NORTH QUEENSLAND BULK PORTS CORPORATION

Sustainable sediment management assessment

for maintaining navigational infrastructure

PORT OF **HAY POINT** | 2017

Preface

Ports have been the single most important demographic and economic driver in many countries, to the extent that most of the major cities of the world have developed alongside a trading port.

Trade by sea remains vital to the day-to-day function of our globally connected modern society. As societies continue to grow and advance, both economically and in terms of their standards of living, ports and the associated navigational infrastructure needs to be maintained, developed and modernized to meet the demands and dynamics of global trade.

For Australia as an island nation, over 99% of our trade with the rest of the world is by ship. Safe navigation to our Ports is therefore essential to the economic and social prosperity of our country. It can certainly be considered that navigational infrastructure in Port areas is every bit as important as our landside supply networks, being our roads and railways.

Navigational areas also require maintenance (just like roads and rail), but instead of filling potholes most of the maintenance is associated with moving the seafloor that has accumulated in previously constructed shipping channels, swing basins, departure aprons and berthing areas. Mobilisation of sediments (sand, mud and silt) in the marine environment often accumulates in these slightly deeper areas that are calmer and encourage sediments to settle out from the water column at a faster rate than the surrounding shallower areas. Siltation in Port areas can affect the safe navigation of ships, interfere with the operational efficiency of a port, impact trade and result in significant economic losses.

Each year, 25% of Australia's trade (approximately $50 billion) enters or leaves the country through one of Queensland's ports. Agricultural products, mineral resources, clothes, household goods and fuel are examples of products traded by sea. Over 50% of Queensland's trade, by volume, passes through the ports managed by the North Queensland Bulk Ports Corporation (NQBP).

NQBP is the Port Authority responsible for the management and operation of the seaports at Weipa, Abbot Point, Mackay and Hay Point, three of these being within the Great Barrier Reef World Heritage Area. NQBP is the only port authority in the world to manage three priority ports within a World Heritage Area, a privilege that drives a leading practice culture and vision to lead the sustainable development of Queensland ports.

The Port of Hay Point was established in 1971 and is NQBP's southernmost port and is home to two coal terminals - Dalrymple Bay Coal Terminal and Hay Point Coal Terminal. The Port of Hay Point is a coastal Port with offshore trestle jetties extending approximately 4km seaward. The Port has seven dedicated coal loading berths, with over 100 Million tonnes of coal currently exported each year. The Port directly supports hundreds of local jobs and indirectly thousands associated jobs along the supply chain and mining sector.

In 2006 a major capital program saw the development of a 9km departure channel, and 4km apron area extending offshore from the trestles. Since 2006, there have been two occasions where maintenance dredging has been necessary to remove accumulated sediments (192,294m^3 in 2008 and 157,936m^3 in 2010), each time material was relocated to the approved "sediment relocation area" approximately 7km NE of the main Port area.

NQBP recognise that for the continued long-term operation and prosperity of the Port of Hay Point it is critical to effectively maintain navigational areas into the future and to do this within the setting of the Great Barrier Reef World Heritage Area. A sustainable maintenance strategy is one that explores the balance between continued port prosperity along with environmental values and the important social and cultural values of our community.

This "values-based" approach is the foundation of NQBP's "Sustainable Sediment Management Assessment" that aims to:

- Map the type and properties of marine sediments that accumulate in the Port's navigational areas.
- Understand the patterns and drivers of siltation at the Port.
- Investigate ways to avoid or reduce the need for maintenance dredging within the Port's navigational areas, both in the short-term (1-5 years) and long-term (20 years+).
- Explore opportunities to beneficially reuse or recycle the marine sediments that do need to be dredged, again over the short and long-term.
- Validate alternatives to bring the material ashore, now and into the future.
- Ensure that decisions are genuinely informed by what is important to other stakeholders in a transparent way.

NQBP has been a valuable part of the Mackay Whitsunday community for a long time and plans to continue being so for many generations to come. The ***Port of Hay Point Sustainable Sediment Management Assessment*** will ensure that the port continues to operate at the highest operational, social and environmental standards.

Kevin Kane
Senior Manager Environment

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SUMMARY REPORT

Sustainable sediment management assessment for navigational maintenance

SYNOPSIS

Independent technical specialist

Kaveney et al

January 2017

Purpose of study:

- Assess the feasibility of avoiding or reducing the need for maintenance dredging at the Port of Hay Point.
- Comprehensively investigate opportunities to beneficially reuse accumulated material that must be dredged.
- Consider alternatives to at-sea disposal, based on environmental values and constraints in the region.
- Compare the range of alternatives in a way that considers (at a minimum) risks to the environment, health and safety, social and economic values and the exclusion of future uses.
- Consider the 'immediate' (1-3 years) and 'long-term' (25 years) suitability of alternatives.

Broad study approach:

This report summarises eleven detailed technical reports (provided as appendices).

The approach is shown below, linking how each of the various technical reports contribute to the overall understanding of sustainable sediment management.

Hay Point sustainable sediment management assessment approach

AVOID OR REDUCE	REUSE OR RECYCLE	ALTERNATIVES TO AT SEA
Where do sediments come from? *Appendix C*	*What are the engineering qualities of the material?* *Appendix J*	*What are the environmental values to consider on land and at sea?* *Appendix L*
Where do sediments accumulate in the port area? *Appendix D, E*	*Can the material be used beneficially?* *Appendix I*	*What are the details of onshore containment alternatives?* *Appendix K*
What effect will this have on the port? *Appendix F, G*		*How do all the disposal alternatives compare?* *Appendix B*
Can this be managed without dredging? *Appendix H*		

Key findings:

AVOID OR REDUCE

- Marine sediment transport at the Port of Hay Point is dominated by the natural south to north transport process of littoral drift.
- Catchment runoff has minimal influence on sediment transport dynamics at Hay Point, and as such actively reducing catchment runoff would not alter the accumulation of marine sediments in navigational areas of the Port.
- Sediment accumulation patterns are not consistent within the navigational infrastructure areas of the Port.

Analysis of 15 years of bathymetric data has shown:
  - The 9km departure path has minimal sediment accumulation, the transit of ships helping to keep sediments mobile.
  - Predictable sediment accumulation occurs in the northern apron area and in berth pockets, particularly the northern Dalrymple Bay Coal Terminal (DBCT) berth pockets.
  - Left unmanaged, approximately 200,000m^3 to 300,000m^3 is predicted to accumulate in navigational areas, particularly berth pockets, over each 3-year period.
  - Tropical cyclones can significantly change sediment accumulation. Three major cyclones have been experienced over the last 10 years, one resulting in erosion, one in minimal change in depth profile and the most recent (TC Debbie) resulting in significant accumulation (initially over 400,000m^3 immediately post cyclone).
- Left unmanaged, sediment accumulation in navigational infrastructure, particularly berth pockets, would result in increased tidal delays and significantly affect the safe and efficient loading of vessels.
- A continued reduction in water depth due to sedimentation at the Port of Hay Point is predicted to result in:
  - Reduced port terminal capacity
  - Increased vessel delays and reduced vessel loading capacities
  - Reduced coal export revenue
  - Reduced Government royalties.
- A range of siltation management and reduction solutions were then considered, within the strategies of ‘keep sediment out’, ‘keep sediment moving’ and ‘keep sediment navigable’. The main findings were:
  - Drag barring (bed levelling) in berths is a feasible option and will reduce ongoing siltation, but not completely eliminate it. Although more expensive and generating greater GHG emissions, used in conjunction with traditional maintenance dredging is expected to reduce ongoing maintenance dredging requirements considerably.
  - Traditional maintenance dredging provides the most cost effective and lowest GHG emissions solution, with low environmental and operational impacts and high effectiveness.

REUSE OR RECYCLE

- Clay-rich, finer materials were generally found inshore, near existing jetties and berths.
- This finer material constitutes most of the maintenance dredging requirements at the Port, by volume.
- The finer material has very high moisture content, which is likely to limit beneficial reuse options.
- A comprehensive beneficial reuse assessment examined the performance of twelve potential beneficial reuse options. The study concluded:
  - Although no on-land beneficial reuses were identified, many of these reuses would require the construction of an on-land containment facility to store and dry the material for reprocessing. It would be prudent to include an analysis of on-land containment facilities or structures when assessing disposal options.
  - Land reclamation, although costly and not suitable for port related uses, is worthy of assessing as a potential disposal option, as the land use plans of both the Port of Hay Point and Port of Mackay include potential future land reclamations.
  - Direct habitat restoration has merit as a beneficial reuse, although it is acknowledged that considerable additional scientific research and a thorough feasibility assessment would be necessary before the option can be considered viable.

ALTERNATIVES TO AT-SEA DISPOSAL

- A wide-ranging Environmental Values Assessment for the Hay Point / Mackay area was used to inform constraints analysis and aid in site selection for both onshore and at-sea disposal options.
- Eight discrete alternatives for reuse and disposal were identified.
  - **On-land x 2** – onshore containment facilities at Dudgeon Point and Port of Mackay (35-50ha)
  - **Land reclamations x 2** – at Half-tide Tug Harbour and Port of Mackay (20ha)
  - **Reuse x 1** – habitat restoration at Dudgeon Point (approx. 60ha)

  - **At-sea x 3** – existing approved Dredge Material Placement Area (DMPA), new mid-shelf and coral sea DMPA (approx. 4km, 25km and 300km seaward respectively).

- An initial analysis of these 8 options indicated:
  - At-sea disposal at the existing or potential new mid-shelf DMPA would be necessary to deal with the immediate maintenance needs at the Port.
  - Other alternatives, if feasible, would take 4-5 years to implement.
  - Habitat restoration, if feasible, may only be a 'one-off' solution and would require several years lead time.
  - Disposing of dredged material within a constructed reclamation at the Port of Mackay was found to be the worst performing single alternative across most themes and did not warrant further analysis.
  - A combination of these alternatives may be required as part of a long-term solution (~25 years).

- Eleven long term strategies were developed, combining the various alternatives, over a 25-year timeframe.
- The structured decision-making process showed how each of the eleven strategies compared when equally considering each of the key themes (Environmental, Cultural Heritage, Port Economics and Operations, Health and Safety, Social, Innovation, World Heritage).
- The structured decision-making process was able to show how the comparison would change if the outcomes were significantly weighted (75%) to any one particular theme.

Long Term Strategy	At Sea Existing x 1 Reclamation Hay Point x 4	At Sea Existing x 1 Habitat Rehabilitation x 1 At Sea Existing x 3	At Sea Existing x 1 Habitat Rehabilitation x 1 Reclamation Hay Point x 3	At Sea Existing x 1 Habitat Rehabilitation x 1 Onshore Dudgeon Point x 3	At Sea Existing x 1 Onshore Dudgeon Point x 4	At Sea Existing x 1 Habitat Rehabilitation x 1 Onshore Mackay x 3	At Sea Existing x 1 Onshore Mackay x 4	At Sea Existing x 5	At Sea Mid-shelf x 5	At Sea Existing x 1 At Sea Coral Sea x 4	At Sea Mid-shelf x 1 Habitat Rehabilitation x 1 At Sea Mid-shelf x 3
Equal weights	41	70	45	54	52	47	44	71	68	56	68
Environment (75%)	39	69	44	63	60	61	57	65	72	46	75
Social (75%)	36	57	41	54	53	37	31	57	56	52	56
Economic (75%)	44	80	44	48	49	39	40	89	74	59	69
Cultural (75%)	74	92	78	73	68	71	65	92	91	88	91
WHA (75%)	42	68	50	64	60	62	57	65	55	68	60

■ Best score for an option under a particular weighting scenario

■ Second best score for an option under a particular weighting scenario

■ Worst score for an option under a particular weighting scenario

- A sensitivity analysis was undertaken to ensure that no one measure was substantially biasing the results.
- The results identified three higher performing options:
  - continued and ongoing at-sea disposal at the existing Dredged Material Placement Area (DMPA).
  - a combination of continued at-sea disposal at the existing DMPA and habitat restoration at some time in the future (pending a range of additional studies and feasibility assessment), reverting to continue at-sea disposal thereafter.
  - a combination of at-sea disposal at a new mid-shelf DMPA and habitat restoration at some time in the future (pending a range of additional studies and feasibility assessment), reverting to continue at-sea disposal thereafter.

Maintenance Needs

- Hay Point is susceptible to cyclonic activity, although the impacts often differ. At the time of writing this report, cyclones had not been shown to result in significant additional siltation. TC Debbie has since resulted in significant siltation in berth pocket areas of the Port.
- Based on an analysis of bathymetric data at the time of this report (February 2016), the maintenance dredging requirements to achieve design depths were:

Location	Volume (m^3)
Apron and departure channel	59,300
DBCT berths	139,800
HPCT berths	6,700
Total maintenance requirement *(pre – TC Debbie)*	**205,800**

- Since this report, TC Debbie significantly added to the immediate total maintenance dredging requirements at the Port.
- The impacts of TC Debbie are included in Appendix D2 (Sep 2017) and revised immediate maintenance dredging requirements to achieve design depths are listed in the table below:

Location	Volume (m^3)
Apron and departure channel	74,085
DBCT berths	242,525
HPCT berths	8,636
Half Tide Tug Harbour	31,307
Total maintenance requirement *(post – TC Debbie)*	**356,553**

- Current and modelled future maintenance dredging requirements are provided below, resulting in a total permit amount over a 10-year period of **956,553m^3**.

Period	Volume (m^3)
Current	356,553
1 – 5 years	200,000
5 – 10 years	200,000
Cyclone contingency	200,000
Total 10-year permit requirement	**956,553**

Port of Hay Point

Sustainable Sediment Management Assessment for Navigational Maintenance

Summary Report

January 2017

ADAPTIVE STRATEGIES

DOCUMENT TRACKING

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North Queensland Bulk Ports Corporation (NQBP) manages four ports in Queensland and is one of Australia's largest port authorities by throughput with more than half of Queensland's trade (by tonnage) passing through NQBP ports.

NQBP's aim is to be a recognised leader in the delivery of bulk cargo infrastructure. The seaport facilities they manage are vital to the export and import performance of Queensland and Australia.

NQBP Ports handle bulk shipments of coal, bauxite, sand, sugar, grain, petroleum and general cargo. Coal is the main commodity handled at two of NQBP's Ports, but each port and each commodity is important in its own right.

The Port of Hay Point is one of NQBP's four ports and is home to two coal terminals: Dalrymple Bay Coal Terminal and Hay Point Coal Terminal. The Port of Hay Point is a crucial component to the welfare of the Mackay Whitsunday Region.

GREAT BARRIER REEF WORLD HERITAGE AREA

Three of the ports NQBP manages, including the Port of Hay Point, are in the Great Barrier Reef World Heritage Area (GBRWHA). NQBP is a proud custodian of the ports and environments in which it operates, and is strongly committed to environmental sustainability and ensuring that the natural, social and cultural values in and surrounding port areas are conserved and protected.

NQBP are focused on sustainable management of the Port of Hay Point to provide for long-term social and economic prosperity in an environmentally sensitive way. They have undertaken a strategic assessment for the ongoing management of marine sediments at the Port. This project is the *Port of Hay Point - Sustainable Sediment Management Assessment for Navigational Maintenance* (The SSM Project).

Figure 1: Ports managed by NQBP

The work being done at Hay Point is leading practice and is striving to provide a long term – 25 year – plan and understanding of navigational infrastructure maintenance at the Port. Such a plan will provide greater certainty to port users, community, governments and those interested in the sustainable management of ports within a world heritage area.

REEF 2050 LONG TERM SUSTAINABILITY PLAN

The work being undertaken is consistent with the Reef 2050 Long Term Sustainability Plan and in particular picks up on the following actions by either advancing the implementation of the action or by adopting the policy intent:

- GA5: Adopt an approach of continuous improvement as part of adaptive management of the World Heritage Area.
- EHA1: Acknowledge Traditional Owners in new and existing policy and plans.
- HA6: Facilitate robust consideration of heritage values in planning processes, including development and associated activities.
- WQA16: Develop a state-wide coordinated maintenance dredging strategy.
- WQA17: Understand the port sediment characteristics and risks at the four major ports and how they interact.

In particular the work undertaken has been used to inform the development of the Queensland Maintenance Dredging Strategy that has been developed in response to action WQA16.

MARITIME SAFETY

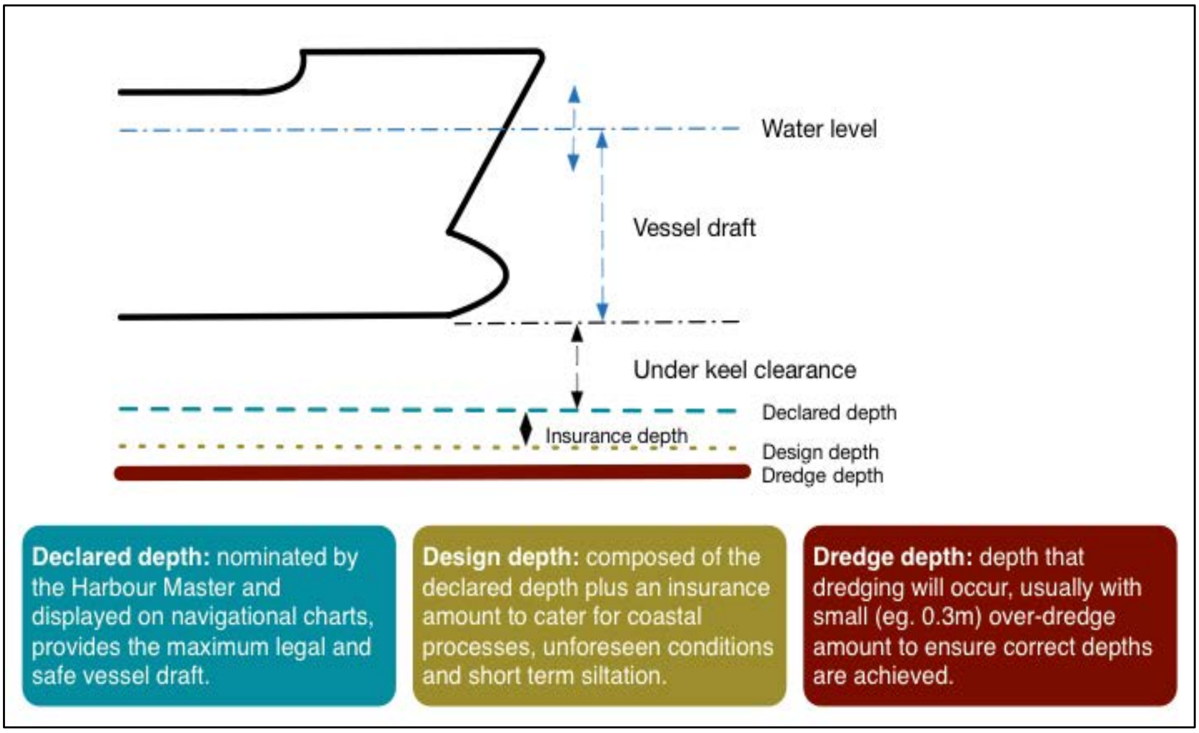
For safety reasons ships must sit a prescribed distance above the seabed. Maintaining this safe distance is critical and must take account of the ships' load and the approaching tides.

In most ports in order for large modern vessels, such as container ships and bulk cargo vessels, to enter and load or unload commodities it has been necessary to increase depths by constructing shipping channels, berths, swing basins and apron areas.

Due to the natural transport of sediments in the marine environment, sand, mud and silt will often accumulate in channels, berths and apron areas as these slightly deeper areas are calmer and promote sediment accumulation.

Figure 2 presents the basics of ship keel clearance and the key terms used to describe channel depths. These depths are needed to maintain safe vessel movement.

Figure 2: Typical shipping channel terms and depths (Ports Australia 2016)



The sediment that accumulates in shipping channels can come from a variety of sources and this will vary from port to port. For example, river ports differ from coastal ports, while differences in tides, currents and weather (such as strong winds, floods and cyclones) all affect the source and rate of sediment accumulation. The Port of Hay Point is a coastal port with trestles and offshore wharfs. The majority of the sedimentation at the Port is from the movement of mobile seabed, rather than direct river flows and catchment runoff.

As sediment accumulates in shipping areas the size of the ships or the load capacity of each ship entering and leaving the port may be limited for safety reasons. In extreme cases this may result in parts of the port being closed to shipping. The effects on trade, economics, jobs and services supported by the port will all be negatively impacted, the risk of a safety incident or environmental hazard occurring also increases. For instance it is estimated that north Queensland has approximately two weeks of petroleum supply in the event that fuel imports are halted for any reason (AECOM 2013).

REGULATORY SETTING

Activities to manage marine sediment in ports are highly regulated, in particular any dredging and dredged material placement is subject to detailed and complex regulatory approval processes under international conventions, by both national and state legislation.

Australia is a signatory to the London Protocol, a global convention that aims to "protect and preserve the marine environment." Under the Protocol, member nations may allow (subject to certain conditions) the placement of certain materials in the marine environment (including dredged material).

However, prior to any decision to dredge and place material a comprehensive assessment is required. These assessments are primarily based on the waste management hierarchy of avoid, reduce, reuse or recycle.

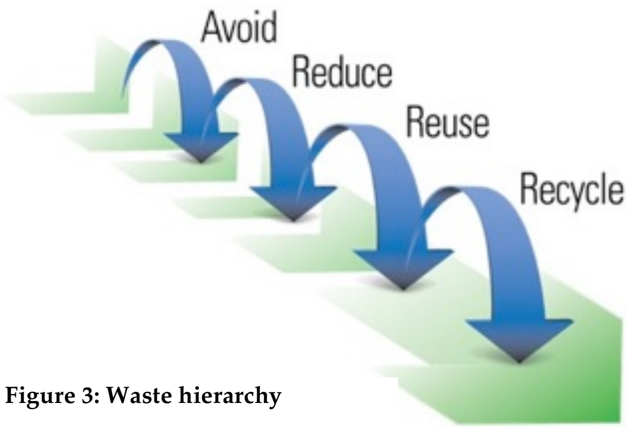


Figure 3: Waste hierarchy

Historically, maintaining operating navigational channels at most Queensland ports has been achieved through dredging and at sea disposal of the material; no feasible alternative to this management approach has been identified to date. Some ports have found alternative disposal options, mainly as a result of the type of sediments they are dealing with. For instance high sand content is often useful for construction fill or for the reclamation of land (as seen at the Port of Brisbane).

Options to avoid or reduce sediment accumulation are often limited. During the initial construction of navigational channels it may be possible to design the channel shape and alignment in a manner that reduces the sediment accumulation rate by maximizing natural water movements to assist in keeping the channels clear of sediment. Design of the navigational channel to minimise sediment accumulation was considered as part of the departure path project at the Port of Hay Point in 2006. In some river ports there has also been efforts made to reduce the sediment inputs coming from up stream.

Assessments undertaken are based on a terms of reference prescribed by regulators consistent with the environmental management hierarchy, London Protocol and the National Assessment Guidelines for Dredging (NAGD). The NAGD is an industry-leading guideline that provides the framework for the environmental impact assessment and permitting of the ocean disposal of dredged material.

The framework and steps contained within the NAGD are outlined in Figure 4.

Much of the traditional focus for assessments related to navigational channel maintenance has focused on managing contamination of the sediments, particularly toxic elements from anti-fouling paints used on ship hulls. With the application of new regulations, technologies and methods to avoid contamination most sediments are now free of toxic elements and are shown to be clean by laboratory testing.

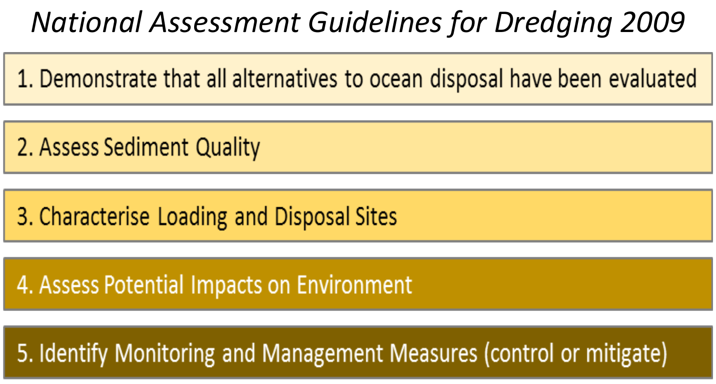


Figure 4: National assessment framework

Present day assessments are now more and more being focused on avoiding or reducing the potential impacts form the disturbance and placement of sediments in the marine environment which may cause sediment plumes, siltation or light attenuation impacts on sensitive organisms. This has particularly been the case for dredging activities in the Great Barrier Reef region.

This framework of legislation, approvals and condition setting is implemented to protect the environment, meet community needs and expectations of transparency and accountability, while enabling dredging and material placement to be undertaken responsibly and effectively.

The SSM project

The aim of the SSM Project is to understand how the day to day operations at the Port of Hay Point are affected by marine sedimentation and to determine, if necessary, the best way to manage operations and sediments.

NQBP have been investigating where specifically the sediment at the Port of Hay Point comes from, what impact it has on Port operations, whether accumulation can be eliminated or reduced, and what alternatives are available to reuse or dispose of any sediment that might need to be dredged.

At this point the key task for NQBP, along with its port customers, is to determine what is the best short and long-term approach to managing sediments within the Port. Having determined what that business case might look like, the following steps will most likely involve further investigations, impact assessments and regulatory approvals.

SSM Questions

Within the context of maintaining safe and efficient port operations:

1. Is it necessary to manage sediment at the Port of Hay Point in the short and/or long term?
    - *What is the source of the sediment?*
    - *Where does Sediment accumulate at the port and in what volumes and rates?*
    - *What affect will it have on the port (safety/operations/economics)?*
    - *Can the sediment be managed without dredging, now and in the future?*
2. If yes, what are the feasible ways to manage sediment within the context of needing to maintain port operations and meet legal requirements?
    - *If dredging is required, what are the feasible alternatives for use or placement of the material?*
3. What is the best package of measures to provide for long-term sustainable management of marine sediments at the Port of Hay Point?

These questions need to be considered both in the short term for any immediate siltation issues and in the long-term (25 years) for continued port operations and stakeholder certainty. The work provides valuable context for long-term management at the Port, including understanding the economic effects of sedimentation and drafting a long-term sediment management strategy.

The Project has involved consultation with stakeholders including Commonwealth, State and Local Government; port operators; conservation groups; the local community including indigenous people, fishing groups and community bodies; researchers; and tourism operators.

Based on the results of the SSM Project, NQBP will proceed with a preferred option for managing sediment.

DECISION MAKING PROCESS

A central component of the SSM Project is a structured decision making process that has focused on what is important to all stakeholders, not just the port authority and port customers. Contained within this structured process is a detailed comparative analysis of the various alternatives that are available to manage sediment to determine the best long-term strategy. See **Appendix B** for a detailed report on the comparative analysis.

The decision making process for the SSM Project is a complex task dealing with social, economic and environmental factors. The principles of Structured Decision Making (Gregory *et al*, 2012) were used to provide a robust method for the Project. The process involved the following five steps:

Figure 2: Steps in the Structured Decision Making Process (adapted from Gregory *et al*, 2012)

TEMPORAL AND SPATIAL SCOPE

It is recognised that the sediment management needs of the Port are different in the short term compared with the long term. Decision-making in the context of maintaining port operations needs to accommodate both of these timeframes. In this instance:

- Short term relates to the management of sediment at the Port of Hay Point over the next three years.
- Long term relates to the management of sediment at the Port of Hay Point over the next 25 years.

The spatial scope of the decisions is defined by the Port boundary and any onshore and offshore locations relating to the various sediment management alternatives.

STAKEHOLDER INVOLVEMENT

It was recognised that the views and input of stakeholders are critical to the decision making process.

A structured decision making process is particularly useful for understanding and incorporating the views of stakeholders.

There are a wide range of people with interest in the management of the Port, the SSM Project and the decisions related to marine sediments.

The Port of Hay Point Technical Advisory and Consultative Committee (TACC), along with other interested stakeholders, were used to provide a reference group for the project (refer to **Appendix A** for a list of members). The Comparative Analysis Report (**Appendix B**) provides further details on stakeholder involvement in the process to date.

OBJECTIVES AND PERFORMANCE MEASURES

A critical component of the decision making process involved identifying what is important to stakeholders within the context of managing sediment at the Port. These are best described as the things that really matter in relation to the decisions being made by NQBP.

Based on stakeholder views a set of specific objectives and measures were identified across seven themes. The objectives help frame the comparative analysis and the selection of a preferred alternative.

The objectives aimed to be (Gregory *et al*, 2012):

- Complete – objectives were designed to capture all of the things that matter at the Port in the context of the decisions being made.
- Concise – easily understood; unnecessary or similar objectives were removed to avoid double counting.
- Sensitive – objectives were developed that distinguish between the alternatives, thereby helping to differentiate them to aid decision-making.
- Independent – objectives were developed in a way that ensures that performance against an objective could be considered independently of any other objective.

Performance measures were then defined for each objective. These measures provided a mechanism for predicting how well each of the alternatives performed against the objectives. Similar to the objectives, the performance measures were developed to ensure they were useful and appropriate. The key issues considered when defining a performance measure were (Gregory *et al*, 2012):

- Coverage - the measures addressed the range of relevant consequences of each alternative.
- Practicality – the measures needed to be predictable, which means the data required to assess them could be obtained or generated.
- Direct and specific – the measures reported directly on the relevant consequences and effectively highlight differences in the alternatives to allow informed value trade-offs.

Eleven objectives and fourteen performance measures were defined. These are shown in Table 1 below.

Further discussion of each of the performance measures, including a rationale for their use and how they have been calculated and analysed is provided in the Comparative Analysis Report at **Appendix B**.

Table 1: SSM Project Objectives

Theme	Objective	Measure
ENVIRONMENT	1. Avoid and minimise impacts to coastal ecosystems	A) Predicted performance in relation to avoidance and minimisation of impacts to coastal ecosystems
		B) Predicted risk on dredge material placement plumes and/or tailwater discharge exceeding ambient variation (based on days above threshold)
	2. Minimise carbon emissions	C) Forecast Greenhouse gas emissions
CULTURAL HERITAGE	3. Minimise impact on cultural heritage within the area	D) Nature and scale of any impact on cultural heritage
PORT ECONOMICS & OPERATION	4. Maintain effective and efficient port operations	E) Number of days disruption to terminal loading operations
		F) Predicted lead time to dredge material placement
		G) Capacity to provide a long term solution for the port
	5. Ensure solution is cost effective	H) Assessment of costs
	6. Avoid significant loss of future port expansion opportunities	I) Strategic Port Land (SPL) affected
HEALTH & SAFETY	7. Avoid or mitigate health and safety risks	J) Relative risk
SOCIAL	8. Minimise interference to social activities within the region	K) Scale and duration of any impacts on social activities
	9. Provide increased economic and social opportunities	L) Predicted number of FTE jobs created
INNOVATION	10. Promote innovation in port management	M) Ability of a solution to advance current dredging practice information, technology and techniques
WORLD HERITAGE	11. Avoid and minimise impacts to the Great Barrier Reef World Heritage Area	N) Scale and duration of activity within the Great Barrier Reef World Heritage Area

THE SSM PROJECT FRAMEWORK

In order to deliver the SSM Project with robust information and sound decision making principles a comprehensive set of studies, analysis and key steps have been planned and undertaken with a clear focus on identifying a business case that answers the key SSM Questions. The steps in the process are shown in **Figure 3** and the key studies are listed in Table 2

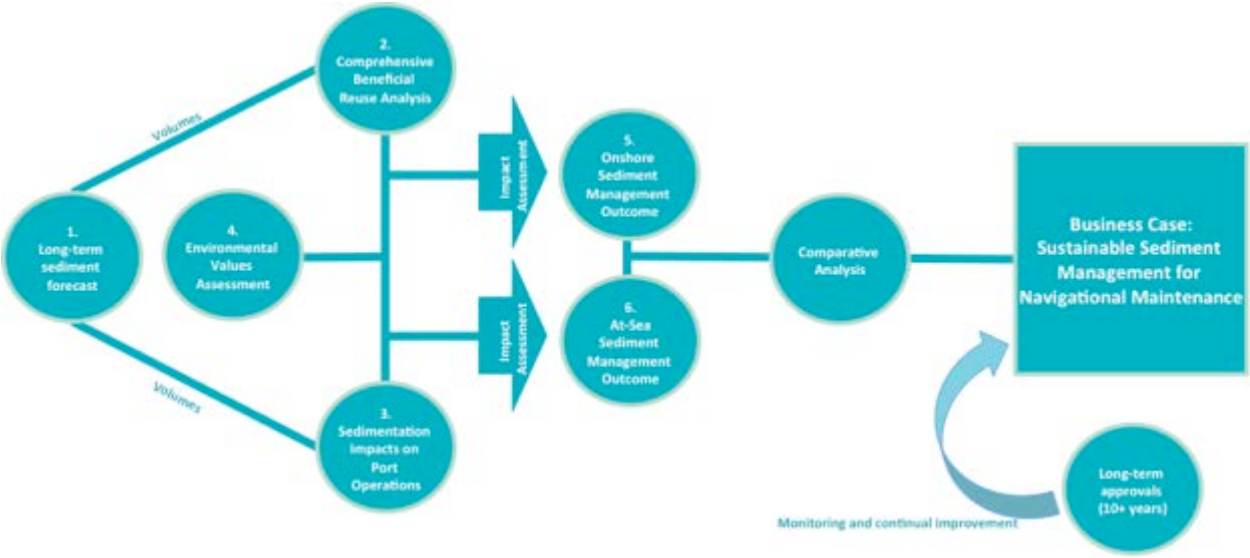


Figure 3: SSM Project Framework

Table 2: SSM Project Framework – key studies

Sustainable Sediment Management (SSM) Framework			
Waste Hierarchy Principles	**SSM Questions**	**Work Undertaken**	**Reference**
Avoid or reduce	Is it necessary to manage sediment at the Port of Hay Point in the short and/or long term? *What is the source of the sediment?*	**Appendix C:** Port of Hay Point Sediment Dynamics – Sediment Budget	Gibbs et al., 2016
	Where does Sediment accumulate at the port and in what volumes and rates?	**Appendix D:** Hay Point Port Bathymetric Analysis and Modelling	Symonds and Donald, 2016
		Appendix E: Hay Point Bathymetric Analysis – Predictive Model	Symonds and Loehr, 2016
	What affect will it have on the port (safety/operations/economics)?	**Appendix F:** Port Operations and the Effects of Sedimentation	Smith, 2016
		Appendix G: Economic Impacts of Not Managing Sediments at DBCT	DBCT, 2016
	Can the sediment be managed without dredging, now and in the future?	**Appendix H:** Port of Hay Point Assessment for Navigational Maintenance	Symonds et al., 2016
Reuse or recycle	What are the feasible ways to manage sediment within the context of needing to maintain port operations and meet legal requirements? *If dredging is required, what are the alternatives for use or placement of the material?*	**Appendix I:** Comprehensive Beneficial Reuse Assessment	Stalley and Boylson, 2016
		Appendix J: Port of Hay Point: Marine Sediment Properties Assessment	Kochnieff et al., 2016
		Appendix K: Onshore Pond and Reclamation Engineering Design	Cross et al., 2016
		Appendix L: Environmental Values assessment	Powlett et al., 2016
Dredging and Placement alternatives	What is the best package of measures to provide for long-term sustainable management of marine sediments at the Port?	**Appendix B:** SSM Comparative Analysis	Hemphill et al, 2016

Purpose and structure of this report

This report presents the findings of the SSM Project. It works through the key questions and decisions to be made around management of sediment and summarises the detailed technical work behind the analysis.

The report includes:

- A summary of the Port of Hay Point.
- An overview of the environmental, social and cultural values of the Port and the surrounding area.
- Background to the sediment at the Port.
- Analysis of the effects of sedimentation on Port operations.
- Discussion of the alternatives for avoiding or reducing the need to dredge.
- Analysis of sediment reuse or placement options.
- Environmental profiles of the locations for the eight feasible alternatives for reuse or placement.
- An overview of the environmental impact pathways of the eight alternatives for reuse or placement.
- A summary of the comparative analysis of the alternatives for reuse or placement over both the short and long term.
- The business case for a preferred long-term solution to sediment management at the Port of Hay Point.

Port of Hay Point

In understanding the decisions to be made it is necessary to understand the Port, its operations and the environment in which it is located.

The Port of Hay Point is located approximately 40 km south of Mackay in Queensland on Australia's east coast. It is situated close to the neighbouring communities of Louisa Creek, Salonika and Half Tide. The Port lies within the Great Barrier Reef World Heritage Area (GBRWHA) and adjacent to the Great Barrier Reef Marine Park (GBRMP) (Figure 4). The shipping departure path, which is approximately 9 km long, extends in to the Marine Park.

The Port of Hay Point commenced operations on 20 October 1971 with a single coal-loading berth. It is now one of the largest coal export ports in the world with an annual throughput of 115,768,354 tonnes in 2015-16. The Port services mines in the Central Bowen Basin in Queensland and comprises seven berths across two export terminals, linked to the mines by an integrated rail network.

The majority of the coal exported is metallurgical coal used in the manufacture of steel.

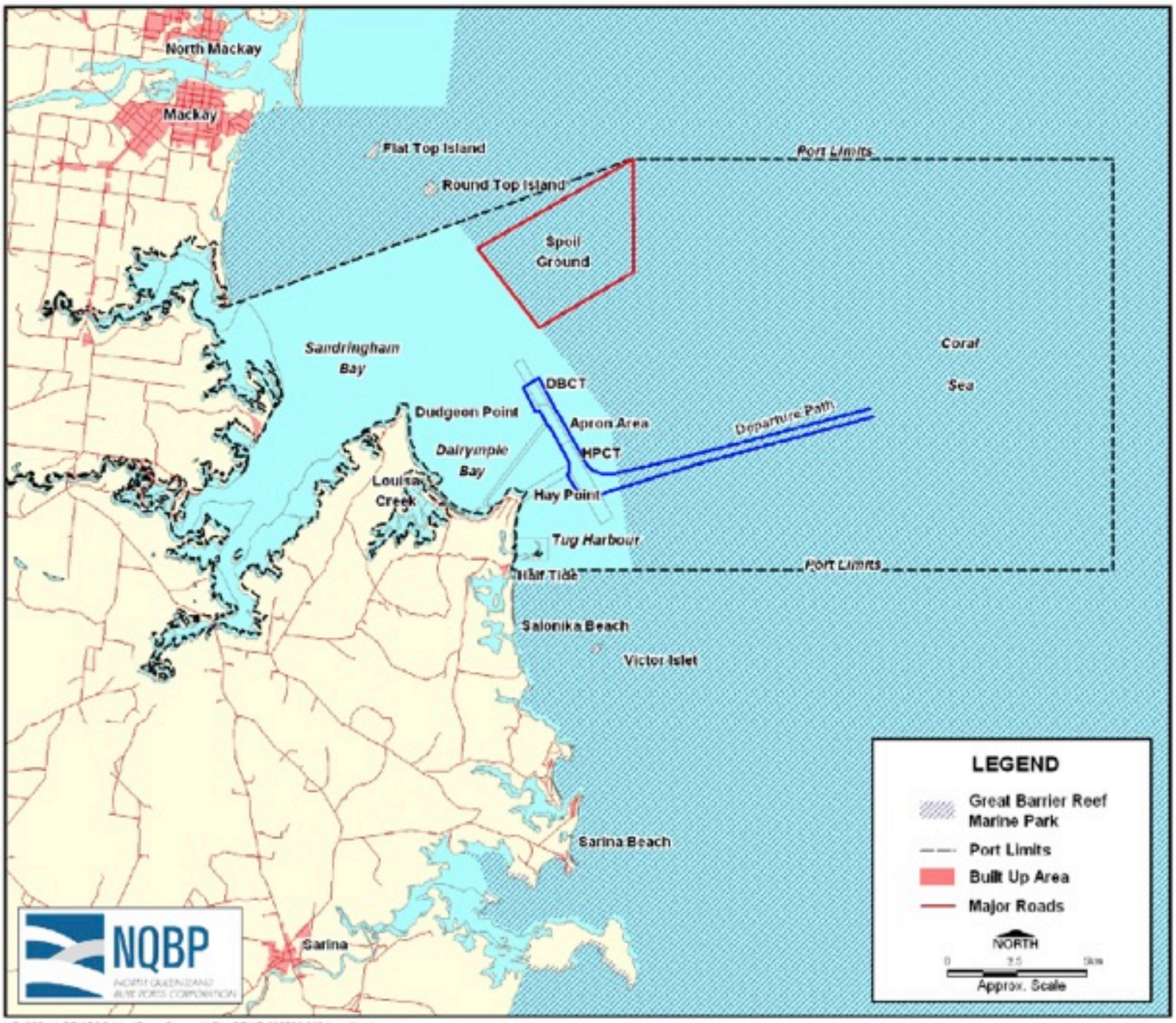


Figure 4: Port of Hay Point

Infrastructure and facilities

The port comprises two separate coal export terminals: Dalrymple Bay Coal Terminal (DBCT) and the Hay Point Coal Terminal (HPCT) (Figure 5).

DBCT is the larger of the two terminals with a total capacity of 85 mtpa. It is a multi-user facility that services a large number of coal mines in the Bowen Basin coalfield area. DBCT consists of four berths, each serviced by a shiploader with a loading capacity varying from 5,500 tph (tonnes per hour) (Berth 1) to 7,200 tph (Berth 4). Dalrymple Bay Coal Terminal Pty Ltd operates the terminal. They are an independent company that is owned by the mining companies exporting through the terminal. The terminal is leased from the State Government by DBCT Management Pty Ltd.

Hay Point Coal Terminal (HPCT) is operated by Hay Point Services Pty Ltd for BHP Billiton Mitsubishi Alliance (BMA). HPCT currently has a capacity of 55 mtpa. The wharf at HPCT is 2.2 km long and has three berths.

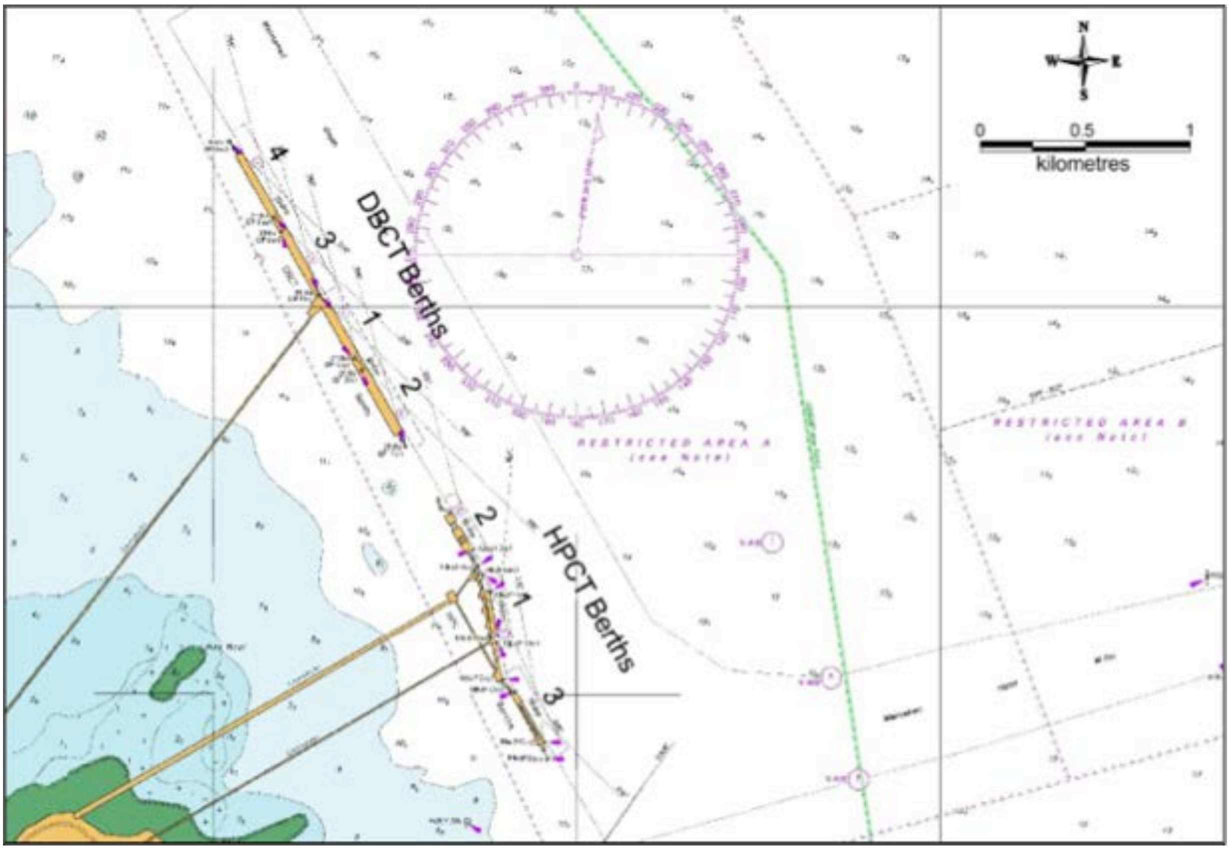


Figure 5: Configuration of the berths, apron and channel at the Port of Hay Point

The Port has a dredged departure channel, apron and seven berths. In October 2006 NQBP completed the development of a departure channel and apron area for shipping at the Port of Hay Point. The capital works involved dredging in the order of 9 million cubic metres of sediment[1], and included:

- A ship manoeuvring apron area approximately 500 m wide adjacent to the existing berths (Figure 5).
- A departure channel from the apron to the sea approximately 9,500 m long. The first 500 m of the channel is 500 m wide, after which it tapers to a width of 300 m.

The environmental impacts associated with such a large campaign were monitored and reported. The impacts were determined to be well within the permit approval conditions.

[1] This volume is significantly larger (40-fold) than future maintenance dredging needs for the Port discussed in this report. Maintenance dredging is also likely to take a considerably shorter timeframe to complete.

Infrastructure at the port consists of purpose-built rail in-loading facilities, onshore stockyards and offshore jetties leading to wharves. The offshore wharves are serviced by conveyor systems that run the coal from the stockyard to the wharves to allow loading in deeper water.

Half Tide Tug Harbour is located just south of Hay Point. The marine facilities at the Tug Harbour consist of a main wharf structure with four tug berths and two service berths. The Tug Harbour has cyclone moorings for five tug boats and three line boats (or smaller vessels). The onshore facilities at the tug harbour include the administration building, amenities building, covered car park structure and fuel bunkering facilities. The Hay Point Tug Harbour area also includes a public boat ramp, which is located on port land.

Trade

The Port of Hay Port is one of the largest coal exporting ports in the world, with DBCT and HPCT exporting 67,517,529 and 48,250,825 tonnes respectively during 2015-16.

The combined export volumes from the two terminals (approx 115 million tonnes) equates to around 1,020 ship calls or 2,040 ship movements. The Port of Hay Point ship movements represent approximately 15% of all large commercial ship movements in the greater GBR region.

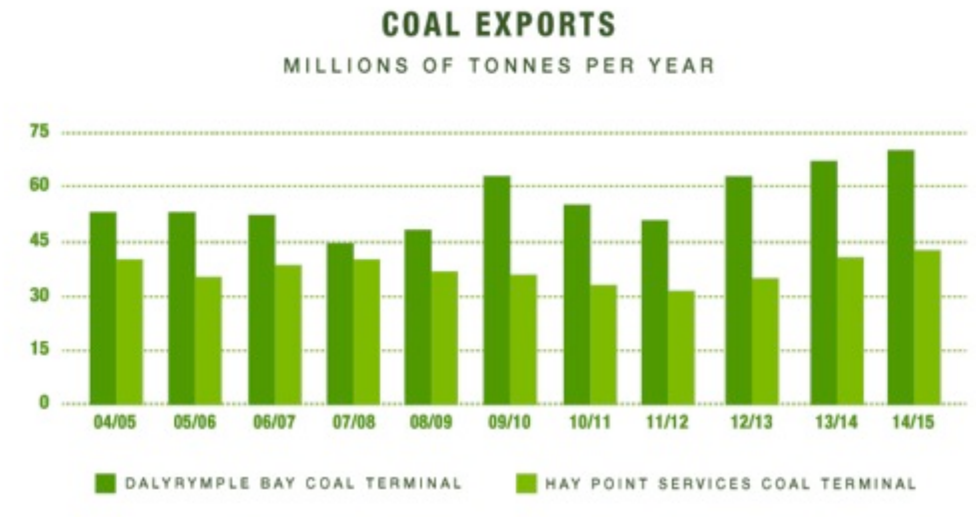


Figure 6: Port of Hay Point coal exports per year

Ship Sizes

There are various types and sizes of commercial ships that trade in the region. However, as the Port of Hay Point is solely a coal export port, all of the vessels calling at the Port of Hay Point are bulk carriers. Bulk carriers are a highly efficient form of transport globally and are able to move large volumes of product effectively around the world.

Bulk carriers vary in size, however, the four main industry standards of bulk carriers are:

- Handy: up to 40,000 dry weight tonnes (DWT).
- Handymax: up to around 50,000 DWT, and around 150 m to 200 m in length.
- Panamax: up to around 90,000 DWT, and averaging around 230 m in length, but limited in beam to 32 m to permit passage through current Panama Canal locks.
- Capesize: upwards of 90,000 DWT, but typically around 100 000 DWT to 250,000 DWT, with a length of around 280 m or more and wider in the beam than a Panamax ship.

Ships calling at the Port of Hay Point are primarily Panamax or Capesize with the average ship cargo parcel (volume) being:

- FY14/15 Average: 109,936 DWT.
- FY15/16 Average: 100,861 DWT.

To accommodate bulk carriers of this size the navigational areas within the port have been deepened to enable the safe departure of loaded vessels. The designed depths of the navigational areas are:

- Departure path and apron area: 14.9 m below Lowest Astronomical Tide (LAT).
- Berth areas from: 16.6 m to 19.6 m below LAT.

Operations

Coal trains arriving at Hay Point have a coal-carrying capacity of up to 10,000 tonnes. This coal is delivered to the terminals via a bottom dump train receival system. Once the coal leaves the rail wagons, it is conveyed into the stockyards where rail-mounted stacker reclaimers place the coal into dedicated stockpiles or direct to the vessel when product type and quality allow.

Operations at both DBCT and HPCT are designed to operate 24 hours a day and can be broken into the following key components:

- Receival of coal from rail services.
- Stockyard storage.
- Yard machines to stack and reclaim coal to and from the stockpiles.
- Blending of different coal types to meet customer requirements.
- Out loading to offshore berths.
- Shiploading.

Coal ships arriving off the Port of Hay Point are assigned a designated anchorage position by Vessel Traffic Services, while waiting berthing instructions. The Port of Hay Point is a compulsory pilotage area. All ships that are 50 m or more proceeding within the pilotage areas must either carry a licensed marine pilot or be under the command of a master who holds a pilotage exemption certificate for the area. Ship movements require a minimum of two tugs.

Environmental, social and cultural values

In developing sediment management alternatives and determining what approaches are most suitable at the Port of Hay Point it is essential to understand the environmental, social and cultural values of the Port and the surrounding area.

The focus of this work is on values that are considered important or notable at a national, regional or local level. The aim is to provide a useful level of detail and relevance to aid decision-making. It is important to note that a number of the sediment management alternatives considered in the SSM Project (see latter sections of this report) are located at the Port of Mackay and various locations of the marine environment. Values are therefore described for that broader area as well as the Port of Hay Point (see **Appendix L** for the complete values assessment).

A more detailed inventory of the environmental, social and cultural surroundings of any preferred sediment management solution will occur as part of any later assessment and approval process.

WHAT IS AN 'IMPORTANT VALUE'?

For the purposes of this review, *important environmental* values are those that are:

- Matters of national environmental significance protected under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).
- Matters of state environmental significance protected under Queensland environmental protection and management laws.
- Habitats or ecosystems that are considered 'important' or 'critical to the survival' of listed species or communities.
- Values that contribute significantly to the Outstanding Universal Value of the GBRWHA.

Important *social and cultural* values are those that are:

- Included in national or state registers.
- Identified by traditional owners or community members.
- Values that contribute to the appreciation culture and heritage in the region.
- Features that provide a connection to the landscape, history or previous or current use of the area.

Environmental values

The area from the south of the Port of Hay Point to north of the Port of Mackay has been highly modified. The area supports agricultural, urban, industrial, port and shipping, and commercial and recreational uses. The sub-catchments in this region are some of the most modified catchments along the Queensland coast, with over 50% of catchment areas used for intensive agriculture such as sugar cane (Reef Catchments 2014).

The region also continues to support areas of international, national and state environmental significance. Historic land use practices have resulted in fragmented remnants of native vegetation throughout the landscape and along riparian corridors. These natural features provide important habitat corridors for a variety of native flora and fauna. The marine environment adjacent to the Port and coastline also contributes to the diversity of values in the region and importantly the Outstanding Universal Value (OUV) of the GBRWHA.

OUV OF THE GBR WORLD HERITAGE AREA

The Port of Hay Point and Port of Mackay are partly within the GBRWHA (listed as a World Heritage Area in 1981). The GBRWHA is listed based on it meeting four World Heritage criteria for OUV:

- Natural beauty and natural phenomena (Criterion (vii)).
- Major stages of the Earth's evolutionary history (Criterion (viii)).
- Ecological and biological processes (Criterion (ix)).
- Habitats for conservation of biodiversity (Criterion (x)).

Of the important environmental values present in the region, three are considered to contribute significantly to the OUV of the GBRWHA. These are:

- Internationally recognised **migratory shorebird roosting sites** at Sandringham Bay and Mackay Town Beach that support 23,000 shorebirds each year during their annual migration.
- A core **aggregation/calving area** for the east-coast population of humpback whales approximately 80 km east of Mackay.
- A high diversity of **mangrove species** within estuarine areas.

Snapshots of the key environmental values present within the study area are summarised in **Table 3** and illustrated in **Figure 7**. More detailed information regarding these values can be found in the Port of Hay Point Environmental Values Report (Jacobs 2009) (**Appendix L**).

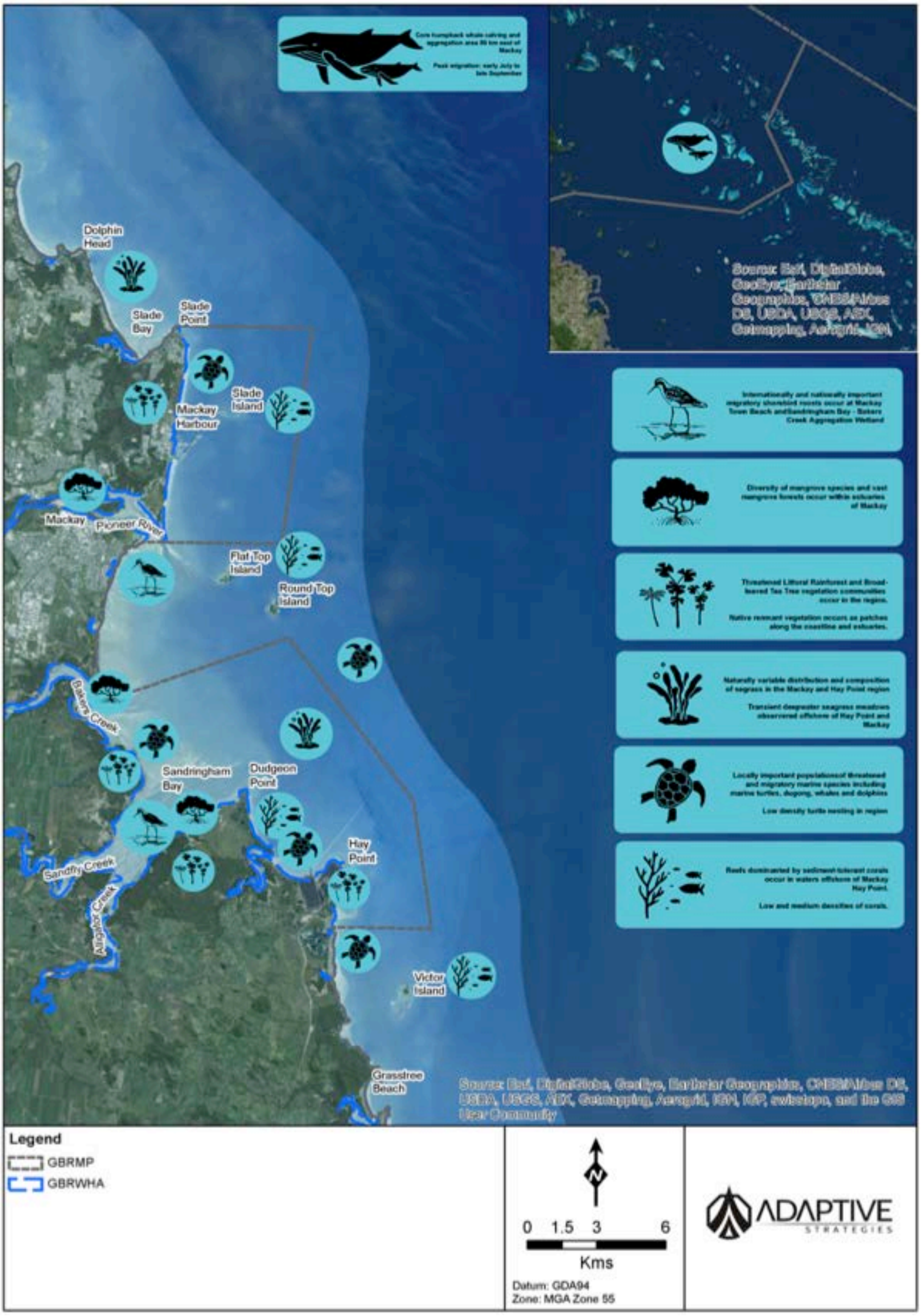


Figure 7: Regional environmental values

Table 3: Regional environmental features

FEATURE	DESCRIPTION
World Heritage	The area lies adjacent to, and within the Great Barrier Reef World Heritage Area. Of the important key environmental features present within the region, three are considered to contribute significantly to the OUV of the GBRWHA. These include internationally recognised migratory shorebird roosting sites at Sandringham Bay and Mackay Town Beach; a core aggregation/calving area for humpback whales 80 km offshore of Mackay; and, a high diversity of mangrove species.
Remnant Vegetation	The Mackay region supports a wide range of remnant vegetation types in varying condition and patch size. Vegetation types mapped within the area include mangroves, dunal vegetation, vine forest, swamps and wetlands, open eucalypt forest and tussock grassland (Jacobs 2016). Of these vegetation types (or Regional Ecosystems) a number are listed as 'endangered' or 'of concern' under the Queensland *Vegetation Management Act 1999* (Jacobs 2016). Approximately 2,875 ha of 'endangered' REs are present and 1,285 ha of 'of concern' REs are present. These vegetation types occur as scattered patches along the coastline and estuaries.
Threatened Ecosystems	Two threatened ecological communities occur within the study area including the Commonwealth listed critically endangered Littoral Rainforest and Coastal Vine Thickets of Eastern Australia (58 ha) and endangered Broad-leaved Tea Tree Woodlands in High Rainfall Coastal North Queensland (121 ha).
Threatened Terrestrial Fauna and Flora	The area supports a number of threatened fauna including birds and mammals, with locally important populations present. Four threatened flora species are known to occur in the area including black ironbox (*Eucalyptus raveretiana*), lesser swamp orchid (*Phaius australis*), holly-leaved graptophyllum (*Graptophyllum ilicifolium*) and *Omphalea celata*. There is also potential habitat for the byfield matchstick (*Comesperma oblongatum*) and *Neisosperma ilneri* within the study area.
Shorebirds	Significant shorebird roosting habitat is present within the area including internationally important habitat at Sandringham Bay and Mackay Town Beach. Nationally important shorebird roosting sites occur at the mouth and banks of the Pioneer River, Armstrong Beach and Sandfly Creek. The area supports over 23,000 shorebirds each year during annual migration. Sandringham Bay is internationally important for the eastern curlew, lesser sand plover and great knot, and nationally important for the terek sandpiper (*Xenus cinereus*), bar-tailed godwit and ruddy turnstone (*Arenaria interpres*). Mackay Town Beach is also an internationally important site for the eastern curlew, the great knot, and lesser sand plover. Mackay Town Beach has large areas of intertidal flats that are suitable for shorebird feeding. Over 4,000 roosting shorebirds have been recorded and it is estimated that the shorebird feeding area density is 25 birds/100 m^2. Other species known to feed at Town Beach include the bar-tailed godwit, whimbrel and grey-tailed tattler.
Mangroves	The Pioneer River and Sandringham Bay – Bakers Creek Aggregation support extensive mangrove communities. These areas contain a diversity of mangrove species that is found throughout the Mackay region. The area suffered significant mangrove dieback in 2002, particularly of the Grey Mangrove due to pesticide use on cane farms within catchment areas.
Rivers	The Pioneer River, which runs through the city of Mackay, and Bassett Basin lie south of the Port of Mackay. Basset Basin is an estuary of the Pioneer River and provides important nurseries. It was declared a Fish Habitat Area in 1993 and is assigned management category B (i.e., where existing or planned use requires a more flexible management approach). Prior to this it was a wetland reserve and managed to enhance existing and future fishing activities. Mangroves and related tree communities make up 4.2 km^2 of the 6.6 km^2 Fish Habitat Area.
Water	The area is influenced by the Alligator Creek, Sandy Creek, Bakers Creek and Sarina Beaches subcatchments of the Pioneer Basin. These catchments are some of the most modified catchments of the Great Barrier Reef coast, with over 50% of their catchment used for intensive agriculture production (Reef Catchments 2013). Water quality in the area is considered to be poor due to the high levels of nutrients and pesticides resulting from the surrounding land uses.

Soils	Soils in the region provide high-quality sugarcane and grazing land. They primarily consist of Quaternary alluvium and lacustrine deposits (sand, silt, mud and gravel). Soils in low-lying coastal areas (<5 m AHD) of Mackay and Hay Point contain Potential Acid Sulfate Soils.
Islands	A small number of islands lie offshore of the Mackay region. The nearest islands to the Port of Mackay and Port of Hay Point include Slade Islet, Round Top Island, Flat Top Island and Victor Islet. Keswick and St Bees Island occur further offshore, to the north-east of the Port of Mackay.
Seagrass	Seagrass in the region is naturally variable in distribution and species composition due to a number of seasonal factors. Deepwater seagrasses are particularly transient, and usually only occur between July and November. Two deepwater seagrass beds and one coastal seagrass bed (north-western shore of Round Top Island) have previously been observed in the waters offshore of the Port of Mackay. Deepwater seagrass meadows have also been recorded offshore of Hay Point. These meadows are particularly variable, and often occur as small patches during December and May. Surveys have also found three small patches of inshore seagrass adjacent to Dudgeon Point.
Coral	There are a number of reefs dominated by sediment-tolerant hard coral species within the waters offshore of Mackay and Hay Point. Hay Reef, Victor Islet, Round Top Island, Flat Top Island, Taroba Rocks, Dudgeon Point, Keswick Island and St Bees Island all support areas of coral. These areas have been shown to support low to medium densities of corals.
Benthic Habitats	The region supports macroalgae and benthic invertebrate communities of varying densities which also vary over time. Macroalgae species observed within the area include *Sargassum* sp., *Udotea* sp. and *Caulerpa* sp. (Rasheed et al 2004; Thomas et al 2010). Low density (<1 – 5%) macroalgae communities are present surrounding both the Port of Mackay and the Port of Hay Point. High macroalgae cover (>20%) occurs on the rocky reef areas surrounding islands within the area including Flat Top and Round Top islands, Slade Islet and Slade Point (Rasheed et. al. 2001). The seafloor offshore of the two ports supports large areas of medium density algae (5-20%), with patches of low and high density occurring in inshore and offshore areas. Most of the seafloor in the area is comprised of open sandy areas with sparse cover of invertebrates such as bivalves, ascidians, bryozoans, echinoids and corals.
Sediments	Marine sediments along the coastal strip of the area can be described as silts and silty sands. Further offshore sediments have been found to be dominated by medium and coarse sand, with small amounts of gravel and finer fractions of silts and clays. The finer fractions of sediments in the marine environment can act as sinks for contaminants. Analysis of sediment quality from the Port of Hay Point and Port of Mackay have found that contaminant substances have tested <u>below</u> the National Assessment Guidelines for Dredging (NAGD, DEWHA 2009).
Threatened Marine Fauna	The area supports locally important populations of a number of threatened and migratory marine species. Marine species known to occur in the area include: marine turtles (green, flatback, leatherback and hawksbill), dugongs, whales and dolphins. Low-density marine turtle nesting has been identified on beaches in the region. There is also an important aggregation area for humpback whales 80 km off the coast of the Port of Mackay. It is thought that whales aggregate for breeding and calving in these waters.

Social values

The closest significant population hubs to the Port of Hay Point are the towns of Sarina, 23 km to the south west of the port, and Mackay 40 km to the north, which is the administrative centre of the region. The coastal communities of Hay Point and Louse Creek are located adjacent to the Port.

The region's economy is based on the mining, livestock, agriculture (in particular sugar cane farming), manufacturing and tourism industries. The sugar industry in the region provides one-third of Queensland's production and Mackay is a mining services hub, with the resources sector exporting more than half of Queensland's coal exports through the region's coal ports. Port operations and construction at the Port of Hay Point provide local and regional employment and investment.

COMMUNITY NEEDS AND INTERESTS

The Mackay region has experienced significant growth in population since 2011 and expects to grow further over the next 20 years. During the recent mining boom, the region experienced pressures in relation to the provision of affordable housing and other infrastructure and service provision. The Mackay Regional Council notes that the region's population is estimated to grow to 180,000 by 2036 from the current 120,000. Plans are that 'the focus of that population will be in urban areas, particularly in Mackay, and also Sarina, Marian, Mirani and Walkerston'.

The region's urban growth has been fragmented, making infrastructure more expensive to deliver and requiring high levels of community subsidy. The development of this situation was due to the pressures of an unprecedented boom in mining and mining services. As well as noting the importance of minimising rate rises and containing the cost of funding new infrastructure, the council notes that a much greater choice of housing needs are required, as well as residential development that is well linked to and serviced by infrastructure and community facilities.

EMPLOYMENT AND HOUSING

The top 10 industry sectors in terms of regional exports, employment, value-added and local expenditure on goods and services in the Mackay Region are:

- Construction Services
- Heavy & Civil Engineering Construction
- Wholesale Trade
- Pre-School, Primary, Secondary & Special Education
- Professional, Scientific & Technical Services
- Sugar & Confectionery Manufacturing
- Health Care Services
- Retail Trade
- Coal Mining
- Agriculture, Forestry & Fishing Support Services

In general, unemployment in the Mackay region has increased due to the recent downturn in the mining industry and related construction activity after a period of significant growth. Mackay has yet to stablise to a more usual business cycle and there continues to be unused capacity in labour markets and commercial activity. There are some indications that construction activity may be recovering and moving to meet residential property demand. It is likely that employment by industry may have shifted somewhat since the previous Census in 2011.

The activities of the port are reflected in the high proportion of employment in the transport sector. Any expansion of port activities at the Port of Hay Point will grow employment in this sector further but may also support an increase in the employment sectors of retail trade and accommodation and food services. Port development would support increased employment in the construction sector for the period of the development work.

More people own and occupy their own house in the area of Hay Point than in the Mackay region more generally. Mortgage payments are lower, as is rent. Median rents across the board in the region have generally decreased significantly in the period since 2012. Current building approval activity in the region is significantly reduced in comparison with 2012 to 2013 and housing prices in the area around the Port have fallen (significantly in Sarina) as they have across the Mackay region generally. Property reports claim that the Mackay region, as elsewhere in Central Queensland, is now stabilising with sales volumes and prices returning to pre-mining boom levels.

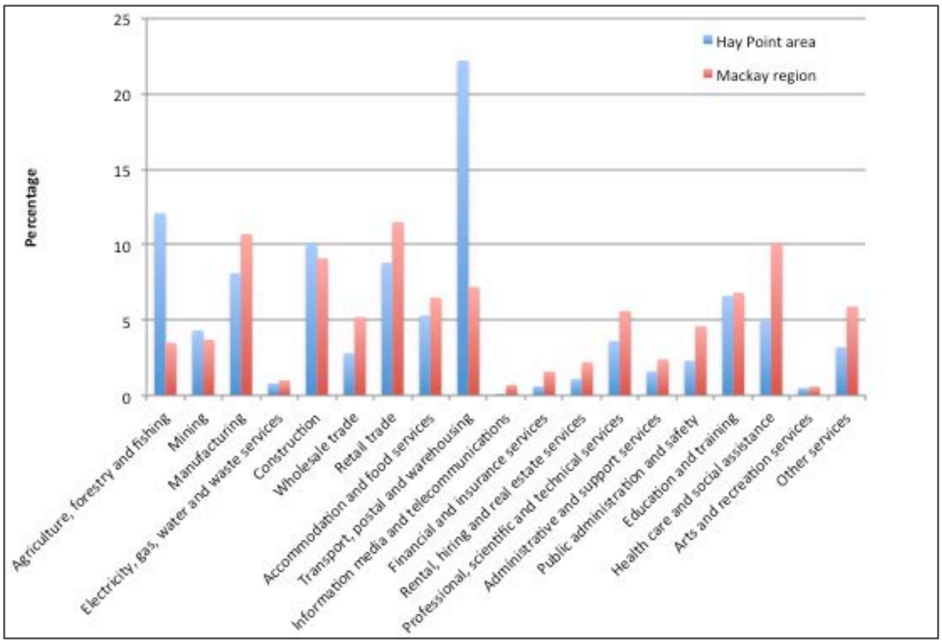


Figure 8: Employment by industry, Hay Point and Mackay region

SOCIAL INFRASTRUCTURE

Half Tide Tug Harbour is located at the Port of Hay Point, and allows safe mooring of the tug boats providing towage to ships in the Port. The tug harbour includes a public boat ramp that provides amenity to the area. There are other public boat ramps available in the areas around the port and Sarina Beach. The administrative building at the Hay Point Coal Terminal operates a viewing platform where visitors can view the handling and export activity of the Port.

Sarina is the service hub for the southern parts of the Mackay region in the vicinity of the Port of Hay Point. Sarina serves as a commercial and community service centre, with capacity for residential expansion and some opportunity for extension to industrial activity. Other services are provided in Mackay.

Snapshots of the key social indicators present within the study area are provided in Table 4.

Table 4: Regional social features

FEATURE	DESCRIPTION
Population & demography	The Mackay region has an estimated population of 123,724 persons and has had an average annual growth rate of 1.7 per cent over five years. The area surrounding Hay Point has a current estimated resident population of 21 193. The area has experienced an average annual growth rate of 0.9 per cent over five years. In 2015 it is estimated that 20.7 per cent of residents were aged under 15 years, 67.2 per cent between 15 and 65 years and 12.1 per cent 65 years and over. This is very similar to that of the Mackay region, but slightly younger demographic than Queensland in general. In 2011, 4.1 per cent of people in the Hay Point area identified as Aboriginal or Torres Strait Islander and 7.3 per cent were born overseas - a significantly lower proportion than that of the Mackay region at 11.7 per cent and 20.5 per cent for Queensland.
Income & disadvantage	Median income for the area surrounding Hay Point is lower than the Mackay region in general but is higher than the average for Queensland. There were 594 low-income families (10.7 per cent of families in comparison 13.0 per cent overall in Queensland). The Index of Relative Socio-Economic Disadvantage value for Sarina indicates that this area is relatively disadvantaged in comparison to other parts of the Mackay region.
Workforce participation & employment	The Hay Point area's labour force at end March 2015 was 11,260. The most recent estimated unemployment rate for Sarina was 8.6 per cent, much higher than Queensland's rate of 6.2 per cent. The Walkerston-Eton unemployment rate was only 4.8 per cent, significantly lower than Queensland and the Mackay local government area's unemployment rate (7.7 per cent). The Transport, Postal and Warehousing industry employs 22.2 per cent of workers in the area and 12.1 per cent were employed in the Agriculture, Forestry and Fishing sector. This contrasts with the 7.2 per cent and 3.5 per cent working in these industries respectively across the Mackay region. Other important areas of employment include Construction (10.1 per cent), Retail trade (8.8 per cent) and Manufacturing (8.1 per cent). People travel into the area from elsewhere to work in industries such as Transport, Postal and Warehousing (22.3 per cent), Agriculture, Forestry and Fishing (12.2 per cent), and to a lesser extent Education and Training (6.6 per cent). They travel out to work in Mining (4.3 per cent), Manufacturing (2.1 per cent) and Health Care and Social Assistance (2.1 per cent).
Housing cost & supply	A greater proportion of occupied private dwellings in the Hay Point area were fully owned in 2011 than in the region generally. Median mortgage repayments are lower in the area than for the Mackay region as a whole. Median rent is also lower than in the greater Mackay area.
Education & training	In 2011, the Mackay Region recorded 46.6 per cent of people with a highest level of schooling of year 11 or 12 (or equivalent). This is lower than for Queensland (55.3 per cent) as a whole. Of people aged 15 years and over, 51.5 per cent had a non-school qualification, in comparison to 54.2 per cent in Queensland. Where people specified the field of their non-school qualification, 30.5 per cent had a qualification in Engineering and Related Technologies and 11.1 per cent in Management and Commerce.
Recreational activities	The region supports a full range of recreational and sporting activities, particularly within Mackay where sporting fields, parks, and community centres provide a focus for community activities. Of relevance to the Port, key recreational activities include: boating, fishing, snorkelling and diving, surfing, beach based activities, walking and sightseeing. There is a public boat ramp at Half Tide Tug Harbour and a public access area on the north side of Mackay Harbour.

Cultural heritage values

BRIEF HISTORY OF HAY POINT

Despite significant sailing activity past Hay and Dudgeon Points in the late eighteenth century, the first Europeans only landed on the Presto at Sandy Creek, just north of Dudgeon Point in 1862.

The process of European settlement had a significant impact on the Aboriginal people of the region. An Aboriginal reserve was established in 1871 in the area with 14,080 acres set aside near the Cape Palmerstone and Homebush pastoral runs. By 1879 government funding for the reserve was cut and the land reclaimed for settlement, forcing the Aboriginal residents to move elsewhere. Between 1898 and 1967 there were 72 documented removals of Aboriginal people from the Mackay district by the Queensland Government. Most were removed to the reserves and missions at Yarrabah, Barambah (now Cherbourg), Woorabinda and Palm Island.

Development began in the southwest of Dudgeon Point in 1896, when a tramway from Plane Creek Sugar Mill to the mouth of Louisa Creek was completed.

In the late 1960s the Utah Development Company (USA) and Mitsubishi (Japan) began coal mining on a large scale at Goonyella, about 150 km south-west of Mackay. The consortium built a separate rail track, running parallel with the Queensland rail route in parts and proceeding through the Sarina district to Hay Point, the site for a large purpose built coal-export terminal. The first coal was loaded from it in 1971. Since 1983 a government-owned facility, leased to the private sector, has operated nearby at Dalrymple Bay.

THE INDIGENOUS PEOPLE OF THE HAY POINT AREA

The Yuwibara (Yuibera) People are the registered claimants of an area that includes the Port of Hay Point (QC2013/007). The Yuwibara people therefore have priority as parties as a registered native title claimant for the area covering the port including coastal waters. These rights are considered registered as an entry has been made on the National Native Title Register. They must be consulted with regard to the Indigenous cultural heritage of the area and any assessment of its significance.

The Wiri (Widi), Barada Barna Kabalbara and Yetimarla, Yuibera (Yuwibara), Birri-Gubba and Kungalburra peoples all have strong associations with the Mackay area and therefore Hay Point. They also have interests in terms of the cultural heritage of the area but recognise that the Yuwibara people have the particular care of the area related to the Port of Hay Point and therefore specific knowledge about traditions, observances, customs or beliefs associated with the area.

The port authority has consulted with the representatives of the Yuwibara people and the other Indigenous people of the area about plans for dredging (including placement of dredged material) and other development. It has also undertaken consultation when developing environmental impact statements and other planning documents.

IDENTIFIED INDIGENOUS CULTURAL HERITAGE AT HAY POINT

Indigenous cultural heritage in Australia can be understood as cultural heritage relating to Aboriginal and Torres Strait Islander communities and may include traditional stories, knowledge and practices, and places with traditional stories and knowledge attached to them. An extensive legislative framework protects Indigenous cultural heritage.

It is also important to note that Indigenous people see the natural environment and the cultural landscape as integral parts of the Aboriginal heritage concept. Indigenous cultural values are viewed as being inextricably linked to the natural attributes of the landscape. The cultural significance of an area is not just due to the presence of tangible sites or objects; it is rooted in the 'connection to country' of its people (Bird 2009).

Few Indigenous cultural heritage surveys and studies have been conducted in and around the Port of Hay Point area. Of those that have many are unpublished or not available in full. However, it is considered unlikely that there are significant unknown heritage sites in the area that have not yet been investigated. It is, however, assessed as likely that the sand dune area in the Lousia Creek area parallel to the freshwater swamp and going along the beach towards Mount Hector may contain sub-surface archaeological material.

DUDGEON POINT AND MOUNT HECTOR

Cultural heritage assessment consistently identifies Dudgeon Point as an area of Indigenous cultural significance. For the Yuwibara people (and other Indigenous groups in the area) the importance of Dudgeon Point is linked to Mount Hector and the coastline.

In 2003 and 2004 some areas of Aboriginal cultural significance were identified primarily in the Dudgeon Point coastal zone. The majority of these sites were concentrated on the bar of sand that extends from Dudgeon Point to Mount Hector along the coast (approximately 3 km). This dune system separates the freshwater lagoon from the littoral zone and appears to have been a focal point for subsistence activity in the past. In general the whole dune could be described as a Significant Aboriginal Area, but two main concentrations of artefacts have been located. Of these two scatters, the larger, southerly one includes material that suggests a number of activities were occurring in the area. Individual stone artefacts were also found in all of the sub-environments, from the coastal strip, to the cleared grazing land and into the remnant forest strip to the south.

The findings suggested they were part of a larger site spanning all of that section of the sand dune parallel to the freshwater swamp and potentially going much further along the beach towards Mount Hector. This site is large and complex with each of its component areas having a concentration of artefacts that represents a range of activities, and the mobile sand ridge/beach dune presents an ever-changing archaeological record. Therefore considerable quantities of sub-surface archaeological material can be predicted throughout this dunal system.

From the perspective of Aboriginal people living a traditional lifestyle, the Dudgeon Point area offered a range of natural systems that feature access to fresh water and different types of food and raw materials. It was rich in resources, including food and medicine. It is reasonable to suggest that key places for resources would have been:

- Louisa Creek, where extensive shell middens are still visible.
- Sandringham Bay with its wide sandy estuarine conditions.
- Hay Point which contains the remnants of a traditional fish trap.
- The large lagoons along the coastline, such as at Dudgeon Point and west of Half Tide Beach near Hay Point.

The Baker's Creek Reserve is also an important heritage consideration. While the bulk of the reserve was on the northern bank of Baker's Creek, a small sub-section was on its southern bank. Although this part of the reserve was cancelled in January 1880, and was probably never used for camping and living, it is still a place of considerable significance to Aboriginal people including aboriginal parties whose forebears were associated with the area. The Baker Creek Mission site is registered on the State's database.

OTHER CULTURAL HERITAGE

The National Heritage List, the Commonwealth Heritage List, the Queensland Heritage Register and the Mackay Regional Council Local Heritage Register do not include listings for any non-Indigenous cultural heritage sites within the Hay Point area.

Areas of local heritage interest, such as the sugar wharf at Louisa Creek given its role in the development of the region's sugar industry, are recognised and are included in buffer areas relating to development and other port activities. In 2012, sites associated with early settlement, closer settlement pattern, pastoral and agricultural land management, small scale mining and the establishment of transport and communication networks were identified in the port area but were assessed as 'at best of local significance'.

Mining shafts and other remnants in the Dudgeon Point area are representative of the region's early, although unsuccessful, attempt at gold mining. These mining elements and the remains of a dry stone 'cottage' from the late 19th century/ early 20th century in the port area have the potential to yield information that might contribute to a broader understanding of the local area's history.

MANAGEMENT OF CULTURALLY SIGNIFICANT HERITAGE SITES IN THE PORT AREA

Further research and analysis of specific areas and sites may be required to address specific cultural heritage issues arising from future project activities. Continued monitoring will be required to ensure the legislative compliance of any planned expansion activities. Ongoing consultation with the traditional owners and native title claimants, the Yuwibara people, and other Indigenous groups with interests in the port area, will be required.

Although areas may have been previously disturbed, any work should be monitored for artefacts that may be brought to the surface and a protocol for managing unexpected cultural heritage finds should be put in place. The port authority can continue to use buffer zones as a mitigation measure to protect known areas of particular Indigenous cultural significance in consultation with the traditional owners.

Any proposed development or activities in the Dudgeon Point area should include a commitment to entering into a Cultural Heritage Management Plan (CHMP) with the Yuwibara people to ensure that there is appropriate consultation and protection.

Sediment at the Port of Hay Point

Understanding the nature of sediment at the Port of Hay Point is critical to the decision making process around long-term sustainable sediment management options.

Port navigational areas, including shipping channels, aprons and berth pockets, are areas that have been deepened to allow the safe navigation, movement, loading and transit of ships trading at the Port. In these deeper areas of the Port, currents, wave energy and tidal regimes are responsible for mobilising and transporting sediments. This can be different to what is occurring in the adjacent natural seabed areas. The different depths and water movement can cause significant changes in the patterns of sediment scouring and accumulation.

The natural seabed depth at the Port of Hay Point ranges from around 12 m below lowest astronomical tide, (LAT) at the end of the trestles (extending some 3.8 km offshore) with a very gradual slope in natural bathymetry of only 2 to 3 m over a 9 km distance offshore to the end of the departure path. The departure path and apron area is constructed to a designed navigational depth of 14.9 m below LAT, whereas the design depth of the berth areas varies from 16.6 m to 19.6 m below LAT (Table 5).

Table 5: Port of Hay Point declared depths of Port of Hay Point berth areas

	Design Depth (m)	2016 Declared Depth (m)
HPCT Berth 1	16.6	16.3
HPCT Berth 2	16.7	16.9
HPCT Berth 3	19.0	18.8
DBCT Berth 1	19.6	18.1
DBCT Berth 2	19.6	18.1
DBCT Berth 3	19.0	17.9
DBCT Berth 4	19.0	18.0

Accretion of seabed sediments results in ‘high spots’ or ‘high areas’ within the navigational areas, above which safe sailing depths are enforced by the Regional Harbour Master. The result is often reduced ‘declared’ sailing depths (also shown in Table 5), the effects of which may significantly affect the efficiency of the Port.

To identify the opportunities to avoid or reduce the ongoing need for maintenance dredging, and to answer key questions a number of studies were needed that focused on:

- Defining the nature and sources of marine sediments that accumulate in the navigational areas of the Port.
- Describing the forces that drive sediment dynamics at the local, regional and wider Great Barrier Reef lagoon scale.

Nature of the Sediment

Based on laboratory analysis the nature of the sediment accumulating in the navigational infrastructure at the Port of Hay Point was found to be fine clay/silt material with an average of 60%, (with a highly variable range of between 9% in the departure path areas and 80% in the North Apron and DBCT berths), mixed with sand (36%) and small amounts of gravel material (4%) (Advisian, 2016) (see **Appendix J**).

It was noted that the further offshore the higher the sand and gravel content. Also given the mixed nature of the sediment and dominance by fine material, it is considered that it would be unrealistic to be able to separate sediment types during maintenance dredging.. The type and mixture of the sediments is an important consideration when examining the ability to avoid, reduce, reuse or dispose of sediment.

Typical high silt/clay sediment sample from port of Hay Point Navigational Area

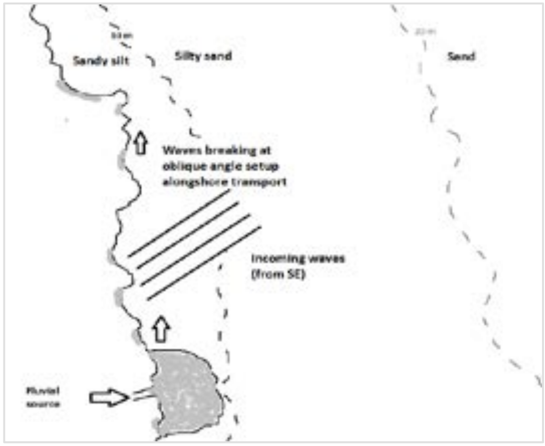
As shown in Table 6, laboratory testing has consistently shown that the sediment is suitable for ocean disposal with very low levels of contamination and bioavailability as per the NAGD (CoA 2009).

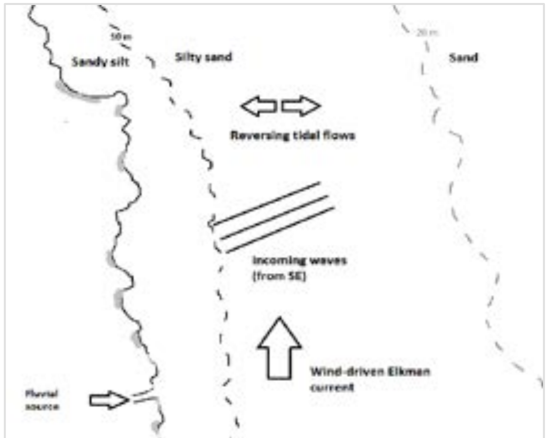
Table 6: Summary result of recent sediment contamination testing at the Port of Hay Point

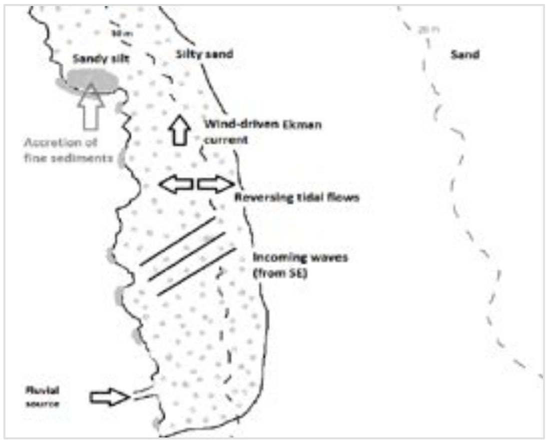
Port area	Dates	Volume	Summary of sampling results
Departure path	May – July 2013	110,000 m^3	TBT below the laboratory detection level Metals, Hydrocarbons, PAHs below screening levels Overall conclusion: suitable for unconfined ocean disposal
Aprons	May – July 2013	110,000 m^3	TBT below screening levels Metals Hydrocarbons, PAHs below screening levels Overall conclusion: suitable for unconfined ocean disposal
Tug harbour	May – July 2013	~37,854 m^3	TBT below screening levels Metals, Hydrocarbons, PAHs below laboratory detection level or screening levels Overall conclusion: suitable for unconfined ocean disposal
HPCT Berth 1	May – July 2012 Nov 2012	30,492 m^3	TBT above screening levels (95%UCL of 15.3 ugSn/kg+). Total sediment, dilute acid extraction, elutriate testing – all below screening levels Metals, hydrocarbons, PAHs below laboratory detection level or screening levels Overall conclusion: suitable for unconfined ocean disposal
HPCT Berth 2	May – July 2012 Nov 2012	32,765 m^3	TBT above screening levels (95%UCL of 30.47 ugSn/kg). Arsenic, copper, lead, zinc above 95%UCL screening values. Total sediment, dilute acid extraction, elutriate testing – all below screening levels Hydrocarbons, PAHs below laboratory detection level or screening levels Overall conclusion: suitable for unconfined ocean disposal
DBCT Berth 1	August 2014	38,500 m^3	TBT reported a 95% UCL of 6.9 ugSn/kg (< screening criteria). Five locations initially reported TBT concentrations above screening. Each sample (original plus the 3 replicates) were averaged and applied to the 95% UCL calculation. All metals remained below the screening criteria. Several individual PAHs were identified, leading to low level total PAHs. 95% UCL of 216 ug/kg and maximum of 1232 ug/kg, well below the NAGD screening criteria of 10,000 ug/kg. Overall conclusion: suitable for unconfined ocean disposal
DBCT Berth 2	July 2014	38,500 m^3	TBT reported a 95% UCL of 1.3 ugSn/kg (< screening criteria). All metals remained below the screening criteria. Several individual PAHs were identified, leading to low level total PAHs. Berth 2 reported a 95% UCL of 149 ug/kg and maximum of 636 ug/kg, well below the NAGD screening criteria of 10,000 ug/kg. Overall conclusion: suitable for unconfined ocean disposal
DBCT Berth 3 & 4	March 2016	58,504 m^3	All analytes below screening levels Overall conclusion: suitable for unconfined ocean disposal

Sediment Budget

An in-depth examination of the sediment transport and dynamics in the central Great Barrier Reef (Gibbs *et al.*, 2016) identified and clarified the major sediment types and distributions in the region. This appears to be the first integrated or consolidate work of its type and has enabled the development of an integrated conceptual model of the sediment transport mechanisms and provides the first estimates of sediment transport rates and fluxes (see **Appendix C**).







This work has shown that the dominant source of sediments accumulating in the navigational areas at the Port of Hay Point are large stores of available sediments on the inner continental shelf which are transported through coastal processes. Cyclones are also known to be a contributing cause of sediment movement and accumulation within the navigational areas of the Port.

Annual sediment transport volumes were estimated using the Mackay wind and wave data, published tidal heights and rates, available grain size data and the 'Sedtran05 1-d model'. The conceptual sediment budget for the Hay Point region was produced using 'ArcGIS' and the 'United States Army Corps of Engineers Coastal Inlets Research Program Sediment Budget Analysis System (SBAS)'. The sediment budget calculations indicate that sediment is generally moving northwards within three defined sediment transportation processes:

- ***Littoral drift*** - littoral transport along the surf zone is one of the major sediment transport pathways on exposed coastlines. The offshore reefs of the GBR act as efficient dissipaters of ocean swells and hence the energy contained in the wave environment by the time it reaches the coast is substantially reduced by comparison to coastal areas south of Fraser Island.

  Fluvial (river) or 'new' sources of fluvial sand inputs, while important, are of a tiny magnitude in comparison to the existing available seabed sources of coarse sediments available for littoral transport.

- ***Nearshore turbidity pathway*** - re-suspension which is not driven by breaking waves but rather the transient orbital flows beneath waves, along with tidal flows, act on the seafloor to create a bed shear stress large enough to mobilise fine sediments. Once mobilised, waves, wind and tidal movements transport the finer particles northwards along the coastline.
- ***Inner-shelf bed load transport*** - Larger waves (~ 1 m) and stronger tidal currents (> 0.25 m/s) are able to re-suspend larger sand particles. As in the turbidity pathway, once the bed shear stress is sufficient to mobilise sand particles, a near bottom current flow is required to generate the transport of material. The wind generated water movements established during prolonged wind events, the same winds that generated the waves, are able to mobilise the sands and transport these northwards.

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The model indicates that the volume of sediment deposition (storage) is relatively small compared to the overall volume of sediment moving within the system. In areas where there is high tidal activity or where fluvial currents are strong and dynamic, much higher gravel content is found in the sediment than in other areas where sand, carbonates, or muds are more prevalent.

As a result, the system is considered balanced, meaning almost the same volumes of sediments that are entering a location are leaving, other than in an area of sand accumulation well to the north of Mackay.

When investigating the contribution of catchment derived sediments in consideration of reducing sedimentation in the Port area, the model proposes that reducing fluvial sources of sediment through in-catchment sediment control measures will result in very little reduction in sediment accumulation.

The analysis shows that even if catchment management measures were successful in reducing river sediment discharge by 50%, the reduction in sediment to the navigational areas at the Port of Hay Point would only be in the order of 0.1% and 4% of total sediment inputs.

Sediment accumulation within the Port

To better understand exactly where sediment accumulates and in what quantities with the Port's navigational areas, an examination was undertaken of the historic siltation in the channel, apron and berths at the Port of Hay Point (Symonds & Donald, 2016; Symonds & Loehr, 2016) (see **Appendix D and E**).

The work was designed to:

1. Provide quantitative changes in bathymetry since the completion of the capital dredging work in October 2006.
2. Analyse the cause and reasons behind any changes.
3. Develop a predictive tool for use in future sediment management decision making.

Coastal processes were defined using a wide range of hydrodynamic, meteorological, water quality and sedimentation data. Some of the key findings around coastal processes are shown in Table 7.

Table 7: Coastal processes and site conditions at the Port of Hay Point

Tides	• The Port is located in an area of the Queensland coast that experiences very high tidal ranges, with semi-diurnal tides and a peak tidal range of 7.14 m (MSQ, 2015).
Wind Climate	• Local wind climate is governed by the east to south east trade winds, with lighter land breezes from the south-west sector during the winter months and lighter north-easterly afternoon sea breezes common during summer afternoons.
Wave Climate	• The Port is largely protected from swell waves as a result of the GBR and islands. • Large open fetch to the south east and predominant south easterly trade winds dominate the local wave direction.
Current Regime	• Water currents at Hay Point are predominantly driven by the large astronomical tides with tidal currents in excess of 0.5 m/s measured adjacent to the berths. • Measured data at the port suggests that the ebb tidal currents to the north-west are slightly stronger than the flood currents to the south-east, • Predominant south easterly trade winds act to reinforce the net northerly tidal current.
Rainfall / Fluvial Flows	• The major catchment areas discharging nearby to the port include the Pioneer River (approximately 17 km to the north-west) and Plane Creek (approximately 14 km to the south) with both playing a role in the delivery of sediments to the marine environment.
Cyclones	• Recent notable cyclones include TC Ului (March 2010), TC Dylan (January 2014) and TC Debbie (March 2017).
Water Quality	• Concentrations of suspended sediment in waters adjacent to the Port are predominantly driven by bed sediments being suspended through current and wave action. • During the summer months higher suspended sediment concentrations occur compared to the winter months (16.6 mg/l compared to 6.6 mg/l) as a result of stronger winds and the increased occurrence of higher energy waves from cyclones and storm events.
Deposition	• It is evident from data collected nearby to Hay Point (JCU, 2014-2015) that periods of elevated suspended sediment result in subsequent peaks in deposition. • Deposition at Hay Reef does not occur regularly over time, rather it is a periodic event. • Hay Point is not an accretional environment, with deposition typically only occurring following resuspension of existing bed sediment during specific events.
Sediment Properties	• Areas of the North Apron and DBCT berths exhibit the highest percentages of silt and clay with 80% of the sediment being made up of finer fractions (silts and clays).

Hydrographic survey data of the Port of Hay Point apron, departure channel and berths (MSQ 2003 to 2015) was used to inform the bathymetric changes in the navigational areas of the port.

Figure 12 shows the cumulative change in bathymetry since development of the apron and departure path in 2006.

The majority of the bathymetry is still below the design depth of 14.9 m below LAT, indicating that, generally, limited erosion (blue areas) has occurred over the apron and channel areas during this 10-year period.

The most extensive siltation (red areas) has occurred in the North Apron, with some localised accretion also occurring in the gap between the DBCT and HPCT berths.

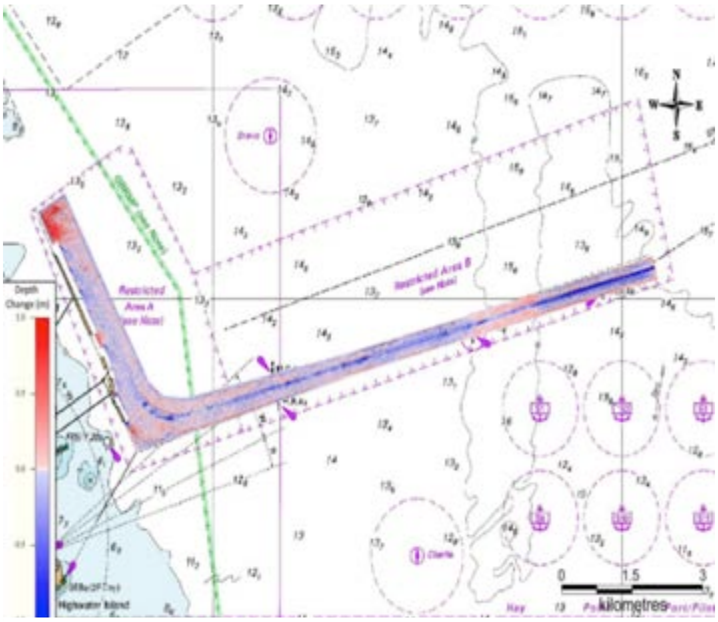

Figure 12: Difference in bathymetry (February 2007 to October 2015) red represents areas of accretion and blue areas of erosion

A clear deepening along the centreline of the departure channel up to the southern corner of the apron with the erosion being most pronounced in the Outer Channel area. This centreline deepening is assumed to be a result of localised erosion due to propeller wash from the larger vessels departing the port fully laden (and so the propeller is closer to the seabed), although there is a low level of accretion either side of the erosion in the centre of the channel and apron.

The largest accretion in this area has occurred in the natural deep trench located in the Mid Outer Channel where accretion of up to 0.4 m has occurred, although the area is not expected to fill or interfere with navigational depths.

Extreme events that result in strong winds and large waves, such as tropical cyclones, have the potential to result in relatively large changes to the seabed bathymetry. Two[2] significant tropical cyclones (TC) occurred during the period of analysis 2006-2015, TC Ului in March 2010 and TC Dylan in January 2014. Both cyclones resulted in similar wave conditions at the Port of Hay Point, although the bathymetric changes were significantly different.

TC Ului did not appear to result in any significant change in the bed elevation, whereas TC Dylan resulted in erosion of between 300,000 and 725,000m^3 (the large range is due to possible bias with a survey) of the apron and departure channel, with average erosion depths of between 0.1 and 0.2 m across the navigational area.

The only navigational areas in the Port of Hay Point that showed discrete patterns of sedimentation where the northern apron and berth pocket areas. Figure 13 shows reasonably uniform sedimentation rates in each of these areas, allowing for better predictability in modelling future maintenance needs. Due to the high trapping efficiency of the berths, resulting from their depth relative to the adjacent bed elevations, these areas are able to trap more fine grained silts and clays than the apron and departure channel.

The variation from cyclone to cyclone highlights how difficult it is to predict potential impacts of an extreme event.

[2] Subsequent to the preparation of this report, but prior to going to final print, a third cyclone TC Debbie in March 2017, caused significant sediment disruption and movement resulting in the deposition of sediment in the Port of Hay Point. See Appendix D2.

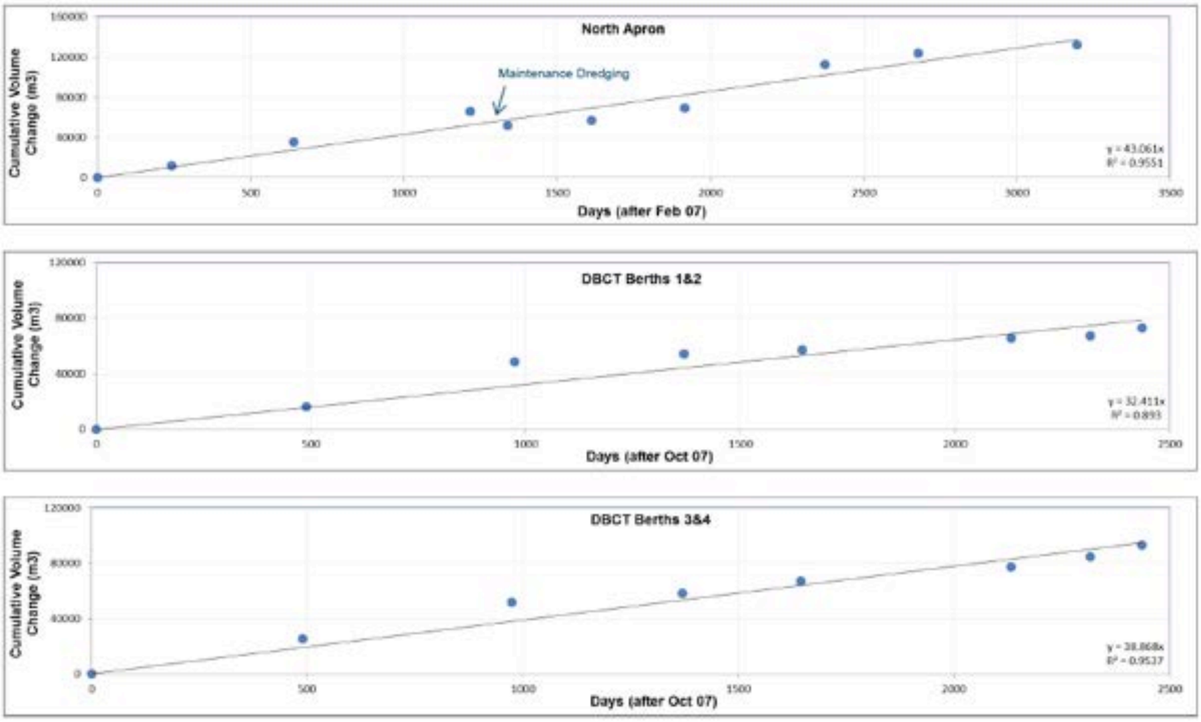

Figure 9: Siltation over time at northern apron area and DBCT berth pockets

Based on analysis of the most recent hydrographic data (October 2015)[3] the current maintenance dredging requirements at the Port of Hay Point to re-establish design depths are:

• Apron and departure path	59,300 m^3
• DBCT berths	139,800 m^3
• HPCT berths	6,700 m^3
• **Total re-establishment volume**	**205,800 m^3**

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Total siltation volume above the design depth over the next 20 years was predicted to be between 885,000 m^3 and 1,129,000 m^3 depending on the occurrence of tropical cyclones.

Given the varying rates of accumulation across the Port it can be expected that dredging of critical areas will be needed approximately every 3 years if designed depths and port efficiency is to be maintained. Volumes may vary between 200,000 m^3 and 270,000 m^3 if no sedimentation reduction measures are adopted.

[3] Subsequent to the preparation of this report, but prior to going to final print, a third cyclone TC Debbie in March 2017, caused significant sediment disruption and movement resulting in the deposition of sediment in the Port of Hay Point.

The effects of sedimentation on Port operations

Before exploring the alternatives for dredging and or sediment reduction, it is important to provide some appreciation of the potential affects sedimentation may have on operations at the Port of Hay Point. In addition, an economic analysis of potential impacts resulting from loading delays has been developed.

Today's 175,000 – 200,000 DWT vessels are favoured by coal buyers and draw between 17.5 m and 18.2 m of draft when fully loaded. If Port navigational depths are reduced the coal terminals at Hay Point may not be able to accommodate a vessels fully loaded, which can result in either:

- A reduction of the maximum cargo exported per ship.
- Delays in the vessel's loading, possibly resulting in loading not being finished in time for the vessel to sail on necessary high tide.

Delays to a vessel's loading sequence not only affects that particular vessel, but also has a consequential flow on effect on other vessels waiting to berth. These consequences flow along the supply chain as the coal 'buyer' will often need to extend the vessel's charter hire (increasing the cost of the sea freight), and the 'miner', may be exposed to increased demurrage which occurs when the vessel takes longer to load than the sales contract allows (see **Attachment F** for a detailed analysis of the impacts of sediment on Port operations).

A vessel's 'Plimsoll Line' (Figure 14) will indicate how far the vessel can be immersed to sail safely in the ocean. However, any navigation in a shallow restricted waterway requires an extra tolerance between the shallowest part of the channel and the deepest part of the immersed ship. This tolerance gap is known as "Underkeel Clearance" (UKC) and must take into account tidal changes across the length of the channel as well as wave conditions that may affect the position of the deepest part of the vessel, relative to the sea bed.

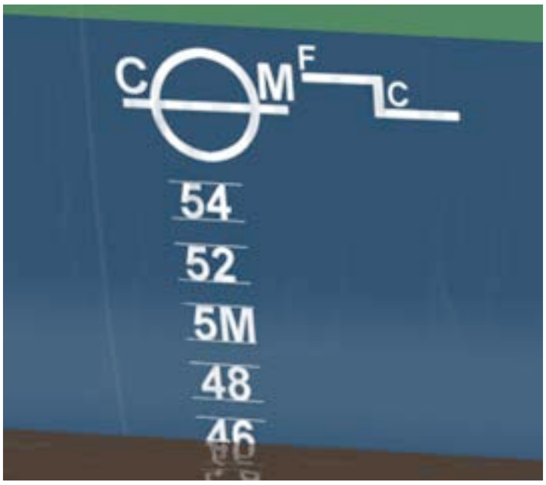


Figure 14 Plimsoll line on a vessel

The Port of Hay Point operates on a Dynamic Underkeel Clearance (DUKC) system that calculates the most efficient sailing drafts for vessels based on the current and upcoming tide. When alongside the berth, a vessel must maintain a minimum of 1.5 m UKC.

Siltation in berth pockets results in a reduction of clearance under the ships keel as loading progresses. Tidal and weather predictions, coupled with loading rates and ship characteristics, allow numerical models to determine if the designated clearance will be breached during vessel loading. A predicted breach of the UKC will cause "stop loading" delays to maintain a safe distance between the bottom of the ship and the seabed.

Where siltation has occurred, as the tide falls during loading operation the terminal will be forced to stop the loading and wait for the rising tide to ensure preservation of the minimum underkeel clearance. This delay has a variety of possible impacts from extending the loading time (increasing demurrage) to short-loading the ship to meet the tide, thus reducing sales revenue and royalties.

Figure 10 provides a useful summary of the direct and indirect effects of this occurring.

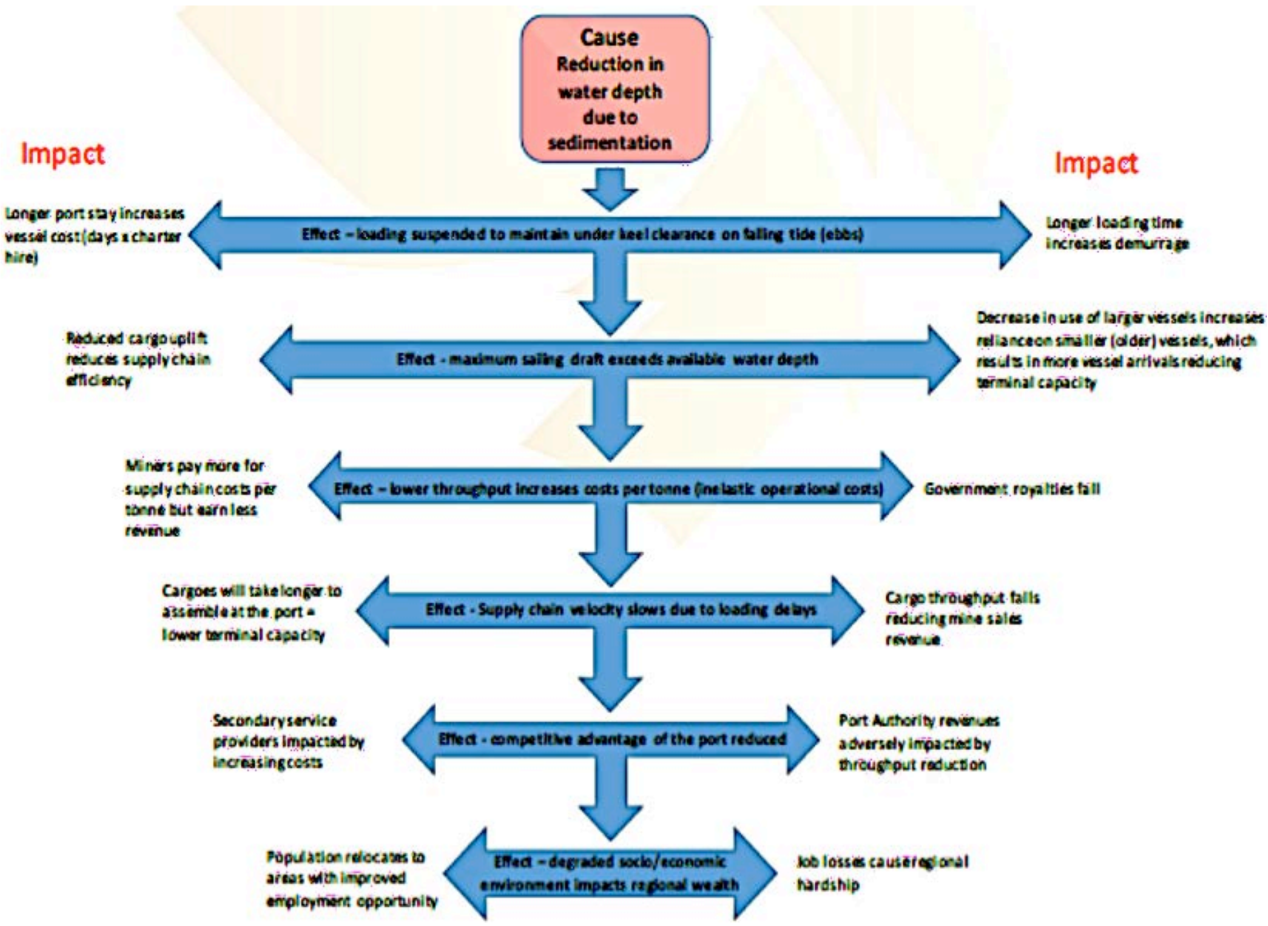


Figure 10: Cause and effect diagram of reduced water depth due to sedimentation

ECONOMIC IMPACTS OF SEDIMENTATION

Revenue from the export facilities at the Port of Hay Point is based simply on tonnes loaded into a vessel and the price of coal (DBCT, 2016) (**Appendix G**). One way of estimating lost revenues can be calculated using the variance in 'spot price' of coal. The variation in coal prices for the period December 2007 to April 2015 is as follows.

Table 8: Coal prices

Coal Type	Hay Point Export Proportion	Lowest Price	Highest Price
Thermal (Energy)	20%	$70.75	$198.65
Coking (Metallurgical)	80%	$104.50	$426.50

Using these details, along with the lost terminal capacity resulting from delays, the potential revenue losses as a result of increasing siltation can then be calculated. These calculated losses are shown for DBCT in Figure 11. Revenue losses clearly start to occur at berth pocket depths of 18m-LAT. At 16m-LAT revenue losses in the order of $500 million per year to $2,500 million per year can be predicted, whilst at 14.5m -LAT the losses could be expected in the order of $1,000 million per year to $4,500 million per year.

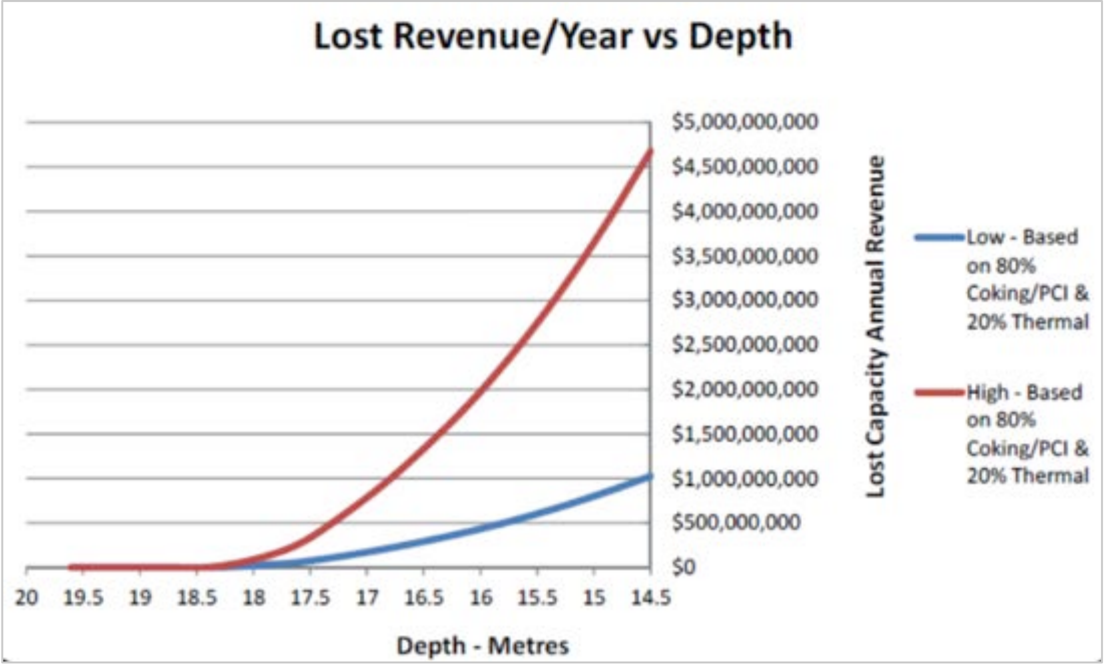


Figure 11: Calculated lost revenue resulting from decreasing berth pocket depths and associated loading delays

In addition to revenue losses, an estimate of potential losses to State royalties can also be calculated, this is shown in Figure 12.

State Government royalty fees ranged in value from $4.95/Tonne for the lowest price thermal coal to $54.65/Tonne for highest price metallurgical coal. At 16m-LAT losses are in the order of $50 million per year to $250 million per year, whilst at 14.5m-LAT this increases to between $100 million per year to $600 million per year.

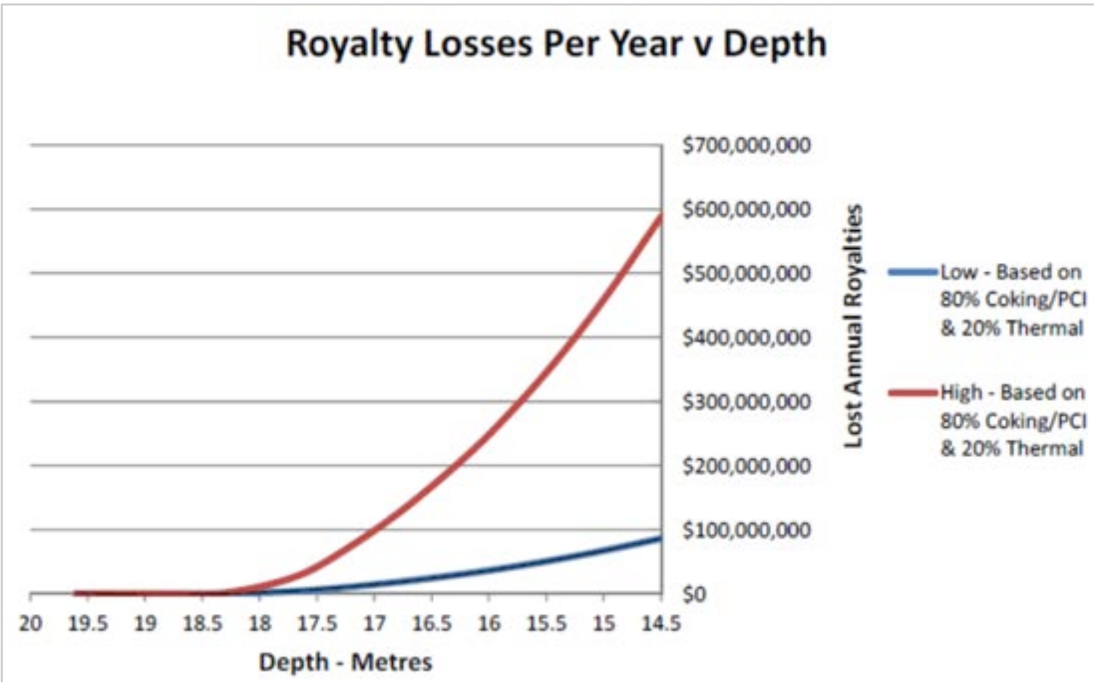


Figure 12 ***Calculated lost State royalties resulting from decreasing berth pocket depths***

FINDINGS

As one of Queensland's major ports supporting a major industry the potential losses outlined above are not acceptable. Sedimentation within the Port of Hay Point needs to be managed to avoid this situation occurring.

Alternatives for avoiding or reducing the need to dredge

Based on the conclusion in the previous chapter that the sedimentation within the Port of Hay Point needs to be managed, the first approach is to consider possible alternatives to avoid or reduce sedimentation occurring within the navigational areas of the Port.

Avoiding or reducing the volumes or rates of sedimentation is seen as the first and possibly ideal way to manage sediments in the Port area. The key aims of this investigation were to:

1. Describe the sediment and hydrodynamic environment at the Port of Hay Point in the context of possible solutions to 'keep sediment out' or 'keep sediment moving' from the Port infrastructure areas.
2. Identify both engineered and technological solutions to avoid or minimise future maintenance dredging and consider their feasibility based on the Hay Point environment, port layout and infrastructure design.
3. Undertake a constraints analysis of the solutions for any feasible alternatives.
4. Estimate the potential impact of any feasible solutions to existing and future maintenance dredging at the Port of Hay Point.

Appendix H provides the detailed report of the investigation into the different avoidance and sedimentation reduction options.

The potential applicability of approaches to reduce sedimentation must be considered on a case-by-case basis as the suitability is dependent on the port configuration, sediment type, natural environment and processes. Three broad strategies that can be implemented to reduce siltation at ports and harbours are:

- **Keep Sediment Out** – keeping sediment out of the area of interest that might otherwise enter and deposit.
- **Keep Sediment Moving** – raising flow velocities in quiescent areas to prevent sediment from settling as it passes through the area of interest.
- **Keep Sediment Navigable** – applicable to sites characterised by high turbidity near-bottom sediment regimes where navigability of fluid mud zones is permitted, thereby reducing the required dredged depth.

The range of approaches is provided in Table 9.

Table 9: Outline of approaches to avoiding or reducing sedimentation

Strategy	Approach	Example
Keep Sediment Out	Control sediment sources	Reduce sediment inputs through better catchment management
	Divert sediment-laden flows	Divert river inputs away from port
	Trap sediments before entering port	Sediment traps and insurance trenches
	Blocking sediment entry	Pneumatic barriers, silt screens, barrier curtains
	Habitat creation	Seagrass, saltmarsh, mangroves to stabilise and promote accretion away from port areas
Keep Sediment Moving	Structural solutions to train natural flows	Training walls to divert flow and prevent local deposition of sediment.
	Devices to increase bed shear stresses	Hydraulic jets, mechanical agitators
	Methods to reduce sediment flocculation	Adopting designs that reduce turbulence and therefore flocculation (e.g. solid wharf walls instead of piling supported wharfs).
Keep Sediment Navigable	Adopt a 'nautical depth' navigation approach which includes fluid mud	Nautical depth is the distance from the water surface to a given wet density, typically in the range of 1,100 to 1,300 kg/m^3.

The investigation showed that many of the alternatives were simply not achievable in an offshore coastal port such as the Port of Hay Point, many being more suited to ports located in rivers, estuaries or enclosed by breakwalls or similar structures.

The alternatives that were considered achievable at the Port of Hay Point included:

- Traditional maintenance dredging.
- Constructed sediment traps.
- Installation of ***Jet Arrays.***
- Using a ***drag bar*** or ***sea rake*** to mobilise the seabed sediments within berth areas.
- The use of propeller wash agitation.

For each of these alternatives, as well as for traditional maintenance dredging, an estimate of the associated costs and greenhouse gas emissions (tonnes/CO^2_{eq}) was calculated. In addition, a constraints analysis for each of the alternatives has been developed to get a high level understanding of environment impacts, operational impacts, ongoing maintenance requirements, the confidence in achieving the desired outcomes and consideration of the regulatory pathways or approvals. A summary of findings is provided in Table 10.

Table 10: Constraints analysis for each of the reduction alternatives

Approach	Environment Impacts	Operational Impacts	Ongoing Maintenance	Confidence	Regulated Activity	Cost (M$)	GHG emissions (tonnes/CO^2_{eq})
Maintenance Dredging	Low	Low	No	High	Yes	4.9	6,369
Sediment Trap	Low	Low	Low	Medium	Yes	6.6	8,860
Jet Array	Low	Low	High	Low	Yes	70.9	242,214
Drag Barring	Medium	Medium	No	High	No	6.8	21,454
Propeller Wash Agitation	Low	Low	No	Medium	No	13.2	23,640

FINDINGS

An important finding of this investigation was that out of all the alternatives considered, only traditional maintenance dredging would be successful in the removal of the existing material that has accumulated in the Port of Hay Point navigational areas.

The other key findings of the reports are:

- **Traditional maintenance dredging** provides the most cost effective and lowest GHG emission solution, and there are defined approval pathways.
- **Drag barring** or **sea raking** in the berths is a feasible solution to prevent ongoing high accretion rates. Application of this approach in the berth areas could extend the period between maintenance dredging activities from 3 to 5 years (approximately). It is not expected that drag barring would be as effective in other navigational areas of the Port or for removal of consolidated sediments within the berth pockets.
- **Propeller wash agitation** by tugs is not a feasible solution for managing the siltation. It has been considered that operational changes to the manoeuvring of ships and tugs during berthing activities, could assist in mobilisation of seabed sediments in the north apron area and would have little to no cost or increased GHG emissions. Such activities would have minimal impacts on water quality due to their short duration and localised mobilisation of sediments. Neither option offers a complete solution to sedimentation.
- Only the northern Apron area would benefit from a **sediment trap**, by deepening the northern apron area to act itself as a sediment trap. The solution could reduce the frequency of the required maintenance dredging in the northern Apron from every four years to every 10 years. However, it would result in an increase in the dredge volumes of 160,000 m^3 over a 20 year period due to the initial establishment dredging required.

- Excluding the northern apron from the declared navigational area could reduce maintenance dredging by 260,000 m^3 over a 20 year period. However an analysis of the vessel tracking data to see what current usage of the northern apron area looks like (Figure 13) shows that most of the apron area is used in the manoeuvring and transit of ships at the Port of Hay Point, and as such the northern apron area could not be excluded.

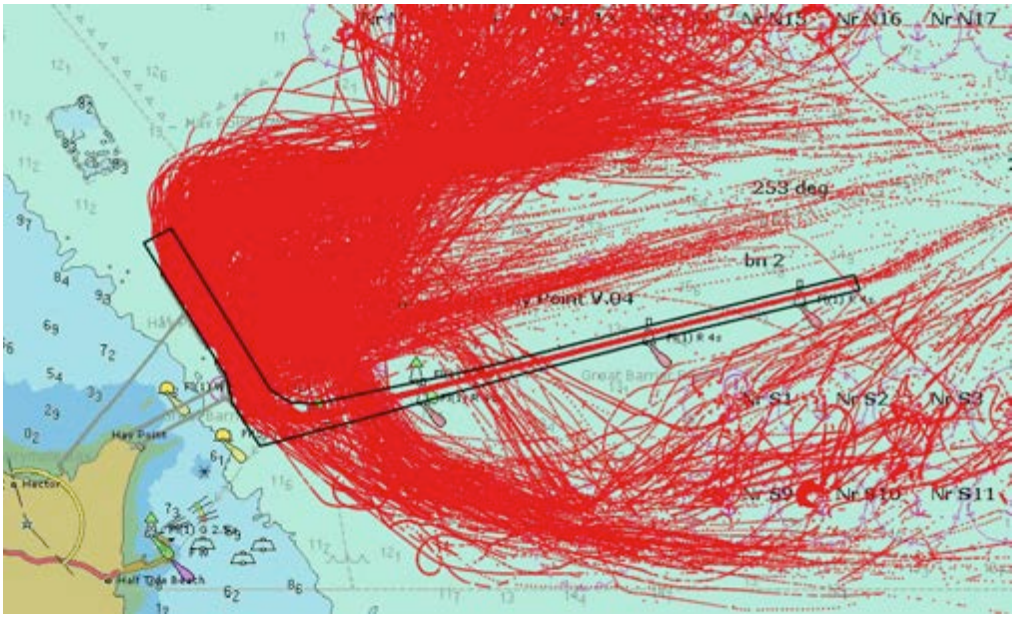


Figure 13: Example of vessel track data from January to June 2015

Accordingly, based on theses findings it is recommended that continued operational measures be employed to reduce sedimentation and extend the period between maintenance dredging activities (from a predicted 3 year interval to potentially 5 yearly). Most effective in this regard will be to continue to drag bar/sea rake the berth areas and the varied alignment of vessel movements with in the departure path, offset from the centre line.

Sediment reuse or placement solutions

Eliminating the need to conduct maintenance dredging at the Port of Hay Point is not a feasible option if Port operations and safety are to be maintained at efficient levels. Accordingly determining the most suitable use or placement location for any dredged material is essential.

It is expected that maintenance dredging of around 200,000 m^3 will be required approximately every five years for the foreseeable future, depending on cyclonic effects. In comparison to other ports in Australia, this amount and timeframe between maintenance dredging campaigns is on the lower end of the spectrum. Maintenance dredging volumes in Australian ports over the past decade ranged from less than 10,000 m^3 to as much as 1.3 Mm^3. For example, the Port of Brisbane requires annual maintenance dredging with volumes ranging from 450,000 m^3 to 1.3 Mm^3 per year (HaskoningDHV, 2016). Port Hedland requires the removal of 114,000 m^3 to 730,000 m^3 every 3 to 4 years (Ports Australia 2014).

Unlike routine maintenance dredging volumes that can be predicted and managed routinely, the management of sediments accumulated in navigational areas from tropical cyclones is much more challenging. Volumes of sediment accumulated within channels or berths from cyclone activities may be significantly larger than predicted maintenance dredge volumes. The Port of Townsville required removal of ~814,000 m^3 in 2011 from channels and berths following the passage of Tropical Cyclone Yasi. This was significantly higher than its usual annual maintenance dredging requirement, which ranged from ~115,000 m^3 to ~500,000 m^3 over the last decade (HaskoningDHV, 2016). There is therefore potential that the total quantity of predicted maintenance dredging volumes at the Port of Hay Point could suddenly and significantly increase as a result of cyclone activity.

The majority of the material to be dredged from the Port is fine clay/silt material (60%), mixed with sand (36%) and small amounts of gravel material (4%). Given the mixture of sediment type, dominated by fine material, which has accumulated in relatively confined areas, it is considered that it would be impractical to separate sediment types during dredging for alternate use or placement options.

In line with both the waste hierarchy and the NAGD (CoA 2009) it is essential that an examination of reuse or recycle options is undertaken before considering disposal or placement options. To achieve this and to look at the most appropriate solutions for reuse of any maintenance dredging material a comprehensive reuse assessment investigation has been undertaken (refer to **Appendix I**).

Beneficial reuse assessment

In identifying potential beneficial reuse options a number of analyses and considerations are relevant in determining if an option is viable and feasible. Factors considered were:

- Sediment suitability (Sed. Suit).
- Greenhouse gas emissions (GHG's).
- Opportunity or demand (Opp).
- Conceptual cost (Cost).
- Confidence in beneficial reuse process (Process).
- Duration from construction to use (Duration).
- Environmental implications (Enviro).
- Socio-economic implications (Social and Econ).
- Environmental approvals (A&P).
- Constraints (Constr).
- Knowledge gaps (requiring research) (Gaps).
- Longevity of the beneficial reuse option (Future).

One of the primary considerations is the physical and chemical properties of the sediment to be dredged. The analysis of the geotechnical properties of the material to be dredged shows that the sediment is:

- Free of contamination.
- Likely to contain high plasticity clay.
- Likely to have very high moisture content, and therefore significant effort would be required to dry out the sediment.

- Likely to have very low to medium compressibility and have some potential to swell and shrink, making it unsuitable for heavy load bearing uses.
- Is likely to be potential acid sulfate soil (PASS); however the sediment contains sufficient acid neutralising capacity to buffer inherent acidity to negligible concentrations and as such are unlikely to require ASS treatment.

The next stage of assessment comprised:

1. Identification of potential beneficial reuse options.
2. Analysis of the opportunity, potential feasibility and achievability of the options in the context of the Port of Hay Point.

Each option was assessed against a performance evaluation key (Table 11) that defined what high, moderate and low performance consisted of for each performance criteria.

Table 11: Performance evaluation criteria (Advisian 2016)

Performance criteria	HIGH PERFORMANCE	MODERATE PERFORMANCE	LOW PERFORMANCE
Opportunity	There is an existing demand in a location accessible to the Port of Hay Point, requiring minimal infrastructure needs	Potentially a demand reasonably accessible to the Port of Hay Point, requiring infrastructure construction	No demand identified, poor access to the Port of Hay Point, requiring extensive infrastructure construction
Sediment suitability	Reuse option well suited to the dredge material. Requires no additives or treatment (other than dewatering if necessary)	Reuse option potentially suited to the dredge material. Requires treatment, processing and/or additives to make material suitable	Reuse option poorly suited to the dredge material. Requires substantial treatment, processing and/or additives to make material suitable; or treatment to a suitable level is considered un achievable
Cost	Less than \$10M in a 5 year period	\$10M to \$17M in a 5 year period	More than \$17M in a 5 year period
Process	The proposed process is well understood and clearly demonstrated in similar environments to the Port of Hay Point using maintenance dredge material	The proposed process is sound but there are few examples of it being applied in environments similar to the port of Hay Point using maintenance dredge material	The proposed process is mostly unproven
Duration	Less than 1 year to construct and function as the proposed final use	1 to 3 years to construct and function as the proposed final use	Greater than 3 years to construct and function as the proposed final use
Greenhouse Gas Emissions (GHGs)	<2500t CO_2 equivalent in 5 year period	>2500t and <5000t CO_2 equivalent	>5000t CO_2 equivalent
Environmental implications	Net benefit opportunities exist for positive environmental outcomes with manageable nuisance of harm issues	Nuisance or harm issues identified, but for the most part are considered manageable	Nuisance or harm issues unlikely to be easily managed
Social implications	Positive social opportunities exist for local communities and other key user groups	Social effects for the most part are considered manageable	Negative social impacts are unlikely to be easily managed
Economic implications	Positive economic opportunities exist enhancing port or	Limited economic opportunities exist enhancing port of	Lost or negative economic opportunities to enhance port or community

Performance criteria	HIGH PERFORMANCE	MODERATE PERFORMANCE	LOW PERFORMANCE
	community capability	community capability	capability
Approvals and Permits	Recognised approvals pathway with few management issues identified	Recognised approvals pathway with significant management issues identified	Not supported but current legislation. Policy or would require high level offset considerations
Constraints	There are few constraints which are for the most part considered manageable	Constraints are identified and there is a degree if uncertainty in the ability to overcome or manage them	Multiple constraints are present that would limit realistic implementation
Knowledge Gaps	There are few knowledge gaps and less than 1 year of further research work would be required to progress the reuse option	There are multiple knowledge gaps and 1-3 years of further research work would be required to progress the reuse option	There are multiple and/or complex knowledge gaps and greater than 3 years of further research work would be required to progress the reuse option
Future considerations	The reuse option provides a long term solution for the Port of Hay Point for a period greater than 10 years	The reuse option would cater for immediate needs and has some scope in the short term (several years) although options would need to be regularly reassessed	The reuse option has only a single or limited application

A summary of the assessment finding and ranking for each of the options (against the performance evaluation criteria as shown in the table above) investigated is provided in Figure 14.

The full Beneficial Reuse Assessment report is at **Appendix I.**

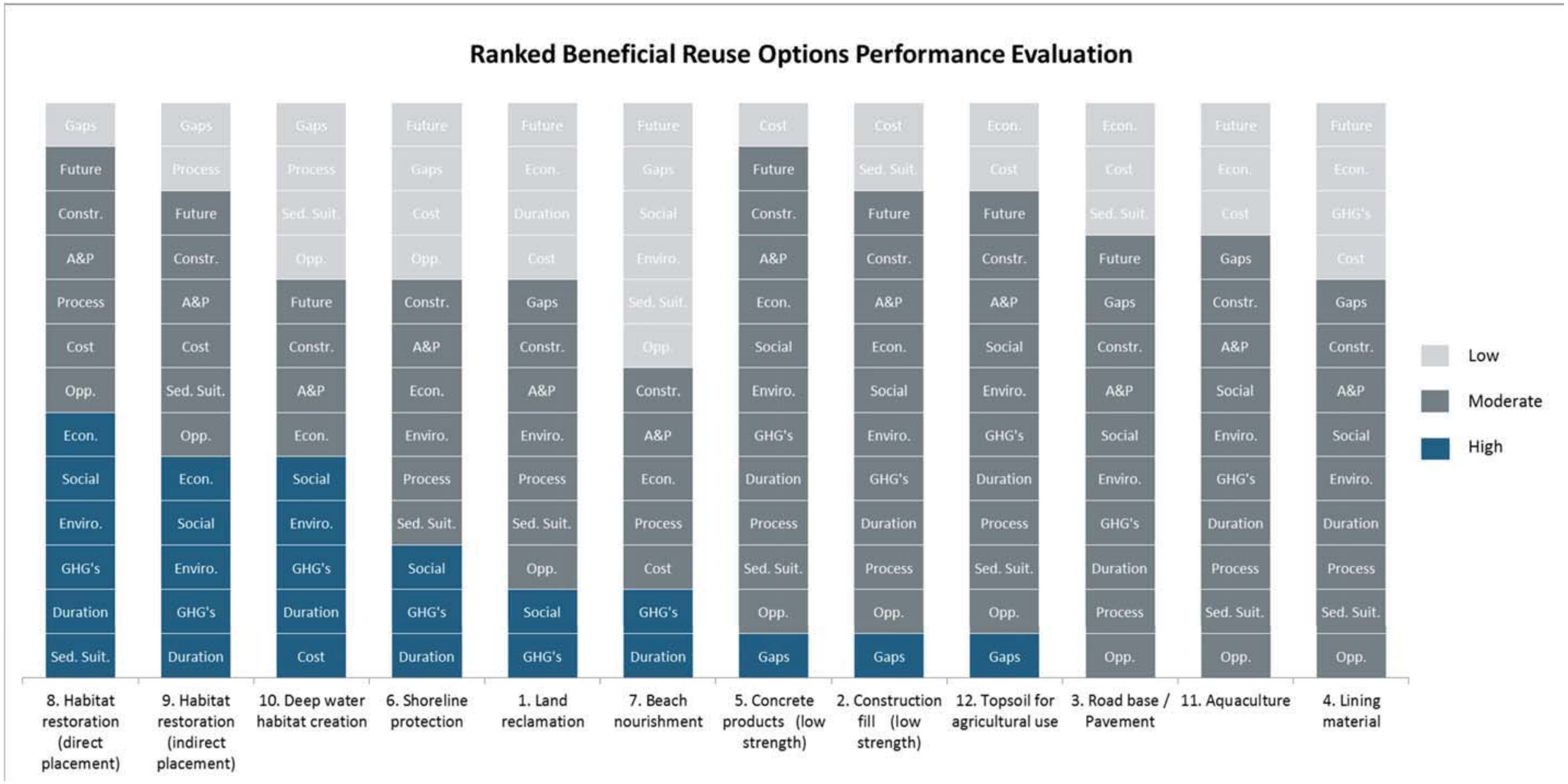


Figure 14: Performance evaluations of beneficial reuse options[4]

[4] Note: Habitat restoration (direct placement): sediment is pumped ashore to create artificial environmental bunds; Habitat restoration (indirect placement): sediment is 'fed' into natural currents and sediment transport systems to increase the volume of natural siltation rates, and creates habitat such as mudflats.

BENEFICIAL REUSE OUTCOMES

From the higher ranked options shown in Figure 14, two broad options have been selected for further consideration, these are 'Habitat rehabilitation' (combining direct and indirect placement) and 'Land reclamation'. These options were selected as they ranked highly on the primary consideration of sediment suitability and also were considered to have high or moderate demand /opportunity. While all factors are seen as important, these two factors were used to narrow the options as they are factors that cannot be controlled, managed or altered by NQBP. All other factors can be managed or influenced to some degree.

The two other highly ranked options of deep water habitat creation and shoreline protection have been discounted as the opportunity and need for these are not clearly identified in the Hay Point-Mackay area.

From these two selected beneficial reuses, three alternatives have been developed based on likely suitable locations where the opportunity is know to present, these are:

1. Land reclamation - Port of Hay Point.
2. Land reclamation - Mackay Harbour.
3. Habitat (mangrove) rehabilitation - Sandringham Bay.

These alternatives were identified based on the following:

Port of Hay Point land reclamation - the master plan for the Port of Hay Point contemplates a small reclamation area (approximately six hectares) within the Half Tide Tug Harbour. This reclamation area within the master plan has been identified to accommodate heavy lift of materials to support future port development. An immediate need for such an area is not apparent at this time.

Mackay Harbour land reclamation - the land use plan for the Port of Mackay identifies proposed future strategic port land, including a small reclamation area (approximately 16ha) adjacent to the existing north harbour wall. The reclamation area within the land use plan was identified in order to accommodate heavy lift of materials, including break bulk cargo, to support future port operations.

Sandringham Bay habitat rehabilitation - within the region mangrove dieback was observed up to 2002 which affected greater than 30 square km of mangroves in at least five adjacent estuaries of the Pioneer River. The mangrove species that were most adversely impacted is *Avicennia marina*. It is notable that there have previously been activities targeted at the rehabilitation of mangroves in Sandringham Bay. Additionally, an area of degraded mangroves habitat has been identified on the boundary of port land at Dudgeon Point within Sandringham Bay.

Placement Alternatives

Additional to the reuse analysis, a number of material placement alternatives and locations were identified.

A number of studies were undertaken to identify potential locations for the placement of dredge material from the Port of Hay Point. These studies included examination of options for both maintenance dredging material and material from capital dredging projects, including:

- Spoil Ground Site Selection – Port of Hay Point (WBM 2004a).
- Assessment of Land Disposal Options for Dredge Spoil at the Port of Hay Point (WBM 2004b).
- Dredge Spoil Disposal Options Assessment Hay Point Coal Terminal Expansion BM Alliance Coal Operations Pty Ltd (Connell Hatch 2009).
- Literature Review and Cost Analysis of Land-based Dredge Material Re-use and Disposal Options, Revision 2.4, (SKM 2013 for GBRMPA Strategic Assessment).
- Dudgeon Point Coal Terminals Project: Dredge Material Relocation Options (Worley Parsons 2012).
- Maintenance Dredging Management Plan Port of Hay Point (Worley Parsons 2013).

Investigations for land disposal at Hay Point and Dudgeon Point indicated that all terrestrial areas are highly constrained due mainly to a combination of existing or proposed uses, existing environmental values, steeply sloping terrain and/or potential impacts on nearby residential uses. Previously, no land at Hay Point had been identified as having any potential suitability for dredge spoil disposal.

All previous studies were conducted on the basis that the likely volume of material to be dredged (maintenance or capital) would be large and potentially in excess of 1 million m^3. Following work undertaken as part of the SSM Project the exact volumes and maintenance dredging requirements have been revised downwards considerably, with a current volume requirement of around 200,000 m^3, with a similar volume every 5 years.

While available land to accommodate such a volume does not exist at Hay Point there is land owned by NQBP and zoned as Strategic Port Land at Mackay Harbour that could potentially be suitable. Additionally, previous studies had also been under the assumption (true at the time) that Strategic Port Land at Dudgeon Point was constrained by future port development requirements, in particular for the Dudgeon Point Coal Terminals Project. The Dudgeon Point Coal Terminals Project is no longer proposed in its current form, potentially freeing up an area of suitable land.

The amount of land required to adequately contain the initial 200,000 m^3 of material onshore and decant the excess water used to pump the material is approximately 50 ha. Review of potential onshore placement sites was undertaken considering:

- Location of the site to minimise potential impacts on ecologically sensitive areas, both for the placement location and the pipeline route from dredge area to placement site.
- Proximity of the site to a watercourse for returning waters.
- Location of a sufficiently large area and generally level, yet as close as possible to deep water to allow a dredge to access within 1,500 m of the site to facilitate pumping.

Additionally, a number of offshore placement locations have been considered in the past, of these three were selected for consideration. These were selected on the basis that:

- One is the existing placement area that has been used at the Port for a number of years with success, monitoring has shown very low levels of environmental impact.
- A mid shelf option in deeper water less influenced by tides and currents and well away from known inshore sensitive environments.
- A third option beyond the eastern limits of the Great Barrier Reef WHA and Marine Park, well away from sensitive environments and internationally listed areas.

In total eight (8) alternatives for sediment reuse or placement have been identified and included in the comparative analysis, these are:

REUSE

1. Land reclamation - Port of Hay Point.
2. Land reclamation - Mackay Harbour.
3. Habitat (mangrove) rehabilitation - Sandringham Bay.

ONSHORE

4. Onshore pond at Dudgeon Point.
5. Onshore pond at Mackay Harbour.

OFFSHORE

6. Existing offshore dredge material placement area.
7. Mid-shelf offshore dredge material placement area.
8. Coral Sea offshore dredge material placement area.

Figure 15 shows the likely locations of the eight beneficial reuse and disposal alternatives. A summary of each option is provided below.

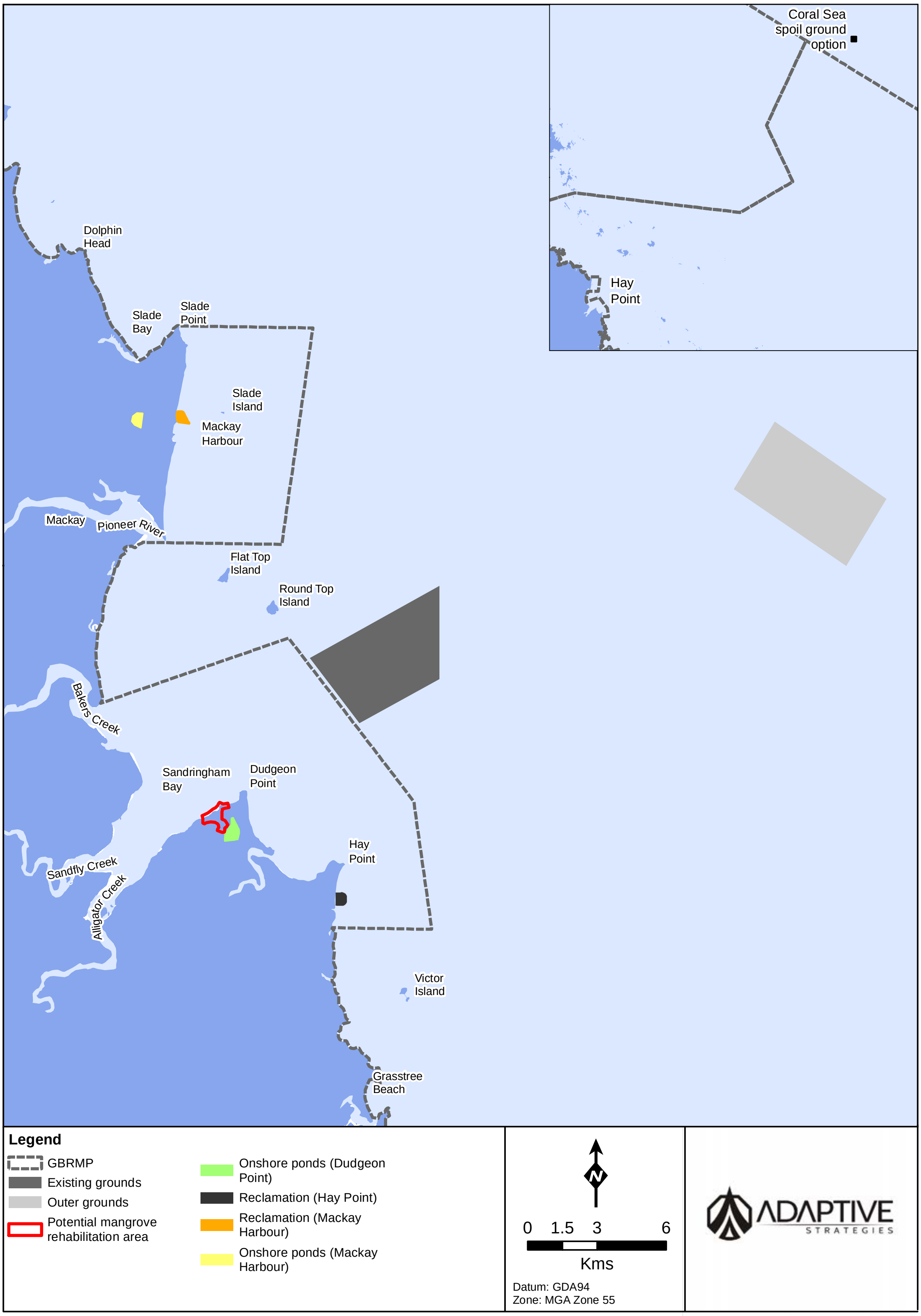


Figure 15: Reuse and placement option locations

Summary of reuse and placement alternatives

Reuse

HABITAT REHABILITATION

Overview

Dredge material would be used to create intertidal mudflats to support new areas of mangrove habitat. This option offers a unique opportunity to achieve environmental gains. Mangrove habitats provide an important ecological function including stabilising shorelines, improving water quality and providing habitat and nutrients for a variety of fauna species. An additional benefit is that mangroves also have a large capacity for absorbing substantial amounts of greenhouse gases.

The process may involve the use of coarser dredge material to create an underwater bund (if feasible), with fine dredge material deposited behind the bund and retained to form new mudflats in which mangrove habitat can be created. This option is estimated to have capacity for one dredging campaign.

This process is generally well understood; however there are few examples of it being used in environments similar to Hay Point using maintenance dredge material. There are significant knowledge gaps around coastal dynamics, sediment material and potential impacts on foreshore dynamics, demand for habitat rehabilitation and detailed design that would be need to be addressed if this option is pursued. At least three years of further scientific investigations are expected to be required.

Site selection

From desktop analysis and local knowledge a site on the north side of Dudgeon Point within Sandringham Bay has been identified as a potential location. The area previously supported mangroves that have been lost due to dieback and land use practices. The area contains a small tidal waterway that has been degraded from loss of vegetation. Further evaluation of the indigenous cultural significance of the selected site is required to ensure impacts to important sites do not occur at Dudgeon Point.

Sediment suitability

Sandy or coarse material is preferred for environmental bunds to have sufficient strength for construction purposes. Other built-structures may also be used to assist during the establishment phase. The fine sediment material can be used to backfill behind the main bund. Sediments sampled from areas where regular high rates of siltation has occurred show that the accumulated sediment is predominantly fine grained (approximately 90% silt and clay) with small quantities of sand (approximately 10%) (Advisian 2016).

The sediment at Hay Point is considered to be suitable based on properties identified through laboratory testing. Little or no processing of the sediments would be required; although targeted dredging to first obtain coarse sand material from the departure path to build the outer bund would be desirable, followed by dredging fine material from the berth area to backfill behind the established bund.

Dredging execution

Dredge material would be dredged using a Trailing Suction Hopper Dredge and transported to the placement site. Construction of the bunds may be undertaken hydraulically by discharging through the bow coupling to a floating pipeline and spreader pontoon in shallow water.

Infrastructure required to facilitate the pump-out would likely be temporary, and would include a pipeline (potentially floating, along with a pump out coupling) and a mooring system for the dredge during pump-out.

The Trailing Suction Hopper Dredge is expected to travel approximately 10 km from the dredging area to access the pump-out point.

- A general contingency of 30% has been assumed given the depth limitations around Sandringham Bay (i.e. extensive tidal flats exposed during low tides) that may affect dredge access, the potential for weather conditions to influence suitable periods for bund wall construction and the unique nature of the option.

It is assumed that the dredge will operate almost continuously i.e. typically 24 hours a day, seven days a week, however due to the large tidal range some downtime (approx. 30%) will occur when the dredge cannot access the inshore pumping point. Accordingly, the dredge campaign would last approximately 7 weeks.

Material for the environmental bund may be dredged from the channel areas first and/or to some extent dredged selectively by using overflow to separate the fines in the other areas of dredging (apron and berth areas). If insufficient coarse material is available for use, the environmental bunds may be constructed through the use of imported material, with the dredge material placed behind the bunds.

RECLAMATION – HAY POINT

Overview

Dredge material would be used to construct a reclamation area of approximately 20 ha located to the north of the existing tug harbour at Hay Point. This option involves construction of a 1,250m rock wall embankment. It is estimated to have capacity for approximately four dredging campaigns.

Proposed land use of the reclaimed area following completion of the dredging campaigns is yet to be determined. The reclaimed area would have low strength due to the use of predominantly fine-grained sediments from the maintenance dredging. It would therefore be unsuitable for industrial use with heavy load bearing, although ground improvement measures could be undertaken to increase the strength, but it is considered the long-term uses would be limited to low load-bearing uses.

Reclamation site

The Port of Hay Point 10 year development Master Plan identifies the need and proposed location for three new reclamation areas within the Half Tide Tug Harbour. The Master Plan identified a location to the south of the existing creek that drains into the harbour.

This area is not sufficiently large for the proposed volume of dredge material that will need to be contained assuming the time between future maintenance dredging campaigns will be approximately 5 years and that each maintenance dredging campaign will require an in-situ volume of approximately 200,000 m^3 to be dredged. For this reason, the selected site for the reclamation area is now north of the creek outlet and situated on a rock bed that would reduce any sinkage of the rock walls during construction. Confirmation of the presence or absence of indigenous cultural heritage values at the reclamation site would need to occur during the planning phases of this approach.

Wall design and construction

The reclamation area will be protected by a rock wall structure. The rock wall will be approximately 1,250m in length. Design is based on numerical model results for a 50-year ARI cyclonic event and an assumed water level approximately equivalent to a 50 year ARI (which due to the large tides in the area is only just above HAT).

The reclamation site has been designed on the basis that sediment will settle out in the reclamation area and the supernatant water will be able to flow through the porous rock wall. The use of a geotextile layer within the rock wall construction will restrict fine material from flowing through the rock wall.

The rock walls for the reclamation alternatives will be constructed using rock material sourced from local quarries.

The rock will be delivered to site by 40 tonne capacity dump trucks. The rock will be end-tipped and the rock wall will be formed using bulldozers and excavators. A mobile crane will be used to ensure that the primary armour rock is placed according to the design profile, particularly at the lower extremities of the rock wall near the toe.

Construction of the rock wall is expected to take up to 57 weeks.

Dredging execution

Dredge material would be dredged using a Trailing Suction Hopper Dredge (TSHD) (such as the 'Brisbane') and transported to the reclamation site. The 'Brisbane' would need to travel 4.5 km from the dredging area to the mooring location for the Hay Point reclamation site.

The hopper capacity is 2,900 m^3 and dredge material can be pumped ashore through bottom dump valves. Disposal would be undertaken from a mooring through a floating pipeline. The pumping distance from the mooring to the reclamation site would be 0.75 km. This pumping distance can be achieved using the pumping system on the 'Brisbane' without the need for a booster station.

Altogether the dredging and pumping ashore is expected to take approximately 23 days to complete.

The following temporary infrastructure would be required for the duration of the dredging and pumping:

- Pump out coupling to allow the pipeline to attach to the nozzle mounted on the bow of the 'Brisbane'. The coupling would be attached to a floating line, which would connect to the submerged pipeline.
- Submerged pipeline to transport the dredged material to the reclamation area. This is typically a steel pipeline with a diameter of 650 mm, which is assembled on the beach and then dragged out to its installed location.
- Mooring for the 'Brisbane' to hold the vessel into position without swinging during pumping. This could either be through pick up moorings or by using a small tug to hold the vessel while pumping.

Once the reclamations are full with maintenance dredged material, the remaining volume capacity of the reclamations could be filled with material with good engineering properties. Prior to adding a material that has good engineering properties, it may be necessary to undertake deep soil mixing of the dredged material (e.g. adding cement or the like to improve engineering properties). This would improve the load bearing of the reclamation; however further detailed geotechnical assessment is required to determine the exact measures to be implemented.

RECLAMATION – MACKAY HARBOUR

Overview

Dredge material would be used to construct a reclamation area of approximately 20 ha adjacent to the existing north harbour wall. The reclamation area will be protected by a rock wall approximately 860 m in length. It is estimated to have capacity for approximately five maintenance dredging campaigns.

The area has been identified for use as future strategic port lands. However, as with the Hay Point reclamation area, the reclaimed area at Mackay Harbour would have low strength due to the use of predominantly fine-grained sediments from the maintenance dredging. It would therefore be unsuitable for industrial use with heavy load bearing, although ground improvement measures could be undertaken to increase the strength.

Reclamation site

The area adjacent to the existing north harbour wall is considered a suitable site for the reclamation area as it has the following advantages:

- The construction costs would be reduced as the reclamation could make use of the existing north wall of the harbour.
- Construction would be simplified as there would already be access available along the existing harbour wall for plant to allow construction of the other walls.
- A temporary mooring for the dredger could be setup within Mackay Harbour, ensuring calm conditions for the pumping out of dredged material from the hopper of the dredger and only a short distance for pumping.
- By combining the structure with the existing harbour structure there would be no additional interruption to the longshore drift of sand as would occur if the structure was separate to the existing harbour.

Wall design and construction

The rock wall will be approximately 850 m in length. Design is based on numerical model results for a 50 year ARI cyclonic event and an assumed water level approximately equivalent to a 50 year ARI (which due to the large tides in the area is only just above HAT).

The reclamation site has been designed on the basis that sediment will settle out in the reclamation area and the supernatant water will be able to flow through the porous rock wall. The use of a geotextile layer within the rock wall construction will restrict fine material from flowing through the rock wall.

The rock walls for the reclamation alternatives will be constructed using rock material sourced from local quarries.

Construction approach will be the same as that described for the Hay Point reclamation area. Although construction of the Mackay Harbour wall is expected to take less time – up to 42 weeks in total.

Dredging execution

The dredging approach and temporary infrastructure would be the same as that described for the Hay Point reclamation site with the following details specific to the Mackay Harbour option:

- The 'Brisbane' would need to travel 18.5 km from the dredging area to the mooring location for the Mackay Harbour reclamation site.
- The pumping distance from the mooring to the reclamation site would be 0.25 km.
- Altogether the dredging and pumping ashore expected to take approximately 31 days to complete.

Onshore placement

ONSHORE POND- MACKAY

Overview

Dredge material would be pumped into an onshore pond located to the west of Slade Road in the Port of Mackay (**Appendix K**). The pond would comprise an area of approximately 20 ha and would be contained within bund walls constructed using material from the site.

The site has capacity for one dredging campaign. However, future campaigns could be accommodated by either removing the dried out dredge material from the pond to create sufficient capacity for any subsequent maintenance dredging campaign or by increasing the height of the bunds to increase the capacity of the pond.

Onshore site

A 32 ha site to the west of Slade Road has been selected from a number of alternative sites as the preferred location for the onshore pond. This area is relatively flat and the furthest from the existing port and so less likely to be required for other immediate port development infrastructure. In selecting this location, a range of other factors were also considered including environmental constraints, conservation status of habitats, social and cultural values and engineering constraints.

Pond design

The pond has been sized to accommodate all of the dredge slurry from a single dredge campaign, requiring a minimum bund wall height of 4 m.

As the dredge material flows through the pond, the solids will settle out leaving a relatively clear supernatant to be discharged at the outfall. The onshore pond has been designed using internal bunds to achieve the required flow path length between the intake (where the dredge material enters the primary pond) and outfall (where the supernatant flows out of the secondary pond) to achieve the target discharge concentration. The Mackay option has a total flow path length of approximately 900 m with basin width ranging from approximately 150 m to 250 m. The calculated discharge concentration based on USACE (1987) is ≈50 mg/l.

The bunds have also been designed with consideration of vehicle access during construction and also for future maintenance requirements.

To prevent the flow of water through the bund and the potential risk of the bund failing, the bunds will be lined with a containment barrier.

The ponds will contain two weir boxes - one in the internal bund to manage overflow between the primary pond and the secondary pond to retain a high percentage of solids in the primary pond and one to manage discharge from the secondary pond and ensure that the target discharge concentration is achieved.

Horizontal drainage will be included to promote the drying out process. The horizontal drainage system will consist of a 200 mm thick stone layer placed over the base of each pond over the containment barrier. Over the stone layer is a permeable geotextile that will allow water to flow through, but not fine sediments. A series of drainage pipes will be installed at the same level as the stone layer at a fall of 2% through the bund to a water drainage system that runs around the perimeter of the pond.

Pond construction

Following site clearance, bulk earthworks will be undertaken on a cut-and-fill basis to create a platform for the ponds. The earthworks will also include stockpiling of material for the bund formation.

Once the platform has been established, the bunds will be constructed and lined and the drainage pipelines will be installed.

Total construction time is expected to take approximately 13 weeks.

Dredging execution

The dredging approach and temporary infrastructure required for the Mackay onshore pond would be the same as that described for the Hay Point reclamation option. The following details are specific to the onshore pond at Mackay:

- The 'Brisbane' would need to travel 18.5 km from the dredging area to the mooring location for the Mackay onshore site.
    - Removing the dry material from the pond. A site for disposing of the dry material, or reuse option would need to be identified.
    - Increasing the height of the bunds using the dredged material to increase the capacity of the pond. The effectiveness of this approach is dependent on the engineering quality of the dredge material. Considering that the material to be dredged is predominantly silt and clay, it is expected the quality would need to be improved by adding imported material.
- The pumping distance from the mooring to the onshore site would be 1.9 km. This pumping distance can be achieved using the pumping system on the 'Brisbane' without the need for a booster station.
- Altogether the dredging and pumping ashore is expected to take approximately 31 days to complete.

Pond management

During the dredging activity and in the five years between maintenance dredging campaigns, the onshore pond will need to be managed in the following way:

- Dredge material will be pumped into the primary settling pond through an intake pipeline. Overflow between the primary pond and the secondary pond will be managed using the weir box to retain a high percentage of solids in the primary pond.
- The discharge from the secondary pond will also be managed using the weir box. The overflow through the weir box will be adjusted to ensure that the target discharge concentration is achieved. Sampling and testing would be undertaken as part of an Environmental Management Plan to demonstrate compliance. It is likely that a total suspended solids (TSS) versus turbidity relationship would be developed to facilitate monitoring/compliance. Provided the target discharge concentration is met, discharging of the supernatant can then proceed with the overflow to be directed back towards the ocean.
- As the water level in the ponds drop due to discharging of supernatant and through evaporation, the ratio of sediment to water will gradually increase. The objective is to achieve a dry material that can be mechanically handled and which has sufficient bearing capacity to accommodate an excavator or similar type of plant travelling over it.

ONSHORE POND – DUDGEON POINT

Overview

Dredge material would be pumped into an onshore pond located at Dudgeon Point. The pond would comprise an area of approximately 50 ha and would be contained within bund walls constructed using material from the site.

The site has capacity for one dredging campaign. However, future campaigns could be accommodated by either removing the dried out dredge material from the pond to create sufficient capacity for any subsequent maintenance dredging campaign or by increasing the height of the bunds to increase the capacity of the pond.

Onshore site

There are a range of constraints limiting the options at Dudgeon Point, including environmental issues, indigenous cultural heritage values, existing and proposed port development and land elevation considerations. A 180 ha site has been identified as the most suitable area for an onshore pond, noting that this area will still require significant cut and fill due to variable elevation. Further evaluation of indigenous cultural heritage values of the proposed site would be required during the planning phases of this scenario if selected.

Pond design

Design characteristics for the onshore pond are the same as those described for the Mackay onshore pond, with the following details specific to the Dudgeon Point option:

- The pond will require a minimum bund wall height of 3m.
- The Dudgeon Point option has a flow path length of approximately 1500 m with a basin width ranging from approximately 200 m to 350 m. The calculated discharge concentration based on USACE (1987) is ≈ 25 mg/l.

Pond construction

The construction approach will be the same as that described for the Mackay onshore pond. Although construction at Dudgeon Point is expected to take more time – up to 27 weeks in total. The main differences between the two alternatives is the larger size of the site that needs to be cleared at Dudgeon Point and the volume of earthworks needed to create a working platform.

Dredging execution

The dredging approach and temporary infrastructure required for the Dudgeon Point onshore pond would be the same as that described for the Hay Point reclamation option. The following details are specific to the onshore pond at Dudgeon Point:

- The 'Brisbane' would need to travel 4.5 km from the dredging area to the mooring location for the Dudgeon Point onshore site.
- The pumping distance from the mooring to the onshore site would be 2.1 km.
- The pumping distance is expected to be achieved using the pumping system on the 'Brisbane' without the need for a booster station.
- Altogether the dredging and pumping ashore is expected to take approximately 23 days to complete.

Pond management

Management of the onshore pond at Dudgeon Point would be the same as that described for the Mackay onshore pond option.

Offshore placement

EXISTING PLACEMENT AREA

Overview

Dredge material would be placed on the seabed within an offshore Dredge Material Placement Area (DMPA) location approximately 3 km to the north east of berth facilities. This location has previously been used to dispose of maintenance dredge material from the Port of Hay Point since 2006 and is approximately 1,800 ha.

This alternative provides the decision process to consider an option that is:

- In close proximity to the berth area to be dredged.
- In a previously disturbed area.
- Uses dredge material relocation techniques that are well understood.

Placement area description

Water depths within the site range from between 12 and 16 m. The site has a remaining capacity of approximately 15.5 million m^3 if filled to RL -12 m LAT (the preferred minimum depth in that location for shipping purposes) (Worley Parsons 2013a). The site is within the General Use Zone of the Great Barrier Reef Marine Park, with a small portion of the northern part of the placement area within a Habitat Protection Zone, and entirely within the boundaries of the Great Barrier Reef World Heritage Area.

The location is characterised by flat sandy sediments that support seagrass meadows and macrobenthic communities that are highly variable in density and extent throughout the year.

Sediments within the DMPA are primarily sand (<90%) with smaller amounts of gravels (5-10%) and silt and clay described as 'fines '(<5%%) (Worley Parsons 2013a). The low proportion of fines at the DMPA reflects the frequent mobilisation of seabed sediment in inshore regions of Hay Point.

Dredging execution

Once the TSHD (most likely the '*Brisbane*') hopper has been filled, the dredge would steam to the designated DMPA location and open its bottom hopper doors to release the dredge material whilst slowly moving forward. Travel time to the existing inshore DMPA would be less than 1 hour return. Release of dredged material would take approximately 15 to 20 minutes. The dredge would then return to the berth area and repeat the process, continuing to operate 24 hours per day until the campaign was completed. A single dredging program would take approximately 14 days to complete.

Bathymetric surveys and sediment plume modelling for the placement of dredge material within the existing inshore DMPA indicates that:

- The site is retentive with approximately 75% of material previously deposited remaining on site.
- The turbid plume generated travels north.

- Suspended material tends to accumulate predominantly between the dredge area and Round Top Island.
- Elevated levels of suspended sediment may occur at sensitive sites (Slade Islet, Flat Top and Round Top Island, Dudgeon Reef, Hay Reef and Victor Island) but these are within and well below background levels of suspended sediments.
- Negligible changes to ambient suspended sediment concentrations are expected south of Victor Island.

MID-SHELF PLACEMENT

Overview

Dredged material would be placed on the seabed at a mid-shelf Dredge Material Placement Area (DMPA). This area is located approximately 25 km north-east of berth facilities at the Port of Hay Point. Typical travel time to the mid-shelf disposal location by a TSHD would be approximately 6 hours return. A single dredging program would take approximately 23 days to complete.

This alternative provides the decision process to consider an option that:

- Is located in deep water offshore.
- Is within an area that has not been previously disturbed.
- Uses dredge relocation techniques that are well understood.

Placement area description

Water depths within the proposed mid-shelf DMPA range between 18 to 21 m. The DMPA would cover an area of approximately 2,000 ha, and have a capacity of approximately 120 million m^3 if filled to RL -12 m LAT (the preferred minimum depth in that location for shipping purposes).

The site is within the General Use Zone of the Great Barrier Reef Marine Park, and entirely within the boundaries of the Great Barrier Reef World Heritage Area. The closest island to the DMPA is Bailey Islet (10 km NE) and Keswick Island (15 km N). Round Top Island is greater than 15 km from the proposed mid-shelf DMPA.

Sampling at the proposed mid-shelf DMPA indicates the sediments are mainly sands with a high (19%) proportion of clays. The composition of the substrate in the area is uniform (Worley Parsons 2013d).

The area well offshore from Hay Point is considered to have a low probability of containing deep water seagrass due to the strong tidal currents, regular natural seabed disturbance and elevated water turbidity levels (Coles et al. 2003). On occasions however, transient and isolated patches may occur in deeper water.

Surveys within the mid-shelf DMPA location and across adjacent areas in 2013 found no obvious features of interest and no areas of habitat on which seagrass, benthic macro invertebrates or macroalgae grew (Worley Parsons 2013d). No resources of high conservation value have been identified or are considered likely to be present within the proposed DMPA.

Surveys within the mid-shelf DMPA location indicated benthic infauna communities are typical of sandy or silty sediments in the region, are uniformly distributed with no pattern of distribution and similar to adjacent areas (Worley Parsons 2013d).

Dredging execution

Once the TSHD hopper has reached capacity, the dredge would steam to the designated mid-shelf DMPA location and open its bottom hopper doors to release the dredge material whilst slowly moving forward. Travel time to the mid-shelf disposal location would be approximately 6 hours return with the release of dredged material taking a further 15-20 minutes.

Sediment plume modelling associated with placement of dredge material at the mid shelf DMPA (Worley Parsons 2013a) indicates that:

- The site is expected to be retentive with some dispersion from waves and currents.
- The turbid plume generated by dredge material placement activities is expected to travel north parallel to the coast under the combined current and wave action.
- Elevated levels of suspended sediment may occur at some inshore sites (e.g. Round Top Island) but these are within and well below the background suspended sediment values.
- Negligible changes to ambient suspended sediment concentrations are expected south of Victor Island.

CORAL SEA PLACEMENT

Overview

Dredged material would be placed within an offshore area of the Coral Sea, east of the outer boundary of the Great Barrier Reef Marine Park/World Heritage boundaries. The DMPA would be within the Coral Sea Reserve zoned Multiple Use. This site would be located approximately 300+ km offshore of the mainland.

Placement area description

Water depths of a DMPA in the Coral Sea area, east of the Great Barrier Reef Marine Park/World Heritage boundary, would be greater than 1,000m. The area required for a DMPA would be approximately 2,000ha.

This alternative provides the decision process to consider an option that:

- Is located in deep water offshore well assumed away from sensitive receptors.
- Is outside the GBRWHA and GBRMP.
- Uses dredge relocation techniques that are well understood.

Detailed investigations of the seabed in the area that could potentially be used as a DMPA within the Coral Sea have not yet been undertaken. However, based on expert knowledge, the following assumptions can be made:

- The placement site is likely to be retentive considering the weak currents associated with deep water (>1,000m).
- The capacity of a potential site to accept dredged material is theoretically unlimited.
- Sediments associated with the continental shelf east of the Great Barrier Reef have few fine-grained sediments because of the high wave energy and East Australian Current. The sediments in these locations range from medium to coarse sand on the inner shelf and fine sand (with mud in limited areas) on the mid and outer shelf (Conolly, 1969).

Dredging execution

A larger TSHD (e.g. *Charles Darwin*) would be needed to undertake the dredging and place material offshore due to large distance the dredge would need to travel to reach the proposed Coral Sea DMPA (300 – 400 km). A large dredge vessel would have a hopper capacity of 30,000 m^3 and require fewer trips to the Coral Sea DMPA to complete a single dredge campaign.

Once the dredge hopper had reached capacity, the dredge would travel to the proposed Coral Sea DMPA and open its bottom hopper doors to release the dredge material. The dredger would access the Coral Sea site through Hydrographers Passage, a compulsory pilotage area through the Great Barrier Reef. Travel time to the Coral Sea DMPA using a large dredge vessel that could travel at an average of 10 knots, would be approximately 40 hours return. Dredge material release would probably take 15 to 30 minutes. A single dredge campaign would take approximately 32 days to complete, with operations continuing 24 hours per day.

Sediment plume modelling has not been undertaken for this option. Further studies would be required to understand sediment movement in the water column once it is released from the dredge hopper at the proposed DMPA.

Locations – environmental profiles

Environmental profiles for the reuse and placement option locations have been developed based on the Environmental Values Assessment (Jacobs 2016, Appendix L) and other available information for the Hay Point – Mackay area.

Port of Mackay

Two areas within the Port of Mackay have been identified for possible dredge material placement. These include a reclamation option and an onshore dredge material placement option.

An assessment of the area of influence for the two Port of Mackay alternatives was undertaken to identify the locally important environmental values. The area of possible influence was broadly defined by combining a 5 km radius from the centre of each of the dredge material placement sites. These values are summarised in the maps and tables below.

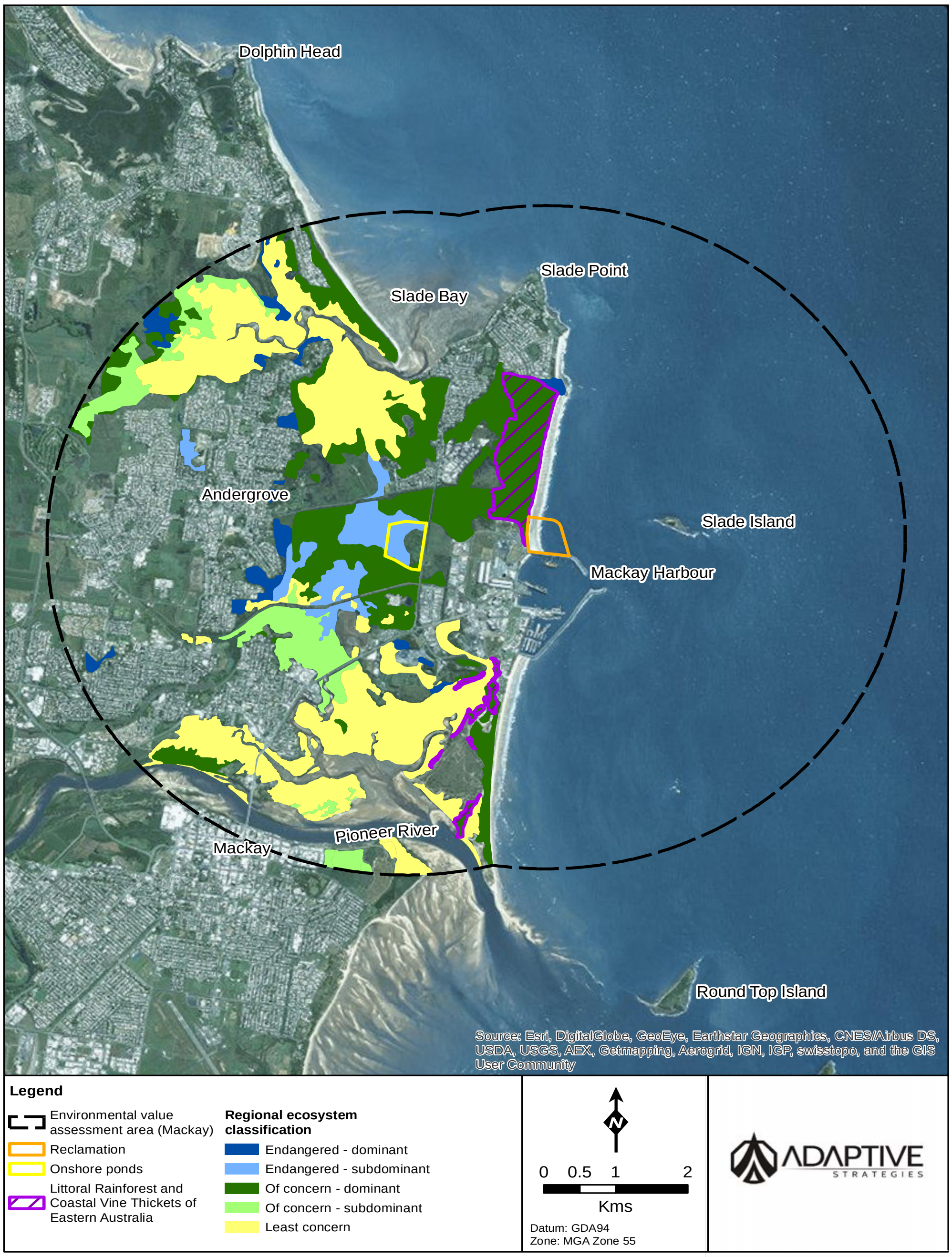


Figure 16: Land environmental values within the Port of Mackay

Table 12: Port of Mackay land values

LAND	
Threatened plants	• There are no records of threatened plants in the assessment area. • There is potential for *Omphalea celata*, the Mount Blackwood holly (*Graptophyllum ilicifolium*) and the minute orchid (*Taeniophyllum muelleri*) to occur within the area (VDM Consulting 2012).
Threatened ecological communities	• One Threatened Ecological Community (TEC), the critically endangered Littoral Rainforest and Coastal Vine Thickets of Eastern Australia is present within the Port of Mackay assessment area. 145.6 ha of the TEC occurs as seven patches within the assessment area, including a large patch (126.5 ha) adjacent to, and north along the coastline of the possible coastal reclamation site. • The total area of the seven patches represents approximately 5.8% of the TEC of the Central Queensland remnant extent (2497 ha) (TSSC 2008).
Native vegetation communities	• 2,032 ha of native vegetation communities have been mapped within the Port of Mackay assessment area. This includes approximately: o 230 ha of 'Endangered' vegetation (VM Act: 89 ha dominant, 142 ha sub-dominant) o 930 ha of 'Of concern' vegetation (VM Act: 713 ha dominant, 217 ha dub-dominant) o 872 ha of 'Least concern' vegetation (VM Act). • The vegetation communities within the area broadly include vegetation on coastal dunes, grassland and sedgelands, paperbark open forest, Moreton Bay Ash forest, Notophyll vine forest and estuarine vegetation including mangroves.
Threatened and migratory birds	**Threatened birds** • Seven threatened bird species have been recorded in the area including the: beach stone curlew (V); curlew sandpiper (CE, M); eastern curlew (CE, M, V); great knot (CE, M); greater sand plover (V, M); lesser sand plover (E, M) and red knot (E, M). • The Mackay region provides important habitat areas for the great knot (DoEE 2016). Mackay Town Beach (adjacent to the southern boundary of the assessment area) is an internationally important site for the lesser sand plover (Milton & Driscoll 2006; DoEE 2016). **Migratory birds (including shorebirds)** • The area supports a high diversity of migratory bird species and the coastline of the Mackay region is recognised as an important migratory shorebird area (Harding & Milton 2003). Records of twenty-six migratory bird species occur within the assessment area (Atlas of Living Australia). There is also potential habitat for the migratory red goshawk (VDM Consulting 2012). • Important migratory shorebird high tide roosts (as defined under the *EPBC Act Policy Statement 3.21*) occur within the assessment area at: Pioneer River Mouth Banks; at Shellgrit Creek and Entrance; and within the Mackay Port Wetland (Harding & Milton 2003).
Threatened mammals	• There are no records of threatened mammals in the Port of Mackay assessment area, however habitat for the threatened false water rat (V) occurs within the shallow wetland areas and mangroves within and adjacent to the assessment area (VDM Consulting 2012).
Soil quality, erosion and sedimentation	• Geology of this area is Quaternary alluvium and lacustrine deposits. The soil consists of sand, silt, mud and gravel (Qa) (Department of Natural Resources, Mines and Energy, 2004). • Land at or below 5 m in the area may have Potential Acid Sulfate Soils (PASS). Evidence of Acid Sulfate Soils has been found in the vicinity of the proposed onshore disposal site (VDM Consulting 2012).

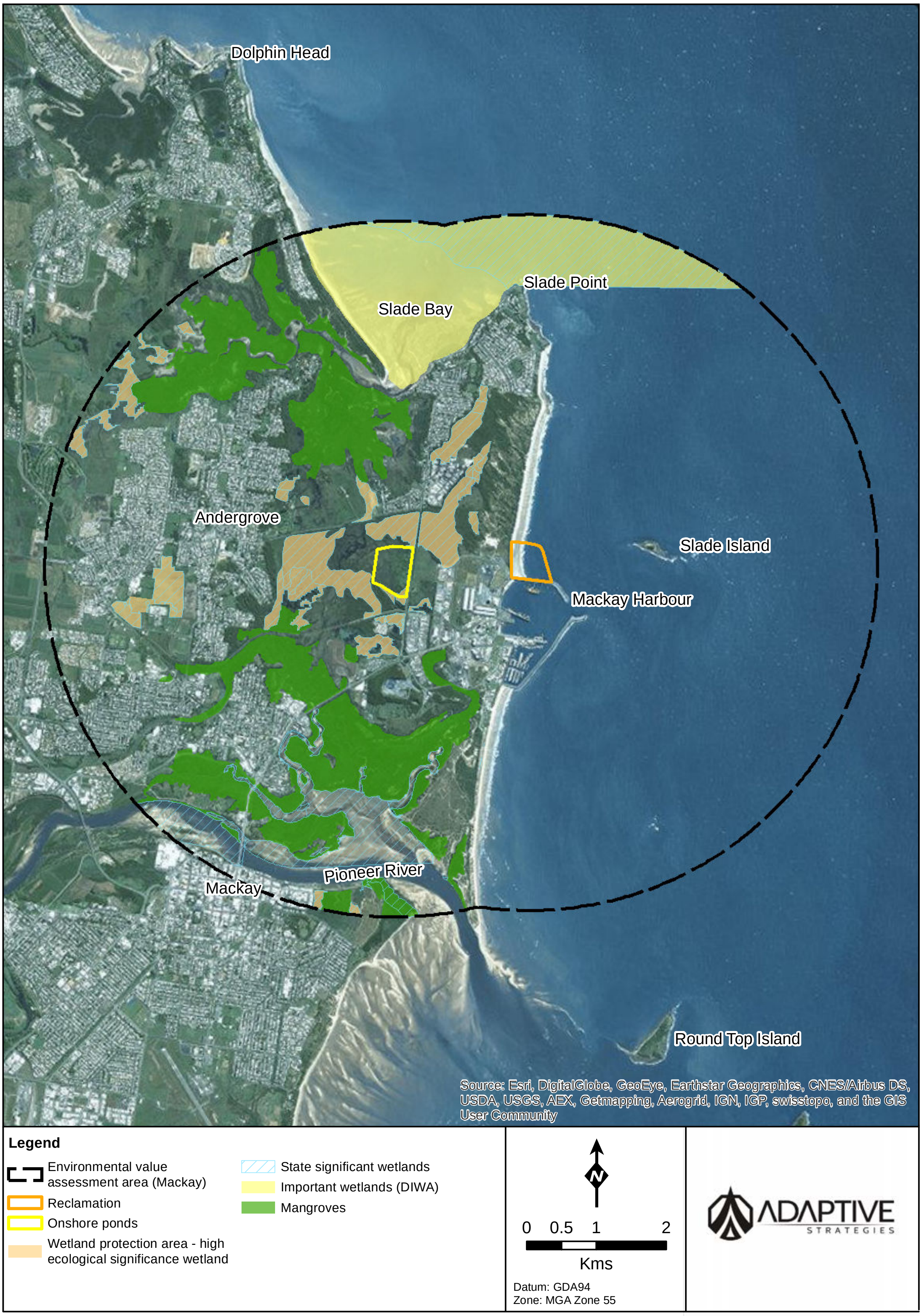


Figure 17: Freshwater and estuarine values

Table 13: Port of Mackay Freshwater and estuarine values

FRESHWATER AND ESTUARIES	
Catchments, waterways and ephemeral waters	• The assessment area lies within the broader Pioneer Basin and Mackay City catchment (Jacobs 2016). The Pioneer River is the dominant waterway, which flows through the south of the assessment area. • The lower Pioneer River main channel has been extensively modified and is subject to numerous pollution sources from surrounding towns and Mackay City (Reef Catchments – Pioneer 2014). The health of the river has been considered to be poor, however improvements are being made in the wider catchment areas by the agricultural industry to improve water quality (Reef Catchments –Pioneer 2014).
Surface and groundwater quality	• Water quality monitoring within the Mackay urban area has only recently commenced with the implementation of a pilot study (Catchment Solutions 2016). Results from the pilot study indicated that water quality surrounding the port lands had exceedences of water quality limits for TSS, Total N, particulate N and dissolved oxygen levels at varying times and sites throughout the sampling (Catchment Solutions 2016). Pesticides such as diuron and atriazine were detected at NQBP sampling sites.
Wetlands	• There are wetlands of high ecological significance within the assessment area (SDAP Module 11: Wetland Protection and Wild Rivers; VDM Consulting 2012), including patches around the possible onshore reclamation area. • The Great Barrier Reef Marine Park boundary also intersects with an area in the north of the assessment area. The GBRMP is listed under the Commonwealth Directory of Important Wetlands.
Mangroves	• Mangroves occur throughout the area. A diversity of mangrove species have been found in these communities including: o Grey mangrove (*Avicennia marina* var. eucalyptifolia). o Small-leaved orange mangrove (*Bruguiera parvifolia*). o Smooth-fruited yellow mangrove *(Ceriops australis*). o Milky mangrove (*Excoecaria agallocha*). o White-flowered black mangrove *(Lumnitzera racemosa*) (GHD 2011; VDM Consulting 2012). o Mangrove dieback, particularly of the grey mangrove occurred throughout the Pioneer River, which is adjacent to the southern boundary of the assessment area (and broader Mackay region). PSII herbicides, including diuron have been linked to the dieback (Bell & Duke 2005).
Freshwater fish	• The Basset Basin Fish Habitat Area intersects with the southern portion of the assessment area. This area provides habitat for barramundi, blue salmon, bream, estuary cod, flathead, grunter, mangrove jack, queenfish, whiting, mud crab, tiger prawns, and grey mackerel nursery (QDPI 2008).

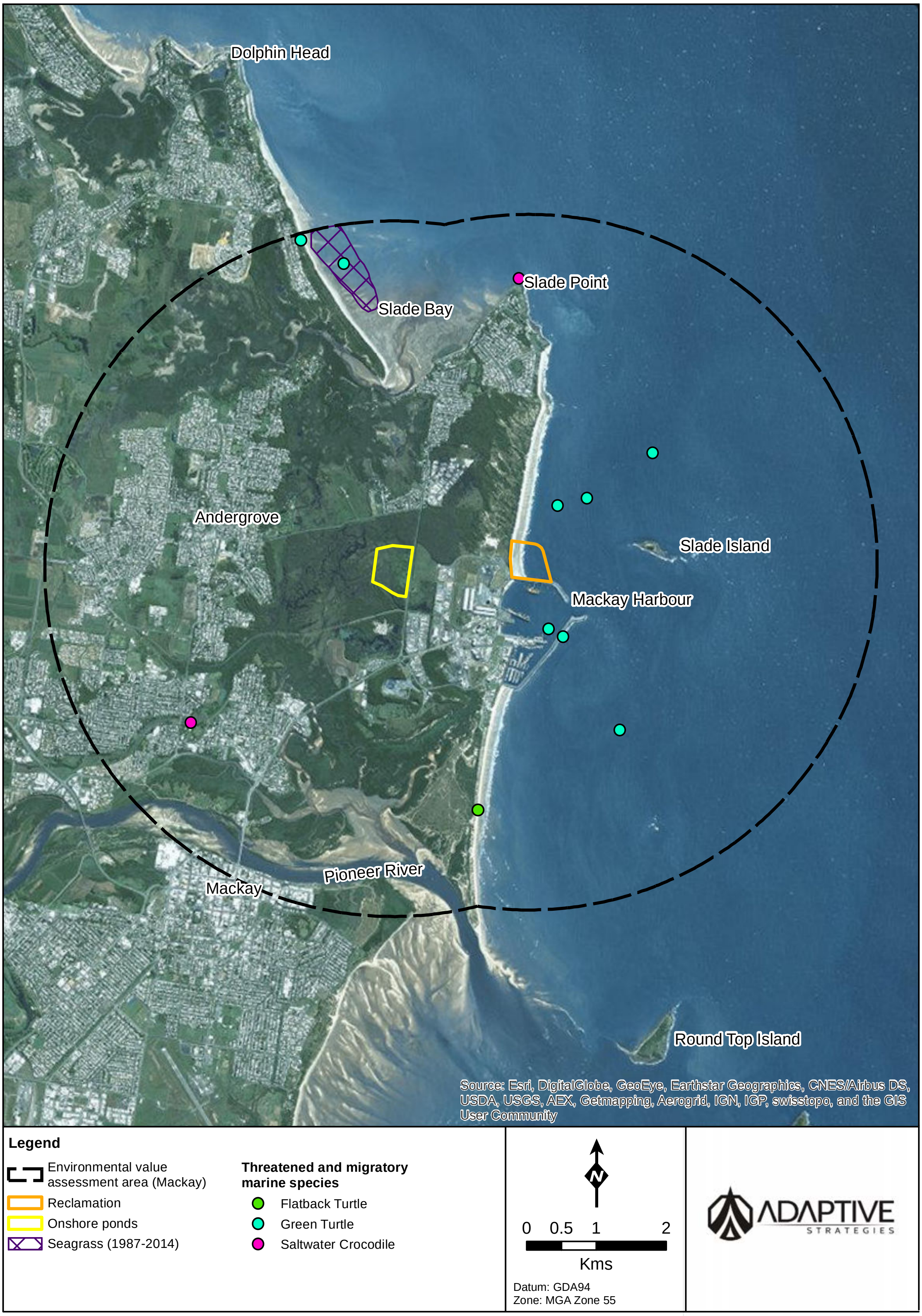


Figure 18: Marine values

Table 14: Port of Mackay marine values

MARINE	
Rocky and coral reefs	• The nearest coral and rocky reef habitats are at: Slade Islet (1.3 km NE); Slade Point (3.5 km N); Slade Rock (2 km N) and Dangerous Reef (3km SE) (NQBP 2011). Flat Top Island (6.1km SSE) and Round Top Island (8.2km SSE) also support coral and rocky reef habitats, however they are outside of the Port of Mackay (5km arch) assessment area (NQBP 2010; NQBP 2011). • Natural fringing reefs at these locations consist of hard corals, sponges, bryozoans and soft corals (NQBP 2011). These rocky and coral reef habitat areas are locally important to fish and other marine species. They are not considered to be regionally significant areas of coral or rocky reef habitat.
Seagrass	• As with other tropical Queensland seagrass habitats, meadows within the assessment area are dynamic both seasonally and inter-annually (Rasheed et al 2001). A small area of seagrass has previously been mapped within Slade Bay in the north of the assessment area. • The following seagrass beds have been recorded within proximity, but outside of the assessment area: o Low density seagrass meadows were confirmed at Round Top and Flat Top islands as part of surveys for the 2006 Hay Point Capital Dredge Program (NQBP 2011). o Earlier surveys have also identified two deep water meadows of 273 ha and 294 ha to the east of the existing harbour (approximately 7 and 12 km) (Rasheed et al 2001). • Species previously recorded during surveys included *Halophila decipiens* (offshore meadows) and *Halodule uninervis/Halophila ovalis* (coastal meadow) (Rasheed et al 2001).
Macroalgae	• Low density (<1-5%) macroalgae communities occur within the seabed surrounding the port (Rasheed et al 2001). • Areas of high macroalgae cover (>20%), including *Sargassum* spp., occur on the rocky reef area surrounding Flat Top Island. Other nearby islands, outside of the Port of Mackay assessment area also contain high cover including Round Top Island, Slade Islet and Slade Point (Rasheed et al 2001).
Benthic invertebrates	• Benthic invertebrates have been found in moderate abundances within the assessment area, including polychaete worms, crustaceans. These invertebrates were found to have high spatial variation throughout the area surveyed (WBM Oceanics 2004; Worley Parsons 2009).
Threatened and migratory marine fauna	• There are no known important populations of threatened or migratory marine animals within the assessment area. The assessment area does however support locally important populations of a number of species. **Marine turtles** • Potential nesting areas for green and flatback turtles are present on the beaches and coastal dunes within the Port of Mackay assessment area (GHD 2011). Flatback turtles are known to nest along Harbour Beach (NQBP 2010). Nesting sites within the assessment area are not recognised as habitat critical to the survival of turtle species, however they are considered to be locally important. An important flatback turtle nesting site is located at Haliday Bay north of the assessment area. Surveys between 1993 and 2003 observed 19 flatback turtles nesting per year, with a maximum of 46 occurring one year (Mackay Regional Council 2010). • Other species of turtles known to occur within the waters of the port limits include the loggerhead, leatherback, olive ridley and hawksbill turtles (NQBP 2010; 2011). **Dugong** • There is potential for dugong (M) to pass through the waters adjacent to the port as small populations have been recorded near Port Newry to the north and Ince Bay to the south (NQBP 2010). The closest important habitat areas for dugong are the Dugong Protected Areas at Repulse Bay, Newry Region and Sand Bay (over 70 km north) and Llewellyn and Ince Bay (37 km south). **Whales and dolphins** • There is potential for the indo-pacific humpback dolphin, the Australian snubfin dolphin,

MARINE	
	and inshore and offshore forms of the bottlenose dolphin to occur within the offshore areas (NQBP 2011). • The humpback whale may also use the nearby offshore waters for transiting and resting during their migration along the east coast (NQBP 2010; 2011). Peak migration in this area occurs between late July to early September (TSSC 2015). The nearest important aggregation area is approximately 80 km east of the Port of Mackay, adjacent to the outer ribbon reefs. **Saltwater crocodile** • The saltwater crocodile has previously been recorded in the area (Atlas of Living Australia). There are no known breeding populations within the area.
Marine water and sediment quality	• Marine water quality in the offshore assessment area is consistent with water quality trends within the broader region which reflect elevated nutrients and pesticides resulting from surrounding land uses (Reef Catchments 2013). The most recent marine water quality results indicate that nutrient levels were elevated (Waltham et al 2015). • Marine water quality within and adjacent to the existing harbour has been monitored since 1998. The tidal range in the area has meant that there have been no significant water quality issues detected within the harbour over the course of the monitoring program (NQBP 2011).

Sandringham Bay, Dudgeon Point and Hay Point

Areas within Sandringham Bay, Dudgeon Point and Hay Point have been identified for a possible mangrove rehabilitation area, possible onshore dredge material placement area and a possible reclamation area. Assessment of the area of possible influence from the three placement scenarios was undertaken to identify the locally important environmental values. The area of possible influence was broadly defined by combining a 5 km radius from the centre of the three alternatives. The following maps and tables document the key features and their relative environmental values.

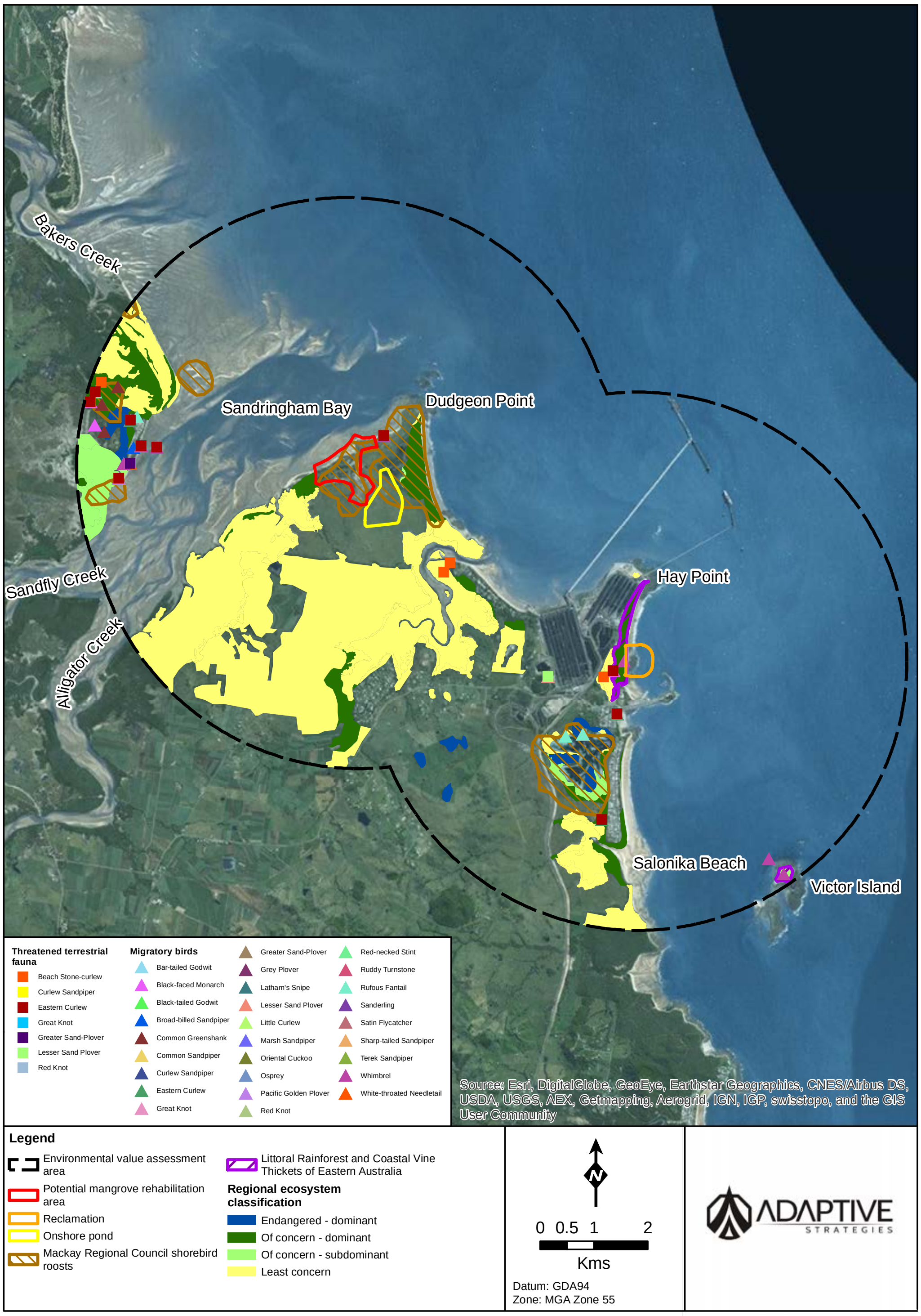


Figure 19: Land environmental values at Sandringham Bay, Dudgeon Point and Hay Point

Table 15: Sandringham Bay, Dudgeon Point and Hay Point land values

LAND	
Threatened plants	• There are no known threatened plant records within the assessment area. • There is potential habitat for two threatened plants including the lesser swamp-orchid (E, E) and the black ironbox (V, V). The lesser swamp-orchid may occur within paperbark swamp forests on sandy soils within the area, while the black ironbox could potentially occur within the paperbark-eucalypt woodlands along watercourses within the assessment area (Worley Parsons 2013).
Threatened ecological communities	• One Threatened Ecological Community (TEC), the critically endangered Littoral Rainforest and Coastal Vine Thickets of Eastern Australia has been mapped as a thin patch along the eastern coastline of Hay Point (33.4 ha), and a small patch on Victor Islet (6.4 ha).
Native vegetation communities	• 2,349 ha of native vegetation communities have been mapped within the assessment area. This includes approximately : 74 ha of 'endangered' vegetation; 472 ha of 'Of concern' vegetation (VM Act: 336 ha dominant, 136 ha sub-dominant); and 1803 ha of 'Least concern' vegetation (VM Act). • Only small patches of 'endangered' and 'of concern' vegetation remain in the assessment area, mostly along the coastal areas of Sandringham Bay, Dudgeon Point and east Hay Point. These include areas of mangroves, sedgeland/tussock grasslands, open forest on dune sands mixed with alluvial materials and marine sediments, woodlands on alluvial plains and areas of rainforest species in open forest on parallel dunes.
Threatened and migratory birds	**Threatened birds** • Seven threatened bird species have been recorded in the assessment area including the: beach stone curlew (V); curlew sandpiper (CE, M); eastern curlew (CE, M, V); great knot (CE, M); greater sand plover (V, M); lesser sand plover (E, M); red knot (E, M) (Atlas of Living Australia; Austecology, 2013). The Australian painted snipe (V, V) has the potential to occur within the area. **Migratory birds (including shorebirds)** • Twenty-eight migratory birds have been recorded within the assessment area (Atlas of Living Australia). • Dudgeon Point has been identified as an important roost site within the Mackay Shorebird Area and contains important habitat for a number of shorebird species, particularly in areas along the point and western banks adjoining the Sandringham Bay – Bakers Creek Aggregation Wetland (BAAM 2012, Harding & Milton 2003). • Dudgeon Point is particularly important habitat for: lesser sand plover; greater sand plover; whimbrel; grey-tailed tattler; ruddy turnstone and red-necked stint as the site has supported ≥0.1% of the flyway population estimate for each species in a number of surveys: (BAAM 2012). • Significant numbers of migratory shorebirds have also been recorded as part of regular monitoring at McEwans Beach (Sandringham Bay) and Lake Barfield (south of the existing terminal leases at Hay Point).
Threatened mammals	• The koala (V, V) has previously been recorded within habitat at Dudgeon Point and the area is considered to support a small population (BAAM 2012, Worley Parsons 2013). • The ghost bat (V) may also be present in the Dudgeon Point area (NQBP 2009). • There is also potential habitat for the vulnerable false water mouse within the saline grassland, saltmarsh, mangroves and margins of freshwater swamps close to the foredunes of Dudgeon Point and areas surrounding Hay Point (NQBP 2009; Worley Parsons 2013). • The water mouse has previously been found to only occur in communities dominated by yellow and orange mangroves (*Cerips tagal* and *Bruguiera* spp.) within the Mackay region (Ball 2004).
Soil quality, erosion and sedimentation	• The coastline of Dudgeon Point has been mapped as an erosion prone area due to storm impact and long term trends of sediment loss and channel migration (DEHP 2015). High hazard storm tide inundation areas have also been mapped within the assessment area, including within the onshore disposal footprint and adjacent Louisa Creek (DEHP 2015).

LAND	
	• Potential Acid Sulfate Soils occur along the shoreline of Sandringham Bay, the banks of Louisa Creek (Aurecon 2011) and on NQBP land in the tidal lands that adjoin, and to the south, of the Hay Point rail loop (NQBP 2009).
Air quality and noise	• The coal terminals at the Port of Hay Point have historically contributed to dust concentrations in the assessment area (Katestone Environmental 2013). Management measures have improved dust levels in the area (Jacobs 2016). The most recent monthly air quality monitoring report for the area indicated that management targets were not exceeded at any of the monitoring sites (ALS 2016). • Noise sources in the assessment area include traffic and port operations, as well as naturally occurring sources (wind and rain). The most recent noise monitoring in the area indicated that no noise management targets were breached throughout March 2016 (ALS 2016).

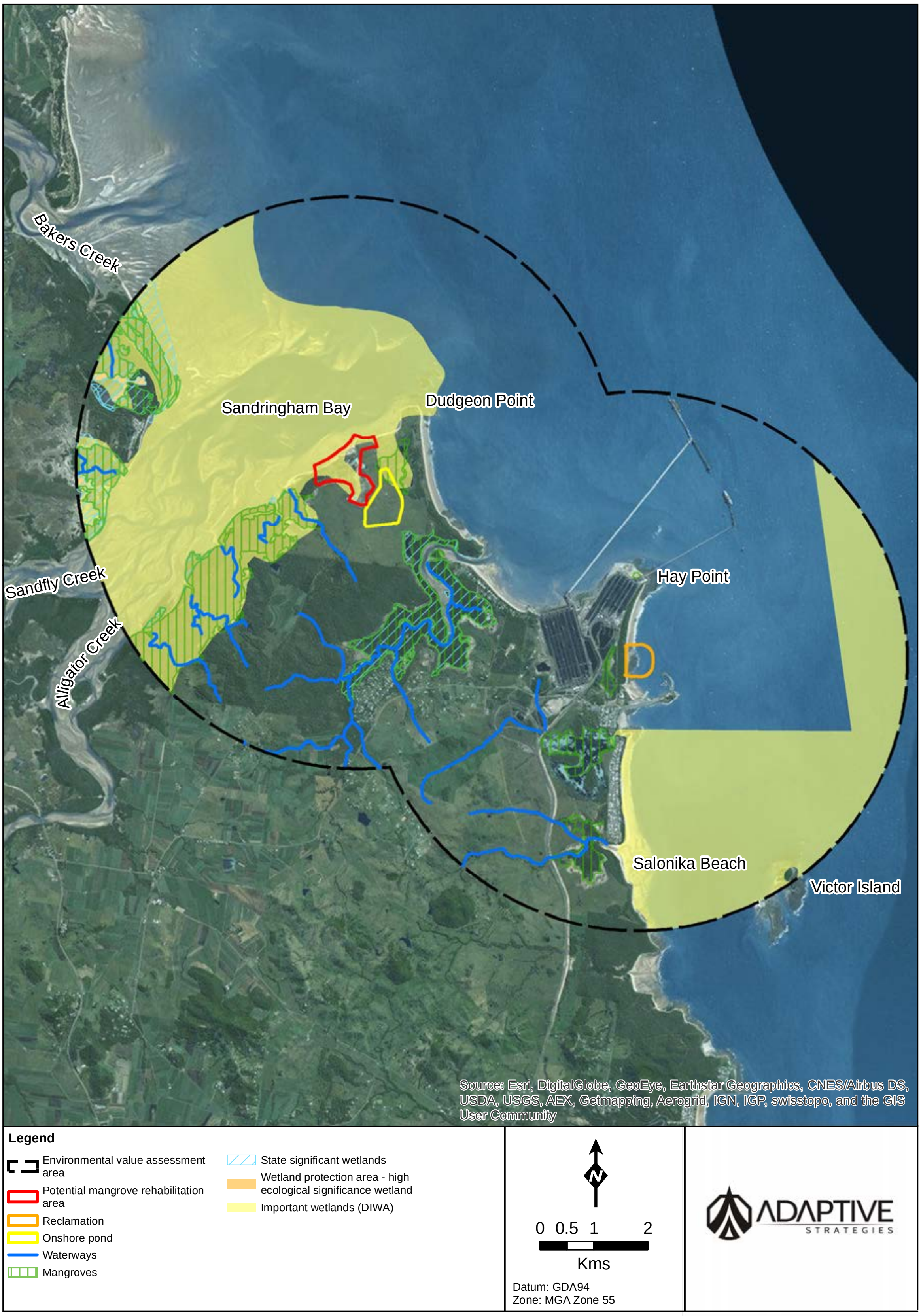


Figure 20: Freshwater and estuarine values within Sandringham Bay, Dudgeon Point and Hay Point

Table 16: Sandringham Bay, Dudgeon Point and Hay Point freshwater and estuarine values

FRESHWATER AND ESTUARIES	
Catchments, waterways and ephemeral waters	• The assessment area is influenced by the Alligator Creek, Sandy Creek, Bakers Creek and Sarina Beaches subcatchments of the Pioneer Basin. These catchments are some of the most modified catchments of the Great Barrier Reef coast, with over 50% of their catchment used for intensive agriculture production (Reef Catchments 2013). • A six meter tidal variation in the assessment area creates extensive foraging areas at low tide (Worley Parsons 2013).
Surface and groundwater quality	• The current condition of freshwater ecosystems within the broader Sandringham Bay area is considered to be poor, resulting from very poor water quality from high levels of nutrients and pesticides (Reef Catchments 2013). • Surface water quality of Dudgeon Point and Louisa Creek have been found to have higher than guideline nutrient levels, typical of areas surrounded by agricultural and grazing land uses (Worley Parsons 2012). Water quality at Grendon and Sandfly Creeks and in Lake Barfield was found to meet the ANZECC (2001) aesthetic water quality guidelines (NQBP, 2009). • Groundwater in the Dudgeon Point and Hay Point area is typically saline and not considered suitable for potable use or consumption by livestock (NQBP, 2009; Worley Parsons 2012). Groundwater quality at Hay Point is generally within the pH neutral range and mildly alkaline in some areas. Concentrations of heavy metals have been found to be below the level of laboratory detection (GHD, 1999 cited in NQBP, 2009).
Wetlands	• The Sandringham Bay – Bakers Creek Aggregation Wetland is a nationally important wetland that overlaps the north-western coastline of Dudgeon Point and extends north to Far Beach. It is significant as it has large intertidal and shallow water habitats, extensive mangroves and diverse shoreline (DEE 2016). It also supports a number of important migratory shorebird roost sites (Harding & Milton 2003). • The assessment area also supports State Significant Wetlands along the west coastline and areas adjacent to Louisa Creek. • Lake Barfield is a notable freshwater wetland located south of the existing terminal leases at Hay Point (Harding and Milton, 2003). It is not listed as a nationally or internationally important wetland.

Mangroves	• Mangrove shrublands (RE 8.1.1) dominate the coastline of Sandringham Bay and the shoreline of Louisa Creek (Worley Parsons 2013). Mangrove habitats are also present in the Mount Hector Conservation Park (adjacent to the northern banks of Louisa Creek), adjacent to the eastern side of the existing coal terminals at Hay Point (Austecology, 2013), as well as to the north and west of the terminals (BMA, 2009).
	• A range of mangrove species has previously been recorded in the area:
	  o Northern white mangrove (*Avicennia marina* ssp. *eucalyptifolia*).
	  o Large-leaved orange mangrove (*Bruguiera gymnorhiza*).
	  o Yellow mangrove (*Ceriops tagal*).
	  o Long-styled Stilt Mangrove (*Rhizophora stylosa*).
	  o Club mangrove (*Aegialitis annulata*).
	  o River mangrove (*Aegiceras corniculatum*).
	  o Milky mangrove (*Excoecaria agallocha*) (Worley Parsons 2013; BMA 2009).
	• Mangroves in the assessment area provide habitat for a number of threatened and migratory animals (Worley Parsons 2013).
	• PSII herbicides have been a continuing concern in the Mackay region (Mitchell et al., 2005), and have been linked to the dieback of mangroves in the region (see Bell & Duke, 2005).

Freshwater fish	• The nearest Fish Habitat Area is located at Bassett Basin, approximately 15 km north of the assessment area. • Freshwater fish sampling within Louisa Creek, upstream of the assessment site, found nine species of fish, including the swamp eel, marbled eel, mosquito fish, empire dudgeon, spangled perch, eastern rainbow fish, guppy and the banded scat

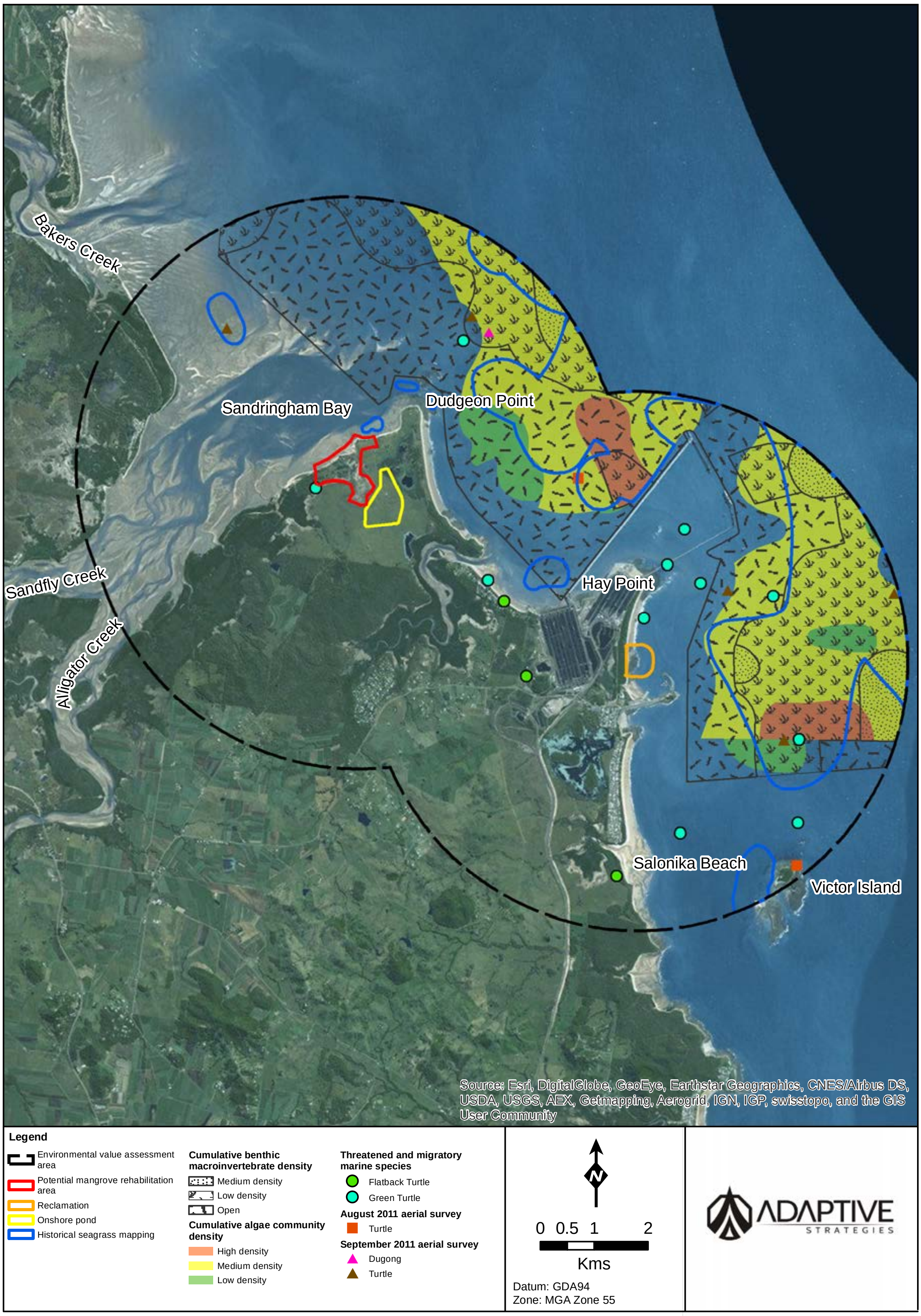


Figure 21: Marine environmental values within Sandringham Bay, Dudgeon Point and Hay Point

Table 17: Sandringham Bay, Dudgeon Point and Hay Point marine values

MARINE	
Rocky and coral reefs	• A rocky ledge extending southward from Dudgeon Point in the shallow waters of Dalrymple Bay supports a sparse coral community (known as Dudgeon Reef), and is dominated by macroalgae (particularly *Sargassum*) (Worley Parsons- Marine 2012). • Hay Reef is located between the existing coal terminal jetties at Hay Point and comprises small rocky outcrops. Hay Reef has a moderate to high coral cover (5-60%) on the northern and eastern sides, with the south-eastern side supporting scattered hard coral individuals (Worley Parsons – Marine 2012). • Fringing reefs occur at Victor Islet in the east of the assessment area. Other reefs in the region occur at Round Top Island (9 km north-east). These islands support low to moderate cover of soft and hard coral communities (Worley Parsons- Marine 2012).
Seagrass	• Low to medium density seagrass cover has previously been observed within the inshore and offshore boundaries of the assessment area (Rasheed et al 2004; Chartrand et al 2008; Thomas & Rasheed 2010; Thomas et al 2012). • The most recent seagrass surveys at Dudgeon Point observed three small meadows adjacent to the point, totalling approximately 13.7 ha (McKenna et al 2016). The patches contained two seagrass species: *Halophila decipiens* and *Halodule uninervis*. • Surveys of nearshore meadows since 2010 have shown that the meadows adjacent to Dudgeon Point have expanded and contracted in size, and changed in species composition (McKenna et al 2016).
Macroalgae	• Algae densities within the assessment area have been observed to vary over time. Surveys between 2001 to 2011 show that patches of low, medium and high density algae have been present (Rasheed et al 2004; Chartrand et al 2008; Thomas & Rasheed 2010; Thomas et al 2012). The most recent surveys in 2010 observed one patch of low density algae in the inshore waters between Dudgeon Point and the existing Port of Hay Point jetties (Thomas & Rasheed 2010).
Benthic invertebrates	• The seafloor within the assessment area is made up of an open sandy seafloor with a sparse cover (4% of total survey area) of macro invertebrates such as bivalves, ascidians, bryozoans, echinoids and corals (Worley Parsons – Marine 2012).
Threatened and migratory marine animals	**Marine turtles** • Green, flatback and leatherback turtles have been recorded foraging in the Hay Point region (Atlas of Living Australia, Bell 2003). There is also potential for Hawksbill turtles to forage on the rocky reefs in the area (Worley Parsons – Marine 2012). • Low density turtle nesting has been anecdotally reported at beaches surrounding Dudgeon Point (Worley Parsons – Marine 2012). Suitable nesting habitat has been identified at the: o beach between Dudgeon Point and Mount Hector o Louisa Creek Beach and o the beach area close to the Tug Harbour (Worley Parsons- Marine 2012). **Dugong** • Dugong (M) have previously been identified within the vicinity of Dudgeon Point during an aerial survey(Worley Parsons- Marine 2012). The nearest locations considered to be important habitat for dugong are outside of the assessment area at Llewellyn Bay/Ince Bay (20 km south) and Sand Bay/Newry region (55 km north). These areas are identified as Dugong Protection Areas under the Queensland *Nature Conservation Act 1992*. **Whales and dolphins** • Humpback whales have previously been observed within the waters offshore of Dudgeon Point during an aerial survey (Worley Parsons – Marine 2012). • Inshore dolphins have the potential to occur within the inshore waters of the assessment area.

MARINE	
Marine water and sediment quality	• The current condition of the broader Sandringham Bay area receiving waters is considered to be very poor (Reef Catchments 2013). This is attributed to poor water quality from the surrounding subcatchments that are highly modified and used for agricultural purposes (Reef Catchments 2013). • Sandy Creek, which drains into Sandringham Bay (and the waters within the assessment area) have previously recorded the highest concentrations of the herbicide diuron of any waterways within the Great Barrier Reef Lagoon (Reef Catchments 2013). Diuron was the only herbicide detected (Waltham et al 2015). This herbicide and other PS II herbicides have been linked to mangrove dieback in the Mackay region (Bell & Duke 2005). • Recent, more localised marine water quality results for Dudgeon Point indicated nutrient concentrations were above relevant guidelines for the region (Waltham et al 2015). This elevation is consistent with trends in nutrient levels for the Mackay-Whitsunday Area and could be attributed to local land use or remobilisation of coastal sediments and release of available nutrients (Waltham et al 2015). Other water quality parameters measured at the site were within relevant guideline limits (Waltham et al 2015). • Studies of sediment quality within the Sandringham Bay area are limited. Studies of sediments offshore of the Bay, within the existing DMPA indicate sediments are dominated by medium and coarse sand (>85.5%) and gravel (6.4%), the finer fractions <63 μm in size (silt and clay) represent <4% of the sediments (Worley Parsons – Marine 2012).

Offshore dredge material placement areas

Two offshore areas adjacent to Hay Point and one location past the Great Barrier Reef ribbon reefs (Coral Sea) have been identified as potential sediment placement areas. Assessment of the area of possible influence from the three disposal scenarios was undertaken to identify the locally important environmental values. The area of possible influence was broadly defined by combining a 15 km radius from the centre of each dredge material placement site. The following maps and tables document the key features and their relative environmental values.

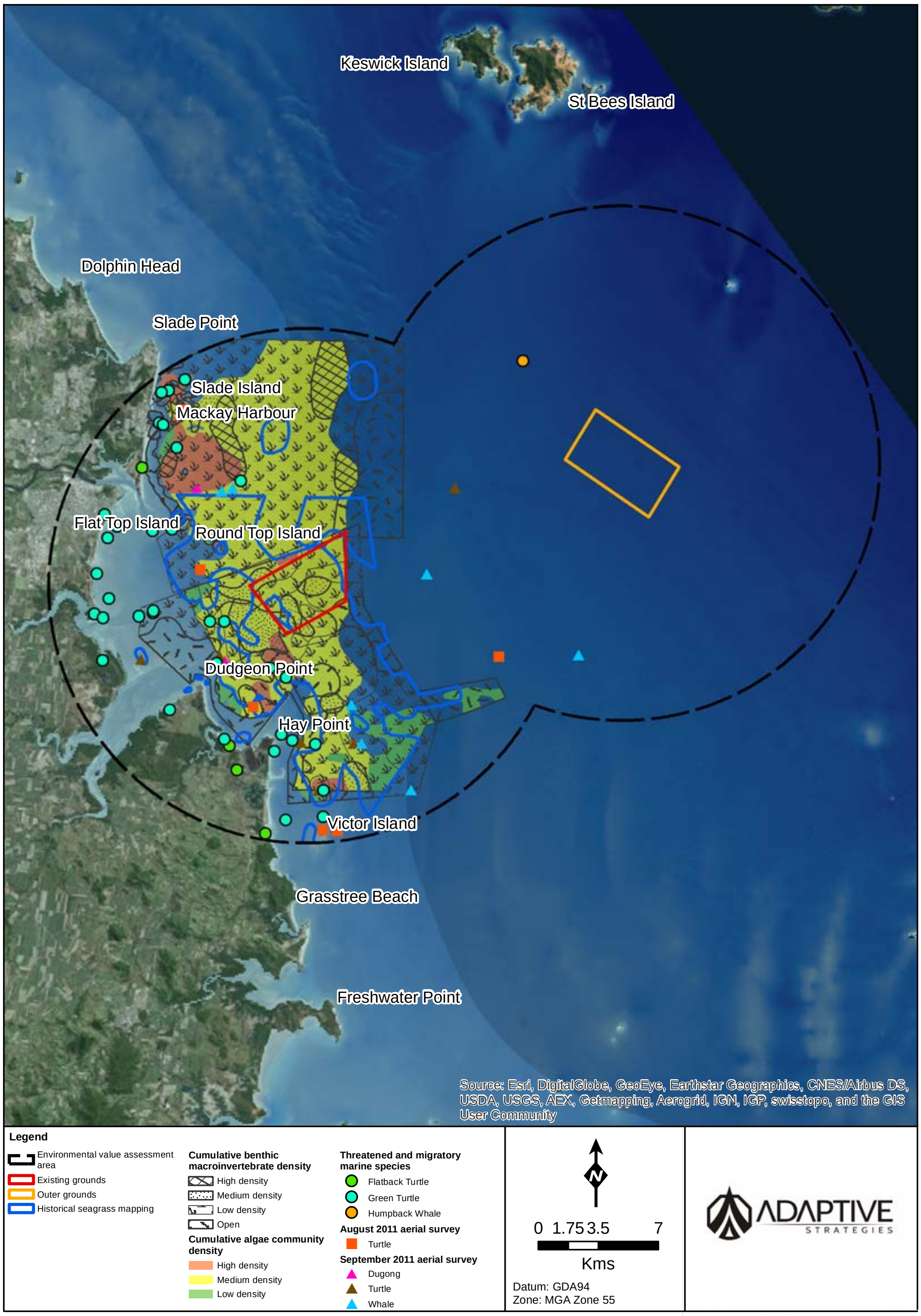


Figure 22: Marine and coastal environmental values of the existing and proposed outer Dredge Material Placement Areas (DMPA)

Table 18: Existing and mid-shelf DMPA marine values

MARINE	
Rocky and coral reefs	• Round Top Island, Flat Top Island, Slade Islet, Victor Islet, Dudgeon and Hay Reefs are known to support small rocky fringing reefs. Reefs in these areas are comprised of hard coral species common to turbid marine environments in the Great Barrier Reef (genera Montipora, Acropora, Pocillopora and Turbinaria) and a diverse range of soft corals, sponges, sea fans, ascidians and hydroids similar to fringing reefs in areas experiencing large tidal variations (Ayling et al 1998). • These rocky and coral reef habitat areas are locally important to fish and other marine species. They are not considered to be regionally significant areas of coral or rocky reef habitat.
Seagrass	• Seagrass beds within the assessment area are likely to be ephemeral (Rasheed et al 2001; Rasheed et al 2004). Historically, seagrass has been found within survey areas in low and medium densities (2001 -2011). The most recent seagrass surveys located offshore *Halophila decipiens* beds within and adjacent to the existing disposal area (McKenna et al 2016). These seagrasses were considered to be in a satisfactory condition (McKenna et al 2016). • Seagrass beds have also historically occurred in inshore areas at Dudgeon Point, Flat Top and Round Top islands. • Surveys for seagrass have not been undertaken within the potential outer disposal ground. However, there is potential for the area to support deep water seagrass beds.
Macroalgae	• Cumulative algae cover in areas within and surrounding the existing dredge material placement area indicate the region supports large areas of medium density algae (5-20%), with patches of low (<1-5%) and high density (>20%) occurring in inshore and offshore waters. Algae species observed in the area have been found to generally include *Sargassum, Udotea* and *Caulerpa* (Rasheed et al 2004; Thomas et al 2010). • There have been no surveys for macroalgae in the outer dredge material placement area, therefore the extent and composition of macroalgae is unknown for that location.
Benthic invertebrate communities	• Surveys of benthic invertebrate communities within the existing spoil ground indicated the area was predominately comprised of low density communities (1-10%) with a small patch of moderate density (>10%) communities (Thomas & Rasheed 2001). These regions had a mostly open seafloor (with small areas of rubble patches) with a moderate density of encrusting bryozoans and polychaete worms (Thomas & Rasheed 2001). • Surveys of the outer dredge material placement area indicated that there was a range of species present. The most commonly found where polychaeta, mollusca and crustacea (Worley Parsons – Macrobenthic 2013).

Threatened and migratory marine fauna	• There are no known important populations of threatened or migratory marine animals within the offshore assessment area. The assessment area does however support marine species foraging or resting in the area these include:
	  o flatback, green, loggerhead, leatherback, olive ridley and hawksbill turtles forage in the algal, seagrass and rocky reef areas
	  o dugong forage in the inshore and offshore seagrass areas
	  o humpback whales use the nearby offshore waters for resting during their migration along the east coast
	  o saltwater crocodile transit through the area (NQBP 2010; 2011).
	• There is also potential for the indo-pacific humpback dolphin, the Australian snubfin dolphin, and inshore and offshore forms of the bottlenose dolphin to occur within the offshore areas (NQBP 2011).
	• The intertidal wetlands of Sandringham Bay- Bakers Creek Aggregation provide seasonally important feeding habitats for waders and other migratory shorebirds, particularly between August and April (Harding & Milton 2003).

MARINE	
Marine water and sediment quality	• Water quality in the offshore waters of the Port of Hay Point is influenced by wind driven currents and large ranging tidal currents, causing naturally turbid waters as a result of constantly resuspended sediments. Water quality analysis in areas surrounding the existing port infrastructure indicate that offshore areas have a lower percentage of total nitrogen than inshore sites. The offshore areas also have higher salinities, DO (% saturation) and pH than inshore sites (Worley Parsons MDMP 2013). • Sediments within the existing DMPA are dominated by medium and coarse sand (>85.5%) and gravel (6.4%), the finer fractions <63 μm in size (silt and clay) represent <4% of the sediments (Worley Parsons – Marine 2012). Sediments within the potential outer DMPA are comprised of mostly sand (80.6%) with small fractions of silts (10.5%) and clays (8.6%) (Worley Parsons 2013).

Coral Sea

The area proposed for offshore placement of dredged material is in water depths of over 300 m. The area falls within the boundaries of the Coral Sea Commonwealth Marine Reserve, and is currently zoned "Conservation Zone" (Figure 23). The zoning of the area is currently under review. The area is not within close proximity to known areas of high ecological significance including mapped Coral Sea islands, reefs or cays.

Deepwater ecosystems within the Coral Sea, however, have not been extensively studied. Recent studies have however found deep-water habitats that support ecological communities (Woerheide and Reitner 1996; Beaman et al. 2009). In these areas, the substrate composition and geomorphic features can create hotspots of high productivity. Deep-sea benthic communities may provide foraging areas for deep diving cetaceans (Brewer et al. 2007).

Further investigation of the proposed disposal placement area would need to be undertaken to understand the relative importance of environmental values within the site to marine species in the area.

The dredge vessel would likely need to traverse through an area that is recognized as a core humpback whale aggregation area (Figure 23). This area is located approximately 80 km east of Mackay. Humpback whales are thought to aggregate in this region near the ribbon reefs of the GBR between the winter months of June to September (Smith et al. 2012).

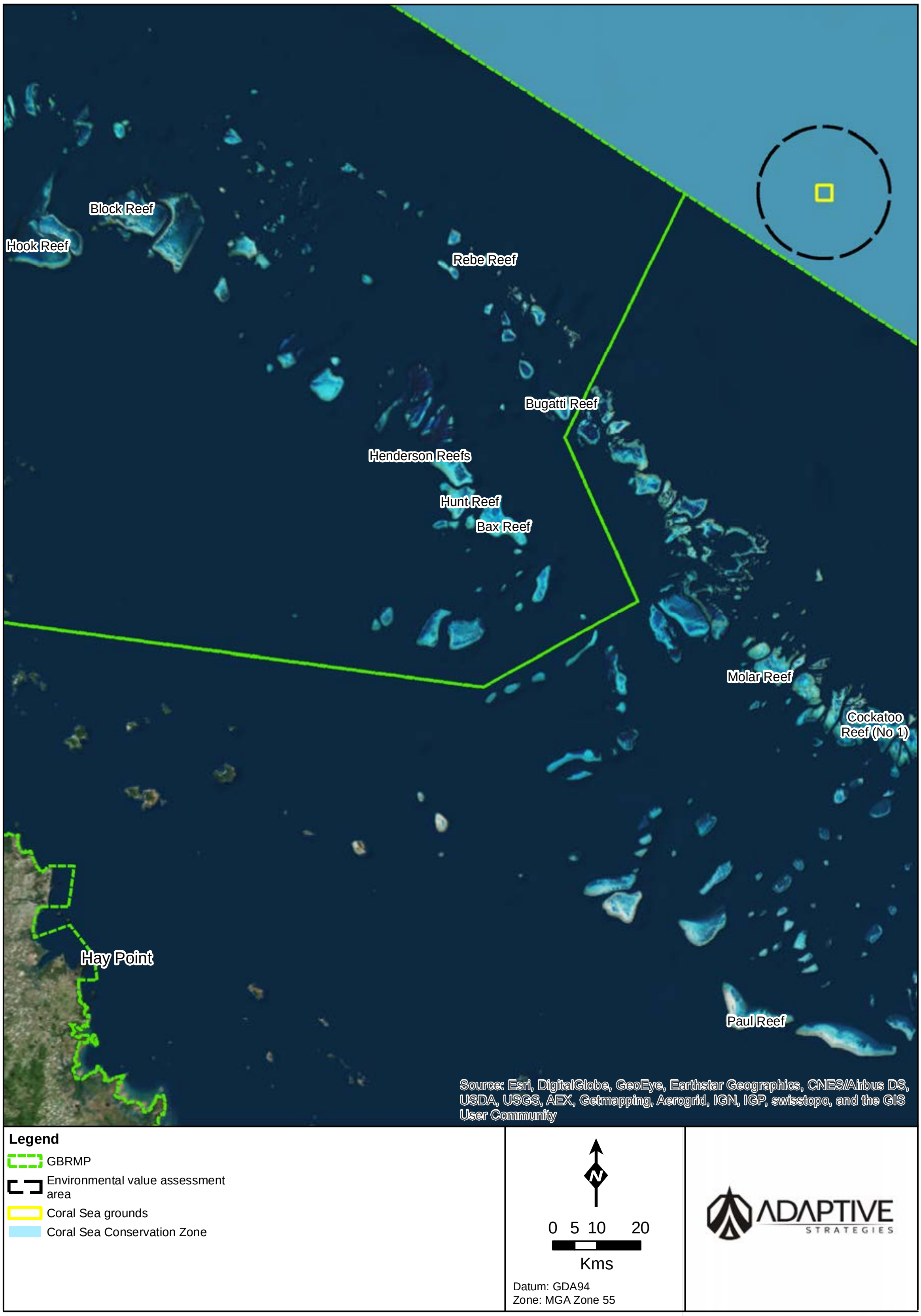


Figure 23: Proposed offshore Corals Sea Dredge Material Placement Area

Potential environmental impact pathways

Each alternative involves a range of activities with the potential to impact environmental values to varying levels and extent. This section provides a description of the potential impact pathways of each alternative.

The purpose of this analysis is to provide decision makers and stakeholders with a high level understanding of how potential impacts associated with each sediment management scenario could be expected to interact with key environmental values.

This is not a detailed environmental impact assessment or constraints analysis. A detailed environmental impact assessment will be required once a decision on the preferred option for sediment management has been determined.

For each alternative, the following has been qualitatively described:

- Potential type of direct and indirect impact pathways.
- Potential severity of impacts to environmental values.
- Potential management complexities associated with possible impacts identified.

Potential impacts to environmental values have also been considered as part of the comparative analysis. However, the comparative analysis considers impacts to a specific set of terrestrial and marine values using quantitative measures that allow direct comparison of each alternative. The assessment presented here is designed to complement the comparative analysis by providing additional context around activities, impacts and values.

The following tables summarise the potential impact pathways and likely causes that could result from each option. The table also highlights the key environmental values that may be affected by construction and operational activities. Potential impacts to these values will need to be managed through appropriate best practice management measures and controls.

Mackay Harbour – Reclamation

The reclamation of a 26 ha area adjacent to the north wall of Mackay Harbour will result in the permanent alteration of a small area of coastline adjacent to the existing harbour. Direct impacts from the construction of the reclamation area will include the removal of small areas of marine habitat, beach and potentially an area of vegetation along the eastern boundary of the site. The reclamation area is within the boundaries of the GBRWHA.

Development may affect a number of key environment values, including a small area of beach habitat which may support low density turtle nesting and migratory shorebirds, and a small area of vegetation that may support critically endangered (EPBC Act) Threatened Ecological Community 'Littoral Rainforest and Coastal Vine Thicket of Eastern Australia'. Further investigation is required to determine the presence and extent of these values should this option be selected.

Reclamation will also potentially cause a range of indirect impacts in the area, as detailed in the table below. These potential impacts can all be managed through appropriate best practice measures; noting that there will be ongoing management and monitoring obligations as part of both construction and operation phases of the project.

Table 19: Mackay Harbour reclamation - potential impacts

Impact pathway	Potential cause(s)	Potential key environmental receptors
Removal of coastal and marine habitat	• Construction of embankments • Disposal of dredge material within reclamation area • Construction of access road	• Integrity of GBRWHA • Low density marine turtle nesting • Foraging area for migratory shorebirds • Littoral Rainforest and Coastal Vine Thickets
Changes to marine water quality	• Construction of embankments • Dewatering of reclamation area • Runoff from constructed reclamation area	• GBRWHA water quality • Rocky reef habitat at Slade Islet • Small area of seagrass at Slade Bay • High density macroalgae and benthic invertebrate communities • Transitory threatened and migratory fauna

Impact pathway	Potential cause(s)	Potential key environmental receptors
Increased onshore and underwater noise	• Operation of machinery during construction • Ongoing use of reclaimed area	• Transitory threatened and migratory birds • Transitory threatened and migratory marine fauna (e.g. dugong, turtles, inshore dolphins)
Increased artificial lighting	• Construction machinery operation • Ongoing use of reclaimed area	• Transitory threatened and migratory birds • Nesting marine turtles
Alteration of coastal sediment transport processes	• Construction of embankment wall and reclamation area	• Beach habitat for nesting turtles • Small area of seagrass at Slade Point

Mackay Harbour – Onshore

Onshore placement of dredge material will permanently remove a small area of wetland and associated remnant vegetation a short distance inland from the existing Mackay Harbour. The proposed footprint of the pond is surrounded by existing infrastructure, and is within a highly modified catchment area. Direct impacts are not likely to be significant as they are unlikely to remove any known important habitat.

A range of indirect impacts may also occur. Notable environmental receptors within, and adjacent to the proposed onshore pond location at Mackay Harbour include 'of concern' state listed remnant vegetation, State Significant Wetland areas and Wetland Protection areas, adjacent GBRWHA waters and potential habitat for the threatened water rat. Indirect impacts likely to result from the activities associated with this option could be managed through appropriate best practice measures.

Table 20: Mackay Harbour onshore placement - potential impacts

Impact pathway	Potential cause(s)	Potential environmental receptors
Removal of wetland and remnant native vegetation	• Dredge material placement	• Remnant vegetation (19 ha of mapped REs 8.1.3/8.3.12/8.1.4 and 1ha mapped REs 8.2.7a/8.2.6)
Changes to water quality	• Runoff from containment pond during construction • Disturbance of Potential Acid Sulfate Soils (PASS) • Seepage of containment pond	• Adjacent State Significant Wetland areas and Wetland Protection areas. • Adjacent GBRWHA waters.
Changes to wetland flows	• Construction of embankment walls • Temporary placement of delivery and return pipelines	• State Significant Wetland areas and Wetland Protection areas. • Adjacent GBRWHA waters. • Adjacent areas of remnant vegetation and mangroves.
Changes in habitat connectivity	• Construction of embankment walls • Temporary placement of delivery and return pipelines	• Threatened water mouse (if confirmed present)
Increased artificial lighting and noise	• Construction of containment pond • Dredge material placement • Dredge vessel operation	• Transitory threatened and migratory birds and mammals • Transitory threatened and migratory marine species

Sandringham Bay – mangrove rehabilitation

The option of rehabilitating an area of mangrove habitat within Sandringham Bay is expected to result in a positive outcome for the environment. If successful, the rehabilitated area would re-create 70 ha area of mangrove habitat that could support a range of species and important ecosystem processes.

Notable environmental values within the area for this option include the waters of the Sandringham Bay- Bakers Creek Aggregation (listed under DIWA) and GBRWHA, foraging and roosting habitat for migratory shorebirds, and potential turtle nesting habitat.

The construction phase of the project will cause temporary changes to largely undisturbed mudflat areas within the boundaries of the GBRWHA and Sandringham Bay area. The existing macroinvertebrate communities within the marine sediments of the proposed rehabilitation area would be covered with the dredge material. It is expected that these communities would recolonize to similar benthic macroinvertebrate composition and densities over a period of one to two years once the rehabilitation area becomes stable.

The activities associated with the rehabilitation process could also result in a number of indirect impacts to environmental values in the surrounding area. These include the potential for temporary changes to water quality within the GBRWHA and Sandringham Bay – Bakers Creek Aggregation and temporary disturbance of shorebirds and other fauna in the area during operational periods. These would require management and monitoring to ensure that impacts to environmental values in the area are avoided and minimised as far as practicable.

This option would require significant lead-time. Site selection and method development would need to be thoroughly investigated to ensure success of the project, and would likely be quite complex. Approvals for the project could also require a significant amount of time. The project is also likely to be subject to complex management and monitoring obligations. It will be occurring within a sensitive environment, and approval agencies would expect certainty around the success of the project, and avoidance and minimization of negative impacts.

Table 21: Sandringham bay rehabilitation - potential impacts

Impact pathway	Potential cause(s)	Potential environmental receptors
Changes to benthic invertebrate composition	• Construction of bund • Dredge material placement	• Benthic macroinvertebrate communities within the GBRWHA
Changes to marine water quality	• Increased turbidity and sedimentation resulting from: o Construction of bund o Dredge material placement	• Small seagrass beds adjacent to Dudgeon Point • Areas of recovering mangrove within Sandringham Bay • Receiving water of Sandringham Bay – Bakers Creek Aggregation (DIWA) and GBRWHA
Changes to estuarine and sediment transport processes	• Construction of bund	• Foraging and roosting habitat for migratory shorebirds • Marine turtle nesting habitat • Small seagrass beds adjacent to Dudgeon Point
Increased noise and lighting	• Construction of bund • Dredge material placement • Mangrove planting • Ongoing monitoring activities	• Foraging and roosting habitat for migratory shorebirds • Marine turtle nesting habitat
Increased human activity	• Construction of bund • Dredge material placement • Mangrove planting • Ongoing monitoring activities	• Foraging and roosting habitat for migratory shorebirds • Marine turtle nesting habitat

Dudgeon Point – Onshore

The onshore placement of dredge material at Dudgeon Point would occur within an area that is currently used for grazing cattle. Adjacent to the area for potential containment pond are a number of important environmental values. These include a migratory shorebird roosting site (with counts of >1,000 shorebirds), the Sandringham Bay-Bakers Creek Wetland Aggregation Area (listed on Directory of Important Wetlands in Australia (DIWA)) and the GBRWHA. A small area of the mapped extent of the shorebird roosting habitat will be replaced with dredge material that will remain as a raised area once complete. The area that would be removed would result in a loss of roosting habitat.

As there are sites of significant environmental value directly adjacent to the proposed onshore containment pond, management of indirect impacts will be critical. Management and monitoring techniques to ensure indirect impacts are avoided and minimised are well understood. Such measures would need to mostly be undertaken during the construction phase of the containment pond. Ongoing monitoring and management of the area containing the dredge material would need to be carried out.

Table 22: Dudgeon Point onshore placement - potential impacts

Impact pathways	Potential cause(s)	Potential environmental receptors
Loss of mapped shorebird roosting habitat	• Dredge material placement	• Important migratory shorebird roosting habitat
Temporary loss of coastal habitats	• Sediment delivery and return water pipeline placement	• Important migratory shorebird roosting habitat • Marine turtle nesting habitat
Changes to water quality	• Pumping of return water • Runoff from containment pond • Disturbance of PASS • Seepage from containment pond	• Adjacent GBRWHA, Sandringham Bay (DIWA) and State Significant Wetlands water quality • Inshore seagrass beds • Important migratory shorebird roosting habitat
Increased noise and artificial lighting	• Onshore machinery operation during construction phase • Dredge vessel operation	• Threatened and migratory birds • Nesting marine turtles • Threatened mammals • Transitory threatened and migratory marine animals
Increased human activity	• Construction of containment pond • Ongoing management and monitoring activities	• Threatened and migratory birds (including

Hay Point – Reclamation

Dredge material placement within an area adjacent to the existing tug harbour at Hay Point will result in the loss of a small area of potential turtle nesting habitat, potential foraging shorebird habitat and a small area of vegetation potentially supporting the critically endangered (EPBC Act) Threatened Ecological Community 'Littoral Rainforest and Coastal Vine Thicket of Eastern Australia'. Further investigation of the presence and extent of important environmental values within the footprint of the reclamation area would be required. However, given the small scale of the proposed development it is unlikely that significant impacts would occur to environmental values in the area.

This option also has the potential to cause a number of indirect impacts as outlined in the table below. The indirect impacts associated with reclamation are well understood, and it is likely that they would be successfully managed through standard best practices.

The reclamation and ongoing use of an area adjacent to the tug harbour would also require ongoing management and monitoring activities once the construction phase is complete.

Table 23: Hay Point reclamation - potential impacts

Impact pathways	Potential cause(s)	Potential environmental receptors
Loss of coastal and inshore habitat	• Dredge material placement	• Marine turtle nesting habitat • Migratory shorebird foraging habitat • Threatened Ecological Community 'Littoral Rainforest and Coastal Vine Thicket of Eastern Australia'
Changes to marine water quality	• Rock embankment placement • Dredge material placement • Return water discharge	• Marine turtle nesting habitat • Benthic macroinvertebrate and algae communities • Transient seagrass beds and habitat • Threatened and migratory marine animal habitat • Water quality within the GBRWHA
Increased onshore and underwater noise	• Construction machinery • Dredge vessel operation • Ongoing operational activities	• Transitory threatened and migratory marine animals • Transitory threatened and migratory birds
Increased artificial lighting	• Construction activities • Ongoing operational activities	• Marine turtle nesting • Transitory threatened and migratory birds

Offshore – Existing DMPA

Dredge material placement within a large (1840 ha), previously disturbed offshore area would result in temporary changes to the benthic environment. This option would result in the short-term loss of benthic macroinvertebrate and algal communities and transient seagrass beds or seagrass habitat as a result of smothering from the dredge material. Over time (1-2 years), benthic communities and transient seagrass would be expected to recolonise the area.

The indirect impacts of dredging placement projects are well understood. The placement of dredge material in the existing Dredge Material Placement Area (DMPA) will result in a number of temporary indirect impacts as outlined in the table below. Increased turbidity and sedimentation from the dredge plume has the potential to reach sensitive environmental receptors to the north of the existing DMPA. However, the low level and short duration of these increased levels means that potential impacts are not of substantial concern.

The activities associated with this option are well tested and understood. It is considered that existing ongoing management and monitoring requirements would continue once the placement of dredged material has been completed.

Table 24: Existing DMPA - potential impacts

Impact pathway	Potential cause(s)	Potential environmental receptors
Temporary loss of benthic habitat	• Dredge material placement	• Transient seagrass beds and seagrass habitat • Benthic macroinvertebrate communities
Changes to water quality	• Dredge material placement and associated sediment plume	• Transient seagrass beds and seagrass habitat • Benthic macroinvertebrate communities • Coral and rocky reef habitats at Round and Flat Top islands, and Slade Islet • Transitory threatened and migratory marine animals
Sediment deposition	• Dredge material placement and associated sediment plume	• Transient seagrass beds and seagrass habitat • Benthic macroinvertebrate communities • Coral and rocky reef habitats at Round and Flat Top islands, and Slade Islet
Increased potential for vessel strike	• Movement of dredge vessel from the Port of Hay Point to the DMPA	• Transitory threatened and migratory marine animals

Offshore – Mid-shelf DMPA

The option of dredge material placement in a previously undisturbed area of seabed 25 km north east from the Port of Hay Point would result in temporary, moderate-scale impacts (~1800 ha), similar to the existing DMPA. The location for dredge material placement currently supports a range of worm, crustacean and mollusc species. It would be expected that these communities would recolonize over time (1-2 years).

As with all dredging material placement activities within the marine environment, there are a number of indirect impacts that occur. Changes to water quality through increased turbidity and sedimentation from the sediment plume occurs at different scales and durations depending on a number of influencing factors. Dredge plume modelling for the placement of dredge material at this newly proposed DMPA indicates that the plume will not extend as far as the placement of material in the existing ground. The modelling also indicates that suspended sediment would not reach any inshore environmental receptors.

This option would require management of indirect impacts throughout the dredge placement activities. Ongoing management and monitoring will be required to confirm low impact predictions.

Table 25: Mid-shelf DMPA - potential impacts

Impact pathway	Potential cause(s)	Potential environmental receptors
Temporary loss of benthic habitat	• Dredge material placement	• Transient seagrass beds and seagrass habitat • Benthic macroinvertebrate communities
Changes to water quality	• Dredge material placement and associated sediment plume	• Transient seagrass beds and seagrass habitat • Benthic macroinvertebrate communities • Transitory threatened and migratory marine animals
Sediment deposition	• Dredge material placement and associated sediment plume	• Transient seagrass beds and seagrass habitat • Benthic macroinvertebrate communities
Increased potential for vessel strike	• Movement of dredge vessel from the Port of Hay Point to the DMPA	• Transitory threatened and migratory marine animals

Offshore – Coral Sea DMPA

There are a number of uncertainties in relation to the option of placing material in an area of deep water in the Coral Sea. The area where dredge material may be placed has not been surveyed and there is limited information regarding the environmental values present within the area.

It would be expected that impacts from the placement of dredge material in this area would be similar to other dredge material placement activities. These impacts are summarised in the table below. However, it should be noted that the list of potential environmental receptors may not be complete as ecological investigations of the proposed site needs to be undertaken.

Placement of dredge material in this area would likely require a long lead in time to undertake the required investigations to assess potential impacts and obtain the necessary approvals. There is also a review currently underway into the management arrangements of the Coral Sea Commonwealth Marine Reserve, in which the proposed material placement area is located. The outcome of the review may influence the types of activities that would be allowed (or excluded) within the area proposed for this option.

Table 26: Coral Sea DMPA - potential impacts

Impact pathways	Potential cause(s)	Potential environmental receptors
Temporary loss of benthic habitat	• Dredge material placement	• Benthic macroinvertebrate and algae communities
Changes to water quality	• Dredge material placement and associated sediment plume	• Benthic macroinvertebrate communities • Transitory threatened and migratory marine animals
Sediment deposition	• Dredge material placement and associated sediment plume	• Benthic macroinvertebrate and algal communities
Increased potential for vessel strike	• Movement of dredge vessel from the Port of Hay Point to the DMPA	• Breeding and calving humpback whales • Transitory threatened and migratory marine animals

Comparative analysis

In order to objectively and transparently compare the various alternatives for reuse and placement of dredge material a comparative analysis using a structured decision making process has been undertaken. This process is based on repeatable methods that use the objectives and measures that were developed in consultation with all stakeholders.

The goal of a Structured Decision Making process is to inform difficult choices, and to make them more transparent and effective (Gregory *et al*, 2012).

The comparative analysis process is somewhat complex although it uses standard statistical approaches and logic. The objectives and measures relate to a range of social, economic and environmental factors that are measured in different ways with different scores and ranking. Accordingly a method involving normalisation, sensitivity analysis and weighting is used to make the work balanced and understandable.

The comparative analysis involved the application of a process to:

1. Initially compare the alternatives against the objectives and performance measures.
2. Based on the results of that initial analysis, develop a set of long term strategies for management of sediment at the port by combining alternatives over a 25 year period.
3. Analyse and compare the long term strategies against the objectives and performance measures to arrive at a preferred solution.

The process was extensive and involved:

- Removing clearly inferior alternatives (e.g. alternatives that performed extremely poorly against one or more objectives).
- Ranking alternatives using various methods (e.g. different weightings, sensitivity analysis).
- Refining alternatives as needed to reach an optimal long term solution.
- Identifying a preferred solution based on the outcomes of the analysis.

The results of this work are presented in this Chapter, more detailed information is included in the SSM Project Comparative Analysis Report at **Appendix B**.

Initial comparison of alternatives

The initial comparison of alternatives examined the eight possible alternatives for reuse or placement of sediment:

1. Land reclamation - Port of Hay Point (Rec - HP).
2. Land reclamation - Mackay Harbour (Rec – M).
3. Habitat (mangrove) rehabilitation - Sandringham Bay (Rehab).
4. Onshore pond at Dudgeon Point (Onshore – DP).
5. Onshore pond at Mackay Harbour (Onshore – M).
6. Existing offshore Dredge Material Placement Area (Existing).
7. Mid-shelf offshore Dredge Material Placement Area (Mid-shelf).
8. Coral sea offshore Dredge Material Placement Area (Coral sea).

RAW SCORES

The raw scores from each performance measure were determined and recorded in a consequence table. A consequence table is a matrix that illustrates and compares the performance of each alternative with respect to the objectives. Table 27 provides the raw scores for each measure and alternative, noting:

- The table indicates which direction is better for each performance measure in the "Dir" column. "H" is higher, and "L" is lower.
- The best scores for a performance measure are highlighted in green.
- The worst scores for a performance measure are highlighted in red.

Table 27: Raw scores for single dredge campaign

Theme	Objectives	Performance measure	Units	Dir	Rec - HP	Rec - M	Rehab	Onshore - DP	Onshore - M	Existing	Mid-shelf	Coral sea
ENV	1. Avoid and minimise impacts to coastal ecosystems	A) Coastal ecosystems performance	4-16	H	4	4	16	7	6	6	8	8
		B) Water quality performance	0-21	L	0	0	0	0	0	6	1	0
	2. Minimise carbon emissions	C) GHG emissions	tCO2-e	L	24,774	19,485	1,674	7,421	4,886	618	1,012	6,693
CULTUR	3. Minimise impact on cultural heritage within the area	D) Cultural heritage performance	3-9	L	4	4	3	5	5	3	3	3
ECON	4. Maintain effective and efficient port operations	E) Port disruption	Days	L	23	31	20	23	31	14	23	16
		F) Lead time	Years	L	4	4	5.5	3.75	4.25	1	1.5	4
		G) Long term solution	Years	H	20	25	10	20	20	25	25	25
	5. Ensure solution is cost effective	H) Cost	$ million	L	$35.26	$26.02	$6.97	$22.94	$15.56	$1.83	$2.97	$29.47
	6. Avoid significant loss of future port expansion opportunities	I) SPL area affected	ha	L	40	40	20	50	50	0	0	0
H&S	7. Avoid or mitigate health and safety risks	J) Relative risk	8-24	L	16	16	10	15	16	8	11	15
SOCIAL	8. Minimise interference to social activities within the region	K) Social performance	3-9	L	6	7	3	3	7	3	3	3
	9. Provide increased economic and social opportunities	L) Employment	FTE	H	8.37	5.46	1.58	5.77	2.73	0.25	0.5	0.175
INNO	10. Promote innovation in port management	M) Innovation	3-9	H	3	3	8	3	3	3	5	5
WH	11. Avoid and minimise impacts to the Great Barrier Reef World Heritage Area	N) World Heritage performance	4-12	H	7	6	11	9	9	9	8	10

Best score for a performance measure

Worst score for a performance measure

ANALYSIS

An analysis of the eight alternatives shows how they each perform against the objectives and measures. One of the critical findings is that only two alternatives have the potential to be implemented within three years – the existing and mid-shelf offshore dredge material placement areas.

The other critical objective to consider when looking at each alternative is the long-term sediment management requirements of the Port. There is a demonstrated need for ongoing maintenance dredging every five years in the order of 200,000 m^3 of material for the next 25 years. Looking at Table 27, only four alternatives have the potential to provide this capacity over a 25 year period – reclamation at Mackay and the three offshore alternatives.

With only two offshore alternatives able to deliver on both the three year lead time objective and the 25 year capacity, the next stage of the analysis therefore looked at combinations of alternatives to determine whether performance against the full range of objectives could be better optimised. This next step recognised that there is merit in the other alternatives as long as they are considered as part of a combined option that provides for both a short and long term solution.

Long-term strategies

Further analysis of the individual alternatives was undertaken in order to generate a combination of alternatives that could form long-term strategies that: provide for maintenance dredging within the next three years; and offers a solution over 25 years.

The detailed analysis of the eight individual alternatives helped to generate eleven combined strategies that have the potential to address both the short and long-term sediment management needs of the Port. It is important to note that in the configuration of the long-term strategies:

- In order to provide for maintenance dredging within the next three years, the existing or mid-shelf offshore DMPA's were always included.

Reclamation at Mackay was dropped entirely as it was deemed clearly inferior to the other seven alternatives.

The identified long-term strategies (25 years) based on a 5 yearly campaigns are:

	Campaign 1	Campaign 2	Campaign 3	Campaign 4	Campaign 5
Strategy 1	At-sea existing	Hay Point Reclamation	Hay Point Reclamation	Hay Point Reclamation	Hay Point Reclamation
Strategy 2	At-sea existing	Mangrove habitat	At-sea existing	At-sea existing	At-sea existing
Strategy 3	At-sea existing	Mangrove Habitat	Hay Point Reclamation	Hay Point Reclamation	Hay Point Reclamation
Strategy 4	At-sea existing	Mangrove Habitat	Dudgeon Point Onshore	Dudgeon Point Onshore	Dudgeon Point Onshore
Strategy 5	At-sea existing	Dudgeon Point Onshore	Dudgeon Point Onshore	Dudgeon Point Onshore	Dudgeon Point Onshore
Strategy 6	At-sea existing	Mangrove habitat	Mackay Onshore	Mackay Onshore	Mackay Onshore
Strategy 7	At-sea existing	Mackay Onshore	Mackay Onshore	Mackay Onshore	Mackay Onshore
Strategy 8	At-sea existing	At-sea existing	At-sea existing	At-sea existing	At-sea existing
Strategy 9	At-sea mid-shelf	At-sea mid-shelf	At-sea mid-shelf	At-sea mid-shelf	At-sea mid-shelf
Strategy 10	At-sea existing	At-sea Coral Sea	At-sea Coral Sea	At-sea Coral Sea	At-sea Coral Sea
Strategy 11	At-sea mid-shelf	Mangrove habitat	At-sea mid-shelf	At-sea mid-shelf	At-sea mid-shelf

COMPARISON OF LONG TERM STRATEGIES

The performance of the long term strategies were scored against the objectives and performance measures over a 25 year time frame.

It is important to note that two performance measures did not flow through to the long term assessment. These were the performance measures relating to lead in time (measure F) and the capacity to provide a long term solution (measure G). These were removed from this stage of the analysis as all of the long term solutions were designed so they could be implemented within the next three years and provide capacity for 25 years.

The analysis for the long-term strategies involved the same steps and similar level of detail to the analysis described for the individual alternatives. Noting that in addition to reviewing the raw scores an analysis of weighted scenarios and sensitivity were performed to help address uncertainty.

RAW SCORES

The raw scores for each long term strategy are shown in Table 28. These scores indicate that:

- The strategies comprising solely of the existing or mid-shelf offshore DMPA's generally perform well across a range of measures.
- Strategies that include onshore disposal at Mackay and reclamation at Hay Point generally perform poorly.
- Strategies that include mangrove habitat rehabilitation perform moderately well.

WEIGHTED SCORES

Weighting is an important step in the decision making process. It is a process that people often undertake subconsciously by placing more value on some objectives over others when trying to make a decision between options. The structured decision making process provides a transparent way of applying and testing weightings.

The weighting of normalised scores enables a comparison of the long term strategies when a particular theme (environment, social, economic) is favoured (or considered to be of more value). This enables preferred long term solutions to be identified even when a particular theme is considered more important to a particular stakeholder or decision maker. It also identifies which strategies perform well across the various themes and which ones generally perform badly.

It is recognised that stakeholders value objectives differently and will therefore apply different weightings. Given this, no attempt was made to reach a consensus on how to apply weightings or indeed what weightings are considered representative. Rather a number of different weighting scenarios were generated to see how each alternative would perform.

For the equal weighting scenarios all performance measures were weighted equally. For the themes focus the performance measure related to that theme were attributed a 75% weighting all other measures were equally weighted using the remaining 25%.

A summary of the overall performance of each long term strategy under the six weighting scenarios is provided in Table 29. The best performing option under each scenario is highlighted in darker green, the 2nd best in light green and the worst performing is highlighted in red.

Table 28: Raw scores for each long term option

Theme	Objectives	Performance measure	Units	Dir	Strat 1	Strat 2	Strat 3	Strat 4	Strat 5	Strat 6	Strat 7	Strat 8	Strat 9	Strat 10	Strat 11
ENV	1. Avoid and minimise impacts to coastal ecosystems	A) Coastal ecosystems performance	20-80	H	22	40	34	43	34	40	30	30	40	38	48
		B) Water quality performance	0-105	L	6	24	6	6	6	6	6	30	5	6	4
	2. Minimise carbon emissions	C) GHG emissions	(tCO2-e)	L	27,777	4,146	28,656	11,303	10,424	9,544	9,053	3,090	5,060	32,018	5,722
CULTU R	3. Minimise impact on cultural heritage within the area	D) Cultural heritage performance	15-45	L	19	15	18	21	23	21	23	15	15	15	15
ECON	4. Maintain effective and efficient port operations	E) Port disruption	Days	L	106	76	103	103	106	127	138	70	115	78	112
	5. Ensure solution is cost effective	H) Cost	$ millions (present value)	L	$25.73	$7.57	$20.76	$17.33	$20.72	$16.13	$14.49	$4.38	$7.11	$42.93	$9.60
	6. Avoid significant loss of future port expansion opportunities	I) SPL area affected	ha	L	40	20	60	70	50	70	50	0	0	0	20
H&S	7. Avoid or mitigate health and safety risks	J) Relative risk	8-24	L	16	10	16	15	15	16	16	8	11	15	11
SOCIAL	8. Minimise interference to social activities within the region	K) Social performance	15-45	L	27	15	24	15	15	27	31	15	15	15	15
	9. Provide increased economic and social opportunities	L) Employment	FTE jobs created	H	0.3748	0.1032	0.428	0.344	0.3008	0.2224	0.1792	0.05	0.1	0.038	0.1432
INNO	10. Promote innovation in port management	M) Innovation	15-45	H	15	20	20	20	15	20	15	15	25	23	28
WH	11. Avoid and minimise impacts to the Great Barrier Reef World Heritage Area	N) World Heritage performance	20-60	H	37	47	41	47	45	47	45	45	40	49	43

Table 29: Summary scores for long term strategies

	Strat 1	Strat 2	Strat 3	Strat 4	Strat 5	Strat 6	Strat 7	Strat 8	Strat 9	Strat 10	Strat 11
Equal weights	41	70	45	54	52	47	44	71	68	56	68
Environment focus	39	69	44	63	60	61	57	65	72	46	75
Social focus	36	57	41	54	53	37	31	57	56	52	56
Economic focus	44	80	44	48	49	39	40	89	74	59	69
Cultural focus	74	92	78	73	68	71	65	92	91	88	91
WHA	42	68	50	64	60	62	57	65	55	68	60

	Best performer
	2nd best performer
	Poorest performer

Analysis across various weighting scenarios indicated that:

- Three strategies clearly outperformed the rest. These strategies ranked as the three highest performers under all scenarios, although equal under the World Heritage weighting scenario (where the World Heritage performance measure was attributed 75% of the weightings). They were:
  - Strategy 8: '5 x exist' which performed the best under the equal, social, economic, and cultural heritage scenarios. It still performed well (ranking third) under the environment scenario and moderately well under World Heritage.
  - Strategy 2: '1 exist, 1 mangrove, 3 exist' which ranked best under a social and cultural scenarios, equal best under World Heritage and second under all other scenarios.
  - Strategy 11: '1 mid-shelf, 1 mangrove, 3 mid-shelf' which performed the best under the environment scenario, ranked second under the Social and Cultural Heritage scenarios, and third under equal weighting.
- The performance of the three top options listed above indicates that they can be expected to respond well to a broader range of stakeholder values and factors that might influence decision makers when compared to the other options. It should be noted, that these three strategies still perform well up to the point that the World Heritage performance measure is attributed up to 40% of the weightings (a significant proportion for a single measure). This is discussed further in the sensitivity analysis below.
- The '1 exist, 4 rec HP' strategy generally performed the worst, ranking amongst the lowest across all scenarios other than cultural heritage. This option performed the worst under the equal, environment and World Heritage scenarios.

Business case

The SSM Project has provided considerable useful information on a whole range of issues related to the management of sediment; environmental, social and cultural values; as well as improving our understanding of best practice approaches to decision making.

However, at its core the SSM Project was about informing and developing a business case for the *"Sustainable Sediment Management for Navigational Maintenance at the Port of Hay Point."*

To develop this business case a set of key questions were identified that would frame both the work undertaken and the outputs derived.

SSM Questions

Within the context of maintaining safe and efficient port operations:

1. Is it necessary to manage sediment at the Port of Hay Point in the short and/or long term?
2. If yes, what are the feasible ways to manage sediment within the context of needing to maintain port operations and meet legal requirements?
3. What is the best package of measures to provide for long-term sustainable management of marine sediments at the Port of Hay Point?

The answers to these questions leads us to a clear proposed solution that will form the business case for short and long-term sediment management at the Port of Hay Point.

QUESTION 1

Is it necessary to manage sediment at the Port of Hay Point in the short and/or long term?

Short-term - Yes!

Siltation of the navigational areas has occurred and is impacting on port operations.

- Bathymetric surveys conducted in October 2015, determined that there is approximately 205,800m^3 of maintenance material above design depth, most of this occurring in DBCT berth areas (apron and departure path, 59,300m^3, DBCT Berths 139,800m^3, HPCT Berths 6,700m^3).
- A report investigating opportunities to keep sediments out, keep sediments moving or keep sediments navigable identified practices that may reduce future sedimentation, no solutions other than traditional maintenance dredging would completely remove the existing accumulated material.
- Impacts from decreased berth pocket depth have been documented (in a report provided by DBCT). Analysis shows that economic impacts occur when berth pockets shallow to 18m below LAT or less. This impact increases significantly as depth further reduces. The average berth pocket depth for DBCT berths is currently 18.0m below LAT.

Long term - Yes!

Siltation of the navigational areas is a result of natural sediment transport processes (predominantly littoral drift) that is unable to be avoided. Some opportunities to reduce future rates of sedimentation where identified, although these would be most effective once design depths are re-established.

- Bathymetric modelling showed that siltation would continue to be prevalent in the northern apron area and berth pockets. Although some siltation may occur in the rest of the apron area and departure channel, it is expected to be minimal and may require periodic maintenance dredging (approximately 10,000m^3 every, once in every 10 years).
- Based on current siltation rates, the total maintenance volume to be managed over the next 20 years is forecast to be between 885,000m^3 and 1,129,000m^3 (in the absence a cyclone influences).
- Sediment transport at the Port of Hay Point is driven predominately by the process of littoral drift (derived mostly from the wave and wind environment).
- Sediment movement and accumulation from tropical cyclone events is likely to occur in the future. Emergency sediment management measures will need to be considered and included in future permit application processes.

- A sediment budget demonstrates that even if catchment loads were reduced by 50% in the region, a maximum benefit of no greater than 4% would be seen in navigational areas at the port.
- Once design depths are re-established, the continued use drag barring of berths can extend the periods between dredging to a predicted frequency of maintenance dredging to approximately 200,000m^3 every 5 years.

QUESTION 2

What are the feasible ways to manage sediment within the context of needing to maintain port operations and meet legal requirements?

Traditional maintenance dredging is the only feasible means of removing the existing accumulated material.

Operational measures may reduce the frequency of future maintenance dredging needs but it is expected that traditional maintenance dredging will be required to remove approximately 200,000m^3 every 5 years.

Operational measures (non dredging)

Operational measures to avoid or reduce siltation are limited. Improvements can be achieved by extending the period between dredging activities.

- A detailed examination of possible intervention techniques including built infrastructure (e.g. groin walls) and technology (e.g. jet sprays) revealed that at Hay Point most known approaches would be either ineffective or extremely costly both economically and environmentally.
- Slight re-alignments in vessel tracks along the departure path and the use of a drag bar in berth pockets are seen as effective and will reduce the volumes and/or frequency at which dredging needs to occur.

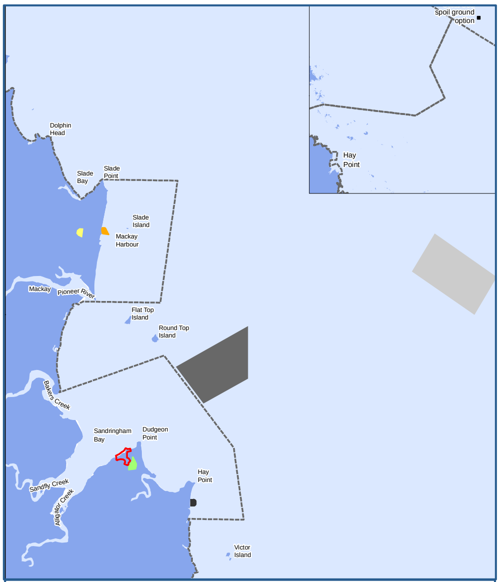
Beneficial reuse

Feasible opportunities are currently limited to mangrove rehabilitation or reclaiming land for recreational (or low load-bearing) uses.

- The sediments that comprise the maintenance material to be dredged consist mostly of fine silts and clays (<60%) and have very poor structural properties.
- Some of the beneficial reuses investigated require the material to be first pumped ashore and dried, including concrete products, road base/pavement, construction fill, manufactured soils, aquaculture and lining material. None of these onshore options provided a feasible opportunity for beneficial reuse.
- The material was considered suitable for use in shoreline protection, but no opportunity or need has been identified in the region.
- The material is considered unsuitable for beach nourishment, due to the high silt and clay composition.
- Deepwater habitat creation could be achieved, but is not supported by current regulation and policy.
- The material could be used for land reclamation, although the end use would only be suitable for low load-bearing uses (such as for recreation or car parking). Current known potential locations would result in a loss of useable port land or community amenity.
- Habitat rehabilitation, specifically mangrove rehabilitation, was considered a feasible use for the maintenance material. A likely location has also been identified adjacent to NQBP's Dudgeon Point landholdings, although it is important to note that considerable further research would be necessary before implementation can occur.

Sediment placement options

Through the range of work undertaken eight reuse/placement alternatives were identified for the material that will need to be dredged to maintain navigational safety.



Refer to Figure 15 **for full-scale map**

Reuse

- Land reclamation - Port of Hay Point.
- Land reclamation - Mackay Harbour.
- Habitat (mangrove) rehabilitation - Sandringham Bay.

Onshore

- Onshore pond at Dudgeon Point.
- Onshore pond at Mackay Harbour.

Offshore

- Existing offshore dredge material placement area.
- Mid-shelf offshore dredge material placement area.
- Coral Sea offshore dredge material placement area.

These alternatives are further explained in Table 30. To assess and compare these alternatives a structured decision-making process and comparative analysis has been undertaken with input from all stakeholders (see Question 3 below).

Table 30 Reuse/placement alternatives

Alternative	Summary description
Alternative 1	***Reclamation Hay Point*** – a 20 hectare land reclamation at half-tide tug harbour – in the area identified for future reclamation in the Port's Land Use Plan.
Alternative 2	***Reclamation Port of Mackay*** – a 20 hectare land reclamation adjacent to the northern breakwall – in the area identified for future reclamation in the Port's Land Use Plan.
Alternative 3	***Mangrove Rehabilitation*** – a 60 hectare are adjacent to NQBP's Dudgeon point land holding – Sandringham Bay.
Alternative 4	***Onshore Dudgeon Point*** – a 50 hectare onshore bunded area on NQBP's Dudgeon point land holding - seaward of the previously proposed development footprint for the site.
Alternative 5	***Onshore Port of Mackay*** – a 32 hectare onshore bunded area on NQBP's Port of Mackay land holding - located in 'Bedford Paddocks, west of Slade Point Road.
Alternative 6	***At-sea Existing*** – an at-sea relocation area that has been used since 2006 Capital dredging at the port of Hay Point – approximately 7km travel distance from main dredging area.
Alternative 7	***At-sea Mid-Shelf*** – a deeper water at-sea relocation area further offshore – approximately 25km travel distance from main dredging area.
Alternative 8	***At-sea Coral Sea*** – an at-sea relocation area outside the marine park – approximately 315km travel distance from main dredging area.

QUESTION 3

What is the best package of measures to provide for long-term sustainable management of marine sediments at the Port of Hay Point?

A stakeholder informed process was developed to identify what was important to a diverse group of stakeholders and how we could measure, or predict, the impact (negative or positive) of each of the proposed alternatives on the on the values they had identified.

Eleven objectives (things of value), along with fourteen measures (way to gauge impact) were developed through the consultation process.

Table 31: SSM Project Objectives

Objective	Measure
1. Avoid and minimise impacts to coastal ecosystems	A) Predicted performance in relation to avoidance and minimisation of impacts to coastal ecosystems
	B) Predicted risk on dredge material placement plumes and/or tailwater discharge exceeding ambient variation (based on days above threshold)
2. Minimise carbon emissions	C) Forecast Greenhouse gas emissions
3. Minimise impact on cultural heritage within the area	D) Nature and scale of any impact on cultural heritage
4. Maintain effective and efficient port operations	E) Number of days disruption to terminal loading operations
	F) Predicted lead time to dredge material placement
	G) Capacity to provide a long term solution for the port
5. Ensure solution is cost effective	H) Assessment of costs
6. Avoid significant loss of future port expansion opportunities	I) Strategic Port Land (SPL) affected
7. Avoid or mitigate health and safety risks	J) Relative risk
8. Minimise interference to social activities within the region	K) Scale and duration of any impacts on social activities
9. Provide increased economic and social opportunities	L) Predicted number of FTE jobs created
10. Promote innovation in port management	M) Ability of a solution to advance current dredging practice information, technology and techniques
11. Avoid and minimise impacts to the Great Barrier Reef World Heritage Area	N) Scale and duration of activity within the Great Barrier Reef World Heritage Area

An initial assessment of the eight alternatives against these objectives and measures showed that:

- Land reclamation at the Port of Mackay using the maintenance material was consistency the poorest performing alternative across the range of fourteen defined performance measures.
- The only alternatives that delivered an immediate solution (next 1-3years) for the current 205,800m3 maintenance requirements were the existing and mid-shelf at-sea solutions. All other alternatives had an estimated implementation time of 4-5 years.
- The two onshore containment alternatives (Port of Mackay and Dudgeon Point) and the Half-tide Land Reclamation offer a solution for a 20 year period only, after which another solution would need to be found.
- Only one area has been identified for mangrove rehabilitation, the extent of which may only be suitable for one 200,000m^3 maintenance dredge campaign.

Based on this initial assessment it was obvious that a number of long-term strategies would need to be considered, using either the at-sea alternatives or a mixture of alternatives. Eleven long-term strategies were developed.

Table 32: Long-term (25 year) strategies

	Long-term strategy (25 years)				
	Campaign 1	**Campaign 2**	**Campaign 3**	**Campaign 4**	**Campaign 5**
Strategy 1	At-sea existing	Hay Point Reclamation	Hay Point Reclamation	Hay Point Reclamation	Hay Point Reclamation
Strategy 2	At-sea existing	Mangrove Habitat	At-sea existing	At-sea existing	At-sea existing
Strategy 3	At-sea existing	Mangrove Habitat	Hay Point Reclamation	Hay Point Reclamation	Hay Point Reclamation
Strategy 4	At-sea existing	Mangrove Habitat	Dudgeon Point Onshore	Dudgeon Point Onshore	Dudgeon Point Onshore
Strategy 5	At-sea existing	Dudgeon Point Onshore	Dudgeon Point Onshore	Dudgeon Point Onshore	Dudgeon Point Onshore
Strategy 6	At-sea existing	Mangrove Habitat	Mackay Onshore	Mackay Onshore	Mackay Onshore
Strategy 7	At-sea existing	Mackay Onshore	Mackay Onshore	Mackay Onshore	Mackay Onshore
Strategy 8	At-sea existing	At-sea existing	At-sea existing	At-sea existing	At-sea existing
Strategy 9	At-sea mid-shelf	At-sea mid-shelf	At-sea mid-shelf	At-sea mid-shelf	At-sea mid-shelf
Strategy 10	At-sea existing	At-sea Coral Sea	At-sea Coral Sea	At-sea Coral Sea	At-sea Coral Sea
Strategy 11	At-sea mid-shelf	Mangrove Habitat	At-sea mid-shelf	At-sea mid-shelf	At-sea mid-shelf

A comparative analysis of each of the strategies was undertaken using the fourteen measures (see Comparative Analysis chapter).

In addition to weighting each of the measures equally, a normalised and scaled weighting process was used to focus weighting on the key themes of \`environment', \`social', \`economic', \`cultural' and 'world heritage". Table 33 shows the results of this analysis.

Table 33 Summary results of comparative analysis

	Strat 1	Strat 2	Strat 3	Strat 4	Strat 5	Strat 6	Strat 7	Strat 8	Strat 9	Strat 10	Strat 11
Equal weights	41	70	45	54	52	47	44	71	68	56	68
Environment focus	39	69	44	63	60	61	57	65	72	46	75
Social focus	36	57	41	54	53	37	31	57	56	52	56
Economic focus	44	80	44	48	49	39	40	89	74	59	69
Cultural focus	74	92	78	73	68	71	65	92	91	88	91
WHA	42	68	50	64	60	62	57	65	55	68	60

	Best performer
	2nd best performer
	Poorest performer

The outcomes of the comparative analysis presented some very clear results:

1. All strategies that included reclamation performed poorly.
2. Both strategies including onshore placement performed poorly, except when a 'world heritage' focus was applied to the weighting, where they then performed well due to locations being outside GBRWHA.
3. The Coral Sea (Strategy 10) was consistently lower performing than the other two at-sea alternatives.
4. The at-sea existing (Strategy 8) was consistently the highest performing long-term approach.
5. Mangrove rehabilitation, in combination with at-sea placement also performed very well and is the only alternative to provide a positive environmental outcome. Specifically when mangrove rehabilitation was combined with campaigns involving the mid-shelf (Strategy 11). This strategy performed the best when weighting was applied to the 'environment' theme.

Conclusion

Based on the extensive work undertaken a clear business case has been established for proceeding with the development of a short and long-term sediment management strategy that involves:

- ✓ Use of operational measures (i.e. vessel track re-alignments and regular use of drag bar in berth areas) to extend periods between maintenance dredging campaigns.
- ✓ Use of traditional dredging to maintain navigational areas at safe design depths – probably every 5 years in a volume of between 200,000 and 250,000 cubic metres (plus a contingency for any extreme weather events resulting in significant sediment deposition)
- ✓ Placement of dredged material at the existing DMPA. Additionally, options involving disposal at a new Mid-shelf DMPA also performed strongly and could be considered if for environmental or other reasons it became unacceptable to use the closer to shore existing DMPA.
- ✓ Commitment to a detailed investigation into mangrove rehabilitation in Sandringham Bay with the intention of executing, if feasible, a rehabilitation program in the next 10 years which may include the beneficial re-use of up to 200,000 m^3 of dredged material.

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