Ports Australia

# Dredging and Australian Ports

## Subtropical and Tropical Ports

April 2014

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# CONTENTS (continued)

## RELIANCE STATEMENT

This report has been prepared for Ports Australia by RMC Pty Ltd with support from Sprott Planning and Environment Pty Ltd.

The opinions, conclusions and recommendations are based upon interpretations and assumptions made by the authors and do not necessarily reflect those of Ports Australia.

The report has been prepared on the basis of information supplied by various Australian ports and Ports Australia that has been presumed accurate. Wherever possible, reasonable checks of published and peer reviewed or compliance related information have been undertaken to confirm the accuracy of supplied information.

The report was reviewed by Dr. Ian Irvine, Pollution Research Pty Ltd, who has extensive experience in water and sediment pollution, marine environmental assessment and management, and ecological risk assessment. He is a current specialist advisor to the Commonwealth Department of Environment on dredging and ocean disposal assessments and has been engaged by the Great Barrier Reef Marine Park Authority as an independent expert providing advice on sediment quality, dredging and ocean disposal issues. He has also been engaged as an independent expert for many major dredging projects both nationally and internationally. He was the principal author of the technical sections of the National Assessment Guidelines for Dredging. Dr. Irvine advised that:

*Though I have not been able to independently check the monitoring reports referred to, it is my professional opinion that the information presented in Appendix 1, and the conclusions in the report, are generally consistent with my knowledge of the environmental performance of a broad range of dredging programs throughout subtropical or tropical areas of Australia over the past 20 years. I am not aware of other dredging projects conducted in subtropical or tropical areas of Australia that would substantially alter the report's conclusions.*

## ACKNOWLEDGMENTS

This report was commissioned by Ports Australia. The input in defining the scope of the study, reviewing the draft report and assistance during the study is greatly appreciated.

The contribution of the various Australian port authorities and companies [Ports North (Cairns), Port of Townsville Ltd, Gladstone Port Corporation, North Queensland Bulk Ports Corporation, Darwin Port Corporation, Dampier Port Authority, and Port Hedland Port Authority] in providing information on their dredging monitoring programs is gratefully acknowledged. Port of Brisbane Pty Ltd, Geraldton Port Authority, Fremantle Ports, Albany Port Authority and Esperance Ports also provided relevant information which is appreciated and will be included in a future report that addresses temperate zoned Australian ports.

## ABBREVIATIONS

| | |
|---|---|
| **ANZECC** | *Australian and New Zealand Environment and Conservation Council* |
| **COAG** | *Council of Australian Governments* |
| **CSD** | *Cutter Suction Dredge* |
| **cum** | *cubic metres* |
| **DoE** | *Commonwealth Department of Environment* |
| **DMPA** | *Dredged Material Placement Area* |
| **EIS** | *Environmental Impact Statement* |
| **EPBC** | *Environment Protection and Biodiversity Conservation Act* |
| **GBRMP** | *Great Barrier Reef Marine Park* |
| **GBRMPA** | *Great Barrier Reef Marine Park Authority* |
| **LNG** | *Liquefied Natural Gas* |
| **Mcum** | *Million cubic metres* |
| **Mtpa** | *Millions of tonnes per annum* |
| **NAGD** | *National Assessment Guidelines for Dredging* |
| **NQBP** | *North Queensland Bulk Ports* |
| **PASS** | *Potential Acid Sulphate Soils* |
| **RMC** | *Rick Morton Consulting Pty Ltd* |
| **SEWPaC** | *Commonwealth Department of Sustainability, Environment, Water, Population and Communities (now Department of Environment)* |
| **TBT** | *Tributyltin* |
| **TEU** | *Twenty Foot Equivalent (describes the capacity of a container ship)* |
| **TSHD** | *Trailing Suction Hopper Dredge* |
| **ULCC** | *Ultra Large Crude Carrier* |
| **USACE** | *United States Army Corps of Engineers* |
| **UNCAT** | *United Nations Conference on Trade and Development* |


Photo courtesy of the Port of Townsville.

Ports Australia

# EXECUTIVE SUMMARY

The objective of this report is to provide a basis for improved discussion on port related dredging in subtropical and tropical areas of Australia and associated environmental impacts. It also highlights the importance of ports and shipping channels to the Australian economy and the critical role of dredging in port o perations and growth.

The report provides an overview of the approval processes associated with dredging and at-sea placement of dredged material, the nature of environmental monitoring programs associated with recent port related dredging projects and, through a comparison of monitored environmental impacts with those approved by government, determines that recent port related dredging projects in northern Australia have performed well.

The report relates specifically to dredging and at-sea placement of dredged material in subtropical and tropical Australian ports (northern Australia) as;

- large capital dredging projects are frequently occurring and proposed in these regions (eg for mineral resource development in the Pilbara and Queensland);
- public interest is focused on dredging in these areas (eg the Great Barrier Reef Region); and,
- because dredging environmental risks and associated management needs differ to southern temperate regions of Australia. Legacy contamination issues are much less frequently involved in dredging projects in northern parts of Australia than the historically more developed parts of southern Australia where dredging in old established ports with a long industrial history can involve large volumes of contaminated sediments that require specific management approaches.

A complementary report will be prepared in the near future that relates to Australian ports located in temperate areas and the environmental performance of their dredging projects.

### The Importance of Ports and Shipping to the Australian Economy

Australia, being an island country, relies heavily on its maritime links with some one third of our GDP generated by seaborne trade. Australia is the 12th largest economy in the world (IMF 2012) and has the fourth largest shipping task.

Our ability to trade goods with the world and grow the Australian economy depends heavily on ports. Efficient, commercial ports are critical for the export of our agricultural and mineral commodities and for a range of imports including household goods, manufactured products, vehicles, machinery and fuel. Maintenance and growth of our economy depends directly on seaborne trade.

Ports are our largest freight hubs servicing these trades and a major component of Australia's international supply chains. The capacity of ports to operate efficiently directly impacts our ability to grow and develop as a sustainable society.

### The Need for Dredging and At-Sea Placement

Shipping channels are of equal importance to our road and rail networks and, like these networks, need to be maintained and developed as trade grows.

Dredging of shipping channels is an essential part of port operation in Australia and globally. Although shipping channels are declared in naturally deep-water areas, thus enabling the safe passage of shipping, dredging will always be required.

Maintenance dredging is regularly required to remove sediments (eg silts) that have been transported by currents from nearby areas and accumulate in the artificially deepened channels and berths. Maintenance dredging is essential to remove shoaling and maintain designated channel depths so as to allow ships to safely access wharves and associated road and rail connections.

Capital (also termed developmental) dredging is also required to create new or improve existing channels and berths. Channel widening and deepening is necessary to ensure ports can accommodate the increasing numbers of ships trading with all Australian ports as the international economy grows and larger ships are used to achieve economies of scale. Ports in northern areas of Australia are being developed or expanded to meet the growing mineral resource export trade and regular channel improvements will be required (major size increases in bulk vessels have occurred over the past few decades given the cost advantages and may continue in the future).

Dredging may necessarily involve placement of material at sea. Land based or reuse options for dredged sediment are often not viable in northern Australia where adjacent coastal lands may have high conservation or cultural value or are viable only for small amounts of material or one-off projects. Recent technical studies for the Great Barrier Reef Strategic Assessment concluded that on land placement of dredged material (particularly fine grained maintenance material) was not a long term viable option for the six major ports in the Great Barrier Reef region (SKM 2013a).

Material placed at sea must be non-toxic and placed at an approved Dredged Material Placement Area (DMPA). DMPAs form an essential part of the port infrastructure, their location and operation taking into account environmental, social and economic considerations.

Port related dredging and, for many ports, at-sea placement of dredged material is an economic imperative required to maintain and develop shipping channels. It ensures that our supply chains to overseas markets can operate efficiently, provides economies of scale and enables the Australian economy to grow in an increasingly competitive global market.

## The Increased Focus on Environmental Issues

Port operation and growth in Australia is of considerable public interest and attention as many ports are located adjacent to areas of environmental and conservation value (e.g. seagrasses and corals, Great Barrier Reef Marine Park). The significant growth in the bulk export resources trade (eg iron ore, coal and LNG) being experienced in subtropical and tropical areas of Queensland, Western Australia and the Northern Territory will require improvements to existing ports or the development of new cargo specific facilities (eg ore loading facilities). Some of these developments will involve major dredging operations in relatively undeveloped regions near areas of conservation value.

Historically, significant areas of high value habitat have been lost in Australia as a result of dredging for coastal development including port activities. However, over the past twenty years there has been an increased awareness of the conservation, ecological and economic value of habitats such as seagrass and corals.

Environmental risk is now far more effectively managed than in the past. Port related dredging is far more regulated than in the past to prevent and reduce environmental impacts to high value ecological communities. Over the past few decades, environmental regulations have become stricter, environmental impact assessment procedures have improved and project-specific dredge management and mitigating measures are now standard components of a dredging project. Additionally, ports now have qualified environmental staff and have implemented environmental management systems to identify and manage environmental risk. Port dredging works are now carefully planned and monitored to proactively avoid and minimise environmental impacts.

Importantly, the acceptable level and extent of environmental impact is now clearly defined in government approvals for dredging. All major dredging projects are required to include environmental monitoring based on the latest scientific research to enable impacts to be managed during dredging or at-sea placement and assessed following project completion.

## Public Information on Dredging In Australia

Port related dredging has been recently subject to considerable public and media attention given the increasing development of northern Australia, national economic growth and the associated demand for port expansion. Most readily available information on dredging relates to historic experiences, overseas projects in different environmental settings, or projects undertaken by historic ports in southern Australia where legacy contamination issues from nearby industry require management and are of public concern.

Little information is available for stakeholders on dredging by ports in less developed subtropical/tropical areas of Australia and how effectively environmental impacts, especially to areas of high conservation value (e.g. coral reefs), have been managed in recent years. Dredging and at-sea placement of dredged material are often assumed to result in widespread and unintended environmental impacts. Community concern often focuses on the effects of toxicants such as heavy metals, however, the vast majority of dredging in northern Australian ports involves clean sediments and, where any toxic material is identified, it is disposed of on land, not at sea.

This report collates information on why dredging needs to occur, how dredging and dredged material placement is regulated and whether dredging and at-sea placement projects by northern Australia ports have protected environmental resources in accordance with government project approval conditions.

## Key Report Findings

Section 11 of this report provides a comprehensive list of findings. Salient details include:

- Dredging and dredged material placement are subject to detailed and complex approval processes under international, commonwealth and state legislation.
- Australia's National Assessment Guidelines for Dredging (NAGD), which form the basis of impact assessment for all dredging projects, are recognised internationally as industry-leading guidelines.
- Any application to place material at sea must comprehensively evaluate alternatives such as beneficial re-use or land based placement.
- Any dredged material approved for at-sea placement must use a designated Dredged Material Placement Area (DMPA), many of which have been successfully used for decades. These are typically located in unvegetated areas distant from coral reefs or similar.
- Toxic material cannot be placed at sea.

- Rigorous site selection and master planning endeavours to ensure relevant environmental values and potentially impacting processes are properly understood as part of port infrastructure planning may assist in avoiding or minimising the need for capital or maintenance dredging.
- Dredging and at-sea placement of dredge material in northern Australian ports over recent years has been subject to environmental monitoring designed to ensure a designated level of environmental protection, especially to any nearby areas of high conservation value (all major capital works are monitored although some maintenance works may not be as impacts, or lack of, are well understood).
- Most monitoring programs involved reactive monitoring during dredging so that, where necessary, management actions (eg modify or cease dredging) could be taken in time to prevent or minimise ecological impacts.
- Monitoring programs associated with recent dredging and dredged material placement projects in northern Australia examined in this review almost all showed reported impacts consistent with (generally no impact to a sensitive receptor), or less than, those approved or predicted.
- Two exceptions were noted where project water turbidity impacts were greater. Monitoring indicated one of these resulted in lesser impacts to corals than approved but is likely to have prevented the normal seasonal recruitment of a deep water seagrass species for one year (with higher than pre-dredging seagrass cover recorded the following year). Monitoring of the other project did not indicate impacts to sensitive receptors (seagrass).
- A risk based approach based on scientific assessment is essential to the approvals process for future dredging and dredged material placement projects and defining potential environmental monitoring requirements. This needs to take into account the results of previous monitoring programs undertaken in similar environmental settings.
- Monitoring during many dredging projects has shown that regular natural events such as cyclones or floods may result in much greater and more prolonged environmental changes to coral and seagrass communities than those related to dredging.

Dredging is an essential part of port operation. It will always be required to ensure shipping channels are developed and maintained to enable international trade and the economic growth of Australia.

Many ports operating and developing in northern Australia have implemented monitoring programs in association with dredging that demonstrate leading practice. These reduce the level of uncertainty associated with predicting dredging related impacts and enable continual improvement in managing the environmental impacts of dredging and at-sea placement.

Assumptions by some stakeholders of widespread and unintended impacts to areas of high conservation value, such as the Great Barrier Reef, are not supported by the results from extensive monitoring of many recent dredging projects in northern Australia undertaken in similar environmental settings.

It is important that ports and regulators inform stakeholders of the effectiveness of existing management measures for dredging, that recent dredging and dredged material placement projects in northern Australia have not resulted in unapproved impacts to environmental resources of high conservation value and that impacts have been consistent with those approved by regulatory agencies.

Improved stakeholder awareness of both the impact assessment process and the actual extent of impacts from recent dredging/ at-sea placement projects would improve public confidence in the environmental management of port related dredging enabling a more informed and factually based discussion on future projects.

*Photo courtesy of Darwin Port Corporation.*

# 1. INTRODUCTION

## Background

Australia is the 12th largest economy in the world (IMF 2012) and has the fourth largest shipping task.

Our nation has relied greatly on its maritime links since early settlement. Our ability to trade goods with the world relies heavily on our seaports with some one third of our GDP generated by seaborne trade.

> *'The ocean is the highway for international trade, with 90% being seaborne'*
>
> ***(Lloyd's Register, 2013)***

Australian ports are clearly infrastructure nodes of national and international importance.

Efficient, commercial seaports are critical for the export of our agricultural and mineral commodities and for a range of imports including household goods, manufactured products, vehicles, machinery and fuels to maintain and grow the Australian economy.

> *'Australia is an island whose place in the international economy and whose productivity, living standards and quality of life depend on trade performance'*
>
> ***(Infrastructure Australia, National Ports Strategy, 2012)***

In 2011/2012, Australian ports facilitated the export/import of over 1 billion tonnes of cargo. Over the past ten years (2001/2002 through to 2011/2012), trade growth has grown at 5.8% annual average across the Australian port sector (Ports Australia, 2012).

Sea transport, via Australian ports, offers the most economical, energy efficient and environmentally friendly transportation for large-scale movements of all cargo types.

As an island country, there are limited alternatives available to the use of sea transport for the movement of general freight and bulk commodities, particularly mineral resources. Other forms of transport are typically constrained by the volumes that can practically be carried at any one time.

> *'We live in a global society which is supported by a global economy – and that economy simply could not function if it were not for ships and the shipping industry. Without shipping, intercontinental trade, the bulk transport of raw materials and the import/export of affordable food and manufactured goods would simply not be possible'.*
>
> ***(IMO, 2013)***

Australia has an extensive network of ports along its coastline, ranging from world-class resource export terminals such as those along the north-west Pilbara coast in Western Australia to capital city multi-cargo ports such as Melbourne, Sydney, Brisbane, Fremantle and Adelaide. Some ports in northern Australia, eg Townsville and Darwin, are key import hubs servicing the communities and industries of their respective regions, as well as servicing Australia's defence interests and the growing cruise ship industry. Figure 1.1 shows the significant geographic variance in Australian ports and the location of the northern ports referred to in this report.

Ports are a major component of Australia's supply chain and economy, facilitating trade and the development of the regional, state and national economies.

Importantly, Australian ports also provide an important role in facilitating the social development of our nation. Remote and regional communities rely on ports for access to a range of goods and services.

Ports also help administer the nation's emergency response and national security needs.

## Port Infrastructure Requirements

Despite the significant geographic and operational differences, all Australian ports rely on a range of supportive logistic and allied infrastructure networks to facilitate the safe and efficient exchange of goods.

Critical to ports is the range of allied infrastructure to enable their efficient operations. Landside infrastructure such as road and rail corridors, and waterside infrastructure such as shipping channels are fundamental to the successful and safe operation of our seaports.

Dredging is an essential part of port operations to facilitate safe and efficient waterside access.


Figure 1.1: Location of Australian Ports (Ports Australia 2012)

*'Ports are fundamental to Australia's economy and well planned dredging activities, in conjunction with timely and effective environmental assessments, are essential to maximise their efficiency'.*

***(National Assessment Guidelines for Dredging (NAGD Commonwealth of Australia 2009)***

Many ports in northern Australia are located in sheltered and naturally shallow areas. However, shipping channels are declared in naturally deep-water areas wherever possible thus increasing shipping safety (viz: avoiding potentially severe environmental consequences of vessel groundings etc) and minimizing the need to undertake both initial capital and ongoing maintenance dredging works.

Capital (also termed developmental) dredging, however, has often been required to deepen shallower areas to enable shipping to access land-based infrastructure such as wharves, rail and road corridors. Channels and berths also need to be periodically improved (extended, deepened and widened) to cater for the increasing numbers of ships using Australian ports as the international economy grows and larger ships are used to achieve economies of scale.

The expected future growth in world trade, and associated growth in global sea transport, will ensure the volume of cargo handled by Australian ports will increase. Subtropical and tropical regions of Queensland and Western Australia in particular are likely to continue to experience significant growth in bulk export resources trades (eg iron ore, coal and LNG).

Periodic maintenance dredging will also be required to remove sediments that are naturally transported, by waves or currents or down rivers and creeks, into the port channel and berth areas. Without maintenance dredging to maintain appropriate water depths, shoaling can occur with major implications in terms of a ship's carrying capacity (hence trade value), port efficiency (hence cost of trade) and safety. The cost of importing and exporting goods would increase with additional costs being ultimately borne by the community.

## Environmental Challenges

The challenge for Australian ports is to ensure that they can safely and efficiently address increases in trade by providing and maintaining the required infrastructure (channels, wharves and connecting land based road and rail systems) whilst minimising their environmental footprint.

Port operation and growth in northern Australia is of considerable public interest as many ports are located adjacent to areas of environmental and conservation value (eg seagrasses and corals, Great Barrier Reef Marine Park etc). The significant growth in bulk export resources trade (eg iron ore, coal and LNG) being experienced in Queensland, Western Australia and the Northern Territory will require improvements to existing ports or the development of new cargo specific facilities (eg ore loading facilities), some of which will involve major dredging operations near areas of conservation value. Channel development and maintenance dredging, whilst required, have the potential to affect such values and consequently dredging works, even when carefully planned and managed to protect the environment, attract public attention.

Historically, significant areas of high value habitat (including seagrasses and corals) have been lost as a result of dredging (Erftemeijer and Lewis 2006 ) for a range of purposes, including residential/industrial waterfront and port development. Adverse impacts have occurred due to a combination of factors including poor environmental management practices and development approval conditions not adequately accounting for environmental aspects as impacting process were poorly understood.

More recently, however, there has been an increased awareness of the conservation, ecological and economic value of habitats such as seagrass and corals and an emphasis on ensuring adverse environmental impacts to such communities from dredging operations are avoided or minimised. The quality of environmental impact assessment has also improved as marine research has increased the understanding of environmental resource tolerance limits and improved predictive modelling techniques have enabled environmental risk to be more effectively managed.

Environmental risk is now far more effectively managed than in the past. Port related dredging is considerably more regulated than in the past to prevent and reduce environmental impacts to high value ecological communities. Over the past few decades, environmental regulations have become stricter, environmental impact assessment procedures have improved, and project-specific dredge management and mitigating measures are now standard components of a dredging project. Additionally, ports now have qualified environmental staff and have implemented environmental management systems to identify and manage environmental risk. Port dredging works are now carefully planned and monitored to proactively avoid and minimise environment impacts.

The acceptable level and extent of environmental impact is now clearly defined in government approvals for dredging and dredged material placement at sea. All major dredging projects are required to include environmental monitoring based on the latest scientific research to enable impacts to be managed during dredging and assessed following project completion.

## The Need for this Report

Port operation and growth in Australia is under intense and increasing public scrutiny. Port growth and the bulk export resources trade in northern Australia will require major dredging operations often near areas of conservation value (eg seagrasses and corals, Great Barrier Reef Marine Park). Government and industry are being challenged to ensure port expansion occurs in a balanced and incremental way to support economic development while maintaining the considerable environmental resources that occur within and near many ports.

All port related dredging requires regulatory approval. Regulators are keenly aware of the community concerns with port growth and associated dredging.

Any significant dredging project is required to go through a detailed impact assessment process and regulators prescribe site-specific environmental management, monitoring and reporting requirements to ensure a defined level of environmental protection.

Despite the heavily regulated environment in which dredging is managed, some stakeholders continue to have ongoing and significant issues with port related dredging and dredged material placement at sea. Many are unaware of the importance of port related dredging and at-sea placement, its role in the sustainable operation of a port, the associated regulatory requirements and environmental performance of various projects. Assumptions by some stakeholders of widespread and unintended impacts to areas of high conservation value, such as the Great Barrier Reef, often do not consider the results of recent dredging projects in northern Australia undertaken in similar environmental settings.

Information on the extent to which dredging projects meet the required level of environmental protection is not easily accessible or is technical in nature and relates to that specific project only. Most relates to temperate areas (eg the Port of Melbourne's Channel Deepening Project). Little information is available for stakeholders on dredging projects in the less developed subtropical and tropical regions of Australia, particularly those near high value environmental resources and whether environmental impacts were greater, lesser or consistent with impact predictions and regulatory approvals. No overview of a range of projects in similar environmental settings is available to enable an appreciation of the level of effectiveness of environmental management associated with the port dredging industry in northern Australia (although regional reviews have been carried out by Hanley (2011) for the Pilbara region and SEWPaC (2013) for the Gladstone area).

Consequently, it is difficult for many stakeholders to have an understanding of why dredging occurs, the overall environmental performances of recent dredging projects in northern Australia and whether environmental resources have been protected in accordance with government required approval conditions. Accordingly, Ports Australia commissioned this report.

### Structure of this Report

As shown in Figure 1.2, this report provides information on the importance of channels associated with ports, why they need to be dredged and how dredging and dredged material placement is regulated. A brief overview of potential environmental impact processes associated with dredging and at-sea placement of dredged material is then provided.

It then collates the results of recent dredging and dredged material placement monitoring programs undertaken by ports in subtropical and tropical regions (generally as a result of an approval condition) and describes the nature of the monitoring programs, how they are developed and, importantly, how the actual impacts compared to those approved by regulators. It then considers the results of these comparisons and discusses management implications for future dredging and at-sea placement projects in northern Australia.

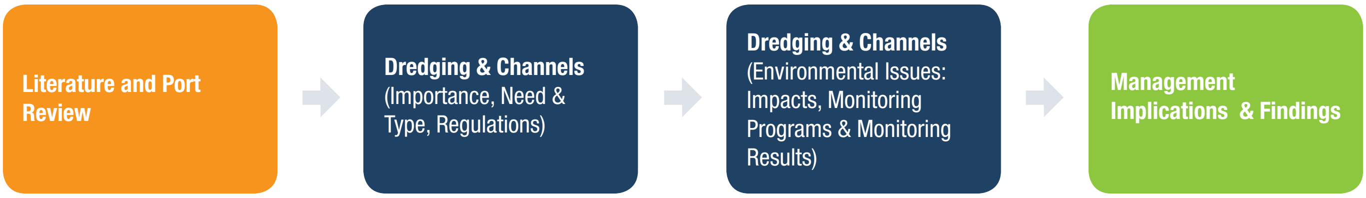



Figure 1.2: Report Structure

# 2. STUDY OBJECTIVES, METHODS AND SCOPE

### Objectives

The aims of this study are to:

- Describe the critical importance and role of port navigation channels;
- Describe the environmental impact assessment and approval process associated with dredging by Australian ports;
- Describe the nature of recent environmental monitoring programs associated with port related dredging projects in subtropical and tropical regions of Australia;
- Compare the monitored environmental impacts of those dredging and at-sea placement projects to those approved by the governments.

### Scope

The report relates specifically to dredging in subtropical and tropical Australian ports ("northern Australia") as:

- large capital dredging projects are frequently occurring in these regions (eg for mineral resource development in the Pilbara and Queensland);
- public interest is focused on these areas (eg the Great Barrier Reef Region); and,
- because dredging and at-sea dredged material placement environmental risks and associated management needs differ from those in temperate regions. Legacy contamination issues are much less frequently involved in dredging projects in northern Australia than in the historically more developed regions of southern Australia (eg capital dredging in old established ports with a long industrial history can involve large volumes of contaminated sediments that require specific management approaches).

The term subtropical and tropical are used to define the region in Australia that lies north of the Tropic of Capricorn. This report relates only to ports in this region but does include the Port of Gladstone given its proximity to the Tropic of Capricorn (110 km south).

For this report, dredging relates to the excavation of the seabed whilst dredged material placement (also referred to as spoil dumping) involves the placement of dredged material at a designated Dredged Material Placement Area (DMPA).

The report provides information on dredging activities since 1990 associated with Australian subtropical and tropical ports. It is based on information provided by ports and is likely to include most (if not all) major capital projects undertaken by ports in these regions.

The report focusses on the larger, mostly capital, dredging projects associated with these ports as these have had the greater degree of environmental risk and associated regulation and required monitoring. It does not include small scale capital works (eg berth expansion), many routine maintenance dredging and several large projects undertaken by private companies.

The report does not include the result of dredging often undertaken by the Department of Defence (eg Navy) and much of that undertaken by private companies (eg major mineral resource companies) unless the information was publically available. Whilst projects for Defence are generally minor, those undertaken by mineral resource companies may be substantial. For example, dredging in Port Hedland in 2011 and 2012 involved 7.8 Mcum of works undertaken by the Fortescue Metals Group and other major capital works projects associated with the resource industry are underway especially in the Pilbara.

### Methodology

The report is based on a review of published and unpublished literature and information supplied by subtropical and tropical Australian ports. A request was sent to relevant ports to supply information on the results of monitoring programs associated with dredging and dredged material placement. This was collated and summarised (Appendix A) and returned to ports for their confirmation. Emphasis was placed on reports that had either been peer reviewed or subject to regulatory approval.

The report describes the nature of the monitoring programs associated with recent dredging and dredged material placement projects in subtropical and tropical ports. It also provides, based on the conclusions of the associated monitoring programs, a high level assessment of the extent to which dredging and dredged material placement projects resulted in environmental impacts consistent with approval conditions.

The report was subject to peer review by Dr Ian Irvine (see Reliance Statement) and revised based on his comments.

# 3. NAVIGATION CHANNELS

This Section provides an overview of the critical importance of waterside port infrastructure, in particular, shipping channels and pathways to Australian ports in general. It describes the importance of such infrastructure for Australia's trading activities and to state/territory and national economies.

### 3.1 Importance of Port Infrastructure and Port Planning

Planning and infrastructure efforts cannot be simply focused on the requirements at the port – but must be considerate of surrounding networks providing key logistic support.

Clearly, efficient and safe port operations rely on provision and protection of both landside and waterside infrastructure as shown in Figure 3.1 and 3.2.


Figure 3.1: Essential Port Infrastructure


Figure 3.2: Logistics/Supply Chain nodes
[Source: National Oceanic and Atmospheric Administration (NOAA 2013)]

It is the successful integration of this wide range of infrastructure along the entire logistics chain which leads to increased port efficiency and ultimately reduced costs of transport for local, regional, national and global economies.

The need for comprehensive Port Master Planning has been raised in various national strategies such as the National Ports Strategy and National Land Freight Strategy. In their endorsement of these significant strategies, the Council of Australian Governments (COAG) has directed a stronger focus towards the planning and protection of port infrastructure.

This focus extends to areas beyond traditional port boundaries and into supply chains, freight corridors and supporting infrastructure networks.

Ports Australia in its recent publication *Leading Practice Port Master Planning: Approaches and Future Opportunities* highlighted the need for comprehensive planning for both land and waterside infrastructure areas. The report showcased a whole of network approach to port planning.

Clearly, comprehensive port master planning must consider both land and waterside infrastructure requirements – one of which being the ability of ports to ensure that access to channels and waterside areas such as anchorages, wharf areazs, berth pockets, approach/departure paths and Dredged Material Placement Areas (DMPAs) is planned to allow for the safe and efficient movement of commercial vessels.

In particular, the careful planning (and ongoing management) of DMPAs as part of the overall port master planning task is of particular relevance.

### 3.2 Waterside Infrastructure and Access

This report principally focuses on waterside infrastructure elements, in particular, the need to develop and maintain safe and efficient shipping access and navigation channels.

As noted above, the provision of safe and efficient waterside access for commercial shipping is critical for national productivity, our continued connection to world markets and our ability to grow and develop as a society.

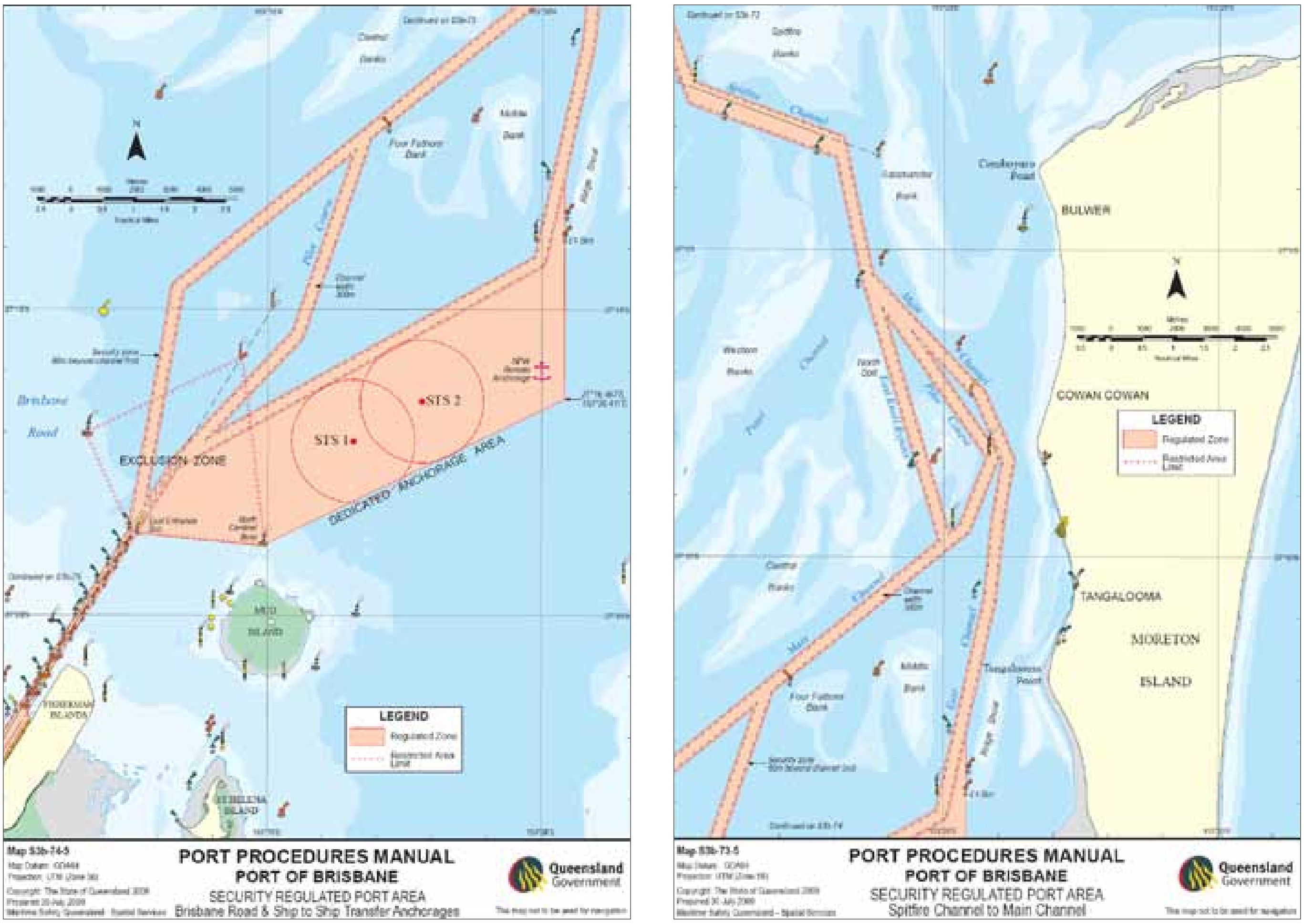



Figure 3.3: Sections of Port of Brisbane Designated Shipping Channels (Maritime Safety Queensland 2012)

> *'Shipping is truly the lynchpin of the global economy: without shipping, intercontinental trade, the bulk transport of raw materials and the import/export of affordable food and manufactured goods would simply not be possible'*
>
> ***(International Maritime Organization, International Shipping Facts and Figures – Information Resources on Trade, Safety, Security, Environment 2012)***

> *'International shipping transports more than 90% of global trade and is therefore a crucial underpinning of sustainable development. Both developing and developed countries benefit from seaborne trade'.*
>
> ***(IOC/UNESCO, IMO, FAO, UNDP 2011)***

Whilst shipping areas may be designated at a regional level (for example within the *Great Barrier Reef Marine Park Zoning Plan 2003* which designates where commercial shipping is permitted within the marine park), shipping channels are typically determined by a state/territory maritime agency (eg Maritime Safety Queensland (MSQ) in Queensland) in close consultation with the relevant port and other agencies such as the Australian Maritime Safety Authority (AMSA). Determining suitable areas relies on a number of factors including the need for pilotage at both a port and region-wide level as seen throughout certain areas within the Great Barrier Reef Marine Park.

The spatial form of shipping channels at Australian ports varies widely and depends largely on the local environmental and operational conditions present within the port environment including the presence of naturally deep-water areas not requiring initial or ongoing maintenance dredging.

It is important to note that, both historically and presently, port managers aim to have shipping channels declared in naturally deep water areas thus increasing shipping safety and minimizing the need to undertake both initial capital and ongoing maintenance dredging works. This may result in an apparently unorthodox alignment of port channels which may not necessarily follow the shortest travel distance. An example can be seen in Figure 3.3, which shows parts of the declared Port of Brisbane shipping channels through Moreton

Bay that largely follow naturally deep water areas. Similar examples occur in most ports in northern Australia.

Clearly the ability to avoid dredging in the first instance provides substantial benefits for the port concerned, including lower capital costs and lower ongoing maintenance, whilst also resulting in reduced potential for environmental impacts.

This in turn equates to transport cost savings for all stakeholders and minimizes the environmental operational footprints of Australian port channels.

### 3.3 The Need to Dredge

Shipping channels, berth pockets and swing basins must work together and collectively provide for the safe passage of commercial shipping vessels enabling Australian ports to support our trades in the global trading market safely and effectively.

'From the beginning of civilisation and the evolution of established communities, there has been a need to transport people, equipment, materials and commodities by water. This resulted in the requirement that the channel depths of many waterways be increased to provide access to ports and harbours'.

(International Association of Dredging Companies & International Association of Ports and Harbors 2010)

Throughout the global industry, the activity usually takes the form of either capital or maintenance dredging.

#### Capital Dredging

Many of Australia's commercially trading or tourism-orientated ports require capital dredging projects. Capital projects may, for example, involve the dredging of:

- new or re-aligned shipping channels (including arrival and departure paths);
- new development footprints;
- berth pockets; and/or
- swing basins.

Capital programs may also be required from time to time to augment existing operational areas (ie previously dredged areas) to accommodate changes in commercial vessel characteristics such as wider or deeper draft[1] vessels. Capital dredging may also be required for incidental infrastructure works at and around port areas to address matters of operational safety or emergency response.

On a smaller scale, many public and private marinas, public boat ramps and allied marine infrastructure areas also require dredging works.

> *'Ongoing technological developments and the need to improve cost effectiveness have resulted in larger more efficient ships. This, in turn, has resulted in the need to enlarge or deepen many of our rivers and canals, our aquatic highways, in order to provide adequate access to ports and harbours.*
>
> *Nearly all the major ports in the world have at some time required new dredging works – known as capital dredging – to enlarge and deepen access channels, provide turning basins and achieve appropriate water depths along waterside facilities.'*
>
> ***(Central Dredging Association (CEDA) 2012)***

[1] *Draft is the distance between the waterline and the ships keel.*

*Photo courtesy of Ports North.*

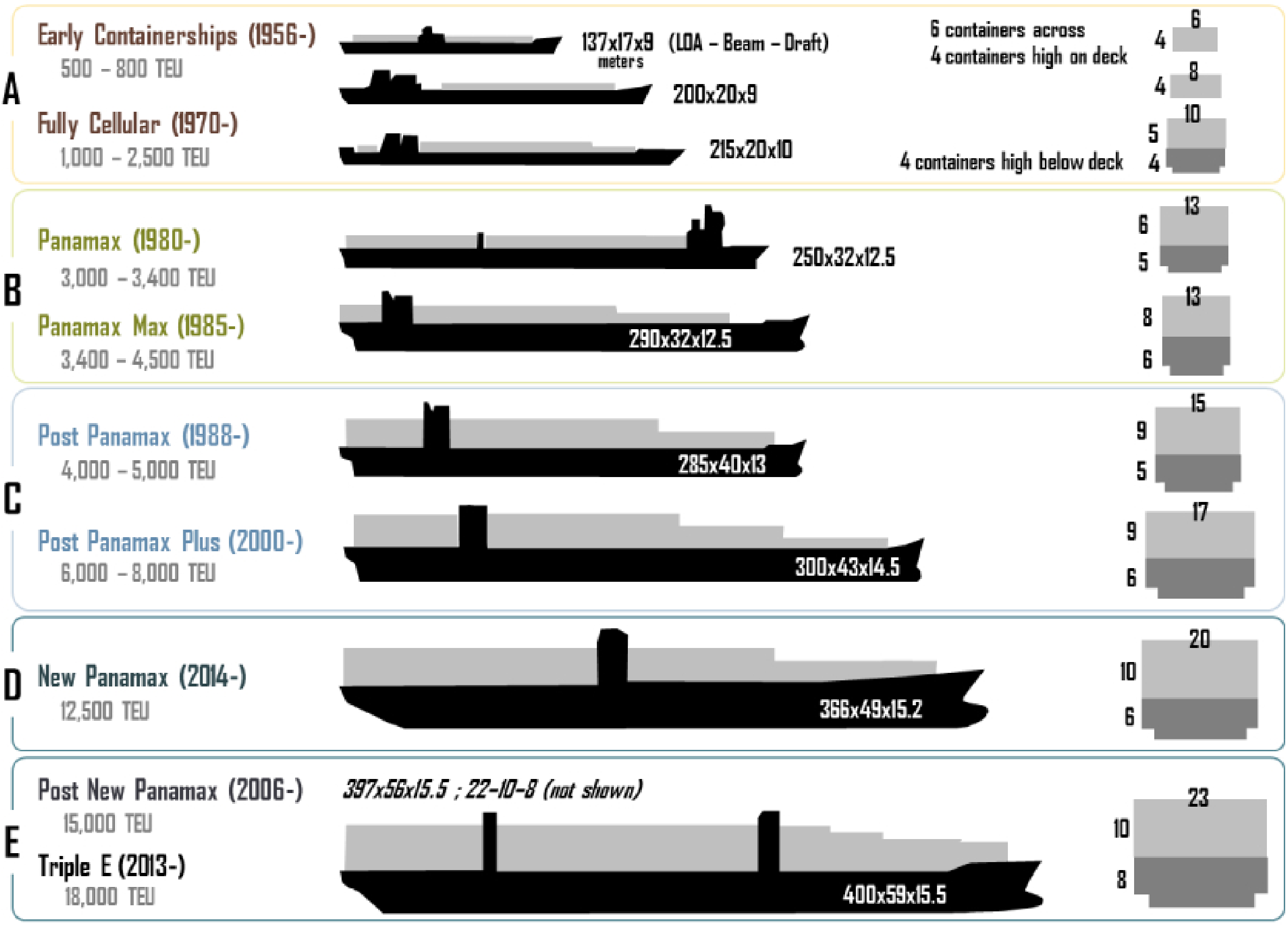



Figure 3.4: Evolution of Container Ships (Source: Rodrigue, et al. (2013)

| Year | Oil | Main bulks[a] | Other dry cargo | Total (all cargoes) |
|---|---|---|---|---|
| **1970** | 1 442 | 448 | 676 | 2 566 |
| **1980** | 1 871 | 796 | 1 037 | 3 704 |
| **1990** | 1 755 | 968 | 1 285 | 4 008 |
| **2000** | 2 163 | 1 288 | 2 533 | 5 984 |
| **2006** | 2 698 | 1 849 | 3 135 | 7 682 |
| **2007** | 2 747 | 1 972 | 3 265 | 7 983 |
| **2008** | 2 732 | 2 079 | 3 399 | 8 210 |
| **2009**[b] | 2 649 | 2 113 | 3 081 | 7 843 |

Source: Compiled by the UNCTAD secrerariat on the basis of data supplied by reporting countries as published on the relevant government and port industry websites, and by the specialist sources. The data for 2006 onwards have been revised and updated to reflect improved reporting, including more recent figures and better information regarding the breakdown by cargo type.
a: Iron ore, grain, coal, bauxite/alumina and phosphate. The data for 2006 onwards are based on *Dry Bulk Trade Outlook* produced by Clarkson Research Services Limited.
b: Preliminary

Table 3.1: Development of international seaborne trade, selected years (million tons loaded)
(Source: UNCTAD 2011)

Increased demand for maritime transport around the world has given rise to a need for better economies of scale through the use of larger vessel sizes. Figure 3.4 provides a review of container vessel size increases over the last sixty years and how such changes have influenced draft requirements for the safe transit of this particular vessel class.

Figure 3.5 provides an illustrative view of increasing under keel clearances of bulk vessels, such as those engaged in the mineral export trade, over the past 50 years.

Table 3.1 demonstrates the increase in trading volumes (in terms of overall vessel numbers) over time – indicating strong growth in all vessel types – necessitating more efficient ways of transporting cargoes.

In order to deal with these increasing trading volumes bulk vessels are also increasing in size. Figure 3.6 shows the increasing size of bulk carriers which will normally be stated as the maximum possible dead¬weight tonnage (dwt) corresponding to the fully loaded deadweight. Figure 3.6 also indicates the increasing draft requirements of larger vessels.

Australia's international competitiveness, particularly in the commodity markets against countries such as Brazil, South Africa and Indonesia, depends on keeping pace with these trends.

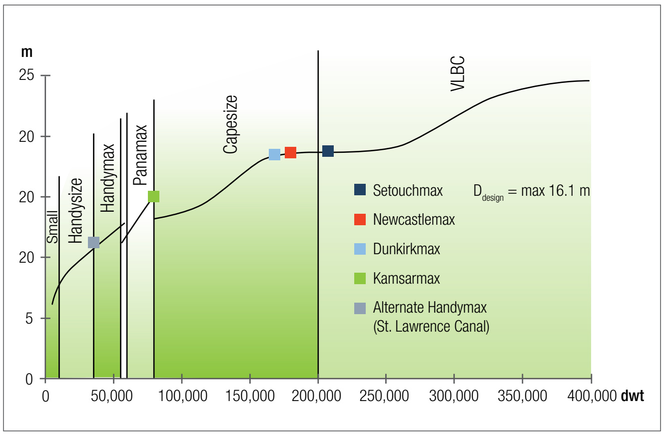



Figure 3.6: Increasing size of bulk carriers and increasing draft requirements (Source: MAN 2010)

This increase in the size of vessels means that ports have to provide deeper access channels allowing greater economic efficiencies whilst also ensuring vessel, infrastructure and environmental protection.

According to Lloyd's, about 103,000 ships of more than 100 tons are in operation around the world, half of them performing transport functions and the other half performing service functions (eg tugs). The most significant trend has been the growth of the average

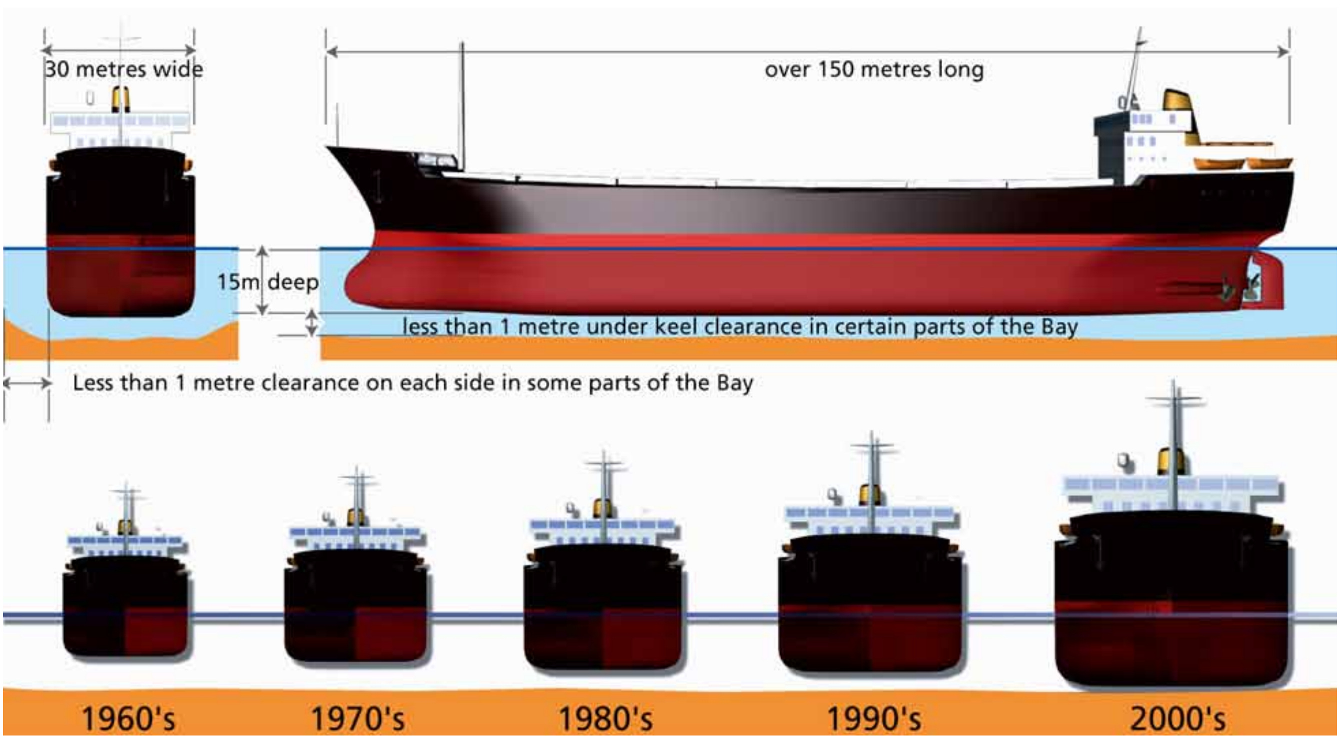



Figure 3.5: Increasing Under Keel Clearances-Bulk Vessels (Source: Brisbane Marine Pilots, 2013)

tonnage, notably after the Second World War (post 1945). As economies of scale became dominant in maritime shipping in the 1990s, the growth in tonnage resumed and increased substantially in the first decade of the 21st century. This is the outcome of the application of economies of scale in shipping.

Figure 3.7 provides an overview of recent global maritime movement patterns.

This clearly shows the significant trading role and continuing need for safe and efficient maritime infrastructure around the world – including the need for well-planned and managed shipping channels and waterside infrastructure to ensure safe access to world markets.

The dramatic changes in commercial vessel characteristics has seen dramatic changes in commercial vessel characteristics (across all vessel types – bulk, container and general cargo etc), including an increase in the average size of vessels calling at our ports, thereby necessitating a change in average channel depth to provide adequate draft.

To highlight this point, Table 3.2 shows the approximate change over a 30+ year period of declared channel depths at a selected group of Australian ports.

These channel augmentation programs have facilitated greater transport efficiencies throughout the freight network and ensured continued safe passage for commercial vessels calling at Australian ports.

Importantly, other waterside infrastructure such as berth pockets and swing basins must also be augmented or deepened over time (taking into consideration tidal considerations within the port area) to ensure the safe and efficient passage and loading and unloading of commercial vessels.

Whilst the tidal influence or range of a port can also be taken into consideration when designing and planning the need for deeper and wider infrastructure, the clear trend throughout the global industry is for deeper and wider waterside access paths to facilitate trading activities.

### Maintenance Dredging

As part of normal port operating procedures, parts of port channels may also require periodic maintenance dredging (ie the removal of sediments which have accumulated within the shipping channels) to ensure water depths are compliant with depths declared by the Harbour Master as safe for shipping.

Depending on the location of the port and typical coastal processes at play, shipping channels, berth pockets and swing basins are commonly subject to a wide range of sediment accumulation processes.

> The primary aim of maintenance dredging at Australian ports is to ensure the continued safe and efficient passage for commercial vessels.

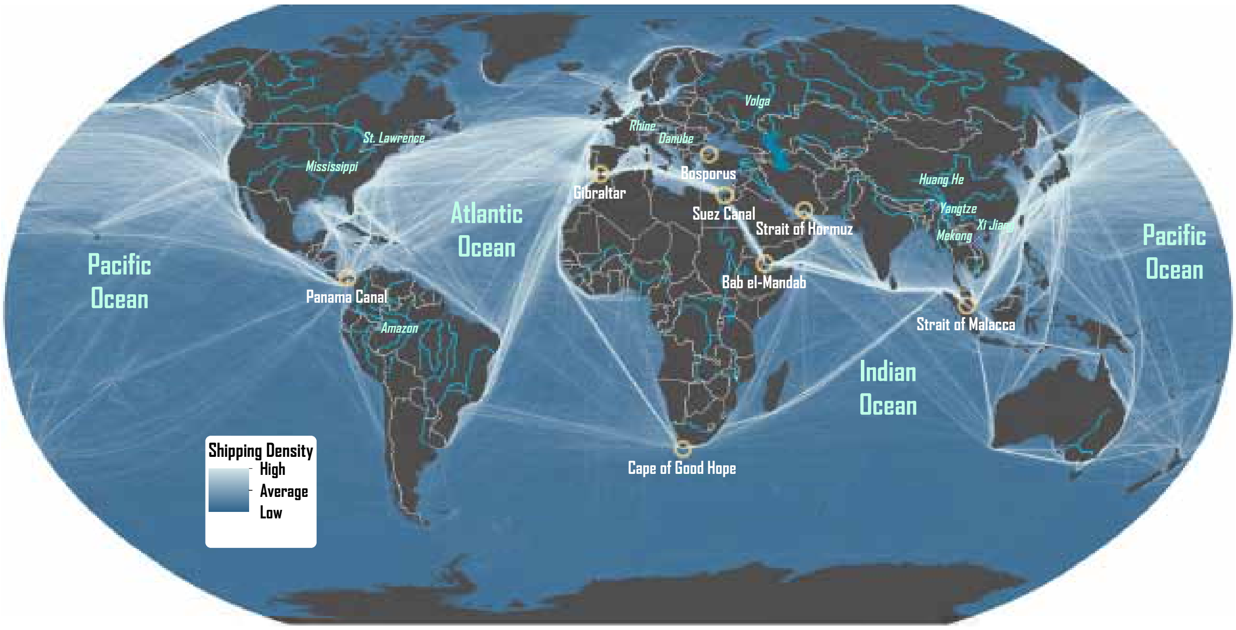



Figure 3.7: Domains of Maritime Circulation (Source: Rodrigue, et al. (2013)

Natural events such as cyclones and major flooding periods, which are common in subtropical and tropical regions, can also deposit large amounts of material within operational zones. If severe enough, such events could effectively reduce or shut down port operations for a period until hydrographic surveys have been taken and maintenance dredging has been carried out to the satisfaction of the responsible Harbour Master.

Other examples include those witnessed at various northern Queensland ports in the period following Tropical Cyclone Yasi in 2010 where channel and berth siltation was atypically high.

It is also important to note that once shipping channels are established, they typically do not require maintenance dredging along their entire length. For example, it is estimated that only 10% of the declared 90km shipping channel through Moreton Bay at the Port of Brisbane requires regular maintenance dredging to maintain declared channel depths (Port of Brisbane 2008). In addition, not all ports are required to undertake maintenance dredging on an annual basis due to natural channel or harbor pre-conditions (such as at Dampier).

Seasonal weather patterns influence the annual maintenance dredging campaigns which may result in year-to-year variances in maintenance volumes.

### 3.4 Use/Management of Dredged Material

Both capital and maintenance dredging programs result in material which requires re-use or relocation or placement at an appropriate site.

A recent study by SKM (2013a) acknowledged that the fate of dredged material may be subject to significant operational and environmental considerations by project proponents and environmental regulators. The study acknowledged the difficulties in handling this material out of the marine environment:

#### Emergency Maintenance Dredging Case Study

In early 2013, approximately 1.4 million cubic metres of silt and sediment accumulated in the Port of Brisbane channels and berths as a result of flooding rains and multiple dam water releases within the Brisbane catchment. This volume equates to more than 920 ship loads of dredged material and took 20 weeks to remove. By comparison, the average maintenance dredging program in a normal year would remove approximately 300,000 cubic metres over a four to eight week period. More than 450 hydrographic surveying events were also performed which is almost double that of a non-flood year.

Oil tankers supplying fuel to Brisbane with drafts measuring 14.2 meters deep were temporarily delayed while vital surveying and dredging works were undertaken to ensure these large vessels could berth safely. ***(Port of Brisbane, 2013)***

*'Dredged material is often considered to be a waste product of little value requiring disposal in a cost-effective manner that minimises environmental harm. This is particularly so when sediments are of a fine grain size (silt or clay) and are therefore generally difficult to de-water and re-use on land. Where sandy sediments are present and suitable for beneficial re-use on land, their use may be hindered by operational constraints associated with de-watering, handling, storage and transport, or by the difficulty of separating materials of differing particle sizes.'*
***(SKM 2013a)***

Ultimately, the final disposal and/or placement site will, in part, depend upon the results of detailed environmental assessments and scientific analysis in accordance with relevant regulations (see Section 4 for greater explanation of such determinations).

| Port (and dominant cargo type) | Declared Channel Depth | | | approximate channel depth increase |
|---|---|---|---|---|
| | 1980 | 2000 | 2012 | |
| **Brisbane (mixed)** | 12.8m | 14.0m | 15.0m | 17% |
| **Weipa (bulk cargoes)** | n/a | 10.8m | 11.5m | 6.5% (between 2000 and 2012) |
| **Hay Point (bulk)** | 13m | 13m | 14.9m | 13% |
| **Gladstone (bulk and mixed use cargoes)** | 10.4m | 16.1m | 16.1m | 55% |
| **Townsville (mixed)** | 10.7m | 11.3m | 11.7m | 9% |
| **Mackay (mixed)** | 8.5m | 8.2m | 8.6m | 1 % |

Table 3.2: Approximate change in declared channel depths 1980-2012 (Source: Queensland Port Authorities – 2014)

Typically though, the following options are available for disposal of dredged materials.

### Beneficial Re-use

Beneficial re-use is the practice of using dredged material for another purpose that provides social, economic or environmental benefits (Lukens 2000).

The SKM (2013a) report highlights that beneficial re-use opportunities around the world can be divided generally into three main categories depending on the physical characteristics of the material:

- Engineered and product uses – land creation, beach nourishment, fill material for future infrastructure projects, park creation, shoreline stabilisation and erosion control.
- Agriculture and related uses – used to enhance soils in agriculture, forestry, and aquaculture, and related uses such as mine rehabilitation. These uses generally rely on dredged material from freshwater dredging which is common in Europe and North America whereas the overwhelming volume of dredged material in Australia is from saline waters and generally not useful for these purposes because of the salt content.
- Environmental enhancement – habitat development, restoration of tidal flats, mud flats, salt marshes, wetlands, nesting habitats.

In general terms, potential uses include:

- as a fill supplement for land fill or construction products (acknowledging specific engineering or geotechnical characteristics and limitations);
- as fill material for port or airport reclamation areas commonly seen throughout the global port industry (eg: Port of Brisbane (Aust), Port of Rotterdam (NLD), Hong Kong airport, etc) ;
- as fill material for non-port reclamation (ie for the creation of industrial or similar land use areas);
- creation of constructed habitat for marine based fauna such as bird roosting sites (acknowledging the significant construction costs of such areas).

The SKM (2013a) report stated that there are several challenges in the beneficial re-use of dredged material as the actual viability of re-use (on land) is strongly related to its physical and chemical properties of the sediment, particularly grain size and chemical contamination status. It should be noted, however, that contaminant levels in material dredged by subtropical/tropical Australian ports (see Section 5.4) are rarely a significant constraint to onland reuse.

One of the underlying constraints of beneficial re-use options is often the cost, time, and feasibility of processing the material into a form that can be used effectively.

In general terms, difficulties with such options include:

- high variability of dredged material volumes requiring re-use – seasonal and operationally reliant;
- inconsistency of evident engineering properties or characteristics;
- economic cost; and
- operational restrictions regarding the inability to relocate marine materials over long distances.

Australia's preferred position regarding the beneficial re-use of dredged material is consistent with that of the United Kingdom and USA. However, as highlighted above, practical implementation of such programs is difficult and more often than not extremely expensive which is a matter to be considered under the NAGD.

### Land Based Placement

Land-based placement options are sometimes used where traditional beneficial re-use options are not available. This typically involves the placement of the material in a dedicated bunded area or storage facility.

Whilst sometimes stated as a simple solution to the issue of how best to deal with dredged material there are, however, major constraints to land based disposal, including:

- the underlying principle of moving marine material out of the marine environment or coastal system and placing on terrestrial areas and associated costs of material handling, de-watering, treatment, transport and site management;
- the significant volumes of dredged material typically involved in port dredging campaigns thereby requiring very large areas of land (potentially thousands of hectares) for placement;
- the high terrestrial conservation or residential value of coastal areas around Australia and issues associated with potentially impacting upon these areas or sterilising them for future use;
- timeframe variances of dredging campaigns which provide difficulties for site consolidation and management;
- operational ability to relocate material over long distances sometimes through, or adjacent to, highly urbanised areas or sensitive coastal zones;
- management of interface (eg safety and reverse amenity issues etc) around disposal sites; and
- ongoing and costly land and safety management at and around disposal sites.

The recent SKM (2013a) report on dredged material management in the Great Barrier Reef region stated:

> *'Direct impacts of dredged material placement on land may include clearing of vegetation for construction of drying or final disposal areas, reduced marine water quality from turbid tail water discharges, surface and groundwater contamination from runoff and leachates, high use of water resources for material processing, terrestrial habitat loss and species displacement, disturbance of potential acid sulphate soils (PASS) and associated runoff/leachate issues, health and safety issues associated with handling of material, and decreased air, noise and aesthetic quality of an area.'*
>
> ***(SKM 2013a)***

It is important to note that most marine sediments involved in dredging projects in inshore subtropical and tropical Australian waters are Potential Acid Sulphate Soils (PASS). Specific management techniques need to be adopted to avoid water quality impacts should such material be placed on land. Aerial exposure of these soils can lead to the production of sulphuric acid and the release of toxic quantities of iron, aluminium and heavy metals. Land placement of such material is liable to require costly long-term management and monitoring to avoid issues associated with acidic water discharges unless all such material is placed below the water table. This can be a major logistical and extremely expensive undertaking.

Dredging and disposal of PASS-containing sediments in the marine environment are unlikely to result in either significant oxidation of this material, acid production, or release of significant quantities of heavy metals to the water column (SEWPAC, 2013).

As stated previously, and consistent with the findings of the SKM study, whilst the NAGD typically identifies the re-use of dredged material on land as preferable to its placement at sea, operational experience is that in the majority of port and harbour developments, project costs, technical and logistic constraints, land-use considerations, terrestrial environmental factors and social factors have limited the viability of land-based re-use.

The SKM (2013a) report examined options for beneficial re-use and land-based placement of dredged material at six ports fringing the Great Barrier Reef (Port of Gladstone, Rosslyn Bay Boat Harbour (150 km north of Gladstone), Port of Hay Point, Port of Abbot Point, Port of Townsville and the Port of Cairns). It concluded that options for management of dredged material onshore or for a beneficial use are limited largely due to physical properties of the sediments involved and the lack of available land for drying out the dredged material to enable it to be transported and used elsewhere. In sensitive coastal zones, this presents a major challenge.

Critically, the report concurred with other recent reports such as the GHD (2013) report in stating that the exact properties of the particular dredging material need to be examined on a case-by-case basis taking into consideration local conditions and availability of land which may assist in pursuing alternative use options.

Such considerations are analysed and addressed during the impact assessment process within Australia at both commonwealth and state levels which are explained in more detail in Section 4.

**At-Sea Placement – Use of Dredged Material Placement Areas**

At-sea placement remains as an environmentally appropriate technique to manage dredged material. As noted in Section 4.0, material needs to be subject to detailed scientific and laboratory analysis prior to any approval being granted by government.

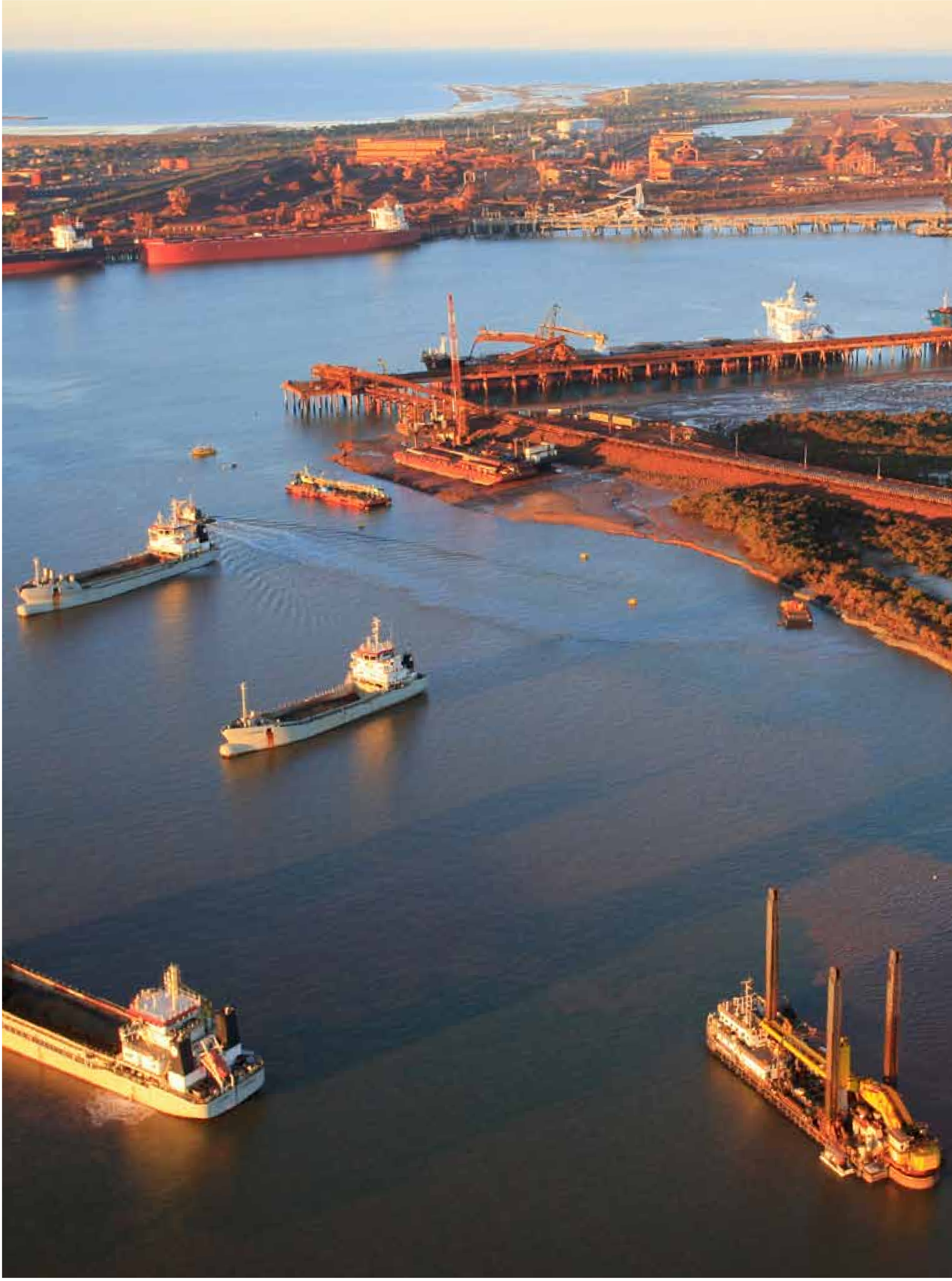
At-sea placement involves the use of a Dredged Material Placement Area (DMPA).

DMPAs are an essential part of port infrastructure and most ports have an approved designated offshore DMPA where dredged material is relocated.

DMPAs are approved by government regulators after a defined selection process examining a range of environmental, social and economic factors. Assessment of suitable DMPAs includes consideration of:

- Physical environment (eg bathymetry, grain or particle size, water temperature, location of surrounding sensitive areas or marine habitats);
- Biological environment (eg biological characteristics of a site may include important, listed, threatened species or communities and migratory species that use the area);
- Economic and operational feasibility (eg sizing of site, capacities);
- Other users (or uses) within the area (eg shipping lanes, fisheries, military, historic/heritage items).

Additional commentary on DMPAs is provided in Sections 4.0 and 10.0.



# 4. REGULATION AND LEGISLATION

This Section provides an overview of the key regulatory issues and legislation relating to dredging and dredged material placement in Australia. The approval process for dredging works may involve a much broader range of legislation including project specific issues (eg for shipwrecks, quarantine, or nearby infrastructure) than highlighted in this review.

## 4.1 Relevant Legislation, Conventions and Regulations

Dredging in Australia is highly regulated and subject to international agreements, commonwealth and state legislative requirements, and local port rules.

### 4.1.1 International Conventions/Agreements

All dredging in Australia must be consistent with the requirements of an international agreement to which Australia is a signatory known as the *Protocol to the London Convention* (previously known as the *Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972).*

The London Protocol is one of the first global conventions to protect the marine environment from human activities and has been in force since 1975. Over 42 countries have adopted the Protocol. The International Maritime Organization (IMO) hosts the permanent Secretariat of the Protocol.

The stated aim of the Protocol is to:

> *'protect and preserve the marine environment from all sources of pollution and take effective measures, according to their scientific, technical and economic capabilities, to prevent, reduce and where practicable eliminate pollution caused by dumping or incineration at sea of wastes or other matter. Where appropriate, they shall harmonize their policies in this regard'*
>
> ***(Article 2, London Protocol 2006)***

Under the Protocol all at-sea placement is prohibited, however, permits may be issued to allow the placement of the specified materials contained in Annex 1, subject to certain conditions. Such material includes:

- dredged material;
- sewage sludge;
- fish waste, or material resulting from industrial fish processing operations;
- vessels and platforms or other man-made structures at sea;
- inert, inorganic geological material;
- organic material of natural origin;
- bulky items primarily comprising iron, steel, concrete and similarly unharmful materials for which the concern is physical impact, and limited to those circumstances where such wastes are generated at locations, such as small islands with isolated communities, having no practicable access to disposal options other than at-sea placement;
- carbon dioxide streams from carbon dioxide capture processes for sequestration.

The requirements for the assessment of wastes or other matter that may be considered for at-sea placement are set out in Annex 2 of the Protocol and include:

- undertaking a waste prevention audit and development of waste prevention strategies;
- consideration of alternative options other than disposal at sea, including re-use, recycling, treatment to remove hazardous materials, disposal on land etc;
- description and characterisation of the waste material;
- development of a proactive action list to enable determination of the levels of contamination that will be considered acceptable for sea disposal;
- identification of suitable disposal sites considering physical, chemical and biological characteristics of the water-column and the seabed and a number of other factors such as economic and operational feasibility;
- assessment of potential effects;
- proposed monitoring of disposal sites;
- relevant permit conditions to ensure proper management of disposal etc.

In Australia, the London Protocol is administered by the Commonwealth Department of Environment and takes effect via the Environment Protection (Sea Dumping) Act 1981 (the Sea Dumping Act) which applies to all Australian waters (other than waters within the limits of a state or the Northern Territory inland waters).

### 4.1.2 Commonwealth Legislation

In Australia, three key Commonwealth Acts relate to the regulation of ocean disposal:

- *Environment Protection (Sea Dumping) Act 1981 (the Sea Dumping Act);*
- *Environment Protection and Biodiversity Conservation Act 1999 (the EPBC Act); and*
- *Great Barrier Reef Marine Park Act 1975.*

Commonwealth approval of dredging is required if dredging or placement is proposed to occur in Australian waters (excludes state waters), an area of high conservation value (eg Great Barrier Reef Marine Park) or is likely to influence species or communities of national environmental significance.

#### *Environment Protection (Sea Dumping) Act 1981*

As described above, the *Environment Protection (Sea Dumping) Act 1981 (Sea Dumping Act)* was enacted to meet Australia's international responsibilities under the Protocol to the London Convention.

The Sea Dumping Act regulates the loading and at-sea placement of dredged material, wastes and other matter at sea.

Under the Sea Dumping Act, the Commonwealth aims to minimise pollution risks by:

- prohibiting ocean disposal of waste considered too harmful to be released in the marine environment; and
- regulating permitted waste disposal to ensure environmental impacts are minimised.

SEWPaC (at the time, now the Department of Environment) issued national guidelines (the NAGD) for the sampling and testing of sediment by accredited laboratories which must be followed in order for an application for an at-sea placement permit to be assessed and issued (if appropriate). The guidelines also require a detailed evaluation of alternatives to at-sea disposal to be undertaken which includes assessment of environmental, social and economic impacts, consistent with the requirements of the London Protocol.

Importantly, opportunities to beneficially re-use dredged material are a key consideration in the assessment framework. These guidelines are internationally considered to be world-leading standard.

The importance of proper analysis, given the exact environmental setting of the dredging campaign, is critical.

> *'The regulatory framework seeks to balance the needs of ports with the protection of the marine environment and the interests of other stakeholders. It provides for the case-by-case assessment of individual dredging proposals but also encourages longer-term strategic planning to align the needs and goals of ports with our shared objective of protecting Australia's marine environment'.*
>
> ***(NAGD Commonwealth of Australia 2009)***

As the NAGD states:

> *'Dredging in Australian waters occurs in a diverse range of environments involving a range of sediments which vary from clean to contaminated. In areas remote from pollution sources, sediments are unlikely to contain contaminants, while in ports and harbours adjacent to urbanised or industrialised areas, sediments may contain high levels of contamination from metals or synthetic organic compounds. Some marine environments are also more sensitive than others, for example, coral reefs or fish nursery areas, and require a higher level of protection and/or management'*
>
> ***(NAGD Commonwealth of Australia 2009)***

The Sea Dumping Act is administered by the Commonwealth Department of Environment, although the Great Barrier Reef Marine Park Authority (GBRMPA) holds the delegation for assessment and issuing of permits under the Act where dredged material is proposed for loading or placement within the Great Barrier Reef Marine Park.

In assessing any proposal under the Act, where necessary the proposal is also assessed under the Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act). Such assessments occur concurrently.

#### *Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act)*

The EPBC Act is the primary environmental law instrument in Australia.

The Act is administered by the Commonwealth Department of Environment and provides a framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places and other areas of importance (defined as matters of national environmental significance).

The Act identifies the following matters of national environmental significance:

- World Heritage properties;
- Ramsar Wetlands;

- Commonwealth listed migratory species;
- Nuclear actions;
- Commonwealth marine areas;
- National Heritage places;
- Commonwealth listed threatened species and ecological communities;
- Great Barrier Reef Marine Park;
- a water resource, in relation to coal seam gas development and large coal mining development.

Under the EPBC Act, the Environment Protection and Biodiversity Conservation Regulations 2000 provide for the issuing of approvals and permits for a range of activities in relation to matters of national environmental significance.

The EPBC Act establishes a referral and assessment process which requires the Commonwealth Environment Minister to approve any action which is likely to have a significant impact on a matter of national environmental significance.

A referral under the EPBC Act is also considered to be an application under the *Great Barrier Reef Marine Park Act 1975 (GBRMP Act)* for actions to be undertaken in the Marine Park.

***Great Barrier Reef Marine Park Act 1975***

The GBRMP Act provides a framework for the establishment, control, management and development of the GBRMP and is administered by the GBRMPA.

Applications for works within the GBRMP are assessed to determine the potential to impact on the environment and on the social, cultural and heritage values of the Marine Park. The GBRMPA can grant, refuse or condition permit applications.

State marine park legislation is also assessed and a joint marine parks permit is considered where boundaries overlap.

### 4.1.3 State Legislation

There is a variety of state government legislative requirements which relate to dredging and dredged material placement that differ between states. Whilst these vary between states, typical issues needing to address as part of permit applications include:

- Impacts to marine plants or benthic (bottom dwelling) primary producers (eg seagrasses or mangroves);
- Fisheries;
- Cultural heritage;
- Environmental issues (eg contamination, air quality, noise);
- Navigation and shipping safety;
- Biodiversity;
- Sustainability;
- Environmental offsets;
- Land use and planning;
- Coastal management and processes.

*Photo courtesy of Wayne Young.*

In most cases, several permits will be required. The issues covered by these state permits may, on occasions, duplicate those of the commonwealth especially in regard to application of the EPBC Act. A review of bilateral agreements between the states and the commonwealth is underway for dredging applications to reduce the need for duplication of state and commonwealth approval assessments.

### 4.1.4 Standards, Guidelines and Policies

There a numerous policies, standards and guidelines relevant to dredging and the monitoring and management of marine water quality in subtropical and tropical ports. These include:

- National Water Quality Management Strategy;
- State government water quality policies;
- State government water quality guidelines (often these are area specific);
- Australian and New Zealand Environmental Conservation Council (ANZECC) Guidelines for Fresh and Marine Water Quality;
- GBRMPA policies and position statements (eg Dredging and Spoil Disposal Policy, Environmental Impact Management Policy);
- Regional management plans;
- Water Quality Guidelines for the Great Barrier Reef Marine Park, Revised Edition 2010 (GBRMPA 2010);
- Local individual catchment environmental values and water quality objectives (various).

Monitoring and reporting should always be based on the most locally-specific available guidelines and many of the above relate to assessing long-term changes on broad spatial scales.

**Legislative Snapshot – Summary**

The international agreement relating to the relocation of wastes and other matter in Australian waters, including dredged material, is called the London Protocol (see Section 4.2 for greater detail on regulatory processes).

↓

Australia implements its obligations under the London Protocol through the Commonwealth *Environment Protection (Sea Dumping) Act 1981 (the Sea Dumping Act*). Through the Sea Dumping Act, the Australian Government assesses formal proposals regarding the disposal of wastes and other matter at sea.

↓

The National Assessment Guidelines for Dredging (NAGD) set out the framework for the environmental impact assessment and permitting of the ocean disposal of dredged material.

↓

State specific legislation eg *Environment Protection Act, 1994 (Qld)*

↓

Codes, Policies & Operational Guidelines (eg water quality guidelines, operational codes)

## 4.2 Description of Assessment Process

As detailed above, applications for dredged material disposal proposals require the supply of detailed information including environmental impact assessments for the dredging activity itself and the placement or disposal of dredged material.

A key aspect of the dredging application process is the need for proponents to demonstrate that the material to be dredged has been subject to detailed site specific assessment to ensure toxic material is not placed at sea and that all alternatives to at-sea placement (eg beneficial re-use or land-based disposal) have been comprehensively evaluated.

Most large scale dredging programs in Australia require approval under both commonwealth and state legislation already described. In some instances, similar information may need to be supplied to both levels of government see Figure 4.1.

The approvals process is often complex and can take many years depending upon the specific project involved. Applications can take up to two years to process, depending upon the nature and extent of the dredging project being contemplated.

The process is highly iterative between the regulating bodies and the project proponents (typically the port authorities).

The assessment framework for consideration of management of dredged material, encapsulated in the NAGD, is shown in Figure 4.2.

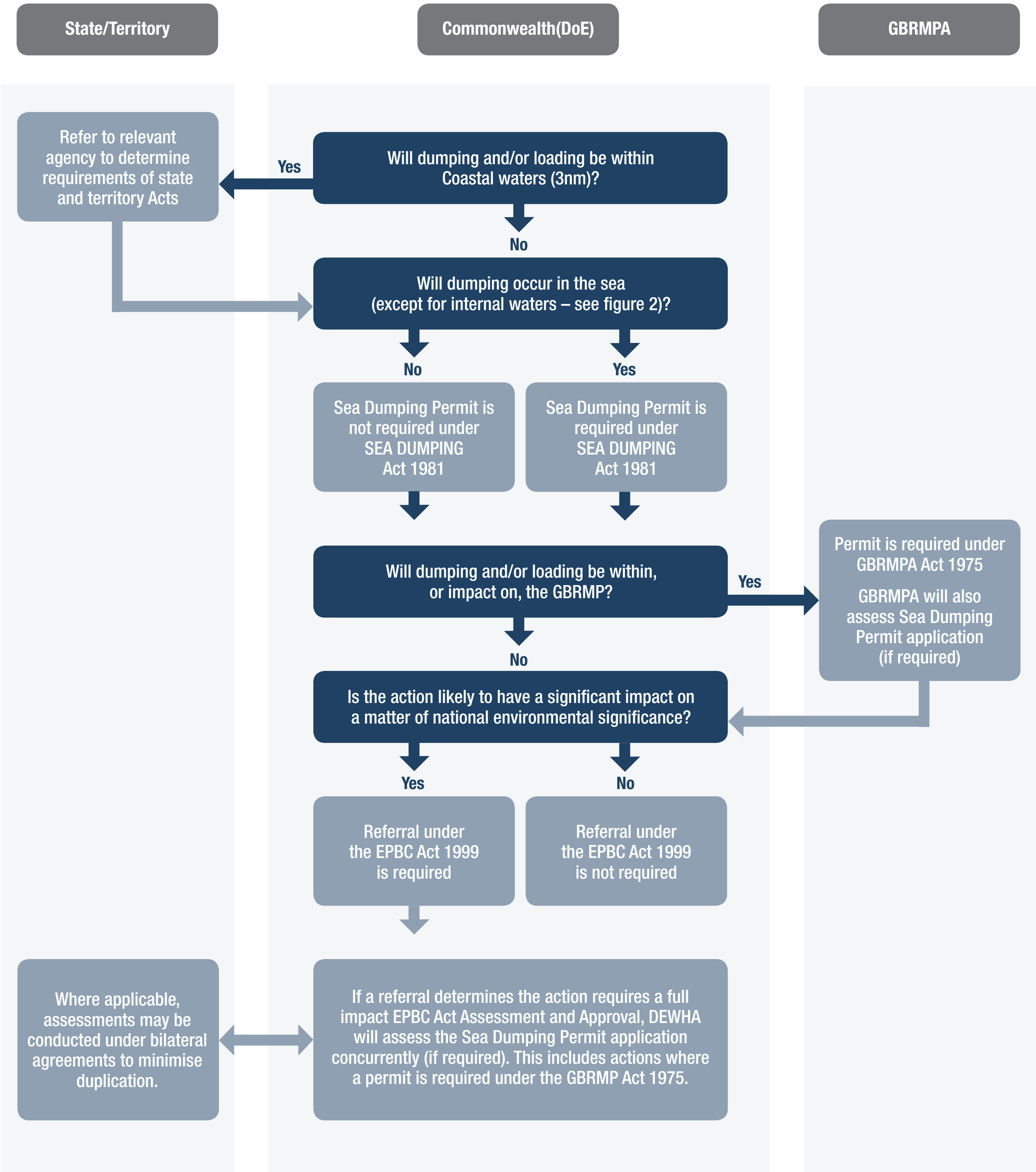



Figure 4.1: Australian Regulatory Framework and Stakeholders

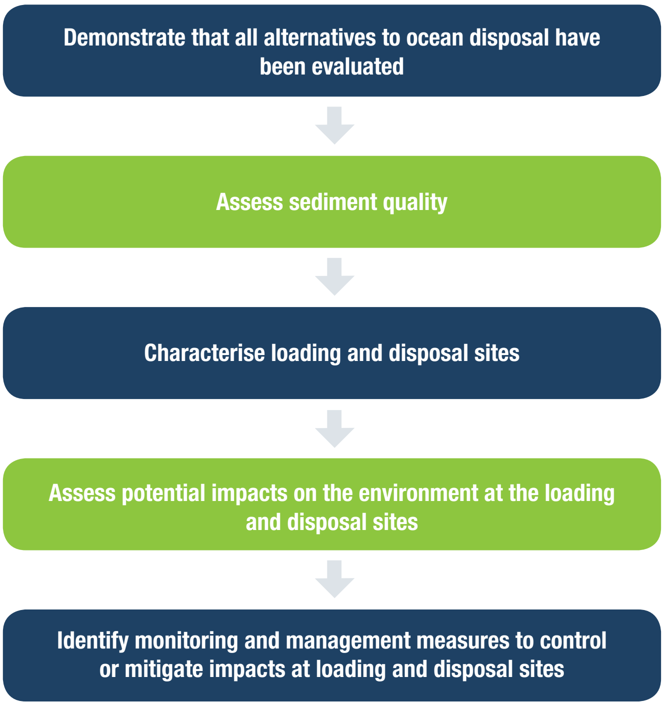



Figure 4.2: NAGD Assessment Framework

### Step 1: Evaluating disposal alternatives and waste minimisation methods

The objectives of the London Protocol and commonwealth regulations enshrined in Australian law include minimising pollution caused by ocean disposal. As such, evaluating options for waste prevention and alternatives to ocean disposal are important first steps in the assessment process.

As the NAGD states:

> *'All alternatives to ocean disposal need to be evaluated, including the environmental, social and economic impacts of each disposal option. Consultation with potentially affected stakeholders or potential users of the dredged material will be required.*
> *Important elements of assessing disposal options for dredged material are:*
>
> - *Are there opportunities to beneficially use or recycle such materials?*
> - *If they have no beneficial use, can they be treated to destroy, reduce or remove the hazardous constituents?*
> - *If hazardous constituents are destroyed, reduced or removed, do the materials have beneficial uses?*
> - *What are the comparative risks to the environment and human health of the alternatives?*
> - *What are the costs and benefits of the alternatives?*
>
> *It is important to recognise the potential value of dredged material as a resource.*
> *Possible beneficial uses include engineered uses (land reclamation, beach nourishment, offshore berms, and capping material), agriculture and product uses (aquaculture, construction material, liners) and environmental enhancement (restoration and establishment of wetlands, upland habitats, nesting islands, and fisheries).*
> *Material which is unacceptable for ocean disposal is, in many cases, quite acceptable for onshore disposal. Often the contaminants of concern will not readily leach in land disposal sites and the dredged material may even gain an inert or solid waste classification, rather than hazardous or industrial waste. Suitability and requirements for determining onshore disposal options should be discussed with state or territory authorities.*
> *A permit shall be refused if the determining authority finds that appropriate opportunities exist to re-use, recycle or treat material without undue risks to human health or the environment or disproportionate costs.'*
>
> ***(NAGD Commonwealth of Australia 2009)***

Consideration of alternative disposal options is a critical step in the overall planning and design of necessary dredging programs at Australian ports.

Importantly, and as the NAGD recognizes, the following factors must be considered in the process:

- environmental (eg potential groundwater contamination, leachate and runoff impact, permanent alteration of the site etc);
- social (eg interface management – access, dust, operational noise, safety etc);
- economic (eg financial cost of alternative site placement and ongoing management costs etc).

Whilst alternative disposal options may be technically feasible in some cases, the costs associated with such options may render the dredging program (and allied project) financially unviable, resulting in the inability to raise project finance and necessary equity.

Consideration of potentially disproportionate costs is a key consideration under the NAGD.

### Step 2: Assessing sediment quality

Should no alternative option to at-sea placement be deemed appropriate, the second stage in the assessment framework is the scientific analysis of sediment quality.

Under the NAGD, this assessment is undertaken across five phases using a decision-tree approach as shown in Figure 4.3. Importantly, due to the highly variable nature of sediment chemical, physical and biological properties, assessment of the impacts of contaminated sediments on organisms is complex. A number of lines of evidence may need to be used, such as chemical, toxicity and bioavailability testing.

It is also important to recognise that the focus of the London Protocol, the Sea Dumping Act and the NAGD is on preventing pollution of the marine environment (particularly by toxic chemicals) rather than on environmental protection generally and may not sufficiently address non-pollution impacts.

In accordance with the NAGD, accredited laboratories must be used to undertake rigorous scientific analysis of material recovered from the marine environment. The results then form part of an assessment of material disposal and/or placement options under the Sea Dumping Act.

The guidelines specifically require a detailed evaluation of disposal and/or placement options for the material recovered from the seabed, such as at-sea disposal or the need to dispose of material in appropriately designed, land-based facilities.

Importantly, material found to be toxic is not allowed to be placed at sea.

### Step 3: Assessing loading and disposal sites and potential impacts on the marine environment

If dredged material is deemed suitable for ocean disposal, the NAGD requires a detailed assessment of the potential impacts on the receiving environment – ie taking into account the physical location of the ocean placement site. This assessment will help determine the suitability of placement sites and will assist in developing adaptive management measures.

Potential impacts of loading dredged material must also be taken into consideration, ensuring appropriate management of operational sites, as loading and disposal of material may have direct and/or indirect physical impacts, biological impacts, and impacts on other users of the marine environment.

The NAGD therefore requires the nature, temporal and spatial scales and duration of expected impacts to be defined, so that an appropriate assessment can be undertaken.

In terms of site assessment, four key elements need to be considered:

- physical environment - physical, biological and chemical characteristics of the water column and seabed;
- biological environment - listed, threatened species or communities and migratory species that use the area, including temporal or seasonal and spatial characteristics;
- other uses - other maritime users such as commercial fisherman, military, public uses, shipping safety and operations etc;
- Economic and operational feasibility including consideration of the location, size and proximity to the actual dredging site.

Impact analysis at these sites (loading and/or disposal sites) is then conducted in accordance with the Australian/New Zealand Standards for risk management including AS/NZS 4360:1999, HB 203:2000.

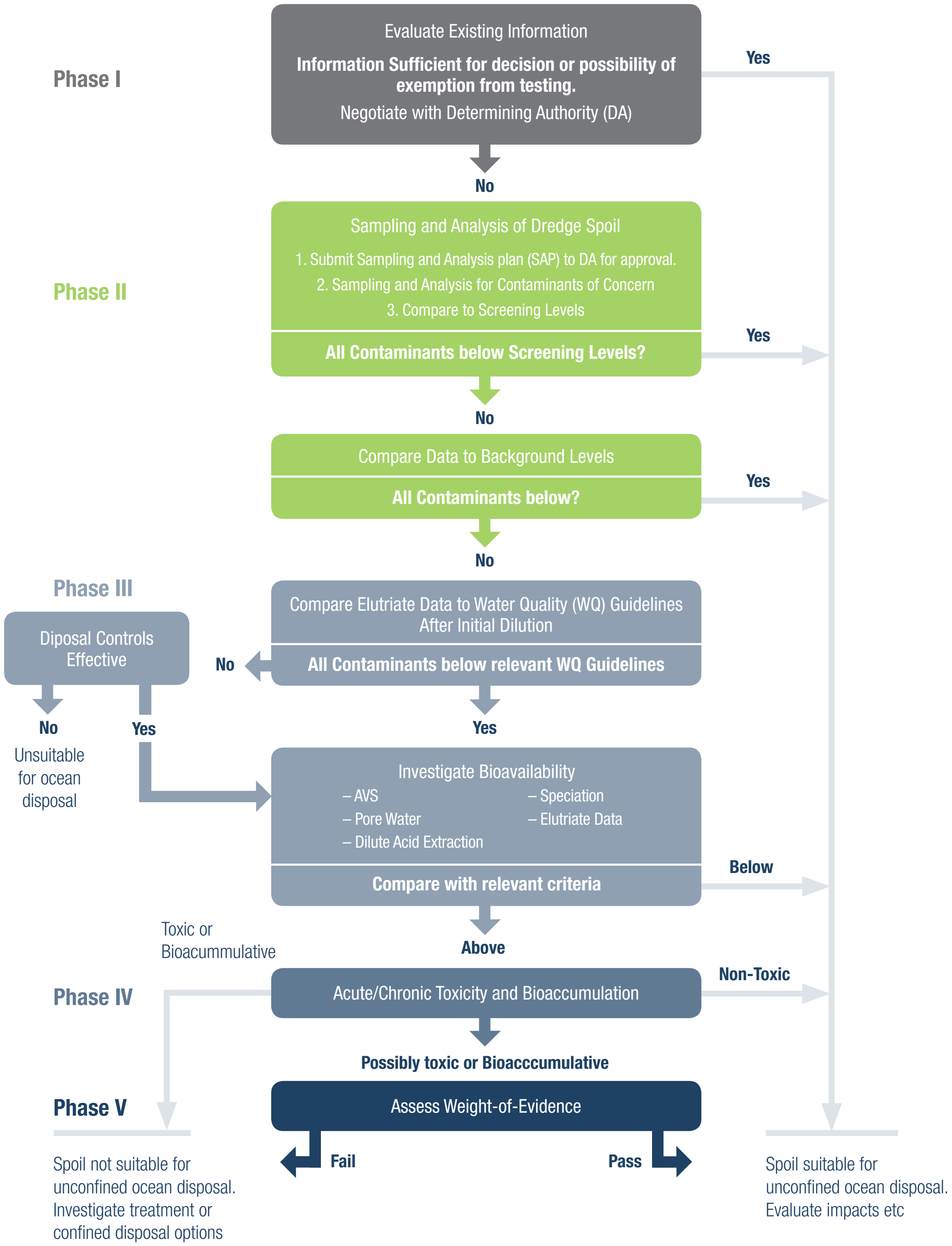



Figure 4.3: Assessment of dredged sediment and materials.

### Step 5: Determining management and monitoring requirements

Once the likelihood and consequence of possible impacts are better known and the physical characteristics of the dredged material are understood, appropriate management and monitoring programs can be developed.

Critically, such programs need to be adaptive in their development allowing for flexibility over time and able to take on new information and changes to management techniques.

Consideration should be given to adoption of assessment and management approaches consistent with the Environmental Quality Management Framework of the National Water Quality Management Strategy (ANZECC/ARMCANZ 2000).

The NAGD outlines:

*'Management measures include:*

- *dredged material treatment – to reduce levels of contaminants;*
- *loading and disposal management – to reduce dispersal of turbid plumes in sensitive environments;*
- *changing the location and/or timing of dredging and disposal – to avoid or reduce impacts on sensitive benthic communities;*
- *altering the time of year of dredging and disposal – to avoid critical life-cycle phases such as coral spawning or whale calving periods; and*
- *use of specialised dredge equipment – such as turtle excluding devices, to reduce potential impacts on marine species.*

*Related issues which need to be considered include:*

- *availability of suitable equipment for proposed dredging/ disposal options;*
- *ability to control placement of the material; and*
- *ability to monitor the site adequately.'*

***(NAGD Commonwealth of Australia 2009)***

## 4.3 Summary

The array of environmental regulations in place to control dredging activities is substantial.

Australia, using a multi-level assessment approach via the Environment and Biodiversity Conservation Act, the Sea Dumping Act and National Assessment Guidelines for Dredging has strong environmental and governance control around dredging works at and around Australian ports and other infrastructure nodes.

The efficacy of environmental regulations relating to dredging activities is high due in part to the cooperation between commonwealth, state and territory governments.

The continued focus on strong governance and appropriately administered regulatory systems, including the appropriate consideration from field experience, is critical and forms a fundamental part of continued management improvement within the Australian coastal environment.

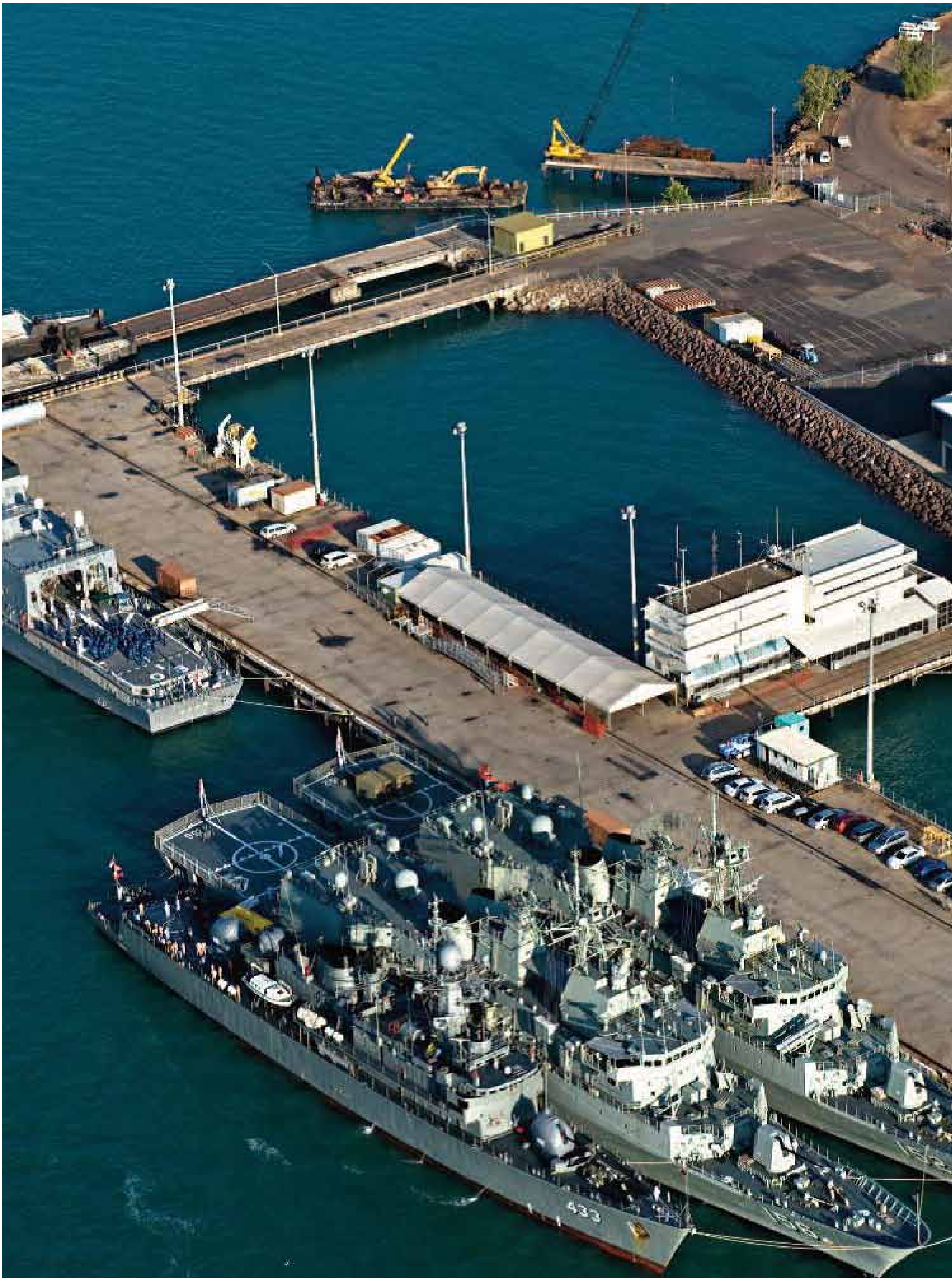


*Photo courtesy of Darwin Port Corporation.*

# 5. ENVIRONMENTAL IMPACT PROCESSES

This Section provides a brief overview of impacting and recovery processes associated with dredging and dredged material placement in subtropical and tropical regions of Australia with particular emphasis on marine communities.

## 5.1 Seabed Disturbance from Dredging

Dredging results in the physical removal of the seabed and associated flora/fauna from the dredge site. The environmental impact of this removal process depends upon the nature of dredging, the nature of existing communities in a particular area and recolonisation/environmental recovery processes.

Seabed disturbance is an unavoidable consequence of dredging. Impacts can only be minimised by ensuring the dredge footprint is small as possible. Ports typically seek to reduce dredging as associated costs are high.

### Maintenance Dredging

Maintenance dredging involves the removal of sediments that have accumulated in the artificially deepened channels or berths between maintenance dredging periods (generally once every few years). Each maintenance dredging exercise generally involves disturbance of the same area or dredge footprint.

Sediments generally comprise fine materials (eg silts or fine sands) that have been transported by currents into the deeper channels and berths. Most of the fauna/flora that colonises the accumulating sediments between dredging episodes are species that are adapted to exploiting disturbed habitats and typically involve common and widespread species such as shellfish, crabs, worms and algae. Material is almost always unvegetated (other than microalgae). Seagrasses or corals rarely colonise areas associated with maintenance dredging given the frequency of dredging.

Unless environmental conditions change markedly, which may occur as a result of capital dredging, direct impacts associated with maintenance dredging removing the seabed are generally localised and short term (Engler et al 1991).

### Capital Dredging

Capital dredging involves the excavation of virgin or previously undisturbed areas of the seabed. In general, recent capital dredging in subtropical/tropical Australia has involved unvegetated or sparsely vegetated soft sediments (clays, silts and sands). However, on some occasions, port related capital dredging has involved the removal of seagrasses (eg Gladstone Western Basin Project) and, far less frequently, corals.

Impacts to the seabed from capital dredging may be much greater than for maintenance dredging and recover slower (if at all) especially when marked changes occur to environmental conditions (eg increased depths and changed currents). Many of the soft bottom infauna communities may re-establish in the dredge area (depending on the level of shipping and maintenance disturbance) but are likely to differ from those originally present.

Removal of seagrasses or corals from the dredge footprint generally results in their permanent loss unless the final substrate is suitable for recruitment. The potential for recovery depends upon the extent to which dredging results in changes to environmental conditions.

Few studies have examined the recolonisation of dredged areas, however, recolonisation processes are known to occur rapidly in many instances (Section 10.0).

## 5.2 Turbidity Plumes and Sedimentation Effects

Dredging and dredged material placement may cause sediment to be introduced to the water column (turbidity) and result in impacts as these sediments settle (sedimentation).

Turbidity and sedimentation effects can result from the dredging operation (eg through hopper overflow waters, disturbance to the seabed by the dredge draghead or propeller wash), the placement of material at the DMPA (eg through Trailing Suction Hopper Dredge discharges or barge releases) and through dispersion of placed material from the DMPA.

DMPAs in subtropical and tropical regions vary, depending on location and associated hydrodynamic and climatic processes, from retentive to dispersive. Many DMPAs are located in inshore high energy areas where sediment resuspension and dispersion is common whilst others are sited in deeper offshore areas that may be less dispersive. Dispersion of placed dredged material does not necessarily result in unacceptable environmental impacts and potential environmental impacts need to be considered on a case specific basis.

The level of impacts and rates of recovery from turbidity and sedimentation effects depend on several factors such as the timing, duration, intensity, and scale of the dredging and dredged material placement works as well as the type of species affected.

Turbidity plumes and sedimentation effects:

- These are generally less with stationary equipment such as Cutter Suction Dredges (CSDs) or grab dredges than with mobile equipment such as Trailing Suction Hopper Dredges (TSHDs). Effects associated with stationary dredges tend to be confined to the dredge area and only a minor proportion of sediments may be introduced to the water column (PIANC 2010).
- These vary depending upon the nature of dredging. Few projects are the same. Maintenance dredging typically involves fine grained sediments although works mostly involve relatively small volumes. Capital dredging can involve a broad range of sediment types depending upon local geological conditions. Capital dredging generally involves larger dredges operating for a longer period than maintenance dredging and so plumes are proportionally greater and of longer duration.
- These may result from placement of material at a DMPA. Such effects reduce over time as fine material on the seabed is gradually dispersed. Much of the finer sediments will tend to be armoured from resuspension in the presence of coarser material and consolidation occurs over time. Studies of dredged material placement from hopper vessels have shown that generally, only a small proportion (5-10 per cent) of the lighter sediments will become suspended (e.g. Wolanski et al 1992, SKM 2013b) during placement.
- These are associated with dredging and dredged material placement and may be similar to those associated with natural events such as storms or in extreme cases cyclones (Pickett and White 1995, Pennekamp et al 1996). Many inshore communities regularly experience short term periodic increases in turbidity and sedimentation and are adapted to such effects.

Suspended materials may either settle at the dredge/DMPA site contributing to direct effects or cause indirect effects as they are transported by currents to adjacent areas (depending upon the sediment particle sizes involved and the hydrodynamic regime of the dredge area).

Settled suspended sediments may smother benthic communities, such as corals and seagrass, affecting growth rates and in extreme cases, result in mortality.

Corals are subject to natural sedimentation and can clear sediment settling on their surface. However, if the sedimentation rate exceeds their clearance capacity, the accumulation of sediment can lead to sublethal effects (eg reduced growth) and mortality (Fabricius et al 2003, Gilmour et al 2006). Corals are generally impacted by lower levels of sedimentation than seagrasses, filter-feeding invertebrate communities, or macroalgae communities.

Dredging and dredged material placement may also affect benthic communities as a result of turbidity plumes reducing the light available for photosynthesis.

Elevated levels of turbidity may limit the capacity of zooanthellae (symbiotic algae within corals which require light) to photosynthesise leading to adverse impacts. If increased turbidity is of sufficient intensity, duration and/or frequency, the tolerance levels of coral assemblages may be exceeded, resulting in stress and/or mortality. Light reduction impacts vary depending upon the coral species, extent and elevation of light intensity reductions and the time of year when impacts occur (Erftemeijer et al 2012, see Section 6.3).

Seagrass species vary in their resilience to increases in turbidity as minimum light requirements both within and between species can be up to an order of magnitude difference (Erftemeijer et al 2013).

Many subtropical and tropical seagrass species are resilient to short term reductions in light such as result from dredge plumes (the extent would depend upon the severity of light reduction and for how long this reduction persists). Research has shown some seagrass species can survive light intensities below their minimum requirements for weeks as they have an ability to undergo physiological and morphological adjustments in response to reduced light conditions (eg Mulligan 2009; Chartrand et al 2012).

Mangroves are naturally adapted to highly turbid waters and are generally not affected by increases in turbidity, however, excess sedimentation can cause stress as a result of smothering and burial of root systems. Impacts can range from reduced vigour to death, depending on the amount and type of sedimentation and the mangrove species involved (Ellison 1998).

High levels of turbidity/suspended sediments may have a potential to clog the gills of filter feeding benthic organisms (eg bivalves) and affect the functioning of fish gills. Experience to date suggests these impacts are not large and are localised to the immediate vicinity of the dredging and placement operations (Essink 1999; Vic EPA; 2001; Wilber and Clarke 2001). Studies by the US Army Corps of Engineers (USEPA and USACE 1992) concluded that turbidity effects rarely influence pelagic (open water) or mobile organisms as levels of turbidity and suspended sediments resulting from dredging are an order of magnitude (or more) less than lethal concentrations and persist for only hours.

### 5.3 Smothering of the Seabed at the Dredged Material Placement Area

Placement of dredged material at the DMPA results in burial and smothering of resident benthic communities. Similar to dredging footprints, impacts to a DMPA are an unavoidable consequence of placing material at-sea. As noted in Section 3.0, DMPAs are designated for this impact process and are specifically located in recognition of the inevitability of such impacts and the need to minimise adverse effects to adjacent areas.

The extent to which smothering results in environmental impacts is generally site specific and varies depending upon the nature of dredged material placement, volume of material involved, frequency of DMPA use, nature of the placement site and resiliency of the benthic communities. Available literature indicates that impacts vary from few or no detectable effects to large, long-term impacts (Roberts and Forrest 1999, Smith and Rule 2001, Erftemeijer and Lewis 2006).

Seagrasses and other permanently attached benthic fauna are particularly vulnerable to the effects of smothering as they cannot avoid placed material and have limited capability of emerging from beneath sediment once they are covered. Such communities are uncommon at frequently used DMPAs and the selection process to define a new DMPA takes into account such issues.

Many benthic species are well adapted to burrow back to the surface following burial. Polychaetes and bivalves have been reported to be highly resilient (Maurer et al 1979, Dauer 1984). Impacts are generally more pronounced when large quantities of sediment are placed over a small area. However, where sediment is placed in thin layers, the effects may be relatively minor as many species can migrate up through the deposited sediments (OSPAR 2008).

Impacts tend to be less where DMPAs are located in near-shore high energy areas. In such situations, the upper layers of the seabed are often disturbed by waves or currents leading to high rates of re-suspension and sedimentation. Animals living in such habitats need to be mobile and capable of withstanding both the removal of sediment by wave or current action and variable rates of sedimentation. Regular use of a DMPA (eg as a result of maintenance dredging) may result in resident communities being preconditioned or having a high level of resilience to dredged material placement (Section 5.6).

### 5.4 Contaminants

All material proposed to be placed at sea is tested under rigorous requirements set out in the NAGD using accredited laboratories. As noted in Section 4.1, Australia is a signatory to an international agreement ensuring dredged material disposed of at sea is not toxic and does not result in associated environmental impacts.

Capital dredging projects by Australian subtropical or tropical ports (particularly in areas remote from major development) rarely involve sediment with significantly elevated levels of contaminants and are typically non-toxic. Capital dredging involves virgin material and although consolidated deeper layers rarely have contaminants, surface layers in some cases may contain contaminants.

Most contaminant issues in subtropical or tropical ports relate to maintenance dredging of inner harbour areas (eg berths) where sediments may contain levels of contamination resulting from port activities (eg runoff or spillage from wharves), ship antifouling paint (eg TBT) and upstream catchment influences (eg urban stormwater).

As noted in Section 3.4, PASS-containing sediments are commonly dredged in inshore subtropical or tropical areas and specific management techniques need to be adopted to avoid water quality impacts (eg production of sulphuric acid and the release of toxic quantities of iron, aluminium and heavy metals) should such material be placed on land and aerially exposed. Dredging and disposal of PASS-containing sediments in the marine environment are unlikely to result in either significant oxidation of this material, acid production, or release of significant quantities of heavy metals to the water column (SEWPAC, 2013).

Irrespective of the nature of dredging, all material proposed for at-sea placement is tested according to the NAGD and subject to strict testing and approval protocols to ensure potential impacts relating to the resuspension or placement of contaminated material are assessed. The NAGD prohibits the placement of toxic material at sea.

### 5.5 Nutrients

Dredging and dredged material placement may release nutrients held within the seabed sediments. The ecological impact of additional nutrients depends on a broad range of factors including the background concentrations in the water column, nutrient release rates and dredging techniques and needs to be considered on a site specific basis. The NADG does not provide guidance in relation to nutrient levels in marine sediments.

Elevated nutrient levels in the water column are of interest as there may be a potential to stimulate algae growth with both positive and negative effects. Whilst increases in nutrient levels may increase the risk of algal blooms, the turbidity created by dredging reduces light and hence may reduce the risk of blooms.

Most assessments of nutrient related impacts indicate any increase in nutrient concentrations is likely to be localised and short-lived and comparable to the effects of storms which affect much more extensive areas (Vic EPA 2001). Adverse effects on eutrophication-related (algal bloom) water quality issues are rare because the events are short lived, there is typically fairly rapid dilution and, relative to the dilution, nutrient release is small (Jones and Lee 1981). Eutrophication issues are more likely to be an issue in enclosed water bodies where rates of dilution are low.

Outbreaks of the Crown-of-Thorns starfish are a significant issue in parts of the Great Barrier Reef damaging large areas of coral and this is thought to be linked to elevated nutrient levels. Outbreaks have followed large, drought-breaking floods which release large amounts of nutrients from the adjacent catchment into the reef ecosystem (GBRMPA 2013a). The elevated nutrient levels cause an increase in phytoplankton which is the main food source for Crown-of-Thorns starfish larvae, increasing larval survival. The potential for dredging related nutrient releases to contribute to nutrient levels would depend upon the nature of the dredging project (eg timing in relation to Crown-of-Thorns spawning period, scale and nutrient release levels from dredged sediments) and the specific location.

Disturbance of sediments by dredging may release organic materials that can temporally enhance the population density and diversity of organisms adjacent to the immediate zone of sediment deposition (see Newell et al 1998 for review). In some cases, there may be a short-term measurable beneficial effect for several kilometres (Poiner and Kennedy 1984).

### 5.6 Environmental Recovery Processes

Environmental recovery[2] or recolonisation of dredged/dredging material placement areas has been the subject of considerable research and numerous publications are available (eg Bolam et al 2004). In general, recolonisation of impacted environments by benthos occurs via the following processes:

- Vertical migration of buried individuals through dredged material - if the depth of material is not too great, many species can migrate up to the sediment surface. Many benthic species are well adapted to burrow back to the surface following burial.
- Horizontal immigration of post larval individuals from the surrounding community – in the case of dredged areas, slumping of the sediment (and fauna) from the channel banks may assist in such processes. Rapid recovery of the DMPA at the Port of Townsville may have been due to active or passive migration of adults from nearby undisturbed or less disturbed areas (Motta 2000).
- Larval recruitment from the water column whereby nearby undisturbed areas may provide a source to recolonise the area.
- Transport (and survival) of benthic individuals from the dredge area to the DMPA by the dredge – rapid recovery at a DMPA in NSW was considered partially due to the transport of individuals from the dredge area within the dredge (Jones 1986).
- Recolonisation through a proportion of the original community remaining in the dredge area (which may be significant if only a portion of the DMPA is used).
- Overflow waters from THSD dredges returning undamaged benthic organisms to the dredged area.

In general, where impacts at DMPAs have been monitored (Section 10.0), recovery processes involve an increase in the abundance of benthic fauna prior to a recovery of diversity (Kenny and Rees 1994, Harvey et al 1998, De Grave and Whitaker 1999, Wilbur et al 2008).

Some investigations have noted a rapid initial increase in biomass and postulated that the placement of dredged material may have provided a fresh source of nutrients for organisms at the site with some species to exploit these inputs (Poiner and Kennedy 1984, Chartrand et al 2008).

A more detailed discussion of recovery times associated with dredged material placement is provided in Section 10.0 which indicates that recovery can occur within months in shallow wave influenced or estuarine environments. Similar processes may occur for many dredged areas.



*[2] The term 'recovery' has been used within the literature to describe various processes including the recolonisation process, restoration of a functional property (eg productivity), return to the original community structure, or the restoration of a community parameter (eg diversity).*

# 6. RECENT DREDGING MONITORING PROGRAMS – PROJECTS, APPROACHES AND APPROVALS

This section provides a list of dredging projects associated with subtropical and tropical ports included in this review, a general description of why monitoring is undertaken and the process for the design of monitoring programs. It also includes a discussion on the key limitations associated with using sensitive receptors, such as corals or seagrasses, as indicators of environmental impact recognising the increasing use of this monitoring approach.

## 6.1 Dredging Projects

Monitoring of dredging and dredged material placement has been a standard condition of all large capital dredging projects and many maintenance dredging projects in Australia over at least the past 20 years.

A collective analysis of such monitoring programs has not previously been undertaken, although regional reviews have been carried out by Hanley (2011) for the Pilbara region and SEWPaC (2013) for the Gladstone area.

Projects conducted by subtropical and tropical Australian ports included in this review are shown in Table 6.1. Summary results of these projects are presented in Section 7.0 whilst Appendix A provides a detailed description of each project including:

- year of completion (some projects have been staged);
- duration;
- key regulatory approvals required (other project-specific approvals may also have been involved, eg in relation to shipwrecks, marine pests or works near infrastructure);
- monitoring program design (an overview is provided to enable program complexity to be recognised);
- consistency with approved (or predicted) environmental impacts;
- comments on the specific project in relation to consistency or otherwise with approvals or impact predictions;
- references for monitoring program information.

Appendix A also contains general details of maintenance dredging projects and associated monitoring programs. These are included for information purposes and do not form part of the statistics referred to in this section or Section 7.0 as many involved limited monitoring considering previous monitoring results in the same location (see Section 7.1).

## 6.2 Monitoring Approaches

A broad variety of approaches have been adopted to monitor dredging and dredged material placement projects in Australia depending on their objective. Monitoring programs have mostly been designed by expert consultants and provided to regulators for their review and approval (see below). Regulators rarely design monitoring programs, although they will often specify key components that must be included

Not all dredging projects may require monitoring. Routine maintenance dredging where the project involves dredges, volumes and techniques that are very similar to previous projects may not require monitoring as the short and long term impacts (or lack of) are well understood.

Many projects since the early 2000s have been required to undertake pre-and post-dredging surveys aimed at assessing the actual impacts of a dredging and dredged material placement project following its completion (ie before and after surveys).

More recently, however, there has been a requirement, especially for large or prolonged projects, to monitor during dredging and dredged material placement using a reactive management program. That is, an approach aimed at detecting potentially stress inducing conditions (generally related to water quality) in time to take management actions to prevent or minimise ecological impacts. This reactive approach seeks to ensure a designated level of environmental protection and involves comparisons to relevant water quality criteria (eg based on ANZECC or local data) or monitoring data on the health of sensitive receptors (eg corals and seagrass).

Reactive monitoring of ecological receptors has become the most common monitoring approach adopted by subtropical and tropical Australian ports for large projects. This approach is often used in conjunction with water quality monitoring as water quality monitoring approaches alone do not provide direct evidence of the impacts (acute or chronic) to sensitive receptors such as corals or seagrass.

More recent dredge monitoring programs have involved a multi-tiered reactive management program commencing with investigative triggers and ramping up to more proactive management responses at higher levels of exceedance. The definition of trigger or threshold values can be complex (see Section 6.3).

Reactive monitoring programs adopted by subtropical and tropical Australian ports during dredging have generally been developed as part of a phased approach, consistent with the NAGD that includes:

- An Environmental Impact Assessment (EIA) phase which focuses on identifying potential impacts and associated processes. This includes reviews of available data/information, plume and sedimentation modelling, and identification of sensitive receptors and predicted zones of impact. Various guidelines (eg GBRMPA Guidelines for Hydrodynamic Numerical Modelling of Dredging in the Great Barrier Reef Marine Park, GBRMPA 2012) and approaches (eg the Western Australia EPA zones of impact approach, WA EPA 2011) may specify the modelling technique to be adopted.
- Development of an Environmental Management Plan (EMP). This includes assessing the sensitivity of the receptors (taking into account their resilience, conservation status etc), selection of monitoring sites (both impact and reference) and establishing trigger values. More recent reactive monitoring programs have incorporated triggers based on site-specific baseline data that may require 12 months data collection to include seasonal variations. In such cases, the definition of threshold values may occur as part of the EIA phase.
- An EMP implementation phase. This involves actual monitoring of dredging, review of the acceptability of threshold values taking into account actual monitoring results and implementation of any necessary management responses.

| Location | Project |
|---|---|
| **QUEENSLAND** | |
| Cairns | Cityport North Marina (2002) |
| Townsville | Eastern Port Development Capital Dredging (1993) |
| Hay Point | Apron and Departure Path Project (2006) |
| | Coal Terminal Expansion Project Phase 3 (2011) |
| Gladstone | Western Basin Dredging and Placement Project (2011-2013) |
| **WESTERN AUSTRALIA** | |
| Port Hedland | South West Creek Tug Boat & Small Vessel Cyclone Mooring Facility (2011) |
| | South West Creek Dredging and Reclamation Project (2012) |
| | Stingray Creek Cyclone Moorings (2012) |
| Cape Lambert | Robe-Cape Lambert (2007) |
| Dampier | Mermaid Sound-Hamersley Iron Parker Point and Dampier Port Bulk Liquids berth (2004) |
| | Mermaid Sound-Hamersley Iron (2007) |
| | Woodside Pluto-Mermaid Sound (2007-2010) |
| Barrow Island | Gorgon (2012) |
| **NORTHERN TERRITORY** | |
| Darwin | East Arm Ichthys (2012-2013) |

Table 6.1: Capital dredging projects associated with subtropical and tropical ports included in this review.

In most cases, the initial phases of monitoring program design have involved hydrodynamic modelling to estimate areas subject to dredging related change (intensities, frequency and duration) in terms of turbidity or suspended sediments. This information was then combined with data on the distribution of environmental resources in the region to define those ecological resources that may be influenced (ie sensitive receptors) and predict the differing degree to which they may be impacted.

Impact predictions rely upon defining threshold values for turbidity or sedimentation above which a level of impact is considered likely and a management action is required.

However, as noted below, defining thresholds for marine communities (eg corals or seagrasses) is difficult. Published information is limited and environmental conditions and potential impact pathways may vary depending upon the specific dredging or placement project. Consequently, thresholds are often developed on a site specific basis taking into account results from previous monitoring programs in similar environmental settings and relevant information from research on species that may be impacted. This may involve defining thresholds for one or several "sentinel" species recognising that there are no generic thresholds that can accurately predict turbidity or sedimentation impacts on all marine communities potentially affected by a dredging or dredge material project.

### 6.3 Defining Sensitive Receptor Trigger or Threshold Values for Management Actions

Monitoring programs associated with port related dredging may involve a broad variety of indicators. These are generally project-specific depending upon the nature of dredging or placement works, impacting processes and the environmental resources (eg seagrass or corals) in potentially impacted areas. Monitoring may include both environmental (sediment chemistry, water quality, flora and fauna) and social (eg recreational use or commercial fishing) indicators.

Detailed monitoring programs in subtropical and tropical ports are most commonly associated with large capital dredging projects (see Section 6.4) given the higher level of environmental risk compared to maintenance dredging projects. These capital projects generally involve clean natural sediments. Some capital projects have contained a proportion of surface sediments with low levels of contamination though these have generally been found, after testing, to be non-toxic (see Section 5.4). Whilst water quality monitoring has been a prerequisite of all recent monitoring programs in subtropical and tropical ports (see Section 7.0), there has been an increasing requirement to monitor corals and seagrasses as these:

- are of high environmental and conservation value;
- are considered to be sensitive to key turbidity and sedimentation impacts;
- have been considered to provide a more direct measure of potential environmental impacts than water quality approaches.

However, defining thresholds for a particular site is difficult as sensitive receptors such as corals and seagrass vary widely in their response to turbidity and sedimentation.

Defining meaningful impact thresholds requires site-specific information on ambient turbidity and sedimentation and on the species composition of coral or seagrass communities potentially influenced (PIANC 2010, Erftemeijer et al 2012).

Threshold definition is particularly difficult for inshore areas where most dredging by subtropical and tropical ports occurs. Benthic communities in such areas are naturally exposed to high and variable background conditions of turbidity and sedimentation and may show high tolerances to increases in turbidity and sedimentation caused by dredging.

Coral reefs with high coral cover and diversity occur in inshore areas where very high levels of turbidity (over 100 NTU) similar to those that could occur immediately adjacent to an operating dredge, can occur naturally as a result of wave-induced resuspension (Browne et al 2012).

Periods of high sedimentation rates (as high as 100 mg/cm2/day) may occur naturally for several days to weeks without any major negative effects (Benson et al 1993) to inshore corals. The durations that corals can survive high sedimentation rates range from <24h for sensitive species to a few weeks (>4 weeks of high sedimentation or >14 days complete burial) for very tolerant species. Thresholds for sedimentation rate in individual coral species range from < 10 mg/cm2/d to > 400 mg/cm2/d (Erftemeijer et al 2012).

At present, known tolerance thresholds are most applicable to seagrass receptors. These may be higher than for corals for sedimentation but lower for turbidity and light related impacts. Some tropical seagrasses can tolerate elevated turbidity levels similar to those resulting from dredging for days or even weeks (Chartrand et al 2012).

Little is known of threshold values for other inshore communities such as macroalgae, soft corals, ascidians, sponges and anemones. Most monitoring programs in subtropical and tropical ports have been founded on the premise that if dredging and placement activities were managed to ensure water quality conditions met required standards, and the health of corals and seagrass was maintained, then other key ecological assets would be protected.

Research to establish site specific thresholds, particularly for subtropical and tropical inshore communities that often naturally experience periodic high levels of turbidity or sedimentation (eg due to cyclones or floods) can be time consuming (years) and expensive. Dredging project schedules may not be sufficiently flexible to allow for such research. The use of locally derived tolerance thresholds is generally only feasible for major, long-term projects. For example, development of a site specific light based trigger value for intertidal seagrass at Gladstone took at least 2-3 years (Chartrand et al 2012).

Consequently, thresholds from similar locations have been "adapted", or a highly sensitive threshold value has been selected (with varying reference to the specific location). This has resulted in a conservative approach being adopted to defining threshold values as part of the design of monitoring programs for most dredging projects over recent years.

### 6.4 Monitoring Program Approval and Conditions

Port related dredging is subject to an extensive range of legislation (see Section 4.0). As previously described, dredging and dredged material placement in many cases has required both commonwealth and state government approval.

Regulators review impact predictions in environmental assessments (see Section 6.2) and, if considered appropriate, specify project approval conditions. Impact predictions are used to assist in defining acceptable levels of environmental change (ie determine a level of environmental impact) and required monitoring sites, parameters and frequency to measure that change.

*Photo courtesy of North Queensland Bulk Ports.*

For most projects requiring approval, the proposed monitoring program has been provided to regulators as part of the EIA phase, or more commonly within an EMP, as part of the permit approval phase following approval of the EIA.

Regulators review the program to ensure it will meet the monitoring program objectives (eg to ensure a level of environmental protection), recommend changes where necessary and, if appropriate, approve its implementation subject to certain conditions.

Monitoring approval conditions specified by regulators vary significantly between projects and states. This review did not include an assessment of specific approval conditions but it was noted that conditions for projects tended to vary considerably between states. The "zones of impact" approach prescribed by the Western Australia Environmental Protection Authority (WA EPA 2011) involves predictive modelling of zones of high impact, moderate impact and influence based on quantitative threshold criteria for the boundary of each zone, and is becoming more frequently adopted.

Specific approval conditions are refined through a process of negotiation between the proponent and the regulator taking into account predictions of environmental impact, associated management strategies and relevant government policy. Negotiations often relate to the nature of modelling used to predict changes to turbidity or sedimentation (eg consideration of specific scenarios such as "worst case") and definition of threshold values which as noted above may be difficult to define.

Monitoring approval conditions typically include a high level of conservatism, given the uncertainties associated with defining threshold values, to ensure a specified level of environmental protection. This has consequences in terms of the nature of monitoring program design (and hence costs) and public perceptions of the potential environmental impacts of the project – see Section 9.0).

> *'Proponents could expect the highest monitoring and management burden in situations where the environmental values are high and where there are high levels of predictive uncertainty'.*
>
> ***Western Australia, EPA, 2011. Environmental Assessment Guideline for Marine Dredging Proposals***

Both commonwealth and state government approvals include reporting conditions that evidence is provided of compliance with environmental management plans, auditing and reporting of non-compliance incidents [eg maintain records relevant to the conditions of approval, report on potential non-compliance within a specified number of business days (generally five), produce annual compliance reports to the regulator and publish the reports on the proponent's website by a specified date].

# 7. RECENT DREDGING MONITORING PROGRAMS – CHARACTERISTICS

This Section describes the nature of the port related dredging projects (e.g. volume, duration) and related monitoring programs in subtropical/tropical Australia.

## 7.1 Scale and Duration of Dredging

### Capital Dredging

The volume of material dredged in the capital dredging projects included in this review ranged from 0.28 Mcum to 25.0 Mcum (Figure 7.1) with most projects involving volumes 3-10 Mcum. The largest project was the Gladstone Western Basin project which involved the dredging of 25 Mcum with excavated material being placed both onshore and at sea.

The duration of capital projects ranged from a few weeks to 2.5 years although most extended for 4-6 months (Figure 7.2). The duration of dredging was primarily linked to the volume to be dredged, the equipment used (ie type and number of dredges) and the nature of material to be excavated (harder material takes longer).

Dredging over these periods would have been undertaken in a variety of locations within the dredging footprint and it would be unusual for a dredge to be confined to the one location for significant periods (ie several months). Most large dredging projects involved mobile TSHDs.

Some dredging projects were undertaken in stages specifically to minimise environmental impacts (eg dredging associated with the Ichthys project in Darwin is occurring primarily in the wet season when turbidity levels are naturally elevated). Many projects were subject to environmental window approval conditions that prevented dredging at specific times as a mechanism to avoid impacts at periods of known environmental sensitivity. For example, dredging is generally not permitted five days prior to the autumn and spring coral spawning events in Western Australia. Environmental windows are also part of dredging approvals in Queensland in relation to corals, turtle nesting and prawn spawning.

### Maintenance Dredging

The volume of material involved, and duration of maintenance dredging, varied depending upon the interval between dredging periods and the distribution of material that required removal to restore channels or berths to designated depths. Maintenance dredging needs vary significantly depending upon weather conditions (eg cyclones) which may affect the rates of sediment accumulation.

Maintenance dredging projects in Queensland were typically undertaken in the dry season to enable removal of sediments that had accumulated in the channel and berths over the wet season

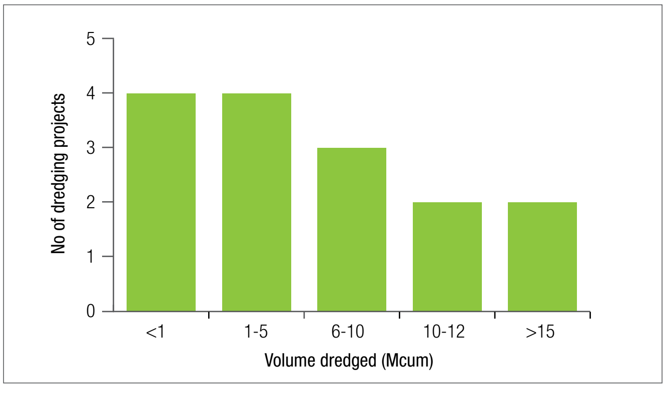



Figure 7.1: Volume of material dredged

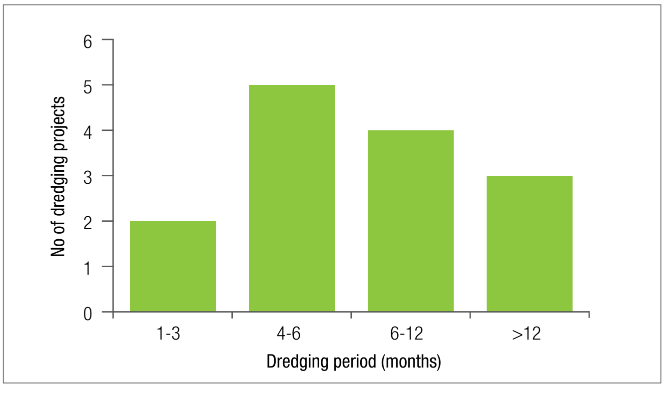



Figure 7.2: Duration of dredging

(ie after cyclone season). Maintenance dredging volumes varied considerably between ports and over time but generally ranged from 300,000 cum each year to 1 Mcum every 5 years depending upon the specific port. Dredging duration was generally 2-4 weeks (SKM 2013b).

Maintenance dredging in Western Australia is much more variable between ports and years compared to Queensland. Volumes are difficult to quantify as development is ongoing and maintenance dredging is often undertaken in conjunction with a capital dredging project. Maintenance dredging can occur any time of year depending upon plant availability and regulatory conditions. Maintenance dredging projects are typically 4-10 weeks in duration and involve volumes of < 500,000 cum. Port Hedland generally undertakes annual maintenance dredging (mainly berths) whilst others (eg Dampier) have minimal maintenance dredging requirements (not being at a river mouth) with maintenance dredging generally being restricted to berths every 3 -5 years (volumes may range up 200-300,000 cum).

On occasions, cyclones and floods resulted in the need to remove larger than typical volumes of material. Failure to rapidly restore channel depths in such situations may prevent vital shipping access to the port (eg for fuel supplies, see Section 3.3) or result in reduced cargo loads for ships to ensure appropriate under keel clearance and ship safety is maintained.

## 7.2 Monitoring Program Design

A broad variety of monitoring designs were adopted for monitoring the various dredging projects and associated relocation of dredged material to land or sea (Appendix A) ranging from:

- extremely complicated designs (for areas where previous information on potential dredging or relocation related impacts and the status of environmental resources was not well known), to
- simple assessments of plumes (in instances where the potential environmental risks were well understood from previous dredging projects).

Most programs were designed on the basis of a site-specific risk assessment that considered the dredging and dredged material placement works and whether associated activities were likely to pose a risk to environmental values of the potentially affected area(s). Most involved sampling at multiple sites that included impact and reference sites and reactive monitoring during dredging and placement works was common. As noted in Section 9.3, risk based approaches to monitoring are considered leading practice.

Various statistical designs were adopted with many using a Multiple Before-After, Control-Impact (MBACI) approach that involves statistical analyses that test for an interaction between predicted impact and (multiple) reference areas across periods of time before and after predicted impacts occur. Studies of DMPAs (eg Cairns) tended to adopt a gradient analysis approach seeking to detect a spatial gradient in, for example, species abundance with effects decreasing with distance away from the DMPA.

Most monitoring programs did not discuss the statistical basis for monitoring program design (eg the power of the statistical analyses to detect differences between periods or locations). A discussion of the issues needing to be considered in monitoring program design for dredging and dredged material placement is provided in SKM (2013c).

## 7.3 Monitoring Parameters

### Water Quality

All of the capital dredging and dredged material placement projects included in this review monitored water quality (Table 7.1). Water quality parameters typically monitored included turbidity, suspended sediment, salinity, pH, temperature and dissolved oxygen.

Sampling approaches included the use of data loggers, telemetry and collection of discrete samples. Telemetry (real time data collection) has been commonly adopted to allow reactive monitoring of dredging operations.

Monitoring programs have not routinely been required to include metal or pesticide levels as toxic sediments are not common in subtropical/tropical Australian ports. Levels of contamination may be present (more so in maintenance dredging projects than capital projects), however, all material must be tested for contaminant levels before dredging as part of the approval process to ensure toxic material is not placed at sea (see Section 4.2). Regulators require monitoring of contaminants if there are any issues of concern. However, monitoring for metal or pesticides has been included in several projects (eg Gladstone Western Basin, Darwin Ichthys Project) apparently in response to local or stakeholder concerns as to perceived potential influences from nearby industry.

Water quality monitoring has not been required for all maintenance dredging projects. Works are generally short term (Section 7.2), involve much smaller volumes than capital dredging projects and, in most ports, information from previous monitoring of maintenance dredging and larger projects in the same location has indicated no unacceptable impacts to nearby sensitive receptors.

Consequently, regulators in Queensland and Western Australia ports often require less frequent and complex water quality monitoring for maintenance dredging than capital works.

| Port | Monitoring parameters | | | | | | |
|---|---|---|---|---|---|---|---|
| | Water Quality | Benthic infauna | Seagrass | Coral | Mangrove | Fish | Other |
| Cairns | ✓ | | ✓ | | | | |
| Townsville | ✓ | | ✓ | ✓ | | | ✓ |
| Hay Point | ✓ | ✓ | ✓ | ✓ | | | ✓ |
| Gladstone | ✓ | | ✓ | ✓ | | ✓ | |
| Port Hedland | ✓ | | | ✓ | ✓ | | |
| Cape Lambert | ✓ | | | ✓ | | | |
| Dampier | ✓ | ✓ | | ✓ | | | |
| Barrow Island | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Darwin | ✓ | | ✓ | ✓ | ✓ | | ✓ |

Table 7.1: Summary of monitoring parameters for capital dredging monitoring programs

### Sensitive Receptors

Subtropical and tropical Australian ports have monitored a broad variety of sensitive receptors including corals, seagrasses, mangroves, macroalgae, benthic infauna, birds, dolphins, dugong, turtles and fish in association with dredging and dredged material placement (Table 7.1).

Many sensitive receptors (and factors affecting them such as sedimentation levels) were included in monitoring programs to inform broader management needs, or to address local community concerns, and were not part of project approval conditions.

Corals and seagrasses have been most commonly monitored in subtropical and tropical ports over recent years, particularly in the GBRMP and the Pilbara (Table 7.1). Monitoring approaches for corals vary but transect approaches and the use of tagged corals to measure coral health has been common. Seagrasses have been routinely monitored in most Queensland ports but less so in the Pilbara as seagrass communities are either not present in areas influenced by dredging or are ephemeral. Seagrass monitoring has generally involved surveys of seagrass distribution and cover and has recently incorporated light based approaches. As noted in Section 6.3, defining the susceptibility of corals or seagrasses to dredging or placement related effects and hence their suitability as indictors of environmental health can be difficult.

Mangroves have been less commonly used for monitoring dredging impacts as they mostly occur in areas that often experience high levels of turbidity and rates of sedimentation and are adapted to such conditions. Mangroves have tolerance limits, however, and may be affected by extremely high rates of sedimentation. This review indicated that mangroves have been monitored to assess dredging related impacts at three locations (Port Hedland, Gorgon and Darwin, Table 7.1).

# 8. RECENT DREDGING MONITORING PROGRAMS – CONSISTENCY WITH APPROVED IMPACTS

This Section provides a high level assessment of the extent to which port related dredging projects in subtropical and tropical Australia have resulted in impacts consistent with approval conditions.

It is not a review of project compliance with specific conditions but rather in the broader sense of whether impacts substantially differed from those anticipated and approved.

## 8.1 Approach

This intent of this review of port related dredging and dredged material placement projects (Appendix A) in northern Australia is to provide a high level assessment of the extent to which environmental impacts associated with specific capital dredging projects were consistent with environmental approval conditions.

In most cases, EIA predictions are used to frame project approval conditions and it is highly unlikely that a level of impact greater than that predicted would be approved. Consistency with approval conditions therefore implies that environmental impact assessment predictions would not have been exceeded.

The review relates to the reported results of monitoring programs associated with both dredging and dredged material placement. These two activities are generally part of the same project and monitoring programs are designed to concurrently assess impacts from both activities. In some instances, however, dredged material was placed ashore and impacts relate only to dredging (see Appendix A).

The reported results of the monitoring programs for each capital dredging project were used to classify the project as having environmental impacts that were:

- greater than approved (in many cases, a defined level of impact was approved, eg < 5% net coral mortality at an impact monitoring site);
- consistent with the level approved (a defined level of impact may have been approved, eg < 5% net coral mortality at an impact monitoring site - more commonly, this category related to a requirement to have no impact to a sensitive receptor);
- less than the level approved (in many cases, a defined level of impact was approved, eg < 5% net coral mortality at an impact monitoring site);
- unable to be determined. In some cases, a major cyclone or other extreme weather event occurred during the period of monitoring compromising the ability of the program to detect impacts using the monitoring design adopted. In others, the statistical limitations of the monitoring program could not confirm whether the small (generally) levels of change were statistically significant.

In some cases, certain parameters were monitored (eg fish) which were not associated with an approval condition that defined a designated level of impact. In such instances, reference is made to the extent to which monitoring reported impacts to be consistent (or otherwise) with those predicted as part of the environmental impact assessment process.

All of the monitoring programs included in this review relate to assessment of short to medium term impacts (ie acute impacts) associated with capital dredging. None aimed to detect longer term chronic impacts. This would require a different monitoring program design given the high natural variability of inshore areas and the difficultly in separating dredge related impacts from other anthropogenic influences or natural changes.

However, many ports undertake long term monitoring of environmental resources that may be affected by port activities (eg Queensland Fisheries/James Cook University have been monitoring seagrass in Queensland ports for more than 7 years, see Rasheed and Taylor, 2008). Such programs are not specifically designed in relation to dredging and dredged material placement issues but include sites that would be influenced by dredging activities in the longer term. Additionally, there a number of longer term regional water quality programs that are designed to assess long term trends in ecosystem health such as the GBRMPA Reef Rescue Marine Monitoring Program.

## 8.2 Results

The review indicated that dredging and dredged material placement projects by subtropical and tropical Australian ports in recent years have been reported to have mostly either met required approval conditions (generally "no impact" to a sensitive receptor) or have resulted in impacts less than those approved or predicted.

Of the 43 monitoring programs reviewed (Appendix A), 62% reported impacts that were consistent with approvals, 21% reported impacts less than approved, 5% reported impacts that were greater than approved and, in 12% of the cases, impacts could not be determined primarily due to extreme weather effects (Figure 8.1).

Two projects, the Gladstone Western Basin and Hay Point Departure Path projects, reported water turbidity impacts significantly greater than approved or predicted. However, associated monitoring of seagrass did not indicate any impacts greater than permitted at Gladstone (Gladstone Ports Corporation 2013). Impacts to corals at Hay Point (Trimarchi and Keane 2007) were much less than approved (< 1% vs 20%) although recruitment of an annual seagrass species appeared to have been prevented for a year (though seagrass cover the following year was higher than prior to dredging).

This result reflects both the comprehensive and conservative nature of the prescribed impact assessment process and the effectiveness of environmental management strategies adopted during dredging and dredge material placement. More detailed aspects of how actual compared to approved impacts are discussed below.

## 8.3 Water Quality

**The review indicated that reported water quality monitoring results for the various dredging projects were consistent with, or less than, approved changes to water quality, with two exceptions. In many instances, water quality was much better than predicted and potential impacts had been overestimated.**

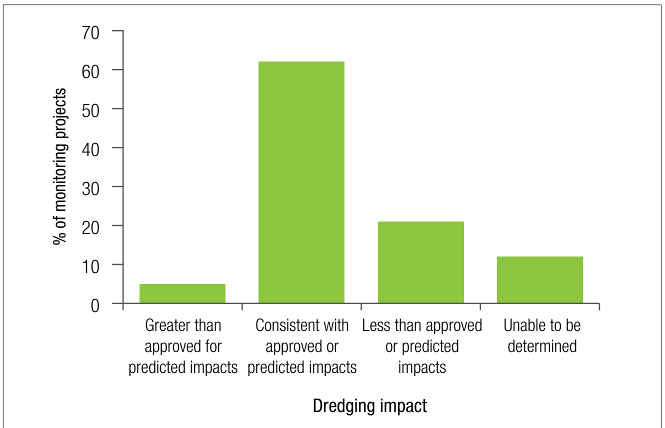



Figure 8.1: Approved or predicted impacts compared to monitored impacts for capital dredging projects

Most dredge monitoring programs by subtropical and tropical ports reported few exceedances of water quality triggers that required management actions, as opposed to exceedances of lower trigger levels requiring investigative action which were more common. Water quality conditions associated with the dredging projects were generally within prescribed criteria and approval conditions were routinely met.

Water quality was often better than predicted by impact assessments used to frame approval conditions as, on many occasions, the hydrodynamic models used overestimated the extent and intensity of turbidity. A review of capital dredging projects in Western Australia (Hanley 2011) noted that dredge plume models routinely overestimated areas of influence due to a conservative approach being adopted in the model design.

Key exceptions where turbidity levels were higher than predicted or approved on several occasions related to the Hay Point Departure Path Project (2006) and the early phases of the Gladstone Western Basin Project (2011).

Modelling for the Hay Point Departure Path project may not have sufficiently accounted for the complex interactions between wind and tides. Turbidity plume intensity and extent differed markedly from that predicted and water quality trigger exceedances occurred on several occasions.

Turbidity levels in Gladstone Harbour periodically increased whilst the Western Basin project was underway. This apparently was the result of a number of factors including the influence of large spring tides, major flood events, unexpected seepage of fine sediments from a reclamation area until a remedial bund sealing operation was complete, hydrodynamic changes, and a major increase in boating traffic (over 20,000 movements per month) with associated wash effects. Changes to dredge management procedures (including frequent stopping of dredging) were required over many months in response to exceedances of water quality triggers that required project management action. Additionally, larger dredge equipment was used to that assumed in the EIS water quality modelling and, whilst this markedly reduced project duration, it may have resulted in turbidity plumes being more extensive on occasions than predicted.

The Gladstone Western Basin Dredging Project was subject to considerable public interest. Concerns were raised regarding the potential for dredging of PASS and/or contaminated sediments to affect water quality resulting in adverse environmental impacts (eg to fish health). The Independent Review of the project (SEWPaC 2013) noted that dredged sediments were compliant with the requirements of the NAGD for ocean disposal, water and sediment quality testing demonstrated that dredged sediments were not contaminated to levels that would lead to toxicological effects and, that dredging and disposal of PASS-containing sediments in the marine environment was unlikely to result in release of significant quantities of heavy metals to the water column. No clear single cause for the fish health issues observed in the Port of Gladstone in 2011 was identified and multiple pressures, in particular extreme weather events and associated overcrowding from fish that moved into the area after overspilling from Awoonga Dam, were considered likely. The Review concluded, in relation to the environmental performance of the project, that "it appears from the evidence available that compliance and enforcement is being managed in an appropriate way, relative to the environmental risks of non-compliance" (SEWPaC 2013).

Impacts to sensitive receptors for both the Hay Point Departure Path and the Gladstone Western Basin Project projects did not exceed those approved (Trimarchi and Keane 2007, Gladstone Ports Corporation 2013 and see below).

In several projects, the investigative water quality action triggers were conservative and were often exceeded due to resuspension of bed material by natural causes (Gladstone Western Basin and Port Hedland projects). In other cases, major water quality trigger exceedances occurred due to weather events (eg cyclones and floods during the Hay Point Coal Terminal Expansion Project and Gladstone Western Basin project). The authors of several monitoring reports noted the difficulties in separating natural from dredge-related turbidity or sedimentation and associated issues in terms of demonstrating project compliance (Trimarchi and Keane 2007, BMA (2011) cited in SKM 2013a, Gladstone Ports Corporation 2013).

Given that all dredging and placement projects undertaken by tropical and subtropical ports included in this review involved non-toxic sediments, it is not surprising that no monitoring reports indicated elevated levels of metals or nutrients that were considered to be of environmental concern. None of the monitoring programs included in this review reported algal blooms that were considered dredging related.

It should be recognised that the water quality monitoring programs included in this review were designed for reactive management to prevent acute ecological impacts during dredging and placement operations. They would be unlikely to detect long term cumulative impacts. As noted previously (Section 8.1), this would require a different monitoring program design involving broad-scale and longer term monitoring. Such a program would be unlikely to provide information on changes in water quality quickly enough to take management actions during a specific dredging project.

### 8.4 Sensitive Receptors

**The review indicated that in almost all cases (with one exception), the reported impact of dredging on monitored sensitive receptors was either consistent with, or less than, those approved. This was the case irrespective of compliance with water quality approvals.**

Monitoring programs involving corals in northern Australian ports reported impacts consistent with approvals (mostly no impact) or less than approved. In many cases, impacts were markedly less than approved. No dredging projects were identified where the impact on corals was greater than approved or predicted.

In some cases (eg Dampier 2004), dredging occurred extremely close to monitored corals (500 m – 1 km) which were influenced by turbidity plumes, yet impacts were not observed (Stoddart and Anstee 2005). In others, long term and complex monitoring indicated no dredging related impacts (eg the Pluto project in Mermaid Sound Dampier had 25 routine coral monitoring sites that were surveyed 61 times over more than two years after dredging started and no individual impact site was shown to suffer coral mortality which could be attributed to dredging).

In some instances, significant elevations in turbidity occurred without apparent adverse effects to monitored corals. Turbidity plume extent and intensity was underestimated for the Hay Point Departure Path dredging, yet coral mortality was < 1% compared to the approved impact of 20% within the approved dredging area. The Port Hedland South West Creek Dredging and Reclamation Project monitoring program reported that turbidity at impact sites reached 15 NTU for periods of up to six weeks, compared to a median of 6 NTU during the baseline period, and yet there were no detectable impacts on coral health at the impact site relative to the reference site (Tennyson 2011).

Whilst there were no reported instances of coral mortality above that allowed, one or two projects noted there may be having been some impacts to community structure in areas close to dredging (within defined Zones of High and Moderate Impact) that may have been due to dredging (eg Gorgon 2012).

A previous review of compliance reports (Hanley 2011) for dredging related coral monitoring in Western Australia for 2003-2010 was unable to find any non-compliance of the permitted levels of impact. This highlights the difficulty in defining impacts and compliance thresholds, particularly for inshore communities routinely subject to naturally high levels of turbidity and sedimentation, as discussed in Section 9.2.

Similarly, adverse impacts to seagrass as a result of dredging were rarely reported and most impacts were consistent with or less than those approved.

This absence of observed impacts to seagrasses may be because some seagrasses species common in inshore areas have limitations as sensitive receptors as they can tolerate turbidity and sedimentation increases for days or weeks at a time (Chartrand et al 2012). Dredging rarely results in extended periods of light reduction at a specific location as turbidity plumes are typically transient and large

TSH dredges are mobile. This was presumably a factor associated with the Gladstone Western Basin Project where, although turbidity management triggers were exceeded, monitored light conditions at seagrass beds remained above trigger values throughout the project and no dredging related impacts to seagrass were recorded.

The Hay Point Departure Path project in 2006 was the only dredging or dredged material placement project undertaken by subtropical or tropical ports that reported potential dredge related turbidity or sedimentation impacts to seagrass. Dredging may have prevented the normal seasonal recruitment of a deep water seagrass species for one year. The species (Halophila spp.) is a pioneering transient species and predicting impacts to such communities is difficult. It is noteworthy that recruitment occurred the following year with higher levels of cover than before dredging (Chartrand et al 2008).

The few projects that have included monitoring of mangroves did not indicate any adverse effects to mangroves. In most cases, impacts were not expected as mangroves have a high tolerance to sedimentation and extremely high levels are required to cause impacts. However, the Ichthys project in Darwin predicted levels of sedimentation that could adversely affect mangroves. Monitoring indicated that expected rates of sedimentation had not occurred (monitoring is still in progress) and no detrimental effects have been recorded.

The review also indicated that monitoring of other sensitive receptors such as fish, prawns and macroalgae did not indicate any exceedances of allowed (or predicted) impacts that could be related to dredging or at-sea placement activities. To some extent, this may relate to the highly variable nature of communities such as fish and the limited statistical robustness of some of the associated monitoring programs.

Several monitoring programs (eg Hay Point Coal Terminal Expansion Project 2010-2011) were compromised by extreme weather events such as cyclones or floods during the dredging project which lead to the widespread loss of seagrass, bleaching or destruction of coral and damage to mangrove communities. Such natural changes resulted in impacts to the monitored communities far greater than associated with dredging and prevented the definition of dredging related effects.

### 8.5 Overview

**This review has indicated that the monitored environmental impacts of dredging and dredged material placement at sea over recent years in subtropical/tropical Australia ports were within the level of those approved or predicted with two exceptions.**

Exceptions related to the Hay Point Departure Path project (where inadequate predictive dispersion modelling occurred) and the Gladstone Western Basin Project (where turbidity was high during dredging works probably because of a variety of factors including the influence of large tides, major floods, high levels of boating traffic, larger dredges being used than assumed in the EIS and leakages from a reclamation bund wall early in the project due to engineering design failures).

No dredging or placement related impacts were recorded to monitored sensitive receptors (seagrasses) at Gladstone whilst it is probable that the normal seasonal recruitment of a deep water seagrass species was prevented for one year at Hay Point (with higher than pre-dredging seagrass cover recorded the following year).

# 9. RECENT DREDGING MONITORING PROGRAMS – MANAGEMENT IMPLICATIONS

This Section provides a brief review of the management implications arising from the review of monitoring programs associated with recent dredging and dredged material placement projects undertaken in subtropical and tropical Australian ports.

Environmental monitoring of dredging and dredged material placement projects is vital for overall management of potential environmental impacts, stakeholder transparency and improved environmental management of dredging activities in future years.

Many projects are conducted in areas of high conservation value and effective monitoring and management of potential impacts must occur to ensure those values are not diminished.

Monitoring allows the accuracy of environmental predictions to be assessed and hence the effectiveness of the environmental impact and management processes. Monitoring dredging and dredged material placement provides information not only for regulators but also for the proponent, contractor, affected stakeholders and the general public.

This review of recent monitoring studies provides valuable information for managers to address many of the issues raised by stakeholders with the environmental performance of port related dredging. The review indicated that, with the exception of two projects, recent port related dredging and dredge material placement projects in northern Australia:

- have not resulted in reported environmental impacts greater than those approved by the government regulatory agencies; and
- in many instances, have led to impacts much less than approved or predicted.

Those exceptions (Hay Point Departure Path and the Gladstone Western Basin projects) could have, at least partially, been avoided through improved modelling impact assessment and project design and management. This aspect of modelling is being continuously improved.

## 9.1 Public Perceptions of Dredging

Little information is available for the public in relation to dredging or dredged material placement and associated impacts in areas of subtropical and tropical Australia. Most information provided relates to individual dredging projects or projects conducted in historically more developed southern regions of Australia where different issues (eg higher levels of contamination) may be involved.

Impact assessments such as EIAs for dredging projects, especially major projects, are provided to a broad range of stakeholders and/or made publically available (eg on specified websites). Public display of information and consultation with stakeholders is often a key requirement of the approval process.

However, this information is often technical in nature and relates to the specific project only. Information to address broader public perceptions of dredging and the extent to which dredging projects in northern Australia have met the required level of environmental protection is not easily accessible.

Most approvals for dredging projects contain conditions in relation to compliance reporting and audit (see Section 6.4). However, these maybe complex and not readily understood by stakeholders and consequently perceptions of non-compliance associated with dredging projects in areas of conservation value are common. Implementation of the recommendation of the Independent Review of the Port of Gladstone (SEWPaC 2013) that *"all confirmed cases of non-compliance be publicly announced on both the department's and proponent's website along with details of any remedial actions"* would assist in this regard.

Assumptions of widespread and unintended impacts, particularly to areas of conservation value, are often based on historic dredging projects and do not appreciate recent improvements to dredge management practices globally and the results of recent dredging projects in northern Australia. For example, improved environmental management of dredging in Singapore has seen changes from a situation where 60% of the coral reefs around Singapore were destroyed between the 1970s and 1990s due to reclamation and dredging activities (Hilton and Manning 1995) whereas since 2006, 9 million m3 of material has been dredged and no detectable impacts have been recorded more than 300 metres outside the direct impact zone (Doorn-Groen 2007). Recent dredging projects in northern Australia have also performed well although many members of the public would not be aware that almost all of these dredging projects have resulted in impacts well within approved levels and that, with one exception, significant unanticipated impacts on organisms have not been recorded.

Similarly, concerns are often raised in relation to dredging and at-sea placement of contaminated sediments and the associated potential for impacts to environmental resources (eg the Great Barrier Reef).

In many southern Australian and overseas ports, contamination of sediments is a major issue reflecting the region's historical and ongoing industrial development. Large volumes of contaminated material may be involved in major capital projects and can be a significant environmental risk requiring special management techniques. Additionally, disposal of contaminated (and probably toxic) sediments at sea has occurred historically (pre-1990) in Australian waters. However, this practice occurred prior to the introduction of the current detailed sediment quality assessment process, the NAGD, which ensures toxic material is not placed at sea.

There is an assumption that similar legacy contamination issues associated with southern ports and historic offshore disposal of toxic materials are relevant to future dredging proposed by subtropical and tropical ports in northern Australia. However, significant manufacturing industries are not present in most subtropical or tropical Australian ports or, if present, have been developed in recent years and have been subject to modern pollutant discharge requirements. Sediment contamination in northern Australian ports most commonly relates to catchment runoff and port related activities or industries (eg spillage or runoff from wharves, or slipway operations). A few northern ports may have historically had industries such as tanneries or metal works that occurred in their catchment. Contaminated sediments, whilst present in many subtropical or tropical Australian ports, are typically associated with localised inner port areas (eg berths), generally involve low volumes at a much lower contaminant level than in older southern ports and are rarely present at toxic levels. Port managers adopt specific management techniques to excavate and relocate the comparatively minor volumes of contaminated sediments and ensure all material is tested according to the NAGD before dredging and, if appropriate, placement of material at sea. Sediment identified as toxic is never disposed of at sea, always to land.

There is a need for stakeholders to routinely receive more transparent and understandable information on the impacts of dredging or at-sea placement projects undertaken in subtropical or tropical Australian ports.

The Independent Review of the Port of Gladstone (SEWPaC 2013) noted how there was limited reporting of the at-sea placement permitting process and that this contributed to mistrust amongst community and non-government organisations. The Review noted the benefits of an improved information management system to ensure at-sea placement permitting information was more readily accessible. It would be advantageous if this information management system also included the results of required monitoring programs. Increased information availability for both of these processes could help to improve public confidence that dredging projects are managed effectively and have not resulted in unanticipated impacts.

Improved awareness of both the impact assessment process and the actual nature and extent of dredging and at-sea placement impacts would permit a more informed and factually based discussion on future dredging projects.

### 9.2 Monitoring Program Design

Most dredging and dredged material placement monitoring programs associated with subtropical and tropical ports reviewed were complex and conservative. This reflects both:

- the short development history of many subtropical or tropical Australian ports (the port may not have been subject to recent major dredging works that could serve as an information source for evaluating impacts and designing a monitoring program for new dredging operations); and
- the high value of environmental resources in northern Australia that may occur close to dredging activities (hence the need to ensure these resources are not unintentionally adversely affected).

Whilst a conservative approach is appropriate, few stakeholders recognise that impacts have been commonly, and often intentionally, overestimated. Overestimation of impacts apparently occurs because:

- There is a need to ensure that approval conditions provide a margin of error or conservatism. Proponents and regulators often strive to reduce the risk of actual impacts exceeding the approved impacts and hence tend to adopt a conservative approach to avoid non-compliance.

- A conservative modelling approach is often utilised in the impact assessment process. There are few standards or accepted values for some of the parameters used in hydrodynamic modelling approaches and, consequently, various and often conservative approaches are adopted that do not sufficiently reflect actual conditions. This aspect of modelling is improving based upon recent dredging project experiences and regulatory requirements for model validation and expert peer review (eg GBRMPA Guidelines for Hydrodynamic Numerical Modelling of Dredging in the Great Barrier Reef Marine Park).
- Ecological impact thresholds can be difficult to establish (see Section 6.3). Port related dredging and dredge material placement mostly occurs in inshore areas where communities generally experience, at least infrequently, highly turbid conditions. Such communities may have a high tolerance to short term elevations of turbidity and sedimentation rates and the predicted spatial extent of potential impacts may be greater than may occur in reality.
- Mapping techniques are often insufficiently accurate for sensitive receptors. Approval conditions are often based upon prescribed allowable areas of habitat loss. However, mapping techniques inevitably incorporate errors associated with measurement and analysis. Such errors may be significant with some techniques (eg aerial photography or satellite imagery).

However, this review also noted that for two port dredging projects in northern Australia, turbidity impacts were underestimated (see Section 8.0). One project related to inaccurate predictive hydrodynamic modelling, however, the more recent requirement for improved model validation and peer review adopted by regulatory agencies should be noted. Model accuracy is vital in ensuring effective monitoring program design and needs to be a priority in impact assessment. The other project potentially involved an engineering design failure and different dredge equipment being used to that envisaged in the project EIS, although the extent to which these aspects contributed to the underestimation of turbidity impacts is unclear as others factors significantly influencing water quality such as record floods and massive increases in boating traffic were involved.

### 9.3 Monitoring Costs

The need to consider risk and associated monitoring program design requirements on a site specific basis is important. Many of the monitoring programs included in this review were designed using a risk-based approach.

However, several ports responding to this review reported a general trend of specific approval and monitoring conditions becoming more extensive and involving a greater number of monitoring parameters over time with associated cost increases. In some cases, monitoring conditions associated with a particular project have apparently been adopted for a different project as “continual improvement” without regard to assessing the value or management benefit of that condition to reducing environmental risks.

Monitoring program requirements need to be based upon project specific risk assessments. This requires a site-specific assessment to identify environmental values, identify the risks to those values and then use this information to identify appropriate dredging methods, mitigation techniques and monitoring requirements.

Risk based approaches to monitoring and managing dredging projects are increasingly being considered best practice (GHD 2013). This approach has been the subject of considerable research (PIANC 2006, Palermo et al 2008) and is also referred to in the NAGD as a potential approach to identify and manage impacts.

Overestimation of impacts will result in unnecessary monitoring with more sites, increased monitoring frequency and potentially additional monitoring parameters. These all result in increased cost. This is important as dredge related monitoring, especially in northern Australia, is expensive as field costs can be high to obtain samples, conduct surveys and maintain equipment. Weather conditions can limit access and standby costs are typically required. Workplace health and safety issues are considerable in marine environments especially for remote areas in northern Australia.

Underestimation of impacts may result in insufficient monitoring during dredging reducing opportunities to identify the need for necessary reactive management actions and must be avoided considering the often high conservation value of nearby environmental resources. Unintended impacts to areas of conservation value can not only have direct conservation losses but also indirect economic consequences (eg fishing and tourism impacts). This review indicated that this has rarely occurred with recent dredging or at-sea placement projects.

### 9.4 Environmental Offsets

Environmental offsets are now commonly required to compensate for predicted dredging related impacts. These are generally negotiated as part of project approval and, in most cases, need to be committed or implemented before the dredging or placement project occurs.

If potential impacts are overestimated then greater offsets will be required. This has direct cost implications for the dredging proponent, the port and ultimately the community as offset costs are incorporated in the cost of trade through the port (eg port charges).

### 9.5 Improved Understanding of Impact Processes

An effective and efficient monitoring program should result in a better understanding of impacting processes and provide useful data for future management. Monitoring design needs to aim to collect data that could assist in determining the actual impacts resulting from dredging and at-sea placement which could then be used to inform stakeholders and enable better definition of the tolerance of sensitive receptors.

### 9.6 Key Findings for Future Management

This review identified a number of key issues that need to be considered in association with future management of port related dredging and dredge material placement in subtropical/tropical Australian ports.

- Rigorous site selection and master planning endeavours should be encouraged as part of port infrastructure planning to ensure relevant environmental values and potentially impacting processes are properly understood. Consideration of such aspects early in the design phase may avoid or minimise the need for capital or maintenance dredging.
- Environmental monitoring of dredging and dredged material placement projects, particularly near areas of high conservation value, is vital for overall management of potential environmental impacts, stakeholder transparency and improved environmental management of dredging activities in future years.
- A risk based approach based on scientific assessment is essential to the approvals process for dredging and at-sea placement projects and defining potential environmental monitoring requirements. This needs to take into account the results of previous monitoring programs undertaken in similar environmental settings. An overly conservative approach to monitoring results in additional costs (which may be significant) and the potential for missed opportunities to collect data that can better inform definition of threshold values and dredging related impact processes. Underestimation of impacts also needs to be avoided considering the need to protect high value environmental resources near northern Australian ports.
- There is a need to communicate to stakeholders that toxic sediments are very rarely associated with port related dredging in northern Australian and that a detailed assessment process (defined in the NAGD) is required to assess contamination levels and associated environmental risks prior to any dredging or at-sea placement of dredged material.
- There are benefits in broadly communicating to stakeholders that recent dredging and dredged material placement projects in northern Australia have not resulted in impacts to environmental resources of high conservation value and that monitored environmental impacts have been almost entirely consistent with or less than those approved by regulatory agencies.
- Improved stakeholder awareness of both the impact assessment process and the actual extent of impacts from recent dredging/at-sea placement projects would improve public confidence in the environmental management of port related dredging enabling a more informed and factually based discussion on future projects.


*Photo courtesy of the Port of Townsville.*

# 10. REVIEW OF ENVIRONMENTAL RECOVERY FROM DREDGED MATERIAL PLACEMENT

This Section provides an overview of the few studies that have investigated environmental recovery processes at a subtropical/tropical port Australian DMPAs. These studies provide an indication of the time that a DMPA takes to recover from placement of dredged material and the longer term environmental status of the DMPA.

DMPAs are an essential part of port infrastructure and most subtropical/tropical ports have a designated offshore DMPA where dredged material is relocated.

A key consideration in the approval process for using, or establishing, a DMPA is the recognition that the designated area will be unavoidably impacted by the placement of dredged material. However, the environmental consequences of this impact will depend upon:

- the area of the DMPA;
- the environmental values of the area before use;
- whether the material disperses from the DMPA and associated impacts to adjacent areas;
- the rate of recovery of the affected area; and
- whether, following recovery, the recolonised area differs from nearby areas.

DMPAs occupy a relatively small area of the coast in northern Australia (generally individual DMPAs are a few km2 and are specifically located to minimise potential environmental and social impacts, see Section 3.4). The GBR Strategic Assessment notes that DMPAs for Queensland ports occupy < 0.02% of the GBRMP (GBRMPA 2013).

A complex environmental impact assessment process is required to obtain an approval to place material at sea (see Section 4.0) in a designated DMPA. This assessment process takes into account the potential for environmental and social impacts (eg at the defined placement area and to nearby areas from dispersed material).

Monitoring the environmental impacts of dispersion of material from a DMPA is generally included as part of the monitoring program initiated for the entire dredging project. As noted in Section 8.0, monitoring programs associated with recent dredging and dredge material placement projects in subtropical and tropical Australia did not indicate unapproved or unpredicted turbidity or sedimentation related impacts from dredged material placement (although two projects exceeded approved water quality triggers due to dredging operations).

Few studies in subtropical and tropical Australia have assessed recovery of DMPAs to assist in assessing their longer-term environmental status although studies have been undertaken at Queensland ports (Cairns, Townsville and Hay Point; Motta 2000, Neil et al. 2003, Chartrand et al 2008, WorleyParsons, 2009). All have focussed on soft bottom benthos because new DMPAs are not located where seagrass or corals occur and ongoing use of a DMPA prevents their long term presence.

The Queensland studies of recovery at DMPAs all found similar results in that:

- seabed fauna (eg polychaetes, bivalves, and anemones) in the DMPA were initially adversely affected due to burial and smothering (reduced abundance and diversity);
- community recovery (increased biomass and diversity) began within a short time (< 2 months) after the completion of placement activities;
- placement of dredged material may have provided a fresh source of nutrients for organisms at the site with some species rapidly colonising the new material;
- surveys undertaken 3-11 months after placement activities (port and year dependent) indicated the benthic community of the DMPA had recovered and was not substantially different from adjacent or reference locations (some minor changes in community structure occurred but were restricted to close to the DMPA);

- there was some evidence of opportunistic rapid colonisers (mainly polychaetes) being more common at the DMPA than at reference sites.

Table 10.1 compares the results of recovery times at subtropical/tropical Australian ports and includes some reported from overseas. All studies relate to macrobenthos recovery times associated with placement of fine grained sediments from dredging in shallow coastal areas in subtropical/tropical locations. These studies include different volumes being placed at different times of the year at different spatial scales. A detailed review of recovery processes associated with placement of dredged material is provided by Bolam and Rees (2003).

Surveys undertaken following three annual dredging campaigns indicated the benthic community of the Port of Townsville DMPA was not different from adjacent and reference locations 3 -11 months (year dependent) after placement and that that placement of dredged material did not have a long-term impact on benthic communities of the DMPA (Motta 2000). Studies of the Cairns DMPA (Neil et al 2003, WorleyParsons 2009) examining recovery aspects noted that there was no clear pattern of difference between benthic assemblages at the DMPA regularly used for maintenance dredging material and adjacent areas in terms of abundance, richness and diversity and that benthic macroinvertebrate assemblages were generally similar throughout the study area.

Research (eg Bolam and Rees 2003) indicates that whilst impacts and recovery processes are site specific, recovery from dredged material placement may occur within months in shallow wave influenced or estuarine environments. Key criteria for rapid recovery were reported to relate to:

- the material placed on the DMPA being of a similar grain size to that of the DMPA itself (this is the case for Cairns and Townsville DMPAs and at some other Queensland ports but may not be so for all northern ports);
- contaminants not being present at levels of concern; and
- the DMPA being in a high energy region that seasonally experiences significant disturbances such as from cyclones/storms. Recolonisation in such regions was rapid apparently because communities in such high energy areas were adapted to high rates of environmental stress associated with frequent sediment erosion and deposition.

Recovery may be much slower (if at all) if markedly different grain sized material is placed at the DMPA (Borja et al 2010) and the area is a stable deep water area where communities are not subject to frequent natural disturbance. Recovery rates may also be much longer in temperate climates where biological process may operate at longer time scales. Studies of recovery in coastal waters of the United Kingdom (Bolam et al 2006) found that recovery rates were site specific but could often take several years and that the establishing community was often different to the original community.

Overall, the limited results of monitoring inshore DMPAs used by subtropical and tropical Australian ports for maintenance dredging (no studies could be located in relation to capital dredging) are consistent with findings from overseas assessments. These indicate that even though DMPAs are designated as impact areas, impacts from dredged material placement in many cases are likely to be short term and recovery of the area could be expected to occur within 12 months.

*Photo courtesy of Ports North.*

| Recovery Period | Habitat Characteristics | Location |
|---|---|---|
| 3-11 months | Shallow wave influenced, fine sediments. | Townsville, Queensland, Australia[1] |
| 5 months | Estuarine, shallow (1-3m). | Atchafalaya River, Louisiana, USA[2] |
| 5 months | Shallow estuary subject to floods. | Louisiana, USA[3] |
| 6 months | Estuarine. | North Edisto River, South Carolina, USA[2] |
| 6-12 months | Shallow wave influenced, fine sediments | Hay Point, Queensland[4] |
| 8-16 months | Shallow, stable | Tampa Bay, Florida, USA[5] |
| 11 months | Shallow, wave exposed | Delaware Bay, Delaware, USA[2] |

References: 1 = Motta (2000); 2= Bolam and Rees (2003); 3 = Flemer et. al. (1997) in Vic EPA (2001); 4= Chartrand et al (2008); 5= Amson (1988).

Table 10.1: Benthic invertebrate recovery rates following one-off placement of fine grained dredged material in subtropical and tropical areas

# 11. KEY FINDINGS

This Section provides an overview of the key findings with regard to the need for and regulation of port dredging related in subtropical and tropical areas of Australia. It includes a description of the nature of monitoring associated with dredging and how monitored impacts compared to those approved.

### The Importance of Port Channels and Associated Dredging

- Australia, as an island-trading nation with a large commercial shipping task, is reliant on seaports for linkages to global markets.
- Shipping remains the most environmentally efficient form of bulk transportation.
- Australian ports are infrastructure nodes of national and international importance.
- Efficient and safe port operations rely on the total combination of waterside (eg channels, berths) and landside infrastructure.
- Dredging, either capital and/or maintenance, is an essential part of port operations in Australia and globally to facilitate safe and efficient waterside access.
- The spatial form of shipping channels at Australian ports varies widely and depends largely on the local environmental conditions and operational needs.
- Ports in northern areas of Australia are being developed or expanded to meet the growing mineral resource export trade and to service the communities and industries in the region as well as Australia's defence interests and the growing cruise ship industry.
- Increasingly larger commercial vessels are calling at Australian ports. A substantial increase in the size of container ships and bulk vessels associated with the mineral resource trade has occurred over the past few decades to achieve better economies of scale.
- This has resulted in the need to enlarge or deepen waterside infrastructure (channels, berth pockets, swing basins etc) in order to provide adequate access to ports.
- Capital dredging at Australian ports is undertaken to facilitate port growth, enable operational efficiency and ensure ship safety.
- Maintenance dredging is required to maintain designated channel and berth depths to ensure the continued safe and efficient passage for commercial vessels.

### Regulations

- Dredging and dredged material placement is highly regulated.
- All dredging in Australia must be consistent with the requirements of an international agreement known as the Protocol to the London Convention (previously known as the *Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972*).
- Australia, using a multi-level assessment approach via the *Environment and Biodiversity Conservation Act*, the *Sea Dumping Act* and *National Assessment Guidelines for Dredging* has strong environmental and governance control around dredging works at Australian ports.
- Australia's *National Assessment Guidelines for Dredging* are recognised internationally as industry-leading guidelines.
- Toxic dredged material is not permitted to be placed at sea.
- The continued focus on strong governance and appropriately administered regulatory systems for dredging is critical and forms a fundamental part of effective management of the Australian coastal environment.

### Dredging Approval Processes

- Dredging and dredged material placement activities require site specific environmental impact assessments as part of a designated approval process.
- Detailed assessments according to the *National Assessment Guidelines for Dredging* are required to support applications to place material at sea. These include site specific investigations to ensure toxic material is not placed at sea and that all alternatives to at-sea placement (eg beneficial re-use or land based disposal) have been comprehensively evaluated.
- Regulators review impact predictions in environmental assessments and, if considered appropriate, specify project approval conditions and acceptable levels of environmental impact.

- Both commonwealth and state government approvals include conditions that define monitoring program attributes (eg locations, parameters and frequency) and require provision of evidence of compliance with environmental management plans, auditing and reporting of non-compliance incidents.

### The Need For Monitoring

- Environmental monitoring of dredging and dredged material placement projects is vital for overall management of potential environmental impacts, stakeholder transparency and improved environmental management of dredging activities in future years.
- Many projects are conducted in areas of high conservation value and effective monitoring and management of potential impacts must occur to ensure those values are not diminished.
- In accordance with strict regulations, monitoring is required for all major capital dredging projects but may not be required on every occasion for routine maintenance dredging works.
- Monitoring programs are required to assess and manage impacts to ensure a designated level of protection for specified environmental resources.

### Monitoring Program Design

- Most programs have been designed on the basis of a site-specific risk assessment consistent with leading environmental practice.
- Monitoring programs are provided to regulators for review (eg to ensure a level of environmental protection) and, if appropriate, approval.
- Regulators approve monitoring program design as part of approval conditions.
- Monitoring may involve before, during and after dredging (or dredged material placement) surveys to assess and manage potential impacts.
- Reactive monitoring during dredging and dredged material placement is recently become common. This involves definition of triggers (generally related to water quality) that, if exceeded during dredging, require a management response (eg halt or a change to dredging activities) to avoid impacts on specified ecological receptors.

### The Scale and Duration of Dredging Projects

- Most port related capital projects undertaken in recent years in subtropical and tropical ports involved dredge volumes of 3-10 Mcum and dredging durations of 3-6 months. The largest project was the Gladstone Western Basin project which involved the dredging of 25 Mcum and took 28 months with excavated material being placed both onshore and at sea.
- Maintenance dredging projects, involving removal of sediments that have accumulated in the channel and berths, typically relate to much smaller volumes (100,000s cum), occur routinely (every 1-3 years) and generally take 2-4 weeks.
- Many dredging projects in subtropical and tropical ports have been subject to environmental window approval conditions that prevented dredging at specific times of environmental sensitivity (eg turtle nesting, coral spawning) to minimise potential impacts.

### The Nature of Monitoring

- Monitoring programs in this review all involved water quality (turbidity, suspended sediment, salinity, pH, temperature and dissolved oxygen).
- Sampling techniques have included the use of data loggers, telemetry and collection of discrete samples. Telemetry (real time data collection) has been commonly adopted to allow reactive monitoring of dredging operations.
- There is an increasing trend of monitoring sensitive receptors such as corals and seagrasses.
- Other sensitive receptors less commonly monitored by subtropical and tropical ports include mangroves, macroalgae, benthic infauna, birds, dolphins, dugong, turtles and fish.
- Not all monitoring undertaken has been required by regulatory agencies. Many programs were initiated by ports to inform broader management needs or to address local community concerns.
- Most monitoring programs associated with major capital dredging projects involve site-specific baseline data collection that may require 12 months of data collection to include seasonal variations for impact assessment and management trigger development.

### Impact Predictions for Dredging Projects

- An appropriately conservative approach is adopted for impact predictions for dredging and dredged material placement by subtropical and tropical ports considering that areas of high conservation value commonly occur nearby.
- Hydrodynamic water quality models often adopt a conservative approach and overestimate potential impacts.
- The definition of thresholds for sensitive receptors, such as corals and seagrass, is particularly difficult for inshore areas where most dredging by subtropical and tropical ports occurs. Benthic communities in such areas are naturally exposed to high and variable background conditions of turbidity and sedimentation and may show high tolerances to short term increases in turbidity and sedimentation caused by dredging.

- A conservative approach that is typically adopted in determining site specific thresholds can be time consuming (years), expensive and development project schedules may not be sufficiently flexible to allow for such research. Results from similar locations have been adapted or a highly sensitive threshold value has been selected (with varying reference to the specific location).
- The ability to accurately predict environmental impacts associated with dredging and dredged material placement impacts is improving as the accuracy of hydrodynamic modelling is improving, models are better validated and the findings of recent dredging projects enable the sensitivity or tolerance limits of sensitive receptors (eg corals or seagrasses) to be better understood.

### Consistency with Approved or Predicted Impacts

- The regulatory impact assessment process prescribed to assess impacts associated with dredging and dredge material placement is conservative and the effectiveness of environmental management strategies adopted during works is comprehensive.
- Dredge and at-sea placement monitoring programs undertaken by subtropical and tropical ports included in this review routinely meet approval conditions for water quality and only two projects exceeded specified water quality triggers requiring management actions.
- Reported impacts to designated sensitive receptors (eg corals or seagrasses) associated with dredging and dredged material placement projects by subtropical and tropical ports included in this review have mostly been consistent with (generally a prediction of no impact), or less than, those approved or predicted by impact assessments.
- Only one project reported adverse impacts to monitored sensitive receptors (potential failure of annual seagrass recruitment for one year with seagrass cover the following year exceeding pre-dredging levels).
- Extreme weather events (eg cyclones) during some port projects resulted in large natural changes greater than those related to dredging or at-sea placement activities compromising the ability of monitoring programs to detect dredging project related impacts.

### Recovery Processes and the Environmental Status of Dredged Material Placement Areas

- This review did not identify any recent dredging projects by subtropical and tropical Australian ports where use of a DMPA had been reported to have unapproved adverse impacts associated with dredged material dispersion.
- The few studies undertaken by subtropical and tropical ports related specifically to maintenance dredging material and indicated DMPA benthic community recovery following dredged material placement was rapid (within 6-12 months).
- Rapid recovery at these sites apparently occurred because the material placed at the DMPA was of a similar particle size to that of the DMPA itself, contaminants were not present at levels of concern, and the DMPAs were in high energy areas that seasonally experience significant disturbances from cyclones or storms.

*Photo courtesy of Darwin Port Corporation.*

- These findings are consistent with overseas experiences where DMPAs in high energy areas (ie subject to seasonal storms, cyclones or floods) rapidly recover as communities in the region are adapted to high rates of sediment erosion and deposition.

### Management Implications

- Comprehensive site selection assessments and master planning are critical elements of port infrastructure planning to ensure relevant environmental values and potentially impacting processes are properly understood. Consideration of such aspects early in the design phase may avoid or minimise the need for capital or maintenance dredging.
- Dredging and at-sea placement of dredge material in northern ports over recent years has been subject to environmental monitoring designed to ensure a designated level of environmental protection, especially with any nearby areas of high conservation value (all major capital works are monitored although some maintenance works may not be as impacts, or lack of, are well understood).
- A risk based approach based on scientific assessment is essential to the approvals process for dredging and dredged material placement projects and defining potential environmental monitoring requirements. This needs to take into account the results of previous monitoring programs undertaken in similar environmental settings.
- Little information is available or readily accessible for the public for dredging or dredged material placement and associated impacts in areas of subtropical and tropical Australia. Most information provided is technical, relates to individual dredging projects or projects conducted in historically more developed southern regions of Australia or overseas where different issues may be involved (eg much higher levels of contamination).
- Assumptions by some stakeholders of widespread and unintended impacts to areas of high conservation value, such as the Great Barrier Reef, are not supported by the results from extensive monitoring of many recent dredging projects in northern Australia undertaken in similar environmental settings.
- Monitoring programs associated with recent dredging and dredged material placement projects in northern Australia examined in this review almost all showed reported impacts consistent with, or less than, than those approved or predicted. Two exceptions were noted where water turbidity impacts were greater and one of these is likely to have affected a monitored sensitive receptor (seagrass). Both could have, at least partially, been avoided through improved modelling impact assessment or project design and management.
- There are benefits in broadly communicating to stakeholders that recent dredging and dredged material placement projects in northern Australia have not resulted in unapproved impacts to environmental resources of high conservation value and that impacts have been consistent with those approved by regulatory agencies.
- The Independent Review of the Port of Gladstone (SEWPaC 2013) noted the benefits of an improved information management system to ensure at-sea placement permitting information was more readily accessible to community and non-government organisations. It would be advantageous if this system also included the results of required monitoring programs.
- Improved stakeholder awareness of both the impact assessment process and the actual extent of impacts from recent dredging and at-sea placement projects would improve public confidence in the environmental management of port related dredging enabling a more informed and factually based discussion on future projects.

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# APPENDIX A – Capital and maintenance dredging projects and monitoring program information for subtropical and tropical Australian ports

*Photo courtesy of the Port of Townsville.*

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| **QUEENSLAND** | | | | | | | |
| **CAPITAL DREDGING PROJECTS** | | | | | | | |
| **Port:** CAIRNS<br><br>**Description:**<br>Cityport North Marina (2002) | 3 | 120,000 cum at sea placement | *Commonwealth*<br>-Environment Protection (Sea Dumping) Act 1981.<br>-Environment Protection and Biodiversity Conservation Act 1999.<br>-Great Barrier Reef Marine Park Act 1975.<br><br>*State*<br>-Integrated Planning Act 1994.<br>-Marine Parks Act 1982<br>- Coastal Protection and Management Act 1995. | *Water quality*<br>Baseline and during dredging. Real time water quality data collection at nearby seagrass meadows. | Impacts consistent with approvals/ predictions. | No exceedance of turbidity triggers. Difficulties separating dredge plume from high natural turbidity during ebb tides. | GHD (2002) |
| **Port:** TOWNSVILLE<br><br>**Description:**<br>Eastern Port Development Capital Dredging (1993) | 4 | 760,000 cum at-sea placement. | *Commonwealth*<br>-Environment Protection (Sea Dumping) Act 1981.<br>-Great Barrier Reef Marine Park Act 1975.<br><br>*State*<br>- Harbours Act 1955<br>- State Development and Public Works Organisation Act 1971 | *Coral*<br>Twice weekly surveys of impact sites and weekly surveys of reference sites during dredging and one post dredging survey of tagged corals.<br><br>Coral photography (video) on transects.<br><br>Impact and reference locations. | Impacts consistent with approvals/ predictions. | Authors report no evidence of significant dredge related mortality. No marked changes to coral composition. Declines in abundance of some soft coral and Favia corals attributable to dredging (these were present in low densities (<6%) prior to dredging). Some coral species were probably close to their turbidity tolerance limits. | Benson et al. (1993) |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| **Port:** TOWNSVILLE<br>**Description:** Eastern Port Development Capital Dredging (1993) | 4 | 760,000 cum at-sea placement | As above. | *Seagrass*<br>Baseline (one survey), during (one survey) and post dredging (one survey – one month).<br><br>Aerial photography, intertidal and diver surveys. | Impacts consistent with approvals/ predictions. | Authors report no evidence of significant dredge related impacts. Seagrass changes variable between sites. Qualitative data. | Goldsworthy (1994)<br><br>Benson et al. (1993) |
| **Port:** TOWNSVILLE<br><br>**Description:** Eastern Port Development Capital Dredging (1993) | 4 | 760,000 cum dredging and at-sea placement | As above. | *Sedimentation*<br>Baseline, during and post dredging surveys.<br>Measurement of suspended sediment concentrations, sediment deposition, and sediment cores. | Impacts consistent with approvals/ predictions. | Authors report no major impacts to suspended sediment concentrations at nearby coral reefs. Sediment concentrations near the DMPA during placement were up to 10 times greater than under non dredging conditions. | Goldsworthy (1994)<br><br>Benson et al. (1993) |
| **Port:** HAY POINT<br><br>**Description:** Apron and Departure Path Project (2006) | 5 | 8.6 Mcum at-sea placement | *Commonwealth*<br>-Environment Protection (Sea Dumping) Act 1981.<br>-Environment Protection and Biodiversity Conservation Act 1999.<br>-Great Barrier Reef Marine Park Act 1975.<br><br>*State*<br>-State Development and Public Works Organisation Act 1971.<br>-Integrated Planning Act 1994.<br>-Environmental | *Coral*<br>Baseline (one survey), during (two surveys) and post dredging (two surveys).<br><br>Sedimentation on corals and coral condition at impact and reference sites. | Impacts less than approved/ predicted. | Coral mortality at impact location much lower (<1%) than approved (20%). Dredging and dredge material placement plumes were more extensive and plume turbidity was greater than approved and may have influenced reference sites.<br><br>Increases in coral cover at both reference and impacts sites following completion of dredging. | Trimarchi and Kane (2007)<br><br>GHD (2006) |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| | | | Protection Act 1994.<br>-Fisheries Act 1994.<br>-Coastal Protection and Management Act 1995. | | | | |
| **Port:** HAY POINT<br><br>**Description:**<br>Apron and Departure Path Project (2006) | 5 | 8.6 Mcum at-sea placement | As above. | *Water quality*<br>Baseline (one survey), during (two surveys) and post dredging (two surveys). | Impacts greater than approved/ predicted. | Water quality trigger exceedances occurred during and after dredging. Model predictions were acceptable for some areas but not others. | Trimarchi and Keane (2007)<br><br>GHD (2006) |
| **Port:** HAY POINT<br><br>**Description:**<br>Apron and Departure Path Project (2006) | 5 | 8.6 Mcum at-sea placement | As above. | *Fish*<br>Baseline (one survey), during (two surveys) and post dredging (two surveys).<br><br>Fish visual surveys on transects at impact and reference sites. | Impacts consistent with approvals/ predictions. | Authors report no detectable impact of dredging. | Trimarchi and Keane (2007)<br><br>GHD (2006) |
| **Port:** HAY POINT<br><br>**Description:**<br>Apron and Departure Path Project (2006) | 5 | 8.6 Mcum at-sea placement | As above. | *Seagrass*<br>Baseline (three surveys), during (five surveys) and post dredging (eight surveys).<br><br>Mapping and biomass sampling via towed underwater video at impact and reference sites. | Impacts consistent with or greater than approved/ predicted. | Dredging may have prevented the normal seasonal recruitment of a deep water transient seagrass species for one year. Recruitment occurring the following year at densities higher than prior to dredging. | Trimarchi and Keane (2007)<br><br>GHD (2006)<br><br>Chartrand et. al. (2008) |
| **Port:** HAY POINT | 5 | 8.6 Mcum at-sea | As above. | *Fish and prawns associated with seagrass* | Impacts consistent with | Authors report no detectable impact of dredging. Reference sites were affected by | Trimarchi and Keane (2007) |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| **Description:**<br>Apron and Departure Path Project (2006) | | placement | | Baseline (one survey), during (five surveys) and post dredging (five surveys).<br>Beam trawls at impact and reference sites. | approvals/ predictions. | larger than approved turbidity plumes. | GHD (2006)<br><br>Chartrand et al (2008) |
| **Port:** HAY POINT<br><br>**Description:**<br>Coal Terminal Expansion Project Phase 3 (2010-2011) | 9 (2 stages) | 275,000 cum reclamation and at-sea placement. | *Commonwealth*<br>-Environment Protection (Sea Dumping) Act 1981.<br>-Environment Protection and Biodiversity Conservation Act 1999.<br>-Great Barrier Reef Marine Park Act 1975.<br><br>*State*<br>- State Development and Public Works Organisation Act 1971<br>-Integrated Planning Act 1994.<br>-Environmental Protection Act 1994.<br>-Fisheries Act 1994.<br>-Coastal Protection and Management Act 1995. | *Corals*<br>Baseline (one survey), and post dredging (one survey).<br><br>Photography at impact and reference transects. | Unable to be determined. | Authors report no detectable impact of dredging as pattern of change was the same at reference and impact sites. Major declines in coral and increases in macroalgae at both impact and reference sites. Plumes did not reach coral receptors. Major influences from a cyclone prior to baseline survey complicated impact assessment. | BMA (2011) cited in SKM (2013a) |
| **Port:** HAY POINT<br><br>**Description:**<br>Coal Terminal Expansion Project Phase 3 (2010-2011) | 9 (2 stages) | 275,000 cum reclamation and at-sea placement. | As above. | *Benthic infauna*<br>Baseline (one survey), and post dredging (one survey after one month and one survey after one year).<br><br>Grab sampling at impact | Unable to be determined. | Authors report no detectable impact of dredging. Baseline survey conducted following major cyclonic influence. Large increases in abundance and diversity during dredging probably reflect associated recovery. | BMA (2012) cited in SKM (2013a) |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| | | | | and reference sites (some had been previously disturbed). | | | |
| **Port:** HAY POINT<br><br>**Description:**<br>Coal Terminal Expansion Project Phase 3 (2010-2011) | 9 (2 stages) | 275,000 cum reclamation and at-sea placement. | As above. | *Seagrass*<br>No baseline survey, survey during and post dredging (on-going quarterly surveys).<br><br>Photography at defined quadrants at impact and reference sites. | Unable to be determined. | Authors report no detectable impact of dredging on seagrass. Seagrass present at low levels or absent for much of monitoring period. Major influence from cyclones and floods limited seagrass extent (absent on many occasions). Recovery observed 18 months after dredging. | BMA (2012) cited in SKM (2013a). |
| **Port:** GLADSTONE<br><br>**Description:**<br>Western Basin Dredging and Placement Project (2011-2013) | 28 | Stage 1 complete: 25 Mcum reclamation and 11 Mcum at-sea placement. | *Commonwealth*<br>-Environment Protection (Sea Dumping) Act 1981.<br>-Environment Protection and Biodiversity Conservation Act 1999.<br><br>*State*<br>-State Development and Public Works Organisation Act 1971.<br>-Integrated Planning Act 1994.<br>-Environmental Protection Act 1994.<br>-Fisheries Act 1994.<br>-Coastal Protection and Management Act 1995. | *Water quality*<br>Real time water quality and light monitoring. Baseline (6 months -3 years), during and post dredging. Impact and reference sites. | Impacts greater than approved/ predicted. | Turbidity values and plume extent greater than approved due to larger dredge equipment than assumed in the EIS and seepage from a reclamation area. Turbidity trigger exceedances due to natural events (e.g. winds, large tides, rain) and a combination of other influences (e.g. marked increase in boating traffic, nearby dredging projects, reclamation seepage and dredging). Water quality affected by major cyclones and floods immediately prior to and during works. No metal or nutrient impact issues related to dredging. | Reports provided on GPC Western Basin website.<br><br>http://www.westernbasinportdevelopment.com.au/environmental_reports |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| **Port:** GLADSTONE<br><br>**Description:** Western Basin Dredging and Placement Project Stage 1 (2011-2013) | 28 | 25 Mcum reclamation and 11 Mcum at-sea placement. | As above. | *Seagrass*<br>Baseline (6 months- >5 years) months), 2 years of monthly surveys during works and 1-5 year post dredging.<br>Seagrass transects, light based monitoring and mapping. Impact and reference sites. | Impacts consistent with approvals/ predictions. | Authors report no dredging related impacts to seagrass. Light levels at seagrass monitoring sites maintained above thresholds throughout project. Some seagrass recolonisation within the approved 100% loss zone during dredging. Seagrass was at very low levels prior to works due to major cyclone effects. Floods during dredging may also have had impacts. Seagrass recovery from floods occurred at key sites during dredging to pre dredging levels. | James Cook University reports provided on GPC Western Basin website. http://www.westernbasinportdevelopment.com.au/environmental_reports |
| **Port:** GLADSTONE<br><br>**Description:** Western Basin Dredging and Placement Project Stage 1 (2011-2013) | 28 | Stage 1: 25 Mcum reclamation and 11 Mcum at-sea placement. | As above | *Coral*<br>Baseline (1 survey), during (1 survey, 12 months after works commenced). Diver transects. | Impacts consistent with approvals/ predictions. | No significant change between years. Authors concluded there was no evidence of dredging or dredge material placement related impacts. Statistical methods not provided. | Oceania Maritime Consultants (2011)<br><br>http://www.westernbasinportdevelopment.com.au/environmental_reports |
| **MAINTENANCE DREDGING** | | | | | | | |
| **Port:** Cairns, Hay Point, Abbott Point, Gladstone, and Townsville.<br><br>**Description:** Regular (mostly annual maintenance dredging) | 0.5 - 1.0 | 200,00 cum to 680,000 cum – at sea placement | *Commonwealth*<br>-Environment Protection (Sea Dumping) Act 1981.<br>-Great Barrier Reef Marine Park Act 1975.<br><br>*State*<br>- Sustainable Planning Act 2010<br>-Environmental Protection Act 1994.<br>-Fisheries Act 1994.<br>-Coastal Protection and | *Water quality* Regular (mainly triennial) monitoring of turbidity plumes. | Impacts consistent with approvals/ predictions. | Dredging is undertaken by the same dredge (*TSHD Brisbane*) operating in the same port channels and berths. Previous monitoring of turbidity plumes has shown they are localised to the dredge area and unlikely to impact upon sensitive receptors. Regular plume monitoring undertaken to confirm previous results. | Information supplied by various Queensland ports |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| | | | Management Act 1995. | | | | |
| **Port:** ROSSLYN BAY BOAT HARBOUR<br>**Description:**<br>Harbour maintenance dredging (2006) | | 31,000 cum at sea placement (CSD pumping to placement area 1.1km distant). | *Commonwealth*<br>-Environment Protection (Sea Dumping) Act 1981.<br>-Great Barrier Reef Marine Park Act 1975.<br><br>*State*<br>- Sustainable Planning Act 2010<br>-Environmental Protection Act 1994.<br>-Fisheries Act 1994.<br>-Coastal Protection and Management Act 1995. | *Benthic infauna and corals*<br>Baseline (1 survey) and post dredging (2 surveys – 2 weeks and 1 year).<br><br>Grab samples for infauna and sediment.<br><br>Coral reef transects (cover, reef community type | Unable to be determined. | Dredging related impacts difficult to determine.<br><br>Reference sites differed from impact sites (in a different habitat type).<br><br>Decreases in infauna abundance and diversity at impact sites (none at control sites) immediately after dredging with increases after 1 year but not to pre dredge levels.<br><br>Significant storms occurred during dredging operations. Impacts to corals not determined (no post dredge survey).Variable changes in sediment characteristics apparently unrelated to dredging. | Alquezar and Straford (2007)<br><br>Alquezar and Boyd (2008) |
| **WESTERN AUSTRALIA** | | | | | | | |
| **CAPITAL DREDGING PROJECTS** | | | | | | | |
| **Port:** PORT HEDLAND<br><br>**Description:**<br>South West Creek Tug Boat and Small Vessel Cyclone Mooring Facility (2011) | 4 | 0.57 Mcum at-sea placement<br><br>Total project 2.5 Mcum at-sea placement. | *Commonwealth*<br>-Environment Protection (Sea Dumping) Act 1981.<br><br>*State*<br>Environmental Protection Act 1986. | *Water quality*<br>During dredging.<br>Telemetry based in situ water quality loggers at two dredging and two reference sites. | Impacts consistent with approvals/ predictions. | One exceedance of 80th percentile trigger threshold. No higher level exceedances. | WorleyParsons (2012).<br><br>Unpublished reports held by Port Hedland Port Authority. |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| **Port:** PORT HEDLAND<br><br>**Description:** South West Creek Tug Boat and Small Vessel Cyclone Mooring Facility (2011) | 4 | 0.57 Mcum at-sea placement<br><br>Total project 2.5 Mcum at-sea placement | As above. | *Mangroves*<br>Baseline (1 survey) and then monthly surveys during dredging. Mangrove community structure and health. Two reference and two impact monitoring sites. | Impacts consistent with approvals/ predictions. | Authors report no indirect impacts on mangroves due to dredging activities. Slight improvements or no changes in mangroves. | WorleyParsons (2012).<br><br>Unpublished reports held by Port Hedland Port Authority. |
| **Port:** PORT HEDLAND<br><br>**Description:** South West Creek Tug Boat and Small Vessel Cyclone Mooring Facility (2011) | 4 | 0.57 Mcum at-sea placement<br><br>Total project 2.5 Mcum at-sea placement | As above. | *Corals*<br>Baseline and Post Dredging surveys. Coral sedimentation levels monitored at impact and reference sites. | Impacts consistent with approvals/ predictions. | Sediment levels at greater depth on corals at one impact site than other sites (predicted in EIA). The increase had no measurable impact on benthic cover at this site. | WorleyParsons (2012).<br><br>Unpublished reports held by Port Hedland Port Authority. |
| **Port:** PORT HEDLAND<br><br>**Description:** South West Creek Dredging and Reclamation Project (2011 –2012) | 12 | Stage 1 involving 7.2 Mcum complete<br><br>Total project 14.2 Mcum dredging and onshore and at- sea placement | *Commonwealth*<br>-Environment Protection (Sea Dumping) Act 1981.<br><br>*State*<br>Environmental Protection Act 1986. | *Mangroves and sedimentation.*<br>Baseline (1 survey) and then bimonthly surveys during dredging at impact and reference sites. Mangrove community structure and heath. Sedimentation levels within mangrove community. | Impacts consistent with approvals/ predictions. | Authors report no direct or indirect impacts on mangroves outside the defined zone of permanent loss. Slight improvements or no changes in mangroves. No exceedances of sedimentation trigger levels. Variation displayed at impact sites was consistent with reference sites for the majority of mangrove health indicators. | WorleyParsons (2012)<br>http://www.phpa.com.au/Environment-and-community/Environment-and-heritage/Port-development-and-the-environment.aspx |
| **Port:** PORT HEDLAND | 12 | Stage 1 involving 7.2 Mcum | As above. | *Corals*<br>Baseline (1 survey) and 1 survey during dredging. | Impacts consistent with approvals/ | Sediment levels increased at one impact site (predicted in EIA). Subsequent surveys found that the coral health at that site had improved | Port Hedland Authority Compliance |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| **Description:** South West Creek Dredging and Reclamation Project (2011 –2012) | | complete.<br><br>Total project 14.2 Mcum dredging and onshore and at- sea placement | | Coral sedimentation levels monitored at 4 impact and 2 reference site. | predictions (final confirmatory coral survey to be undertaken). | post-dredging indicating impacts were temporary and rapid recovery. | Assessment Report 2013 South West Creek Dredging and Reclamation Project DOC-EH02. http://www.phpa.com.au/Environment-and-community/Environment-and-heritage/Port-development-and-the-environment.aspx |
| **Port:** PORT HEDLAND<br><br>**Description:** South West Creek Dredging and Reclamation Project (2011 –2012) | 0.5 | Stage 1 involving 7.2 Mcum onshore complete.<br><br>Total project 14.2 Mcum dredging and onshore and at- sea placement | As above. | *Water quality*<br>During dredging.<br>Telemetry based in situ water quality loggers at 6 monitoring sites comprising of 2 dredging, 2 dewatering and 2 reference sites. | Impacts consistent with approvals/ predictions for all parameters except nickel. | One exceedance of 80th percentile trigger threshold for turbidity. Exceedances of nickel trigger level during dewatering (discharge restricted however no dredging management actions required). | Port Hedland Authority Compliance Assessment Report 2013 South West Creek Dredging and Reclamation Project DOC-EH02 http://www.phpa.com.au/Environment-and-community/Environment-and-heritage/Port-development-and-the-environment.aspx |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| **Port:** PORT HEDLAND<br><br>**Description:** Stingray Creek Cyclone Moorings Project (14 April 2012 – 19 August 2012) | 4 | Stage 1 involving 1.6 Mcum at sea placement complete Total project 5.88 Mcum at-sea placement | *Commonwealth* Environment Protection (Sea Dumping) Act 1981<br><br>*State* Environmental Protection Act 1986 | *Water quality* During dredging telemetry based in situ water quality loggers at 6 monitoring sites comprising 4 dredging and 2 reference sites. | Impacts consistent with approvals/ predictions. | Brief exceedances of investigation trigger values (not at levels requiring formal reporting to regulator or reactive management actions). | WorleyParsons (2012) Unpublished reports held by Port Hedland Port Authority. |
| **Port:** PORT HEDLAND<br><br>**Description:** Stingray Creek Cyclone Moorings Project (2012) | 4 | Stage 1 involving 1.6 Mcum at sea placement complete.<br><br>Total project 5.88 Mcum at-sea placement | As above. | *Mangroves and sedimentation.* Baseline (1 survey) and then bimonthly surveys during dredging at reference and impact monitoring sites. Mangrove community structure and heath. Sedimentation levels within mangrove community. | Impacts consistent with approvals/ predictions. | No indirect impacts on mangroves recorded. No exceedances of sedimentation trigger levels. | WorleyParsons (2012)<br><br>Unpublished reports held by Port Hedland Port Authority. |
| **Port:** PORT HEDLAND<br><br>**Description:** Stingray Creek Cyclone Moorings Project (2012) | 4 | Stage 1 involving 1.6 Mcum at sea placement complete.<br><br>Total project 5.88 Mcum at-sea placement | As above. | *Corals* Baseline (1 survey) and post dredging survey (1 survey) at reference and impact monitoring sites | Impacts consistent with approvals/ predictions. | Coral health parameters did not change significantly at inshore sites between the baseline and the post-dredge survey. | WorleyParsons (2012)<br><br>Unpublished reports held by Port Hedland Port Authority. |
| **Port:** CAPE LAMBERT PORT | 4 | 3.6 Mcum at-sea | *Commonwealth* -Environment Protection | *Coral* Baseline surveys, during | Impacts less than approved/ | Permitted impact of <10% net coral mortality at any impact site. Actual impact was <3% net | Compliance reports cited in |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| **Description:**<br>Robe- Cape Lambert (2007) | | placement | (Sea Dumping) Act 1981.<br>-Environment Protection and Biodiversity Conservation Act 1999.<br><br>*State*<br>-Environmental Protection Act 1986. | (fortnightly) and post dredging (fortnightly).<br>Tagged coral with photography (video and still) on transects at reference and impact (varying distances from dredging) sites | predicted. | mortality at impact sites. | Hanley (2011)<br><br>http://www.riotintoironore.com/documents/Dredging_and_Spoil_Disposal_Monitoring_and_Management.pdf |
| **Port:** DAMPIER PORT AUTHORITY<br><br>**Description:**<br>Mermaid Sound – Dampier Port Authority capital dredging of Dampier Port Bulk Liquids Berth and Hamersley Iron capital and maintenance dredging Parker Point channel and wharf (2004). | 5 (Bulk Liquids Berth)<br><br>7 (5 and 2 months; Hamersley Iron) | 7.2 Mcum at-sea placement | *Commonwealth*<br>-Environment Protection (Sea Dumping) Act 1981.<br>-Environment Protection and Biodiversity Conservation Act 1999.<br><br>*State*<br>-Environmental Protection Act 1986. | *Water quality*<br>During dredging (sampling every 3 days – weekly) for 10 months.<br>Water quality and aerial photography at impact and reference sites. | Impacts less than approved/ predicted. | Authors report modelling for DPA component greatly overestimated water quality impacts. TSS effects very localised temporally and spatially. Improved approvals/ predictions for HI project. Actual levels near the dredging site were much lower than approved and effects rarely detectable after 3 days. | Stoddart and Anstee (2005) |
| **Port:** DAMPIER PORT AUTHORITY<br><br>**Description:**<br>Mermaid Sound – Dampier Port Authority capital dredging of Dampier Port Bulk Liquids Berth and Hamersley Iron capital and maintenance | 5 (Bulk Liquids Berth)<br><br>7 (5 and 2 months; Hamersley Iron) | 7.2 Mcum at-sea placement | *Commonwealth*<br>-Environment Protection (Sea Dumping) Act 1981.<br>-Environment Protection and Biodiversity Conservation Act 1999.<br><br>*State*<br>-Environmental Protection Act 1986. | *Coral*<br>Baseline (1-3 surveys for 2 months), during (fortnightly for 10 months) and post dredging (fortnightly for 2 months) at impact and reference sites.<br>Tagged coral with photography (video and still) on transects at reference and impact | Impacts less than approved/ predicted. | Allowed 30% net mortality at impact sites. No discernible impact due to dredging at predicted impact sites other than coral mortality at 1 of 7 impact sites (immediately adjacent to the dredge area). Changes in coral abundance mainly due to natural events (e.g. cyclones). Sites 500 m- 1 km from dredging were influenced by acute and chronic turbidity increases with no measured effects. | Stoddart et al (2005) |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| dredging Parker Point channel and wharf (2004). | | | | (varying distances from dredging) sites | | | |
| **Port:** DAMPIER PORT AUTHORITY<br><br>**Proponent:** Hamersley Iron<br>**Description:** Maintenance and capital dredging as part of Rio Tinto Port Upgrade (Phase B) (2007). | 10.0 | 3.1 Mcum at-sea placement | *Commonwealth*<br>-Environment Protection (Sea Dumping) Act 1981.<br>-Environment Protection and Biodiversity Conservation Act 1999.<br><br>*State*<br>-Environmental Protection Act 1986. | *Coral*<br>Baseline surveys, during (fortnightly) and post dredging (fortnightly). Tagged coral with photography (video and still) on transects at reference and impact (varying distances from dredging) sites.<br><br>*Water Quality*<br>Water quality monitoring was undertaken two weeks prior, during and two weeks post dredging. | Impacts less than approved/ predicted. | <3% net coral mortality at impact sites compared to an allowable loss of <10% net mortality. | Dampier Port Upgrade Phase B Dredging Program 2006/07<br><br>Compliance reports cited in Hanley (2011) |
| **Port:** DAMPIER PORT AUTHORITY<br><br>**Description:** Woodside Pluto – Mermaid Sound (2007-2010). | 30 | 14 Mcum at-sea placement | *Commonwealth*<br>-Environment Protection (Sea Dumping) Act 1981.<br>-Environment Protection and Biodiversity Conservation Act 1999.<br><br>*State*<br>-Environmental Protection Act 1986. | *Coral*<br>Baseline surveys, during (fortnightly) and post dredging (fortnightly). Tagged coral with photography (video and still) on transects at reference and impact (varying distances from dredging) sites. | Impacts less than approved/ predicted. | Permitted impact of 5 -10% coral mortality at impact sites depending upon zone of impact. Actual impacts were <5% net mortality at impact sites. | Compliance reports cited in Hanley (20011) |
| **Port:** PORT OF DAMPIER | 1 | 98,300 cum | *Commonwealth*<br>-Environment Protection | *Water quality*<br>During dredging (4 water | Impacts consistent with | Levels of turbidity recorded near the dredging site confirmed as approved - the plume settled | Dampier Port Authority (2012) |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| **Description**: Dampier Port Authority: Heavy Load Out Facility Berth and Swing Basin Expansion Project (2012) | | | (Sea Dumping) Act 1981.<br>-Environment Protection and Biodiversity Conservation Act 1999.<br><br>*State*<br>-Environmental Protection Act 1986. | quality monitoring events over the 4 week dredging period). | approvals/ predictions | out within approx. ~250m of the backhoe dredger. | |
| Gorgon Gas Development and Jansz Feed Gas Pipeline (2012) | 6 | 8 Mcum at-sea placement | *Commonwealth*<br>Environment Protection (Sea Dumping) Act 1981.<br><br>*State*<br>Environmental Protection Act 1986. | *Corals*<br>Before and after sampling at 12 monitoring sites. | Impacts less than approved. | Net area of coral loss was 3.26 ha, less than the allowed limit of 8.47 ha. Coral assemblages were variable and some changes (e.g. % coral cover in Zones of High and Moderate Impact) were likely to be dredging related. | Chevron Post-Development Coastal and Marine State and Environmental Impact Survey Report, Year 1: 2011/2012, Document G1-NT-REPX0004461 July 2012. |
| Gorgon Gas Development and Jansz Feed Gas Pipeline (2012) | 6 | 8 Mcum at-sea placement | As above. | *Non-coral macroinvertebrates*- soft bottom assemblages<br>Before and after sampling at 28 monitoring sites | Impacts consistent with approvals/ predictions. | No change in soft bottom benthic macroinvertebrate assemblages between baseline and post dredging survey (possible change in one area but statistical rigour was limited). | Chevron Post-Development Coastal and Marine State and Environmental Impact Survey Report, Year 1: 2011/2012, Document G1-NT-REPX0004461 July 2012. |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| Gorgon Gas Development and Jansz Feed Gas Pipeline (2012) | 6 | 8 Mcum at-sea placement | As above. | *Non-coral macroinvertebrates-* limestone substrate habitat Before and after sampling at 28 monitoring sites | Unable to be determined. . | Changes to benthic macroinvertebrate assemblages (e.g. declines in hard corals, sea whips, variable morphology sponges) associated the limestone substrate habitat may have been due to natural variation, or to dredging and dredge spoil disposal activities. | Chevron Post-Development Coastal and Marine State and Environmental Impact Survey Report, Year 1: 2011/2012, Document G1-NT-REPX0004461 July 2012. |
| Gorgon Gas Development and Jansz Feed Gas Pipeline (2012) | 6 | 8 Mcum at-sea placement | As above. | *Macroalage* Before and after sampling at 20 monitoring sites | Impacts consistent with approvals/ predictions. | Limited statistical robustness in monitoring design. Highly variable community (spatially and temporally). Significant declines in macroalgal percent cover from the baseline to post-dredging survey evident within the Zones of High Impact and Zones of Influence but not at the Zones of Moderate Impact or the Reference Site. Changes were considered unlikely to be associated with the dredging and dredge material placement activities, and more likely to reflect natural temporal and spatial variation | Chevron Post-Development Coastal and Marine State and Environmental Impact Survey Report, Year 1: 2011/2012, Document G1-NT-REPX0004461 July 2012. |
| Gorgon Gas Development and Jansz Feed Gas Pipeline (2012) | 6 | 8 Mcum at-sea placement | As above. | *Seagrass* Before and after sampling at 5 - 14 monitoring sites | Unable to be determined. | Significant changes in seagrass parameters were observed, however the overall magnitude of the changes in the sparse seagrass community was minor. It was not possible to determine if the small changes to seagrass assemblage structure and dominant species were due to natural variation or to dredging and dredge spoil disposal activities. | Chevron Post-Development Coastal and Marine State and Environmental Impact Survey Report, Year 1: 2011/2012, Document G1-NT- |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| | | | | | | | REPX0004461 July 2012. |
| Gorgon Gas Development and Jansz Feed Gas Pipeline (2012) | 6 | 8 Mcum at-sea placement | As above. | *Mangroves* Before and after sampling at 8 monitoring sites | Impacts consistent with approvals/ predictions. | No change in mangrove communities between baseline and post dredging. Overall, the mangrove communities across all monitored sites appeared in good condition with few to no indications of decline. | Chevron Post-Development Coastal and Marine State and Environmental Impact Survey Report, Year 1: 2011/2012, Document G1-NT-REPX0004461 July 2012. |
| Gorgon Gas Development and Jansz Feed Gas Pipeline (2012) | 6 | 8 Mcum at-sea placement | As above. | *Demersal Fish* Before and after sampling at 43 monitoring sites | Impacts consistent with approvals/ predictions. | Some minor changes in the Zone of High Impact but generally changes were considered unlikely to be associated with the dredging and dredge material placement activities, and more likely to reflect natural temporal and spatial variation. Monitoring concluded that activities associated with dredging and dredge spoil disposal at sites monitored had minimal, if any, impact on fish presence and abundance. | Chevron Post-Development Coastal and Marine State and Environmental Impact Survey Report, Year 1: 2011/2012, Document G1-NT-REPX0004461 July 2012. |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| **MAINTENANCE DREDGING** | | | | | | | |
| **Port:** PORT HEDLAND<br>**Description:** Maintenance dredging required every 3 - 4 years. | 0.5-1.5 | 114,000 cum – 730,000 cum at-sea placement | *Commonwealth* Environment Protection (Sea Dumping) Act 1981.<br><br>*State* Environmental Protection Act 1986 | *Water quality*<br>Visual assessment | N/A | Water quality monitoring not required as dredging of short duration and low risk of impacts. Previous monitoring of larger projects has shown no exceedances of trigger values for sensitive receptors. | http://www.phpa.com.au/Environment-and-community/Environment-and-heritage/Port-development-and-the-environment/PDF/PHPA-Long-Term-Dredge-Material-Management-Plan.aspx |
| **Port:** PORT OF DAMPIER<br><br>**Description:** Hamersley Iron Maintenance dredging (2010-12). | 0.5-1.0 | 295,200 cum at-sea placement | *Commonwealth* -Environment Protection (Sea Dumping) Act 1981.<br><br>*State* Environmental Protection Act 1986 | *Water Quality*<br>Turbidity monitored (qualitatively) during the maintenance dredging campaign through aerial photography. | Impacts consistent with approvals/ predictions | Short duration project with relatively low dredge volumes.<br><br>Previous larger volume dredging programmes showed no link between dredging and benthic impacts. | RTIO-HSE-0195421 (Rio Tinto Summary Letter to Dampier Port Authority, 2013) |
| NORTHERN TERRITORY | | | | | | | |
| **CAPITAL DREDGING** | | | | | | | |
| **Port:** PORT OF DARWIN<br><br>**Description:** | Project in progress.<br><br>8 (Stage 1) | 16.1 Mcum at-sea placement | *Commonwealth* -Environment Protection (Sea Dumping) Act 1981. | *Water quality and subtidal sedimentation*<br>Water column profiling and sampling (metals, | Impacts consistent with approvals/ predictions. | No turbidity exceedances (intensity, duration or frequency). | Dredging and Spoil Placement Management Plan - East Arm Inpex |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| Dredging and Spoil Placement Management Plan - East Arm Ichthys Project (2012 - ongoing). | and est. 6 (Stage 2). | | *Territory*<br>-NT Planning Act<br>- NT Environmental Assessment Act (1982)<br>-Waste Management and Pollution Control Act<br>-Water Act<br>-Fisheries Act | nutrients, chlorophyll-a) for baseline (one survey) during dredging (monthly) and post dredging (one survey). Telemetry based *in situ* water quality loggers at impact and reference sites to monitor potential effects to corals, seagrass and at the dredging and dredge material placement site. Water column profiles along transects. | | | Project. INPEX Operations Australia Pty Ltd Document no.: C075-AH-PLN-0028<br>Project monitoring report July 2013 http://www.ichthysproject.com/environment |
| **Port:** PORT OF DARWIN<br><br>**Description:** Dredging and Spoil Placement Management Plan - East Arm Ichthys Project (2012 - ongoing). | Project in progress.<br><br>8 (Stage 1) and est. 6 (Stage 2). | 16.1 Mcum at-sea placement | As above. | *Mangroves and intertidal sedimentation*<br>Baseline (two surveys) during dredging (surveys at three month intervals) and post dredging using satellite imagery.<br>Sedimentation and mangrove health (fauna, foliage, leaf litter) at impact and reference sites | Impacts less than approved/ predicted. | Sedimentation levels far below that which may affect mangrove health. No trigger level exceedance. Slight increase in mangrove condition from baseline survey considered part of natural variability. | Dredging and Spoil Placement Management Plan - East Arm Inpex Project. INPEX Operations Australia Pty Ltd Document no.: C075-AH-PLN-0028.<br><br>Project monitoring report August 2013 http://www.ichthysproject.com/environment |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| **Port:** PORT OF DARWIN<br><br>**Description:** Dredging and Spoil Placement Management Plan - East Arm Ichthys Project (2012 - ongoing). | Project in progress.<br><br>8 (Stage 1) and est. 6 (Stage 2). | 16.1 Mcum at-sea placement | As above. | *Corals*<br>Baseline (three surveys) during dredging (every two months) and post dredging (three surveys). Tagged corals and transects for coral health (eg bleaching, mortality, PAM-fluorometry) and cover at reference and impact sites. | Impacts consistent with approvals/ predictions. | No impacts attributable to dredging. Five bimonthly surveys during dredging have been completed. Substantial coral thermal bleaching recorded from survey 3. | Dredging and Spoil Placement Management Plan - East Arm Inpex Project. INPEX Operations Australia Pty Ltd Document no.: C075-AH-PLN-0028.<br><br>Project monitoring report August 2013 http://www.ichthysproject.com/environment |
| **Port:** PORT OF DARWIN<br><br>**Description:** Dredging and Spoil Placement Management Plan - East Arm Ichthys Project (2012 - ongoing). | Project in progress.<br><br>8 (Stage 1) and est. 6 (Stage 2). | 16.1 Mcum at-sea placement | As above. | *Seagrass*<br>Baseline (2 surveys) during dredging (every 2 months) and post dredging (3 surveys). Seagrass cover, shoot density and distribution at reference and impact sites. | Impacts consistent with approvals/ predictions | Second during-dredging survey showed a marked reduction of seagrass compared to baseline survey and a trigger exceedance. Not considered dredging related but natural variability (e.g. dieback and heavy rainfall). Seagrass species found within the study area are highly ephemeral. | Dredging and Spoil Placement Management Plan - East Arm Inpex Project. INPEX Operations Australia Pty Ltd Document no.: C075-AH-PLN-0028.<br>Project monitoring report February 2013 http://www.ichthys |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
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| | | | | | | | project.com/environment |
| **Port:** PORT OF DARWIN<br><br>**Description:** Dredging and Spoil Placement Management Plan - East Arm Ichthys Project (2012 - ongoing). | Project in progress.<br><br>8 (Stage 1) and est. 6 (Stage 2). | 16.1 Mcum at-sea placement | As above. | *Marine Pests*<br>Surveys at high risk locations and "informative" locations during dredging. | Impacts consistent with approvals/ predictions. | First survey did not identify any pest species of concern. Conducted in conjunction with other sensitive receptor surveys. | Dredging and Spoil Placement Management Plan - East Arm Inpex Project. INPEX Operations Australia Pty Ltd Document no.: C075-AH-PLN-0028<br><br>Project monitoring report June 2013 http://www.ichthysproject.com/environment |
| **Port:** PORT OF DARWIN<br><br>**Description:** Dredging and Spoil Placement Management Plan - East Arm Ichthys Project (2012 - ongoing). | Project in progress.<br><br>8 (Stage 1) and est. 6 (Stage 2). | 16.1 Mcum at-sea placement | As above. | *Primary productivity*<br>Baseline (3 surveys) during dredging (monthly surveys) and post dredging (6 surveys).<br>Mangrove leaf litter fall and canopy cover, microphytobenthos biomass in intertidal mudflats, and<br>light availability and phytoplankton biomass | Impacts less than approved/ predicted. | First during dredging survey did not identify any dredging related impacts to mangroves. Minor changes in Chlorophyll-*a* and microphytobenthos were considered to relate to natural variation. | Dredging and Spoil Placement Management Plan - East Arm Inpex Project. INPEX Operations Australia Pty Ltd Document no.: C075.-AH-PLN-0028<br>Project monitoring report May 2013 |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| | | | | within the water column at reference and impact sites. | | | http://www.ichthysproject.com/environment- |
| **Port:** PORT OF DARWIN<br><br>**Description:** Dredging and Spoil Placement Management Plan - East Arm Ichthys Project (2012 - ongoing). | Project in progress.<br><br>8 (Stage 1) and est. 6 (Stage 2). | 16.1 Mcum at-sea placement | As above. | *Turtles and dugong*<br>Baseline (3 surveys) during dredging (3-5 surveys) and post dredging (3 surveys). Abundance and distribution assessed by aerial/boat/land survey and tagging at reference and impact sites. | N/A | Informative monitoring for improved project management. Population estimates have been spatially and temporally variable before and during dredging. | Dredging and Spoil Placement Management Plan - East Arm Inpex Project. INPEX Operations Australia Pty Ltd Document no.: C075-AH-PLN-0028.<br>Project monitoring report July 2013 http://www.ichthysproject.com/environment |
| **Port:** PORT OF DARWIN<br><br>**Description:** Dredging and Spoil Placement Management Plan - East Arm Ichthys Project (2012 - ongoing). | Project in progress.<br><br>8 (Stage 1) and est. 6 (Stage 2). | 16.1 Mcum at-sea placement | As above. | *Noise monitoring*<br>During dredging. Underwater noise monitors and 3 vessel based surveys at reference and impact sites | N/A | Informative monitoring for improved management. Data collection underway. | Dredging and Spoil Placement Management Plan - East Arm Inpex Project. INPEX Operations Australia Pty Ltd Document no.: C075-AH-PLN-0028 |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| **Port:** PORT OF DARWIN<br><br>**Description:** Dredging and Spoil Placement Management Plan - East Arm Ichthys Project (2012 - ongoing). | Project in progress.<br><br>8 (Stage 1) and est. 6 (Stage 2). | 16.1 Mcum at-sea placement | As above. | *Dolphin monitoring*<br>Before during and after dredging sampling for abundance and movement. | N/A | Informative monitoring for improved management. Baseline and early dredging surveys indicated numbers were stable and the estimated rates of habitat use show no significant variation between locations over time. | Dredging and Spoil Placement Management Plan - East Arm Inpex Project. INPEX Operations Australia Pty Ltd Document no.: C075-AH-PLN-0028<br>Project monitoring report June 2013 http://www.ichthysproject.com/environment |
| **Port:** PORT OF DARWIN<br><br>**Description:** Dredging and Spoil Placement Management Plan - East Arm Ichthys Project (2012 - ongoing). | Project in progress.<br><br>8 (Stage 1) and est. 6 (Stage 2). | 16.1 Mcum at-sea placement | As above. | *Recreational fishing*<br>Before during and after dredging recreational fisher surveys of fishing locations and catch rates and composition. | N/A | Informative monitoring for improved management. Surveys indicated dredging activities were not having a substantial influence on recreational fishing. | Dredging and Spoil Placement Management Plan - East Arm Inpex Project. INPEX Operations Australia Pty Ltd Document no.: C075-AH-PLN-0028<br>Project monitoring report September 2013 http://www.ichthysproject.com/environment |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| **MAINTENANCE DREDGING** | | | | | | | |
| **Port:** PORT OF DARWIN<br><br>**Description:** Fort Hill Wharf Berth (2007) | 0.5 | 7,000 cum at-sea placement | *Territory*<br>Water Act – Waste Discharge Licence | *Water quality*<br>Turbidity, pH, EC, temperature at impact locations. | Impacts consistent with approvals/ predictions. | Minimal impact or exceedance of water quality guidelines. | Information supplied by Darwin Port Corporation |
| **Port:** PORT OF DARWIN<br><br>**Description:** Cullen Bay Marina (2007) | 0.5 | 75,000 cum at-sea placement | *Territory*<br>Water Act – Waste Discharge Licence | *Water quality*<br>Turbidity, pH, EC, temperature at impact locations. Suspended Solids. Acoustic Doppler Current Profiling and sediment deposition assessments. | Impacts consistent with approvals/ predictions. | Minimal impact and/or exceedance of water quality guidelines. | Information supplied by Darwin Port Corporation |
| **Port:** PORT OF DARWIN<br><br>**Description:** East Arm Wharf Expansion (2012-2013) | 2.0 | 685,000 cum reclamation | *Commonwealth*<br>-Environment Protection (Sea Dumping) Act 1981.<br>-Environment Protection and Biodiversity Conservation Act 1999.<br><br>*Territory*<br>- NT Environmental Assessment Act (1982)<br>-Water Act, Waste Discharge Licence | *Water quality*<br>Daily turbidity at several sites and metal sampling weekly at impact sites. | Impacts consistent with approvals/ predictions. | Several exceedances of water quality triggers during periods of spring tides (not thought to be dredging related). Plume limited to 50m of dredge footprint. All dredging must occur outside of wet season. | Annual Monitoring Report. Version 2- 27 March 2013. http://www.eastarmwharf-eis.nt.gov.au/__data/assets/pdf_file/0020/33662/Darwin-MSB-Monitoring-Report-for-DDSP-Activities-Oct-to-Dec-2013.pdf |

| Location/project | Project duration (months) | Dredge Volume | Key regulatory approvals/ predictions | Monitoring receptor and monitoring design | Reported consistency with approved (or predicted) impacts? | Comments | Reference |
|---|---|---|---|---|---|---|---|
| **Port:** PORT OF DARWIN<br><br>**Description:** East Arm Wharf Expansion (2012-2013) | 2.0 | 685,000 cum reclamation | *Commonwealth*<br>-Environment Protection (Sea Dumping) Act 1981.<br>-Environment Protection and Biodiversity Conservation Act 1999.<br><br>*Territory*<br>- NT Environmental Assessment Act (1982)<br>-Water Act, Waste Discharge Licence | *Benthic communities (coral and filter feeders*<br>Sampling at impact and reference sites (10) before and after dredging. | Impacts consistent with approvals/ predictions. | Authors report no adverse effects from dredging. No changes in filter feeder indicators. Decreases (<10%) in coral cover at 2 of 3 designated impact sites. Changes in coral health were ascribed to both natural and dredge factors. . | Annual Monitoring Report. March 2013. *http://www.eastarmwharf-eis.nt.gov.au/__data/assets/pdf_file/0020/33662/Darwin-MSB-Monitoring-Report-for-DDSP-Activities-Oct-to-Dec-2013.pdf* |

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