Dredging and Australian Ports

Temperate Ports

May 2015

Ports Australia

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Cover photo bottom: Courtesy of Port of Melbourne Corporation.

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RELIANCE STATEMENT

This report has been prepared for Ports Australia by Rick Morton Consulting (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 to be 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, I am already familiar with a number of them. It is my professional opinion that the information presented in Appendix A, and the conclusions in the report, are generally consistent with my knowledge of the environmental performance of a broad range of dredging programs throughout temperate areas of Australia over the past 25 years. I am not aware of other dredging projects conducted in temperate 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 [(Port of Brisbane Pty Ltd, NSW Ports, Port Authority of NSW (formerly Sydney Ports Corporation), Port of Newcastle, Port of Hastings Development Authority, Port of Melbourne Corporation, Tasmanian Ports Corporation, Flinders Ports, Mid West Ports Authority (formerly Geraldton Port Authority), Fremantle Ports, Southern Ports Authority (Port of Albany) and Southern Ports Authority (Port of Esperance)] in providing information on their dredging monitoring programs is gratefully acknowledged.

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*

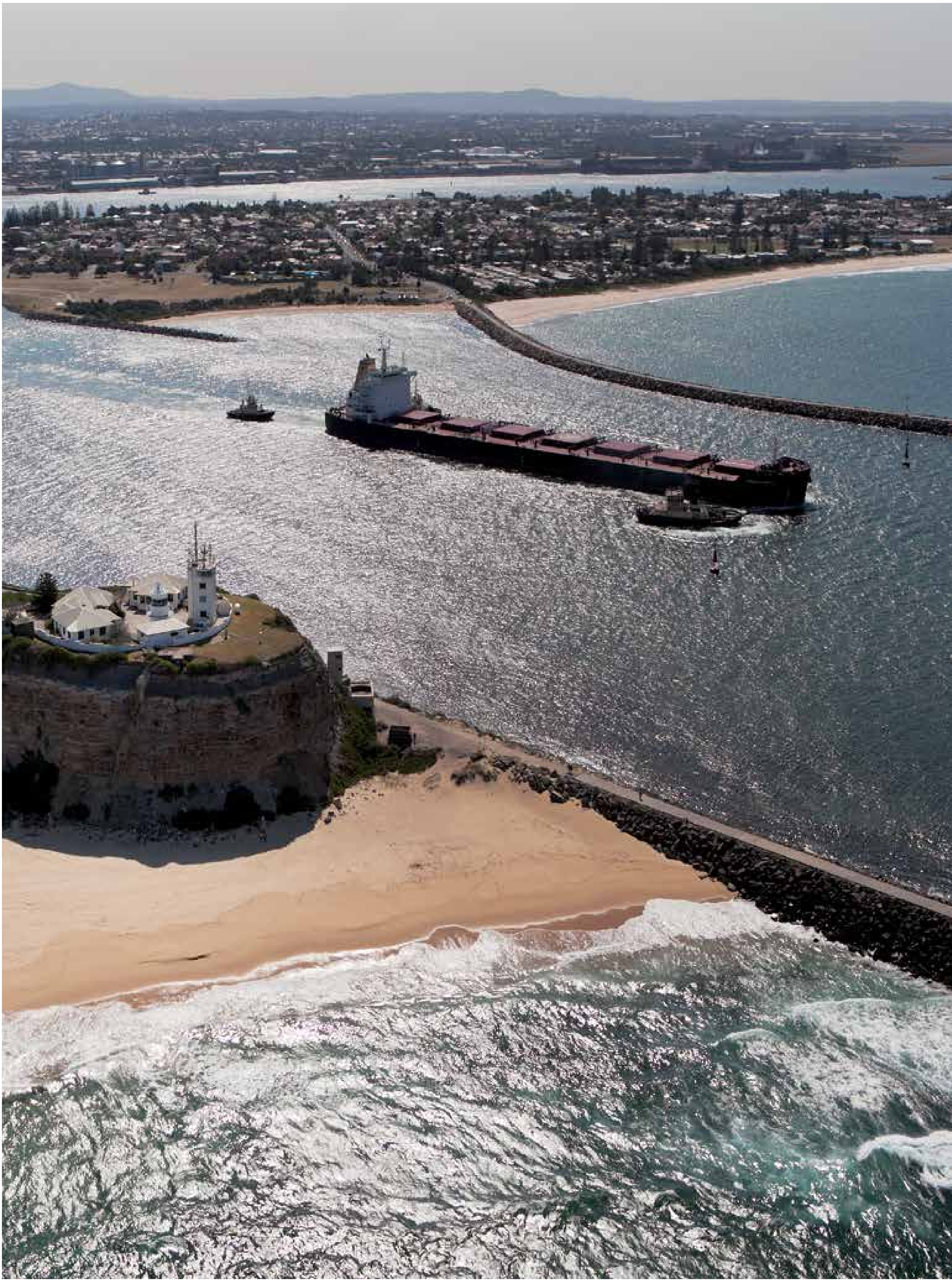

Photo courtesy of the Port Authority of NSW – Newcastle.

Ports Australia

EXECUTIVE SUMMARY

The objective of this report is to provide a basis for improved discussion on port related dredging in Australia and associated environmental impacts.

It focuses on dredging by ports in southern Australia (temperate ports) and complements an earlier report prepared for Ports Australia (Morton and Sprott 2014) which related to northern ports (subtropical and tropical ports).

The report highlights the importance of ports and shipping channels to the Australian economy and the critical role of dredging in port operations and growth. It provides an overview of the approval processes associated with dredging and at sea placement of dredged material and the nature of environmental monitoring programs associated with recent port related dredging projects.

The report compares monitored environmental impacts associated with recent major dredging projects at Sydney, Melbourne and Fremantle ports, along with other important regional dredging projects, with those stipulated by government through the environmental approval process.

The report finds that of the nine major capital projects reviewed, eight resulted in impacts consistent with or less than predicted. One resulted in impacts greater than predicted however recovery occurred over a number of years. This finding is consistent with the report relating to subtropical and tropical Australian ports (Morton and Sprott 2014).

Together, these two reports constitute the first detailed review of all major port related dredging projects undertaken in Australia since the early 1990s and highlight the:

- consistency of compliance with project approval conditions;
- rarity of unpredicted impacts or adverse effects to areas of high conservation value; and
- the high level of environmental performance of often substantial 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. Merchandise trade through ports accounted for approximately 33% of GDP in 2012/13.

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 standard of living depends directly on seaborne trade.

Ports are our largest freight hubs 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 significant ongoing growth of the Australian economy requires greater volumes of export/import cargoes to support the growing populations and large manufacturing industries associated with our southern capital city ports. Containerised trade at Australian ports is forecast to almost double by 2025 (BITRE 2010). Regional ports in southern Australia are increasing their bulk export trade (eg minerals, coal, agricultural products) and in some instances are being seen as alternatives to the increasingly busy capital city ports.

From now to 2025, Australia's trade is forecast to grow by 129%, nearly double the rate of world trade growth. Ports in southern Australia (especially Melbourne, Brisbane, Sydney and Fremantle) will experience the largest growth in total trade movements over this time period (BITRE 2010).

Enabling such growth will require ongoing improvements to existing ports such as channel deepening or the provision of additional cargo loading/unloading facilities (eg for containers).

Public Information on Dredging and Related Environmental Impacts in Australia

Port related dredging has been recently subject to considerable public and media attention given the major port expansion projects undertaken at several capital city ports (eg Melbourne), those proposed at ports such as Hastings and Geelong and the increasing development of ports in the Great Barrier Reef region. Most readily available information on dredging relates to historic experiences or overseas projects in different environmental settings.

Little information is available for stakeholders on dredging by Australian ports and how effectively environmental impacts 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. Communities are often concerned about impacts to areas of high conservation value (eg seagrasses) and the effects of toxicants such as heavy metals, given the legacy contamination issues in many southern ports.

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 southern Australian ports have protected environmental resources in accordance with government project approval conditions.

The Need for Dredging

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 southern areas of Australia are regularly being expanded primarily to cater for larger and more container ships that are required to support the growing economies. It is certain that channel improvements will be required in the future. Major size increases in container vessels have occurred over the past few decades given the cost advantages and will probably continue in the future.

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 supply chains to overseas markets can operate efficiently and to economies of scale and enables the Australia economy to grow in an increasingly competitive global market.

Relocation of Dredged Material

Land based or re-use options for dredged sediment are often not viable in southern Australia. Most coastal land near port related dredging has been developed over decades or centuries for residential or commercial purposes and few large vacant areas are available. Transporting large volumes of dredged material to any available sites (eg by pipeline or truck) is often prohibitively expensive and would result in major social impacts (eg traffic, traversing private properties, dust/odour).

Reclamation activities have been undertaken in most ports to provide commercial land and this has resulted in a beneficial use of the material. However, reclamation opportunities are limited and may lead to a loss of coastal habitat and adverse changes to sediment transport processes.

In some instances, placement of the material at sea at an approved Dredged Material Placement Area (DMPA) may be the most environmentally responsible solution. For example, maintenance dredging removes material that has been transported by currents from shallow areas into deeper channels and relocation of clean material to nearby sub-tidal areas may be an appropriate option.

Any proposal to place material at sea must evaluate alternatives (such as re-use or land based options) as stipulated in the National Assessment Guidelines for Dredging (NAGD). The NAGD also requires testing to ensure material placed at sea is non-toxic. DMPAs form an essential part of the port infrastructure being located and operated taking into account environmental, social and economic considerations.

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 (eg seagrasses and other habitats used by fauna 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.

Some ports in southern Australia have legacy contamination issues as a result of historical inputs from industry and agriculture. Concerns are often publically raised in relation to potential environmental effects associated with dredging contaminated sediments in such ports.

Environmental risk is now far more effectively managed than in the past. Port related dredging is strongly regulated to prevent and reduce environmental impacts to high value ecological communities. Over the past few decades, environmental regulations have become stricter, sediment contaminant testing is now typical, environmental impact assessment procedures have improved, and project-specific dredge management and mitigating measures are now standard components of a dredging project. Modern dredging plant and equipment employ new technologies that reduce impacts on the environment. 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.

Key Report Findings

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

Section 11 of this report provides a comprehensive list of environmental issues relating to the dredging that are applicable to future management. Salient details include:

- dredging and dredged material placement are subject to detailed and complex approval processes under international, commonwealth, state and territory legislation;
- Australia's National Assessment Guidelines for Dredging, 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 in use for decades and these are typically located in un-vegetated areas distant from sensitive habitats;
- toxic material cannot be placed at sea;
- rigorous site selection and master planning endeavours are a key part of avoiding or minimising the need for capital or maintenance dredging;
- dredging and at sea placement of dredge material in southern Australian ports over recent years has been subject to environmental monitoring designed to ensure a designated level of environmental protection (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 management actions (eg to modify or cease dredging) could be taken in time to prevent or minimise ecological impacts;
- in many cases, monitoring was overseen by independent monitors or auditors appointed by government (eg Office of the Environmental Monitor appointed for the Melbourne Channel Deepening Project);
- major and highly complex monitoring programs assorted with large capital projects in Sydney, Melbourne and Fremantle all indicated levels of compliance were consistently met and impacts were less than predicted (eg at the Port of Melbourne – 'there was comprehensive compliance with all environmental approval conditions' (Office of Environmental Monitor 2012);
- monitoring programs examined in this review almost all showed reported impacts consistent with (generally 'no impact' to a sensitive receptor), or less than, than those approved or predicted, (eg at the Port of Melbourne, 'the health of Port Phillip Bay was not compromised and remains consistent with that seen over the last decade' and 'no remedial action or post-dredging recovery activity is required' (Office of Environmental Monitor 2012);
- one exception was noted where capital dredging resulted in temporary water turbidity impacts greater than anticipated resulting in significant impacts to seagrass (Port of Geraldton Channel Enhancement Project in 2002) and seagrass recovery has occurred over several years;
- 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 and this needs to take into account the results of previous monitoring programs undertaken in similar environmental settings; and
- monitoring during many dredging projects has shown that regular natural variations (eg periods of floods or storms) may result in much greater and more prolonged environmental changes to seabed communities than those related to dredging.

The Environmental Performance of Port Related Dredging in Australia

Major port expansion and development projects undertaken in recent years (eg Sydney, Melbourne, Fremantle, Gladstone, Darwin, and Port Hedland) have demonstrated a high level of certainty associated with predicting dredging related impacts and consistent compliance with required approval conditions. Management has enabled impacts to be effectively minimised, often to levels much less than envisaged at project approval. Smaller regional projects have also performed well and unintended impacts have been rare. Monitoring associated with these projects provides a basis for improved performance in the future.

Some future port developments will involve major dredging operations. This review of recent dredging projects undertaken by southern Australian ports (and the previous review of projects by northern ports) indicates that an effective and appropriate high level of environmental management can be expected to ensure unanticipated impacts do not occur.

It is important that ports and regulators inform stakeholders of:

- the effectiveness of impact assessment and environmental management procedures adopted for dredging in Australia;
- monitoring results which show that impacts have been consistent with (or less than) those approved by regulatory agencies; and
- the rarity of unanticipated or unapproved impacts to environmental resources of high conservation value.

Public confidence in the environmental management of port related dredging would be improved through better awareness of both the impact assessment process and the actual extent of impacts from recent dredging/at sea placement projects. Importantly, this would enable a more informed and factually based discussion on future dredging projects.

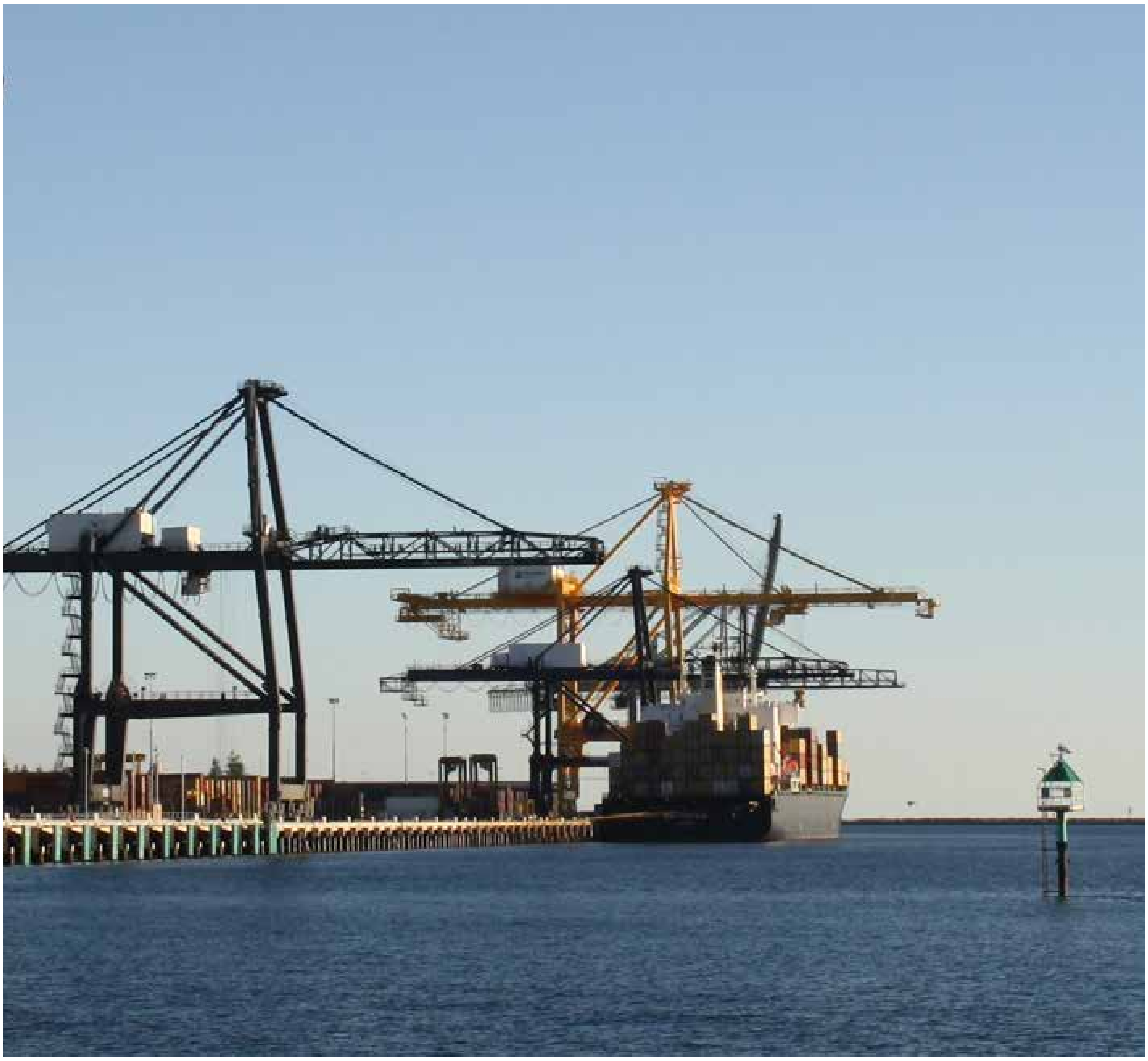

Photo courtesy of Flinders Ports (Port of Adelaide).

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 heavily 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. Australian ports are 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.

There are limited alternatives available to the use of sea transport for the movement of general freight and bulk commodities, particularly mineral resources. Sea transport offers the most economical, energy efficient and environmentally friendly transportation for large-scale movements of all cargo types

> *"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)***

Shipping accounts for over 99% of Australia's total trade, by weight. In 2012–13, Australian ports facilitated the export/import of $502.4 billion of imports and exports involving more than 31,000 vessel calls (BITRE 2010).

> *"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)***

Australia has an extensive network of ports along its coastline, ranging from capital city multi-cargo ports such as Melbourne, Sydney, Brisbane, Fremantle and Adelaide to world-class resource export terminals such as those at Newcastle, Port Kembla, Hay Point and along the north-west Pilbara coast in Western Australia. Figure 1.1 shows the location of Australian ports including those 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

All Australian ports rely on a range of associated logistical and infrastructure networks. These include supporting landside infrastructure, such as road and rail corridors, and waterside infrastructure such as shipping channels. These are fundamental to port operational efficiency and will need to be enhanced and maintained to support the anticipated 129% growth in trade by 2025 (nearly double the rate of world trade growth, BITRE 2010). Ports in southern Australia (especially Melbourne, Brisbane, Sydney and Fremantle) will experience the largest growth in total trade movements over this time period (BITRE 2010).

Dredging is an essential part of operating port waterside infrastructure (ie channels and berths) as it facilitates safe and efficient waterside access to land based infrastructure (ie terminals, rail and road corridors).

> *"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)***

Although many ports in southern Australia are located in sheltered and naturally shallow areas, shipping channels are declared in naturally deep-water areas wherever possible. This minimizes the need to undertake both initial capital and ongoing maintenance dredging works and increases shipping efficiency and safety (viz, avoiding potentially severe environmental consequences of vessel groundings, reduction in greenhouse gas emissions through the use of a lower frequency of larger ships, etc).

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. Channels and berths also

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

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. Southern regions of Australia are likely to experience significant ongoing growth in the demand for containerised cargoes (eg household goods, manufactured products, chemicals) in addition to the growth of mineral exports occurring in ports such as Newcastle and Port Kembla.

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 efficiently address increases in trade by providing and maintaining the required infrastructure (channels and wharves) whilst minimising their environmental footprint.

Port operation and growth in southern Australia is of considerable public interest as many ports are located adjacent to historically developed residential areas, areas heavily used for recreation and features of conservation value (eg seagrasses). The ongoing growth of capital cities and regional growth in bulk export resources trade (eg coal in NSW) will require improvements to the channels servicing major ports or the development of new cargo specific facilities (eg coal loading facilities), some of which will involve major dredging operations. Additionally, growth opportunities at some capital city

ports are limited in the longer term and existing regional ports are proposed for major expansions (eg Port of Hastings).

Channel development and maintenance dredging, whilst required, are often in close proximity to the population and consequently dredging works may attract public attention though carefully planned and managed to protect the environment.

Some ports in southern Australia have legacy contamination issues as a result of historical inputs from industry and agriculture. Concerns are often publically raised in relation to potential environmental effects associated with dredging contaminated sediments in such ports.

Historically, significant areas of high value habitat (including seagrasses and mangroves) 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 that did not adequately account for impacting processes.

Over the past two decades, however, there has been an increased awareness of the conservation, ecological and economic value of habitats such as seagrass and an emphasis on ensuring adverse environmental impacts to such communities from dredging operations are avoided or minimised. Issues associated with sediment contamination are recognised and specialised assessment and management techniques are now adopted. 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.

Port related dredging is far more regulated than in the past to prevent and reduce environmental impacts. 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 will require major dredging operations often near major residential areas, areas of public amenity (eg swimming beaches) or habitats of conservation value (eg seagrasses). In some cases, dredging may involve sediments that were historically contaminated and require specialised management approaches.

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 social values and 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 often do not consider the results of recent dredging projects in Australia undertaken in similar environmental settings.

Whilst information is provided during dredging works (eg the Port of Melbourne's Channel Deepening Project, Port Botany expansion), lesser emphasis is placed on informing stakeholders on the extent to which dredging projects meet the required level of environmental protection. When provided, much of the information relates to that specific project only.

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 port related dredging in southern Australia (although reviews have been carried out for ports in northern Australia by Morton and Sprott (2014) and by Hanley (2011) for the Pilbara region and SEWPaC (2013) for the Gladstone area.

Consequently, Ports Australia commissioned this report to assist stakeholders to have an understanding of the overall environmental performances of recent dredging projects in southern Australia and whether environmental resources have been protected in accordance with government required approval conditions.

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 temperate 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 the future of dredging and at sea placement projects in southern Australia.

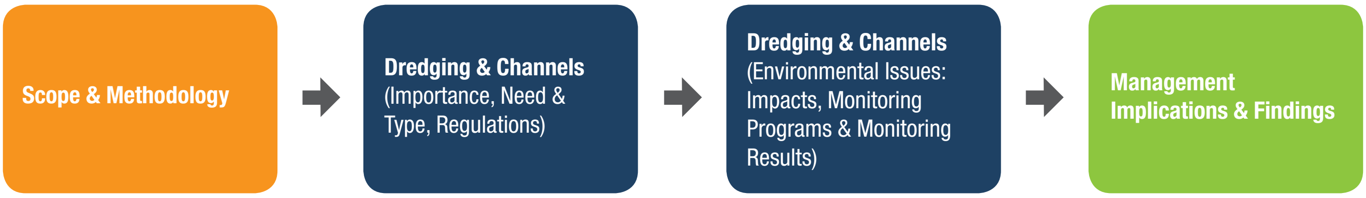

Figure 1.2: Report Structure

Photo courtesy of Port Authority of NSW – Sydney.

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 temperate regions of Australia; and
- compare the monitored environmental impacts of those dredging and at sea placement projects to those approved by the governments.

Scope

This report relates specifically to dredging and at sea placement of dredged material in temperate Australian ports (southern Australia). It complements a recently prepared similar report that relates to subtropical and tropical Australian ports and the environmental performance of their dredging projects (Morton and Sprott 2014).

The term 'temperate' is used to define the region in Australia that lies south of the Tropic of Capricorn.

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

The report provides information on dredging activities since 1990 associated with Australian temperate 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. It does not include the results of monitoring routine maintenance dredging by many ports. In many cases, such monitoring is undertaken to confirm compliance with regulatory approvals and detailed reports are not readily required by regulators.

The report focusses on the larger, mostly capital, dredging projects associated with temperate 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 dredging often undertaken by the Department of Defence (eg Navy) but this is generally minor.

Methodology

The report is based on a review of published and unpublished literature and information supplied by temperate Australian ports. The report does not include specific detail on some of the monitoring undertaken for the Melbourne Channel Deepening Project as this information is no longer publicly available, however, broad overviews were available. This particularly relates to the detailed monitoring results of specific programs associated with dredging and management of the Confined Aquatic Disposal facility.

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 temperate 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.

Photo courtesy of Port of Brisbane Pty Ltd.

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 simply be focused on the requirements at the port but must consider the surrounding networks that provide key logistical support.

Efficient and safe port operations rely on provision and protection of both landside and waterside infrastructure as shown in Figures 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 to 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. The benefits of port master planning have also been recognized by a number of state government agencies in regional planning.

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.

Comprehensive port master planning must ensure access channels and waterside areas such as anchorages, wharf areas, berth pockets, approach/departure paths and Dredged Material Placement Areas (DMPAs) are managed to allow for the safe and efficient movement of commercial vessels. Such planning also commits ports to include environmental considerations as part of infrastructure development and operation.

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.

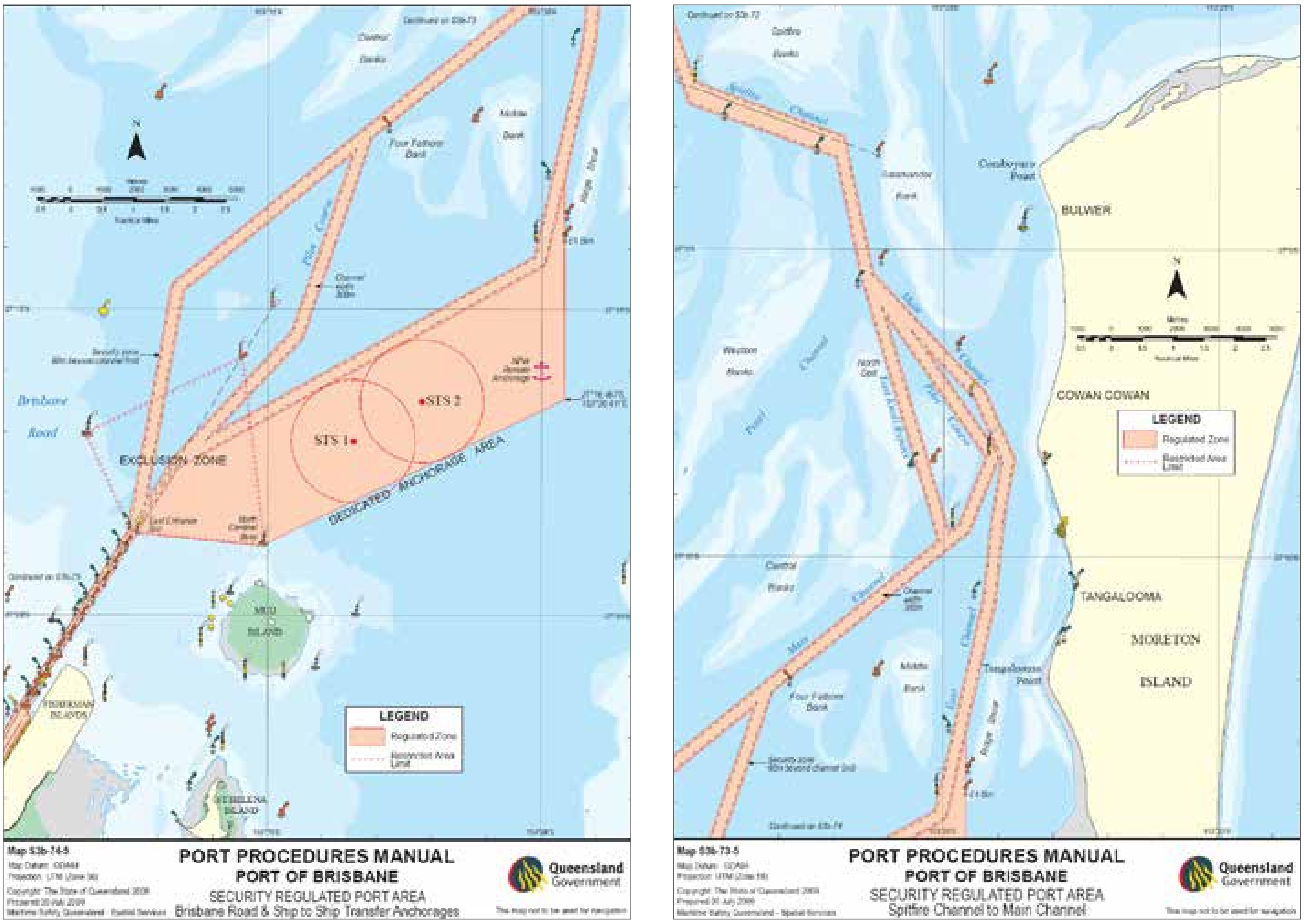

Figure 3.3: Sections of Port of Brisbane Designated Shipping Channels (Maritime Safety Queensland 2012)

> *"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)***

> *"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 Transport for NSW) in close consultation with the relevant port and other agencies such as the Australian Maritime Safety Authority (AMSA).

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. Examples are provided in Figures 3.3 and 3.4. Parts of the declared Port of Brisbane shipping channels through Moreton Bay

largely follow naturally deep water areas. Figure 3.4 shows how the channels near the entrance to Port Philip Bay head east to avoid a large area of naturally shallow sand banks.

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. Future capital dredging needs are reduced through management strategies to optimise channel efficiencies including optimal ship scheduling, the use of tidal windows, and berth optimisation.

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 are operationally linked and collectively provide for the safe passage of commercial shipping vessels enabling Australian ports to operate efficiently in the global trading market.

"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)

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

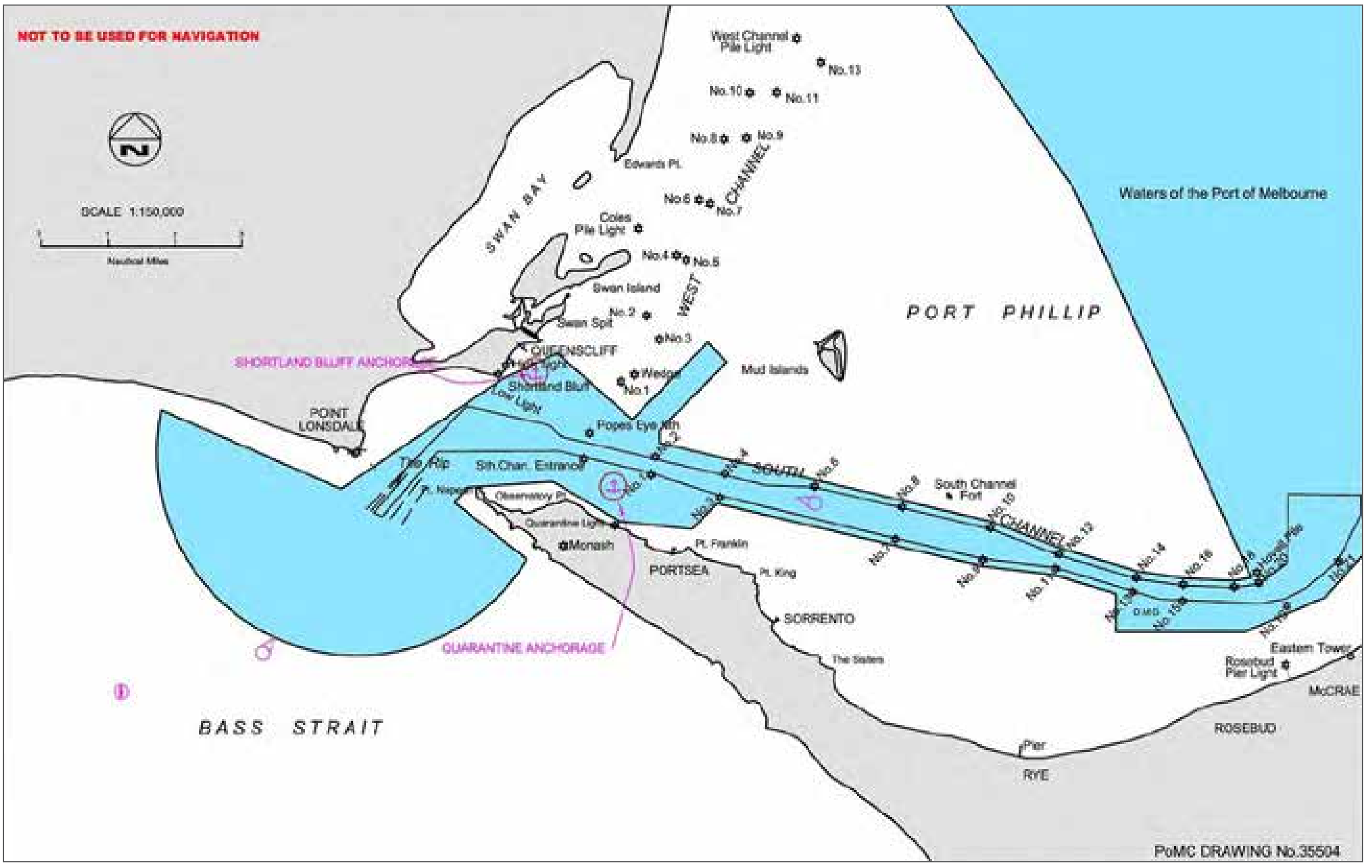

Figure 3.4: Section of Port of Melbourne Designated Shipping Channels (Port of Melbourne Corporation Operations Handbook 2013)

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 is costly and typically only undertaken following the completion of other strategies such as those involving the use of tidal windows and ship scheduling.

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)***

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 3.5 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.

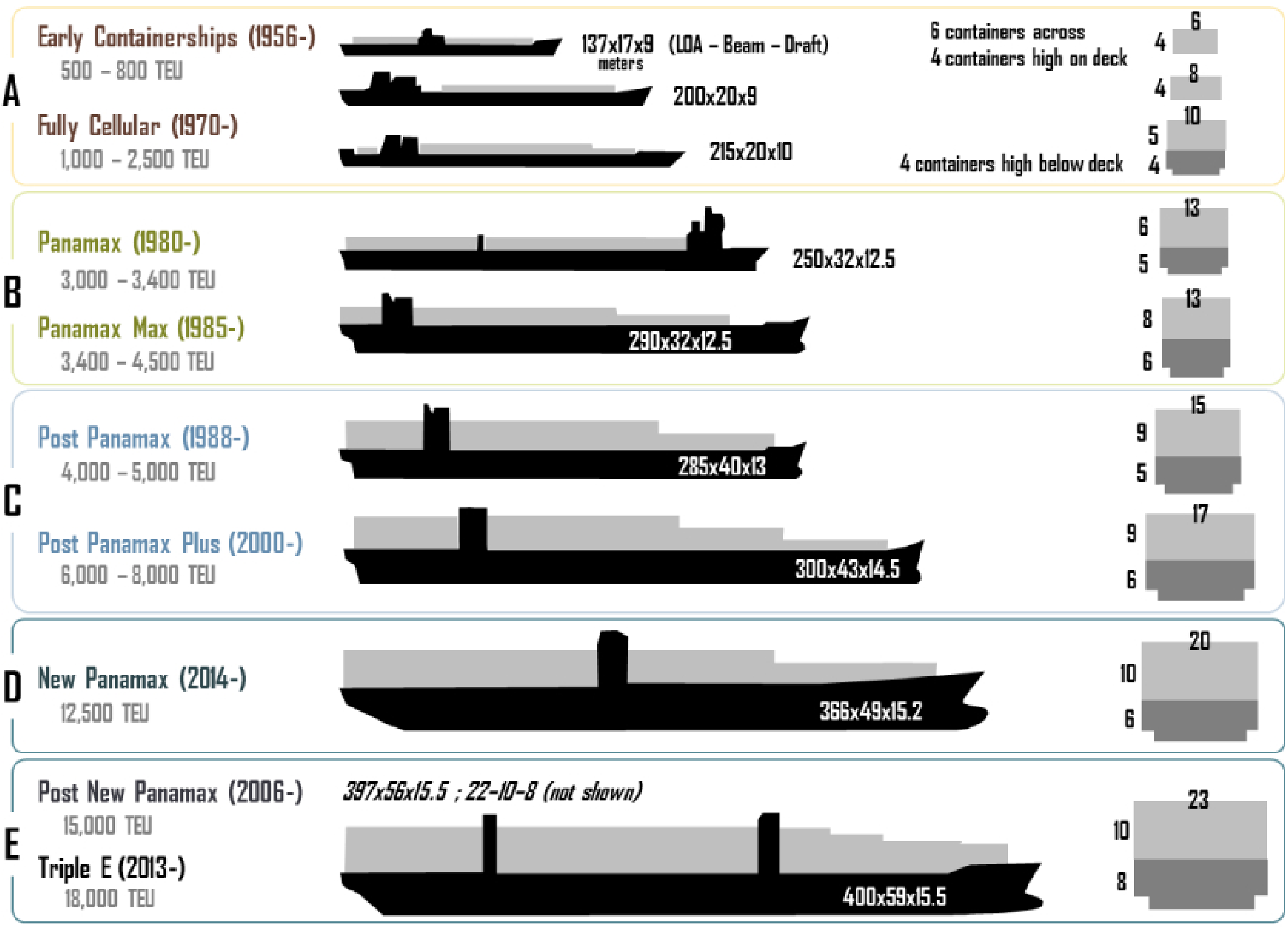

Figure 3.5 Evolution of Container Ships (Source: Rodrigue, et al (2013))

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

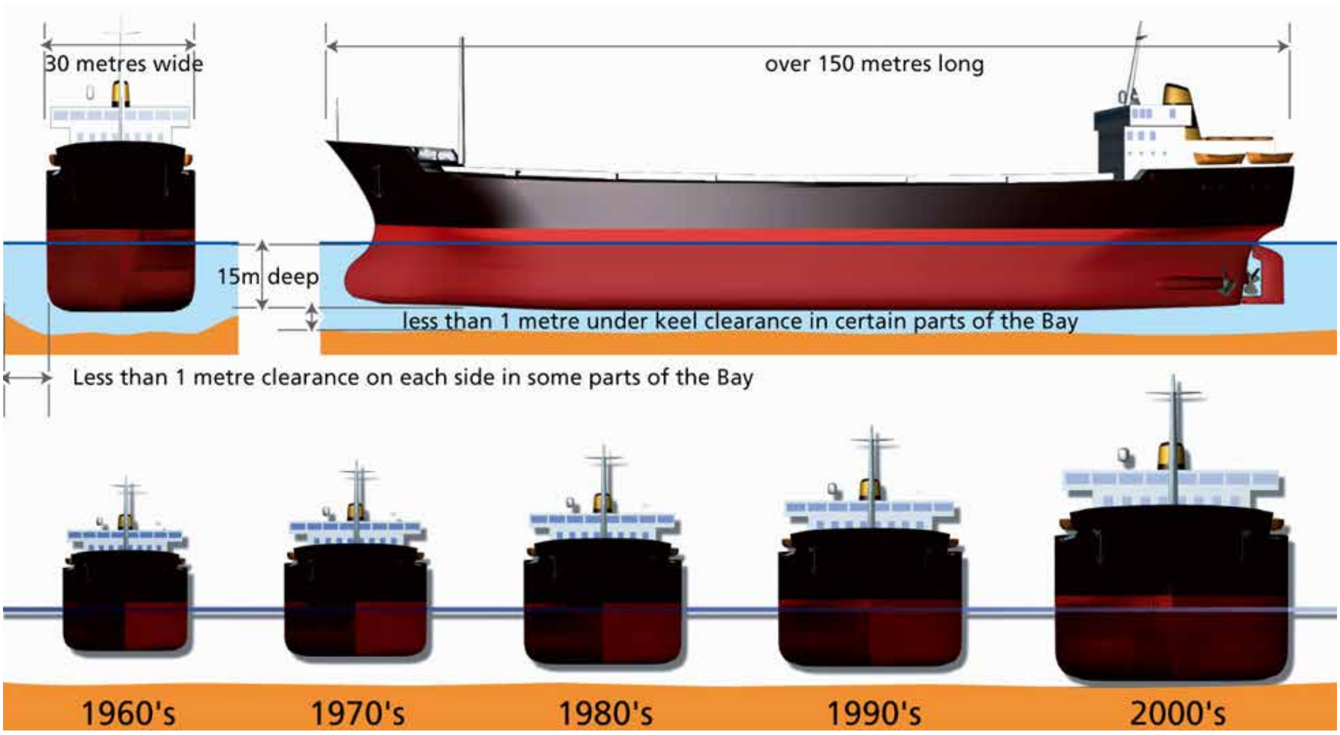

Figure 3.6 Increasing Under Keel Clearances-Bulk Vessels (Source: Brisbane Marine Pilots, 2013)

(i) Changes in vessel sizes

Figure 3.6 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 and necessitating more efficient ways of transporting cargoes.

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 secreratiat 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 year (millions tons loaded) (Source: UNCTAD 2011)

In order to deal with these increasing trading volumes, and the overall competitive position of Australian exporters in a global marketplace, bulk vessels are also increasing in size. Figure 3.7 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 3.7 also indicates the increasing draft requirements of larger vessels.

This increasing size of vessels necessitates ports 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 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.

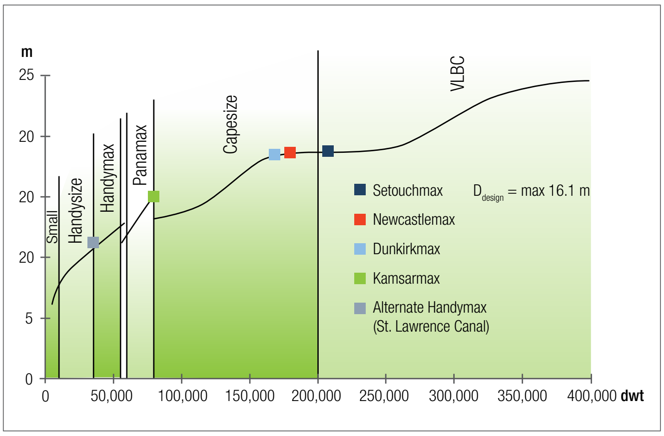

Figure 3.7: Increasing size of bulk carriers and increasing draft requirements (Source: MAN 2010)

Figure 3.8 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.

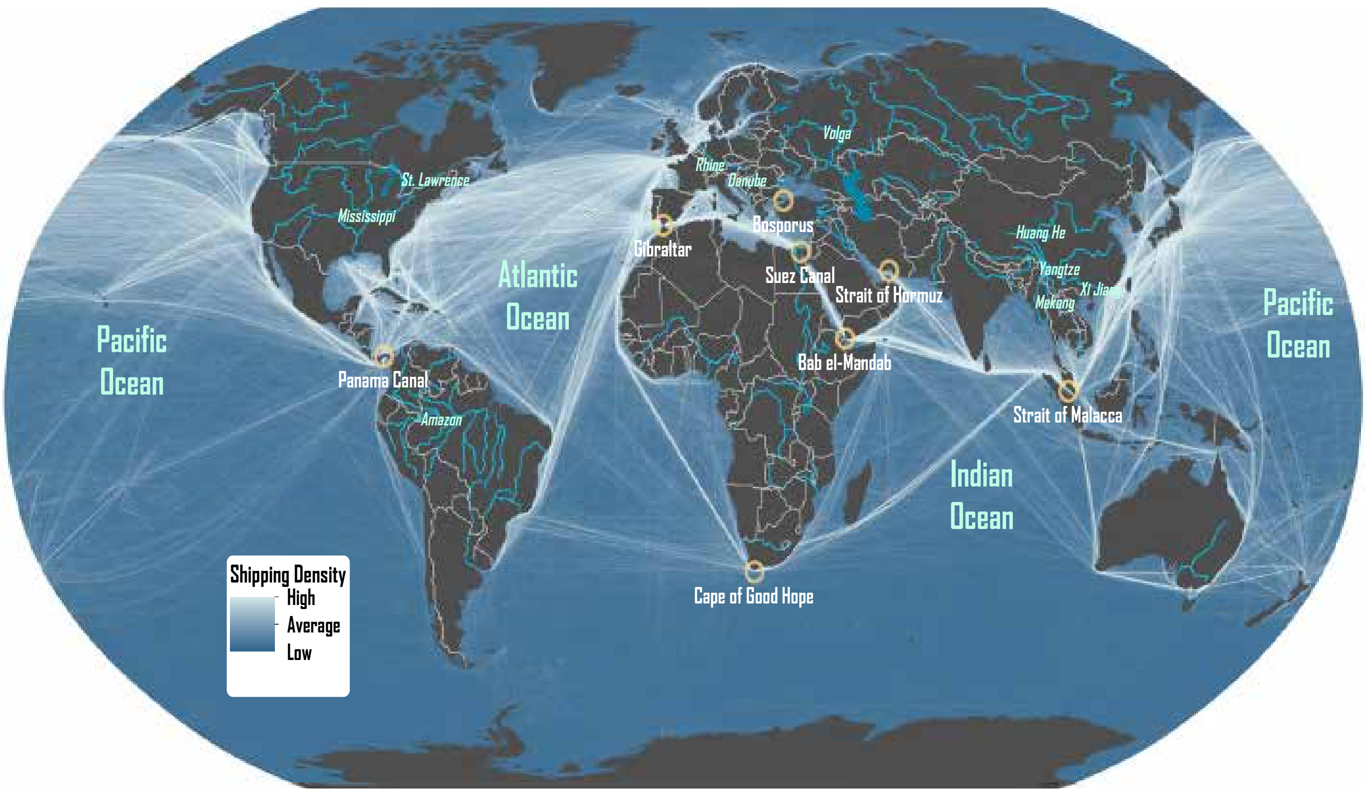

Figure 3.8: Domains of Maritime Circulation (Source: Rodrigue, et al. (2013)

(ii) Changes in channel depths

The Australian port industry has seen dramatic changes in commercial vessel characteristics (across all vessel types eg 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 average change over a 30+ year period of declared channel depths at a selected group of Australian ports. Some ports undertook major channel improvement works much earlier (eg Newcastle had a channel depth of 8m in 1962 but by 1983 the channel was at 15.2m).

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 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.

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.

Maintenance dredging involves dredging the same area for each exercise unlike capital dredging which is restricted to previously un-dredged areas.

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

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.

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

Natural events such as major storms and major floods, which are common in temperate 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 such time as hydrographic surveys have been taken and maintenance dredging has been carried out to the satisfaction of the responsible Harbour Master.

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) as the channels have been established in deep water to minimize the need to undertake ongoing maintenance (and initial capital) dredging works (see Section 3.2).

Port (and dominant cargo type)	Declared Channel Depth			
	1980	2000	2012	% increase over period
Brisbane (mixed use cargoes)	12.8m	14.0m	15.0m	17%
Adelaide (bulk cargoes)	11.2m	12.2m	14.2m	27%
Melbourne (mixed use cargoes)		11.6m	14.0m	17%
Fremantle (mixed use cargoes)	11.0m	13.0m	14.7m	33%

Table 3.2: Approximate change in declared channel depths 1980-2012 (Source: various port agencies)

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)***

Maintenance dredging needs are further minimized through the use of drag bar (or bed levelling) operations which involves dragging a heavy bar across the seabed (using a tug or work boat) to remove high points and to pull the material into a lower point (levelling out the bottom). In some areas, material is pulled into a naturally deeper part of the channel or an area that has been artificially deepened to store material. This is a key part of reducing the need for maintenance dredging and in some ports is undertaken regularly.

Not all ports are required to undertake maintenance dredging. Some are naturally deep and are subject to minor channel siltation (such as Port Botany and the Port of Hastings) requiring maintenance dredging only every 5-10 years and that may involve minor volumes. Others, particularly those near rivers, such as Newcastle, Melbourne and Brisbane, require ongoing maintenance dredging to keep channels at designated depths.

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) highlighted that the fate of dredged material may be subject to significant operational and environmental considerations by project proponents, community stakeholders and environmental regulators. The study acknowledged the difficulties in handling this material out of the marine environment:

> *"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 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 a greater explanation of such determinations).

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 – use 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 (the overwhelming volume of dredged material in Australia is from saline waters and is 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/geotechnical characteristics and limitations);
- as 'fill material' for port/airport reclamation areas commonly seen throughout the global port industry (eg Port of Brisbane (Australia), Port of Rotterdam (Netherlands), Hong Kong Airport etc);
- as 'fill material' for non-port reclamation (ie for the creation of industrial or similar land use areas); or
- the creation of 'constructed habitat' for marine based fauna such as bird roosting sites (acknowledging the significant construction costs of such areas).

Photo courtesy of Port of Brisbane Pty Ltd.

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 the physical and chemical properties of the sediment, particularly grain size and chemical contamination status.

In some instances, contaminant levels in material dredged by temperate Australian ports (eg Newcastle, Port Kembla, Sydney, Geelong) have been elevated due to historical contamination by past industries. This has limited re-use opportunities and specific management techniques (eg containment cells, leachate collection) have been required for land based disposal. The Newcastle Kooragang Island Waste Emplacement Facility which has been used to store sediments contaminated by the now closed Mayfield BHP Steelworks provides an example of such contaminant containment practices.

The underlying constraints of beneficial re-use options primarily relate to 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/characteristics;
- economic cost; and
- operational restrictions regarding the inability to relocate marine materials over long distances.

Australia's preference for beneficial re-use of dredged material rather than at sea placement is consistent with that of the United Kingdom and USA. However, practical implementation of re-use 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 and coastal system and placing it on terrestrial areas and the 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 ssues associated with potentially impacting upon these areas or sterilising them for future use;
- the potential hydrodynamic impacts to coastal sediment 'budgets' resulting from the removal of sediments from the coastal system;
- the timeframe variances of dredging campaigns which provide difficulties for site consolidation and management;
- the operational ability to relocate material over long distances sometimes through, or adjacent to, highly urbanised areas or sensitive coastal zones;
- the management of 'interface' (eg safety and reverse amenity issues etc) around disposal sites; and
- the ongoing and costly land and safety management at and around disposal sites.

The recent SKM (2013a) report on dredged material management 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 many marine sediments involved in dredging projects in inshore temperate Australian waters are Potential Acid Sulphate Soils (PASS). PASS are more commonly associated with capital than maintenance dredging projects. 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).

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.

Options for management of dredged material onshore or for a beneficial use are limited largely due to the 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. Reclamation may be an option but in highly developed or sensitive coastal zones, this presents a major challenge.

Such considerations are analysed and addressed during the impact assessment process within Australia at Commonwealth, State and Territory levels which are explained in more detail in Section 4.

At sea placement – use of Dredged Material Placement Areas

At sea placement may be an environmentally appropriate technique to manage dredged material. As noted in Section 4, material needs to be subject to detailed scientific and laboratory analysis prior to any approval being granted by government for disposal at sea.

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 offshore DMPA designated for the disposal of dredged material.

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 the 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 or threatened species, or communities and migratory species that use the area);
- economic and operational feasibility (eg sizing of site, capacities); and
- Other users (or uses) within the area (eg shipping lanes, fisheries, military, historic/heritage items).

Additional commentary on DMPAs is provided in Sections 4 and 10.

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 in relation to 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, State and Territory 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 non-harmful 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; and
- 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; and
- 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 in respect of 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 (GBRMP Act).

Commonwealth approval of dredging is required if dredging or placement is proposed to occur in Australian waters (excluding state or territory 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 of a 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 also 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. 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;
- The Great Barrier Reef Marine Park; and
- 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.

4.1.3 State and Territory Legislation

There is a variety of state and territory government legislative requirements which relate to dredging and dredged material placement that differs between the states and the Northern Territory. Whilst these vary between jurisdictions, 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; and
- coastal management and processes.

In most cases, several permits will be required. The issues covered by these state and territory 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, territories and Commonwealth is underway in relation to dredging applications to reduce the need for duplication of state, territory 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 temperate ports. These include:

- National Water Quality Management Strategy;
- State Government Water Quality Policies;
- State Government Water Quality Guidelines (often these are area specific);

Photo courtesy of Port of Brisbane Pty Ltd.

- Australian and New Zealand Environmental Conservation Council (ANZECC) Guidelines for Fresh and Marine Water Quality;
- Western Australia Environmental Assessment Guidelines;
- Regional Management Plans; and
- 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)

4.1.5 Environmental Code of Practice for Dredging and Dredging Material Management

Australian ports are in the process of preparing a Dredging Code of Practice. The Code will set out a series of principles that Australian ports follow when undertaking dredging and dredge material relocation. It describes the specific standards and processes that Australian ports adopt to minimize the environmental effects when dredging and relocating excavated seabed material. The Code recognizes the importance of other maritime users and stakeholders and describes how environmental risk assessment and management is incorporated into the planning and execution of dredging related activities.

The Code will be subject to regular review on the effectiveness and relevance of the Code against industry leading practice globally and regulatory requirements nationally. The Code will be available on the Ports Australia website, once finalised.

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 commonwealth, state and territory legislation already described. In some instances, similar information may need to be supplied to all levels of government – see Figure 4.1.

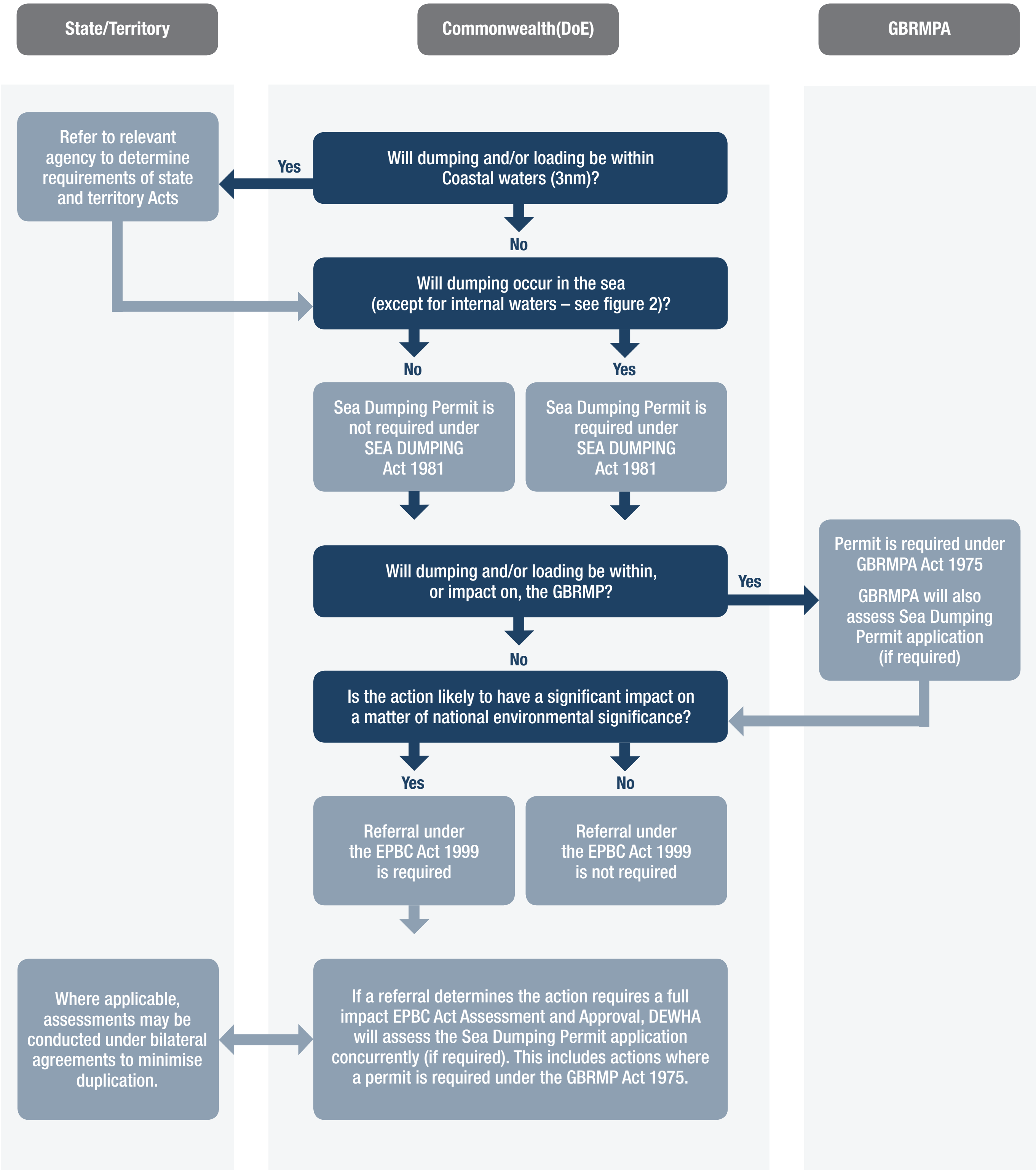

Figure 4.1: Australian Regulatory Framework and Stakeholders

The approvals process is often complex particularly for large projects in sensitive areas. Projects involving multiple jurisdictions, large volumes of material and prolonged dredging periods can take a number of years to be approved. The approvals process may require baseline data collection before works can commence and this may extend for periods of greater than a year. Smaller projects in developed areas, especially routine maintenance dredging, can be approved within a much shorter timeframe.

Recent public concern over disposal of dredged material at sea have led to approvals for this activity becoming far more complex with reviews of alternatives now involving a much broader range of stakeholder input.

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.

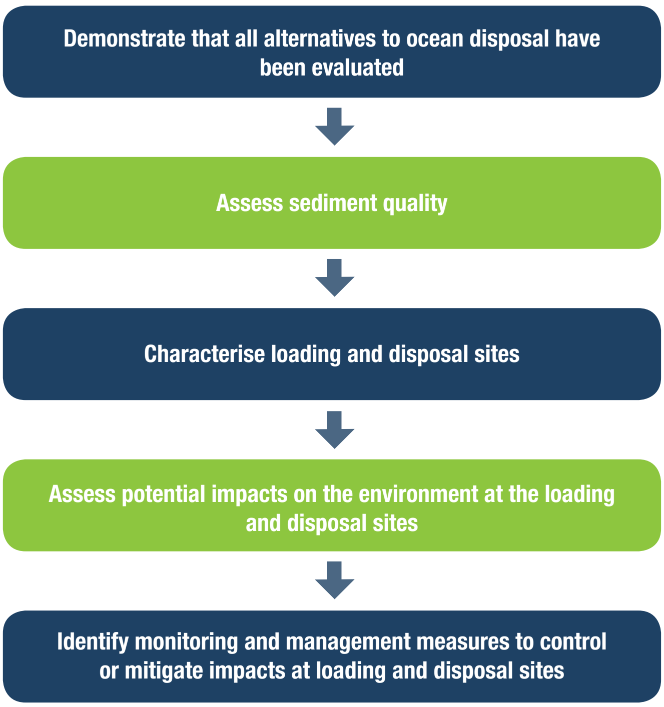

Figure 4.2: NAGD Assessment Framework

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 NAGD states (emphasis added):

*"**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 recognises, 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); and
- **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 (eg release of nutrients from sediments).

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.

Photo courtesy of Tasmanian Ports Corporation Pty Ltd.

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 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/ seasonal and spatial characteristics;
- Other uses – other maritime users such as commercial fisherman, military, public uses, shipping safety and operations etc; and
- 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 Australian/New Zealand Standards for risk management including AS/NZS 4360:1999, HB 203:2000.

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.

Through cooperation between Commonwealth, state and territory governments, the efficacy of environmental regulations relating to dredging activities is high.

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.

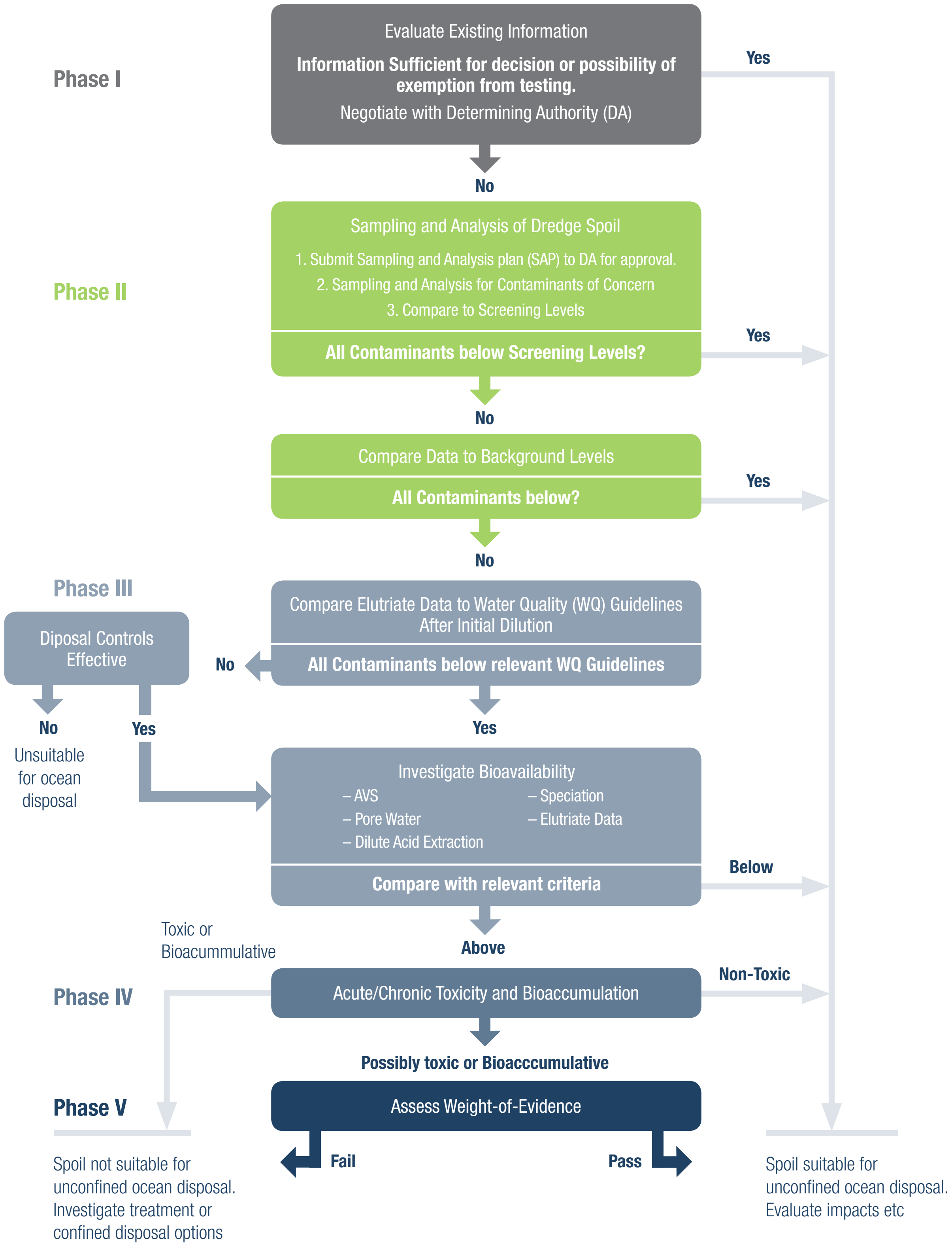

Figure 4.3: Assessment of dredged sediment and materials.

Photo courtesy of Port of Melbourne Corporation.

5. ENVIRONMENTAL IMPACT PROCESSES

This Section provides a brief overview of impacting and recovery processes associated with dredging and dredged material placement in temperate 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 and fauna from the dredge site. The environmental impact of this removal process depends upon the nature of dredging, the nature of existing communities and recolonization and environmental recovery processes.

Seabed disturbance is an unavoidable consequence of dredging. Impacts can only be minimised by ensuring the dredge footprint is as 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. Maintenance dredging exercises generally involve repeated disturbance of the same area. Dredging frequency varies from annual to periods of 5 years or more.

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 and 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.

A study of benthic fauna removed as a result of maintenance dredging at the Port of Brisbane indicated that recovery appeared rapid with dredged and undredged areas comparable 9 months after dredging (Johnson 2003).

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 temperate Australia has involved unvegetated or sparsely vegetated soft sediments (clays, silts and sands).

Impacts to the seabed from capital dredging may be much greater than for maintenance dredging and recovery slower (if at all) especially when marked changes occur to environmental conditions (eg significantly 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. In Botany Bay Sydney, comparisons between dredge and undredged areas indicated that where dredging exposed different sediments, a different benthic community recolonised areas and re-established in two to four years (SPCC 1979).

Removal of seagrasses or macroalgae 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).

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 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 temperate regions vary, depending on location and associated hydrodynamic and climatic processes, from retentive to dispersive. Many DMPAs are located in in-shore high energy areas where sediment re-suspension and dispersion is common (eg Newcastle and Port Kembla) whilst others are sited in deeper offshore areas that may be less dispersive (eg Port Adelaide). Dispersion of placed dredged material does not necessarily result in unacceptable environmental impacts as influenced communities may be adapted to periods of sediment erosion and deposition. 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 depends 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:

- 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).
- 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.
- 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 re-suspension 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 (eg Wolanski et al 1992, SKM 2013b) during placement.
- may be managed though the use of specially designed equipment. The Geelong Arm Channel Improvement project (1997) adopted a unique approach to managing surface turbidity associated with disposal of material to the seabed. This involved a specially designed 'cooking pot', a device that surrounded the discharge pipe of the cutter suction dredge with a cylindrical plastic screen that extended four metres below the surface which caused the sediment laden water to flow directly to the seabed and minimise surface plumes (Marine Science and Technology Pty Ltd 2006).
- associated with dredging and dredged material placement 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 or 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 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 turbidity increases as minimum light requirements both within and between species can be up to an order of magnitude different (Erftemeijer et al 2013).

Many seagrass species are resilient to short term reductions in light such as those resulting 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). Experience in Australia indicates dredging related impacts are extremely rare (Morton and Sprott 2014).

High levels of turbidity or 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 or mobile organisms as levels of turbidity and suspended sediments resulting from dredging are an order of magnitude (or greater) less than concentrations known to cause mortalities 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 footprint impacts, impacts to a DMPA are an unavoidable consequence of placing material at sea. As noted in Section 3, 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 10).

5.4 Contaminants

All material proposed to be placed at sea is tested under rigorous requirements set out in the NAGD using accredited laboratories. Assessments not only relate to assessment of contaminant levels in sediments but also include elutriate tests which indicate the potential for contaminant release from sediments to the water column during dredging and disposal operations, and ecotoxicology, which includes potential sub lethal effects tests.

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 temperate ports may involve sediments with significantly elevated levels of contaminants given the prolonged history of industrial development near many ports, especially capital city ports or large regional ports. Although discharges of heavy metals have declined and use of many persistent organics has ceased since the 1970s, both surface and subsurface layers in industrialised ports often contain contaminants. Capital dredging may involve historical layers which may have contaminants associated with earlier industrialisation of the catchment. For example, sediment was found to be contaminated to depths of ten metres in the Port of Newcastle (I. Irvine pers. comm.)

Contaminant issues in temperate ports often 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). In many ports (eg Newcastle and Brisbane), the key contaminant sources for port sediments are associated with industry and catchments external to the port.

As noted in Section 3.4, PASS-containing sediments are often dredged in in-shore temperate 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 re-suspension or placement of contaminated material are assessed. The NAGD prohibits the placement of toxic material at sea.

Ports that have ongoing or legacy contamination issues invest considerable time and resources in addressing such issues as part of port operation and growth to ensure environmental impacts are effectively managed. The Case Study below relates to the extensive studies at the Port of Newcastle in relation to managing contaminated sediments over the past few decades. Similar approaches and studies have also been part of the operation of Port Kembla and Melbourne. The Port of Melbourne has undertaken a broad range of monitoring associated with its use of a Confined Aquatic Disposal facility to manage contaminated material (see below).

Contaminants and Dredging Case Study

Contaminated sediments are common in many southern Australian ports reflecting their long history of development. Dredging and dredge material disposal approaches need to be carefully planned to avoid environmental impacts.

The Port of Newcastle has to manage contaminated sediments in association with dredging. Much of the inner port area has been influenced by heavy industry for almost 100 years, most notably the BHP Steelworks (closed in 1999). Harbour sediments contained large quantities of sediments contaminated with hydrocarbons and metals although much of that has now been remediated. Contaminated river sediments have been removed and placed onshore in dedicated containment cells (eg Kooragang Island Waste Emplacement Facility). Due to the high shipping volumes, TBT contamination has been historically elevated at a number of locations and particularly within the more confined dock areas.

The port has worked with a variety of consultants, including CSIRO, to assess the risks posed by the port sediments associated with dredging and disposal of maintenance dredging material at the designated offshore spoil ground. This information is used to confirm the most appropriate approach for maintenance dredging to ensure environmental impacts are effectively managed.

Over 55 studies both within the port and at the disposal area have been undertaken since 1990 (summarised in Simpson et al 2014). Appendix B provides a list of the studies undertaken from 1999 to 2009 to indicate the diversity of assessments (studies were well underway before 1999).

These studies represent one of the most prolonged and complex investigations into the management of contaminated dredge material in Australia. Notable components include field sampling and laboratory assessments (eg elutriate tests) focused on assessing the bioavailability of a range of contaminants, the use of sediment types to assess the dispersal of material placed at sea (Norman et al 1992), comprehensive ecotoxicology laboratory investigations and biological recovery surveys (NPC 2011).

The port has instigated a regular sediment testing program, consistent with the NAGD, for all maintenance dredging. Surveys indicate that improved catchment management and remediation of land based contaminated sites over the past 20 years has resulted in concentrations of historical contaminants continually declining or remaining constant. Material resulting from maintenance dredging is now consistently confirmed as suitable for unconfined offshore disposal (Simpson et al 2014a).

Harbour sediment requiring dredging is now primarily contaminated as a result of stormwater input from the adjacent urban catchment. A Stormwater Management Plan is being implemented by the local authority to reduce contaminant inputs to the harbour.

The port will need to undertake capital dredging works in the longer term to support port growth. Consequently, the port commissioned CSIRO to prepare a Port-Wide Strategy (Simpson et al 2014b) that aimed to ensure contamination issues were proactively addressed. This considered how the understanding of potential impacts has changed over numerous surveys conducted at the port and used newer and more sensitive ecotoxicology techniques to assess sediment in areas that would be subject to capital dredging

The Strategy provides a scientifically rigorous and defensible basis for assessing potential risks associated with future capital dredging and placement at sea and will form a key component of planning for port growth.

5.5 Aquatic Disposal of Contaminated Material

One option to manage contaminated dredge material involves the use of Confined Aquatic Disposal facilities (CADs). These isolate the contaminated dredged material by disposal of the contaminated dredged material at a specific aquatic site and capping. The disposal can be in natural depressions in the seafloor, or in specifically designed and constructed cells to contain the contaminated dredged material.

Many industrialized countries (eg Netherlands, Norway, United Kingdom, and USA) have effectively used nearshore CADs for disposal of contaminated dredged material (see Vogt 2009 for review). Confined ocean disposal is commonly practiced in Europe where historic contamination of sediments often precludes unconfined ocean disposal (Netzband et al, 2002). GHD (2003) reports that approximately 90% of the dredged material in the Netherlands and Germany is placed in Confined Disposal Facilities (CDFs).

CADs are an acceptable technique to manage contaminated material when costs, regulatory acceptance, environmental risk, and public perception and acceptance are considered, and have a number of advantages over on-land disposal of contaminated dredged materials. PIANC (2009) provides information on the technical aspects of design and construction of CDFs as well as the ongoing management of these sites.

Since 1990, CADs have been used in Australia at the Port of Melbourne and Port Kembla.

A total of 1.4 million cubic metres of contaminated material from the Yarra River and Williamstown Channel was dredged as part of the Port of Melbourne Channel Deepening Project (2008) and confined within an underwater CAD cell at the Port of Melbourne Dredged Material Grounds disposal site. The CAD was in water 15 metres deep, a depth at which wind and currents generally do not affect the sea floor and therefore the sediments are not moved by winds or tides. A 5 metre high clay bund with 40 metre crest width to enclose an area of approximately 12 square kilometres was built by the TSHD Queen of the Netherlands with clay dredged from the northern Bay channels. Capping, involving clean dredged sand, was used to seal off contaminated material to prevent any adverse influence on water quality. Capping did not occur until sufficient settling of the sediment had occurred (about 140 days) and took about 6 weeks. A specialised dredge pipeline fitted with a 12 metre wide spreader/diffuser lowered the material directly to the seabed to reduce the potential for sediment dispersion.

The Port of Melbourne CAD area continues to be used for the disposal of dredged maintenance material including contaminated material. The bund and capping have been subject to regular inspections and independent auditing to confirm that they had been built in accordance with the design specification and that their integrity did not decline over time (GHD 2013). Detailed monitoring for contaminants has occurred since the CAD was constructed, however, this information was not available for this report.

Dredging associated with the construction of the General Cargo Handling Facility at Port Kembla (2007-2008) involved the placement of 275,000 cubic metres of material (some of which had elevated levels of contaminants that were not suitable for unconfined open water disposal) in an inner harbour area that was proposed for future reclamation and development. Clean material was placed offshore.

The decision to retain the contaminated materials within the Port Kembla harbour area rather than adopting land based disposal was made in view of the nature of the contaminants in question and the fact that silty clays and slag, which comprised most of the material, an effective means of binding contaminants (NSW Department of Planning 2006). Regulators noted that contaminated sediments did not pose a significant risk of harm to the environment or human health but it was preferable that they be emplaced in a manner conducive to future encapsulation (ie reclamation) to prevent future disturbance and spread of the materials.

5.6 Nutrients

Dredging and dredged material placement may release nutrients held within the seabed sediments either into the water column or air (in the form of nitrogen). The ecological impact of additional nutrients (eg toxicity or eutrophication) 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 NAGD does not provide guidance in relation to nutrient levels in marine sediments.

Most assessments of nutrient related impacts associated with dredging or dredged sediment disposal at sea indicate any increase in nutrient concentrations is likely to be localised and short-lived.

Nutrient concentrations due to dredging or at sea disposal are unlikely to reach levels that could result in toxicity. Batley et al (2015) reviewed a variety of published papers on nutrient releases resulting from dredging and concluded 'there appears to be a general consensus that increases in soluble concentrations of ammonia through release of pore waters and desorption from particles (Kalnejais et al 2010) are the most common concern, while dissolved nitrite, nitrate and phosphate release were also possible but generally minor and much lesser concern'.

Several studies have noted that whilst ammonia concentrations may be high initially, marked decreases occur within minutes and typically reach background concentrations within an hour (see Batley et al 2015 for review). Phosphate is readily removed by adsorption

Photo courtesy of Southern Ports Authority – Esperance.

to particulates. Field assessments at the Mud Island Material Placement Area (MPA), Moreton Bay, Queensland, indicated that ammonia concentrations rapidly decreased from 22 µg/L within 10 minutes of disposal to <2 µg/L within an hour (Richardson, private communication, discussed in Batley and Simpson (2009)).

Elevated nutrient levels in the water column as a result of dredging or sediment placement at sea are also of interest as there may be a potential for eutrophication-related (algal bloom) water quality issues. The potential for algal blooms will depend on turbidity levels and how much this reduces the light regime as well as the ratio of nitrogen to phosphate and on the duration of the nutrient pulse.

Batley et al (2015) reported that the duration of the localised exposure and the near-field dilution should be sufficient to ensure there was little likelihood of nutrient releases associated with dredged sediment placement at sea resulting in eutrophication or algal blooms. Morin and Morse (1999) and Cornwell and Owens (2011) concluded that nutrient re-suspension associated with dredging does not contribute to eutrophication. Eutrophication issues are more likely to be an issue in enclosed water bodies where rates of dilution are low.

Jones and Lee (1981) in a keystone paper examined nutrient release at over 20 dredging sites and 9 disposal sites. Assessments indicated that 1% of total nitrogen and <0.1% of total phosphate was released during sediment disposal. The authors concluded that 'in general, dredged sediment-associated nutrients will rarely have an adverse effect on eutrophication-related water quality at the disposal site mainly because the events are short-lived, there is typically fairly rapid dilution of the disposed-of sediment, and, relative to the dilution, nutrient release is small. The potential impact must be evaluated on a site-by-site basis.'

Several authors have compared nutrient releases from dredged material placed at sea with natural events. Batley et al (2015) noted that the measured total nitrogen and total phosphate concentrations associated with dredged sediment disposal practices in Queensland (Gladstone and Townsville) are not that different from what might be

introduced to nearshore waters as a result of flood events. The key difference is that nutrients resulting from dredged sediment disposal persist for minutes whereas the plume of flood events will persist for longer (days to weeks). The Victorian EPA (2001) commented that nutrient increases due to dredging are comparable to the effects of storms which affect much more extensive areas. Larcombe and Ridd (2015) noted that tropical Cyclone Winifred (1986) resuspended approximately 140 million cubic metres of sediment (Carter et al 2009), so that, assuming the total nitrogen content of the sediment is 0.03% (Furnas et al 2011), the cyclone disturbed 50,000 tonnes of nitrogen, compared with perhaps 1,000 tonnes for a large three million cubic metres capital dredging project.

As the quantities of nutrients involved with dredging/at sea placement are typically very small, there is little potential to contribute to longer term nutrient levels. Dredging related releases are at least an order of magnitude less than natural nutrient fluxes associated with exchanges between the top layer of the sea bed and the water column (Larcombe and Ridd 2015).

Cornwell and Owens (2011) concluded that overall release of nitrogen (as ammonium) via dredging was <0.5% of the upper Chesapeake Bay (USA) nitrogen loading and <1% of the sediment N nitrogen flux in the same area. They concluded that because of the good flushing and rapid dilution in Chesapeake Bay, dredging was expected to have only a minor impact on nitrogen releases.

Studies for the Melbourne Channel Deepening project indicated that only a small fraction of the nitrogen released by dredging would be in a form that can be utilised by marine organisms (ie bioavailable). The Independent Expert Group advised that, considering the quantity and variability of ambient nutrients, the dredging would not be expected to result in major or long-lasting changes to the Bay's nutrient cycling processes. The Statement of Environmental Effects concluded that 'the risk of indirect effects is predicted to be typically very low or at most minor because the effects of the plume and the dredging are limited in time and space' Victorian Government (2007). Monitoring during dredging indicated that there was 'no evidence of measurements outside expected variability' and 'no deleterious changes to nitrogen cycling in Port Phillip Bay' (Longmore and Nicholson 2008).

In some cases, 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). Dredging of sand in Moreton Bay Queensland resulted in a short-term measurable beneficial effect to benthic infauna for several kilometres, apparently due to localised nutrient releases (Poiner and Kennedy (1984).

5.7 Environmental Recovery Processes

Environmental recovery[2] or recolonisation of dredged or 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.
- **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 the Hawkesbury River 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), 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 able 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 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 (e.g. diversity).

Photo courtesy of Fremantle Ports.

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

This section provides a list of dredging projects associated with Australian temperate 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 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 for southern Australian ports, although reviews have been carried out for ports in northern Australia by Morton and Sprott (2014) and by Hanley (2011) for the Pilbara region, and SEWPaC (2013) for the Gladstone area.

Projects conducted by temperate Australian ports included in this review are shown in Table 6.1. Summary results of these projects are presented in Section 7 whilst Appendix A provides a detailed description of each project including:

- year of completion (some projects have been staged);
- duration;
- 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; and
- 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 (the list is not comprehensive) and do not form part of the statistics referred to in this section or Section 7 as many involved limited monitoring considering previous monitoring results in the same location (see Section 7.1).

6.2 Monitoring Oversight

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 have rarely designed monitoring programs, although they typically specify key components that must be included. On some occasions (eg the Melbourne Channel Deepening Project) regulators provided proposed monitoring programs to independent third parties for review.

Some states require the involvement of independent parties as part of dredge monitoring programs. The Office of the Environmental Monitor (part of the Victorian Audit Office) was established in 2007 to oversee and review monitoring associated with the Melbourne Channel Deepening Project whilst in South Australia an Independent Verifier is appointed to review and report on the monitoring process including the reliability of results. Similarly, the approval conditions for the Port Botany Expansion required an annual independent audit of compliance against approval conditions.

It is noteworthy that the Office of the Environmental Monitor was also appointed to 'communicate all available information on the Project's environmental performance in a timely manner to stakeholders and the community' rather than the Port of Melbourne (see Section 9.1). This is unusual and most communication for large capital projects has been undertaken by ports.

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 thereof) are well understood.

Some monitoring for maintenance dredging involves periodic water quality sampling or visual assessments only.

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).

The larger dredging projects in capital cities (and some of the smaller projects) have all been required 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 seagrass).

Reactive monitoring of ecological receptors has become the most common monitoring approach adopted by temperate 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 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 temperate 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 Victorian EPA Guidelines for Dredging) and approaches (eg the Western Australia EPA 'zones of impact' approach, WA EPA 2011) may specify issues to be addressed and 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.

Location	Project
QUEENSLAND	
Brisbane	Spitfire Channel Realignment (2002-ongoing)
NEW SOUTH WALES	
Newcastle	NCIG Berths 8 and 9 Dredging Project (2007-2010)
Sydney	Port Botany Expansion (2011)
Port Kembla	General Cargo Handling Facility (2007-2008)
VICTORIA	
Melbourne	Channel Deepening Project (2008-2009)
Geelong	Geelong Arm Channel Improvement Program (1997)
SOUTH AUSTRALIA	
Port Adelaide	Outer Harbour Deepening (2006)
WESTERN AUSTRALIA	
Fremantle	Fremantle Ports Inner Harbour Deepening Project (2010)
Geraldton	Channel Enhancement Project (2001-2002).

Table 6.1: Port capital dredging projects included in this review.

Photo courtesy of Port of Brisbane Pty Ltd.

- 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.

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 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 to monitor potential turbidity or sedimentation impacts to a broader range of marine communities.

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) 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 temperate 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.

Whilst water quality monitoring has been a prerequisite of all recent monitoring programs in temperate ports (see Section 7), there has been an increasing requirement to monitor seagrasses as these:

- are of high environmental and conservation value;
- are considered to be sensitive to key turbidity and sedimentation impacts; and
- 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 seagrasses vary widely in their sensitivity to turbidity

and sedimentation. Defining meaningful impact thresholds requires site-specific information on ambient turbidity and sedimentation and on the species composition of seagrass communities potentially influenced (PIANC 2010, 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 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 temperate 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 seagrass or other sentinel indicators was maintained, then other key ecological assets would be protected.

Threshold definition is particularly difficult for inshore areas where most dredging by temperate 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. Research to establish site specific thresholds 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 two to three 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). As previously described, dredging and dredged material placement in many cases has required commonwealth, state and territory 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.

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. This may involve the use of the third party reviewers (see Section 6.2).

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 (Western Australia 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).

> *"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***

Commonwealth, state and territory 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 (eg volume, duration) and related monitoring programs in temperate Australia.

7.1 Scale and Duration of Dredging

Capital dredging

The volumes of material dredged in the capital dredging projects included in this review are shown in Table 7.1 with the Port of Melbourne being the largest project conducted over the past 20 years. Two of the three largest projects (Port Botany and Fremantle) used dredged material to reclaim land for future port uses.

The two largest projects were associated with Sydney and Melbourne.

The duration of capital projects ranged from a few weeks to two years and was primarily linked to the volume to be dredged, the equipment used (ie type and number of dredges) and the nature of the 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 TSHD and CSD.

Location	Project	Volume (Mcum)	Duration (months)
QUEENSLAND			
Brisbane	Spitfire Channel Realignment (2002-ongoing)	15.0 (max. of 4.0/yr,<0.5/yr to date).	< 1 (ongoing)
NEW SOUTH WALES			
Newcastle	NCIG Berths 8 and 9 Dredging Project (2007-2010)	0.60	30
Sydney	Port Botany Expansion (2011)	7.8	26
Port Kembla	General Cargo Handling Facility (2007-2008)	0.28	16
VICTORIA			
Melbourne	Channel Deepening Project (2008-2009)	22.9	24
Geelong	Geelong Arm Channel Improvement Program (1997)	5.0	8
SOUTH AUSTRALIA			
Port Adelaide	Outer Harbour Deepening (2006)	2.7	8
WESTERN AUSTRALIA			
Fremantle	Fremantle Ports Inner Harbour Deepening Project (2010)	3.1	6
Geraldton	Channel Enhancement Project (2001-2002).	4.1	13

Table 7.1. Volume and duration of capital dredging projects associated with temperate ports included in this review.

None of the projects were restricted to dredging at specific time periods to minimise environmental impacts ('environmental windows') unlike projects in subtropical/tropical Australia (Morton and Sprott 2014). This is presumably because alternative management techniques were available or there were fewer well defined periods of environmental sensitivity (eg coral spawning events) in the dredge project area.

Maintenance Dredging

Maintenance dredging operations in temperate ports vary considerably from continual dredging (as at the Port of Newcastle) to periodic dredging often involving large volumes (such as at the Port of Melbourne and Brisbane) to minimal dredging (as at Port Botany).

Periodic dredging is mainly undertaken in the summer months when weather conditions are favourable. Overall, maintenance dredging in temperate ports is much more variable between ports and years compared to northern Australian ports which may be subject to regular wet season influences.

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 and berths to designated depths. Maintenance dredging needs vary significantly depending upon weather conditions which may affect the rates of sediment accumulation.

The Port of Brisbane TSHD, the Brisbane, undertakes maintenance dredging of Queensland ports but on occasions has been used for southern ports such as Melbourne and Launceston.

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 there was significant stakeholder demand for environmental impact information or 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 to 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. Some studies used a gradient analysis approach post dredging seeking to detect a spatial gradient in, for example, seagrass condition with effects decreasing with distance away from the dredge area (eg Tanner and Rowling 2008).

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).

Some dredge monitoring programs were an extension of existing programs especially with regard to water quality. The Victorian EPA had been monitoring water quality in Port Phillip Bay at six sites for over 30 years but expanded the monitoring program for the duration of the Melbourne Channel Deepening Project and for two years following its completion from 2008 to 2011.

7.3 Monitoring Parameters

Water Quality

All capital dredging and dredged material placement projects included in this review monitored water quality (Table 7.2). Water quality parameters typically monitored included turbidity, suspended sediment, salinity, pH, temperature and dissolved oxygen. Nutrients and or associated effects (eg algal blooms) were also monitored for projects where such issues were considered potential risks (eg the Melbourne Channel Deepening Project).

Sediment quality has also been measured where contamination issues are involved. For example, Melbourne, Newcastle and Port Kembla have undertaken comprehensive assessments of sediment quality at and near the at sea disposal sites. Some of these programs have extended for many years (see Section 5.4).

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.

Port	Monitoring parameters				
	Water Quality	Seagrass	Mangrove	Sediment Quality	Other
Brisbane	✓				
Newcastle	✓			✓	
Sydney	✓	✓	✓	✓	✓
Port Kembla	✓			✓	
Melbourne	✓	✓		✓	✓
Geelong	✓	✓		✓	
Adelaide	✓	✓			
Fremantle	✓	✓		✓	✓
Geraldton	✓	✓			

Table 7.2. Summary of monitoring parameters for capital dredging monitoring programs

Monitoring programs have often been required to include metal or pesticide levels as contaminated sediments are common in many temperate Australian ports (more so in maintenance dredging projects than capital projects). Monitoring for metal or pesticides was included in several projects (eg the Melbourne Channel Deepening Project, Port Adelaide Outer Harbour Development, and Newcastle Berths 8 and 9) in relation to potential influences from historic industrial activities.

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 temperate ports typically require less frequent and complex water quality monitoring for maintenance dredging than capital works (see Appendix A - monitoring design). Monitoring often involves confirmatory assessments of water quality in relation to plume extent and, on occasions, pre and post dredging surveys of a nearby sensitive receptor (typically seagrass).

Sensitive Receptors

Temperate Australian ports have monitored a broad variety of sensitive receptors including seagrasses, mangroves, corals, macroalgae, birds and fish in association with dredging and dredged material placement (Table 7.2).

Seagrasses have been the most common sensitive receptor monitored in temperate ports over recent years (Table 7.2). 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 seagrasses to dredging or placement related effects, and hence their suitability as indicators of environmental health, can be difficult.

The nature of the receptor monitored was often highly location specific (eg Little Penguin monitoring at Melbourne). This, to some extent, reflects the large residential populations that occur near dredging operations in temperate ports and the associated greater desire for a broad range of information than occurs at the more isolated northern Australian ports.

For example, monitoring for the Melbourne Channel Deepening Project and Port Botany Expansion each included over 20 separate monitoring programs. The Melbourne project involved 13 bay-wide monitoring programs that collected information on the bay's health for up to 2 years post dredging. These also included monitoring programs in relation to effects on fisheries such as contaminant levels in recreational fish and monitoring of juvenile snapper and whiting fish stocks.

Many of the sensitive receptors monitored by ports (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.

Photo courtesy of Port of Melbourne Corporation.

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 temperate Australia have resulted in impacts consistent with approval conditions.

8.1 Approach

This intent of this review of port related dredging and dredged material placement projects (Appendix A) in southern 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 seagrass mortality at an impact monitoring site;
- **consistent with the level approved** – a defined level of impact may have been approved; eg most commonly, this category related to a requirement to have no impact to a sensitive receptor; or
- **less than the level approved** – in many cases, a defined level of impact was approved, eg < 5% net seagrass mortality at an impact monitoring site.

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 were 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 monitoring programs were an extension of existing programs especially with regard to water quality, such as the enhancement of the Port Phillip Bay EPA program for the Melbourne Channel Deepening Project, which would increase the potential to detect longer term or chronic effects.

8.2 Results

The review indicated that dredging and dredged material placement projects by temperate 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 nine major capital dredging projects reviewed (Appendix A), eight reported impacts that were consistent or less than those approved and one reported impacts that were greater than approved. Approval application documentation for one dredging project predicted that impacts would occur to a sensitive receptor (seagrass) but the consequent extent could not be quantified due to inadequacies in the monitoring program design.

Water quality conditions associated with the capital dredging projects were generally within prescribed criteria and approval conditions with one key exception (Port of Geraldton Channel Enhancement Project 2001-2002). Monitoring of parameters related to contamination was common given the nature of some sediment dredged, No programs 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 (recognising none were predicted).

As noted earlier the monitoring requirements for maintenance dredging are typically much less than for capital, reflecting the lower volumes, shorter duration and lower environmental risks. Levels of impact are rarely specified and requirements most commonly involve confirming that predicted water quality impacts (eg plume extent) are meet. All of the maintenance projects listed in Appendix A reported compliance with approval conditions.

8.2.1 Capital City Ports

The two largest projects undertaken in southern Australia over the past few decades were the Melbourne Channel Deepening (2009) and Port Botany Expansion (2011) projects. Both had substantial environmental management and monitoring budgets (>$50M) and involved over 20 separate monitoring programs. Both incorporated local scale monitoring and broader region monitoring (eg Melbourne had 13 bay-wide monitoring programs). The range of attributes monitored was extensive including water quality, contaminants, birds, and fisheries (see Appendix A).

Both projects were subject to independent monitoring, review and auditing which concluded that the projects were completed well within prescribed levels of impacts. Impacts to water quality were much less than prescribed compliance levels throughout the projects and no dredging related impacts were detected in regard to biological indicators.

Many monitoring programs associated with these two large projects indicated that impacts were far less than predicted and no unanticipated impacts occurred. The Office of Environmental Monitor, formed specifically to independently monitor and assess the impacts of the Melbourne Channel Deepening Project, reported that for all monitoring 'the environmental impacts of the project were well within the acceptable ranges which were set at project approval and there was comprehensive compliance with all environmental approval conditions' (Office of Environmental Monitor, 2012). Importantly, the Office of Environmental Monitor (2012) also noted that 'the health of Port Phillip Bay was not compromised and remains consistent with that seen over the last decade and no remedial action or post-dredging recovery activity is required'.

The Fremantle Ports Inner Harbour Deepening Project (2010) also involved monitoring of a broad range of attributes including corals, macroalgae, and seagrass. Monitoring did not detect any unanticipated dredging related impacts and impacts were generally much less than predicted or approved. In several instances, there was a net gain of the monitored habitat (eg seagrass and macroalgae) over the project in contrast to the predicted losses. This may have been the result of limitations of the habitat mapping technique (aerial photography and satellite imagery) or a general regional increase in seagrass over the dredging period (reflecting the significant influence of natural variability associated with environmental resources).

The Outer Harbour Deepening Project at Port Adelaide (2006) undertook an extensive water quality monitoring program during dredging. In most cases, the Independent Verifier concluded that criteria were met although there were several occasions were action turbidity triggers were exceeded and dredging had to halt. Exceedances were short term and it was noted that levels experienced at such times were comparable to those associated with routine shipping movements (eg using the swing basin or berthing). Documentation associated with the approvals process for the project indicated that seagrass near the channel to be dredged could be impacted (KBR 2004). The port commissioned a seagrass survey (Tanner and Rowling 2008) after dredging was completed which indicated dredging had adversely affected seagrass that may have fringed the channel. Unfortunately no pre-dredging seagrass surveys were conducted to assess the distribution of seagrass before works commenced, however, it was recorded in surveys two years prior to dredging. One year after dredging, the seagrasses at all study sites showed good signs of recovery (Tanner and Rowling 2008).

The ongoing deepening of Spitfire Channel at Brisbane involves the excavation of clean sand with extremely low fines content. Turbidity plumes are minimal and no sensitive receptors are located nearby. Consequently monitoring is only required for turbidity and is infrequent. Results of monitoring indicate short term localised impacts only.

8.2.2 Regional Ports

The largest dredging projects in regional southern Australia have occurred at Geelong and Geraldton.

Monitoring at Geelong for the Geelong Arm Channel Improvement (1997) works indicated that seagrass communities adjacent to the dredge area were virtually unaffected by dredging, consistent with predicted impacts. Turbidity and sediment deposition near the channel was significant in some instances but apparently only led to minor seagrass impacts (some leaf necrosis) at two sites closest to dredging towards the end of the program. One unanticipated impact

was that filamentous algal associated with seagrass declined due to increased light attenuation and that this may have resulted in increased seagrass growth (Marine Science and Technology Pty Ltd 2006).

In contrast, the Geraldton Channel Enhancement Project (2002) resulted in dredging impacts to water quality and seagrass communities that were much greater than predicted. The project resulted in the fine sediments being suspended and transported large distances by currents. The turbidity plume was substantial for up to nine months and extended for up to 70 km along the coast (Mulligan 2005 reported in McMahon et al 2011). Seagrass decline (72%-100%) immediately following dredging was extensive (up to 5 km from the dredging operation). Substantial recovery of seagrass has reportedly occurred since then but by 2007 had not reached pre-dredging levels (Babcock et al 2008). Potential causes for the higher than predicted turbidity levels for the Geraldton project are unclear but may have been the result of a poor understanding of how the limestone material being excavated would fragment into very fine particles when dredged.

Other regional capital dredging projects included those at Newcastle and Port Kembla. Both involved monitoring of water quality (mainly turbidity) in highly developed port areas distant from sensitive receptors. Consequently, monitoring primarily related to assessments of sediment quality associated with placed sediments and ensuring plumes were consistent with those predicted and water quality impacts were confined to predicted areas.

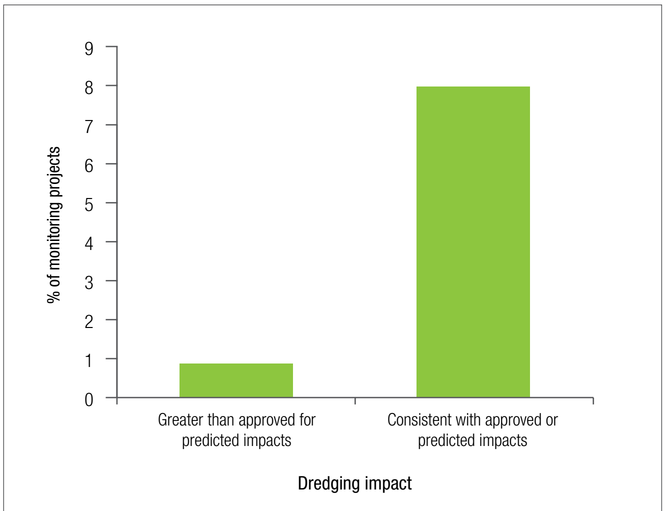

Figure 8.1: Approved or predicted impacts compared to monitored impacts for capital dredging projects

8.3 Overview

This review has indicated that the monitored environmental impacts of dredging and dredged material placement at sea over recent years in temperate Australia ports were within the level of those approved or predicted with one exception.

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.

The Geraldton Channel Enhancement Project (2002) resulted in significant dredging related impacts to water quality and seagrass communities that were much greater than predicted. Learnings from this project have been incorporated into future dredging impact assessments.

Photo courtesy of Port Authority of NSW – Newcastle.

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 temperate 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 social and conservation value and effective monitoring and management of potential impacts must occur to ensure those values are not diminished. This is particularly important when sediments may have elevated levels of contaminants and project specific management techniques need to be adopted (eg uses of Confined Aquatic Disposal facilities).

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 in relation to the environmental performance of port related dredging. The review indicated that, with the exception of one project, recent port related dredging and dredge material placement projects in southern 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.

The single confirmed exception (Geraldton Channel Enhancement Project) resulted in major and widespread impacts due to dredge plumes being quite different in composition and extent to those predicted. In recognition of this significant impact, far greater emphasis is now placed on geotechnical aspects in turbidity plume predictions.

9.1 Public Perceptions of Dredging

Little information is available for the public in relation to the environmental performance of dredging projects in temperate Australian ports despite the considerable monitoring programs associated with most projects.

Most public information is technical in nature and relates to the specific project only. 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) often as a key requirement of the approval process. However, this generally relates to descriptions of management practices to reduce impacts rather than the actual effectiveness of such measures.

Information to address broader public perceptions of dredging and the extent to which dredging projects in Australia have met the required level of environmental protection is not easily accessible. Consequently, assumptions of widespread and unintended impacts have become commonplace and are generally based on historic dredging projects or single projects where unanticipated impacts occurred.

Few appreciate the considerable recent improvements to dredge management practices globally that have occurred since the 1990s. 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 cubic metres of material has been dredged and no detectable impacts have been recorded more than 300 metres outside the direct impact zone (Doorn-Groen 2007).

Large dredging projects in Australia are now subject to a high level of environmental management and monitoring. For example, the Port Botany Expansion was subject to more than over 100 development conditions relating to environmental issues. Similarly, the Melbourne Channel Deepening Project had 58 project environmental controls that

prescribed when, where and how the project works should be delivered. Each of these was independently audited throughout the project by the Office of the Environmental Monitor which was established by the Victorian Government to provide an independent scrutiny of the project's environmental performance. The monitor's audit concluded that 'there was a high level of compliance with the requirements, and the non-compliance identified was of a minor nature and not likely to give rise to a serious, adverse environmental effect'.

This high level of compliance is a feature of most recent dredging projects in Australia. Both this review of recent major capital dredging projects in southern Australia (9 projects) and an earlier review of the performance dredging projects in northern Australia (14 projects, Morton and Sprott 2014) involving more than 50 monitoring programs indicated a high level of environmental performance. Many members of the public would not be aware that almost all of these dredging projects have resulted in impacts well within or less than approved levels.

However, there have been two projects in Australia (Geraldton and Hay Point) where significant unanticipated impacts on seagrass communities were recorded. In both instances, monitoring has indicated rapid recovery of the affected areas (Babcock et al 2008, Chartrand et al 2008).

Concerns over contamination issues are common given that, in many southern Australian 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 (eg Melbourne Channel Deepening Project) and can be present significant environmental risks requiring special management techniques.

However, adoption of the current detailed sediment quality assessment process (the NAGD), enables effective management of contaminated material. Monitoring studies have shown that water quality has not been adversely affected and unacceptable levels of contaminants such as heavy metals or pesticides have not been recorded during dredging.

Given the levels of public concern expressed in relation to dredging, there is a need for stakeholders to routinely receive more transparent and understandable information on the impacts of dredging projects undertaken by Australian ports.

The Independent Review of the Port of Gladstone (SEWPaC 2013) noted how there was limited reporting of the 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 dredge 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.

Importantly, improved awareness of both the impact assessment process and the actual monitoring results 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 temperate ports reviewed, particularly those in capital city ports, were complex and involved a broad suite of parameters. This reflects both:

- the substantial urban populations occurring in or near such ports and hence the broad range of social values potentially affected and range of stakeholder concerns; and
- the high value placed on environmental resources (near capital city ports especially) as there may be remnants of habitats and populations that were far more extensive prior to development of the port environs (eg Little Penguins associated with Port Phillip Bay).

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 Western Australia, Environmental Assessment Guideline for Marine Dredging Proposals).
- **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 such as potentially occurred with the Fremantle Ports Inner Harbour Deepening Project (2010).

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 to 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 is expensive.

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).

The Port Botany Expansion approvals required a broad range of offsets including about $8 million to rehabilitate and expand the Penrhyn Estuary so as to secure the area for protected migratory birds.

9.5 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 temperate Australian ports.

- Port infrastructure planning needs 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. This review indicated that such issues have routinely been considered as part of capital dredging projects.
- Environmental monitoring of dredging and dredged material placement projects, particularly near areas of high conservation or social 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.
- There is a need to communicate to stakeholders 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.
- Far more emphasis needs to be placed on broadly communicating to stakeholders that:
  - almost all recent dredging and dredged material placement projects in Australia have not resulted in impacts to environmental resources of high conservation value; and
  - 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 enable a more informed and factually based discussion on future projects.

Photo courtesy of the Port of Brisbane Pty Ltd.

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 temperate 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 temperate ports have a designated offshore area where clean dredged material is relocated. DMPAs occupy a relatively small area of the coast (most individually are a few square kilometres) and are specifically located to minimise potential environmental and social impacts, see Section 3.4).

In some cases, material is contaminated and not suitable for unconfined offshore placement and is instead relocated to specially designed Confined Aquatic Disposal facilities as occurs at the ports at Melbourne and Port Kembla. Both forms of dredge sediment relocation are subject to monitoring to confirm their effectiveness and consistency with impact predictions and approval conditions.

A key consideration in the approval process for using, or establishing, a DMPA is the recognition that the designated area will be unavoidably severely 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.

A complex environmental impact assessment process is required to obtain an approval to place material at sea (see Section 4) 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).

Areas influenced by placed dredged material will recover over time. There is no consensus in the literature as to what constitutes recovery (Wilber and Clarke 2007). Some studies refer to recovery as a return to pre-disturbance conditions whereas others indicate recovery is attained once the impacted area is equal to or exceeds an undisturbed reference area in terms of biological metrics.

Published information on biological recovery processes at DMPA used by temperate Australia ports is scarce. Impact assessments for the Melbourne Channel Deepening Project suggested that infauna assemblages associated with disposal areas would be expected to recover in 6 to 12 months of project completion (Victorian Auditor-General 2012).

Anecdotal reports indicate that biological recovery monitoring has occurred at Port Kembla, Sydney, Newcastle and Port Phillip Bay. Much of this occurred in the late 1980s and early 1990s and details could not be located for this report.

Studies at Queensland ports (Cairns, Townsville and Hay Point; Motta 2000, Neil et al 2003, Chartrand et al 2008, WorleyParsons 2009) have shown that:

- community recovery 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; and
- surveys undertaken 3-11 months after placement activities (port and year dependent) indicated the benthic community of the DMPA was not substantially different from adjacent or reference locations.

A literature review (eg Bolam and Rees 2003) of recovery at DMPAs indicates that impacts and recovery processes are site specific.

However, the review also noted that recovery from dredged material placement may occur within months in shallow wave influenced or high energy environments presumably because communities were adapted to sediment erosion/deposition processes and placed material was of similar grain size to that at the DMPA.

Recovery may be much slower (if at all) if markedly different grain sized material is placed at the DMPA (Borja et al 2010). Investigations of seabed communities at the Port of Newcastle DMPA showed that the biodiversity and benthic productivity was reduced compared to nearby areas (The Ecology Lab 2003). This was attributed to the differing physical characteristics of the placed material (muds and silts) to the nearby seabed (sandy material).

Wilber and Clarke (2007) reviewed recovery processes at 50 dredging and disposal sites and noted that recovery in shallow areas typically occurs within months. Recovery in stable deep water areas where communities were not subject to frequent natural disturbance was found to be more prolonged, potentially taking years. Recovery rates were also much longer in cooler temperate climates where biological processes may operate at longer time scales than more tropical areas. They concluded the most important factor determining recovery rates was the prior disturbance of the habitat in question. Benthic recovery occurs more rapidly in shallow areas where the resident species assemblages are adapted to shifting sediments.

Overall, the limited results of monitoring inshore DMPAs used by 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 high impact areas, impacts from dredged material placement in shallow inshore areas are likely to be short term and recovery of the area could be expected to occur within 12 months. Slower recovery can be expected if material is placed in more stable (often deeper) habitats.

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.
- Capital city ports need to expand to support the ongoing growth of the Australian economy. This requires greater volumes of export and import cargoes to support the large populations and manufacturing industries associated with city ports.
- Regional ports in southern Australia are increasing their bulk export trade (eg minerals, coal, agricultural products) or are being seen as alternatives to the increasingly congested capital city ports.
- Increasing numbers and larger commercial vessels are calling at Australian ports. A substantial increase in the size of container ships and bulk vessels 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.
- Ports adopt a variety of channel and berth optimization strategies (eg use of tidal windows and ship scheduling) to minimise the need for capital dredging.
- 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 Protection 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.
- Commonwealth, state and territory 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 near areas of high social and conservation value or involve contaminated sediments. 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. However, large maintenance dredging programs are normally subject to a range of monitoring conditions associated with permit approval.
- 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. More generalised designs are often adopted for routine maintenance dredging.
- Monitoring programs are provided to regulators for review (eg to ensure a level of environmental protection) and, if appropriate, approval. On some occasions these are provided for third party review.
- 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 has 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 change 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 temperate ports involved dredge volumes of 3-10 million cubic metres and dredging durations of 3-6 months.
- The two largest projects undertaken in southern Australia over the past few decades were the Melbourne Channel Deepening (2009) and Port Botany Expansion (2011). Both projects involved dredged material being placed 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 (tens of thousands to several hundred thousand cubic metres). Some southern ports rarely require maintenance dredging (eg Port Botany).

The Nature of Monitoring

- Monitoring programs in this review all involved water quality (turbidity, suspended sediment, salinity, pH, temperature and dissolved oxygen).
- Monitoring of sediment quality associated with dredging and at sea placement activities is much more common in temperate Australian ports than tropical ports considering more frequent occurrence of contaminated sediments.
- 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.
- Sensitive receptors monitored by temperate ports included seagrasses, macroalgae, benthic infauna, birds, penguins, 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 and broader region monitoring. In some cases (eg Melbourne Channel Deepening Project), monitoring was an extension of existing long term programs and continued for several years following completion of dredging.

Impact Predictions for Dredging Projects

- An appropriately conservative approach is adopted for impact predictions for dredging and dredged material placement by temperate ports considering that areas of high social and conservation value commonly occur nearby.
- The definition of thresholds for sensitive receptors, such as seagrass is particularly difficult for inshore areas where most dredging by temperate 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 is typically adopted as 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 seagrasses) to be better understood.

Consistency with Approved or Predicted Impacts

- Dredge and at sea placement projects undertaken by temperate ports included in this review mostly met approval conditions with one confirmed exception.
- Monitoring was often long term, extensive and occurred over several years.
- Reported impacts to designated sensitive receptors (eg seagrasses) associated with dredging and dredged material placement projects 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.
- One project reported adverse impacts to monitored seagrass over a broad area with recovery occurring after several years.
- These results indicate that 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.

Recovery Processes and the Environmental Status of Dredged Material Placement Areas

- This review did not identify any recent dredging projects by temperate 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 ports in Australia and overseas in similar settings have indicated rapid recovery of DMPA benthic communities following dredged material placement (within 6-12 months).

Management Implications

- Comprehensive master planning early in the design phase of port infrastructure planning ensures relevant environmental values and potentially impacting processes are properly understood. Consideration of such aspects may avoid or minimise the need for capital or maintenance dredging.
- Dredging and at sea placement of dredge material in southern ports over recent years has been subject to detailed environmental monitoring designed to ensure a designated level of environmental protection; especially to any nearby areas of high social or conservation value (all major capital works are monitored although some maintenance works may not be as impacts, or lack of, are well understood).
- Management of several major projects at Melbourne, Sydney and Adelaide) involved independent parties to review dredge monitoring programs. The Office of the Environmental Monitor (part of the Victorian Audit Office), established in association with the Melbourne Channel Deepening Project, also had the role of communicating the environmental performance of the project to stakeholders.
- Assumptions by some stakeholders of widespread and unintended impacts resulting from dredging are not supported by the results from extensive monitoring of many recent dredging projects in both southern and northern Australia.
- There are benefits in broadly communicating to stakeholders that recent dredging and dredged material placement projects in Australia have not resulted in unapproved impacts and that impacts have been consistent with those approved by regulatory agencies.
- Public confidence in the environmental management of port related dredging would be improved with greater stakeholder awareness of both the impact assessment process and the actual extent of impacts from recent dredging/at sea placement projects. This would enable a more informed and factually based discussion on future projects.

Photo courtesy of the Tasmanian Ports Corporation Pty Ltd.

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APPENDIX A – Capital and maintenance dredging projects and monitoring program information for temperate Australian ports

Photo courtesy of Southern Ports Authority – Albany.

Location/project	Project duration (months)	Dredge volume	Monitoring receptor and monitoring design	Reported consistency with approved (or predicted) impacts?	Comments	Reference
QUEENSLAND						
CAPITAL DREDGING						
Port: BRISBANE **Description:** Spitfire Channel Realignment (2006-ongoing)	N/A	Project has removed 6.8 Mcum of an approved total of 15 Mcum dredging (max permitted annual vol = 4 Mcum/yr and all material to be placed on land.	*Water Quality* Water quality monitoring of dredging undertaken triennially.	Impacts consistent with approvals/ predictions.	Dredging involves periodic removal of clean sands from a mobile unvegetated sandy area to progressively develop a new channel. No sensitive receptors nearby. Dredge area selected through a comprehensive review of potential environmental impacts (MBSES, 2005). Triennial confirmatory water quality sampling of plumes undertaken.	WBM (2005) Spitfire Channel Realignment Impact Assessment Environment Protection Agency, Moreton Bay Sand Extraction Study; MBSES, prepared for Premiers Dept. Queensland Government (2005)
MAINTENANCE DREDGING						
Port: BRISBANE **Description:** Outer Bar and Moreton Bay shipping channel maintenance (annual ongoing program)	1.5	0.3	Triennial assessment of plume extent		Surveys indicated plumes generally remain within the channel confines. Plumes from dredging clean sand in Moreton Bay extended 800m, had a maximum turbidity of 10 NTU and persisted for 0.75hrs. Plumes from dredging clays/silts/muds in Brisbane River extended 300-400m, had a maximum turbidity of 140 NTU and persisted for 1.5hrs.	BMT WBM (2013)

Location/project	Project duration (months)	Dredge volume	Monitoring receptor and monitoring design	Reported consistency with approved (or predicted) impacts?	Comments	Reference
NEWS SOUTH WALES						
CAPITAL DREDGING						
Port: PORT OF NEWCASTLE **Description:** NCIG Berths 8 and 9 Dredging Project (2007-2010)	24	5.0 Mcum with 3.0 Mcum placed at sea and 2.0Mcum placed on land	*Water Quality* Plume monitoring at specified distances from dredging works,	Impacts consistent with approvals/ predictions.	Plumes confined to close proximity to works.	Annual returns to EPA by the Port of Newcastle
Port: PORT BOTANY **Description:** Port Botany Expansion (2011)	26	7.8 Mcum with material used for port expansion	*Water Quality* Continuous water quality and turbidity monitoring at 9 sites Monthly heavy metals and organic contaminants Monthly sediment deposition Seagrass monitoring (distribution and condition) , light Penetration (PAR) , Chloro-a at 10 sites	Impacts consistent with approvals/ predictions.	Turbidity associated with dredging was generally lower than predicted and project water quality licence criteria were met. Independent audit found that the predictions and conclusions in the EIS were largely realised. All environmental performance goals were achieved.	Sydney Ports (2012)

Location/project	Project duration (months)	Dredge volume	Monitoring receptor and monitoring design	Reported consistency with approved (or predicted) impacts?	Comments	Reference
Port: PORT KEMBLA **Description:** General Cargo Handling Facility (2007-2008)	16	275,000 cum at sea (in specifically designed inner port bund)	*Water Quality* Turbidity and pH monitoring at least twice daily at 4 – 9 locations depending on the stage of dredging works	Impacts consistent with approvals/ predictions	No exceedance of turbidity or pH triggers. Silt curtain effectively used.	Annual returns to EPA by Boskalis Australia (2008) and Georgiou Group (2008, 2009)
VICTORIA						
Port: PORT OF GEELONG **Description:** Geelong Dredging Program (2014)	3	200,000 cum and at-sea placement				
Port: PORT OF GEELONG **Description:** Geelong Arm Channel Improvement (1997).	8	5 Mcum and at-sea placement	*Seagrass* Monthly pre-dredging (14 surveys), during dredging (14 surveys) and post dredging (3 surveys) . Photography, video and biomass assessments.	Impacts consistent with approvals/ predictions.	No changes in seagrass communities were detected that could be attributed to dredging. Sites closest to dredging experienced moderate to high increases in turbidity and sediment deposition leading to minor leaf necrosis towards the end of the project. Filamentous algal associated with seagrass declined due to increased light attenuation resulting in increased seagrass growth.	Marine Science and Technology Pty Ltd (2006)

Location/project	Project duration (months)	Dredge volume	Monitoring receptor and monitoring design	Reported consistency with approved (or predicted) impacts?	Comments	Reference
Port: PORT OF GEELONG **Description:** Geelong Arm Channel Improvement (1997).	8	5 Mcum and at-sea placement	*Water Quality* Baseline (12 months pre-dredging), during and post dredging monitoring at dredge and DMPA locations. Spatial surveys at nominally fortnightly intervals and the operation of continuously-recording turbidity meters at six locations.	Impacts consistent with approvals/ predictions	Turbidity levels well below compliance requirements with the exception of two months at one site when the 80th percentile values marginally exceeded the prescribed limits, but the average over the dredging period was well below the limit. Post-dredging monitoring indicated turbidity returned to pre-dredging levels and very little evidence of re-suspension at the DMPA. .	Provis and Taylor (1999).
Port: PORT OF MELBOURNE 2008-2009). **Description:** Melbourne Channel Deepening Project	24	22.9 Mcum	*Water Quality* Weekly and monthly continuous monitoring of turbidity at 16 sites ranging from Port Phillip Bay entrance throughout the bay to the mouth of the Yarra River.	Impacts less than approved/ predicted.	Turbidity was generally far below compliance triggers.	Office of the Environmental Monitor (2012).
Port: PORT OF MELBOURNE 2008-2009). **Description:** Melbourne Channel Deepening Project	24	22.9 Mcum	*Water Quality Monitoring Program* Beach Monitoring Program Turbidity Monitoring Program Plume Intensity & Extent	Impacts consistent with approvals/ predictions.	Office of Environmental Monitor reported that for all monitoring "*the environmental impacts of the project were well within the acceptable ranges which were set at project approval*".	Victorian Auditor-General (2012)

Location/project	Project duration (months)	Dredge volume	Monitoring receptor and monitoring design	Reported consistency with approved (or predicted) impacts?	Comments	Reference
			Monitoring Program Nutrient Cycling Monitoring Program Algal Blooms Monitoring Program Water Quality in Port Phillip & Westernport Catchment Monitoring Program Bacterial Contamination in the Yarra River Monitoring Program			
Port: PORT OF MELBOURNE 2008-2009). **Description:** Melbourne Channel Deepening Project	24	22.9 Mcum	*Plants and Animals:* Little Penguins Monitoring Program Seagrass Monitoring Program Ramsar-Listed Wetlands Monitoring Program	Impacts consistent with approvals/ predictions.	Office of Environmental Monitor reported that for all monitoring "*the environmental impacts of the project were well within the acceptable ranges which were set at project approval*".	Victorian Auditor-General (2012)

Location/project	Project duration (months)	Dredge volume	Monitoring receptor and monitoring design	Reported consistency with approved (or predicted) impacts?	Comments	Reference
			Biodiversity in Marine Protected Environments Monitoring Program Entrance Deep Reef Impact Assessment Field Report Entrance Deep Reef Impact and Recovery Assessment Report Two Year Post-Construction Survey of the Deep Reef Habitat at the Entrance to Port Phillip Bay			
Port: PORT OF MELBOURNE 2008-2009). **Description:** Melbourne Channel Deepening Project	24	22.9 Mcum	*Fish Stocks* Fish Stock & Recruitment Monitoring Program Commercial Catch & Effort Monitoring Program Juvenile Snapper	Impacts consistent with approvals/ predictions.	Office of Environmental Monitor reported that for all monitoring “*the environmental impacts of the project were well within the acceptable ranges which were set at project approval”.*	Victorian Auditor-General (2012)

Location/project	Project duration (months)	Dredge volume	Monitoring receptor and monitoring design	Reported consistency with approved (or predicted) impacts?	Comments	Reference
			Monitoring Program Commercial Catch of Snapper Monitoring Program Juvenile King George Whiting Monitoring Program Commercial Catch of King George Whiting Monitoring Program			
Port: PORT OF MELBOURNE 2008-2009). **Description:** Melbourne Channel Deepening Project	24	22.9 Mcum	*Contaminants in Fish* 2009 Lower Yarra River Fish Study Victorian Shellfish Quality Assurance Program	Impacts consistent with approvals/ predictions.	Office of Environmental Monitor reported that for all monitoring "*the environmental impacts of the project were well within the acceptable ranges which were set at project approval*".	Victorian Auditor-General (2012)
Port: PORT OF MELBOURNE 2008-2009). **Description:** Melbourne Channel Deepening Project	24	22.9 Mcum	*Environmental Limits* Turbidity Monitoring Program Noise Monitoring	Impacts consistent with approvals/ predictions.	Office of Environmental Monitor reported that for all monitoring "*the environmental impacts of the project were well within the acceptable ranges which were set at project approval*".	Victorian Auditor-General (2012)

Location/project	Project duration (months)	Dredge volume	Monitoring receptor and monitoring design	Reported consistency with approved (or predicted) impacts?	Comments	Reference
			Programs			
MAINTENANCE DREDGING						
Port: PORT OF MELBOURNE (1994). **Description:** Maintenance dredging water quality assessment at Westernport Bay	4 days	35, 000 cum (sandy sediments)	Turbidity monitoring of dredging and DMPA before, during and after activities.	N/A	Peak of 30 mg/l for either dredging or disposal activities. Background concentrations achieved with 5-10mins. Concluded that "*there would be no significant sedimentation outside the spoil grounds and the main shipping channel and that there is no need to carry out long term turbidity monitoring of the effects of the dredging operations*". ,	McCowan and Ruddock. (1995).
Port: PORT OF MELBOURNE (2009-2011). **Description:** Maintenance dredging northern Port Phillip Bay and Yarra/Maribyrnong Rivers	8	297, 000 cum (silty contaminated sediments) placed within bunded area at Port of Melbourne Dredge Material Ground and capped with 110,000 cum sand.	Turbidity and noise monitoring during dredging.	Impacts consistent with approvals/ predictions	Independent audits commissioned by the Office of the Environmental Monitor (OEM) found that the maintenance dredging program was conducted in full compliance with the EMP, with the exception of one minor non-compliance regarding notification of ballast water management arrangements.	Port of Melbourne Corporation (2012).

Location/project	Project duration (months)	Dredge volume	Monitoring receptor and monitoring design	Reported consistency with approved (or predicted) impacts?	Comments	Reference
Port: PORT OF MELBOURNE (2009-2011). **Description:** Maintenance dredging South Channel (2012)	1	300,000 m3 of clean sand placed at sea	Turbidity monitoring at 3 sites during dredging	Impacts consistent with approvals/ predictions	Port of Melbourne advise "*full compliance with the project EMP*" .	Port of Melbourne Corporation (2012).
TASMANIA						
MAINTENANCE DREDGING						
Port: PORT OF DEVONPORT 2005. **Description:**		0.2 Mcum	*Water quality* Reference and disposal area during dredging. In-situ measurement of light attenuation and turbidity profiles during representative "worst case" disposal episodes.	Impacts consistent with approvals/ predictions	Dredge plume mostly on seabed, surface plumes disappeared rapidly. Did not disperse toward nearshore seagrasses.	EE Consultants Pty Ltd (2005). Port of Devonport Corporation. April - May 2005 Dredging Campaign. Water Clarity Monitoring. Report to Port of Devonport Corporation by CEE Consultants Pty Ltd. Richmond VIC.
			Seagrass	Impacts consistent with approvals/ predictions	No impacts on shoreline *Amphibolis antarctica* seagrass beds	EE Consultants Pty Ltd (2008). Port of Devonport Dredging Program. Long Term Management Plan. Marine Monitoring 2007. Report to Port of Devonport Corporation by CEE Consultants Pty Ltd. Richmond VIC.

Location/project	Project duration (months)	Dredge volume	Monitoring receptor and monitoring design	Reported consistency with approved (or predicted) impacts?	Comments	Reference
			Marine Pests	Impacts consistent with approvals/ predictions	No recruitment of key pests to disposal area. No change in key pest composition of port.	EE Consultants Pty Ltd (2008). Port of Devonport Dredging Program. Long Term Management Plan. Marine Monitoring 2007. Report to Port of Devonport Corporation by CEE Consultants Pty Ltd. Richmond VIC.
SOUTH AUSTRALIA						
CAPITAL DREDGING						
Port: FLINDERS PORT **Description:** Port Adelaide Outer Harbour Deepening (2007)	8 (CSD) and 4 (THSD)	2.7 Mcum and at sea placement	*Water Quality* Daily and weekly turbidity monitoring up and downstream of dredge (4 sites), at fixed sites (2 sites), a mangrove site (1 site), at the DMPA (4 sites) and near seagrass beds. Heavy metal sampling at dredge site and DMPA before during and after dredging	Impacts consistent with approvals/ predictions.	Investigation and Action level turbidity triggers exceeded on several occasions leading to temporary halt to dredging. Ship movements (berthing, using swing basin etc) were noted to increase turbidity and result in short term (1 hr) plumes. Heavy metal concentrations were within criteria but slight elevations were noted during dredging due to sediment re-suspension.	Correspondence to Flinders Ports dated 9/2/2007 from Independent Verifier.

Location/project	Project duration (months)	Dredge volume	Monitoring receptor and monitoring design	Reported consistency with approved (or predicted) impacts?	Comments	Reference
			Seagrass Post (1 year) dredging survey (leaf density and length) and comparison to earlier reports (no specific baseline survey was undertaken).	Impacts consistent with approvals/ predictions.	The Project Development Application noted that temporary impacts to seagrass fringing the channel were likely but did not quantify the extent (KBR 2004). Post dredging survey reported an apparent substantial short-term effect of dredging on the seagrass surrounding the dredge site. No pre-dredging survey was undertaken to confirm impact extent or magnitude. Surveys two years before dredging indicated seagrass was present in the presumably impacted areas. Recovery was rapid (high leaf density within one year) at the sites studied.	Tanner, J.E. & Rowling, K. (2008).
Port: FLINDERS PORT **Description:** Port Giles (2001)	3	100,000 cum to reclamation	Turbidity monitoring (direct measurement and second disk readings) at fixed monitoring stations by assessments of extent and duration.	Impacts consistent with approvals/ predictions.	Independent verifier confirmed compliance against the water quality and turbidity approval conditions.	Ewers et.al.(2005)
MAINTENANCE DREDGING						
Port: FLINDERS PORT **Description:** Maintenance dredging Berth 7 and 8 (2010).	2.5	8000cum and on shore placement	*Water Quality* Turbidity, pH and Do at sites up and downstream of dredging and on land placement area (8 sites).	Impacts consistent with approvals/ predictions.	No issues of concern. Dredge plumes reported to be confined to close proximity of the dredge (largest plume recorded extended 350m from dredge). Occasional low DO values at control sites and near dredge (not considered to be dredging related).	Correspondence to dredge operator (copy provided to Flinders Ports) dated 27/5/2010 from Independent Verifier.
Port: FLINDERS PORT **Description:**	0.3	2300cum and on shore placement	*Water Quality* Turbidity, pH and Do at	Impacts consistent with approvals/	No issues of concern. Dredge plumes reported to be confined to close proximity of the dredge (largest plume recorded extended 150m from dredge). Occasional high	Correspondence to dredge operator (copy provided to Flinders Ports) dated 7/4/2010

Location/project	Project duration (months)	Dredge volume	Monitoring receptor and monitoring design	Reported consistency with approved (or predicted) impacts?	Comments	Reference
Maintenance dredging Berths M and N (2009)			sites up and downstream of dredging and on land placement area (5 sites).	predictions.	turbidity attributed to ship movements rather than dredging.	from Independent Verifier.
WESTERN AUSTRALIA						
CAPITAL DREDGING						
Port: PORT OF FREMANTLE **Description:** Inner Harbour deepening (2010).	6	3.1 Mcum reclamation and at-sea placement	*Benthic Primary Producer Habitat (seagrass, coral and macrolgae distribution)* Baseline (1 survey) and post dredging (1 survey). Satellite imagery and ground truthing.	Impacts less than approved/ predicted.	Authors report a net gain in seagrass habitat (3.1% increase vs 4.6 %loss approved), net gain in macroalgal habitat of (6.8% increase vs 5.5% loss approved), and no change in the spatial extent of coral habitat (no loss approved). Potential mapping limitations may have influenced mapping accuracy. Seagrass also expanded elsewhere in the region over the dredging period.	Oceanica (2011)
Port: PORT OF FREMANTLE **Description:** Inner Harbour deepening (2010).	6	3.1 Mcum reclamation and at-sea placement	*Water Quality (light attenuation and toxicants)* Baseline (1 survey) - light measured by continuous loggers, discrete samples for toxicants. Sampling at impact and reference sites.	Impacts less than approved/ predicted.	No exceedance of toxicant trigger levels. Modelling was consistent with, or overestimated, turbidity plumes.	Oceanica (2011)
Port: PORT OF FREMANTLE **Description:** Inner Harbour	6	3.1 Mcum reclamation and at-sea placement	*Seagrass* Baseline (2 surveys), during (3 surveys) and	Impacts less than approved/ predicted.	Large degree of natural variation noted. Seagrass shoot density post dredging was either significantly higher or not significantly different to the baseline survey at most (21 out of 24) sites. Lower densities were recorded at 3 sites but	Oceanica (2011)

Location/project	Project duration (months)	Dredge volume	Monitoring receptor and monitoring design	Reported consistency with approved (or predicted) impacts?	Comments	Reference
deepening (2010).			post dredging (1 survey). Seagrass sampling (shoot density) at impact and reference sites.		these were considered to relate to natural variability and not dredging related.	
Port: PORT OF FREMANTLE **Description:** Inner Harbour deepening (2010).	6	3.1 Mcum reclamation and at-sea placement	*Corals* Baseline (2 surveys), between dredging phases (1 survey) and post dredging (1 survey). Coral health and cover sampling at 2 sites near to dredging (approved to be subject to slight turbidity increases but not to be impacted). No suitable reference sites.	Impacts consistent with approvals/ predictions.	Authors report no dredging related impacts. Reduced coral mortality between pre and post dredging with no significant changes in cover. Large degree of natural variation noted.	SKM (2011).
Port: PORT OF GERALDTON **Description:** Channel Enhancement Project (2001-2002)	13	4.5 Mcum at-sea placement	*Water Quality and Light Attenuation* Turbidity monitoring occurred but details could not be located.		Turbidity monitoring occurred but details could not be located.	Referred to in Westar et al (2006),
Port: PORT OF GERALDTON **Description:** Channel Enhancement Project (2001-2002)	13	4.5 Mcum at-sea placement	*Seagrass* Specific studies commissioned and research undertaken for 3-5 years to assess recovery. Various methods including mapping, seagrass shoot	Impacts greater than approved/ predicted.	Extensive declines in seagrass cover (72-100%) up to 5 km away from the dredging operation, much greater than the 30ha loss approved/ predicted. Some recovery occurred after three years (33%-68% relative to pre-dredging conditions). Dredge sediment inputs markedly different to approved/ predicted. Dredging created a turbid plume ~ 70 km for approximately 9 months.	Westar et al (2006) Mulligan (2009).

Location/project	Project duration (months)	Dredge volume	Monitoring receptor and monitoring design	Reported consistency with approved (or predicted) impacts?	Comments	Reference
			density, biomass etc.			
MAINTENANCE DREDGING						
Port: PORT OF BUNBURY **Description:** Annual maintenance dredging.	6	400,000 - 600,000 cum to at-sea disposal	*Water Quality* Monitoring at dredging and DMPA.	Impacts consistent with approvals/ predictions	Turbidity monitoring indicated "*minor effects outside the boundary of the Port Harbours where dredging took place and at the Spoil Ground compared to reference locations Any changes were of a short-term nature and water quality returned to pre-disturbance conditions within days*".	SKM (2011)
Port: PORT OF GERALDTON **Description:** Maintenance dredging (2012)	1	130,000 cum to reclamation	*Water Quality.* Visual (twice daily) and aerial assessment (fortnightly) of turbidity plumes. Turbidity monitoring at 8 sites *Seagrass* Monitoring at 5 sites (different species at varying distances from works) pre and post dredging	Impacts consistent with approvals/ predictions	Monitoring indicated compliance with all approval conditions.	Barton et al. 2013
Port: PORT OF ESPERANCE	2	64,000 cum to at-sea	*Water Quality*	Impacts consistent with	Monitoring indicated compliance with all approval conditions.	BMT WBM (2014).
Description: Maintenance dredging (2014)		disposal	Visual (daily) and depth integrated sampling for metals.	approvals/ predictions		

APPENDIX B – List of studies undertaken by Newcastle Port over the period 1999 to 2009 in relation to maintenance dredging

Photo courtesy of the Port Authority of NSW – Newcastle.

Specific details on reports are contained within NPC (2011)

Author and report title and Dredge Area	Year
Dredge Area	
Patterson Britton & Partners: Walsh Point vibrocoring;	1999
Robert Carr & Associates: MPT Stage 1 sampling;	1999
Patterson Britton & Partners: MPT Stage 1 vibrocoring;	2000
Robert Carr & Associates: MPT Stage 2 sampling;	2000
Patterson Britton & Partners: South Arm vibrocoring	2000
Patterson Britton & Partners: MPT Stage 1 vibrocoring;	2000
Patterson Britton & Partners: surface sampling adjacent to former BHP site	2001
GHD-Longmac: MPT Stage 1 vibrocoring;	2001
GHD-Longmac: MPT Stage 2/K7 vibrocoring;	2001
GHD-Longmac: South Arm vibrocoring;	2001
Patterson Britton & Partners: Surface sampling adjacent to former BHP site	2002
GHD-Longmac: Dec/Jan vibrocoring adjacent to former BHP site	2002
Patterson Britton & Partners: Vibrocoring along southern bank of the South Arm of the Hunter River from the former BHP steelworks site to Tourle Street Bridge	2003
Patterson Britton & Partners: Bulk sampling adjacent to former BHP steelworks site	2003
Patterson Britton & Partners: Surface sampling in Kooragang Swing Basin	2003
Patterson Britton & Partners: Sediment Sampling & Testing for NPC's Five Year 2006-2011 Maintenance Dredging Sea Disposal Permit Application	2006
WorleyParsons: Newcastle Maintenance Dredge Areas Mid-permit Sediment Sampling and Testing, 2006-2011 Five Year Maintenance Dredging Sea Dumping Permit	2009
At-sea Placement Area	
Stauber, J L, Brockbank C I, Adams M S and Binet, M T. *Ecotoxicological Testing of Dredged Sediment in Newcastle Harbour*	2000
Patterson Britton & Partners: *ROV Investigations of the Current Spoil Ground and Adjacent Areas* Prepared for NPC, November 2001 CSIRO (2001) *Relationship Between Chemical Contaminants and Ecotoxicological Effects for Dredged Newcastle Harbour Sediments*	2001
Patterson Britton & Partners: *Offshore Sediment Sampling and Testing*	2002
Patterson Britton & Partners (2003) *Benthic Macroinvertebrate and Sediment Textural Sampling and Testing of the Proposed Offshore Dump Ground*	2003
The Ecology Lab (2003) *Newcastle Offshore Spoil Disposal – Baseline Studies of the Benthic Ecology*	2003
WorleyParsons (2009) *Newcastle Offshore Dumping Ground Sediment Investigation for the 2006-2011 Five Year Maintenance Dredging Sea Dumping Permit*	2009

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