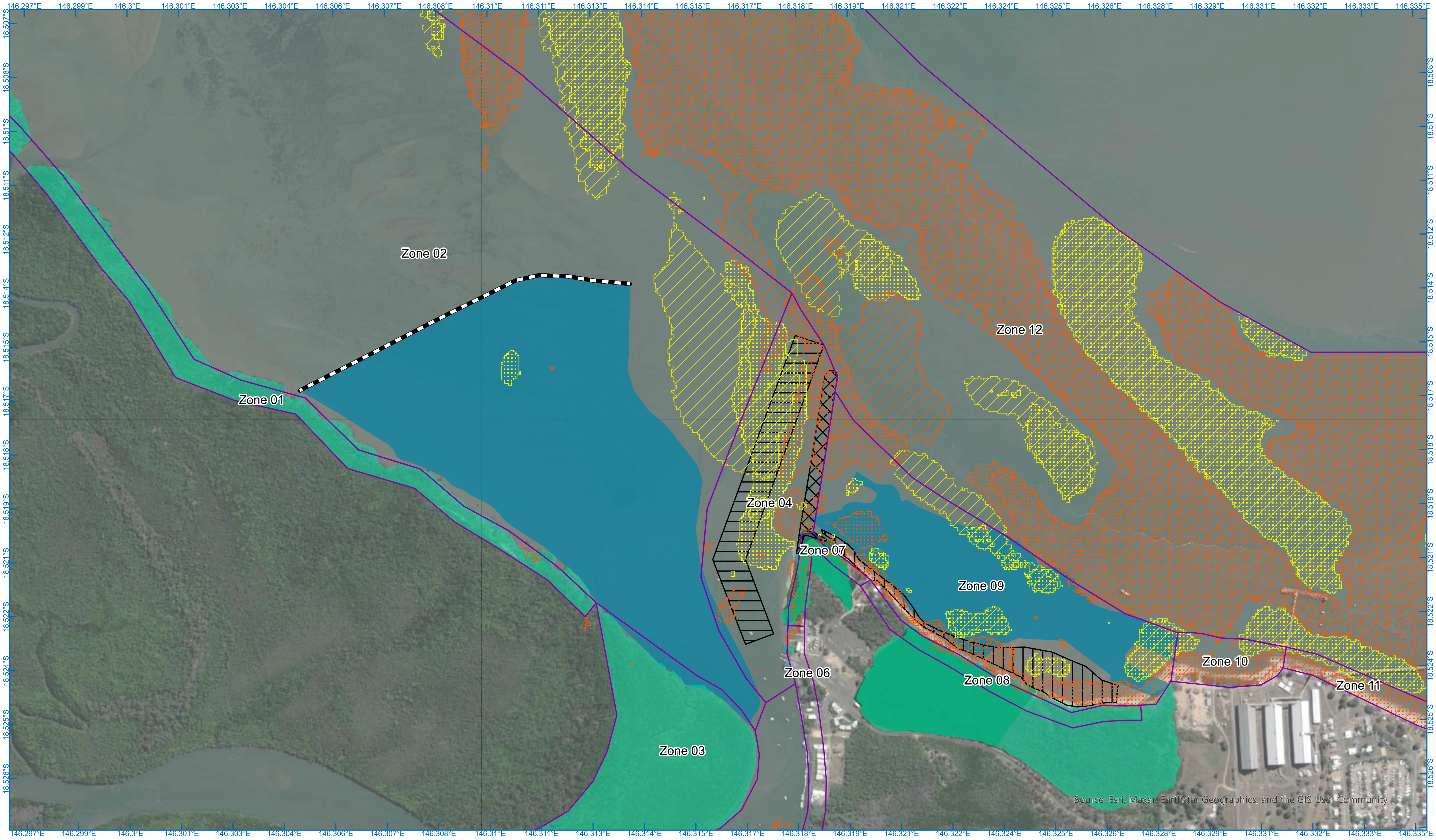

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Dungeness Enterprise Proposed Dredge and Coastal Structure Works

Map 6: Modelled Deposition and Erosion for Coastal Structure Scenario During El Niño

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LEGEND

Modelling zones

Modelling results (WaterTech 2024)

Coastal structure scenario
- Deposition area
- Erosion area

Base scenario
- Deposition area
- Erosion area

Proposed works
- Channel
- Placement of dredge spoil
- Coastal structure

Distribution of marine plants (frc environmental 2018, 2021 & 2024)
- Mangrove 2018 & 2021
- Seagrass 2018 & 2021
- Mangroves 2024

Limit of seagrass mapping

N

SCALE

0 40 80 160 240 320 400
Meters

Scale: 1:10,000 @ A3

PROJECTION
Coordinate System: GDA2020 MGA Zone 55
Projection: Transverse Mercator
Datum: GDA2020

DATE
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JA

VERSION
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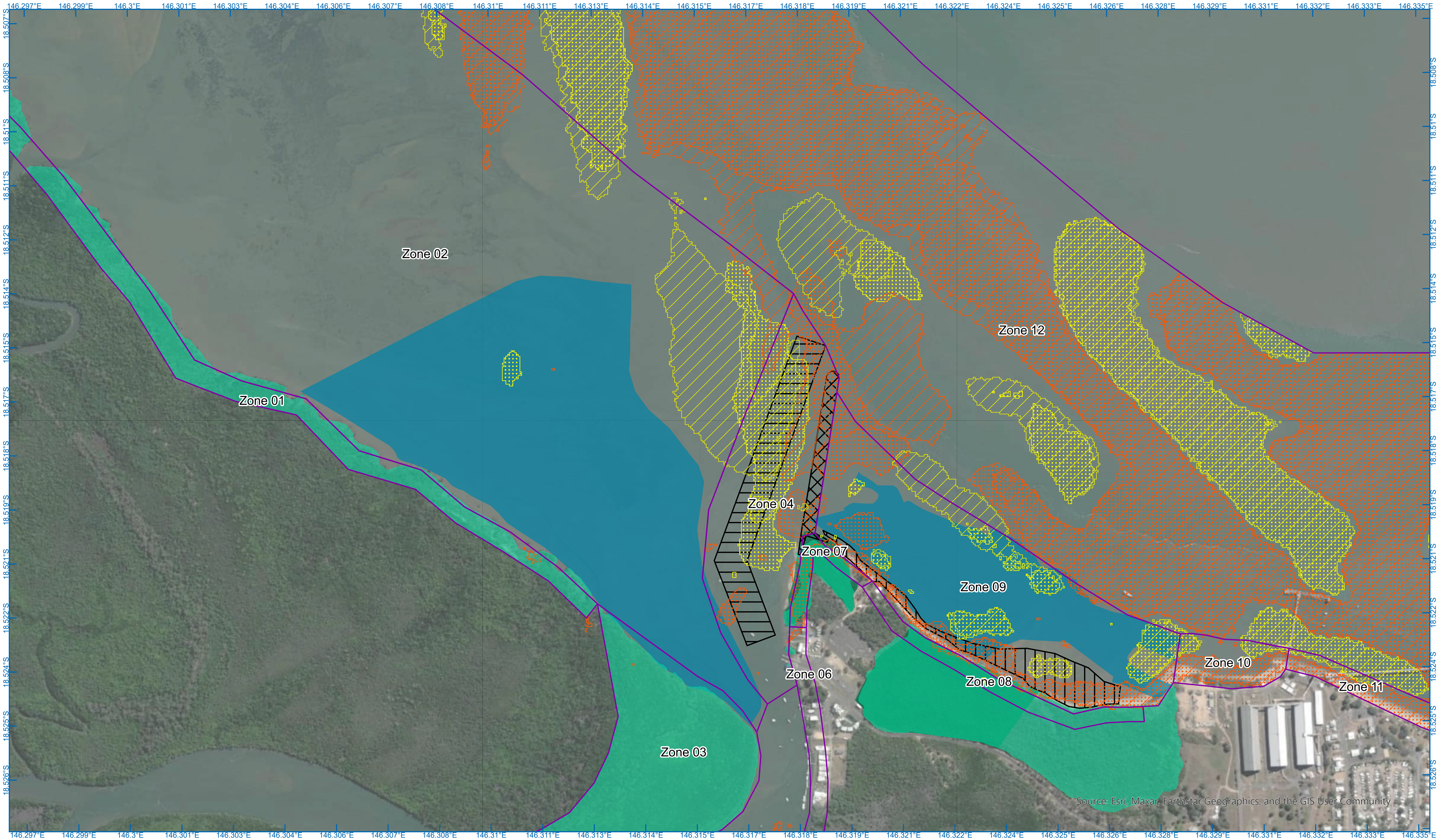

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deep thinking. science.
PART OF SLR

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Wellington Point
Q 4160 Australia

P 07 3286 3850
E info@frcenv.com.au
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Dungeness Enterprise Proposed Dredge and Coastal Structure Works

Map 6: Modelled Deposition and Erosion for Coastal Structure Scenario During El Niño

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LEGEND

Modelling zones

Modelling results (WaterTech 2024)

Coastal structure scenario
- Deposition area
- Erosion area

Base scenario
- Deposition area
- Erosion area

Proposed works
- Channel
- Dredge placement
- Coastal structure

Marine plant mapping (frc environmental 2018 & 2021)
- Mangrove
- Seagrass

Indicative mangroves 2024

N

SCALE

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Meters

Scale: 1:10,000 @ A3

PROJECTION
Coordinate System: GDA2020 MGA Zone 55
Projection: Transverse Mercator
Datum: GDA2020

DATE
2024-09-26

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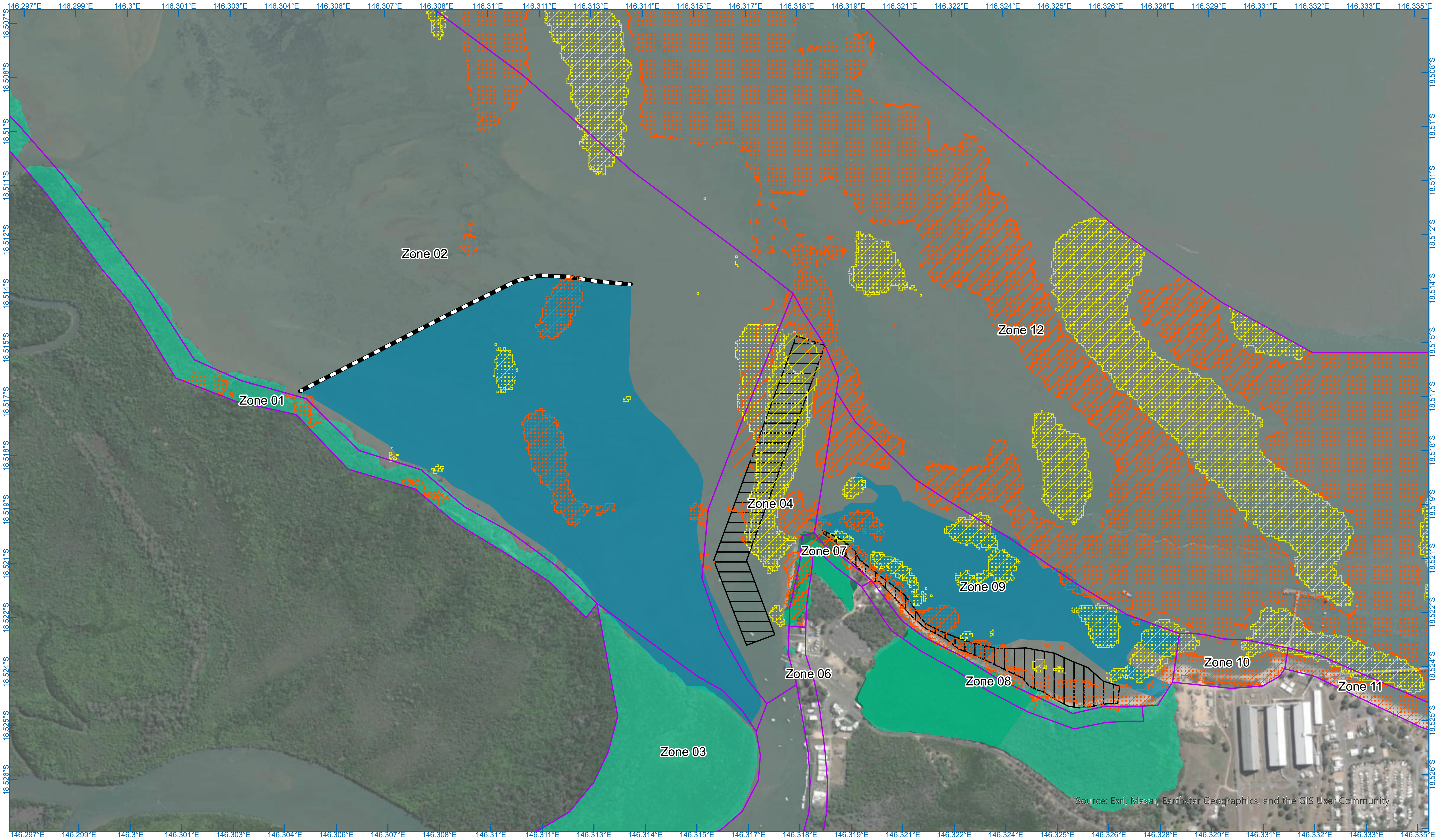

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Wellington Point
Q 4160 Australia

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Dungeness Enterprise Proposed Dredge and Coastal Structure Works

Map 7: Modelled Deposition and Erosion for Dredge Scenario During La Niña

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LEGEND
Modelling zones
Modelling results (WaterTech 2024)
Dredge scenario
Deposition area
Erosion area
Base scenario
Deposition area
Erosion area
Proposed works
Channel
Placement of dredge spoil
Distribution of marine plants (frc environmental 2018, 2021 & 2024)
Mangrove 2018 & 2021
Seagrass 2018 & 2021
Mangroves 2024
Limit of seagrass mapping

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SCALE
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Kilometres
Scale: 1:10,000 @ A3

PROJECTION
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Projection: Transverse Mercator
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DATE
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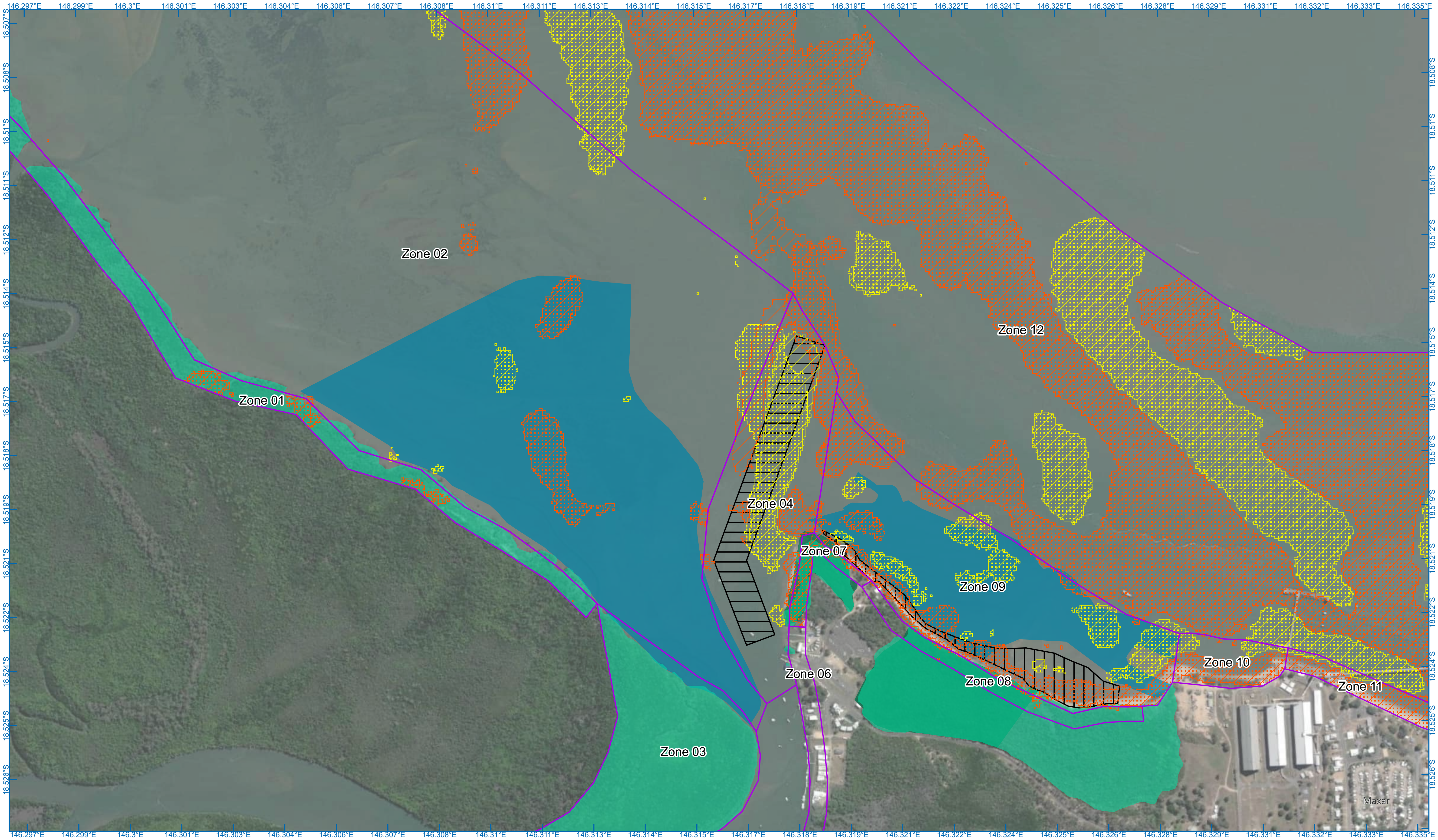

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Wellington Point
Q 4160 Australia

P 07 3286 3850
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Dungeness Enterprise Proposed Dredge and Coastal Structure Works

Map 7: Modelled Deposition and Erosion for Dredge Scenario During La Niña

SOURCES

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LEGEND

Modelling zones

Modelling results (WaterTech 2024)

Dredge scenario
- Deposition area
- Erosion area

Base scenario
- Deposition area
- Erosion area

Proposed works
- Channel
- Dredge placement

Marine plant mapping (frc environmental 2018 & 2021)
- Mangrove
- Seagrass
- Indicative mangroves 2024

N

SCALE

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Kilometres

Scale: 1:10,000 @ A3

PROJECTION
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Projection: Transverse Mercator
Datum: GDA2020

DATE
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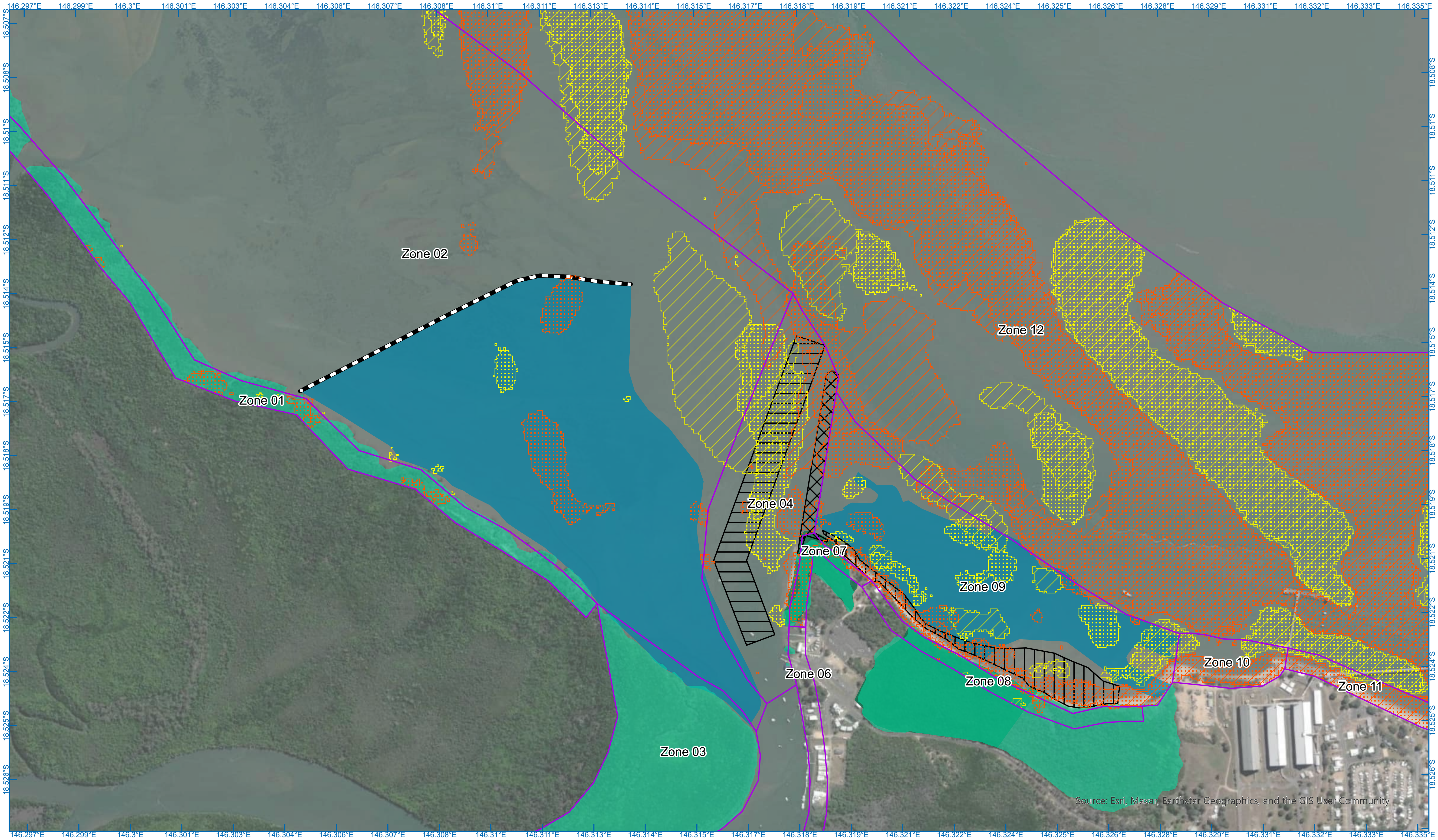

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deep thinking. science.
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PO Box 2363
Wellington Point
Q 4160 Australia

P 07 3286 3850
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Dungeness Enterprise Proposed Dredge and Coastal Structure Works

Map 8: Modelled Deposition and Erosion for Coastal Structure Scenario During La Niña

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LEGEND
Modelling zones
Modelling results (WaterTech 2024)
Coastal structure scenario
Deposition area
Erosion area
Base scenario
Deposition area
Erosion area
Proposed works
Channel
Placement of dredge spoil
Coastal structure
Distribution of marine plants (frc environmental 2018, 2021 & 2024)
Mangrove 2018 & 2021
Seagrass 2018 & 2021
Indicative mangroves 2024
Limit of seagrass mapping

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Meters
Scale: 1:10,000 @ A3

PROJECTION
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Projection: Transverse Mercator
Datum: GDA2020

DATE
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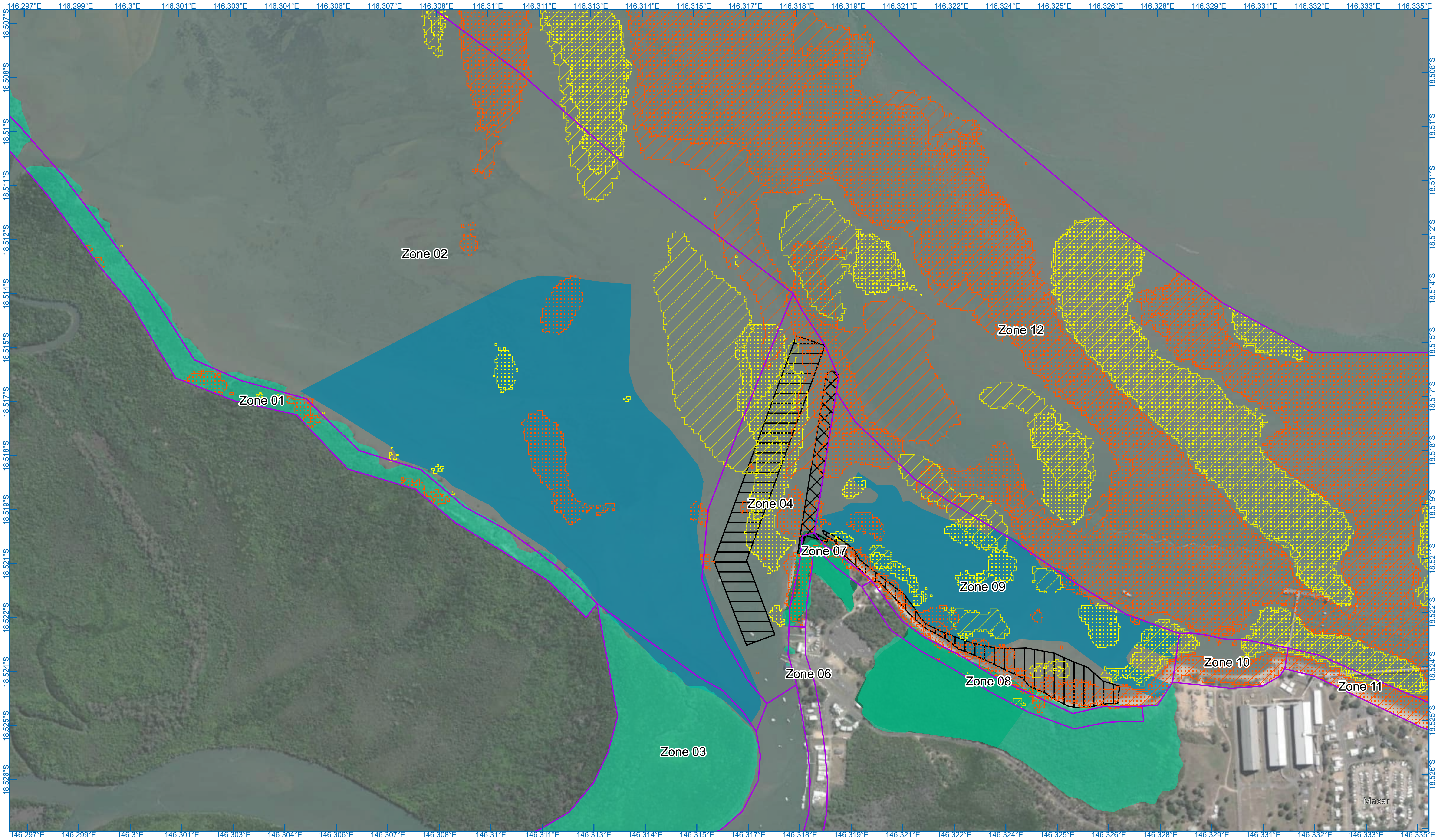

frc environmental
deep thinking. science.
PART OF SLR

PO Box 2363
Wellington Point
Q 4160 Australia

P 07 3286 3850
E info@frcenv.com.au
www.frcenv.com.au

Dungeness Enterprise Proposed Dredge and Coastal Structure Works

Map 8: Modelled Deposition and Erosion for Coastal Structure Scenario During La Niña

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LEGEND
Modelling zones
Modelling results (WaterTech 2024)
Coastal structure scenario
Deposition area
Erosion area
Base scenario
Deposition area
Erosion area
Proposed works
Channel
Dredge placement
Coastal structure
Marine plant mapping (frc environmental 2018 & 2021)
Mangrove
Seagrass
Indicative mangroves 2024

N
SCALE
0 40 80 160 240 320 400
Meters
Scale: 1:10,000 @ A3

PROJECTION
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WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Melbourne

15 Business Park Drive
Notting Hill VIC 3168
Telephone (03) 8526 0800

Sydney

Suite 3, Level 1, 20 Wentworth Street
Parramatta NSW 2150
Telephone (02) 9354 0300

Brisbane

Level 5, 43 Peel Street
South Brisbane QLD 4101
Telephone (07) 3105 1460

Adelaide

1/198 Greenhill Road
Eastwood SA 5063
Telephone (08) 8378 8000

Perth

Ground Floor, 430 Roberts Road
Subiaco WA 6008
Telephone (08) 6555 0105

New Zealand

7/3 Empire Street
Cambridge New Zealand 3434
Telephone +64 27 777 0989

Wangaratta

First Floor, 40 Rowan Street
Wangaratta VIC 3677
Telephone (03) 5721 2650

Geelong

51 Little Fyans Street
Geelong VIC 3220
Telephone (03) 8526 0800

Wimmera

597 Joel South Road
Stawell VIC 3380
Telephone 0438 510 240

Gold Coast

Suite 37, Level 4, 194 Varsity Parade
Varsity Lakes QLD 4227
Telephone (07) 5676 7602

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