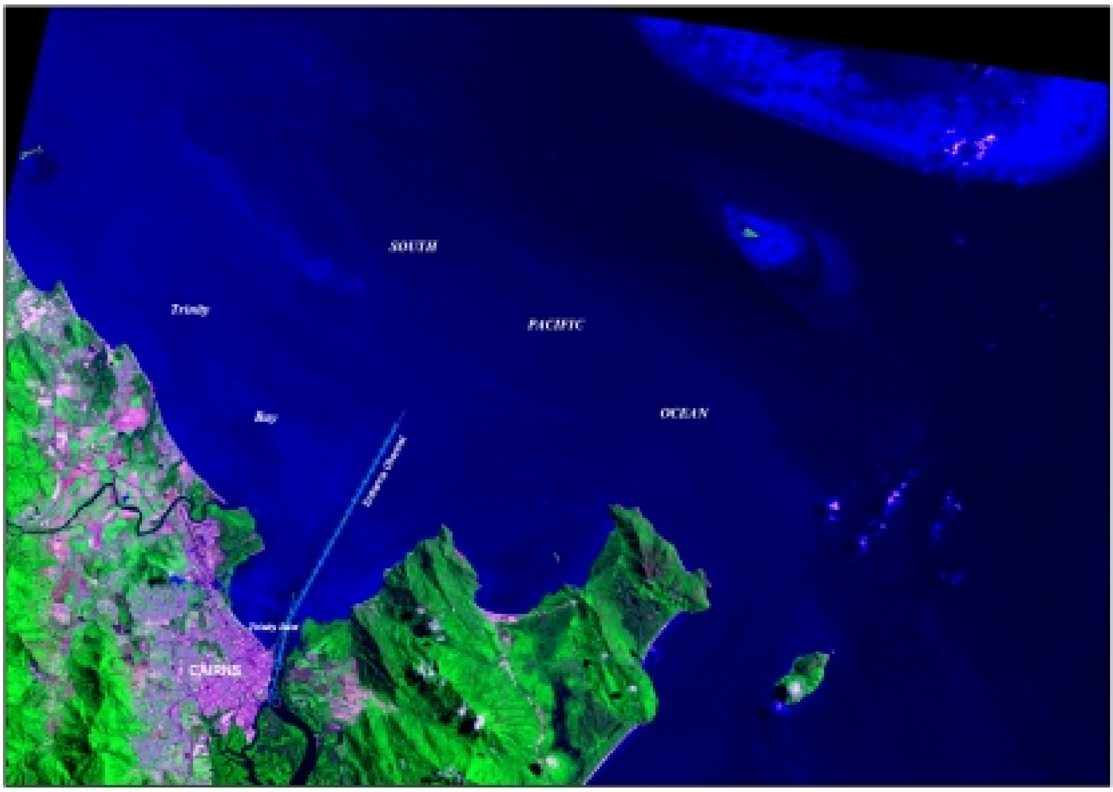
CAIRNS HARBOUR DREDGING
LONG TERM DREDGE SPOIL DISPOSAL MANAGEMENT PLAN



Prepared For:

CAIRNS PORT AUTHORITY

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Job No 379

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DOCUMENT CONTROL CERTIFICATE

PROJECT AND CLIENT DETAILS

Project name:	Cairns Harbour Dredging	Job Number :	379
Title:	Long Term Dredge Spoil Disposal Management Plan		
Client:	Cairns Port Authority		
Contact:	Kim Kelleher		
Description of report:	This report provides information required in support of a sea dumping permit under the *Impact of Proposals (Sea Dumping) Act 1981* and the *Great Barrier Reef Marine Park Act 1975*. It includes: • a history and background to dredging and disposal of dredged material at the Port of Cairns, • a consideration of options for dredge spoil disposal, • a description of current and future dredging needs (including an identification of the long term dredging needs for the term of the permit (5 years) and methods to be used for dredging and off-shore disposal), • a description of the marine environment of Trinity Bay and Trinity Inlet, • a detailed summary of previous environmental monitoring of dredging and sea disposal (including a description of the properties of the dredge spoil and the condition of the Spoil Ground), • an examination of the potential impacts of dredging and sea disposal and of the opportunities for minimising dredging (reduce quantity) and for mitigating contamination (increase quality), and • a proposed monitoring program.		

PREPARATION AND DISTRIBUTION DETAILS

Version	Purpose	Prepared by	Checked by	Date
1a-1g	Internal draft	David Rivett *et al.* (see **Table 1.2**)	Various	to 10 May 2004
2	Client Review	David Rivett	Tas Graham	17 May 2004
3	Issue (CPA Final Review)	David Rivett	Tas Graham	11 August 2004
4	Issue	David Rivett	-	5 November 2004
5	Revised after GBRMPA review and 2nd TACC meeting	David Rivett	Ross Smith Jamie Corfield	2 March 2005

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CONTENTS

FIGURES

TABLES

PLATES

APPENDICES

1. INTRODUCTION

1.1 OUTLINE OF PROJECT AND ITS AIMS AND OBJECTIVES

Cairns Port Authority (CPA), as the administering body for both the airport and seaport of Cairns, has commissioned the development of this Long Term Dredge Spoil Disposal Management Plan[1] (LTDSDMP) for the seaport.

The seaport is a multi-purpose port catering for a wide range of shipping operations including resident and visiting cruise vessels, bulk cargo vessels, commercial tourist craft, privately owned leisure craft and one of the largest commercial fishing fleets in Australia. The shallow waters of the seaport are in an accreting environment, requiring that dredging to maintain an entrance channel and a navigable port area is an integral facet of port management.

Disposal of this dredged material at sea has been a component of dredging programs at the Port for much of its history, with dredge spoil currently being disposed of at a designated ocean disposal site (Spoil Ground) within the Great Barrier Reef Marine Park. The Great Barrier Reef Marine Park Authority (GBRMPA) permits this use subject to approvals and conditions issued under the *Great Barrier Reef Marine Park Act 1975* (Cwlth) and the *Environment Protection (Sea Dumping) Act 1981* (Cwlth). The existing Spoil Ground has been in use since 1991 with an average in-situ volume of 300,000 to 400,000 m^3 of material being placed at the site annually. More recently, the average annual in-situ quantity dredged between 2001 & 2003 is approximately 500,000 m^3 of which 90% is removed from the Entrance Channel (450,000 m^3) and 10% is removed from the Inner Port area (50,000 m^3) which comprises the berth pockets and marinas etc.

CPA has undertaken a number of studies over the past decade and more to investigate terrestrial and marine dredge spoil disposal options, concluding that sea dumping is the preferred method. Robust environmental and other assessments have been undertaken at the spoil disposal site and these confirm the suitability of the current site.

The Long Term Dredge Spoil Disposal Management Plan project is required to guide CPA in future management of dredge spoil disposal and will be used to support applications for on-going dredging and spoil disposal activities. Also required is an assessment of the current situation and prudent and feasible alternatives.

A ‘Study Area’ map showing the Port of Cairns and the study area is given in **Appendix A**.

1.2 TERMS OF REFERENCE

Terms of Reference for the study were provided by CPA and a copy is included in **Appendix B**. These Terms of Reference cover all of the requirements of the National Ocean Disposal Guidelines for Dredged Material (Environment Australia 2002) – see **Section 1.4**.

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[1] Also referred to as a Long Term Dredge Disposal Management Plan (LTDDMP) or Long Term Dredge Material Management Plan (LTDMMP).

1.3 APPROVALS REQUIRED

CPA's investigations over many years have concluded that sea dumping at the current site is the preferred method of disposing of dredge spoil. Approvals have been issued over the years for the placement of dredged material ("dumping") at this site and its predecessor and a copy of the previous permit is attached in **Appendix C**.

In order to continue dumping at the current site, CPA requires a permit under the *Environment Protection (Sea Dumping) Act 1981* (Cwlth) – the "Sea Dumping Act". This Act is administered by the Commonwealth Department of the Environment and Heritage (DEH, formerly Environment Australia) and gives effect to Australia's commitments under the Protocol to the London Convention and the United Nations Convention on the Law of the Sea 1982 (UNCLOS) which relate to the dumping of wastes at sea.

DEH has delegated authority to the Great Barrier Reef Marine Park Authority (GBRMPA) for dredging and disposal of the associated spoil within the Great Barrier Reef Marine Park (GBRMP) and GBRMPA is the regulatory assessment manager. This assessment process also includes that required under the *Great Barrier Reef Marine Park Act 1975* (Cwlth).

CPA has, to date, obtained a number of permits under these arrangements from GBRMPA, and currently use an area of one nautical mile in diameter within Cairns Port Limits, in the inner reef area, for the dumping of up to 500,000 dry solid tonnes of dredge spoil annually.

In addition to the Sea Dumping Act and the *Great Barrier Reef Marine Park Act*, the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) - the "EPBC Act" also applies to World Heritage Areas (i.e. the Great Barrier Reef World Heritage Area which includes the GBR Marine Park). However, no separate referral under the EPBC Act is required if the activity only involves sea dumping, and the assessment manager (GBRMPA) decides if further assessment under the EPBC Act is required.

Dredging within state waters normally requires an environmental licence under the *Environmental Protection Act 1994* (Qld) (Environmentally Relevant Activity 19(b) *Dredging material – 5000 tonnes or more but < 100,000 tonnes per year*). However, CPA has a deemed approval under this Act for harbour maintenance dredging. CPA also undertakes dredging on contract for others (e.g. for the Navy at HMAS Cairns) and this is done under Environmental Authority No. is 5010000065. This authority is subject to annual renewal and requires the submission of a Dredging Environmental Management Plan to the Licensing Authority in advance of any dredging taking place. This work also includes a specific water quality monitoring program (refer CPA (2003a)).

1.4 NATIONAL OCEAN DISPOSAL GUIDELINES FOR DREDGED MATERIAL

The DEH's National Ocean Disposal Guidelines for Dredged Material (described in this report as the Ocean Disposal Guidelines) provide an outline of the information needed in support of an application for sea dumping. The particular requirements of the LTDSDMP, and the sections of this report where these are addressed, are tabulated below.

Table 1.1 Requirements of a Long Term Management Plan under the Ocean Disposal Guidelines

GUIDELINE REQUIREMENT	CHAPTER
Include a history and background about Cairns Port Authority and the Port of Cairns	2
Identify opportunities for minimising dredging (reduce quantity) and for mitigating contamination (increase quality)	7
Identify long term dredging needs for the term of the permit (5 years) and methods to be used for dredging and off-shore disposal	4
Characterise the dredge spoil (physical and chemical properties and bioavailability, toxicity)	Partly 5, mostly 6
Characterise the Spoil Ground (water column, sediments, biota, other uses)	Mostly 5, partly 6
Characterise the area adjacent to the Spoil Ground (i.e. sites of potential impact)	5
Devise proposed dredge spoil strategies including: • evaluation of disposal options • economic, environmental and social impacts of options • relevant regulatory frameworks • reason for selecting the Spoil Ground • impacts on Spoil Ground and surrounding area • opportunities for mitigation	7and 8
Provide a summary of research and monitoring to date	Throughout the report, mainly in Chapter 6 and in appendices
Describe the proposed monitoring program	8

Source: Study team compilation.

1.5 STUDY TEAM

The study team of the project is as tabulated below.

Table 1.2 Study Team

ROLE	NAME	ORGANISATION
Project Management		
Project Manager	David Rivett	Environment North
Scientific Tasks Coordinator	Tasman Graham	Hydrobiology
Technical Experts		
Dredge Spoil Disposal (background)	David Rivett	Environment North
Terrestrial Environmental Planning	David Rivett	Environment North
Analysis of Alternatives and Reporting	David Rivett Tasman Graham	Environment North Hydrobiology
Sediment Quality and Coastal Oceanography	Tasman Graham	Hydrobiology
Ecotoxicology and Marine Biology	Dr Ross Smith	Hydrobiology
Coastal and Marine Ecology	Dr Jamie Corfield and Dr Don Morrisey	NIWA Australia
Marine Pests	Dr Oliver Floerl	NIWA Australia
Coastal Oceanography	Shirley Connelly	Hydrobiology
Consultation		
Agency, Traditional Owner and Industry Consultation	David Rivett and Tasman Graham	Environment North/Hydrobiology

Source: Study team compilation.

1.6 CONSULTATION SUMMARY

1.6.1 Introduction

This section of the report summarises the consultation undertaken for the study. This consisted of:

- formal stakeholder consultation via the Technical Advisory and Consultative Committee (TACC),
- technical meetings between the consultants and CPA and the Great Barrier Reef Marine Park Authority, and
- targeted consultation with members of the Yarrabah community to discuss issues of concerns and CPA's intentions regarding dredging and dumping.

1.6.2 Technical Advisory and Consultative Committee

a) *Outline*

Under the Ocean Disposal Guidelines, in order to obtain a long term permit, the proponent must establish a TACC to help guide the on-going development of the LTDSDMP for dredging and dumping activities.

A TACC is intended to assist the determining authority (GBRMPA) and the proponent in protecting the local environment and reconciling various stakeholder interests. Membership is typically drawn from relevant Commonwealth, State and Local Government and non-Government organisations with expertise, responsibilities or an interest in the subject matter.

As required by the Ocean Disposal Guidelines, the TACC is intended to:

- provide continuity of direction and effort in protecting the local environment,
- aid communication between stakeholders and provide a forum where points of view can be discussed and conflicts resolved,
- assist in the establishment, as appropriate, of longer term permitting arrangements, including reviewing the development and implementation of Sampling and Analysis Plans, Long Term Management Plans and research and monitoring programs,
- review on-going management of dredging and dumping in accordance with these guidelines and permitting arrangements, and
- make recommendations to the proponent and the determining authority as necessary or appropriate.

b) *Membership*

Membership of the Technical Advisory and Consultative Committee is currently as detailed in **Table 1.3**.below. CPA intends that the TACC will be available to advise on matters related to the sustainability of the port to ensure that all aspects of sustainability (environmental, economic, and social) are considered in the development and application of the LTDSDMP.

Table 1.3 Membership of the Technical Advisory and Consultative Committee

INTEREST	**GROUP**	**REPRESENTATIVE**
Proponent	Cairns Port Authority	Kim Kelleher Stephen Day
Determining Authority	Great Barrier Reef Marine Park Authority	James Monkivitch
Commonwealth Government	Department of Environment and Heritage	Frank Antram
State Interests	Department of Primary Industries (Northern fisheries Centre)	Anne Clarke (Regional Manager)
	Environmental Protection Agency	Brynn Matthews
	Queensland Parks and Wildlife Service	Jesse Lowe
	Queensland Transport	Capt Alan Boath (Regional Harbour Master)
Local Government	Cairns City Council	Peter Tabulo (City Planner)
Commercial Interests	Cairns Port Advisory Group	Alf Callaghan (Chairman)
	Fertiliser Industry	Paul Rylewski (Incitec)
	Sugar Industry	Steve Anderson (Queensland Sugar)
	Petroleum Industry	Kym Condon (Mobil Oil)
	Tourism	John McIntyre (Tourism Tropical North Queensland)
Non Government Organisations	Cairns and Far North Environment Centre	Dirk McNicoll
	Sunfish	Bill Dwyer (Mossman Representative)
Native Title /indigenous interests	North Queensland Land Council	To be determined

Source: Study team compilation.

1.6.3 Role of TACC in Developing the LTDSDMP

The TACC has met once to date (January 2004) at the commencement of the project. This involved a full day meeting on 19 November 2003. Key matters discussed were as follows:

- Overview of study:
  - nature of approvals and permits needed
  - outline of aims and objectives
  - timeframe
- Role of TACC
- Environmental context (including environmental sedimentology of Trinity Bay)
- Disposal options:
  - review of previous work on a search for suitable terrestrial and marine sites
  - disposal options and investigation of alternatives

- Current dredging and disposal:
  - outline of the scope of maintenance and capital dredging over past years and into the future
  - nature of the material
  - reduction and mitigation options
  - flora and fauna survey of the Spoil Ground
  - long term seagrass monitoring program
  - identification of opportunities for further input (meetings, comments on draft report, other input).

The TACC reviewed Version 4 of this report and changes have been incorporated.

2. BACKGROUND TO DREDGING AND DISPOSAL

2.1 INTRODUCTION

This chapter provides background information relevant to the permit application, namely:

- an overview of previous studies,
- brief history of the Port of Cairns,
- analysis of dredging and dumping issues, and
- details of previous permits.

A detailed description of previous studies into dredge spoil disposal options is provided in **Chapter 3** and an analysis of historic dredged quantities is described in **Chapter 4**.

2.2 PREVIOUS STUDIES

CPA has commissioned a large number of studies over the past decade and more into the issue of dredging and dredge spoil disposal. Key studies and their broad content are summarised below. These studies have been referred to extensively in the compilation of this report. References for these studies are provided in **Chapter 8**. CPA has also undertaken sediment and water quality monitoring, for several years, to confirm sediment suitability for sea disposal and that effects on water quality of dredging and sea disposal are confined and short lived. A summary of previous environmental monitoring associated with dredging and sea disposal is given in **Chapter 6**.

Table 2.1 Key Previous Studies.

REFERENCE	COVERAGE	COMMENTS
Bunt (1989)	Assessment of environmental risks of (then) current dumping strategy.	Recommended the full suite of investigations recommended by the various Connell Wagner reports. Also recommended that alternative sites and strategies be investigated.
Connell Wagner (1990a) and (1992)	History of and need for dredging, nature and quantity of spoil, search for on-shore and off-shore disposal sites (broad and general).	Confirmed the need for dredging and selected the current off-shore disposal site. Detailed summary provided in **Chapter 3**.
Connell Wagner (1991)	Results of monitoring of dredging and dumping.	Extensive monitoring of the then Spoil Ground (nearby the current site), coastal currents, and dredger plume dispersal.
Carter *et al.* (2002)	Description of the environmental sedimentology of Trinity Bay.	Confirmed the earlier work by Connell Wagner (1990a) regarding siltation and sediment movement. Fine sediments (silts and clay) were shown to move along-shelf to the north-west (well in side the reef tract). Negligible amounts of terrigenous sediments cross the sediment-starved mid-shelf plain to impinge on the reef tract. Also addressed a range of issues of concern regarding dredging (see **Section 2.4**).

REFERENCE	**COVERAGE**	**COMMENTS**
Campbell *et al.* (2002)	Monitoring of seagrass meadows in Cairns Harbour and Trinity Inlet.	Over the sampling time (2001 – 2002), distribution and above ground biomass remained stable and increased in some areas. A decline in the western region of Cairns Harbour was related to climatic conditions occurring in 2002.
Neil (2002); Neil *et al.* (2003a)	Results of two episodes of fieldwork investigating marine pests (especially the Asian green mussel and the Caribbean tubeworm).	The survey encompassed a representative area of the proposed dredging area. Hard substrates suitable for attachment of exotic taxa were found to be present in the dredging area however no exotic fouling was present indicating that the risk of exotic taxa being transferred onto the dumping grounds is minimal.
Neil *et al.* (2003b)	Flora and Fauna Survey: Cairns Port Authority Ocean Disposal Site.	Specifically examined the effect of the Spoil Ground on flora and fauna at the Spoil Ground and surrounding sites. A higher similarity of inhabitants between the Spoil Ground and northern control location indicated that there was a northerly drift of sediment, consistent with Carter *et al.* (2002).

Source: Study team compilation.

2.3 HISTORY AND DEVELOPMENT OF THE PORT OF CAIRNS

2.3.1 Early Years

The following is an extract from Connell Wagner (1990a) prepared by the John Oxley Library:

> The strategic positioning of Trinity Inlet and Trinity Bay has been responsible for the development of the Port of Cairns, as it had every asset except deep water.
>
> A geological phenomenon up to 100,000 years ago saw the damming and diversion of the Mulgrave River south to its current mouth at Russell Heads, and cessation of the normal major flushing of what is now Trinity Inlet. Without the tropical river flushing, the Inlet and Bay began to silt up to create the series of sandhills, swamps and gullies which confronted the first settlers to the area.
>
> When G E Dalrymple explored the Johnstone, Russell and Mulgrave Rivers in 1873, providing the first complete description of the Inlet, the area was being used by beche-de-mer fishermen gathering firewood. The port was, in fact, founded to serve the Hodgkinson Goldfields and on Tuesday 3 October 1876 Captain Lake and S F Walker (shipping agent) arrived in the *SS Victoria* and landed passengers on the shore of Trinity Inlet. They marked out a navigable channel in the port.
>
> On the following day the '55 Porpoise', with a 62 tonne displacement, left Townsville for Trinity Bay with a government party to take up the management of the port. Its complement included David Spence, the subcollector of customs who was appointed harbour master from 1 October, and R T Hartley, the assistant collector of customs. Also on board were Captain John Mylchreest (who was appointed pilot) a surveyor and 40 passengers. The pilot buoyed the channel entrance, and the lead light was hoisted to the top of a ti-tree on the reserve opposite where the Strand Hotel was later built. This site is currently occupied by the Pacific International Hotel.
>
> On 1 November 1876, Cairns was declared a 'port of entry and clearance'. However, with the discovery of an easier route from the goldfields to Port Douglas, the port of Cairns languished, with only small timber trade providing some activity. The decision to link Cairns and Herberton by rail in 1885 - because Cairns was the better port - saw a boost in activity and a subsequent decline in the fortunes of Port Douglas.

The channel cutting had to be dredged a distance of some 4,000 metres to make the port available to the larger boats of that time. The residents of Cairns petitioned the Government to have the dredging done urgently, as the cost and difficulty of lightering (removing some cargo while still at sea) was seriously affecting the timber trade, a large government revenue source. The *Platypus* dredger commenced working on 21 November 1887, and by the end of that year had provided a channel 40 metres wide and 4 metres deep at low water for a distance of 1020 metres from the bar. The silting problem with the channel continued, and by 1894 the channel depth was reduced to a minimum depth of 2.6 metres for its full width over about half its length. The *Platypus* was engaged from 1896 cleaning the bar cutting to 4 metres and although this was completed in August 1897, the dredge remained for another 12 months to deepen the channel to 4.6 metres. Time soundings showed that 0.3 metres of silt had settled in the channel behind the dredger and within 10 months there was only 3.8 metres depth at low water and by February 1900, it was down to 3.2 metres. The *Platypus* returned from Brisbane but could not match the growth of siltage, which was causing increased delay to coastal traffic.

In an attempt to stabilise the port, the Harbours and Rivers Department invited tenders in Europe to build a new dredge and on 16 March 1913, the dredger *Trinity Bay* arrived in Brisbane to take up its task. The suction dredger *Trinity Bay* had dredged the bar channel to 6.7 metres depth at low water with a bottom width of 45 metres by 1929. During the twelve months to June 1932, the 'Trinity Bay' removed 721,650 tonnes of silt from the bar entrance channel and the wharf berths. Some 100,000 tonnes were used to reclaim areas behind the wharfs and in Smith's Creek[2].

By 1940, the harbour channel bottom had been widened to 60 metres. During 1970, the Cairns Harbour Board engaged a contractor to widen the entrance channel to 75 metres and deepen it from 7 metres to 8.2 metres at low water. Since 1974-75, the Port of Brisbane Authority's dredger *Sir Thomas Hiley* has visited Cairns to perform annual maintenance dredging. The dredger *Trinity Bay* was finally retired in 1976.

The port now averages over a million tonnes annually in cargo handling, as well as being the major far northern haven for tourist and pleasure craft.

2.3.2 Current Situation

Since the above description was produced, the Port has continued to grow and major capital investment has been made in Port infrastructure via the Cityport project in particular which involved the upgrade of marine facilities and re-development of waterfront land, allowing for increasing demand for access to the Great Barrier Reef Marine Park and to improve integration between the waterfront and Central Business District. The following extract from CPA’s annual report 2001/02 reveals key statistics.

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[2] The text does not indicate where the balance was disposed of.

Table 2.2 Key Statistics from CPA 2001/02 Annual Report.

CATEGORY	KEY STATISTICS
Cargo	Total cargo movements increased by 7.1% on 2000/01 to 1,133,039 tonnes, reflecting an increase in sugar exports. Exports increased by 19.1% to 511,419 tonnes, Sugar increased 40.6% to 323,420 tonnes. General cargo has also shown growth increasing 5.9%. Molasses and petroleum, products decreased 29.0% and 8.4% respectively on 2000/01. Imports decreased by 1.0% to 621,620 tonnes. Petroleum products increased by 1.3%. LP Gas and fertiliser decreased 21.4% and 10.8% respectively on 2000/01.
Vessels	Total shipping arrivals decreased by 3.2% to 13,559. Total scheduled ferries and tourist vessels decreased 3.2% reflecting the impact of Ansett's collapse. International cruise liner visits decreased to 18, September 11 impacted the result with 9 cancellations received.
New Trade	Three international cruise liners visited Cairns for the first time during 2001/02.
Industry Groups	Active participation in the Great Barrier Reef Super Yacht Cluster, which offers significant business opportunities for the Port and Port related industries.
Financial	Seaport revenue increased 0.6% to $12.5 million, expenditure increased 14.2% to $14.5 million

Source: Cairns Port Authority Annual Report 2001/2002.

The Entrance Channel is currently 13 km long, 90 m wide, with a design depth of 8.3 m at Lowest Astronomical Tide (LAT). The Inner Port area includes 12 Berth Pockets of varying dimensions and design depths, the Marlin Marina, commercial fishing bases, and swing basins.

The *Sir Thomas Hiley* was replaced by the Port of Brisbane Corporation's self-loading and discharging trailing suction hopper dredge the *Brisbane* in 2001. The *Brisbane* (see Plate 2.1 below) is used to dredge the Entrance Channel under an annual maintenance dredging contract, which takes place within a two to four week period each year.

CPA also uses a Priestmen grab dredge, the *Willunga* (see Plate 2.2), to undertake smaller scale maintenance and capital dredging projects of berth pockets and confined areas of the Inner Port area, that occur throughout the year. Dump barges are used to take the dredged material from the operation of the *Willunga* to the Spoil Ground.

Maintenance spoil has been disposed of at sea since 1980 at a number of designated sites.

Plate 2.1 The current dredge used for the Entrance Channel, the Port of Brisbane Corporation's *Brisbane*

Photo courtesy of Port of Brisbane Corporation

Plate 2.2 The current dredge used for the Inner Port areas, the Cairns Port Authority's *Willunga*

2.4 ANALYSIS OF DREDGING AND DUMPING ISSUES

2.4.1 Introduction

Over the past ten and more years there has been occasional public concern about environmental issues that have been attributed to dredging and/or dumping of dredge spoil. These have been addressed by Carter *et al.* (2002) and relevant extracts from that work are included below.

The first section (**Section 2.4.2**) describes the dominant physical processes at play and provides a background to sediment behaviour under normal and extreme conditions while the second section (**Section 2.4.3**) explores several issues raised by concerned observers.

2.4.2 Sediment Sources, Transport Paths and Sinks

Computer modelling, analysis of maps of ocean currents, and beach observations all predict that a parting exists near Ellie Point between northward coastal transport along the Northern Beaches and southward coastal transport into the south-east corner of Trinity Bay.

On geological timescales of hundreds of years, sediment input into the bay by the Barron River has therefore been partitioned along several transport pathways, namely:

- sand is retained on the beaches, and passes north along the shoreline,
- finer sand and coarse silt is moved south to accumulate in pro-delta depocentres in south-eastern Trinity Bay, and
- fine silt and clay passes offshore and along-shelf to the north-west.

Bottom currents in the offshore bay generally flow offshore or north-west longshelf during periods of strong trade wind; and strong north-west longshore currents up to 1.6 m/s in speed characterise the passage of cyclones, causing sorting and transport of bottom sediment to the north-west. These currents are illustrated on the ‘Physical Environment’ map given in **Appendix A**.

Currents within Trinity Inlet and the near-shore bay are dominated by semi-diurnal tidal movements, which at spring tides may attain velocities up to 0.8 m/s. The tidal asymmetry results in:

- a net landward flux of mud (fine sediments) during neap and intermediate tides, and
- a net seaward flux of sand and mud at spring tides.

As typifies the Great Barrier Reef shelf in general, the great majority of terrigenous sediment input into the Trinity Bay system is deposited either in intertidal depocentres or in the local shore-connected sediment prism, or alternatively is advected along the inner shelf to be added to the sediment prism further north.

Negligible amounts of terrigenous sediment cross the sediment-starved mid-shelf plain to impinge on the reef tract.

2.4.3 Dredging and Dumping Issues

Carter *et al.* (2002) reviewed adverse anthropogenic changes which have been claimed to affect the Cairns region. These include:

- seabed chemical pollution,
- beach damage (erosion, mud pollution),
- Spoil Ground contamination, and
- mud suffocation of offshore coral reefs.

The authors found that:

- Pollutant levels for most sediment samples from Trinity Bay and Inlet fall within currently recommended environmental limits.
- Tidal flows through the mouth of Trinity Inlet are ebb-dominated, which results in the transport into Trinity Bay of potentially polluted sediments from the Smith Creek / Cairns Port area, and their dispersion within the natural system.
- There is no significant threat to Green Island or other offshore reefs by coast-derived sediment from the Trinity Bay area.
- The Cairns Esplanade beach-mudflat system is "stable", apart from naturally encroaching sand (and mud trapped behind it) from Ellie Point, and its vulnerability to erosion during a major cyclone.
- Neither the high turbidity in coastal waters nor the presence of mud-lumps on the Northern Beaches are related to the presence of the offshore Spoil Grounds (current or disused).
- Sediment which is reworked from the present dredging Spoil Ground has no discernible geochemical effect at distant locations, and its volume is insignificant compared with the natural sediment flux through the system.

2.5 DETAILS OF CURRENT AND PREVIOUS PERMITS

CPA's previous permit G01/656 under the Great Barrier Reef Marine Park Regulations (Cwlth) and the Marine Parks Regulations 1990 (Qld) is for:

> Dumping of up to 500,000 dry solid tonnes of dredge spoil resulting from the maintenance dredging of the Cairns port and port channel and emergency dumping[3].

A copy of this permit, which was valid until February 2004, is included in **Appendix C**. An interim permit valid until February 2005 to authorise dredging and dumping activities has been issued pending the completion of this report.

CPA has held annual permits for maintenance and capital works dredging as required by the legislation.

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[3] Emergency dumping is that associated with dredging required to re-establish navigable depth should rapid loss of depth occur as a result of, for example, a flood or cyclone.

2.6 CURRENT SPOIL GROUND

2.6.1 Location

The current Spoil Ground is located within the GBRMP, approximately 2.8 nm to the north of the Channel Fairway. The Spoil Ground is a circular area of 1 nm (1,852 m) in diameter, centred on latitude S16°47'24'' and Longitude E145°48'48''. The current Spoil Ground is shown on the 'Study Area' map in **Appendix A**. It is located in approximately 12 m of water (to LAT) and was re-located to that site in 1991 from the previous site which was one nautical mile to the south, between the 5 and 10 m depth contours. See also the 'Study Area' map in **Appendix A**.

2.6.2 Sediment Accumulation Rate

The following information on sediment accumulation rates at the current Spoil Ground were provided by Mr Rob Harris (Senior Surveyor, CPA).

The seabed topography of the site prior to commencement of dumping in 1991, and derived from pre-dredge survey CPA Drawing No. 6-01-560 dated 02/08/91 may be described as follows:

The site has a relatively uniform fall of approximately 0.12% taken along a line through the centre of the circle from the south-west to the north-east. A minimum depth of 10.8 m LAT occurs at the edge of the circle in the south-west quadrant and a maximum depth of 13.1 m LAT occurs at the edge of the circle in the north-east quadrant. A depth of 11.7 m LAT occurs at the centre of the circle.

The seabed topography of the site at the conclusion of channel dredging in 2003, and derived from post-dredge survey CPA Drawing No. 6-01-715 dated 24/09/03 may be described as follows:

The site has a pronounced hump in the south-east and south-west quadrants. The minimum depth of this hump is 9.6 m LAT in the south-east quadrant and 9.7 m LAT in the south-west quadrant. The minimum depths of this hump occur midway between the centre and the edge of the circle. A depth of 10.5 m LAT occurs at the centre of the circle. The site has a relatively uniform fall of approximately 0.28% from the centre along a line to the north-east. A depth of 10.8 m LAT occurs at the edge of the circle in the south-west quadrant and is consistent with the 1991 survey. A depth of 13.1 m LAT occurs at the edge of the circle in the north-east quadrant and is consistent with the 1991 survey.

An estimate of the accumulated volume of dredge material over the Spoil Ground from the commencement of dumping in 1991 until completion of channel dredging in 2003 is approximately 2.5 million m^3. This estimate is derived from an approximate terrain model of the 1991 survey. This estimate gives an annual average accumulation volume of nearly 200,000 m^3, and an average increase in thickness across the Spoil Ground of 70 to 75 mm.

2.6.3 Capacity for Life of 5-Year Permit

The above annual average accumulation volume estimate of 200,000 m^3 corresponds reasonably well with the estimate made by Carter *et al.* (2002) of a 50% rate of redistribution (i.e. 50% retained at Spoil Ground), from seismic survey work undertaken in their study. The Carter *et al.* (2002) estimate was based on an annual dredge volume of 300,000 m^3 which gives retention of approximately 150,000 m^3 at the Spoil Ground.

Using a conservative estimate of sediment thickness increase at the Spoil Ground of 75 mm per year (based on an accumulation volume of 200,000 m^3 per year), the net accumulation over the next 5 years (life of the permit sought) would be approximately 620 mm based on the estimated disposal quantity of 3,300,000 m^3 and an average 50% accumulation rate (see **Section 4.4**). As the depth of water decreases the effects of wave action and tidal currents would become greater at bed level, and might increase the rate of re-suspension of dredged material and hence reduce the rate of increase in sediment thickness. However, a 600 mm decrease in water depth would represent a 5% overall reduction in water depth and so would not likely result in any significant change to the rate of increase in sediment thickness or levels of turbidity although this could be confirmed by monitoring. The current rates of sediment re-suspension and transportation from the Spoil Ground are not considered to be having a significant impact on the wider environs of Trinity Bay (as discussed in **Section 2.4.3** above and further explored in **Chapters 6** to **8**).

In summary, it is clear that there is adequate capacity at the current Spoil Ground for the required 5 year permit and for many years to come. Carter *et al.* (2002) observe that 'the location of the present dredge spoil heap is close to optimum' (p 9).

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3. DREDGE SPOIL DISPOSAL OPTIONS

3.1 INTRODUCTION

The Ocean Disposal Guidelines require that dredge spoil management strategies be developed and that their development should include an evaluation of all disposal options and, where sea disposal is the preferred alternative, the reasons for selecting the sea disposal option given. A detailed options identification and evaluation exercise was undertaken by CPA between 1990 and 1992, as summarised below.

Between 1990 and 1992, studies were undertaken in support of a sea dumping permit associated with major capital works dredging (which saw the main channel widened from 76 m to 90 m) and on-going maintenance dredging. This capital works was necessary to accommodate the *Ampol TVA*, the first of the *Panamax* class of vessel to visit Cairns and an essential part of the fuel import business which represents one of the Port's two major import activities.

These studies (Connell Wagner 1990a and 1992) addressed the history of and need for dredging, the nature and quantity of spoil, and a major project to search for on-shore and off-shore disposal sites. Associated with this work was a suite of modelling and monitoring studies in support of the site selection process for marine sites.

This work led to the selection of the current ocean disposal site and associated monitoring strategies. This chapter provides an overview of this work and an update to the present.

3.2 PHASE 1 STUDY (1990)

3.2.1 Overview

This 1990 Phase 1 study investigated a number of issues including:

- the geologic history of the area,
- early human settlement,
- current and historic dredging,
- alternatives to shipping as a transport mode,
- properties and quantities of spoil generated,
- spoil disposal options including beneficial uses and rehabilitation opportunities,
- physical attributes of the study area, and
- the area's numerous legal, environmental, and other constraints.

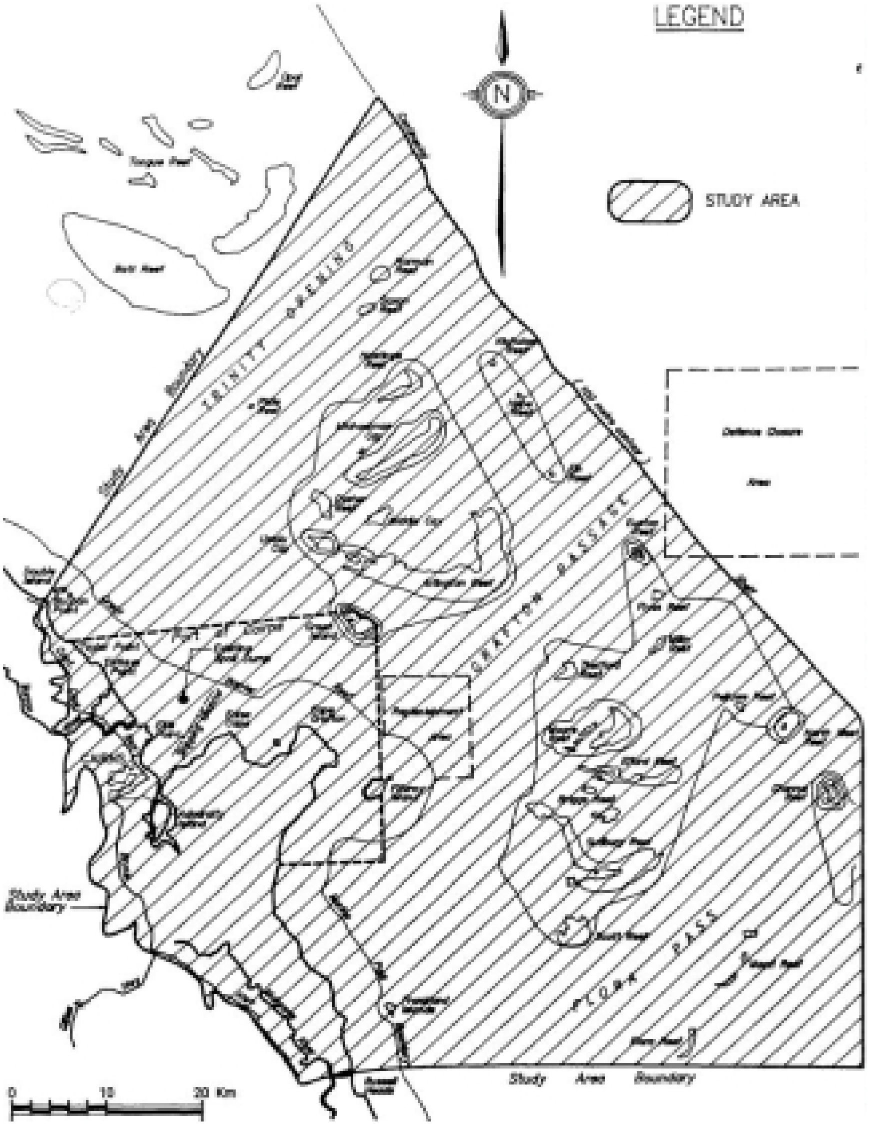
This section details the findings of the 1990 Phase 1 study with respect to spoil disposal options.

3.2.2 Spoil Disposal Options

a) *First Stage Screening*

A first stage screening was undertaken to review the entire study area which comprised the area between Buchans Point in the north, Russell heads in the south, the coastal range in the west, and the continental shelf in the east (see Figure 3.1).

Figure 3.1 Phase One Study Area



Source: Connell Wagner (1990a).

This screening applied a number of acceptance / rejection criteria based on, for terrestrial sites:

- statutory constraints (e.g. national parks, world heritage areas, fisheries reserves),
- environmental constraints (e.g. areas of locally important biological resources as mapped in various resource inventories),
- good quality agricultural land,
- slope and slope stability issues,
- residential development, and
- size (at least 275 ha of land was required to provide a reasonable life of a land disposal facility).

For marine sites, criteria included:

- statutory constraints (e.g. other than general use areas of marine parks),
- oceanographic processes, and
- other marine issues including navigation, communication cables and military zones.

Maps showing each constraint type were produced and overlayed to reveal any suitable areas. This resulted in nine terrestrial sites and eleven marine sites (see **Section 3.2.3** below).

b) ***Second Stage Screening***

Each of these 20 sites was then subjected to a second stage screening which involved a more rigorous application of the acceptance / rejection tests and a more detailed examination of the specific parcels including the following additional constraint criteria for terrestrial sites:

- flood prone land,
- the presence of freely draining soils,
- the presence of infilled drainage lines, and
- insufficient buffers between the sites and adjoining exclusions areas such as national parks

The second stage screening resulted in two terrestrial sites and three marine sites.

3.2.3 Findings

In summary, the whole area was filtered through a series of acceptance and rejection criteria based on the above constraints and a number of possible sites selected for further investigation. These included (see Figure 3.1):

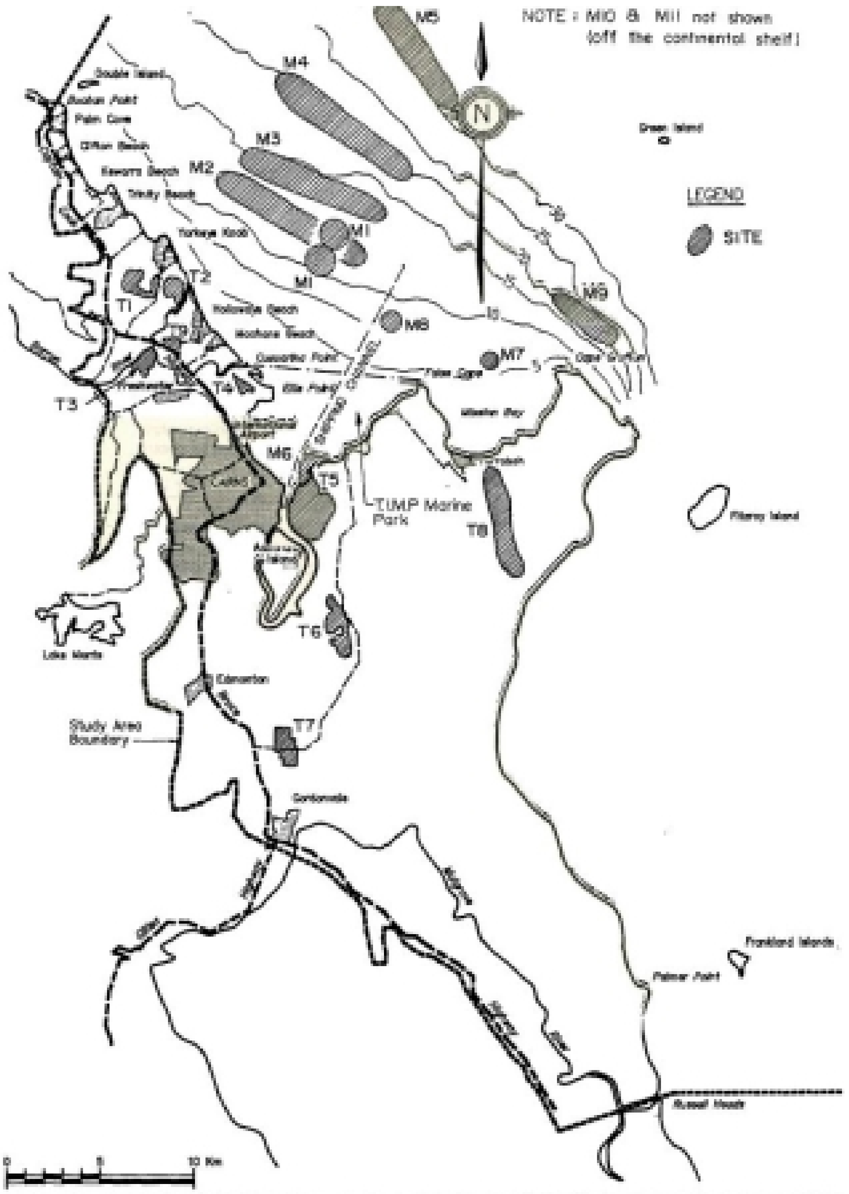
- two terrestrial sites (T5 and T7), and
- three marine sites (M3, M4 and M5).

The overall conclusions of the 1990 Phase 1 study are set out below:

- Historic geomorphological processes created an environment of accretion and this situation is likely to continue.
- The Harbour has been dredged since European settlement with quantities increasing as ship sizes have grown.
- Cairns shares a maintenance dredging requirement with other Queensland ports.
- Modern spoil dumping has been largely off-shore while in earlier years significant dumping involved reclamation of urban areas and future industrial land.
- The Port handles 1.1 million tonnes of cargo per year with major export being sugar (68% of exports) and major import being petroleum (77% of imports).
- The Port services 77% of the entire Far North Statistical Division with a gross value of relevant production being $175 Million (1985 figures).
- There is a possible need to deepen (and lengthen) the channel to cope with full *Panamax* class vessels, with a potential generation of 3 million tonnes of spoil.
- Reduction of maintenance dredging spoil quantity is unlikely.

- No practical across-the-board alternatives to shipping, and Port viability would suffer if selected major commodities were diverted.
- Spoil material is chemically benign for both sea and land disposal, although acidification following land disposal has potential to release heavy metals of elevated concentrations (but still below threshold values).
- Spoil material is weak and difficult to handle on land, consolidates slowly, and contains large volumes of water which, together with runoff from rainfall, would require treatment prior to discharge in sensitive areas.
- The Cairns climate is marginally suitable for evaporative drying of spoil and site drainage Is critical.
- Future dredge spoil quantities could approach 4 million tonnes in the next 10 years (maintenance, swing basin widening, and allowance for one extreme event).
- Six main methods of spoil disposal were identified - three on-shore and three off-shore.
- Limited beneficial uses of dredge spoil because of material properties and restrictions within the study area.
- Rehabilitation options exist, although the material does not represent an attractive agricultural or structural medium.
- The study area is heavily constrained by:
  - residential development
  - habitat, heritage, and resource protection areas
  - Aboriginal land
  - high value agricultural land
  - scenic and recreational areas
  - flood-prone land.
- Coastal processes are not completely understood although extensive monitoring and data collection work is underway.
- The first screening produced twenty sites (9 terrestrial and 11 marine) while the second screening eliminated all but five with perhaps two possible additions.
- Further investigations were found to be warranted, particularly on the marine sites which appear the more favourable.

Figure 3.2 Sites Investigated in Second Stage Screening



Source: Connell Wagner (1990a).

3.3 PHASE 2 STUDY (1992)

3.3.1 Overview

The 1990 Phase 1 report was reviewed by CPA and the then Technical Advisory and Consultative Committee and the study was then expanded to investigate the following issues:

- Opportunities to reduce spoil disposal quantities:
    - consider Port options where dredging would not be required,
    - consider options to reduce the quantity of silt entering the channel, and
    - consider other methods of removing the need to dredge.

- Confirm the quantity and nature of spoil:
  - revise assessment of extreme events, and
  - review physical and chemical properties.
- Investigate certain additional spoil disposal options:
  - agitation dredging,
  - side-casting,
  - other dispersion techniques,
  - creation of artificial habitats in the intertidal zone, and
  - beneficial terrestrial disposal including creation of a useable ‘product’.
- Revise and reapply screening process:
  - reassess selection criteria and explain in more detail,
  - apply a weighting system to consider sensitivity to cost, life and environmental criteria.
- Consider selected sites in more detail:
  - incorporate commercial and recreational fishing sector input, and
  - undertake preliminary field investigations of selected sites.
- Consider effect of replacement of the *Sir Thomas Hiley*.

3.3.2 Spoil Disposal Options

Further analysis of the 20 Phase 1 sites (see **Section 3.2.3**) was undertaken by the Connell Wagner team using more robust environmental and oceanographic criteria and the application of a weighting system and associated sensitivity testing.

This work is described below.

a) *Scoring System*

Attributes were divided into four groups:

- cost,
- life,
- beneficial attributes, and
- non-beneficial attributes.

Three separate analyses were undertaken as follows:

- high weighting to cost / life compared with environmental attributes,
- equal weighting to cost / life compared with environmental attributes, and
- low weighting to cost / life compared with environmental attributes.

The sensitivity testing showed that the preferred sites recorded high scores for all analyses, providing some level of confidence in the process.

b) *Environmental Assessment: Terrestrial Sites*

Environmental specialists Environment Science & Services were engaged to conduct assessments of the top four sites (based on a desktop assessment supplemented by fieldwork) and the following detailed criteria were applied:

- maintenance of productivity,
- protection of nursery areas,
- protection of water quality,
- maintenance of estuarine flushing,
- protection of bird habitat,
- maintenance of habitat continuity,
- maintenance of biological diversity,
- protection of scenic qualities, and
- identification of rehabilitation potential.

The detailed Environment Science & Services assessment was included as Appendix D to the 1992 report (Connell Wagner 2002).

c) *Environmental Assessment: Marine Sites*

Input was received from the commercial and recreational fishing sectors and additional oceanographic assessments made using the following rejection criteria (i.e. all areas not complying were ruled out):

- near-bed currents >0.34 m/s for more than 5% of the year,
- < 10 m deep,
- < 6 km of sensitive sites,
- > 20 km fetch and < 50 m deep[4], and
- with strong stratification.

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[4] shallower sites with smaller fetches were not automatically rejected.

3.3.3 Conclusions

The overall Conclusions of the Phase 2 Report were:

- The Cairns region needs a port.
- The existing Port is in an area of siltation and this siltation interferes with the operation of the Port.
- Relocating the Port clear of the area of siltation is prohibitively expensive and would cause significant environmental impact.
- The methods considered for reducing siltation of the Entrance Channel are not viable for cost, environmental and practical reasons.
- Dredging and spoil disposal therefore need to continue.
- The long term average annual spoil disposal quantity is 540,000 dry tonnes.
- The dredge spoil is chemically benign, of low strength and low agricultural value.
- A number of potential alternative terrestrial and marine disposal sites have been identified.
- A scored screening process has shown one terrestrial and three marine sites to be worthy of further investigation. These are sites T5, M2, M3, and M4. (The latter have been grouped into a composite site named Site M1/M2/M3/M4).
- Conversion of spoil to a useful product does not appear promising and no further investigation in Phase 3 is recommended.
- The *Sir Thomas Hiley* or a suitable replacement dredge is expected to be available for Port of Cairns dredging for the foreseeable future.
- The existing sea dump at Site M1 has an estimated remaining life of 13 years for disposal of maintenance dredging spoil.
- Timing considerations dictate that sea dumping at the present site will need to continue at least until 1994.

3.4 POST-1992 DECISIONS

3.4.1 Dumping

In summary, the key findings of the 1990-92 studies regarding a spoil disposal site were:

- the preferred marine site was in the M1/M2/M3 area,
- the preferred terrestrial site was T5, and
- the marine site was preferred to the terrestrial site.

With respect to the rejected sites:

- T7, while found from the detailed environmental assessment to be “possibly suitable”, was rejected by Connell Wagner because it would require what were considered to be excessive measures to address environmental constraints (these included the need to dispose of saline water in a freshwater environment and concerns regarding groundwater contamination),
- M4 was considered to be part of a suite of sites in the M1/M2/M3/M4 area and is a possible site for future expansion of the current Spoil Ground, and
- M5 was rejected because the dumping of terrigenous material in that environment (on the 30 m contour) was thought likely to be of concern to the GBRMPA.

Since the 1992 study was completed:

- permits have been issued for a sea dumping site in the M1/M2/M3 area and dumping has occurred at this site yearly since 1991, and
- the terrestrial site T5 is no longer available (it was purchased by the Queensland Government in 2001 for environmental enhancement and has since been undergoing rehabilitation to remove the serious acid sulfate soil problem present at that site).

3.4.2 State and Regional Coastal Management Plans

Since the 1992 work was completed, management plans have been completed under the *Coastal Protection and Management Act 1995* (Qld), namely a state plan and a regional plan for the Cairns area.

a) *State Coastal Management Plan*

Coastal dredging and spoil disposal is addressed in the State Coastal Management Plan (Environmental Protection Agency 2001). This policy notes that:

> dredging from land below highest astronomical tide (e.g. within coastal waters) provides navigational and economic benefits to Queensland and is to be appropriately located and sustainably managed to avoid or minimise adverse impacts on coastal water and their values.

A number of management goals are nominated and these are all consistent with good environmental planning and management. The policy also addresses spoil disposal, noting that:

> … when deciding where dredged material comprising muds, clays and silts will be placed, the choice of site is to provide the best coastal management outcome, having regard to the nature of the spoil, the cost of alternative sites, and the potential impact on coastal resources and their values.

b) *Regional Coastal Management Plan*

The regional coastal management plan for the Wet Tropical Coast (Environmental Protection Agency 2003) repeats the State policy and notes that in the Wet Tropical Coast dredging is:

> … mainly associated with the Cairns Seaport, the Port of Mourilyan, the Port Douglas Boat Harbour and Marina, and the Half Moon Bay Marina. Many land and sea areas in the region may be inappropriate for the disposal of dredge spoil because they are World Heritage listed, national park or have important conservation or recreational values.
>
> Because of the commercial and residential development around the Cairns Seaport … suitable land for the disposal of dredge spoil is limited or not available and [CPA places] spoil at sea.

The policy goes on to state with respect to dredge spoil disposal:

> The disposal of dredge spoil inside the Great Barrier Reef World Heritage Area is supported only when all land placement options have been examined and deemed unsuitable, and the placement is consistent with the National Ocean disposal Guidelines for Dredged Material (Environment Australia 2002).
>
> Continued placement of dredge spoil at sea from the Cairns Seaport … should occur only where there has been full consideration of environmental factors including contamination (e.g. acid sulfate soils [which significantly complicates land disposal]).

The document includes a series of maps that the many areas of environmental significance in the Cairns area (i.e. land disposal constraints), confirming (and updating with additional constraints) the analysis described in Connell Wagner (1990a; 1992).

3.4.3 Constraints to Terrestrial Disposal

In addition, in the decade since the above work was completed, the constraints to terrestrial disposal have increased markedly. Contributing factors are:

- continuing urban and suburban development has seen former rural areas converted to housing,
- further protection of good quality agricultural land via the Far North Queensland Regional Plan, and
- strengthening environmental protection (including the designation of new Fish Habitat Areas and Marine Parks in the study area).

The ‘Seagrass, Mangroves and Management Areas’ map given in **Appendix A** shows the high degree of constraints imposed by statutory conservation management areas, including:

- the Great Barrier Reef Marine Park (and the Great Barrier Reef World Heritage Area),
- Queensland Marine Parks,
- Fish Habitat Areas,
- National Parks and the Wet Tropics World Heritage Area, and
- National Estate (includes the Wet Tropics World Heritage Area).

In addition to these formal constraints there are also the physical constraints identified in the earlier site selection exercise (see **Section 3.2.2**).

It is of interest to note that the DPI’s departmental assessment procedures and policy position on the management and protection of marine plants (Couchman and Beumer 2002) note that the disposal of dredged spoil on tidal lands is an “incompatible activity”.

As explained in DPI’s detailed policy on dredging, extraction and spoil disposal activities (Hopkins and White 1998):

> Although dependent on individual cases, Fisheries Group’s preferred spoil disposal option is land based disposal, where assessment of contamination potential has been conducted and necessary treatments determined. Fisheries Group supports disposal of spoil onto designated spoil disposal sites, or material placement areas, where mitigation measures have been considered. Fisheries Group does not support disposal of dredged spoil onto tidal lands or within declared Fish Habitat Areas.

This policy generally rules out tidal land as a disposal site.

Finally, while it is possible that some of the dredged material may be suitable for land disposal (testing has shown that although the material consists of fine-grained unconsolidated marine sediments predominantly in the clay fraction (<75 microns), sediments from the Main Channel material have a higher percentage of gravel and coarse fractions due to tidal scouring), overall the material is soft and fine-grained. Given the variability in the quality of the sediments and the strict time limitations of the dredging and disposal operations (the *Brisbane* must service many ports on a tight schedule and cannot spend time selectively dredging different areas for different disposal strategies), it is considered not feasible to further contemplate the use of the material for land reclamation.

Advice provided by CPA (K Kelleher pers. comm.) indicates that beneficial use is made of dredged material in many ports (e.g. Brisbane and Townsville) but in these cases the following conditions apply:

- there is a need for reclamation in close proximity to the dredging operations, and
- the dredged material is generally free-draining and coarse-grained, making it suitable for use as an engineering fill.

Neither of these conditions apply at Cairns. Further research into developments in techniques to make beneficial use of dredged spoil is recommended outside the context of the 5 year permit.

3.5 CONCLUSIONS

A strong case exists for continued dumping at the current site based on a consideration of need, suitability of the existing site, and the lack of prudent and feasible alternatives. The following table summarises the findings of this work.

Table 3.5: Conclusions of Studies Into Alternatives to Sea Dumping.

ISSUE	FINDINGS	
The need to dredge	1.1	Cairns needs a port for economic survival, especially importation of fuel and fertiliser, exportation of sugar and mining products, and visiting tourist vessels.
	1.2	There are no practical transportation alternatives (e.g. road and rail) for the above goods.
	1.3	There are no practical regional alternatives (e.g. Mourilyan).
	1.4	There are no practical local alternatives (e.g. Yarrabah, offshore).
	1.5	Natural water depths are insufficient to permit the necessary vessels to enter and manoeuvre.
	1.6	Cairns Harbour is in an accreting environment whereby terrigenous sediments continue to be supplied to the area.
Reducing the quantity	2.1	The quantity of dredging is determined in terms of sediment supply by coastal processes (normal and extreme) while the capture of sediment is a function of channel size.
	2.2	Nothing can be done to significantly alter the quantity of dredging required (as per finding 1.6 above).
	2.3	The channel size is determined by vessel size and handling requirements (set by the case for need – as per finding 1.5 above).
Alternatives to sea dumping	3.1	There are no practical beneficial uses of the dredged material in the study area.
	3.2	The one possibly suitable terrestrial site (T5) is no longer available.
	3.2	Urban growth and growing environmental constraints make land disposal increasingly impractical.
Alternative marine sites	4.1	The current site is the best of all those investigated.
	4.2	As noted in **Chapter 7**, this site is performing satisfactorily.

Source: Study team compilation based on Connell Wagner (1990a) and (1992).

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4. CURRENT AND FUTURE DREDGING NEEDS

4.1 INTRODUCTION

The Ocean Disposal Guidelines require an estimate of long-term dredging needs for the term of the permit (5 years) and a description of methods to be used for dredging and off-shore disposal.

These issues are described below based on earlier reports (especially Connell Wagner (1992)) and figures provided by CPA based on historic and recent data.

Finally, an estimate is made of future needs based on both the historic record and an assessment of likely capital works over the term of the permit.

4.2 SUMMARY OF RECENT DREDGING (SINCE 1973)

The following table lists dredge quantities (derived from dredger logs) for the period since 1973 when detailed records commenced. This table excludes volumes dumped off False Cape.

Table 4.1 Historic Dredge Quantities.

YEAR	DREDGE	WET LOAD (m^3) (Note 3)	DRY LOAD (t)	SPOIL GROUND
1973	S.T.Hiley	381,400	280,590	1 nm at S16º49'24" E145º48'05"
1974 (Note 1)	S.T.Hiley	397,800	298,300	As above
1975	S.T.Hiley	209,050	182,460	As above
1976	S.T.Hiley	277,400	236,820	As above
1977	S.T.Hiley	715,100	538,090	As above
1978	S.T.Hiley	381,550	290,210	1 nm dia at S16º48'12" E145º48'00"
1979	S.T.Hiley	704,200	433,800	As above
1980	S.T.Hiley	423,600	325,990	As above
1981	S.T.Hiley	467,100	341,830	As above
1982	S.T.Hiley	397,300	295,550	As above
1983	S.T.Hiley	549,250	388,890	As above
1984	S.T.Hiley	379,700	276,030	As above
1985	S.T.Hiley	370,950	268,820	As above
1986	S.T.Hiley	452,900	353,480	As above
1987	S.T.Hiley	303,500	194,210	As above
1988	S.T.Hiley	516,800	330,300	As above
1989	S.T.Hiley	645,000	334,200	As above
1990 (Note 2)	S.T.Hiley	1,515,350	824,590	As above
1991	S.T.Hiley	770,000	491,540	1 nm dia at S16º47'24" E145º48'48"
1992	S.T.Hiley	666,300	392,960	As above
1993	S.T.Hiley	610,000	360,360	As above
1994	S.T.Hiley	477,500	287,790	As above
1995	S.T.Hiley	554,550	367,930	As above
1996	S.T.Hiley	427,500	250,450	As above
1997	S.T.Hiley	527,500	312,110	As above
1998	S.T.Hiley	432,500	269,050	As above
1999	S.T.Hiley	390,000	227,700	As above

Table 4.1 Historic Dredge Quantities (cont).

YEAR	DREDGE	WET LOAD (m^3) (Note 3)	DRY LOAD (t)	SPOIL GROUND
2000	S.T.Hiley	365,000	223,720	As above
2001	Brisbane	752,270	341,945	As above
2002	Brisbane	927,939	298,484	As above
2003	Brisbane	757,900	201,663	As above
Total		16,746,909	10,219,862	
Average		540,223	329,673	
Average (excl 1990)		507,719	313,176	

Source: CPA logs (Rob Harris, CPA Hydrographic Surveyor, pers. comms.).

Notes:

1. Detailed logs not available – figures taken from Connell Wagner (1992).
2. Major capital works dredging – Entrance Channel widened from 76.2 to 90 m.
3. 'Wet Load' volumes do not represent sediment volume dredged. Rather, volume in 'Wet Load' includes sediment removed together with water introduced by dredger during action of dredging. 'Dry Load' represents dry weight of sediment removed.

4.3 AVERAGE DISPOSAL QUANTITIES

4.3.1 Assessing Long Term Averages

Connell Wagner (1992) used the (then) dredging record to estimate long term averages as a guide to typical Port operations, based on:

- an "average" year of maintenance dredging (i.e. excluding extreme events),
- an allowance in any given year for a cyclonic event, and
- a long term average taking into account the probability of a cyclonic event.

The effect of extreme events on dredge quantities was assessed by Connell Wagner (1992) where it was noted that wind, wave and tidal action generate the circulatory currents which both re-suspend and transport sediments throughout Cairns Harbour. As cyclonic events can have a major impact on these conditions (specifically wave action), it follows that they can have a major impact on sediment transport. The effect of winds and tides which occur in Trinity Bay (derived from Carter *et al.* 2002) are illustrated on the 'Physical Environment' map given in **Appendix A**.

The following is an extract from the discussion on extreme events from Connell Wagner (1992 pp 19 - 20).

> In the short term, the spoil disposal strategy must have the flexibility to cope with the extra material generated by an extreme event in addition to the 'normal' maintenance dredging quantity. The period of reliable dredging records for Cairns is devoid of severe cyclones, except for Cyclone Joy.[5] A number of cyclonic events occurred during the period, but these did not produce a statistically significant increase in dredging quantities.

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[5] This is still the case.

Although Cyclone Joy was considered a severe cyclone in terms of its central pressure and wind speed, its track towards Cairns was such that winds affecting the Harbour were predominantly south east to easterly. For this wind direction the shipping channel is largely protected from wind induced waves and the associated siltation. While some increase in siltation probably occurred (as indicated above), this increase can not be quantified on the basis of historical dredging quantities as only one annual maintenance dredging program has been completed since the channel was widened in 1990.

In the absence of suitable local data, records for the ports of Townsville and Weipa have been examined for guidance on the influence of severe cyclones on siltation. Pringle (1989) documented the effect of an extreme cyclone (Cyclone Althea) on the Platypus Channel at Townsville. Some 600,000 tons of material were deposited in the channel, reducing its depth by approximately 1.4m. Deposition of this magnitude is approximately twice the annual maintenance dredging quantity (ie. the extreme event tripled the normal annual dredging quantity). Winders Barlow & Morrison (1988)[6] document a similar event where Cyclone Jason deposited an additional volume of material equivalent to the annual average maintenance dredging quantity in the Weipa South Channel (ie. doubling the normal annual dredging quantity). The experiences at these ports would suggest an allowance of between two and three times the annual maintenance dredging quantity for any year in which an extreme event occurs. An allowance of double the annual average maintenance dredging quantity in any given year is therefore adopted as a reasonably conservative figure for Cairns.

Over the long term, an estimate must be made of the additional material deposited in the shipping channel due to a number of extreme events. Again, in the absence of suitable major events in the period of record for Cairns, the records for Townsville and Weipa have been used as the basis for forming an opinion on the likely range of effects of severe cyclones. That opinion is that an annual siltation increment of 10% represents the lower bound and 20% represents the upper bound of the effect of extreme events. In order to be conservative, the upper bound has been adopted for use in the estimation of long term disposal volumes. This is equivalent to one extreme event every five years doubling the normal annual maintenance dredging quantity. It is not considered to be unduly conservative for the present purposes.

4.3.2 Estimated Long Term Average

The Connell Wagner (1992) and current figures are tabulated below. In estimating the current figures, the available records (1973 to 2003) have been used as follows:

- quantities from the capital works year (1991) have been ignored,
- as the channel width increased from 76.2 m to 90 m in 1991 (and it is assumed that on average, the quantity of deposition and hence dredging is proportional to the channel width), annual quantities were converted to per-metre of width figures and recombined to give an overall average deposition quantity), and
- as per the Connell Wagner (1992) study:
  - allowance in any year for a cyclone was taken as the average quantity x 2, and
  - the long term average was taken as the average quantity x 1.2.

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[6] Citation not available

Table 4.2 Estimated Spoil Disposal Quantities.

CASE	CONNELL WAGNER (1992)		THIS STUDY	
	WET LOAD (m^3)	DRY LOAD (t)	WET LOAD (m^3)	DRY LOAD (t)
Normal maintenance dredging (excluding cyclonic events)	640,000	450,000	550,000	350,000
Allowance in any year for a cyclonic event	1,285,000	900,000	1,100,000	700,000
Long term average (including allowance for probability of a cyclone)	770,000	540,000	660,000	420,000
5 year total	N/A	N/A	3,300,000	2,100,000

Source: Adapted from Connell Wagner (1992) together with current estimates (see below).

4.4 ESTIMATED LONG TERM DREDGING NEEDS

Advice from CPA is that for the life of the permit sought at least no capital works dredging is planned.

Accordingly, the five year permit figures are as follows:

- wet load 3,300,000 m^3, and
- dry load 2,100,000 t.

4.5 CURRENT AND FUTURE DREDGING METHODS

4.5.1 Introduction

As previously discussed in **Section 2.3.2**, the Port of Brisbane Corporation's Dredge *Brisbane* (see Plate 2.1) currently dredges the entrance channel to maintain a depth of 8.5 m. It operates for two to four weeks, 24 hours a day per dredging period (which is currently undertaken annually). The Cairns Port Authority's Grab Dredge *Willunga* (see Plate 2.2) dredges the berth pockets and confined areas. The mechanisms used by these dredges are given below.

4.5.2 The *Brisbane* Dredge

The *Brisbane* was designed with careful consideration towards minimising environmental impacts associated with dredging. These include low wash and manoeuvrability in order to increase its capability of working safely in sensitive environments.

The *Brisbane* is a self-loading and discharging *Trailing Suction Hopper Dredge*. The twin trailing arms 'suck' sediment from the seafloor which then travels through a pipe system before being deposited in the hopper. The hopper is located in the hull and has a capacity of 2,900 m^3 (www.portbris.com.au). The sediment sinks to the bottom of the hopper and is quickly removed from the intake water which is removed through a low turbidity overflow valve. The low turbidity valve 'cleans' the water and therefore minimises turbidity. The overflow turbidity system is located at the bottom of the dredger which means it is closer to the sea floor allowing sediment particles to settle quickly.

Other environmental design features of the *Brisbane* include turtle deflectors located on the drag head and the design of the hull which minimises wash and therefore bank erosion.

The Port of Brisbane Corporation undertakes the following preventive measures to reduce the risk of transporting Marine Pests:

- The *Brisbane* is 'slipped' every two years and anti-fouling is replaced,
- all Ballast tanks are filled with fresh water which is not exchanged in any of the Ports[7], and
- a thorough initial inspection and wash down of the dredger is undertaken before entering a new Port[8].

4.5.3 The *Willunga* Dredge

The grab bucket dredge *Willunga* is responsible for maintenance dredging within the Port (Upper Trinity Inlet, Wharf 1- 10, HMAS Cairns and Marlin Marina) along with two hopper barges (GHT 22 and AD 501 and Punt number 1) which transport the sediment to the offshore Spoil Ground. The *Willunga* is a *Priestman 625 Dredge* on a 24.8m x 8.96 m barge fitted with optional bucket grabs (2.2m^3 silt bucket, or 1.9 m^3 mud bucket).

4.6 ASSESSMENT OF FUTURE CAPITAL DREDGING NEEDS

As described previously, CPA has no plans for any future capital dredging.

However, initial work is currently underway on a channel simulation to investigate the performance of a range of vessels under current port conditions. Should this indicate a need for consideration of changes to channel configuration, widths and depths, such needs will be factored into future planning and applications.

No details of any such possible future needs are currently available.

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[7] The only reason the Brisbane would need to exchange waters by 'blowing' is during shallow dredging (in which case a 125% exchange occurs as described in the 'Australian Coastal Voyages' subsection of CRIMP).

[8] At present, the *Brisbane* does not enter any international Ports, reducing its exposure to possible pest species.

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5. THE MARINE ENVIRONMENT OF TRINITY BAY AND TRINITY INLET

5.1 INTRODUCTION

Physical and ecological aspects of the marine environment of Trinity Bay and Trinity Inlet are described in this section, with emphasis given to the areas adjacent to dredged areas and the Spoil Ground. The information presented in this section incorporates the findings of a number of previous studies undertaken within the area.

5.2 PHYSICAL ENVIRONMENT OF TRINITY BAY AND INLET

5.2.1 Introduction

Trinity Bay is a low energy tropical embayment in north Queensland, the limits of which include Double Island to the north-west, Green Island to the north-east and Cape Grafton which shelters the bay from predominantly south-easterly trade winds to the south-east (as shown on the ‘Physical Environment’ map given in **Appendix A**). A mid-shelf sediment starved plain (12 km wide) separates Green Island from Cape Grafton. Green Island is a low Coral Cay which is particularly susceptible to changes in water quality (Connell Wagner 1991). The bay is situated centrally between the Great Barrier Reef offshore, mangrove strands within Trinity Inlet and the northern city, the Barron River system and the tropical rainforests of the Atherton Uplands. This makes it an integral component of the tropical environment and ecosystem. The present sea level was reached 6000 years ago and since then coastal waters have been influenced by considerable land run-off, with the Barron River being the major source of sediment (Carter *et al.* 2002).

5.2.2 Geomorphological History of Trinity Bay and Inlet

In the introduction to the first of two major studies into Cairns Harbour dredging and disposal, Connell Wagner (1990a) observed:

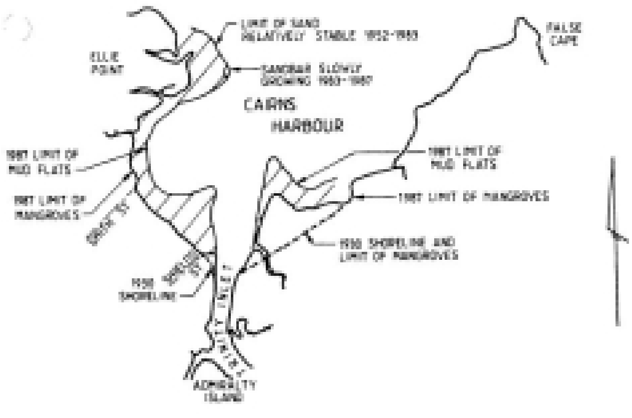
> Perhaps a hundred thousand years ago, Trinity Inlet was the mouth of the Mulgrave River at a time when sea levels were up to a hundred metres lower than they are now.
>
> Following the retreat of the last ice age glaciers, sea levels rose again, reaching their current level about 6000 years ago. As the sea level rose, the abandoned river valley was flooded to form what is now termed Cairns Harbour and Trinity Inlet. Gradual accumulation of muddy sediment (predominantly washed in from the sea) built the mudflats and inlet as we know them.
>
> Most of this sediment came from the Barron River and, as it accumulated, was colonised by mangroves which have trapped sediment and stabilised the mudflats to form the extensive swamp which characterised the area at the time of European settlement [in the 1800s].
>
> The sand ridges upon which much of Cairns is built were formed about 5500 years ago from sand and gravel carried by the Barron River during floods and at a time when its mouth was at Saltwater Creek near Aeroglen. These dunes grew out over the ancient mudflats over a period of a few thousand years, gradually extending the raft upon which the city is now built.

According to one of the area’s most prolific researchers, Prof. Eric Bird (1970):

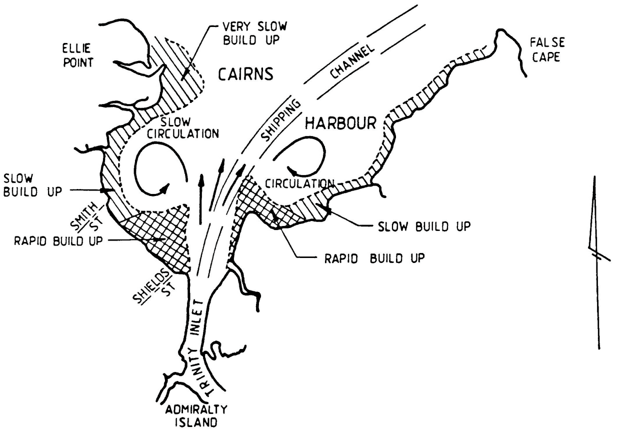
> Ellie Point marks the end of one such spit, still growing into the mangrove swamps along the shoreline south of the airport. Others have been added successively on new alignments seaward to Casuarina Point, which at present is growing rapidly south-eastward, with a sand bar extending beyond it across the muddy bay, towards the dredged navigation channel. The stage is evidently set for new development of beach ridge terrain in this area.

This process is well illustrated by the following sketches taken from Connell Wagner (1990a).

Figure 5.1 Changes in Cairns Shoreline and Harbour



Historic Changes in the Cairns Shoreline



Current Long Term Trends in the Cairns Harbour

Source: Connell Wagner (1990a).

In a major study of the environmental sedimentology of Trinity Bay (Carter *et al.* 2002; a collaborative project by CPA and James Cook University) the geomorphology of Trinity Bay was summarised as follows:

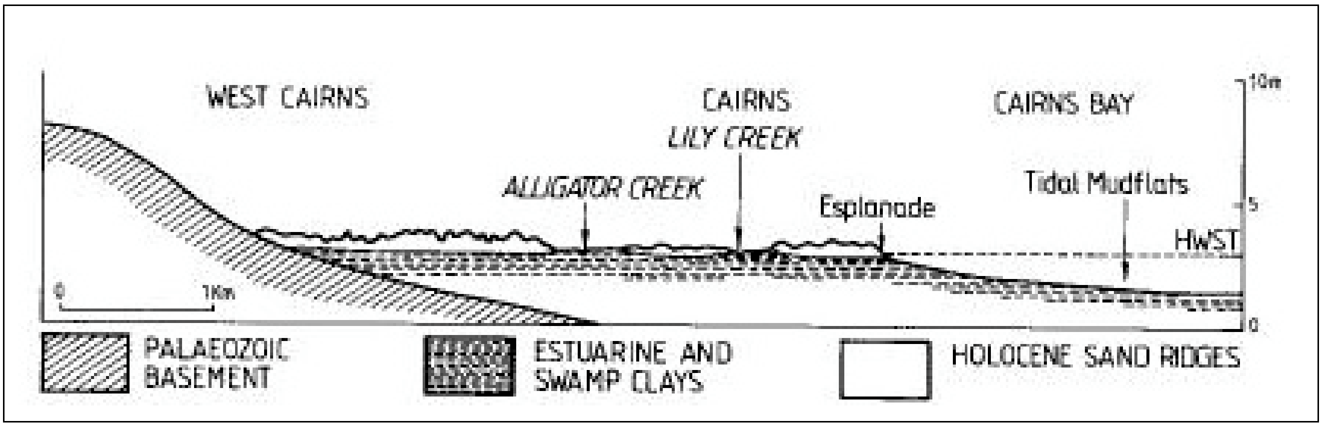
> Trinity Bay contains a landward and seaward tapering prism of up to 20 m of largely mid-Holocene and younger sediment, most of which has been deposited as a seaward-prograding, shore-attached body of sand and mud since c. 6,000 ybp, at rates of up to 1 km/ky [i.e. 1 m per year on average]. Significant volumes of sand and mud have been provided to the bay from the landward side by the Barron River and by northward longshore transport around Cape Grafton; mud, suspended during cyclonic events, enters the bay from the mid-shelf, and is derived from both the reef tract and from far field river flooding and sea-bed re-suspension. Accumulations of mid-Holocene sediment >15 m thick occur in inner Trinity Bay (off the Cairns Esplanade), in the middle bay off the Barron River mouth, and in and around Mission Bay.

The recent history of the mudflats is of some interest as it had led to community views and memories about “sandy beaches”. Connell Wagner (1990a) explain that:

> Robbed of its source of sand once the Barron River moved its mouth to the north, the Cairns Harbour system became dominated by the finer muddy sediments which could be carried further than the heavier sands. Occasionally, when a cyclone approached from the north east, heavy seas distributed thin layers of sand over the mudflats, only to be eroded and covered with fresh mud in calm years.

The siltation process is still continuing as evidenced by very rapid mangrove colonisation east of the Entrance Channel. Since 1930, this shoreline has advanced over 1250 metres seaward and in some places is very close to the Entrance Channel (see **Figure 5.2** and the ‘Seagrasses, Mangroves and Management Areas’ map in **Appendix A**).

Figure 5.2 Section through Cairns City showing Sand Ridges and Mud Flats



Source: Bird (1989).

These conditions also affect water quality. Due to the shallowness of the waters of Cairns Harbour, strong wind and tide driven currents regularly stir up the muddy bottom and create the characteristic brown water which dominates the area. As well as continuing to build the mudflats, the constant supply of silts and clays fill the Entrance Channel and result in a need for regular maintenance dredging to maintain its width and depth necessary for shipping.

5.2.3 Regional Aspects of Sediment Transport in Trinity Bay

The spoil disposal ground and surrounding areas fall within a tropical coastal embayment where short-term weather and long-term climate and geological influences impact its circulation and therefore the transportation and deposition of sediment. The coastal sediment transport processes are complex with variation under these different influences. On the inner shelf, re-suspension from the seabed is dominated by swell waves followed by transport of fine materials by tidal and wind-driven currents. In shallower waters and tidal creeks, re-suspension is dominated by tidal currents and transport directions are variable with grain size and season. The major regional effects on water transport according to Carter *et al.* (2002) include:

- 15 to 25 knot south-east trade winds in the winter,
- North and north-east variable winds and tropical cyclones in summer causing coastal storm surges,
- Daily coastal sea breeze blowing in an easterly (offshore) direction in the morning, moving to north, north-easterly by the evening before fading away at night, and
- Semi diurnal tidal currents also have an influence on water transport flowing west or north-west when incoming (flood tide) and to the north-east when outgoing (ebb tide).

These winds and currents are illustrated on the ‘Physical Environment’ map provided in **Appendix A**.

The study of Trinity Bay carried out by James Cook University (Carter *et al.*) in 2002 discussed in **Section 5.2** has provided much of the information in the following summaries.

a) *South-Easterly Trade Winds and Sediment Transport*

During winter, the south-easterly trade winds dominate the area, causing coastal and shelf waters to drift in a northerly direction at speeds up to 0.5 m/s. As described by Carter *et al.* (2002), Lambeck and Woolfe (2000), using mineralogical data found a trend of increasing sediment maturity in a northerly direction. It was also noted that the Holocene sedimentary wedge within Trinity Bay thins in a northerly direction as well as the sediment trail on Fitzroy Island and the north-directed submerged bar projecting from Cape Grafton. This data forms evidence of a long term northerly transport of sediment.

Northerly longshore currents combined with wave energy dominate the transport of sand and finer grained sediment from south of Cape Grafton and into Trinity Bay. This form of transport has also been found to be dominant from Machans beach, driving sediment from the Barron river along the Northern Beaches.

In the study by Carter *et al. (*2002), COSRAD HF[9] data were collected from the inshore areas of Trinity Bay and found that all the currents measured had a northerly component, and that north of the Barron River mouth, currents had no southerly component at all.

On a regional scale, the south-easterly trade winds result in wave transport driving northern transport of sediment along the Northern Queensland beaches as found by Maxwell (1968) and cited in Carter *et al.* (2002). Due to this transport, coupled with the fact that coastal advection[10] is a major process in North Queensland and the general anticlockwise patterns of circulation in northern lees of projecting capes, mud deposition occurs in the south-eastern areas of the coast proceeding the capes. An example of this is the deposition of sediment in Mission Bay (see 'Physical Environment' map in **Appendix A**).

The study by Carter *et al.* (2002) used a sedimentation modelling program called SEDSIM to model the effects of different wave directions on transportation of sediment. Limitations of this include that the Barron River was assumed to be the only source of sediment to the area, sea level was assumed to be constant, it did not take into account tides, floods and storms, and could only model one wave direction. The results however can be used to show the general influence of these wave directions.

b) *Waves Travelling from the South-East*

The south-easterly waves caused a radial distribution of sediment from the Barron River into the Bay. The coarser grains being in the middle at the river mouth and the fines being further out in the bay.

South-easterly seas are refracted by Cape Grafton, resulting in depocentres forming in the southern parts of the bay (such as Mission Bay). The Cape also has a sheltering effect on parts of the bay, trapping fine grained sediment. The sheltering effects of the Cape according to the model, causes a seaward limit of sediment accumulation at the current 15 m isobath. It was also concluded from the model results that erosion due to these waves was high – especially for coarse sediment, however its influence on the actual transport of sediment was minor. As south-easterly winds dominate the area (apart from summer months), south-easterly waves are important for the long term assessments on sediment transport. North to north-east waves are also important as

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[9] Surface ocean radar instrumentation used to produce synoptic water movement pictures.

[10] Horizontal transport of coastal waters.

they have a significant influence on short term transport which influences the long term patterns. These wave directions are discussed in more detail in **Section 5.2.3c)**.

c) *Variable Summer Winds and Sediment Transport*

From November to January, the variable northerly winds result in weak southerly regional water transport. Coastal waters travelling in a southerly direction can also be caused by winds travelling through the Great Barrier Reef lagoon causing diffracted swell through gaps in the reef and when wind strengths are weak allowing the East Australian Current to dominate. This interpretation is supported by various investigations cited in Carter *et al.* (2002). To the south of Redden Island, the net coastal transport is in a southerly direction as found by Bird 1969, cited and supported by Carter *et al.* (2002) with COSRAD HF data. It was therefore found that the area between Ellie Point and the Barron River marks a significant reversal in littoral sediment transport close inshore.

Cyclone induced currents and their relationship with sediment transport in the area has received little attention due to difficulties in conducting field work at such times. The currents associated with cyclones have been found to be strong north-westerly long shore currents. At such times of a cyclone, sediment re-suspension is probably at a maximum.

Tropical cyclones are often related to intense seasonal rain events resulting in the input of terrigenous sediment to the Great Barrier Reef Lagoon (Taylor 1996). Such events deliver the majority of their annual sediment load within days or weeks. Cyclones are also known to be important to the distribution of shoreline bodies of sand and shell gravel placement, for example cheniers such as those found in the Cairns Basin (Carter *et al.* 2002).

The effects of wave direction on sediment transport is given below according to the SEDSIM modelling discussed above:

- **Waves travelling from the north -** Northerly wave directions result in partitioning of sediment, with sand deltas spreading east into the bay and finer sediment dispersed along the current 20 – 25 m isobath. Small accumulations of sediment were found along the northern beaches with some fine sediment being dispersed into Trinity Inlet, reaching further than under south-easterly seas. The southern end of the offshore mud belt ends in Mission Bay with a pro-delta mud depocentre. Some of the coarser grained sandy sediment is transported south-east around Cape Grafton.
- **Waves travelling from the east -** Erosion of the shoreline is substantial. Coarse sediment close inshore is dispersed parallel to the coast around the Barron River and finer grained sediment is dispersed into the bay. A strong partitioning between the coarser and finer grained sediment also results in a large area of the shelf where no accumulation of sediment occurs.
- **Waves travelling from the north-east -** Under such conditions, all the sediment input from the Barron river was transported in a southerly direction. Coarse sand was found to accumulate in near shore areas and was transported around Mission Bay and Cape Grafton with some sand and sediment dispersed into the Inlet.

d) *Semi-diurnal Tidal Currents and Sediment Transport*

Semi diurnal tides display diurnal inequality in elevation and speed. Carter *et al.* (2002) collected data within Trinity Inlet (where tidal currents are the dominant effect on water transport) using a current meter and nephelometer to show current speeds on spring tides capable of transporting fine sand. These speeds were greatest in the early stages of the ebb tide, 200 mm/s +, greater than the flood tide implying that sand transport due to tides are highly ebb orientated.

The inequality of the tidal system results in:

- net landward flux of mud during neap and intermediate tides, and
- net seaward flux of sand and mud at spring tides.

The tidal asymmetry modelled by Carter *et al.* (2002) at the mouth of Trinity Inlet shows that there is a 15 minute delay between tides within the inlet and adjacent coast. This results in water in the Inlet remaining up to 220 mm higher during ebb tide than the esplanade mud flats and lower during flood due to the phase lag effect.

Tidal measurements taken at Marlin Jetty show that ebb and flood tides flow roughly parallel to the channel. During spring ebb tides, an anticlockwise eddy was found to form at the Inlet mouth (See 'Physical Environment' map given in **Appendix A**), north of Marlin jetty. Although there is a lack of data at neap tides, it is expected the eddy is either weak or not present due to the reduced speed of the ebb tidal jet. Tidal flow at the entrance to Trinity Inlet results in a net flow of water (and suspended sediment) on both tidal phases to move from the channel and onto the south-eastern end of the Esplanade mudflats.

Major sediment depocentres have been found adjacent to the airport and to the north-west of Cape Grafton due to convergences in large ebb and flood tide eddies (See 'Physical Environment' map given in **Appendix A**). The result of convergences with an eddy is generally downwelling of water and therefore sediment in the vortex. These depocentres are located in close proximity to major sediment sources; the first being the Barron River and the second being the longshore sediment drift from the south. The wind was found to have no significant effect on these processes (Carter *et al.* 2002).

Within the mid-shelf off Cape Grafton, stronger wind driven currents of greater than 50 cm/s flow persistently north over all tidal phases. For this reason, regional tides and winds produce a net flow of water and sediment long–shelf to the north except in the presence of strong prevailing winds.

e) ***Summary***

Trinity Bay is a sheltered northerly facing tropical embayment due to the long-term net northerly water motion and therefore sediment transport. The processes controlling sediment transport in the area are complex and vary with season and sediment particle size. Swell wave re-suspension is dominant on the inner shelf, while tidal and wind driven currents drive suspension and transport of fines. Tidal currents dominate transport in shallows and tidal creeks.

Additional to the terrigenous sources of sediment to Trinity Bay (the main one being the Barron River), terrigenous and carbonate mud is advected in from a seaward direction, adding to the Trinity Bay sedimentary prism.

5.2.4 Water Quality of Trinity Bay and Inlet

The following summary information on water quality of Trinity Bay and Inlet has been derived from a number of water quality studies that have been undertaken, which although individually were limited in scope, they together provide some understanding of conditions.

a) ***Trinity Bay***

Water quality variables were sampled at locations of Trinity Bay within the vicinity of the Spoil Ground in the study undertaken by Neil *et al.* (2003). These variables included temperature, salinity and turbidity. Throughout the sampling period, salinity varied between 30.6 and 33.5 ppt, temperature between 26.8 and 28.2°C and turbidity[11] between 9 and 12 mg/L, with variations being independent of site location. It is well known that Trinity Bay is subject to naturally high turbidity (Campbell *et al.* 2003).

The largest impact on water quality in relation to dredging activities is the generation of turbid plumes (SKM 2002). Much of the previous work undertaken in the area involves monitoring of turbidity. In the recent study by Carter *et al.* (2002) natural background turbidity levels within Trinity Bay were found to be generally high, persistently reaching levels of 350 to 450 mg/L. Higher levels of 800 to 2500 mg/L were measured on the Esplanade mud flats, despite the low current speeds in that part of the Bay. The background turbidity levels in Trinity Bay were found by Connell Wagner (1991) to be largely influenced by the freshwater discharge during the annual wet season floods of the Barron River. It was found from review of aerial photography that plumes generated from the flooding events could be expected to extend well out into Trinity Bay.

Turbidity levels within inner Trinity Bay were examined by Connell Wagner (1991) who found that levels were highly variable, dependent on wind condition, tidal state and range, and on the fresh water flows originating from Trinity Inlet and the Barron River. Natural background turbidity was found to reach maximum levels at mid-tide. Minimum suspended sediment at all the sites sampled was 20 mg/L with turbidity found to increase with depth.

b) ***Trinity Inlet***

Water quality sampling has been undertaken within Trinity Inlet as part of a number of sampling programs, all of which were summarised by SKM (2001). Some of the main findings of this report were:

- The water temperature has steadily increased since approximately 1985, both within the Inlet and at the mouth of the Inlet.
- pH readings in the Inlet have often been found below the minimum value recommended ANZECC criteria (as low as 6.2 in Skeleton Creek). Some evidence also suggests that pH levels have declined since 1984, indicating major acidity inputs.
- Dissolved oxygen levels are high at the mouth of the Inlet (80 to 90% saturation), with the lowest levels found in upper and mid Skeleton Creek. Other parts of the Inlet display variability on an annual basis indicating a decline in the five years previous to this report. In general dissolved oxygen levels are satisfactory.
- Chlorophyll levels are high in Chinaman Creek, Smiths Creek and Skeleton Creek. Within Chinaman Creek, chlorophyll levels have consistently exceeded maximum guideline levels of 20 µg/L.
- There has been a general trend of a decrease in total organic nitrogen which is evidence of an improvement in water quality with respect to this parameter.
- The highest levels of total phosphorus are found in the upper areas of Skeleton and Chinaman Creek and these levels have been found to be decreasing, again a sign of improving water quality.

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[11] Actually suspended solids. Carter *et al.* (2002) notes that in the geomorphological work turbidity data measured in NTUs are routinely converted into suspended sediment concentrations using an algorithm developed from previous sampling in similar environments near Townsville. As there are a range of uncertainties involved in this process, the final suspended sediment concentrations have an estimated error of ± 20% on individual measurements. In the balance of this report NTU and mg/L are often used interchangeably to describe turbidity.

Turbidity levels within Trinity Inlet are quite variable with the overall observation. Measurements made along a transect into the Bay by Carter *et al.* (2002) found near-bed turbidity levels to be lowest at neap tides (< 20 mg/L), increasing by double on spring tides. Mud on the bed of the Inlet is plentiful and Carter *et al.* (2002) indicate that measured turbidity levels are likely to represent equilibrium with prevailing hydrodynamic conditions.

Further out towards Marlin Jetty background turbidity levels reach 35 mg/L with intermittent periods of higher suspended sediment concentration due to tidal currents. The highest suspended sediment concentrations (1200 mg/L) were measured on the early ebb tide when material remobilised from the channel is being discharged. Spring flood tides created longer periods of turbidity with suspended sediment concentrations up to 400 mg/L, however during neap tides, suspended sediment concentrations are generally below 50 mg/L. These observations are consistent with earlier work done by Connell Wagner (1991) who found that ebb tides had the effect of clearing the channel of turbid water whereas flood tides mixed the turbid waters throughout the Harbour. The Harbour was found to be well mixed throughout the course of that study. Prevailing currents in Trinity Bay were found to form a buffer preventing any turbid plumes generated from sediment re-suspension in the inter-reef zone from reaching the shoreline and vice-versa (Connell Wagner 1991).

5.2.5 Sedimentology of Trinity Bay and Inlet

a) *Bathymetry and Sediment Distribution*

The bathymetry of Trinity Bay is shown on the ‘Study Area’ map given in **Appendix A**, where depths given are relative to LAT. The sediment distribution within Trinity Bay and Inlet is in part due to the bathymetry. This has been demonstrated through textural analysis of material, showing separations in classes of sediment according to bathymetry (Carter *et al.* 2002). The Inlet floor has a meandering nature, with shallower parts comprising of well sorted sand bars and flats.

Within the main channel lies the Entrance Channel which is maintained to a depth of 8.3 m, and is surrounded by water depths of 2 to 4 m with intermittent sand bars creating shallower depths. Mud flats are present on either side of the channel, with water levels between these of about 1 m. From Cairns Harbour, in an offshore direction, a 5 m depth contour runs from Cape Grafton, past False Cape and parallel to the shore up to the shore side of Double Island. Water depths inshore of this contour show a gradual decrease that parallels the shore line. From the 20 m depth contour east of Cape Grafton, the seaward point of the shore-connected sediment prism runs sub-parallel to the bathymetry in a northerly direction. Therefore, Trinity Bay is entirely within the inner shelf terrigenous zone of sedimentation. Redistribution of this sediment under the influence of wind, waves, tides and cyclones has resulted in this inner shelf containing land-sourced terrigenous sand and mud. The middle shelf, taken as areas offshore of the 20 m depth contour, contains predominantly Pleistocene clay at or near the sea bed, and the outer shelf (greater than 40 m water depth) contains predominantly reef-sourced carbonate gravel, sand and mud (Carter *et al.* 2002).

b) *Surface Sediments*

Surface sediments within Trinity Bay and Inlet were analysed by Carter *et al.* (2002). The sampled sediment was grouped into a number of classes. Four classes were described within the Inlet, and are reproduced below.

Table 5.1 Sediment Classes within Trinity Bay.

SEDIMENT CLASS	LOCATION
Medium Silt – very fine silt	Well sorted innermost shelf and sand rich areas for example offshore Barron delta lobes
Sandy coarse – medium silt	Areas of transition between the shoreface sands and offshore silts
Medium – coarse silt	Bimodal mud facies which characterises deposition in much of offshore Trinity Bay
Coarse – fine sand medium silt	Mid shelf zone poorly sorted

Source: Data from Carter *et al.* (2002).

The main source for sediment in Trinity Bay is the Barron River. Other sources however include:

- Trinity Inlet: there is evidence that in the past, the Mulgrave River was a source of sediment for Trinity Inlet, however, at present the Inlet is composed of a few creeks that transport sediment to the coast on spring ebb tides,
- the offshore reefs contribute fine grained sediment to the Bay. Cyclones may also cause relict carbonate mud to be transported to the shore-connected prism, and
- the dominant south-easterly winds cause wave transport of north-directed bedload from southern areas.

A similar analysis of sediment distribution was undertaken in Trinity Inlet, the results of which are shown below.

Table 5.2 Sediment Classes within Trinity Inlet.

SEDIMENT CLASS	LOCATION
Silt – Very fine sand	Deep areas of the Harbour region of the lower Inlet
Coarse sand	Eastern arm of the inlet and shallow eastern side of the channel
Mud (clayey silt)	Upstream part of the loop
Muddy sand	Deep incision at the mouth of Smiths Creek and some parts of the Port

Source: Data from Carter *et al.* (2002).

As discussed above, the sediment distribution is largely related to the bathymetry and has resulted in a heterogenous inlet floor. Sheets of sand and gravel are advanced seawards, whereas the more cohesive silts line the walls and floor. Lateral bars of well sorted sand also move down the Inlet. An excess of sand can choke the Inlet, as has been seen between Redbank and Skeleton Creek. Temporary muddy accumulations occur in the deeper parts of the inlet and permanent ones in the nearby mangroves. Generally, the sediment found in the dredge area (i.e. both the Entrance Channel and Inner Port Area) is fine grained, unconsolidated sediment that is dominated by silt and clay (<75 µm), with more consolidated, estuarine substrata underlying it.

Sources of sediment to Trinity Inlet include:

- Trinity Bay sediments input during flood tides, mobilised under current and wave action, which settle in areas of low flow during ebb tides,
- agricultural runoff via the numerous creeks feeding the Inlet, and
- fine sediments carried in stormwater drains from the Trinity Inlet catchment including Cairns City; this includes a number of drains which drain large areas of the City including Chinaman Creek, Moody Creek, Cochran Creek and Fernley Street drains (GHD 2000).

The sediment which accumulates in the dredging areas is predominantly unconsolidated silty clay, of annual thickness between 0-0.5 m and 2 m (typically less than 1 m).

c) ***Geochemistry***

The close proximity of Trinity Bay to sources of terrigenous sediment and the Great Barrier Reef results in a natural mixed terrigenous/carbonate environment. The terrigenous input incorporates quartz, feldspar and other silicate minerals whereas the Great Barrier Reef contributes calcareous sediment which has calcite and aragonite in high concentration. Another contributor to the calcareous sediment in Trinity Bay is surface or bottom dwelling organisms with hard calcareous body parts.

In the study by Carter *et al.* (2002), sampling was undertaken to determine the geochemical properties of the sediment. A high range of major element oxides have been found to occur in Northern Queensland waters, however, major element concentrations were less so. The reason for this is that the major element oxides observed in the samples were found to be a mixture of end members of common terrigenous and carbonate minerals.

Various natural processes have resulted in a partitioning of available minerals. Due to the minerals having diverse chemical compositions, mineral and chemical compositions of bulk sediment can characterise different depositional facies. Simple mixing trends are found to occur in the area involving fairly homogenous mixtures of end members.

Table 5.3 and **Table 5.4** illustrate some of these mixtures and where they occur.

Table 5.3 End Members Found to Occur in Trinity Bay.

MIXTURE	COMPOSITION
1	80% quartz, 20% microline
2	20% quartz, 5% microline, 50% clay, 20% carbonate
3	carbonate composition (high magnesium, calcite and aragonite)
4	carbonate composition (low magnesium calcite)

Source: Data from Carter *et al.* (2002).

Table 5.4 Mixing Between End Members at Different Sample Locations.

SAMPLE SOURCE	MIXTURE OF END MEMBERS (SEE Table 5.3)
Barron river delta	1 + 2
Shore connected sediment prism	1 + 2
Mid shelf mixed zone	2 + 3
Slope and basin of Queensland trough	2 + 3 + 4

Source: Data taken from Carter *et al.* 2002.

d) *Mineralogy*

A detailed analysis of mineralogy was undertaken by Carter *et al.* (2002). The main implication of the work was that analysis of heavy metals and quartz:feldspar ratios supported evidence of the following transport patterns:

- northward coastal sediment transport from the Barron River mouth to the Northern Beaches,
- southward transport from the Barron River into Cairns Esplanade, and
- northward transport around Cape Grafton into Trinity Bay.

5.2.6 Spoil Ground

a) *Overview*

The current Spoil Ground is situated in the inter-reef zone of Trinity Bay at a depth of 10 to 13 m approximately 9 km east of Yorkeys Knob and 26 km from Green Island which is the nearest reef area. It is circular in shape, with a diameter of 1 nautical mile. A description of the local bathymetry of the Spoil Ground is given in **Section 2.6.2**. The wave and wind climates of the Spoil Ground are largely influenced by the presence of the Great Barrier Reef as it provides significant shelter from ocean swell (Connell Wagner 1991). Two openings to Trinity Bay are Trinity Opening to the north-east and Grafton Passage to the east, both allowing attenuated ocean waves to access the Bay.

Carter *et al.* (2002) found no geochemical evidence for a halo of contamination around the Spoil Ground. Sediment flux calculations based on a month of instrumental records indicate that over time, and mostly during periods of rough weather, material is gradually removed from the Spoil Ground in a long-shelf and offshore direction. It was also inferred by Carter *et al.* (2002) that the redistributed material blends in with the Bay background sediment as it is re-deposited and bioturbated (mixed by burrowing benthic fauna).

The benthic habitat at the Spoil Ground and in areas immediately adjacent is dominated by fine silt. Sediment transport is predominantly to the north and north-east through a combination of tidal exchange and along-shore drift. Prevailing currents in Trinity Bay form a buffer preventing any turbid plumes generated from sediment re-suspension in the inter-reef zone from reaching the shoreline and vice-versa (Connell Wagner 1991). Sediment transport at the Spoil Ground has varied between weak seaward and along-shelf flow during fair-weather conditions and a strong along-shelf flow during periods of heavy weather such as storms and cyclones.

b) *Tides*

COSRAD HF data showed current flows in Trinity Bay to be dominated by tidal flow and south-easterly winds. Maximum current speeds at the Spoil Ground occur around mid-tide which is typical for tidal waves travelling in relatively deep water (Carter *et al.* 2002). This is different from that found within the Inlet as maximum tidal flows occurred around high tide.

Synoptic surface water motions mapped by the COSRAD HF system in outer Trinity Bay have shown that across most of the Bay, surface water flows offshore to the north-east on ebb tides and west or north-west on flood tides (See 'Physical Environment' map given in **Appendix A**). The result of this is a net water flow along the shelf in a northerly to north-westerly direction. This observation is probably representative of the entire water column in the absence of strong winds and would therefore result in a northerly transport of sediment. When strong winds prevail, developing flows may be complex and 3-dimensional.

c) *Wave Climate*

Wind generated surface waves have a significant influence on sub-surface currents occurring at the Spoil Ground and the wave climate is therefore an important factor in determining its stability (Connell Wagner 1991). Detail on wave conditions in Trinity Bay under varying wind directions as modelled by Carter *et al.* (2002) is given in **Sections 5.2.3a)** and **5.2.3c)**. The sections below describe wave conditions found to occur under specific prevailing conditions at the Spoil Ground.

d) *Strong South-Easterly Winds*

When south-easterly winds reach 20 knots or more in open waters (i.e. at the Spoil Ground), near-bed currents flow between a north-easterly and south-easterly direction on a flood and ebb tide, and the wave heights increase and vary around an easterly direction. Under such conditions, re-suspension of bottom sediments reaches a maximum, resulting in the muddy material from the Spoil Ground being transported predominantly northward (Carter *et al.* 2002).

Connell Wagner had previously found that wind generated surface waves had a significant influence on sub-surface currents occurring at the previous Spoil Ground and the wave climate was therefore an important factor in determining its stability. The current Spoil Ground was sited in deeper water to significantly reduce the effects of wave driven sub-surface currents on bottom sediments.

e) *Cyclones*

Data were collected during cyclone Joy in 1990 by Connell Wagner (Connell Wagner 1991). This cyclone affected Cairns between 22/12/1990 and 26/12/1990 with winds reaching up to 40 knots at the airport. Waves at the Spoil Ground were found to reach 4 metres with current meter records at the bed of the Spoil Ground reaching maximum levels of 1.5 m/s. Turbidity [suspended solids] levels generally within the Bay were significantly raised during a cyclone, and were estimated to reach well in excess of 6 mg/L around the 10 m depth contour, and in excess of 100 mg/L within the Harbour (Connell Wagner 1991).

f) *Water Quality (Turbidity)*

As discussed in **Section 5.2.4**, natural turbidity levels within the Bay are high. See also **Section 6.3** for a discussion on turbidity monitoring at the Spoil Ground in 2000 and 2001.

5.3 ECOLOGICAL ENVIRONMENT OF TRINITY BAY AND TRINITY INLET

5.3.1 Introduction

Trinity Bay and Inlet consist of a diverse range of habitats including:

- mangrove forests,
- seagrass beds,
- tidal mudflats and sandflats,
- claypans and saltmarshes,
- tributary tidal creeks, and
- open waters.

Certain locations within the Inlet and Bay have been designated to be of conservation significance and have been included on the Register of the National Estate – Cairns Tidal Wetlands, Trinity Inlet Fish Habitat Area, and Trinity Inlet/Marlin Coast Marine Park. The Entrance Channel falls within the Great Barrier Reef World Heritage Area (but not Great Barrier Reef Marine Park) and Cairns Marine Park whereas the Spoil Ground falls within the Great Barrier Reef Marine Park. The Inner Port Area and Entrance Channel are excluded from the Trinity Inlet Marine Park and Trinity Inlet Fish Habitat Area. Key management areas are shown on the 'Seagrasses, Mangroves and Management Areas' map given in **Appendix A**.

The conservation values of Trinity Inlet are well known (Weston *et al.* (1998) and the area provides habitat for a range of flora and fauna of conservation significance. Species of fauna found within the Inlet that have been identified to be of conservation significance according to the Queensland Nature Conservation (Wildlife) Regulation 1994, which inhabit the estuary or fringing mangroves include *inter alia*:

- *Esacus magnirostris* (Beach stone curlew),
- *Numenius madagascariensis* (Eastern curlew),
- *Sterna albifrons* (Little tern),
- *Crocodylus porosus* (Saltwater crocodile),
- *Dugong dugon* (Dugong),
- *Chelonia midas* (Green turtle),
- *Kerivoula pauanensis* (Golden tipped bat)
- *Aerodramus spodiopygia* (White-rumped swiftlet), and
- *Xeromys myoides* (False water-rat).

The following sub-sections describe the general ecological environment of Trinity Bay and Trinity Inlet, and specific flora/fauna in the vicinity of the Spoil Ground.

5.3.2 Mangrove Forests

Areas of mangroves are shown on the 'Seagrasses, Mangroves and Management Areas' map given in **Appendix A**. Mangroves have become well developed in Trinity Inlet and form an integral part of the estuarine food chain through leaf litter input and habitat structure. Within the Inlet, mangroves occupy approximately 3,500 ha of which some 3,000 ha are well developed mangrove communities.

Within the operational Port area or any areas likely to be directly affected by dredging, no mature mangrove communities exist. Colonisation of Port areas by mangroves can occur on occasion in intertidal areas although not in areas likely to be dredged. Mature communities exist in close proximity to some of the busier operational areas, such as on the north-western face of Admiralty Island and the “East Trinity” area on the eastern side of the Inlet. The mangrove community between Stafford Point and Bessie Point is expanding westerly in the direction of the Entrance Channel (CPA 2003) (see also **Figure 5.1**).

5.3.3 Seagrass Beds

Seagrass communities are of important ecological value as they are the most productive primary producers in coastal ecosystems. The seagrass communities within Trinity Inlet have been classified as one of two significant areas between Hinchbrook Island and Cooktown (Australian Heritage Commission Database), which is further supported by Coles *et al.* (1993) and Rasheed *et al.* (2004). These communities are present in the inner Inlet in the vicinity of Redbank Creek and on the intertidal flats and sublittoral shoals of the esplanade (Australian Heritage Commission Database). Extensive seagrass beds also occur on the eastern side of the harbour between Bessie Point and False Cape. Significant areas of seagrasses are shown on the ‘Seagrasses, Mangroves and Management Areas’ map given in **Appendix A**. Some fish and prawns spend most or all of their lives in seagrass habitats (Bell 1986; Edgar 1994; Nybakken 1993). The seagrass habitats in inner Trinity Bay and Inlet are considered regionally important according to the Trinity Inlet Management Plan Marine Wetlands Management System (Campbell *et al.* 2002). These Seagrass habitats form critical nursing grounds for prawn and finfish fisheries and also create feeding habitats for ecologically significant species, including the Dugong (*Dugong dugong*), the Green sea turtle (*Chelonia mydas*), and populations of wading birds.

As discussed in **Section 5.2.6**, Trinity Bay is subject to naturally high turbidity (Campbell *et al.* 2003). This means that most seagrass occurs in waters adjacent the shoreline in the first 2 metres where light sufficient for the requirements of photosynthesis can penetrate.

Detailed intertidal and subtidal seagrass surveys of 6 meadows conducted by Campbell *et al.* (2003) in December 2002 and January 2003 recorded 5 seagrass species belonging to 3 Families: *Halodule uninervis* and *Cymodocea rotundata* (Family Cymodoceaceae); *Halophila decipiens* and *Halophila ovalis* (Family Hydrocharitaceae) and *Zostera capricorni* (Zosteraceae).

Although significant impacts of dredging and dredge spoil disposal activities on seagrass have been not ruled out, there is no clear evidence presented thus far to support that these activities are having an adverse effect. Campbell *et al.* (2003) reported results relating to seagrass monitoring sites used as part of a long-term seagrass monitoring program designed to be able to detect the potential impacts of dredging on seagrasses in the shallow inshore areas of Trinity Bay. They suggested that factors other than dredging activities (a complex set of water quality conditions associated with El Nino conditions and atypical wind patterns) were more likely to explain the declines in seagrass meadow size and above ground biomass they observed at some monitoring sites between 2001 and 2003. These findings are supported by the work of Rasheed *et al.* (2004) whose work is proposed to be used to contribute to the overall dredging and spoil disposal monitoring program.

In terms of impacts of the dumping activity, the long term seagrass monitoring program does not currently include offshore sites close to the Spoil Ground and little or no monitoring data are available to indicate how seagrasses in this area might have been changed as a result of spoil disposal activities undertaken at the current and previously used Spoil Grounds. The flora and fauna survey carried out at the current Spoil Ground by Neil *et al.* (2003b) found that seagrasses were completely absent from the Spoil Ground, but sparsely distributed at the southern reference area (the only reference area where it was confirmed to be part of the benthic habitat). Other flora recorded in their survey was also rare in occurrence and sparsely distributed. This sparse distribution pattern and a lack of previous monitoring data for them to compare their results to meant that they could not reach any firm conclusion on whether spoil disposal has had any significant impact on seagrass or other flora at, or near the current Spoil Ground.

5.3.4 Tidal Mudflats and Sandflats

At low tides, approximately 860 ha of mudflats are exposed with the most significant area adjacent to the Cairns Esplanade to the north-west of the Port. The mud and sand flats around the Esplanade and Ellie Point incorporate important wader bird habitats, probably due to the regular removal of mangrove seedlings and the consequent maintenance of highly accessible bare mud. These birds are of significant conservation values in the Marine Park and form an integral part of the marine ecosystem, contributing to the ecology of the mudflats. During a summer peak, approximately 3000 migratory birds have been found in the area at one time (Australian Heritage Commission Database). Cairns is also of regional significance for trans-equatorial migratory wading birds.

Cairns Esplanade forms the most important feeding habitat for birds within the Trinity Inlet, and is nationally important for the following birds (Australian Heritage Commission Database):

- *Actitis hypoleucos* (Common sandpiper),
- *Numenius phaeopus* (Whimbrel), and
- *Pluvialis fulva* (Pacific golden plover).

A number of other significant wader species use the mudflats for both feeding and roosting. In addition to this, the mangroves and intertidal flats inhabit a number of Queensland listed rare and endangered bird species.

These include the following (Australian Heritage Commission Database) which were also given in **Section 5.3.1**:

- *Numenius madagascariensis* (Eastern curlew),
- *Esacus neglectus* (Beach stone curlew), and
- *Sterna albifrons* (Little tern).

5.3.5 Claypans and Saltmarshes

In the intertidal areas, claypan and saltmarshes occur, generally landward of the mangrove forests. These are considered important roosting areas for birds. Brackish areas such as these have not been found in great density in this area, which is unexpected due to its high shoreline to water ratio.

5.3.6 Open Waters

The open waters of Trinity Inlet provide habitat for a number of fauna species of conservation or economic importance as described below.

a) ***Turtles and Dugongs***

A number of threatened and endangered species of turtles and dugong (*Dugong dugong*) occur in Trinity Bay. Although dugong are found in Trinity Bay, much larger populations and significant feeding and breeding grounds occur in coastal waters south of the Cairns region. Despite this, dugong feeding trails are commonly sighted in the *Halodule* seagrass meadows between Bessie Point and False Cape (Michael Rasheed, QDPI &F pers. comm., 2005). Although data are still being compiled to clarify this, the migration patterns of *Dugong dugong* tend to track changes in the status of food supply at particular locations and it is thought that the larger populations of this species south of Cairns are sustained by a larger and less variable (or ephemeral) supply of seagrass (Ivan Lawler, Department of Tropical Environmental Studies & Geography & the CRC Research Centre for Ecologically Sustainable Development, James Cook University, pers. comm. 2004). The above does not diminish the importance of *Dugong dugong* to the Yarrabah community and traditional owners.

The dominant species of turtle in Queensland waters include Loggerhead, Green, Hawksbill and Flatback turtles. All sea turtles are of high conservation significance, with Loggerhead turtles considered endangered and Green and Hawksbill turtles vulnerable (Morton & Nella 2000). There are few large nesting populations of Green, Hawksbill and Loggerhead turtles in the world with Queensland being one of the largest nesting areas in the Pacific (Morton & Nella 2000). Turtles are protected under State and Commonwealth legislation such as the *Nature Conservation Act* (1994) and *Environment Protection and Biodiversity Conservation Act* (1999).

Peak breeding season for Green turtles occurs between November and March. The Green turtle (*Chelonia myalas*) often migrate to breeding rookeries in southern and northern areas of the Great Barrier Reef (Noell 2003). They are protected by international law and therefore protected in all habitats against further predation. As they often migrate through international waters to breed, their conservation requires a cooperative, international approach.

The population of loggerhead turtles (*Caretta caretta*) on the east coast of Australia forms the only significant stock of the species in the Southern Pacific Ocean. This population has declined by 50 to 80% since the 1970s (www.gbrmpa.gov.au). The peak breeding season for loggerhead turtles is between October and May.

The northern Great Barrier Reef Marine Park is internationally significant for Hawksbill turtle nesting. Australia has also been found to be the only place where Flatback turtles breed, mainly on the southern Great Barrier Reef Marine Park (www.gbrmpa.gov.au).

b) ***Fisheries Species***

Surveys of fish and prawn species in Trinity Bay found 20 species of prawns belonging to 6 genera (Olsen 1983) and a fish community similar in nature to that found in similar locations within the Indo-Pacific region (Blaber 1980). Six species of prawn account for the numeric majority of pawns present in Trinity Bay. Of these, Brown tiger prawns (*Penaeus esculentus*) and Grooved tiger prawns (*Penaeus semisulcatus*) are the most commercially important (Olsen 1983). According to Blaber (1980) the inshore and estuarine regions of Trinity Bay are dominated by juvenile marine fish, probably due to the presence of favourable nursery habitats, calm conditions and low numbers of piscivores. More adult fish, particularly piscivores, are present in Trinity Bay than the estuarine and shallow coastal regions. Interestingly, the number of benthic feeding fish in Trinity Bay is relatively low, which Blaber (1980) believed was due to an absence of extensive shallow areas and a low biomass of benthic animals.

5.3.7 Ecological Environment in the Vicinity of the Spoil Ground

A major study was carried out by Neil *et al.* (2003b), looking specifically at the impacts of dredge spoil disposal and benthic communities of flora and fauna. This was carried out by sampling at the Spoil Ground and two control locations 2 km to the north and south of the current Spoil Ground. The study design and range of environmental factors measured as part of that study were based upon information collected as part of previous studies that assessed the physical and chemical nature of benthic habitats at and adjacent to the current Spoil Ground and the role of hydrodynamic processes in sediment transport and spoil plume dispersal.

a) *Benthic Fauna in the Vicinity of the Spoil Ground*

Up until the study conducted by Neil *et al.* (2003b), knowledge of macrobenthic fauna had been restricted largely to Trinity Inlet (see Olsen 1983 for review) and no previous studies had assessed the impacts of dredge spoil disposal activities on the Trinity Bay benthic community. The survey carried out by Neil *et al.* (2003b) reported a diverse tropical benthic community (a total of 1585 individuals belonging to 94 taxonomic groups (identified to Family level) were collected from 54 samples (18 paired but composited samples taken from 3 study areas – the northern and southern reference areas and the current Spoil Ground). Of these, polychaetes, molluscs and crustaceans accounted for 90% of all taxa collected. Within these, gastropod snails belonging to the Mitridae, Ranellidae, Nassaridae, Cerithidae and Turridae families, crustacea such as callianassid, tanaid and gammarid shrimp, ascideans (“sea squirts”), and worms such as sipunculids and maldanid and sigallionid polychaetes were numerically dominant. The remaining taxa were represented by less than 20 individuals each.

Comparisons between the benthic assemblages of the current Spoil Ground and those of two control locations to the north and south of the Spoil Ground reported that there was no evidence of a significant impact of spoil disposal activities on the Spoil Ground benthic assemblage as the taxonomic richness (number of species) and composition of benthic organisms at the Spoil Ground were similar to those found at the two control locations.

There was, however, some evidence to support subtle impacts of dredge spoil disposal on benthos:

- A gradient was detected in taxonomic richness with the Southern Control location exhibiting the highest taxonomic richness, the Spoil Ground hosting the lowest taxonomic richness and the Northern Control site exhibiting a taxonomic richness intermediate between these two locations. Furthermore, there was greater similarity in taxonomic composition between the Northern Control location and the Spoil Ground than between the Southern Control location and the Spoil Ground. This pattern was consistent with predictions made by Neil *et al.* (2003b) based on the results of Carter *et al.* (2002), which suggested that removal of spoil material from the Spoil Ground as a result of long-shore drift would result in spoil material being deposited offsite, almost exclusively to the north of the Spoil Ground.
- There was greater between-sample variability in taxonomic richness at the Spoil Ground compared to the two control locations (which may have been due to differential impacts of dredge spoil disposal across the Spoil Ground due to disposal patterns or the creation of mosaic of benthic habitat types at the Spoil Ground).
- Deposit-feeding polychaetes belonging to families known to be opportunistic rapid colonisers of dredge spoil sites were more common at the Spoil Ground than at either of the two control sites (though this was not tested for statistically).
- There were relatively more taxa with reduced burrowing capabilities at the Southern Control location compared with the Spoil Ground and Northern Control location (which suggests that sediment overburden resulting from dredge spoil disposal might have led to a decline in such taxa at the Spoil Ground and, to a lesser extent, the Northern Control location).

It is relevant to note that diversity is a relative term and can be measured in a number of ways. Neil *et al.* (2003b) did not qualify their statement by either mentioning that this was based only on taxonomic richness and did not mention what other tropical benthic community they compared their figures with.

b) *Flora in the Vicinity of the Spoil Ground*

The seagrass beds of Cairns Harbour present the only large seagrass areas in the immediate coastal region (Coles *et al.* 1993).

Of the seagrass species listed in **Section 5.3.3**, only two were observed in the survey of the Spoil Ground and two control locations conducted by Neil *et al.* (2003b): *Halodule uninervis* and *Halophila decipiens*. These species are able to tolerate lower light levels and can therefore survive in deeper waters, but are pioneering species (Campbell *et al.* 2003) and their presence and abundance at these depths is highly seasonal and variable between years (M. Rasheed, QDPI pers comm. 2003; R. Hilliard, URS, pers. comm. 2003). Neither *H. uninervis* nor *H. decipiens* were observed within the Spoil Ground and most specimens were collected in the Southern Control location. Even at this location, they were sparsely distributed, with no more than 5 leaf strands recorded in any one benthic grab or sled sample. While Neil *et al.* (2003b) did not rule out the possibility that dredge spoil disposal activities may have contributed to the lack of seagrasses at the Spoil Ground, they state that there was not enough evidence available to make any firm conclusion based on their survey.

5.4 CULTURAL VALUES

5.4.1 Introduction

The Aboriginal cultural heritage values of the Trinity Inlet area have been described in the Trinity Inlet Ethnographic Study compiled by Bruno David (1994) in close consultation with the Traditional Owners of lands surrounding the Inlet. Though the study was generally confined to a relatively small area in the north-eastern section and the coastal margins of the Trinity Inlet (David estimated that his survey probably included about 5% of the sites that could be recorded), much of the material in it is relevant to the wider Trinity Inlet catchment.

According to Northern Archaeology Consultancies (1999),archaeological evidence from sites in north Queensland indicate that Aboriginal people have an occupation well in excess of 20,000 years (e.g. David 1994; Cole *et al*. 1995, Rosenfeld *et al*. 1981), but surprisingly little is known of the pre-contact history of the Trinity Inlet catchment area. Aspects of the post-contact Aboriginal history of the Trinity Inlet area have been documented in a number of sources (Bottoms 1990, 1992; David 1994; Cribb and Lee Long 1995, Taylor 1995) and Bottoms is soon to publish a more detailed history which includes this period.

Based on David (1994) and other work (especially Northern Archaeology Consultancies 1999) it appears that Trinity Inlet remains a significant cultural and economic resource for Aboriginal people of the Cairns region. These include traditional and historical owner groups (Yirrganydji, Gimuy Yidinji, Mandingalbai Yidindji, Yidindji, Gunggandji and Giangurra).

5.4.2 Locations of Value

Locations within the Trinity Inlet area are known to have significance for Aboriginal people. These include places used for hunting, fishing, shellfish gathering, mythological locales and rock art sites. The areas which are held most highly with meaningful regard by Aboriginal people are (the list is not exhaustive and in many cases it is not appropriate to disclose the location of cultural sites):

- the Cairns Esplanade - this area was extensively utilised as a traditional shellfish gathering place and was the location of an early Aboriginal camp,
- the Trinity Inlet wetlands – several Aboriginal groups have made and continue to make extensive use of the Inlet's biological resources which are harvested according to traditional methods,
- Admiralty Island - this area has been noted as an important food gathering point, particularly for crab and shellfish,
- Bessie Point - this small beach community was occupied by Aboriginal families who were forcibly removed from the then Yarrabah Mission. It is an area of significance to Aboriginal people and the site of shell middens now buried beneath sand deposits,

- Koombal Park - this beach, adjacent to Bessie Point, has several painting sites known to local Aboriginal people and there are believed to be nearby caves that may have been frequented for shelter in the past, and
- the False Cape area - the Cape is the focal point of a mythological narration relating to the creation of the headland and surrounding mountain range. There is also a rock painting, depicting a whale, which has been concealed by sand drifts.

From a European point of view, the key cultural features of Trinity Inlet are:

- its connection with the early beche-de-mer fishery in north Queensland,
- its role as one of the most important ‘gateways’ for European settlement of north Queensland, and
- its role as a defence base during World War II.

These historical connections provide important links with the past and are worthy of recognition. Historical research is continuing to record and recommend protection of some important sites, including the gun emplacements at False Cape.

There are still relics of wartime occupation by United States and other Allied troops which may be of interest to visitors from that country. One such feature of considerable interest is the ‘Catalina’ memorial on the Esplanade near Upward Street. The memorial is located on the site of a debriefing hut which was used by aircrew of flying boats based in Cairns during the Second World War.

5.4.3 General Sites of Value

Cribb and Lee Long (1995) developed a predictive model of sites least and most likely to contain archaeological material as follows:

- Least likely:
  - coastal mangroves
  - inland mangroves
  - salt pans
  - urban/developed areas.
- Most likely:
  - sand ridges
  - Melaleuca open forest.

Places of contemporary importance included not only hunting, fishing and gathering zones but also living spaces where people carried out their everyday activities.

The traditional, historical and contemporary significance of raised sand ridges and cheniers within mangrove systems is also emphasised from a number of sites which were identified on the western side of the Inlet, within the present International Airport (Bird and Hatte 1995). These sites show occupation extending probably from pre-contact times through to the very recent past. These were primarily places from where the marine resources of the mangroves and the bay were exploited.

5.4.4 Marine Sites

The above references provide no guidance on marine sites and this is a data gap that may need filling.

Initial enquiries (N Horsfall pers. comm.) suggest the possibility of historic wrecks although it is unlikely that the Spoil Ground would be the site of marine incidents due to its distance from reefs or other hazards. It appears that there has been no detailed work on indigenous archaeological underwater sites although some work has been done that suggests that such sites would most probably be associated with old reefs (i.e. limestone caves). It is possible that there could be significant Aboriginal sites or Story places (again, often associated with reefs, also fishing areas).

It is suggested that further discussions be held with the NQLC in order to determine the likely importance of this issue.

6. SUMMARY OF PREVIOUS ENVIRONMENTAL MONITORING OF DREDGING AND SEA DISPOSAL

6.1 INTRODUCTION

This section summarises the previous sediment, water quality, post-placement biological and marine pest monitoring undertaken in relation to dredging and sea disposal by CPA.

The key findings of the previous monitoring described below are:

- Sediment quality assessments of maintenance material have, to date, found it complies with the sea disposal suitability criteria of the Ocean Disposal Guidelines, and are supported by monitoring at the Spoil Ground.
- There are TBT and trace metal concentrations present in sediments in non-dredging areas which are of concern, and have the potential to mobilise into dredging areas.
- TBT and some trace metals have, on occasion, been measured at elevated concentrations in the Inner Port Area.
- The shipyards are considered to be an on-going source of TBT and trace metals associated with antifouling paints.
- Long term seagrass monitoring studies by the Department of Primary Industries and Fisheries(Rasheed *et al.* 2004) reveal that the marine environment appears to be relatively healthy and recent changes to seagrasses appear to be related to climate rather than any human activity occurring in the Harbour or Inlet. So far the seagrass monitoring program indicates that there have been no adverse effects on seagrass meadows from the current dredging program since the beginning of monitoring in 2000.
- The high turbidity in coastal waters was not related to the presence of the offshore ocean disposal site (Section 2.4) and, at present, there are not yet any conclusive links between turbidity generated through either dredging or dredge spoil disposal and the status of seagrass in Trinity Bay.
- The study by Neil *et al.* (2003b) reported an impact of dredge spoil on benthic fauna, which was subtle and decreased with distance towards the adjacent offsite area to the north. Effects on benthos were expressed as a (not significantly) lower taxonomic richness and abundance /occurrence of taxa that were rarer and had limited burrowing capabilities at the Spoil Ground and northern reference areas compared to the southern reference area. The Spoil Ground also had a higher representation of polychaetes considered to be opportunistic. The only two species of seagrass found almost exclusively in the southern reference area. No seagrass was found at the Spoil Ground at all and, due to the absence of samples with roots attached, the presence of seagrass as part of the benthic habitat in the northern reference area could not be confirmed. The sparse distribution patterns and a lack of previous monitoring data do not allow firm conclusions to be drawn on the degree to which dredge spoil disposal activities have impacted on seagrass. Changes in the distribution of seagrass, identified by a long-term seagrass monitoring program conducted at shallower inshore sites, were thought to be more likely the result of natural factors than of dredging activities.
- An initial survey in 2001 to identify non-indigenous species (NIS) established within the Port, did not identify any potential pest species with a propensity to become introduced via ballast water (i.e. the target species surveyed for). However, one individual of *P. viridis* was collected during the survey, and several individuals had previously been collected from the hull of a locally moored vessel (Neil, pers. comm. 2003). During a second targeted survey in 2002 of dredged areas for *P. viridis* and *H. sanctaecrucis* no individuals of these species were encountered, despite the availability of potentially suitable and vacant habitats.

- No NIS species were encountered at the Spoil Ground or the nearby reference locations by Neil *et al.* (2003b) whose study also investigated the presence/absence of introduced species at these sites.

6.2 SEDIMENT QUALITY

6.2.1 Introduction

This section describes the:

- potential sources of contaminants in sediments at the Port of Cairns,
- criteria used for assessing sea disposal suitability,
- manner in which monitoring is undertaken by CPA to make that assessment, and
- major results from previous monitoring.

6.2.2 Sources of Contaminants in Sediments

a) ***TBT and other Antifouling Paint Related Contaminants***

A comprehensive review of sediment quality in Trinity Inlet by GHD (2000) for HMAS Cairns (located in the Inner Port Area) identified that high inputs of tributyltin (TBT, an organotin) at sites upstream of the Base (particularly from slipways) are likely to be the main source of TBT input into sediments of the Inner Port Area. The study found that leaching of TBT (from vessels greater than 25 m) and other antifouling paint related contaminants from all vessels moored in Trinity Inlet will also continue to be a significant contaminant input source to sediments.

The current ban on the use of TBT on ships less than 25 m, and improved environmental management practices at the slipways on Smiths Creek, will have resulted in a reduction in TBT input from these sites, since the mid 1990s. Environmental controls are in place at these sites (as discussed in **Chapter 7**); however, losses of TBT and other antifoul related contaminants to Trinity Inlet will still occur. The principal source of contaminants from slipways is from blast wastes which are generating during paint stripping activities. Blast waste material can find its way into Trinity Inlet through surface water discharge (which at times may exceed the treatment capabilities at the slipways, particularly during spring tides and/or high rainfall events), and via dust deposition. Blast wastes generated at the Slipways on Smiths Creek are tested for landfill acceptability using the Toxicity Characteristic Leachate Procedure (TCLP), by the respective shipyard businesses prior to disposal to landfill. From the limited range of contaminants which are tested for, the contaminants which currently[12] return values well above detection levels (but which are acceptable for land disposal) include TBT, copper, zinc and lead. Hence, these sites may still act as a source of these contaminants into the future.

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[12] Current TCLP contaminants levels of blast waste, destined for landfill, were gleaned from a review of documentation held at one of the slipways during a site visit during the preparation of this LTDSDMP by a member of the study team.

b) *Trace Metals*

Sources of trace metals generally include *inter alia* urban runoff, sewage treatment plants, power generation, industrial manufacturing and agricultural runoff. Metals and principal input sources include (CRC Catchment Hydrology (1997):

- copper – anti-fouling paints, wear of brake linings, pesticides/herbicides and fertilisers,
- chromium – marine paints (at low levels), wear of tyres and brake linings and engine components,
- nickel – wear of brake linings,
- lead – marine paints (including primers and enamels), leaded fuel (greatly reduced), pesticides/herbicides and fertilisers, and
- zinc – marine paints, used in anodic protection of hulls of steel vessels, wear of tyres and brake pads and corrosion of metal objects (e.g. galvanised steel roofs), pesticides/herbicides and fertilisers.

c) *Hydrocarbons*

Hydrocarbons can be input from road runoff, oily bilge waters, fuel tank overflows, engine maintenance, and outboard motors.

d) *Pesticides*

Insecticides and herbicides can be input from agricultural and urban runoff. Certain pesticides (e.g. the herbicide diuron) are also used in anti-fouling paints for small boats.

6.2.3 Sediment Quality Conditions and Monitoring Requirements in CPA's previous Sea Dumping Permit

CPA's previous General Permit under the *Environmental Protection (Sea Dumping) Act 1981* placed the following conditions and monitoring requirements in relation to sediment quality of dredged material:

> The concentration of contaminants within the dredge soil to be disposed of to the GBRMP, must not exceed the 'Maximum Levels' detailed in the ANZECC Interim Ocean Disposal Guidelines, 1998 (or any subsequent version thereof[13]).
>
> Prior to the commencement of an annual dredging campaign, CPA is required to undertake sediment quality monitoring of the material to be disposed to the Marine Park. Summary data is to be presented to the GBRMPA.
>
> The sample design, timing and scope of reporting for all monitoring programs required…is to be determined in consultation with the GBRMPA.

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[13] The current version of the Ocean Disposal Guidelines are the *National Ocean Disposal Guidelines for Dredged Material (2002)*. The 'concentration' of contaminants in dredged material is taken here to mean the average concentration at the upper 95% confidence level (calculated in accordance with the method specified in Section 3.10.5 of the Ocean Disposal Guidelines).

6.2.4 CPA Sampling and Analysis Plans

From October 1995 onwards, sediment quality has been monitored by CPA within the dredging areas of the Entrance Channel (also referred to as the Outer Channel) and the Inner Port Area (also referred to as the Inner Channel), and at the current Spoil Ground (since 1997). These areas are shown on the 'Study Area' map provided in **Appendix A**. The current maintenance dredging sediment monitoring program is detailed in the 2005 Sediment Analysis Plan (SAP) (CPA 2005), and is described briefly below.

a) ***Sampling***

Sampling, as described in CPA (2005), is currently undertaken at 33 sampling locations from within dredging areas and at six locations at the current Spoil Ground. CPA also independently monitors eight non-dredging areas previously identified by CPA as 'hot spot' sites of elevated TBT. Of the 33 sampling locations within dredging areas, 32 are selected randomly from a possible 96 sites (having discretised the dredging area into 96 grid squares of length 160 m), and one site (SS96), adjacent Commercial Fisherman's Base No. 2, is sampled each round, given the relative isolation of that site. The grid from which dredging area sampling locations are chosen, the eight 'hot spot' sampling locations, and the six Spoil Ground sampling locations are shown on CPA Drawing Numbers 900-082 and 900-083, also given at **Appendix A**.

The frequency of sampling is currently undertaken annually pre-dredging. Samples are collected using a stainless steel van Veen grab sampler. At each sampling location (grid square), a composite sample is formed from between four to six grab samples taken in a south to north transect within the gird square.

b) ***Analysis***

Based on the history of sediment analysis of Cairns Port, known potential sources, contaminants and physical properties of sediments from specified locations, the following analytes are examined under the CPA's SAP:

- trace metals (aluminium, arsenic, cadmium, copper, lead, manganese, nickel, silver, zinc),
- total organic carbon (TOC),
- moisture,
- particle size determination (to 75 µm),
- organotins (including TBT and its breakdown products of monobutyltin and dibutyltin),
- total petroleum hydrocarbons (TPH),
- polyaromatic hydrocarbons (PAHs),
- BTEX (benzene, toluene, ethyl benzene and xylene),
- polychlorinated byphenols (PCBs),
- total phenolics,
- organochlorine pesticides (OCs), and
- organophosphorus pesticides (OPs).

Elutriate testing of TBT is also carried out, in accordance with the Ocean Disposal Guidelines, where average TBT concentrations (at the 95% upper confidence level) exceed the Screening Level provided in the Ocean Disposal Guidelines.

c) *Results to Date*

Graphical presentations of the results of previous SAP rounds of sampling for the dredging areas of the Entrance Channel and Inner Port Area, and the Spoil Ground are provided in **Appendix D** for trace metals and TBT (normalised to 1% TOC in accordance with the Ocean Disposal Guidelines[14]). Data are also included on these graphs for one-off targeted sampling, outside of the SAP program, which have been carried out by CPA within the dredging areas of Trinity Inlet. It should be noted when viewing the graphs that results below detection level are not shown. This absence of low concentrations points on the graphs may give a visual impression of a higher median contaminant status than is actually the case where below-detection limit results make up a substantial proportion of the results. These results have been taken from CPA's MS Access database of sediment quality data, which does not encode the detection limit values. The specific findings of the most recent SAP undertaken by CPA are detailed in CPA (2003c). The proposed 2005 SAP (CPA 2005) contains a useful graphical summary of the major findings over the past 10 years (see **Section 6.3.6**).

From the results of the previous rounds of monitoring, the typical contaminant status of the maintenance material relative to the appropriate Screening Level may be summarised as follows:

- TBT – as shown on the graphs provided in **Appendix D**:
  - Spoil Ground – All samples have been below Screening Level, with the exception of samples from the first round in September 1997 where three locations exceeded Screening.
  - Entrance Channel – Since 1998, all samples from the Entrance Channel have been below Screening Level for TBT. Pre-1998, the Screening and Maximum Levels were exceeded at a number of individual sampling locations (see **Appendix D** p8). However, the average concentrations (at the upper 95% confidence level) were below Screening Level.
  - Inner Port Area – The Screening Level has been exceeded at most locations within the Inner Port Area during each round of sampling, but with levels discernibly trending down over time (illustrated by LOESS smoother plot in Appendix D). The material has previously been deemed suitable for sea disposal on the basis that average concentrations (at the upper 95% confidence level) were below Screening Level and elutriate test results were below the water quality guideline (allowing for initial mixing afforded at the Spoil Ground, in accordance with Ocean Disposal Guidelines).
  - Hot Spots (non-dredging areas) – Monitoring of 'hot spot' areas has identified sediment TBT concentrations which significantly exceed the Maximum Level. It was outside of the scope of this project to analyse data from these areas in detail. What can be said is that they remain as areas that could act as an on-going source of TBT contamination for sediment within dredging areas and may pose a risk in the future if mobilised during a storm event into wider dredging areas (this could result in average TBT concentrations exceeding sea disposal suitability criteria). If this occurred it would be detected in the Sediment Analysis Program and the material would not be disposed of at sea.
- Trace metals (aluminium, arsenic, cadmium, chromium, copper, lead, manganese, nickel, silver, zinc) – as shown on the graphs provided in **Appendix D**:
  - Spoil Ground – All samples have been below Screening Levels, with the exception of samples from the first round in September 1997 where a few locations exceeded Screening Levels for cadmium and zinc.

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[14] normalisation to 1% TOC is performed over the range of 0.2 to 10% TOC, in accordance with the Ocean Disposal Guidelines.

  - Entrance Channel – Since 1998, all samples from the Entrance Channel have been below Screening Level for all metals except mercury (two samples in 2003 exceeded the mercury Screening Level). Pre-1998, the Screening Levels were exceeded on occasion at a number of individual sampling locations for arsenic (31), cadmium (11), copper (2), lead (9) and nickel (3). However, the average concentrations (at the upper 95% confidence level) were below Screening Level.
  - Inner Port Area – Arsenic has exceeded the Screening Level on a number of individual sample locations over time. Cadmium exceeded the Screening Level at a number of individual sampling locations prior to 1998. Copper exceeded the Screening Level at a number of individual sampling locations up until 2001. Lead exceeded the Screening Level at two sampling locations in 1999. Nickel and zinc both exceeded the Screening Level at a few sampling locations in 1995 and again in 1999. However, the average concentrations (at the upper 95% confidence level) for all parameters were below Screening Level.

- Hydrocarbons:
  - PAHs – all samples have previously returned values below detection levels for all of these parameters within dredging areas.
  - TPH – these have been measured at a number of sampling locations but at low levels which are not considered toxic (at such levels), particularly where PAHs are not present. Note that the Ocean Disposal Guidelines do not specify any Screening or Maximum Levels for TPH.
  - BTEX – all samples have previously returned values below detection levels for all of these parameters within dredging areas.
  - PCBs, Phenolic compounds and OC/OP Pesticides – all samples have previously returned values below detection levels for all of these parameters within dredging areas.
- A review of total organic carbon (TOC) values recorded over the monitoring period gave average TOC values for the Inner Port Area, Entrance Channel and current Spoil Ground of 3.1%, 2.9% and 2.2% respectively. These average values indicate an overall reduction in TOC in Trinity Bay from levels observed in Trinity Inlet, but with only a minor difference between sediment in the Inlet with those in the Entrance Channel.

6.2.5 GHD (2000) Sediment Quality Review for HMAS Cairns

a) *Sediment Quality Review for HMAS Cairns (2000)*

GHD (2000) undertook a review of sediment quality in Trinity Inlet as part of an investigation and report into the options for land disposal of spoil from dredging of the Outer and Inner Basins at HMAS Cairns. The review also included a consideration of the behaviour of the antifouling paint tributyltin (TBT), which was known to be “relatively high” in those areas requiring dredging, due to concerns over the potential for some sediment TBT to be released by either dissolution or re-suspension. Conclusions of the GHD (2000) investigation, relating to sediment quality, were as follows:

- TBT is continuing to be accumulated in sediments at the HMAS Cairns Base.
- High inputs of TBT at sites upstream of the Base (particularly from slipways) are likely to be the main source of TBT input into sediments at the Base.
- Vessels moored at the Base are likely to contribute some TBT to the sediments below, but this should decrease significantly in the medium to long term (given current Navy initiatives into minimising TBT released from Navy ships).
- The sediments have an acid sulfate soil potential.
- Copper inputs and copper levels in sediment are unlikely to decrease significantly in the short term.

- TBT contamination in marine disposal will reduce over time (note that disposal is only permitted if the pre-dredge monitoring demonstrates that the material is suitable.)

b) *Comparison of Sediment Quality in the Vicinity of No. 11 Navy Wharf with SAP Results*

Sediment quality monitoring undertaken by GHD (2000) at HMAS Cairns indicates that sediment TBT is elevated relative to the Screening Level in the area immediately surrounding the Navy Wharf. The No. 11 Navy Wharf is shown on the 'Trinity Inlet Foreshore Developments' map given in **Appendix A**. The CPA sampling locations (grid squares SS91 and SS92) which are within that area have not been sampled under the random sampling described above, however where sampling has been conducted at nearby sampling locations (grid squares SS90 and SS93) TBT has also been found to be similarly elevated above Screening. The results of sampling undertaken in the vicinity of HMAS Cairns are comparable with other sampling locations in the wider dredging areas of Trinity Inlet, including Smiths Creek.

6.3 WATER QUALITY

6.3.1 Overview of Previous Water Quality Monitoring Studies

Water quality protection during dredging is important given that dredged areas are within the Trinity Inlet/Marlin Coast Marine Park and Great Barrier Reef World Heritage Area, and in close proximity to the Fish Habitat Area and important seagrass beds present in the inshore environment. CPA has carried out a number of water quality monitoring investigations to confirm that the effects of dredging on water quality are confined and short lived. Water quality monitoring has also been required of all new developments at the Port of Cairns. An overview of each of the previous monitoring studies are given below, and summary findings for major water quality variables follow.

a) *Entrance Channel and Spoil Ground*

Previous routine monitoring of these areas was as follows:

- Total suspended solids and nutrient levels were monitored within the Entrance Channel between December 1995 and November 1997 as part of a monthly water quality program, and
- Total suspended solids, trace metals and hydrocarbons were monitored between December 1997 and September 1999.

Surveillance monitoring in the Entrance Channel and at the Spoil Ground has been carried out pre, during and post-maintenance dredging undertaken by the *Brisbane*.

b) *Trinity Inlet*

Routine water quality monitoring has been undertaken throughout the Inner Port area on a monthly basis since 1995. Parameters tested for include:

- trace metals,
- hydrocarbons,
- faecal coliforms,
- TBT (tributyltin), and
- standard in-situ parameters (dissolved oxygen, conductivity, pH, and turbidity).

c) *Cityport*

Monitoring of turbidity was undertaken in the Cityport area in 2001 throughout the Cityport development. GHD carried out the initial background turbidity monitoring and during the initial construction period and CPA undertook continued monitoring during construction. CPA carried out a number of visual and metered monitoring events throughout the construction of Marlin Marina and the dredging associated with the Cityport development.

d) *HMAS Cairns*

Dredging has taken place at this site once a year between 1997 and 2003 (with the exception of 2002), with monitoring of these events undertaken by GHD and CPA. The main focus of this monitoring has been for turbidity, although mobilisation of metals was monitored on two occasions.

A more detailed description of the dates and findings of previous monitoring work is provided in **Appendix E**.

6.3.2 Turbidity

Routine turbidity monitoring undertaken in the Inlet provides valuable information on the range of background turbidity levels that occur there. Dredging-related monitoring in most cases has involved measurements of turbidity being made pre-, during and post-dredging. Summary tables of dredging-related monitoring and synopses and discussion of the results are given in **Appendix E**.

A marked increase in turbidity (above background concentrations), as measured in nephelometric turbidity units (NTU), is observed during dredging within Inner Port Areas, with turbidity increasing with depth. In contrast, there is typically no increase in turbidity that can be detected from the monitoring data during dredging of the Entrance Channel (refer to **Appendix E** for details of this). Increases in turbidity are observed during placement of dredged material at the Spoil Ground, but return to background levels during post-dredging monitoring.

A key finding of the previous investigations (**Appendix E)** was that the tide has a greater influence on turbidity than does dredging activities. For example, GHD (2002) note that turbidity values were found to be strongly related to tidal changes. Such tidal variations and surface water conditions were found to have a stronger impact on turbidity values than the actual dredging operation (see **Appendix E**).Carter *et al.* (2002) notes that currents within Trinity Inlet and the nearshore bay are dominated by semi-diurnal tidal movements and that current speeds are influenced by intertidal topography. Spring tides ebb from the inlet as a concentrated jet with velocities up to 0.8 m/s. The tidal asymmetry results in a net landward flux of mud during neap and intermediate tides, and a net seaward flux of sand and mud at spring tides. These high velocities are known to cause re-suspension of bottom sediments and contribute to turbidity.

6.3.3 Trace Metals and Hydrocarbons

CPA has undertaken a series of water quality monitoring programs associated with trace metals and hydrocarbons. These have been carried out in Trinity Inlet, Entrance Channel and Spoil Ground, and in the vicinity of HMAS Cairns and synopses and discussion of the results are given in **Appendix E**.

Within Trinity Inlet, a selection of metals have been tested on different occasions, with the most recent studies incorporating only those analytes which had been found to have measurable concentrations in earlier rounds of sampling. Of these, arsenic, chromium, and lead were all at very low concentrations. Copper was found to exceed guideline levels on sixteen occasions and at six different sites, and zinc was found to exceed guideline levels on one occasion at one site.

In the Entrance Channel, the only metals that have been in measurable concentrations often were aluminium and zinc. Although these were found to be within guideline limits, they were again monitored during the June 2000 dredging monitoring event. While continued monitoring of TPH was recommended due to the uses of the area, it has however remained below the detection limit of the monitoring.

The number of metals assessed within HMAS Cairns has also been reduced. The only metals in measurable concentrations in 2003 were arsenic, copper and zinc. Arsenic was measured between 0.016 mg/L and 0.02 mg/L; copper, between 0.005 mg/L and 0.008 mg/L; and zinc, between 0.003 mg/L and 0.02 mg/L.

At the Spoil Ground, the metals monitored were reduced to aluminium and zinc (a larger selection of metals was tested in 1999). Aluminium was below the detection limit during the monitoring in 2000, with zinc reaching a maximum concentration of 0.011 mg/L. All hydrocarbon classes tested for were below detection. However, oil and grease were occasionally measured between 1 and 2 mg/L (at sites within the Spoil Ground).

6.3.4 Nutrients, In-Situ Measurements and Coliforms

CPA have undertaken monitoring of nutrient levels in the Entrance Channel and in the Inner Port Area at the same sites as for trace metals. Nutrients tested for included total nitrogen, ammonia and total phosphorus. In order to comply with the *Transport Operations (Marine Pollution) Act* (1995) sewage provisions, faecal coliforms were also monitored within the Inlet. In-situ field measurements were also made of dissolved oxygen, conductivity, pH and temperature at each sampling site. Biological parameters also tested for included chlorophyll-a and phaeophytin-a.

Monitoring undertaken within the Inlet in 2003 found nitrogen and phosphorus consistently while ammonia was undetected. Faecal coliforms were measured at all sites in the Inlet within the same monitoring program and were found to be in excess of TOMA Human Oyster Consumption levels on 41 occasions, yet it exceeded the Primary Contact (Recreational) guideline only once. No clear trend in the distribution of faecal coliform contamination within Port areas could be deduced throughout this monitoring program.

In the Entrance Channel between 1995 and 1997, nutrient levels were found to exceed guideline levels in periods after rainfall. A significant correlation was seen between rainfall and ammonia, total nitrogen, total phosphorus, and chlorophyll–a. Mean levels of suspended solids and chlorophyll-a, were higher during the wet season than the dry.

The majority of nutrients measured in the Entrance Channel are sourced from within the Inlet from the sewage treatment plant and urban and agricultural run-off, and are therefore not Port-related. For this reason, it was concluded that continual monitoring of the nutrient status of the channel would not aid the development of an environmental management plan for the channel.

6.3.5 TBT

TBT has been tested for and detected in the routine monitoring of Trinity Inlet and dredge-related monitoring in the vicinity of HMAS Cairns. The results of this monitoring are described below. For reference, the marine water quality guideline trigger value (for 95% species protection level) given in ANZECC/ARMCANZ (2000) is 6 ng/L Sn which has regularly been exceeded. The 80% species protection level trigger value in ANZECC/ARMCANZ (2000) is 50 ng/L Sn which has on occasion been exceeded.

a) ***Trinity Inlet***

TBT has been tested for by CPA during monthly water quality monitoring since 1995. Data within the CPA Environment Unit database provided for this review gives data collected within Trinity Inlet between March 2001 and September 2003, where TBT was sampled for at selected sites within the Inlet. These included sites adjacent to Wharf No. 8, Coconuts Slipway, and the No 12. Bulk Sugar Wharf. Detection of TBT was fairly consistent throughout this section of the monitoring program, with levels of TBT measured ranging from 1 to 45 ng/L Sn.

b) ***HMAS Cairns***

Dredging-related sampling for TBT has been undertaken at HMAS Cairns from September 1999. Out of four sites sampled for in September 1999 (pre-dredging), two were below screening levels with the other two reaching levels of 5 and 9 ng/L Sn. TBT was tested for between September and December 1999 during dredging. On most occasions, TBT was below screening levels with one sample found to have a TBT concentration of 6 ng/L Sn.

No TBT was detected during dredging in January 2000, however post-dredging (in March 2000), TBT was detected and ranged between 6 and 22 ng/L Sn. Pre-dredging, in July 2000, TBT was detected at all four sites sampled at levels of 7, 15, 40 and 114 (at site WQ3A[15]) ng/L Sn. Monitoring then took place during dredging in July and August 2000. Two out of the four sites sampled in July 2000 detected levels of TBT at 8 and 10 ng/L Sn. During two rounds of sampling in August 2000, one of the four sites sampled on each occasion was found to have detectable levels of TBT at 6 and 8 ng/L Sn. During post-dredging sampling in September 2000, this same site (30 m from the entrance to the covered berth) had a TBT level of 6 ng/L Sn.

These data suggest that background levels of TBT in Trinity Inlet, although elevated, are not affected by dredging.

6.3.6 Assessment of Level of Concern for Contaminants

[The following text has been provided by CPA based on work conducted of the 2005 SAP.]

EA (2002) provides the following definition for contaminants of concern:

> Those chemical substances for which sources are known or suspected in the dredge area or its catchment, based on the historical data. Where good chemical data are available on the sediments, the contaminants of concern are those substances that are present at levels greater than the relevant Screening Level (Table 5).

Based on this definition CPA has reviewed 10 years of historical sediment quality data collected from Cairns Port to classify the various chemicals in relation to the above definition. All individual sample records from 1998 to 2004 for the Channel, Main Wharves, Navy Base and the three Marinas were reviewed to develop this list. Records from the Channel and Inner Port sampling (including sites in Smiths Creek) conducted between 1995 and 1997 were also included.

Contaminants are classified based on records for individual samples as follows:

- Group 1 below detection level (<PQL),
- Group 2 detected above PQL but below SGL (Screening Guideline Level),

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[15] Location of this site is not known.

- Group 3 above SGL but below MGL (Maximum Guideline Level), and
- Group 4 have recorded levels above MGL.

All parameters that meet the criteria of Group 2 or greater fit the first component of being a “contaminant of concern” for Cairns Port. Based on the second component of the definition, those parameters that fit the descriptions for Group 3 or 4 are regarded as the Action List for the 2005 SAP and will be monitored on an annual basis. Those elements for which less than 3 years of data is available, and a SGL or MGL is specified in EA (2002) are also included. One element that fits this description (Antimony (Sb)) and is included for 2005 at all sites, as it has only previously been tested at one of the inner port sites, and although less than the PQL at that site, investigation of its presence in the broader port areas is warranted. These elements are referred to below as the “Action List”. Those elements in Groups 2 or below, referred to as “Not of Concern” will be sampled less frequently (i.e. every third year). A summary of this review is outlined in the following tables.

Several potential contaminants listed in Tables 3 of EA (2002) have not previously been sampled in Cairns Port due to consideration of likelihood of occurrence based on land use or commodities traded at the Port. These contaminants include some pesticides, radionuclides, chlorinated hydrocarbons, dioxins, and trace metals. The requirement to test for these elements is considered in light of recent research activity, and recent findings published in reviews of water quality in the GBRMP lagoon and catchments. Consideration in future years will be given to addressing those contaminants in strategic manner via this plan and through consultation with the Technical Advisory Consultative Committee (TACC).

Table 6.1 Review Summary – Metal and Tributyltin Contaminants.

Element	Inner Port										Outer Channel									
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
As	🟨	🟥	🟥	🟨	🟨	🟨	*	🟦	🟦	🟨	🟦	🟦	🟨	🟨	🟦	🟨	*	🟨	🟦	🟨
Cd	🟦	🟥	🟥	🟨	🟨	🟨		🟨	🟦	🟨	🟨	🟥	🟨	🟨	🟨	🟨		🟨	🟨	🟨
Cr	🟦	🟦	🟦		🟨	🟦		🟦	🟦	🟦	🟦	🟦		🟨	🟦	🟦		🟦	🟦	🟦
Cu	🟥	🟥	🟥	🟨	🟨	🟦		🟦	🟦	🟦	🟦	🟥	🟦	🟦	🟦	🟦		🟦	🟦	🟦
Pb	🟨	🟨	🟥	🟨	🟦	🟦		🟦	🟨	🟦	🟦	🟦	🟨	🟨	🟦	🟦		🟦	🟦	🟦
Hg	🟨	🟨	🟨	🟨	🟨	🟨		🟨	🟦	🟨				🟨	🟨	🟨		🟨	🟨	🟨
Ni	🟦	🟨				🟨		🟦	🟦	🟦	🟦	🟨				🟦		🟦	🟦	🟦
Zn	🟨	🟥	🟥	🟦	🟦	🟨		🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		🟦	🟦	🟦
Ag	🟨	🟥		🟨	🟨	🟨		🟨	🟨	🟦	🟥	🟥		🟨	🟨	🟨		🟨	🟨	🟨
Mn	🟦	🟦				🟦		🟦	🟦		🟦	🟦				🟦		🟦	🟦	
Sn			🟦	🟦	🟦															
Al	🟦	🟦				🟦		🟦	🟦		🟦	🟦				🟦		🟦	🟦	
F				🟦	🟦									🟦	🟦					
Sb										🟨										
TBT	🟥	🟥	🟥	🟥	🟨	🟨		🟨	🟥	🟨	🟨	🟥		🟥	🟨	🟨		🟨	🟨	🟨

* No sampling conducted during 2001, but was completed at end of Dec 2000 and start of Jan 2002

🟨 <PQL
🟨 >SGL but <MGL
🟦 >PQL but < SGL
🟥 >MGL

Source: CPA (2005).

Table 6.2 Review Summary – Organic Contaminants.

Element	Inner Port										Outer Channel									
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Oil and Grease		🟦	🟦	🟦	🟦							🟦	🟦	🟦	🟦					
TPH	🟦	🟦	🟦	🟦	🟦	🟦	🟦		🟦		🟦	🟦	🟦	🟦	🟦	🟦	🟦		🟦	🟦
PAH	🟨	🟨				🟨			🟨		🟨					🟨			🟨	🟨
Chlorinated Hydrocarbons	🟨	🟨									🟨	🟦 #								
PCB's						🟨			🟨							🟨			🟨	🟨
Total Phenolics									🟨										🟨	🟨
BTEX						🟨			🟨							🟨			🟨	🟨
OP's						🟨			🟨							🟨			🟨	🟨
OC's						🟨			🟨							🟨			🟨	🟨
Total Cyanide				🟨	🟨									🟨	🟨					

Element	Dump Ground										Navy Base									
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Oil and Grease			🟨	🟨							🟦	🟦		🟦	🟦					
TPH	🟨	🟨	🟨	🟨		🟨	🟨	🟨	🟨		🟦	🟦	🟦	🟦	🟦	🟦			🟦	🟦
PAH						🟨			🟨		🟨	🟨							🟨	🟨
Chlorinated Hydrocarbons																				
PCB's						🟨			🟨		🟨	🟨							🟨	🟨
Total Phenolics									🟨											🟨
BTEX						🟨			🟨										🟨	🟨
OP's						🟨			🟨										🟨	🟨
OC's						🟨			🟨										🟨	🟨
Total Cyanide															🟨					

🟨 sampled but <PQL 🟦 >PQL

Trichlorethylene was detected in one sample - not referred to in either Table 3 or 5 of EA (2002).

blank cells indicate elements were not sampled

* No sampling conducted during 2002, but was completed at end of Dec 2000 and start of Jan 2002

Source: CPA (2005).

Based on the review of historical data, **Table 6.3** presents the proposed frequency for sampling of the various elements regarded as "of concern" or "not of concern commencing with the 2005 sampling.

Table 6.3 Contaminants of Concern and Monitoring Frequencies.

	Not of Concern	**Contaminants of Concern**		
			Action List	
	Group 1	**Group 2**	**Group 3**	**Group 4**
Elements	PAH, PCB's Total Phenolics, BTEX, Organo Chlorine Pesticides Organo Phosphate Ppesticides Total Cyanide	Cr, Hg, Mn, Sn, Al, F, Chlorinated Hydrocarbons	Ni	TBT, Ag, Zn, Pb, Cu, Cd, As, Sb
Proposed Sampling Frequency	Every 3 yrs or more frequent if incident or change in port/land use is recorded		Annual	

Source: CPA (2005).

The above analysis provides the basis of the current pre-dredge monitoring program.

6.4 BENTHOS

6.4.1 Dredging Sites and Influenced Areas

The Department of Primary Industries and Fisheries have been conducting detailed surveys of seagrasses in Cairns Bay since the late 1980s. The first surveys of seagrass distribution, species diversity and abundance throughout Cairns Harbour were undertaken as part of broad scale surveys in February 1988 (Coles *et al.* 1993). In December 1993 the Cairns Harbour and Trinity Inlet regions were surveyed (Lee Long and Rasheed 1996) and subsequent detailed mapping of Ellie Point seagrasses occurred in December 1996 (Rasheed and Roelofs 1996). A recent survey (see Rasheed *et al.* 2004) was completed in December 2003 and follows a baseline survey in December 2001. It examined selected representative seagrass meadows in Cairns Harbour and Trinity Inlet, determining the total area of each monitoring meadow, species composition and estimates of seagrass density (above ground biomass for comparison with previous surveys).

According to Rasheed *et al.*(2004)*:*

> … results of the 2003 seagrass monitoring indicated that seagrasses in Cairns Harbour and Trinity Inlet were healthy and that there had been an overall increase from values recorded in 2002. The area and density of intertidal seagrass meadows had significantly increased in 2003, reversing the trends observed in the 2001 baseline and 2002 monitoring surveys. Sub-tidal meadows had also continued to increase in area and biomass (density) in 2003. In addition to the monitoring meadows new areas of subtidal seagrass had established in deeper areas of Trinity Inlet.
>
> While there was significant recovery of intertidal seagrasses in 2003, total area and biomass were still substantially smaller than have been recorded in past surveys (1993 and 1996) and recovery to historical levels may take some time. Regional climate was the most likely driver of the observed changes but local characteristics of the seagrass population and physical characteristics of the site were also likely to have had a significant effect on the observed seagrass change.
>
> The seagrass monitoring program is continuing to provide an indicator of the marine "environmental health" of Cairns Harbour and Trinity Inlet. In 2003 the marine environment appeared to be relatively healthy and recent changes to seagrasses appeared to be related to climate rather than any human activity occurring in the Harbour or Inlet. (Rasheed *et al.* 2004)

The monitoring program, combined with similar monitoring in other north Queensland locations, is helping to develop the understanding of the relationships between climatic changes, anthropogenic disturbance and seagrass abundance. This survey was the second in the planned annual monitoring and as such was still establishing the range of natural changes that may be expected within Cairns Harbour and Trinity Inlet. Despite this some of the relationships between climate and seagrass abundance are beginning to emerge. Continued monitoring through a number of years will help to further resolve these relationships and provide a better context for interpreting observed changes and assessing potential human-induced impacts.

6.4.2 Spoil Ground

The study undertaken by Neil *et al.* (2003b) is the only work to date to look directly at the potential impacts of dredge spoil disposal on the benthic flora and fauna of Trinity Bay. It was commissioned as part of the monitoring requirements set out in **Appendix C** under Cairns Port Authority's permit conditions. The primary aims of this study were to characterise the benthic fauna, seagrass and other benthic floral assemblages of the Spoil Ground and nearby reference areas (located 2 km to the north and south) in terms of taxonomic richness, composition and presence / absence and to determine whether any evidence existed of an impact of on-going dredge spoil disposal activities. The study also tested the prediction of near-field impacts of dredge spoil disposal associated with the hydrological transport of spoil material.

The study design chosen by Neil *et al.* (2003b) was guided by the results of past studies on sediment transport in Trinity Bay (Carter *et al.* 2002; Connell Wagner 1990, 1991, 1992) and was of a type that facilitated the testing of specific impact hypotheses relating to both on-site and off-site impacts. There were no significant reductions in taxonomic richness observed at the Spoil Ground relative to the two reference areas. There were, however, significant differences in taxonomic richness along the north-south axis within each of the Spoil Ground and the northern reference area. Neil *et al.* (2003b) suggested that such differences supported predictions, based on predominant sediment transport patterns in Trinity Bay (described by Carter *et al.*, 2002), that any impacts of dredge spoil disposal would likely be evident at the Spoil Ground itself and areas nearby to the north. Differences in taxonomic composition were observed among the Spoil Ground and reference areas, but these comparisons were not statistically based (even though the necessary methods are available and commonly used in benthic research and monitoring). Variation in taxonomic composition among study areas was not expressed in terms of major differences in the representation of dominant taxa. Rather, differences were subtle and related mainly to the relative abundances of rarer species, though it was also stated that the Spoil Ground was characterised by opportunistic polychaete species, a lower representation of taxa with more limited burrowing capabilities and higher between-sample variability (Neil *et al.* 2003b). These results represent, at worst, a subtle impact of dredge spoil disposal at the Spoil Ground, which decreased to the north

The study by Neil *et al.* (2003b) provides a baseline against which future benthic monitoring can be compared. Although it was a one-off survey that involved no collection of benthic data immediately after disposal activity, it did provide an indication of the cumulative response of the benthic fauna to dredge spoil disposal carried out over the preceding 10 years. Results obtained indicate that the benthic faunal assemblage at the Spoil Ground may have acquired a degree of inertia[16] and/or resilience[17] (in that differences in taxonomic composition between spoil-affected and references areas were described as "minor" and there were more taxa with stronger burrowing capabilities at the Spoil Ground relative to the two reference areas: Neil *et al.* 2003b). Because it was a 'one-off'

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[16] The measure of how much disturbance a population can withstand without showing any response at all. Often called 'resistance', but this term implies that there is some process operating in the population to overcome potential changes in numbers. Also called persistence, but this would indicate that there is no change at all with or without a disturbance (Underwood 1990).

[17] The attribute of a population or community to recover from certain magnitudes of disturbance (Underwood 1990).

survey, however, it does not provide a complete picture of the nature and magnitude of the short-term impacts of dredge spoil disposal on benthos, the ability of the Spoil Ground benthic assemblage to recover between disposal events, or how the Spoil Ground benthic assemblage might change once dredge spoil disposal ceases.

Neil *et al.* (2003b) collected data on seagrass distribution and abundance using a 0.01m^2 benthic grab sampler and a benthic sled mounted with an underwater video camera. Unlike the seagrass monitoring conducted by Campbell *et al.* (2003), above ground biomass and areal extent were not quantified as part of this survey. Neil *et al.* (2003b) found only two species *(H. uninervis* and *H. decipiens*) *of* seagrass present within the study area, and these were sparsely distributed and found almost exclusively within the Southern Control location. No seagrasses were recorded within the Spoil Ground and a lack of attached roots to seagrass leaves found in samples taken at the northern control area did not allow a definite conclusion as to whether seagrasses form a part of the benthos in this study area. This result corroborates observations by Neil *et al.* (2003b) that, although these species occur at depths similar to the Spoil Ground and at locations nearby (e.g. southern section of the shipping channel), they are sparsely distributed. No firm conclusions can be drawn on the degree of the impacts of spoil disposal on these species from the above information (as stated by Neil *et al.* 2003b), particularly given that seasonal or yearly variation in the abundance and occurrence of these species (Michael Rasheed, QWDPI & F, pers. comm. 2005) might equally explain why they were not more commonly observed at either the Spoil Ground or the reference areas. It can only be postulated that any impacts, past or future, would probably be minimal given that *H. uninervis* and *H. decipiens* do not generally form stable habitats at depths similar to that at the current Spoil Ground (see **Section 5.3.7**), and that these should, as pioneering species, be able to readily colonise once the site ceases to be used as a Spoil Ground.

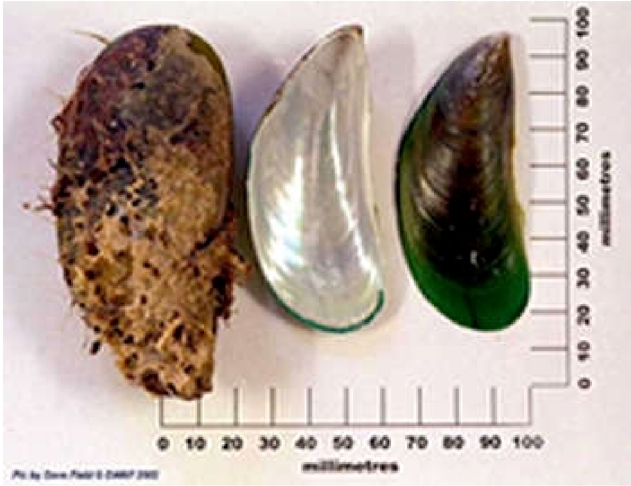
6.5 MARINE PESTS

Two notable NIS have been recorded from the Port of Cairns during the past two years: the Asian green mussel, *Perna viridis*, and the Caribbean tubeworm, *Hydroides sanctaecrucis*, as shown on **Plate 5.1** and **5.2** respectively. Both species are thought to have been introduced via ships' hulls (AMOG Consulting 2002). Both species are prolific fouling organisms with the potential for causing extensive nuisance growths affecting native biodiversity and necessitating maintenance of submerged artificial structures (Rajagopal *et al.* 1994; Somerfield *et al.* 2000). Since it's the discovery of *P. viridis*, efforts have been made to eradicate it from the Cairns area (Neil 2002).

The first comprehensive biological baseline survey of the Port of Cairns was conducted in 2001 by a project team from the Cooperative Research Centre for the Great Barrier Reef World Heritage Area (CRC Reef), James Cook University (JCU), and the Department of Primary Industries (Northern Fisheries Centre), referred to as the CRC Reef Group (Neil *et al.* 2003a). The aim of the survey was to identify NIS established within the Port, in particular those species identified by the Australian Ballast Water Management Advisory Council (ABWMAC) and the CSIRO Centre for Research on Introduced Marine Pests (CRIMP) as potential pest species with a propensity to become introduced via ballast water (these are listed below). The survey adopted (but appropriately modified) the sampling protocols developed by CRIMP (Hewitt and Martin 2001) and targeted all available benthic and pelagic habitats within the Port (intertidal and subtidal hard substrates, subtidal soft substrates and water column) using a variety of methods including visual surveys, quadrat samples, benthic sledding, trawling, trapping and plankton netting (Hoedt *et al.* 2001; Neil *et al.* 2003a). A target survey for *P. viridis* and *H. sanctaecrucis*, using benthic trawls, sled tows and sediment grab samples, was conducted in 2002 specifically in those areas of the Port that were selected for dredging: the Entrance Channel and areas around wharfs and berths for docking of vessels (Neil 2002).

Plate 6.1 ***Perna viridis*** **(Asian Green Mussel)**

Source: www.theage.com.au/articles/2003/07/14/1058034939295.html



Source: http://www.epa.qld.gov.au/environmental_management/water/water_quality_monitoring/projects/introduced_marine_pests/asian_green_mussel/

Plate 6.2 ***Hydroides sanctaecrucis*** **(Caribbean Tubeworm)**

Source: http://www.epa.qld.gov.au/register/p00802aa.pdf

During the baseline survey conducted by the CRC Reef Group, a total of 1,385 taxa were identified that belonged to 379 families within 17 phyla (Neil *et al.* 2003a). Taxonomic identification was taken to lowest taxonomic unit using experts available in Australia. Of the taxa that could not be identified to species level, some were new to science and are yet to be described.

Table 6.4 Species Identified as Potential Marine Pests (with the Propensity to Become Introduced via Ballast Water) by ABWMAC and CRIMP.

COMMON NAME	SCIENTIFIC NAME
Mediterranean fan worm	*Sabella spallanzanii*
Caribbean tube worm	*Hydroides sanctaecrucis* *
European green crab	*Carcinus maenas*
Northern Pacific seastar	*Asterias amurensis*
Japanese oyster (feral)	*Crassostrea gigas*
European clam	*Corbula gibba*
Date mussel	*Musculista senhousia*
Asian green mussel	*Perna viridis* *
Black striped mussel	*Mytilopsis sallei*
Japanese kelp	*Undaria pinnatifida*
Toxic dinoflagellates	*Alexandrium cantenella* *A. miutum* *A. tamarense* *Gymnodinium catenatum*

Source: ABWMAC and CRIMP.

* These species are not on the original ABWMAC or CRIMP target lists, but they were found to be present within the Port of Cairns before the baseline survey had been completed.

None of the ABWMAC or CRIMP target species were encountered during the 2001 baseline sampling of the Port of Cairns and Trinity Inlet. However, one individual of *P. viridis* was collected during the survey, and several individuals had previously been collected from the hull of a locally moored vessel (Neil, pers. comm. 2003). During subsequent eradication attempts, more than 40 Asian green mussels were removed from the Trinity Inlet area. The varying size and reproductive state of the individuals encountered indicate that successful spawning of established parent populations has occurred, with successful settlement and recruitment of F1 progeny individuals (Neil *et al.* 2003a). Individuals of *H. sanctaecrucis* were recorded from hard substrates within the Port of Cairns, especially between the Marlin Marina and Smith's Creek. During the 2002 target survey for *P. viridis* and *H. sanctaecrucis* in those areas of the Cairns Port dredged for shipping movements, no individuals of these species were encountered, despite the availability of potentially suitable and vacant habitats in the form of isolated rocks and rubble, which were sometimes inhabited by other sessile taxa such as sponges and ascidians (Neil 2002). Another NIS collected (in pile scrape samples) was the arborescent bryozoan *Bugula neritina*. This species is of European origin but, today, has a cosmopolitan distribution mediated by transport on ships' hulls (Cranfield *et al.* 1998; Hewitt *et al.* 1999).

Table 6.5 Substrates within the Port of Cairns that were Surveyed in 2001 for Introduced Species, and the Methods Applied.

HABITAT/TARGET ORGANISM	SAMPLING METHOD	SAMPLE UNIT
Wharf and jetty piles (epibenthic assemblages)	Scraping/removal of assemblages Visual surveys	Quadrat (0.1 m^2) Voucher specimens
Benthic infauna	Van Veen Grab	Sediment (0.008 m^3)
Soft-substrate epibenthos	Beam trawl Modified Ockelmann sled-dredge Crab and shrimp traps (baited)	10-minute transects 10-minute transects Catch per trap (~12h)
Water column	Zooplankton and phytoplankton Fish	Plankton nets (100 and 20 µm) Beach seine net
Dinoflagellate cysts	Van Veen Grab	Sediment (0.008 m^3)
Intertidal	Visual surveys	Voucher specimens

Source: Neil *et al.* (2002).

Larval availability and recruitment of marine invertebrate taxa in the same area was previously found to be highly temporally variable throughout the study area (Floerl and Inglis 2003). While the survey carried out by Neil *et al.* (2003a) represents the abundance of sessile taxa in the dredged area for a given point in time, significant recruitment of *H. sanctaecrucis*, *P. viridis* and/or other NIS may have occurred since then.

The 2001 survey also yielded a number of cryptogenic species, i.e. species for which it is not known whether they are introduced or native (**Table** 6.6; Carlton 1996). During the baseline survey of the Cairns Port, some species were recorded as cryptogenic because they had not yet been formally identified by specialist taxonomists. The barnacle, *Balanus amphitrite*, is not native to Australia but was classified as cryptogenic because of the uncertain origin of the species (Hewitt *et al.* 1999). It was found to be abundant on hard substrata around the Port of Cairns and the Marlin Marina, and recruitment of this species to vacant surfaces occurs throughout the year (Floerl 2002; Floerl and Inglis 2003; Neil *et al.* 2003a). A few individuals of the polychaete genus *Polydora* were collected in benthic sled samples. To date, it is not known whether the species collected is *P. ciliata*, a burrowing polychaete introduced to several regions in temperate Australia (Furlani 1996). A number of isopods belonging to the genus *Cirolana* were collected in beam trawl samples from Trinity Inlet. One species within this genus, *C. harfordi*, has been introduced to several regions in temperate Australia (Furlani 1996), but the taxonomic identity of the specimens from Cairns has not yet been determined.

Table 6.6 Non-Indigenous and Cryptogenic Species Encountered.

SPECIES	SCIENTIFIC NAME	HABITAT IN CAIRNS PORT
Non-indigenous species		
Caribbean tube worm	*Hydroides sanctaecrucis*	Hard substrate
Asian green mussel	*Perna viridis*	Hard substrate
Arborescent bryozoan	*Bugula neritina*	Hard substrate
Cryptogenic species		
Acorn barnacle	*Balanus amphitrite*	Hard substrate
Polychaete	*Polydora sp.*	Soft substrate
Isopod	*Cirolana sp.*	Soft substrate

Source: Baseline survey of the Port of Cairns (Neil *et al.* 2003a).

The Asian green mussel and Caribbean tubeworm are regarded as high-risk pest species by local authorities such as the Queensland Department of Primary Industries (QDPI) and the Queensland

Environmental Protection Agency (QEPA). It has been suggested that all other non-indigenous or cryptogenic taxa that have so far been recorded from the Port of Cairns appear to be present in low numbers (except *B. amphitrite*) and do not appear to have obvious impacts on native species. However, in all cases these suggestions were made on the basis of abundance estimates during the Port survey and no experimental evidence for potential impact exists for any of the taxa.

No NIS species were encountered at the Spoil Ground or the nearby reference locations by Neil *et al.* (2003b) whose study also investigated the presence/absence of introduced species at these sites. Unlike the biological baseline survey of the Cairns Port, however, this study did not endeavour to identify collected organisms to species level, as the major objective was to assess the impacts of dredge spoil disposal on benthic communities.

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7. POTENTIAL IMPACTS OF DREDGING AND SEA DISPOSAL, RISK EVALUATION AND TESTABLE IMPACT HYPOTHESES

7.1 INTRODUCTION

The impacts of dredging and sea disposal depend on a number of factors including:

- the quantity of material to be dredged and hence dumped,
- the quality of the material, and
- the interaction of this material and its excavation and dumping with the physical and biotic environment.

Clearly the degree of impact can be reduced by a reduction in the quantity of the dredged material and an improvement in its quality.

Section 7.2 below provides a schedule of expected dredging quantities for the five year permit period. **Section 7.3** provides a discussion of the opportunities for dredge material reduction and mitigation of contaminant sources. Potential impacts of dredging and sea disposal, and the mechanisms of and risk evaluation of those impacts are examined in **Section 7.4**.

Testable impact hypotheses are developed in **Section 7.6** which forms the basis of the environmental monitoring program given in **Chapter 8**.

7.2 SCHEDULE OF QUANTITIES FOR FIVE YEAR PERMIT

As derived in **Section 4.4**, the estimated spoil disposal quantities over the five year permit period are as follows:

- wet load 3,300,000 m^3, and
- dry load 2,100,000 t.

These figures allow for one extreme event during this period and assume that this will result in a doubling of the normal annual quantity of approximately 350,000 dry solid tonnes.

Despite the trend of an increase in the size of vessels wishing to visit the Port, and therefore a need for deepening and/or widening of the channel at some point in the future, CPA do not currently intend to undertake any capital (development) dredging (e.g. channel widening or deepening) during the life of the permit sought (i.e. next five years).

7.3 OPPORTUNITIES FOR DREDGE MATERIAL REDUCTION AND MITIGATION OF CONTAMINANT SOURCES

7.3.1 Introduction

CPA initiatives to reduce the quantity and improve the quality of dredged material are described in **Sections 7.3.2** and **7.3.3** respectively. Wider considerations of the avenues available to CPA for reducing the quantity and improving the quality of dredged material are also given in these sections.

7.3.2 Dredge Material Quantity Reduction Initiatives

Connell Wagner (1992) investigated options to reduce the quantity of dredging required by trying to reduce the amount of sediment that reaches the Entrance Channel (see **Section 3.3.3**). This concluded that the methods considered were not viable for cost, environmental, and/or practical reasons.

The minimum depth of the channel is a business decision by CPA based on the needs of its customers and the requirements of Maritime Safety Queensland (MSQ, Queensland Transport). Although a one-off reduction in dredge volume would be achieved by reducing the depth of the channel, this is not a realistic option.

The design depth provides the minimum clearance at the end of the year (i.e. immediately before dredging) and therefore the channel needs to be over-excavated to accommodate a year's siltation. This is complicated by the fact that annual siltation rates are not consistent throughout the Port. For example, some parts of the Inner Port experience no siltation at all, while some sections of the Entrance Channel experience siltation rates of up to 2 m per year. Target maintenance dredging depths along the channel are the design depth together with an allowance for the annual siltation rate in particular sections. CPA has determined the variation in siltation rates along the Entrance Channel by analysing hydrographic survey data over the previous 12 years.

CPA seeks to responsibly minimise the volume of material dredged each year, through minimising the depth of dredging, by:

- working closely with MSQ in the setting of under keel clearance requirements to pragmatic levels (i.e. so that overly cautious safety factors are not applied),
- on-going review of historic siltation rates (obtained from pre-and post-dredging hydrographic surveys), and
- the on-going development and implementation of a Dredging Environmental Management Plan (Dredging EMP) by CPA, which provides a comprehensive framework for best-practice environmental management of all dredging and sea disposal activities.

The current design depth for the channel is believed to be at the necessary minimum limit for current use. Any loss of design depth affects maximum vessel drafts or arrival/departure times. The current design depth of the channel is not excessive, which is evidenced by vessels like the *QE II* and *Regal Princess* having to anchor off-shore.

CPA's Dredging EMP includes the following measures aimed at dredge material reduction:

- reducing the initial need for dredging via design of facilities where possible or through the use of the sweep bar (i.e. bed levelling) where applicable,
- minimising over-dredging via providing accurate initial estimates of the need to dredge and monitoring of the dredged volume,
- clearly delineating the area and volume which requires dredging, and
- selecting the most efficient dredging apparatus in the circumstances.

Performance criteria are established under the Dredging EMP, which include:

- CPA dredging contracts are to reflect the requirements of the Dredging EMP,
- Dredging EMP procedures and mitigation strategies are to be practical and agreed by the appropriate parties,
- relevant staff of CPA and contractors are to be trained with respect to the applicable Dredging EMP, and
- copies of the Dredging EMP are to be available and up-to-date.

In summary, there is very little opportunity for a reduction in the quantity of material to be dredged and hence dumped.

7.3.3 Sediment Quality Improvement Initiatives

The Ocean Disposal Guidelines recognise that most port contaminants come from diffuse sources on land (as outlined in **Section 6.2.2** above), such as stormwater drains, agricultural runoff or licensed discharges into sewers, which are outside the control of Port Authorities. However, Port Authorities are expected to address polluting activities within their ports.

Opportunities for Port Authorities to improve the quality of sediment which accumulates in navigable areas include:

- materials handling (e.g. reducing product spillage and dust generation),
- storage of goods and waste materials (e.g. proper storage and disposal of fuel/oil and ship’s wastes),
- changing any inappropriate practices (e.g. unnecessary dragging of hulls along berths resulting in paint scraping),
- ballast water management (i.e. reduction in discharge of ballast water where contaminants can contaminate the sediment to be dredged),
- management of surface water adjacent the Port to improve water quality,
- identifying point sources of contaminant input (e.g. potential upstream sources of TBT such as ship repair facilities) and providing stewardship to those responsible for their management in order to reduce pollutant inputs,
- participation in broader scale catchment management to reduce pollutant inputs: urban stormwater, licensed discharges to sewer, sewage effluents, agricultural runoff, groundwater quality etc., and
- participation in policy-setting aimed at reducing pollutant inputs, e.g. restrictions in the application of TBT based antifouling paints on small vessels (currently banned on vessels less than 25 m), and the phasing out (timing has yet to be determined, but may be within the next 10 years in Australia) on all ships.

Specific CPA initiatives to minimise contaminant inputs at the Port include:

- the on-going development and implementation of the Dredging EMP by CPA,
- development and implementation of stormwater management plans for all seaport land under the control of CPA,
- as property manager of Port land, CPA requires lessees for new leases to have an Environmental Management Plan (EMP) in accordance with requirements set out in the conditions of lease (these include provisions for reducing pollutant inputs and associated objectives),
- with respect to existing leases where new conditions relating to EMPs cannot be introduced, CPA is taking an advisory and liaison role to work with lessees, the Environmental Protection Agency, and Cairns City Council to develop practices aimed at achieving improved environmental outcomes for the Port,
- the development of an organisational environmental management system, with a commitment to maintaining a program of environmental audits of CPA and lessee operations,
- participation in coordinated environmental management forums, (e.g. Trinity Inlet Waterways (TIW)[18]),
- communication of monitoring results to Port Users via Port Advisory Group (PAG) – to raise awareness and highlight issues which require management attention by lessees, and
- working closely with regulatory agencies to assist them in their management of licensed activities (Environmentally Relevant Activities under the *Environmental Protection Act (1994)*).

CPA's lessees are required to develop site-specific EMPs including performance criteria and/or objectives for mitigation of contaminant sources relating directly to sediment quality. CPA's own sediment and water quality monitoring programs also provide on-going measurement of contaminant levels and are compared against relevant guidelines. These measurements may vary over time independent of changes in contaminant inputs, e.g. the accumulation of very fine sediments in one year as opposed to coarser sediments in previous years might result in higher observed contaminant levels, even though the contaminant inputs may have significantly decreased that year.

As a member of the *Association of Australian Ports and Marine Authorities*, the peak body representing the interests of ports and marine authorities in Australia, CPA provides input to wider policy development relating to environmental risk management at Ports.

7.4 POTENTIAL IMPACTS, MECHANISMS OF IMPACTS AND RISK EVALUATION

7.4.1 Introduction

The nature of dredging and sea disposal activities have been described in **Section 4.5**. The environmental impacts of these activities are both direct and indirect, and can be classed into short-term impacts associated with the process of dredging and placement at the Spoil Ground, and long-term impacts, associated with changes to habitat conditions as a result of the movement of dredged material. Potential impacts of dredging and sea disposal for the Port of Cairns are

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[18] TIW is a partnership program between CPA, Cairns City Council and the Queensland Government aimed at ensuring the management and maintenance of Trinity Inlet and its catchment as a viable and sustainable ecosystem, through best practice management of land and water based activities to manage and minimise impacts. TIW management group meets at least four times per year and holds an annual forum open to the wider community and key stakeholders. Water quality protection and enhancement is a key issue for TIW and one, which has been given priority. (CPA website, www.cairnsport.com.au).

discussed below and are formally identified and evaluated for environmental risk in **Table 7.1** below.

However, when considering the potential risks from disposal of sediments at the Spoil Ground over the life of this Plan, two points are pertinent:

1. Before any such sediment disposal is to occur, CPA will undertake a SAP (Sediment Analysis Plan) under the National Ocean Disposal Guidelines (NODGDM). This is the nationally accepted framework for assessment of sediment suitability for sea disposal, and requires determination, with specified minimum data quantity and quality requirements, that the sediments are unlikely to cause biological detriment due to contaminant concentrations. This is achieved under a risk framework, initially screening contaminant concentrations against conservative trigger values, but allowing for assessment of bioavailability (in solid and liquid phases) and direct toxicity assessment (acute and chronic testing of whole sediments and pore waters) for contaminant concentrations above these conservative screening levels[19]. This SAP process is an over-riding consideration for all sediment contamination risk evaluations.

2. The Plan does not allow for any substantial increase in the annual amounts of material to be dredged over that experienced during the previous Plan period. While this does not and should not be construed to imply any limitation to re-evaluation of acceptability of sea disposal under the new Plan, this re-evaluation should be based on determination of the acceptability of "more of the same" rather than evaluation of acceptability of a substantial increment to the risks. Furthermore, the Plan calls for disposal at an already used Spoil Ground, not for generation of a new disposal site which would require assessment of acceptability of development of a new impact zone. The Plan does not inherently imply new risks, merely continuation, and potentially some enhancement of risks that have previously been assessed as acceptable.

The following risk evaluation sections should be read with those points in mind.

7.4.2 Short-Term Impacts

a) *Changes to Water Quality*

Turbidity

The most notable effect of dredging and the placement of dredged material at the Spoil Ground is the potential increase in turbidity above background levels. Increased turbidity restricts the ability of seagrass, phytoplankton and phytobenthos to photosynthesise and can clog the feeding apparatus of filter feeding benthic organisms. Therefore, increased turbidity associated with dredging or dredged material release could potentially result in lethal or sub-lethal effects on these flora and fauna. However, a number of factors suggest that turbid dredge and dumping plumes are unlikely to cause a significant impact on flora and fauna in Trinity Bay.

As described in **Section 2.3.2** approximately 90% of the total volume of material dredged each year is placed at the Spoil Ground over a two to four week period by the *Brisbane*. The *Brisbane* uses current best practice methods that minimise the size of plumes generated during extraction and release of dredged material, and only 2,000 to 3,000 tonnes are collected and disposed of per load. The study by Connell Wagner (1991) showed that turbid plumes previously generated by

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[19] Sediment that is not assessed to be low risk under this national framework will not be disposed at the Spoil Ground and is either not to be dredged or, if it is, is to be disposed of at a regulated waste disposal site, the nearest of which is in Townsville.

dredge spoil disposal activities did not travel beyond 1 km of the previous Spoil Ground. This suggests that dredge spoil-related turbid plumes are much smaller than turbid plumes associated with riverine discharge from the Barron River in Trinity Bay during flood events. More importantly, it means that turbid plumes generated from dredge spoil disposal are not likely to reach the major seagrass habitat inshore or the coral reef habitats offshore, except at very low concentrations, as these are significantly more than 1 km away from the potential zone of disturbance (see **Appendix E**).

As detailed in **Section 6.3.2** there is typically no increase observed in turbidity during dredging of the Entrance Channel, and increases in turbidity observed during placement of dredged material at the Spoil Ground return to background levels during post-dredging monitoring (**Appendix E**). Furthermore, the turbidity increases generated from dredge spoil disposal are short-lived (Bob Carter, James Cook University, pers. comm. 2004), so they are not likely to persist long enough to pose a significant threat to biota. Trinity Bay is naturally turbid and plumes generated from natural sediment re-suspension at the Spoil Ground are likely to occur relatively frequently (Connell Wagner l991). Therefore, most of the benthic biota that typically occurs in or adjacent to the Spoil Ground area is likely to be tolerant of elevated turbidity and/or short-term increases in turbidity. Although dredging of the Inner Port area results in localised increases in turbidity, these are short-lived as only minor dredging works are carried out in this area by the *Willunga* at any one time.

Monitoring of the effects of the dredging operation on the nearby seagrass beds is undertaken as part of the long term seagrass monitoring program by the Department of Primary Industries and Fisheries (Rasheed *et al.* 2004). This program is a useful check on the long term impacts of dredge plumes and has revealed that so far, the seagrass monitoring program indicates that there have been no adverse effects on seagrass meadows from the current dredging program since the beginning of monitoring in 2000.

Dissolved Oxygen

There is a risk that dissolved oxygen levels in the water column may decrease during the release of dredged material due to the chemical and biological oxygen demand of the dredged material. Severe declines in dissolved oxygen (from any cause) have been known to cause stress and mortality amongst benthos and fish. As with turbidity, however, any decreases in dissolved oxygen are likely to be localised and short-lived in this case. Similarities between the dredged material and sediment found at and adjacent to the Spoil Ground might mean that the magnitude of decreases in dissolved oxygen concentrations associated with dredge spoil disposal are similar to decreases associated with sediment re-suspension at or near the Spoil Ground. However, natural re-suspension is not likely to put as much material into suspension as spoil disposal at any one time, so a decrease in dissolved oxygen concentration during spoil disposal exceeding that experienced during natural re-suspension is more likely.

In absence of any water quality data collected during disposal activities to benchmark against the default critical values given in the ANZECC/ ARMCANZ (2000) guidelines, the lack of reported fish kills to date associated with dredging or disposal events provides an indication that any decrease in dissolved oxygen (in the water column) associated with spoil disposal activities does not fall

sufficiently to cause acute impacts to fish. Note that in a large embayment such as this, fish can avoid areas of temporarily high turbidity and/or low dissolved oxygen. Impact is, therefore, avoided unless the effect is sufficient to cause acute toxicity, which has not been reported to date.

Nutrients

Marine sediments are often a sink for nutrients derived from riverine sources. The results of the study by Carter *et al.* (2002) indicate that there is considerable nutrient input from the Barron River and that nutrients are unlikely to be biologically limiting. Nutrients released during plume generation associated with dredge spoil disposal may exceed background levels in the water column. Enhanced nutrient levels in the water column can stimulate blue-green algae bloom and promote epiphytic growth on the leaves of seagrasses, which in turn, can lead to a decline in seagrass cover.

As with turbidity and dissolved oxygen, however, any increase in nutrient concentrations is likely to be localised and short-lived. Note that monitoring to date has not identified any Port-related nutrient issues (**Appendix E**). Furthermore, similarities between the dredged material and that found at and adjacent to the Spoil Ground may mean that the magnitude of increases in nutrient concentrations associated with dredge spoil disposal are probably within keeping with increases associated with sediment re-suspension at or near the Spoil Ground.

Contaminant Release

Marine sediment can be a sink for contaminants as well as nutrients. While these are bound up in the sediment, reduced oxygen in the sediment profile can limit their bioavailability, such as via formation of sulfides of binding to organic complexants for metals, particularly to pelagic organisms. Contaminant bioavailability might increase in the water column during plume generation as reduced sediment becomes oxidised during the descent. Under this scenario, contaminants could be taken up by phytoplankton and transferred through the food chain.

However, before disposal the harbour sediments will undergo assessment for suitability for disposal at sea under the NODGDM risk assessment framework. This national standard framework requires that the potential for contaminant release be assessed in a rigorous manner such that material is only assessed to be suitable for disposal where the potential for biological detriment from contaminant release, and from sediment contaminant concentrations is below set levels. This assessment includes determination of sediment contaminant concentrations and contaminant concentrations in elutriates, and in some cases may require further proof via sediment and pore water toxicity testing. Therefore dredge spoil disposal is unlikely to result in an ecologically significant increase in contaminant concentrations in the water column.

b) *Changes to Sediment Quality*

CPA undertake a SAP prior to dredging to determine sea disposal suitability of all dredge material, in accordance with the Ocean Disposal Guidelines. To date, all material previously placed at sea was assessed as having been suitable. While the sediments within the Inner Port Area have routinely been found to be elevated in TBT and some trace metals, they comply with the Ocean Disposal Guidelines and only represent some 10% of the dredged material placed at the Spoil Ground annually. As long as the NODGDM framework is adhered to, the risk of sediment quality alteration from disposal of sediments so assessed is within nationally accepted levels.

The TBT in areas of Trinity Inlet currently monitored by CPA as ‘hot spot’ areas has the potential to mobilise into dredging areas in the future and result in average TBT concentrations (at the upper 95% confidence level) which would exceed the Screening Level specified in the Ocean Disposal Guidelines. This could potentially render a large volume of dredge material unsuitable for sea disposal, subject to further assessment of bioavailability and/or ecotoxicity. Were this to occur, such sediment would not be disposed at the Spoil Ground, and would not constitute any increased risk of sediment quality alteration at the Spoil Ground.

c) *Smothering of Benthic Flora and Fauna*

The dredging operation has the potential to transport sediments that could smother seagrass in the vicinity of the dredged areas. Monitoring of this effect is part of the long term seagrass monitoring work being undertaken by the Department of Primary Industries and Fisheries (Rasheed *et al.*

(2004), This report details results of the second long-term annual monitoring survey conducted in December 2003. The objectives of the survey were to:

- compare results of monitoring with previous seagrass surveys and assess any changes in seagrass distribution and abundance in relation to natural events or anthropogenic port and catchment activities, and
- discuss the implications of monitoring results for overall health of Trinity Inlet's marine environment and provide advice to relevant management agencies.

According to the report, the seagrass monitoring program indicates that so far, there have been no adverse effects on seagrass meadows from the current dredging program since the beginning of monitoring in 2000.

Probably the most profound immediate ecological impact of dredge spoil disposal relates to the smothering of benthic flora and fauna at the Spoil Ground (although see **Section 7.4.3b)** for discussion of the disturbance continuum). Seagrasses and sessile (permanently attached) benthic fauna are particularly vulnerable to the effects of smothering as they cannot elude falling sediment and have limited capability of emerging from beneath sediment once they are covered. Those species of benthic infauna with limited burrowing ability may also be vulnerable, particularly where sediment deposition exceeds 150 mm (Maurer *et al.* 1986); although recent data collected in New Zealand by Norkko *et al.* (2002) indicates that significant impacts of smothering on benthos can occur at deposition depths as low as 30 mm. The Norkko *et al.* (2002) study investigated the smothering of estuarine sandflats by terrigenous clay in a temperate system and so is of limited application to the Cairns situation of placing like material on like material in a depositional muddy environment, in the tropics. Whether the depth of deposited material occurs across a broad range of any given Spoil Ground will depend on the area of the Spoil Ground versus the amount of material disposed of, the pattern of disposal over the Spoil Ground, and the rate of subsequent transport away from the Spoil Ground.

The impacts of smothering (or sediment overburden) on the current Spoil Ground benthic assemblage have not been formally assessed. Such impacts may have declined over time as a result of a shift toward an assemblage dominated by taxa with stronger burrowing capabilities. This is supported by the findings of Neil *et al.* (2003b), who reported that a higher proportion of taxa with relatively strong burrowing capabilities (higher tolerance of burial) were found at the Spoil Ground relative to the reference areas. It is likely that there will continue to be some reduction in diversity and abundance and the loss of certain benthic taxa from the current disposal site benthic assemblage as a direct result of repeated smothering, but this will not involve loss of any resources of special value as the soft sediment habitat affected is well-represented throughout the Bay and there are no significant seagrass beds within the Spoil Ground and immediate surrounds.

d) *Disruption to Breeding-Migration Patterns and Behaviour in other Fauna*

Dredging and sea disposal activities are unlikely to result in a substantial number of mortalities among more mobile taxa such as fish, dugong and turtles, which would generally have the ability to avoid or escape from such activities. While any mortality is significant to threatened and endangered species such as sea turtles, the absence of substantial turtle and dugong populations in Trinity Bay compared with areas south of Cairns (for dugongs) and to ports such as Bundaberg (for turtles, Morton and Nella 2000) probably reduce the likelihood further. While future mortalities to dugongs and turtles associated with continued dredging activity cannot be ruled out entirely, hopper dredging was not recognised as a major impacting process on the turtle populations of Queensland (Morton and Nella, 2000)[20] and management strategies have been implemented to further reduce the risk of mortalities occurring. These include the implementation of turtle deflectors

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[20] Estimated mortality rates prior to 2000 ranged between 2-10 turtles recorded over dredging activities conducted in 5 ports

aboard the *Sir Thomas Hiley* and the *Brisbane*, changes to the draghead suction device that preclude suction occurring when not in contact with the sea floor, and changing the timing of dredging to avoid coinciding with turtle breading seasons.

These activities are unlikely to cause significant disruption to the breeding or spawning of dugongs, turtles and fish at the population level, though a small number of individuals may be affected at a very local scale and, should that occur, probably only for a short duration. Col Limpus, (Queensland EPA, pers. comm.) suggested that recently-dredged areas may even attract turtles to feed on exposed invertebrates. The same behaviour may also be exhibited by benthophagous fish, though evidence of this is lacking.

Although there is no comprehensive guide to the spawning times of fish species that occur in Trinity Bay, it is unlikely that all spawn at the same time, so any dredging and spoil activities could affect some, but not all, taxa. More information is required on whether or not the timing of dredging in Trinity Bay overlaps with the spawning periods of ecologically and/or commercially important fish species. The small area over which dredging and disposal occur relative to the size of the wider Trinity Bay and their short duration would likely ensure that they do not pose a significant threat to the sustainability of the local populations of such species. For threatened species such as turtles and dugongs, this is more of an issue than for fish and prawns; however there are a lack of significant dugong and sea turtle breeding populations in Trinity Bay. Risks of impact on key fauna are particularly low given that dredging and sea disposal has not been found to impact on any significant seagrass areas (key habitat for these species).

7.4.3 Long-Term Impacts

a) *Physical and Chemical Changes to Sediment at the Spoil Ground*

Generally, the sediment found in the dredging area (i.e. both the Entrance Channel and Inner Port Area) is fine grained, unconsolidated sediment that is dominated by silt and clay (less than 63 µm), with more consolidated, estuarine substrata underlying it (below the depth of current dredging).

The current Spoil Ground is located on the inner shelf of Albatross Bay (as defined in Carter *et al.* 2002, i.e. onshore from the 20 m LAT depth contour), which as described in **Sections 5.2.5** and **5.2.6**, contains land-sourced terrigenous sand and mud. In the immediate vicinity of the Spoil Ground, the benthic habitat is believed to be predominantly muddy sediment, consistent with the particle size analysis results of benthic samples obtained by Neil *et al.* (2003b), which were dominated (typically 80 to 95%) by material less than 63 µm (i.e. silt and clay). Neil *et al.* (2003b) did observe strata within both the Spoil Ground and northern reference area that had a greater proportion of coarser material. Therefore, the maintenance dredging material which is placed at the Spoil Ground is broadly comparable with the sediments found in the vicinity of the Spoil Ground.

Given what is known about the physicochemical properties of maintenance material and sediment habitats at the Spoil Ground, there are unlikely to be significant changes to sediment particle size distribution, organic carbon (both quantity and type), redox conditions, or accumulation of contaminants in sediments at the Spoil Ground and immediate surrounds as a result of spoil disposal activities under the present scenario.

However, if any capital dredging were undertaken at some time in the future to increase the navigable depth of the Entrance Channel, and the dredged material is disposed of at the current site, then significant changes in particle size distribution and other sediment characteristics at the Spoil Ground might result. This is because capital dredging would involve the extraction of the thin layer of sand beneath the newly deposited material that is normally dredged, along with Pleistocene clays (that can occur as shallow as 15 m below the surface) (Bob Carter, James Cook University, pers. comm. 2004). The likely consequence of this scenario would be some change in the species composition of benthic fauna at the Spoil Ground. However, once capital dredging material were assimilated through bioturbation (sediment reworking by benthic organisms), transported off-site via hydrological processes, or saturated by the reintroduction of maintenance dredging material, the Spoil Ground benthic assemblage would likely return to a species composition more consistent with that of benthic assemblages in adjacent areas. This is all conjecture as capital dredging is not proposed to occur in the 5 year period of relevance to this management plan.

The levels of contaminants within any future capital dredging material would likely be very low (i.e. unaffected by anthropogenic inputs), so the risk of bio-accumulation or mortality among biota at the Spoil Ground as a result of the disposal would be low.

b) *Impacts of Repeated Disturbance*

Dredge spoil disposal can be considered a regular, acute disturbance event as it occurs over a short time period each year. However, given that it is something that takes place at a defined location on a timescale of decades, it could also be considered a chronic disturbance, particularly if its impacts are cumulative. Frequency, magnitude, and timing of disturbance events affect the resistance and resilience of faunal communities. The study by Neil *et al.* (2003b) does suggest that the Spoil Ground benthic assemblage, although only slightly altered in diversity and composition relative to nearby reference areas, had a higher number of burial-tolerant taxa than those areas. This would afford the current Spoil Ground assemblage a measure of inertia and increased resilience to repeated smothering (see **Section 6.3.6** for a more detailed explanation) during future dredge spoil disposal activities (assuming they do not increase greatly in frequency, duration and magnitude). However, to assess the level of inertia and resilience of the Spoil Ground benthic assemblage properly, it would be necessary to assess both the short-term impacts (immediately post disposal) and their ability to recover between successive rounds of sea disposal (i.e. a follow-up survey conducted immediately prior to the next round of disposal activity).

This is consistent with the approach advocated by the Ocean Disposal Guidelines, which assumes that disposal at a site will necessarily result in the loss of at least a part of the benthic assemblage at that site and that, where a site is used frequently or continuously, that the impacts of dredge spoil disposal will be on-going. The Ocean Disposal Guidelines recommend:

- determining what the initial effects of disposal at the site are,
- whether benthic communities recover between dumping episodes, and
- if there are any long-term changes to the community and whether such changes are acceptable (in terms of their magnitude and the spatial scale they over which they occur).

c) *Impacts of Increased Bed Level*

Increases in bed level through long-term use of the Spoil Ground could increase the amount and frequency of sediment re-suspension (Connell Wagner 1991) due to increased sensitivity to surface currents and wave action. This could create a situation where highly turbid conditions become a more persistent problem for seagrass and filter feeding benthic organisms. However, the current Spoil Ground is situated in deeper water than the one used immediately before it and, with up to 50% of the spoil material transported off-site gradually over the course of a year (Carter *et al.* 2002), bed height is unlikely to increase substantially in the next 5 years of permitted disposal activity.

Calculations indicate that there is likely to be a net accumulation rate of 620 mm over 5 years at the Spoil Ground, which is 5% of the depth of the water column at the Spoil Ground (on average) (**Section 2.6.3**). Bed height might increase above this net accumulation height in isolated areas of the Spoil Ground (as indicated in the CPA bathometric survey in 2003, **Section 2.6.2** and indicated in the report by Neil *et al.* (2003b)). The relatively small size of these areas means that significantly elevated turbidity levels at or near the Spoil Ground as a result of increased resuspension from the seabed is unlikely to occur during the next 5 years of permitted dredge spoil disposal.

To some extent the elevation of bed height is a self-limiting process as the more the sediments build up, the more the upper layers are affected by surface currents and the higher the erosion rate.

d) *Impacts of the Spread of Dredged Material Outside the Spoil Ground*

As noted previously, it is well established that much of the dredged material placed at the current Spoil Ground disperses over time, at an annual rate of redistribution in the vicinity of 50%. The spread of dredged material outside the current Spoil Ground does not appear to have led to major changes in sediment granulometry in the near-field, even to the north (the direction along-shore drift is likely to transport spoil material (Neil *et al.* 2003b). That is not to say that the near-field spread of dredged material has not had some impact on benthos, or will not have in the future. The study by Neil *et al.* (2003) found subtle evidence of an impact of the off-site spread of spoil material on the northern reference area benthic assemblage (as discussed in **Section 6.3.6**). Given the minor nature of the impacts reported and the fact that the study by Neil *et al.* (2003b) was a snap shot, further investigations are required to determine whether such impacts persist or increase in severity over time. Such assessments should, in our opinion, also be based on a much larger range of benthic parameters than those used by Neil *et al.* (2003b) and include multivariate analysis of taxonomic composition data. Sediment which is reworked from the present Spoil Ground has no discernible geochemical effect at distant locations, and its volume is insignificant compared with the natural sediment flux through the system (Carter *et al.* 2002).

Carter *et al.* (2002) conclude that even in cyclonic conditions, when erosion undoubtedly occurs at the Spoil Ground, the sediment removed does not travel shorewards and thus result in impacts on inshore areas. On a time scale of years to decades, the Spoil Ground alternates between weak seawards and along-shelf sediment transport during normal fair weather conditions, and strong along-shelf sediment bypassing during storms.

Hence the on-going transfer of material from the Spoil Ground offshore and northward is not likely to be causing any significant biological impacts, in a system which is highly dynamic with respect to sediment flux. This is supported by the Neil *et al.* (2003b) study which showed little difference between the Spoil Ground and the northern and southern reference locations in terms of sediment particle size distribution or biota.

e) *Introduction of Marine Pests*

The transport of organisms in the ballast water or on external surfaces (hull fouling) of ocean-going ships is the principal vector for the unintentional introduction and spread of marine non-indigenous species (NIS) worldwide (Carlton 1985; Ruiz *et al.* 1997; AMOG Consulting 2002). Currently there are approximately 250 marine NIS in Australia (Thresher 1999) and, like in other parts of the world, their distribution is often disjunct and centred on hubs of shipping activity such as ports, harbours and marinas (Cranfield *et al.* 1998; Hewitt *et al.* 1999; Hutchings *et al.* 2002). NIS can have impacts on native species, ecosystems and economies (e.g. aquaculture) and have been identified as the second largest threat to global biodiversity (Wilcove *et al.* 1998; Pimentel *et al.* 2001).

In recent years, Australia has taken steps to prevent the introduction and secondary spread of further NIS and to manage the distribution and impacts of existing populations. An integral part of these efforts is conducting baseline surveys for introduced marine species in Australia’s main shipping ports (Hewitt and Martin 2001), and the on-going control and management of transfer vectors (e.g. the introduction of mandatory ballast water treatment protocols (Australian Quarantine & Inspection Service 2001)).

The introduction of marine pests to the Spoil Ground through dredge spoil disposal activities poses another long-term threat to the flora and fauna of the Spoil Ground and for Trinity Bay as a whole. Two species of NIS, the Asian green mussel (*Perna viridis*) and the Caribbean tube worm (*Hydroides sanctaecrucis*), have been recorded in the shallow coastal waters of Trinity Bay before and are perceived as a major threat to the ecology of Trinity Bay based on their ability to breed rapidly and out-compete native fauna for food and space.

The process of dredging and disposing of dredged material at a Spoil Ground may facilitate the spread of NIS in more than one way.

- Firstly, NIS present in those areas of the Cairns Port where dredging occurs may be taken up into the hull of the dredge with the sediments, and dumped at the Spoil Ground.
- Secondly, for dredge vessels that operate in different ports at different times, NIS present in residual sediments removed from port A could be translocated to port B where dredging is carried out and dumped at the disposal site for dredge spoil from port B.
- Thirdly, NIS could be transferred to the Spoil Ground via hull fouling on the dredge vessel. Fouling biota could have been acquired by the vessel in either Cairns or in previous ports.

Evidence for translocation of NIS by dredging operations exists elsewhere (Rosenfield and Mann, 1992), and management and prevention measures for the transport of NIS via dredging activities is an important aspect of this Long Term Dredge Spoil Disposal Management Plan (refer **Chapter 8**).

The spread of NIS, as described above, is contingent on the successful passing of the species through a series of stages that begin with the uptake of sediment into the dredge and end with the establishment of the species at or in the vicinity of the Spoil Ground.

The following discussion expands upon the above three processes.

Uptake of the Species by the Dredge

- Epibenthic Organisms (Sessile and Attached)

  A recent survey of locally established marine pests (*P. viridis* and *H. sanctaecrucis*) and availability of hard-substrate habitat in the those areas of the Cairns Port that are subject to dredging indicates that shell rubble, small (< 1 cm) and large rocks (> 1 cm) are present at low abundance throughout the dredge sites (Neil, 2002). Sessile organisms such as sponges and ascidians were found to inhabit these structures at low abundance. Neil (2002) suggests that any of the rocks and shells encountered during the survey could be taken up by the dredging intake pipe of the *Brisbane* (gap size 650 mm) or the grab bucket (2.2 m^3 volume) of the smaller bucket dredge *Willunga*. Consequently, any organisms living on these surfaces would be taken up into the hull of the dredge vessel.

- Infauna and Motile Epibenthos

  Infaunal invertebrates such as bivalves, worms and crustaceans, and motile epibenthos such as crabs, gastropods or even benthic fishes could be taken up by either of the two dredges. Also cyst-forming dinoflagellates that are often found in the top 1-2 cm of soft-sediment benthos (Hallegraeff and Bolch, 1991;Hewitt and Martin, 2001) could readily be taken up by either dredge.

- Planktonic Propagules

Most modern dredging vessels have systems installed that isolate seawater taken up with sediments and discharge it back into the sea. However, despite this separation process it is likely that a small amount of water remains in the hull of the dredge. Like ballast water, this water may contain small holoplanktonic organisms, larval propagules, eggs or spores, and micro-organisms such as bacteria and viruses (Carlton, 1985;Carlton and Geller, 1993;Ruiz et al., 2000a). If the Brisbane and Willunga (the vessels used for dredging operations in the Port of Cairns) also retain some seawater that will be transported to the dredge disposal grounds, there is a possibility that organisms or propagules such as those mentioned above can be transported to the proposed dumping grounds. The liquid phase of the dredge spoil may contain propagules of NIS established within the Port (e.g. *P. viridis* and *H. sanctaecrucis*) or even propagules of NIS not yet established in the Port (e.g. those recently arrived on the hulls or in the ballast water of visiting vessels).

Transport and Discharge

A risk of facilitating the spread of NIS by dredge spoil disposal at a Spoil Ground will only occur if organisms taken up with the dredged material survive the transport from the source to the disposal location. It is likely that hard-bodied taxa such as bivalves, gastropods, crabs and other crustaceans are able to withstand the mechanical forces (crushing) associated with the transfer. Also small infaunal or interstitial organisms such as dinoflagellate cysts are able to survive, as has been observed for ballast water sediments (Hamer *et al.*, 2001;Rigby and Hallegraeff, 2001). A comprehensive assessment of survival of soft- and hard-bodied taxa in dredge spoil has not been undertaken yet, and some survival must therefore be assumed.

Additional mortality of organisms contained within dredge spoil will occur during its disposal from the vessel at the Spoil Ground. In areas where large quantities of dredge spoil are deposited, burial of some organisms may occur at depths greater than those from which they could emerge to the new seabed by burrowing or migration. Mortality due to “overburden” has been documented previously for taxa resident at dredge spoil disposal sites (Smith and Rule, 2001), and mortality of a range of marine taxa has been predicted if a maximum depth of overburden of 15 cm is exceeded (Roberts *et al.*, 1998). A recent report (Neil *et al.*, 2003a) suggests that during discharge of dredged material from the Cairns Port at the Spoil Ground this maximum depth is likely to be exceeded in some places. This may not only cause mortality of native assemblages beneath the discharged material, but also of organisms discharged from the dredge vessel. However, because the dredge spoil is discharged over a relatively large area (approximately 1 nautical mile in diameter), overburden and burial of organisms taken up during dredging operations in the Port are unlikely to occur across the whole area of discharge at one time.

Establishment at the Ocean Disposal Site

If viable individuals or propagules of NIS are present in the dredge spoil dumped at the Spoil Ground, they must establish a local self-sustaining population (whose persistence is not dependent on further repeat inoculations) in order to be a threat to the ecological integrity of surrounding areas and habitats (Mack *et al.*, 2000;Sakai *et al.*, 2001). This requires the availability of suitable habitat and environmental conditions. For sessile hard-substrate organisms (such as barnacles or bryozoans) successful establishment is unlikely if vacant substrate such as rocks, pebbles or shell material is absent. Some suitable habitat (small and large rocks, bivalve shells) is likely to be discharged with dredge spoil from the Cairns Port (Neil, 2002). However, these rocks are also liable to burial/siltation, reducing the potential area of habitat available for colonisation. The occurrence of hard substrate is not specifically mentioned in a recent study on the biota inhabiting this site, but a range of hard-substratum organisms were encountered at low abundance (Neil et al 2003a).”

At the Spoil Ground, infaunal taxa (motile and sessile), motile epibenthic organisms and resting stages (cysts) of toxic dinoflagellates are likely to encounter an abundance of suitable habitat in the form of fine sand, silt and mud. Diverse infaunal and epibenthic assemblages are present at the site as a source of food. Sediment contamination is likely to be limited since, based on the Port Authority’s sediment monitoring , levels of heavy metals and chemicals in the Port are within acceptable limits for sea disposal (Neil *et al.* 2003a). However, the dredge spoil will initially be relatively unconsolidated. Connell Wagner (1991) suggest that this can remain the case for up to several years after dumping ceases, though this does not appear to be in agreement with findings presented by Carter *et al.* (2002), that sediments deposited in Trinity Bay during a cyclone were quickly reworked into the sediment profile by biota.

Carter *et al.* (2002) note that there is no geochemical evidence for a halo of contamination around the Spoil Ground and that sedimentary transport evidence suggests that (p 83):

- over time, and mostly during periods of rough weather, material is gradually removed from the Spoil Ground in a long-shelf and offshore direction, and
- that the redistributed material blends in with the bay background sediment as it is redeposited and bioturbated.

If the spoil material conforms more to the behaviour of that put forward by Connell Wagner (1991) then it may be too unstable for survival of these organisms, but if the spoil material behaves in a manner more consistent with that put forward by Carter *et al.* (2002), then more conducive survival conditions may prevail at the Spoil Ground. This issue warrants further investigation.

The production of planktonic propagules by NIS that manage to establish at the ocean disposal site may present a risk to adjacent areas such as sand flats (soft-bottom dwellers) or reefs (hard-bottom dwellers). During cyclones and trade winds, bottom currents at the current Spoil Ground flow in an offshore direction (Carter *et al.*, 2002) and might facilitate the dispersal of planktonic larvae to suitable habitats including reefs within the Great Barrier Reef Marine Park. **Table 7.2** lists NIS that are:

- already established in the Port of Cairns,
- identified by the Australian Ballast Water Management Advisory Committee (ABWMAC) as likely to become pest organisms in Australia, and
- identified by Hilliard and Raaymakers (1997) as having a moderate to high potential to become introduced or established in Queensland waters.

Of a total of the 33 species that have established, or could establish populations within the Cairns Port, 25 could (if present in the Port) possibly become transported to the ocean disposal site by dredging operations. Of these, 8 species are soft-substrate dwellers, 16 are hard-substrate dwellers, 7 can occur on soft or hard substrate and for 2 species the exact substrate is unknown (**Table 7.2**). Four species within the list – *S. spallanzanii, A. amurensis, C. gibba*, and *U. pinnatifida* – are thought to be unable to thrive in the salinity and water temperature regimes of North Queensland (NIMPIS, 2002). For 23 of the species listed, the habitat at the ocean disposal site (mainly soft sediments with very sparse amounts of hard substrates) may be suitable for colonisation and establishment. It is possible that the majority of hard substrates available at the dump site are rocks, pebbles and shells brought to the site by the dredge.

These are thought to be currently in short supply at the Spoil Ground (based on their limited occurrence in the dredged area rather than confirmed at the site itself). With repeated dredging and disposal at the current site, however, this may not consistently be the case.

As described above, there is a multitude of factors that determine the successful introduction and establishment of NIS or their propagules in new locations. **Table 7.2** considers only some aspects of the environmental conditions (habitat availability, salinity, temperature) required by the various species and those present in the Cairns Port and Spoil Ground. Other, equally important factors, such as the number of individuals or propagules transported at a time, the number of repeat inoculations, the resistance of resident assemblages to invasion by new arrivals or the influence of mechanical stress and darkness on the species in transit are essentially unpredictable at present and have not been considered here (Lonsdale, 1999;Mack *et al.*, 2000;Ruiz *et al.*, 2000b;Byers, 2002). Therefore, **Table 7.2** assigns a possibility to the transfer of a range of NIS by dredging and disposal operations, not a probability.

f) *Inhibited Recovery once Dredge Spoil Disposal Ceases*

The ability of faunal communities to recover post-dredging is paramount, as there will be a cumulative impact of dredge spoil disposal over a wider area in Trinity Bay if successive disposal sites fail to recover. Several factors suggest that recovery post-decommissioning of Spoil Grounds is likely to occur, including:

- Carter *et al.* (2002) note that the former Spoil Ground site is now not detectably different from surrounding areas either topographically or geochemically and that this was to be expected in a shallow bay in which sediment transport processes naturally level out seafloor irregularities.
- Rates of bioturbation (reworking of the sediment) in Trinity Bay are known to be high. Carter *et al.* (2002) found that sediments deposited on the sea floor during a cyclone were quickly worked into the sediment profile by biota.
- Repeated dumping at the current Spoil Ground over the past 10 years has not resulted in the complete loss of benthos from the Spoil Grounds and differences in both taxonomic richness and composition between the Spoil Ground and the two reference area that were observed by Neil *et al.* (2003b) indicate, at worst, a minor impact of this activity. The diverse faunas of the surrounding areas (evidenced by those of the references areas in Neil *et al.*'s study) make it likely that adult or larval immigration into the disposal area would occur. Taxa only present at the benthic assemblages at adjacent sites would not be inhibited from recolonising the Spoil Ground once disposal activity ceases, though Neil *et al.* (2003b) cite Harvey *et al.* (1998) as suggesting that some of those taxa might be slower to migrate to those areas.
- Based on the results of the ongoing sediment monitoring program carried out by the Cairns Port Authority, contaminant concentrations in the sediment at the Spoil Ground are within acceptable limits. Should this situation continue for the next 5 years of permitted spoil disposal activity, as is to be expected due to the application of the NODGDM assessment framework pre-disposal, contaminant concentrations in the sediment at the Spoil Ground are unlikely to reach levels that would significantly inhibit recolonisation by benthos once disposal activities cease.

g) *Long-Term Impacts on Fauna other than Benthos*

The long-term impacts of dredge spoil disposal activities on organisms such as fish, prawns, dugongs, turtles and wading birds are likely to be mainly related to modification and/or reduction to their shelter habitats and food resources, rather than the cumulative impacts associated with direct mortalities. Loss of seagrasses through smothering or persistently high turbidity conditions associated with spoil disposal or re-suspension of spoil mound material poses the greatest risk to the organisms listed above and could also have implications for the entire food web. Loss of seagrass is recognised as both dugongs and turtles (Marsh *et al.* 1996), and such impacts cannot be ruled out. However, more data are needed in order to draw firm conclusions. Long-term monitoring programs of inshore seagrass meadows would aid in the detection of any future dredging impacts but, thus far, there has been no clear confirmation of the impacts of dredging activities on inshore seagrass beds. For offshore seagrass meadows closer to Spoil Ground, no such monitoring program currently exists. We predict that any loss of seagrass as a result of spoil disposal at the current site would likely be localised and effects of any resulting elevated turbidity in that area would cease once this Spoil Ground was decommissioned.

Seagrasses have been noted for their slowness or inability to recover from disturbances, however, and there is potential for a mosaic of impacted seagrass areas in Trinity Bay with the commissioning of each new site should recovery not take place, or only take place at a slow rate. However, we consider this unlikely, given the biology of the seagrass species[21] that occur near the

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[21] pioneer species traits.

current Spoil Ground, which should afford them a greater ability to recover relative to other seagrass species. In addition, a study by Birch and Birch (1984) found that *Halodule and Halophila* near Magnetic Island recovered quite well after a cyclonic disturbance. Therefore, we see it as unlikely that fauna that rely on seagrasses as a source of food and/or shelter will be impacted upon significantly at the population level. Any impacts on behaviour or condition of individual fish, dugong or turtles would likely be sub-lethal and almost impossible to detect against background variation in these parameters.

In addition, dietary information for turtles that occur in the Cairns area suggest that these species may also be at risk if long-term spoil disposal causes a significant reduction in mollusc beds or densities of crabs and sea pens (pers comm. Col Limpus, Queensland EPA, 2004). As with seagrass, this is likely to be more problematic if there were a failure of successive Spoil Grounds to recover from the impacts of dredge spoil disposal[22]. Available evidence suggests that this will not occur. Neil *et al.* (2003b) found that there were no major differences between the Spoil Ground and the two reference areas in terms of the proportional contributions of mollusc and crustacea taxa to the number of taxa recorded in each area. No data were provided on the abundances of these major taxonomic groups in each of the study areas, so the degree to which spoil disposal at the current site may have reduced the absolute abundances of these taxa is unknown. Sea pens (Pennatulacea) were recorded in the study by Neil *et al.* (2003b) but were only found in one strata of the northern reference site. Again, no data were provided on the abundance of this taxon. The limited occurrence of this species in that survey, and its complete absence from the Spoil Ground, could reflect impacts associated with disposal activity, but other factors could equally account for this observation, and no firm conclusion can be drawn. Further monitoring of both the distribution and abundance of sea pens, molluscs and crustacea at the current and any future Spoil Ground would be required to shed light on the risks posed to the food supply of turtles in Trinity Bay.

7.5 RISK EVALUATION

The following table sets out the results of a formal risk evaluation based on the previous discussion.

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[22] Note, this is not relevant for maintenance dredging, which is consistently carried out at the same set of locations (navigation channel and berths).

Table 7.1 Evaluation of Potential Impacts of Dredging and Sea Disposal at the Port of Cairns.

Mechanistic Effect	Main Biota potentially at risk	Reason for potential risk	Scale of mechanistic effect and exposure	Likely outcomes
1) Increased turbidity adjacent to dredged areas and at and/or beyond the current Spoil Ground Activity Related to: Discrete plumes generated during dredging, placement of dredged material, and through re-suspension of dredged material during storm events. Longer-term, more consistent plume generation from the Spoil Ground under normal hydrodynamic conditions if mounding reduces water depths sufficiently.	Phytoplankton, benthic fauna and flora.	Decreases in rates of photosynthesis. Clogging of feeding apparatus of suspension feeding benthic fauna. Abrasion to seagrass leaves and corals by suspended particles.	Scale • Turbid plumes (dredging) could extend for some distance from the dredged areas during dredging although they are rapidly diluted. Monitoring shows no adverse effects on seagrass beds adjacent to the dredged areas. • Turbid plumes (disposal) of short duration and are rapidly diluted so turbidity beyond 1 km of the Spoil Ground is unlikely to be elevated significantly. • Trinity Bay experiences periodic wide scale turbidity levels resulting from natural disturbances such as cyclones and floods that are up to 4 times greater in magnitude than levels associated with spoil disposal (once material has reached the sea floor). • Bed height increase across most of the Spoil Ground over the next 5 years of permitted disposal activity is unlikely to result in ongoing turbid plumes persistently above threshold levels that are linked to increased hydrological forcing at bed level. Exposure • Very low density of seagrass at or near the current Spoil Ground. • Higher densities of seagrass near dredged areas inshore. • Predominant tidal and longshore currents take plumes associated with disposal and any that might occur post-placement away from high density inshore seagrass beds. • Turbid plumes associated with dredging and disposal will certainly not overlap with occurrence of coral in offshore reefs. • some disposal carried out at night when photosynthesis is not occurring. • benthos within a 1 km radius of the Spoil Ground may be affected, particularly in areas to the north of the Spoil Ground.	Effects of dredging plumes on inshore seagrass beds, while being potentially severe, have not so far resulted in any adverse effects on seagrass meadows. Effects of disposal activities on benthos, seagrass and other flora would be localised (probably restricted to a 1 km radius of the Spoil Ground). There may be localised die off of seagrass within this area, but this impact will probably be small relative to the spatial coverage of seagrass in Trinity Bay. Potential for recovery of Spoil Ground and near-field areas by seagrass once disposal activities cease is high, given the biology of the species that occur t these depths. Disposal activities carried out at night partially mitigate the effect of elevated turbidity on photosynthesis. In terms of benthic fauna, elevated turbidity may lead to localised loss of abundance, diversity and some suspension feeding taxa, but magnitude is likely to be subtle based on observed response to 10 years of disposal activities. Adult migration and larval colonisation is likely to yield effective recovery post decommissioning of current site. Some mortality or reduced productivity of phytoplankton associated with turbid plumes generated by dredging or spoil placement, but of limited scale. Quick replenishment to Spoil Ground and near field area afforded through hydrodynamic processes likely.

Mechanistic Effect	**Main Biota potentially at risk**	**Reason for potential risk**	**Scale of mechanistic effect and exposure**	**Likely outcomes**
2) Decreased dissolved oxygen concentrations Activity Related to: Longer-term, more consistent plume generation under normal hydrodynamic conditions if mounding reduces water depths sufficiently.	Benthic infauna, epifauna and pelagic organisms (e.g. zooplankton, fish).	Decreases in respiration and productivity rates.	Scale • Volume of sediment resuspended during dredging and disposal is likely to exceed that resuspended under normal hydrodynamic conditions, so reduced dissolved oxygen concentrations in the water column possible. • Small amount of dredged material disposed of at any one time (main program 2-4 weeks a year and not all spoil material disposed of at once) likely to result in short duration and high dilution of plumes, so concentrations beyond the Spoil Ground are unlikely to be suppressed significantly. • Dredged material unlikely to be organically enriched relative to sediment at or near the current Spoil Ground, so reasonable chance that changes in dissolved oxygen associated keeping with natural variation at these sites. • As above for likelihood of longer term elevated turbidity at or near the Spoil Ground related to increased bed height / forcing at bed level. Exposure • Diverse benthic fauna occur in the potentially affected area, along with zooplankton and pelagic and demersal fish.	Potential for severe effects on fish, resulting in fish kills, should dissolved oxygen concentrations reach very low levels (particularly if these persist for any length of time). However, no fish kills linked to disposal activities have been reported and factors that mitigate any decrease in dissolved oxygen concentration make such scenarios unlikely. In terms of benthic fauna, decreased dissolved oxygen concentrations may lead to localised loss of abundance, diversity and some changes to taxonomic composition, but magnitude is likely to be subtle based on observed response to 10 years of disposal activities. Some benthic fauna are also tolerant of low oxygen conditions. Adult migration and larval colonisation is likely to yield effective recovery post decommissioning of current site. Similarly, potential mortality among zooplankton in affected areas, though any such loss would be localised. Easily and quick replenishment to Spoil Ground and near field area afforded through hydrodynamic processes likely.

Mechanistic Effect	Main Biota potentially at risk	Reason for potential risk	Scale of mechanistic effect and exposure	Likely outcomes
3) Increased nutrient concentrations in the water column Activity Related to: Discrete plumes generated during dredging, placement of dredged material and through re-suspension of dredged material during storm events. Longer-term, more consistent plume generation under normal hydrodynamic conditions if mounding reduces water depths sufficiently.	Phytoplankton, benthic fauna and flora.	Stimulation of blue green algal blooms and epiphytic growth on seagrass leaves (leading to a decline in seagrass cover).	Scale • Volume of sediment resuspended during dredging and disposal is likely to exceed that resuspended under normal hydrodynamic conditions, so elevated nutrient concentrations in the water column possible. • As above for temporal and spatial scale of any plume associated with dredging or disposal activities (i.e. any nutrient enrichment of the water column would be localised and short-lived due to rapid dilution and dispersion. • As above for likelihood of persistently elevated nutrients associated with increased bed height / forcing at bed level (i.e. little likelihood of any chronic elevation of nutrient concentrations in the water column at the current Spoil Ground over the next 5 years of permitted spoil disposal). • Riverine inputs of nutrients into Trinity Bay during floods are much higher and Trinity Bay not thought to be nutrient limited. • dredged material is not likely to be organically enriched relative to the sediments found at or near the current Spoil Ground. Exposure • Phytoplankton and benthic flora and fauna all occur within the areas where episodic nutrient enrichment as a result of dredging / spoil activities occur, though only low densities of seagrass and other benthic flora currently near the current Spoil Ground.	Possible simulation of blue green algae blooms, though this phenomenon has not, to our knowledge, been reported. It would be difficult, in any case, to prove a causal link between dredging and disposal activities and blue green algal blooms (which are difficult to predict and often complex in terms of the combinations of factors that can cause them). Localised blooms of non-toxic phytoplankton may occur, but subject to dispersal by hydrodynamic forces operating in Trinity Bay, these would not remain long at either the dredging or disposal sites. Therefore, their stimulation would be unlikely to lead to secondary food chain consequences at either site. In addition, turbid conditions associated with the dredging / disposal plumes may counteract the benefit to phytoplankton of any additional nutrients in the water column. Epiphytic growth on seagrass and other benthic flora is a possible consequence at both the dredging and current disposal sites. Given the difference in seagrass density between the inshore region near the dredged area and the offshore region near the current Spoil Ground, risk of exposure to increased epiphytic growth is greatest inshore in association with dredging activities.

Mechanistic Effect	**Main Biota potentially at risk**	**Reason for potential risk**	**Scale of mechanistic effect and exposure**	**Likely outcomes**
4) Contaminant release into water column and accumulation in sediments at and/or beyond the Spoil Ground Activity Related to: Discrete plumes generated during dredging, placement of dredged material and through re-suspension of dredged material during storm events. Longer-term, more consistent plume generation under normal hydrodynamic conditions if mounding reduces water depths sufficiently. Accumulation in sediments and foodweb through continued spoil deposition at the current Spoil Ground.	Planktonic organisms, benthic fauna, fish and other marine vertebrates.	Sediment contamination leading to decreases in benthic abundance and diversity and changes in taxonomic composition. Biomagnification of contaminants in the food web.	Scale • Bioavailability of contaminants may increase due to the process of oxidation that might occur during dredging or spoil placement. • The high proportion of fines at or near the current Spoil Ground may enhance the opportunity for contaminants to bind to sediment particles. These, however, are more prone to resuspension and, therefore, offsite removal. Thus contaminant accumulation in the sediments of the Spoil Ground is unlikely to above acceptable limits. • CPA’s sediment quality monitoring data at the Spoil Ground have, thus far, found contaminant concentrations within the dredged material to be within the acceptable limits required to allow for sea disposal. • Elutriate testing is required where contaminant concentrations exceed acceptable limits. This procedure should provide data that can be used to predict the risk they pose to biota. If the risk is deemed high, then management intervention would prohibit the disposal of contaminated dredge material at sea. • Dredged material is similar in nature to that found at and adjacent to the Spoil Ground • only some 10% of the dredged material comes from the Inner Port Area, where contaminant levels (particularly TBT) are found at levels of concern. • a high proportion of contaminants will be bound to sediment particles rather than being in a dissolved form for ready uptake by biota. • Rapid dilution and dispersal of plumes so contaminant water column concentrations beyond the Spoil Ground are unlikely to be enhanced significantly. Exposure • Phytoplankton, benthic fauna, fish and other marine vertebrates do occur at or use the areas used for dredging and spoil disposal, so toxic effects or bioaccumulation of contaminants is possible.	Some opportunity for contaminants to be taken up by planktonic biota while dredged material is in suspension, though the effects would be highly localised. Based on concentrations typical of the bulk of the dredged material, the extent and severity of uptake by planktonic organisms are likely to be low. The dispersal of planktonic organisms would further limit potential for biomagnification to occur at or the dredging and disposal sites. Direct toxic effects or accumulation of contaminants in body tissues of benthic fauna, fish and other invertebrates is unlikely to occur as a result of elevated water column concentrations experienced during dredging or spoil disposal. The low concentrations of contaminants in the spoil material recorded to date, and the management intervention procedures are likely to limit the levels of contaminants released into the water column, while the hydrodynamic conditions at the dredging and Spoil Ground sites and the likelihood that most contaminants will be bound to fine particles is likely to limit their uptake. Direct toxic effects or biomagnification of contaminants in body tissues of benthic fauna, fish and other invertebrates might result from of contaminants accumulation in the sediment at the current Spoil Ground, given the large amounts of fines at this location. However, should the levels of contaminants in dredged material continue to fall within acceptable limits for sea disposal and current management procedures remain in place, this is unlikely to occur.

Mechanistic Effect	**Main Biota potentially at risk**	**Reason for potential risk**	**Scale of mechanistic effect and exposure**	**Likely outcomes**
5) Smothering (sediment overburden) causing long-term benthic community change / Offsite transport of spoil <u>Activity Related to:</u> Placement of dredged material (repeatedly).	Benthic flora and fauna.	Some benthic organisms unable to burrow to surface/ construct burrows that allow them contact with the surface, leading to mortality through lack of light (for seagrasses and algae, and lack of food and oxygen for benthos).	<u>Scale</u> • Dredge spoil disposal campaign usually annual in frequency and takes place over 2-4 weeks and comprises of a series of smaller events rather than a single large event (i.e. not all dredged material is disposed of at once). Smothering at the current Spoil Ground is an episodic disturbance event that is part of a disturbance continuum that has taken place over a decade (and could for another 5 years of permitted dredge disposal). • Mortality resulting from smothering effects takes place on a short time scale, though the consequences of this mortality may carry on over a longer term. • Area of Spoil Ground is small relative to the size of Trinity Bay, so only localised impacts are possible (unless recovery fails to take place at this and subsequent Spoil Grounds). • Spoil material is spread relatively evenly across the Spoil Ground. However, in isolated pockets of the current Spoil Ground, burial depth is likely to exceed sediment overburden thresholds cited in the literature. Uneven spreading, however, will also result in areas where the thickness is less than average (or zero), providing rapid recolonisation sources for benthic organisms. • Sediment overburden is unlikely to occur much beyond the Spoil Ground based on: a) the average accumulation depth predicted to occur beyond 1 km of the Spoil Ground (Connell Wagner, 1991), b) the postulations made by Neil *et al.* (2003b) about the likelihood of smothering impacts in the northern reference area, and c) the statement by Carter *et al.* (2002) that sediment which is reworked from the present dredging Spoil Ground has no discernible geochemical effect at distant locations, and its volume is insignificant compared with the natural sediment flux through the system.	Some mortality will occur at the time of spoil placement, but this is allowed under permitting conditions. In the lifespan of the operation of the Spoil Ground, there may be some loss of diversity and changes in taxonomic composition. However, these are likely to be subtle (if the findings of Neil *et al.* 2003b continue to hold true), manifesting themselves as a reduction in rarer taxa and those with limited burrowing ability, an increase in taxa with opportunistic life traits and greater spatial variability in abundance, diversity and composition at the Spoil Ground. It remains to be seen, however, whether the taxa impacted most by the effects of smothering are those favoured by sea turtles or commercially important fish species, or whether they perform important and irreplaceable functions. Recolonisation of the Spoil Ground in the post-operation phase of the current Spoil Ground should be facilitate relatively easily through adult migration from near-field adjacent areas and larval colonisation from both near-field and far-field sources. Migration by some of the taxa sensitive to burial may take longer than other taxa. Mortality will almost certainly be seagrasses exposed to burial by dredge spoil at the Spoil Ground. However, exposure levels (even assuming that there may be recolonisation of seagrasses at the Spoil Ground from time to time) would be low, due to the fact that the seagrass species most likely to do so, tend to be patchy and in low density. In the absence of ongoing burial, or other

Mechanistic Effect	**Main Biota potentially at risk**	**Reason for potential risk**	**Scale of mechanistic effect and exposure**	**Likely outcomes**
			Exposure • Benthic fauna are present at the current Spoil Ground, but seagrasses were not recorded present in a one-off survey by Neil *et al.* (2003b). The ephemeral nature of the seagrass species that occur at similar depths and in that area mean that seagrasses may not periodically recolonise the Spoil Ground and, thus, become exposed to burial as a result of disposal activity.	spoil placement effects, such as persistent turbidity and elevated nutrient concentrations in the water column, the biology of the seagrasses occurring at the same depth as the current Spoil Ground would indicate that their recolonisation of Spoil Ground post-operation would not be prohibited. However, recolonisation by seagrass is by no means assured.
6) Disruption to breeding, migration or behaviour patterns / direct mortality to fauna other than benthos Activity Related to: The process of dredging and placement of dredged material.	Dugongs and sea turtles, fish.	Plume generation and noise could, if extensive enough, disrupt breeding and/or migration, particularly if the timing of dredging and spoil disposal coincides with these key periods during which breeding and migration are undertaken. This could potentially cause declines in the populations present in Trinity Bay. In the past, turtles were at risk of being sucked into the hoppers of dredging vessels. However, current dredges are fitted with turtle exclusion devices.	Scale • Short duration and areal extent of plumes generated (as outlined above). • Dredging and disposal activities are short-lived (only 2-4 weeks per year for the main campaign). Exposure • It is likely that fish, turtle and dugong will occur at or use the dredging and current Spoil Grounds sites and, therefore, there is some risk of exposure. • Turtles can sometimes use navigation channels as resting areas, exposing them to the risk of being sucked up into dredging hoppers (Morton and Nella, 2000). • Factors that reduce risk exposure include: a) timing of dredging activities planned not to coincide with the turtle breeding season, b) the dugong and sea turtle populations in Trinity Bay are smaller compared to other Queensland sea ports, so chance of exposure comparatively reduced, c) the implementation of on-board management procedures aboard dredging vessels aimed at minimising turtle mortality,	While some individuals may be affected or lost, noise and plume generation is not likely to impact significantly on the populations of fish, dugongs and sea turtles in Trinity Bay. Any change in behaviour impacting negatively on the fitness of these fauna would probably be subtle and difficult to detect against background natural variation. There may also be changes in behaviour that are of benefit to fitness. Turtle and fish may be attracted to dredged areas or to the Spoil Ground immediately after the placement of dredged material to feed on exposed fauna Although the exposure of turtles to direct mortality through dredge suction has been reduced, any mortality to endangered species can be considered as significant. The same applies to dugongs, though the mechanisms of potential mortality relating to dredging activity have not been identified specifically to our knowledge.

Mechanistic Effect	**Main Biota potentially at risk**	**Reason for potential risk**	**Scale of mechanistic effect and exposure**	**Likely outcomes**
		In rare circumstances dugon could be struck by the dredge although this is not considered likely due to the mobility of these mammals.	d) the relatively high mobility of fish, turtles and dugongs compared to seagrass or benthic fauna allows them a greater chance to avoid the hazards associated with dredging or dredge spoil disposal, and e) it is unlikely that all fish species that occur in Trinity Bay will have the migration or breeding patterns that al coincide. Therefore, it is unlikely that the impacts of dredging or spoil disposal will affect the entire range of fish taxa.	
7) Physical changes to the benthic habitat at and beyond the Spoil Ground, such as changes in sediment texture and cohesiveness and/or rugosity (bed height issue considered elsewhere) <u>Activity Related to:</u> Post-placement changes (includes time during the settling of spoil material on sea floor).	Benthic fauna.	Changes in sediment particle size distribution can lead in shifts in taxonomic composition, while changes in the cohesiveness of sediment at the Spoil Ground may reduce the ability of burrowing and tube building organisms to survive or colonise affected areas	<u>Scale</u> • The Spoil Ground area is small relative to the size of Trinity Bay. • Observations by Neil *et al.* (2003b) suggest that, despite 10 years of spoil disposal at the current site, the Spoil Ground was physically similar to reference areas and differences in sediment granulometry were minor. • Scope of changes to physical habitat moderate by: a) dredged material being physically similar to the sediment found at the Spoil Ground and adjacent areas, and b) deposited sediment is quickly reworked into the sediment profile by biota.	Dredge spoil disposal at the current site should has not result in major levels of physical change to the Spoil Ground that are likely to explain differences between the Spoil Ground and reference area assemblages that were observed by Neil e al (2003b). Factors mitigating the scope of change to sediment texture and cohesiveness should prevent significant changes in the benthic assemblage at the Spoil Ground resulting from the alteration of these physical properties.
8) Introduction of marine pests to the Spoil Ground <u>Activity Related to:</u> Translocation of species from dredged area during dredging and placement phase. Post-placement survival and proliferation.	Benthic flora and fauna, as well as higher food chain species.	Introduced marine pests could out-compete native species for resources such as space and food, leading to their decline. Shifts in taxonomic composition may not favour the feeding requirements / preferences of fish and prawns.	<u>Scale</u> • Three introduced and three cryptogenic (of unknown origin) species have been reported from the Port of Cairns (**Table 7.2**). • None of these introduced species have been recorded at the Spoil Ground (Neil *et al.* 2003). However, only one examination of the Spoil Ground biota has been carried out to date, and no monitoring programs are in place. • Factors that might mitigate the spread of NIS to the current Spoil Ground and beyond include: a) monitoring and associated early-response mitigation measures should continue to minimise the risk of a severe outbreak of the two most notorious species (Asian Green Mussel and Caribbean Tube Worm),	The impacts of introduced marine pests vary between species and are often density-dependent. Currently, the Caribbean Tube Worm and Asian Green Mussel have no known impacts in the Port of Cairns. However, both species have the potential to smother native assemblages if allowed to become highly abundant. This is unlikely given the scarcity of hard-substrate habitat observed at the Spoil Ground by Neil *et al.* (2003). Introduced species that are soft-

Mechanistic Effect	Main Biota potentially at risk	Reason for potential risk	Scale of mechanistic effect and exposure	Likely outcomes
			b) continued monitoring for introduced marine pests in the Port of Cairns and the Spoil Ground using a variety of methods should detect the presence of previously absent introduced marine species in time to prevent a major outbreak, c) ocean disposal of ballast waters by large ships before they enter Cairns Port reduces the likelihood of translocating marine pests, d) ship and yacht owners and operators are encouraged to prevent or reduce the amount of hull-fouling organisms on their vessels, e) operation of the main dredge vessel, the *Brisbane*, in accordance with current best practices reduces the risk of transporting marine pests between ports, f) reduced availability of hard surfaces in the dredged area and at the Spoil Ground will reduce the potential for target species such as the Asian Green Mussel and Caribbean Tube Worm to proliferate at the Spoil Ground (however, the abundant soft sediment habitat might suit other introduced species). Exposure • NIS are present in Trinity Bay and dredging and dredge spoil placement can translocate NIS taxa (and the habitats of some) to the Spoil Ground. • The vessels used for dredging also operate in other Australian ports that contain introduced species, and may transport these to Cairns on their hulls.	sediment dwellers are likely to encounter a significant amount of suitable habitat and may attain large populations over a shorter timeframe. Given suitable currents, propagules of introduced species established at the Spoil Ground may be transported to nearby coral reef environments.

Source: Study team compilation.

Table 7.2 Non-indigenous Species Present in the Port of Cairns (Neil *et al.*, 2003b) and those Potential Marine Pests by ABWMAC, CRIMP, and other work (Hilliard and Raaymakers, 1997).

NIS SCIENTIFIC NAME	NIS COMMON NAME	USUAL HABITAT	TOLERANT OF CAIRNS REGION ENVIRONMENTAL CONDITIONS (TEMPERATURE & SALINITY)? [3]	TRANSFER TO SPOIL GROUND POSSIBLE IF PRESENT IN PORT OF CAIRNS?	SUITABLE HABITAT AVAILABLE AT SPOIL GROUND? [5]
NIS recorded from the Port of Cairns					
Hydroides sanctaecrucis	Carribean tubeworm	Hard substrate	Yes	Yes [4]	No
Perna viridis	Asian green mussel	Hard substrate	Yes	Yes [4]	No
Bugula neritina	Bryozoan	Hard substrate	Yes	Yes [4]	No
Balanus amphitrite (cryptogenic)	Barnacle	Hard substrate	Yes	Yes [4]	No
Polydora sp. (cryptogenic)	Polychaete	Soft substrate	Yes	Yes	Yes
Cirolana sp. (cryptogenic)	Isopod	Soft substrate	Yes	Yes	Yes
ABWMAC target species [1]					
Sabella spallanzanii	Mediterranean fan worm	Hard and soft substrate	No - may perish in low salinities during monsoon season		
Carcinus maenas	European green crab	Hard and soft substrate	Yes	Yes	Yes
Asterias amurensis	North Pacific seastar	Hard and soft substrate	No - may perish in water temperatures >25^o C		
Crassostrea gigas	Pacific oyster	Hard substrate	Yes	Yes	No
Corbula gibba	European clam	Soft substrate	No - may perish in low salinities and high temperatures during monsoon season		
Musculista senhousia	Date mussel	Hard and soft substrate	Yes	Yes	Yes

NIS SCIENTIFIC NAME	NIS COMMON NAME	USUAL HABITAT	TOLERANT OF CAIRNS REGION ENVIRONMENTAL CONDITIONS (TEMPERATURE & SALINITY)? [3]	TRANSFER TO SPOIL GROUND POSSIBLE IF PRESENT IN PORT OF CAIRNS?	SUITABLE HABITAT AVAILABLE AT SPOIL GROUND? [5]
Undaria pinnatifida	Japanese seaweed	Hard substrate	No - may perish in water temperatures >25° C		
Alexandrium cantenella *A. miutum* *A. tamarense* *Gymnodinium catenatum*	Toxic dinoflagellates	Soft substrate	Yes	Yes	Yes
Taxa listed by Hilliard and Raaymakers (1997) [2]					
Megabalanus rosa	Barnacle	Hard substrate	Yes	Yes [4]	No
Corophium insidiosum	Fouling amphipod	Hard and soft substrate	Yes	Yes	Yes
Neomysis japonica	Opossum shrimp	Soft substrate	Yes	Yes	Yes
Bugula stolonifera	Bryozoan	Hard substrate	Yes	Yes [4]	No
Zoobotryon verticillatum	Bryozoan	Hard substrate	Yes	Yes [4]	No
Bowerbankia sp.	Bryozoan	Hard substrate	Yes	Yes [4]	No
Sparidentex hasta	Teleost fish	Hard and soft substrate	Yes	Unlikely	Yes
Cliona vastifera	Boring sponge	Hard substrate	Yes	Yes [4]	No
Perinereis vancuaria tetradenta	Ragworm	Hard and soft substrate	Yes	Yes	Yes
Hydroides cf. ezoensis	Polychaete	Hard substrate	Yes	Yes [4]	No
Potamoleios krausii	Polychaete	Hard substrate	Yes	Yes [4]	No
Chthamalus proteus	Caribbean barnacle	Hard substrate	Yes	Yes [4]	No
Acartiella sinensis	Copepod	Not known	Yes	Yes	Needs determining
Pseudodiaptomus marinus	Copepod	Not known	Yes	Yes	Needs determining
Chama elatensis	Red Sea jewel box shell	Hard substrate	Yes	Yes [4]	No

NIS SCIENTIFIC NAME	**NIS COMMON NAME**	**USUAL HABITAT**	**TOLERANT OF CAIRNS REGION ENVIRONMENTAL CONDITIONS (TEMPERATURE & SALINITY)? [3]**	**TRANSFER TO SPOIL GROUND POSSIBLE IF PRESENT IN PORT OF CAIRNS?**	**SUITABLE HABITAT AVAILABLE AT SPOIL GROUND? [5]**
Lyrodus pedicellatus	Black tip ship worm	Wood boring	Yes	Yes	No [7]

Source: Study team compilation based on identified sources.

[1] Adopted from (Hewitt and Martin, 2001).

[2] Species already listed above are not listed again but are included in Hilliard and Raaymakers (1997) list.

[3] Information from (NIMPIS, 2002). Species listed by Hilliard and Raaymakers (1997) were assumed to be tolerant to North Queensland environmental conditions.

[4] Transport of adults most likely to occur by attachment to rocks, pebbles and shells.

[5] This is restricted to naturally occurring habitats and does not include material brought to the Spoil Ground by the dredge.

[6] Can only exist to a depth of 3m.

[7] Requires woody habitat.

7.6 DEFINITION OF TESTABLE IMPACT HYPOTHESES

7.6.1 Introduction

An environmental monitoring program is required to assess the ecological impacts of dredging and sea disposal over the longer term. The various risks of impacts on resources are set out here in a hypothesis testing framework as recommended by the National Ocean Disposal Guidelines. These hypotheses facilitate a performance evaluation of dredging and sea disposal, which may be used as guidelines for assessing whether there is a need to modify or postpone dredging and sea disposal activities in the future.

From the discussion given in **Section 7.4**, the potential impacts associated with dredging and sea disposal may be summarised as follows:

a) ***Short Term***

- increases in turbidity,
- decreases in dissolved oxygen,
- increases in nutrients,
- release of contaminants into the water column, and
- smothering of fauna and flora.

b) ***Long Term***

- accumulation of contaminants in the sediment and biota,
- changes in particle size at the Spoil Ground,
- cumulative impacts relating to repeated burial of fauna,
- increased turbidity as re-suspension becomes more common with increased bed height,
- movement of dredged material outside of the Spoil Ground,
- introduction of marine pests, and
- inhibited recovery after dredge spoil disposal activities cease at a particular Spoil Ground.

c) ***Very Long Term***

In the very long term (i.e. well after the life of the proposed 5 year program and perhaps several decades in the future), sediments at the Spoil Ground can be expected to build up in depth such that its effective life is over. At that time a new site will need to be available.

While this issue is not relevant to the permit application, it is suggested that strategic investigations take place well in advance of this happening, perhaps beginning during the life of the proposed permit.

7.6.2 Impact Hypotheses – Impacts on Water Quality

There appears little ecological risk associated with the changes in water quality during dredging and in the immediate aftermath of dredge spoil disposal, as such changes occur over small spatial and temporal scales which, apart from turbidity, are unlikely to be changes of large magnitude. Monitoring has shown that seagrass beds immediately adjacent to dredged areas do not show any adverse impacts from dredging. In the case of disposal, reductions in water quality do not currently occur in the vicinity of sensitive receptors such as seagrass or coral reefs and, provided new Spoil Grounds are chosen carefully, this should continue to be the case. The impact hypotheses related to changes in water quality parameters are as follows:

> *Impact hypothesis 1: Plumes associated with dredging and/or the deposited material will not reach any sensitive adjacent areas (epifaunal and infaunal assemblages, seagrass beds, reefs) through dispersal of the dredge plume in amounts sufficient to be of concern.*
>
> *Impact hypothesis 2: Disposal will not result in ecologically significant inputs of contaminants to the water column.*
>
> *Impact hypothesis 3: Disposal will not result in ecologically significant reductions of dissolved oxygen concentrations in the water column.*
>
> *Impact hypothesis 4: Disposal will not result in ecologically significant increase in nutrient concentrations in the water column.*

7.6.3 Impact Hypotheses – Impact on Benthos

a) ***Dredging***

Long term seagrass monitoring studies by the Department of Primary Industries and Fisheries(Rasheed *et al.* 2004) reveal that the marine environment appears to be relatively healthy and recent changes to seagrasses appear to be related to climate rather than any human activity occurring in the Harbour or Inlet.

So far the seagrass monitoring program indicates that there have been no adverse effects on seagrass meadows from the current dredging program since the beginning of monitoring in 2000.

b) ***Disposal***

There is currently only a limited understanding of the short-term impacts of smothering on fauna at the Spoil Ground, and smothering may have contributed to a subtle longer-term reduction in diversity of benthic fauna at the Soil Ground compared to the reference locations of the Neil *et al.* (2003b) study. Over the 10 year period since this Spoil Ground was commissioned, it is also likely that repeated smothering has led to a shift in composition towards an assemblage increasingly more dominated by motile taxa with strong burrowing abilities with fewer sessile species. The Neil *et al.* (2003b) study did provide evidence that the current Spoil Ground is having at most subtle effects on benthic biota outside the Spoil Ground.

There will likely be an impact of smothering at the Spoil Ground during its operating life, but this is considered acceptable given that:

- the area impacted is small relative to the size of the Bay,
- the benthic assemblage of the Spoil Ground is well represented in the Bay and is, therefore, not of high environmental value, and
- the Spoil Ground would likely recover in the longer term following the cessation of dredged material placement activities.

Smothering impacts are not an issue for seagrasses, as they are absent from the Spoil Ground and dredged material is unlikely to reach the sparsely occurring seagrasses to the south at corresponding depths, and should not reach the major seagrass habitats in the shallow near-shore regions of Trinity Bay.

> *Impact hypothesis 5: There will be no serious adverse impact from the dredging operation on seagrass beds adjacent to the dredged areas.*

> *Impact hypothesis 6: There will be potential loss of benthic assemblages at the disposal site once disposal commences, but this will not involve loss of any resources of special value in the Bay, i.e. the deposited material will not reach any sensitive receptors (epifaunal and infaunal assemblages, seagrass beds, reefs – excluding those in the Spoil Ground) through re-suspension and dispersal by water movement following disposal, in amounts sufficient to be of concern.*

7.6.4 Impact Hypotheses – Impact on Marine Fauna (other than benthos)

The short-term impacts of dredge spoil disposal on dugongs and turtles are likely to be minor if any. Plumes generated from disposal activity are small in relation to the size of the Bay and large motile organisms such as turtles and dugongs are capable of avoiding them (assuming that this was even necessary). According to EPA's turtle expert Col Limpus (pers. comm. 2004), the Cairns area is not regarded as a major breeding area in Queensland and turtle numbers in Trinity Bay and the population size in Trinity Bay is smaller compared to other ports. Therefore, there is little chance of any disruption to breeding or spawning activities of significance to these species. Dredge spoil disposal activities have been known to attract turtles to Spoil Grounds to feed, but only in situations where a lot of shell material is deposited (Col Limpus, EPA, pers comm. 2004), which is not the case in Trinity Bay.

The short term impacts on prawns are probably also minimal, given that many species, including the Brown Tiger Prawn (*Peneus esculentis*), regularly bury themselves during the day and remerge at night (Keys 2003) and will therefore be unlikely to suffer, at least at the population level, from any effects of localised smothering.

Disruptions to fish behaviour due to dredge spoil disposal activities could include disruption to feeding, spawning or defensive aggregations (Hopkins and White, 1998). However, the limited scale to which water quality is likely to be affected (in terms of spatial and temporal scale of plumes and the magnitude of changes in water quality), would suggest that any effects would be highly localised and, at worst, sub-lethal. Furthermore, the current mode of dredge spoil disposal (at the present site) does not represent a risk of either spawning habitat removal (as only limited changes to the benthic habitat in terms of particle size distribution are likely to occur), or any major obstruction to fish passage. At worst, the dredge spoil plume would represent a minor inconvenience for fish moving between near-shore coastal areas and offshore areas to spawn (or vice versa), in terms of avoidance during spawning migration. The release of nutrients during dredge spoil disposal may even be beneficial to fish in the short term, as it provides a food source for local fish communities and may influence the speed with which fish recolonise Spoil Grounds (Hopkins and White 1998).

While any short-term impacts of dredge spoil disposal on prawns and fish could be mitigated by conducting these activities outside spawning seasons, the information on the spawning habitats of commercially important prawn and fish species that occur in northern Queensland in Hopkins and White (1998) shows that there is no common time of the year that they all spawn. Therefore, achieving this management option would be difficult and unwarranted. A more reliable option may be to undertake both dredging and dredge spoil disposal activities during naturally turbid periods, as advocated by Hopkins and White (1998). Timing of dredging for the Entrance Channel is however limited to the timing of the annual northern campaign of the *Brisbane* which services several ports in northern Queensland each year, typically between May and October whereas the highest natural turbidity exists during the late wet season (November to April).

> *Impact hypothesis 7: There will be no turtle and dugong mortality and only very limited disruption of dugong, turtle, fish and prawn feeding and spawning behaviour as a result of the short-term impacts of dredge spoil disposal, particularly if these activities can be timed to coincide with naturally turbid periods in Trinity Bay.*

7.6.5 Impact Hypotheses – Impact on the Nature of Sediment

The sediment dredged from the Entrance Channel is physically similar to that found at the Spoil Ground, and changes in sediment texture, organic content, or redox conditions at the Spoil Ground are, therefore, likely to be minimal. Should capital dredging occur at some time in the future (outside the period of the five year permit sought), there would likely be changes to sediment particle size distribution at the Spoil Ground, as below navigable depth the sediment is older and of a different texture to that which is deposited between dredging events.

> *Impact hypothesis 8: There will be no significant changes in sediment particle size distribution, organic content or redox conditions at the Spoil Ground as a result of maintenance dredging.*

7.6.6 Impact Hypotheses – Impact arising from Accumulation of Contaminants

The risk of contaminant accumulation in the sediments of the Spoil Ground is very low, given that CPA undertakes pre-dredging SAPs to establish dredged material suitability for sea disposal in accordance with the assessment framework provided in the Ocean Disposal Guidelines. CPA also undertakes surveillance monitoring of the sediment at the Spoil Ground to confirm SAP findings.

> *Impact hypothesis 9: There will be no ecologically significant accumulation of contaminants at the Spoil Ground as a result of dredge spoil disposal.*

7.6.7 Impact Hypotheses – Impact on Turbidity Levels from Sediment Resuspension

There is a small risk that turbidity will increase in the vicinity of the Spoil Ground post-disposal as a result of more frequent and intensive sediment re-suspension as the mound of spoil is raised closer to the surface. However, the build-up of the spoil mound at the present Spoil Ground to a level that will significantly increase the frequency of sediment re-suspension in the life of the proposed permit is unlikely, given that:

- the dredge spoil is spread fairly evenly over the Spoil Ground,
- there is significant seaward and long-shore removal of dredged material each year,
- the depth of water at the Spoil Ground is greater than that of the previous disposal sites (which have largely disappeared as a topographic feature) and it would probably require a substantial increase in the height of the spoil mound for sediment to be exposed to wave generated currents, and
- our predictions indicate that the net average accumulation of sedimentation the Spoil Ground over five years is relatively minor (approximately 75 mm per year).

> *Impact hypothesis 10: There will be no significant increase in turbidity at the Spoil Ground above background levels associated with increased exposure to wave-generated currents, through the build-up of dredged material.*

7.6.8 Impact Hypotheses – Recovery between Dumping Episodes

Repeated dredge spoil disposal at a single site over a long period may affect the resistance and resilience of the faunal communities that are exposed to this type of disturbance. While smothering of flora and fauna at the Spoil Ground may be an unavoidable consequence of sea disposal of dredged material, the continued ability of faunal communities to recover between disturbance events and/or their ability to recover once dredged material disposal ceases is considered important. The ability to recover between dredge spoil disposal episodes is not a necessary requirement of the Ocean Disposal Guidelines. However, if results of monitoring showed a consistent inability to recover between spoil disposal events, this would provide ‘advanced warning’ that the timing, magnitude or frequency of this type of disturbance is not ecologically sustainable and that dredge spoil disposal practices should be modified. The Neil *et al.* (2003b) study provided evidence of only subtle differences between the Spoil Ground and reference locations, despite the 10 years of repeated disposal activity.

The rate at which faunal communities recover after dredge spoil disposal ceases at a particular site represents more of an issue for the ecology of the Bay and to the long term sustainability of sea disposal. Ideally, significant impacts of dredge spoil disposal should only occur during the operational life of the Spoil Ground in use and at the site used immediately before (until it recovers). Should faunal communities not have the ability to recover fully after dredge spoil disposal ceases, however, then there is a prospect of an increased scale of impact of this activity across the Bay with every new Spoil Ground commissioned. This is not an issue of concern for the current permit but has long term implications.

> *Impact hypothesis 11: The Spoil Ground benthic assemblage will continue to recover, at least to a limited degree, between dredging episodes and, once disposal ceases, will recover fully over time.*

7.6.9 Impact Hypotheses – Marine Pest Infestation

As described in **Section 7.4**, the risk of infestation of the dredge spoil site by marine pests is a function of their ability to survive the uptake by the dredge, the transport to the Spoil Ground, and the environmental conditions at the disposal site. Furthermore, sufficient propagules have to survive to form a self-sustaining local population with the ability for geographical spread.

The risk of uptake of viable organisms by the dredge (e.g. shells or rocks with *P. viridis* or *H. sanctaecrucis* attached) is entirely dependent on the distribution and abundance of the species and suitable substrates in the areas that are dredged. Neil *et al.* (2002a) found such substrates only in low abundance and none were inhabited by known marine pests. The chance that any translocation of marine pests to the Spoil Ground would result in a proliferation of these species in Trinity Bay is dependent on their ability to survive the extraction and transport phase and their ability to colonize suitable habitats. Although there are no data on survival rates for *P. viridis* or *H. sanctaecrucis* under conditions relating to dredge extraction and the transport phases, even if survival rates were high during those phases, the proliferation of these two species at the current Spoil Ground is unlikely given that, as with the dredged area, the availability of hard substrata at the current Spoil Ground is extremely low.

> *Impact hypothesis 12: The lack of suitable habitat in both the dredged area and the Spoil Ground will prevent the development of significant populations of Asian Green Mussel or Caribbean Tube Worm at the Spoil Ground.*

Although a large proportion of the habitats for sessile/encrusting species (such as *P. viridis* and *H. santaecrucis*) have to be imported with the dredge spoil for them to survive and proliferate at the

Spoil Ground. This is not the case for infaunal and epibenthic marine pests or resting stages (cysts) of toxic dinoflagellates, which prefer soft sediment habitats of fine sand, silt and mud (see e.g. **Table 7.1**. The diverse benthic assemblage present at the Spoil Ground would provide these organisms with an abundant source of food in conditions where sediment contamination by heavy metals and chemicals from the Port are of little concern. The risk of species transfers and introductions can be reduced significantly if monitoring using a range of sampling techniques is conducted regularly in the Port and dredged areas to detect newly established pest populations and (if translocation occurs) at higher frequencies at the Spoil Ground when their populations are still small and localised and control and/or eradication is possible. The risk of transport and spread of marine pests can be further reduced if the dredging vessels undergo annual regular antifouling paint renewals or quarterly visual inspections of submerged hull surfaces by divers or dry-docking.

> *Impact hypothesis 13: There will be no significant outbreaks of introduced marine pests at the Spoil Ground.*

7.6.10 Impact Hypotheses – Impact on Habitat for Important Fauna

Spoil disposal and dredging will not have any significant impact on important fauna such as wading birds, dugong or turtles through the reduction of seagrass cover, as:

- turbid plumes generated during these activities are likely to be restricted in terms of their temporal or spatial extent, so any effects on seagrass would likely be localised and possibly short-lived,
- seagrass at or near the current Spoil Ground are sparsely distributed and occur at low densities,
- normal hydrological conditions operating in Trinity Bay are likely to prevent turbid plumes generated offshore from reaching the shallow coastline (in most instances) where the seagrass beds used by wading birds occur, and
- the biology of seagrasses occurring near the current Spoil Ground would indicate that recolonisation post-decommissioning of the current Spoil Ground should be possible.

However, note that the risk of turbid plumes associated with dredging activities reaching inshore seagrass areas is much higher than is the risk for plumes from spoil disposal, hence the positioning of sites used as part of the long-term seagrass monitoring program is concentrated in these inshore areas, in the vicinity of regular maintenance dredging activities.

This situation above also applies as much to fish or prawns with strong affinity for seagrass, such as *Peneus esculentis* (the Brown tiger prawn) and *Peneus plebejus* (the King prawn) (Massel and Smallwood *in press* cited in Hopkins and White 1998).

Halophila and *Halodule* are two of the most preferred seagrasses of green turtles (Col Limpus, Queensland EPA, pers comm. 2004) and these two genera are the most likely to be affected by dredge spoil disposal activities, given the depth range to which they can occur. The impacts of spoil disposal activities on the areal cover of these two species of seagrass at any future Spoil Ground sites will depend on the proximity of these sites to high density seagrass habitats, the size of the plumes generated and the strength and direction of local currents in terms of their ability to quickly disperse and dilute turbid plumes.

Although molluscs, crabs and sea pens were recorded at the Spoil Ground and the two reference locations in the study by Neil *et al.* (2003b), there are no records of whether these organisms formed a dominant component of the benthic community prior to dredge spoil disposal at the current Spoil Ground. However, even assuming that there has been a significant reduction in these taxa at the Spoil Ground, the small aerial extent of the Spoil Ground compared with that of Trinity

Bay as a whole means that such impacts will not affect their availability to green turtles significantly.

> *Impact hypothesis 14: There will be no significant loss of dugong, turtle, wading bird, fish or prawn feeding and shelter habitat resulting from sea disposal activity at the Spoil Ground. (This will also be true for future Spoil Grounds, so long as their locations do not coincide too closely with large stands of Halophila or Halodule).*

7.6.11 Impact Hypotheses – Impact on Indigenous Cultural Values

This study has not located any information on the existence of indigenous cultural values that may be under threat from the dredging, transport, or dumping operations other than the fact that turtle and dugong are known to be hunted under Aboriginal tradition. If these species are at some risk from the operations then to some extent associated indigenous values are also at risk. Whilst this is certainly an information gap at present, the effect on indigenous cultural values can still be stated in terms of a testable impact hypothesis.

> *Impact hypothesis 14: There will be no significant impact on indigenous cultural values resulting from dredging, transport, or sea disposal activity at the Spoil Ground.*

Further investigations may be warranted into possible indigenous values that are at risk from dredging and disposal.

8. PROPOSED MANAGEMENT AND MONITORING OF DREDGING AND SEA DISPOSAL

8.1 INTRODUCTION

This chapter describes the proposed management and monitoring program which has been designed to test the previous impact hypotheses. In designing this program, recognition has been given to the fact that over ten years of operations at the current Spoil Ground appear to have resulted in minimal impacts.

It should be noted that the current permit requires that the sample design, timing and scope of reporting for all monitoring programs required is to be determined in consultation with the GBRMPA. Accordingly, the following recommended program is of a provisional nature and will require further discussions prior to being finalised and consolidated into a concise program.

8.2 LONG TERM ARRANGEMENTS

8.2.1 Regulatory Arrangements

The principal determining authority (as described in **Section 1.1**) is GBRMPA, which permits the activity of dredging and sea disposal subject to approvals and conditions issued under the *Great Barrier Reef Marine Park Act 1975* (Cwlth) and the *Environment Protection (Sea Dumping) Act 1981* (Cwlth)

As dredging associated with the major annual maintenance dredging program is considered a Port management activity and no royalty is paid to CPA, it is considered a deemed approval with respect to the *Environmental Protection Act 1994* (Qld). As discussed in **Section 1.3**, CPA holds a licence under the *Environmental Protection Act 1994* for contract dredging. All dredging is undertaken pursuant to a Dredging Environmental Management Plan (Dredging EMP) prepared in advance of all dredging activities. Separate dredging EMPs, discussed in **Section 8.3.2** below, have been prepared for inner harbour and maintenance dredging and are used by CPA to manage environmental risks associated with all dredging and sea disposal activities.

8.2.2 Long Term Role of TACC

The role of the TACC in the development of the LTDSDMP, as described in **Section 1.6.3**, has so far included input in discussions held at the inaugural TACC meeting on 19 November 2003. The on-going role of the TACC is to provide the forum for the on-going review and consultation of the management of dredging and sea disposal by CPA and in particular to advise on matters related to the sustainability of the port to ensure that all aspects of sustainability (environmental, economic, and social) are considered in the development and application of the LTDSDMP.

Key responsibilities of the TACC are to:

- review the development and implementation of Sampling and Analysis Plans, Long Term Management Plans and research and monitoring programs,
- review on-going management of dredging and dumping in accordance with the Ocean Disposal Guidelines and permitting arrangements, and
- make recommendations to the proponent and the determining authority as necessary or appropriate.

8.3 PROPOSED ENVIRONMENTAL MANAGEMENT ACTIONS

8.3.1 Introduction

As discussed in **Chapter 7**, the impacts of dredging and sea disposal depend on the quantity and quality of material to be dredged, and the interaction with the natural environment of that material during dredging, placement and post-placement.

It is proposed that CPA continue to develop and implement Dredging EMPs (discussed in the sub-section below) to be the primary means used to manage the impacts of dredging and sea disposal. In addition to this, initiatives to improve the quality and reduce the volume of dredged material are given below.

8.3.2 Dredging EMPs

The CPA's Dredging EMPs are part of an overall environmental management system (EMS) that provides a framework for the environmental risk management of all of CPA's dredging and sea disposal activities. Different EMPs are produced annually for different CPA activities. The EMP produced for dredging adjacent to HMAS Cairns is a statutory requirement of the dredging permit issued to CPA by the Environmental Protection Agency as described above, while the EMP for the *Brisbane* covers all CPA dredging. This latter document is used as the basis of a Works EMP produced each year by the PBA for the *Brisbane*'s dredging program. The Works EMP converts CPA's performance-based "instructions" into project-specific operational activities.

Each Dredging EMP:

- identifies and describes the major environmental resources within Trinity Inlet, which may be affected by dredging,
- identifies potential environmental risks associated with dredging and sea disposal of spoil and describes means of mitigation,
- describes environmental monitoring programs applicable to the potential impacts of dredging and spoil disposal,
- describes organisational structure, management responsibilities and procedures relevant to the works, and
- facilitates compliance with legislation and necessary approvals.

Dredging EMPs include individual mitigation strategies for:

- waste management,
- emergency procedures,
- water quality,
- air and noise, and
- marine flora and fauna.

Under each Dredging EMP, CPA prepares specific work instructions for staff and contractors as the details of dredging methods and conditions of approval for each project are finalised.

It is recommended that future Dredging EMPs will, where practicable, be expanded to include the following safeguards for marine flora and fauna protection:

- development and implementation of a Marine Pests Mitigation Strategy,
- continuation of even spreading of dredged material across Spoil Ground,
- development of specific controls such as silt curtains and associated reactive monitoring strategies when dredging near sensitive receptors (based on a risk assessment), and
- continued use of turtle deflectors on dredger (as are used on the *Brisbane*) during dredging of the Entrance Channel.

Future Dredging EMPs will also incorporate the Environmental Monitoring Program requirements, where relevant from **Section 8.4** below. In particular, the specific monitoring and management actions outlined in **Section 8.4.5g)** for marine pests will be incorporated into a Marine Pests Mitigation Strategy within the Dredging EMP.

8.3.3 Quality Improvement

CPA currently meets the expectations of a Port Authority under the Ocean Disposal Guidelines to address polluting activities within the Port. The initiatives and activities undertaken by CPA directly, or required of lessees, were described in **Section 7.3.3**, and include wider catchment management efforts.

During the development of this LTDSDMP the need for an increased level of stewardship by CPA of the activities undertaken at the shipyards, as potentially significant sources of TBT, has been identified. This need relates to the vulnerability of the sea disposal suitability of sediments to TBT contamination. The increased stewardship by CPA should include:

- raising awareness with shipyard management of the consequences of TBT contamination of sediments with regard to both environmental impact and the economic viability of the Port, should dredged material be deemed unsuitable for sea disposal,
- review of the suitability and operational effectiveness of the pollutant discharge control measures at shipyards, under the EMPs required of lessees by CPA as property manager of Port land, and
- an on-going program of audits of lessee operations, under CPA’s Environmental Management System which is currently under development.

8.3.4 Quantity Reduction

As discussed in **Section 7.3.2** there is very little opportunity for a reduction in the quantity of material to be dredged and hence dumped, principally because the quantity which accumulates in dredging areas is governed by coastal processes which are outside of CPA’s control. The sediment which accumulates in the Entrance Channel, which represents some 90% of the material dredged each year, is largely from cross-channel siltation. It is recommended that CPA continue to undertake a number of measures to minimise the volume of material dredged, as described in **Section 7.3.2**.

These measures are currently self imposed requirements of CPA's Dredging EMP. Key activities to minimise the volume of material dredged that will be continued include:

- use bed levelling, where applicable, to reduce the need for dredging, and
- collection and analysis of detailed hydrographic data (including review against the historic record) to properly estimate annual dredging requirements, so as to minimise 'over-dredging'.

8.4 PROPOSED ENVIRONMENTAL MONITORING PROGRAM

8.4.1 Introduction

The development of an adequate long–term monitoring program for assessing the impacts of dredging and sea disposal in Trinity Bay requires:

- an understanding of dredge spoil properties, dredge spoil disposal practices and the characteristics of the receiving environment (presented here in **Chapters 1** and **6**),
- definition of resources that are at risk, likely mechanisms of impact, and identification of the ecological maintenance processes that sustain them (presented here in **Chapter 7**), and
- definition of impact hypotheses based on knowledge of nature of disturbance (timing, frequency and magnitude) and the likely resources affected (presented here in **Section 7.6**)

Section 8.4.2 describes the on-going use of SAPs to characterise material to be dredged and to enable a determination of suitability for sea disposal. Approaches to assessing TBT bioavailability and direct toxicity are also given in this section which should be considered where average TBT concentrations (at the upper 95% confidence level) of dredging areas are found to exceed the Screening Level given in the Ocean Disposal Guidelines.

Section 8.4.3 outlines a study to investigate the sources, fate and possible biological impacts of TBT in Trinity Inlet. An important aspect of this study is to examine (risk assess) the potential for 'hot spot' areas of elevated TBT, if remobilised, to impact on the sea disposal suitability of channel material.

Sections 8.4.4 and **8.4.5** provide initial recommendations for future monitoring. Continued monitoring and management strategies for introduced marine pests are detailed in **Section 8.4.5g)**. **Table 8.1** provides a summary of these and outlines the limitations or benefits of monitoring in relation to the impact hypotheses outlined in **Section 7.6** above, based on the risk to resources and ability to distinguish the impacts of dredge spoil disposal over and above changes to the resource status brought about by natural processes.

Some additional monitoring considerations for future reference (outside the timeframe of the sought 5-year permit) which would be relevant if capital dredging were to occur, or a new Spoil Ground needed to be commissioned, are provided in **Appendix F**. These suggestions are provided for information only as they are not relevant to the proposed 5 year permit.

8.4.2 Ongoing SAP Assessments of Dredge Material Suitability for Sea Disposal

The program of SAP assessments undertaken by CPA to determine dredge material suitability for sea disposal, in accordance with the Ocean Disposal Guidelines, will continue. CPA will provide a SAP (a revised version of the current SAP) to DEH for approval for implementation during the life of the long-term permit sought.

a) *TBT Levels in Trinity Inlet and Bioavailability and Direct Toxicity Assessment Approaches*

TBT is currently the contaminant in sediments at the Port of Cairns which has the greatest potential to render future maintenance material unsuitable for sea disposal. Although the areas of Trinity Inlet currently monitored by CPA as ‘hot spot’ areas do not fall within dredging areas, material from these areas has the potential to mobilise and migrate to dredging areas. Given the very low levels at which the Screening and Maximum Levels for TBT are set in the Ocean Disposal Guidelines, a small volume of sediment with an elevated concentration of TBT has the potential, when mixed into a dredging area, to render a much larger volume of dredge material unsuitable for sea disposal.

Where average contaminant concentrations are found to exceed the Screening Levels (for one or more parameters), at the 95% upper confidence level, then bioavailability and/or direct toxicity assessment may still be undertaken to determine sea disposal suitability, except where GBRMPA has made it a specific condition of the sea dumping permit (as is current policy) to apply the Maximum Levels (specified in the Ocean Disposal Guidelines) as strict cut-off thresholds within the GBRMP. For TBT, even were GBRMPA not to apply the Maximum Levels as cut-off levels in the sea dumping permit, the Ocean Disposal Guidelines (under Section 3.8.2) currently preclude direct toxicity assessment (ecotoxicity testing) where the Maximum Level for TBT has been exceeded (by the average concentration at the upper 95% confidence level of a dredging area) and the TBT is considered to be bioavailable. This is because there are currently no ecotoxicity tests commercially available in Australia that are sufficiently sensitive to TBT, which would involve testing for imposex (the development of male characteristics in females) in marine gastropods.

The elutriate test may be used as a measure of TBT bioavailability[23] given that the primary uptake pathway for TBT is via solution. An alternative and more exact measure of TBT bioavailability is via direct measurement of porewater TBT concentrations. To undertake a meaningful comparison of porewater TBT concentrations with relevant marine water quality criteria, a considerable volume of porewater needs to be obtained. This is not generally possible through *in-situ* methods (e.g. peepers), but can be achieved through the collection and pooling of multiple cores (where cores are retained intact/frozen until processed under controlled conditions in a laboratory where porewater is extracted under centrifugation, nitrogen squeezing or similar).

Should bioavailability testing of TBT not meet the relevant marine water quality criteria, then direct toxicity assessment may be undertaken (provided that the average TBT concentration, at the upper 95% confidence level, is below the Maximum Level specified in the Ocean Disposal Guidelines for either of the reasons given above. Section 3.8 of the Ocean Disposal Guidelines outlines the sediment ecotoxicity tests which are currently available in Australia and guidelines for their application.

Methods of bioavailability and/or direct toxicity assessment would need to be ‘approved’ by DEH prior to implementation in a SAP assessment of sediment suitability for sea disposal.

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[23] Note that it would not be appropriate to allow for mixing at the Spoil Ground (as is performed in the application of the elutriate test to assessing water column impacts during dredging and placement) when using the elutriate test as a measure of TBT bioavailability, in the consideration of effects on benthic organisms locally. In considering the effects on water column organisms and distant benthic organisms, a significant dilution of porewater concentrations (as estimated by the elutriate test) would take place when mixed with the overlying and surrounding waters, hence an allowance for mixing afforded at the Spoil Ground would be appropriate for these.

8.4.3 Monitoring to Better Understand the Sources, Fate and Biological Impact of TBT in Trinity Inlet

Although not directly related to dredging, it is recommended that consideration be given into a study aimed at better understanding the levels of TBT in the sediments and water column, the source of TBT, and whether TBT is likely to be having a significant biological impact. Importantly, such investigation should seek to better define the spatial extent and quality of 'hot spots' (for TBT and trace metals) and provide an assessment of the risk this material poses to the sea disposal suitability of sediments in maintained berth areas and channels. The risk assessment should consider the conditions under which the sediment in 'hot spot' areas might become mobile, and if so, whether average contaminant concentrations of dredging areas could be significantly increased relative to sediment quality criteria.

Measurements of total TBT and trace metal concentrations in blast wastes from slipways (over a range of dates, to cover the range of vessels worked on, particularly the larger vessels), would provide an indication of the potential of these sites to act as sources. Elutriate testing of blast wastes would also provide a measure of the potential for these blast wastes to impact on water quality.

If this investigation found that biological impacts of TBT were likely occurring in Trinity Inlet, then field investigation should be undertaken to assess whether there is any measurable TBT bioaccumulation or observable toxic effects (e.g. imposex).

8.4.4 Monitoring for Short-Term Impacts

a) ***Water Quality***

CPA has undertaken water quality monitoring during maintenance dredging campaigns, though this is not required by any permit. On such occasions, monitoring was conducted upstream and downstream of the Spoil Ground before, during and after dredge spoil disposal. While the continuation of this monitoring program at the current Spoil Ground might address impact hypotheses 1 to 4 (given in **Section 7.6**), the ecological risks associated with likely changes in water quality are considered small and further monitoring is not, therefore, warranted. The extent and movement of turbid plumes at the Spoil Ground has already been established through past monitoring, so further water quality monitoring is unlikely to yield much new information. Furthermore, the scope of the water quality monitoring program carried out by CPA could be reduced given that the material requiring dredging has always been found to comply with the Ocean Disposal Guidelines on an assessment of total contaminant concentrations, hence an assessment of water quality impacts is not strictly required under the guidelines. The Ocean Disposal Guidelines state that elutriate testing is the preferred approach to the assessment of water quality impacts of substances such as metals, nutrients and organic chemicals in dredge material. Elutriate testing is the preferred approach under the Ocean Disposal Guidelines because of the difficulties involved in the analysis of trace contaminants in marine waters, including large sample requirements in space, time and depth, and in obtaining reliable and reproducible results.

b) ***Smothering of Benthic Fauna and Flora***

Dredging

As previously described, the Queensland Fisheries Service Marine Ecology Group through the CRC Reef Research Centre's Ports and Shipping program have been conducting an annual long-term seagrass monitoring program in Cairns Bay. This testing is expected to be an on-going annual program and involves two objectives:

- compare results of monitoring with previous seagrass surveys and assess any changes in seagrass distribution and abundance in relation to natural events or anthropogenic port and catchment activities, and
- discuss the implications of monitoring results for overall health of Trinity Inlet's marine environment and provide advice to relevant management agencies.

It is recommended that this work continue to inform the dredging EMPs and provide validation of the relevant impact hypothesis.

Spoil Ground

The assessment of any immediate smothering impacts on fauna and flora at the Spoil Ground is not required under the Ocean Disposal Guidelines and was not required under previous Sea Dumping permits held by CPA. The ability of fauna and flora to recover between disposal episodes or at least after disposal activities at a particular site cease is of greater concern. Given that the current Spoil Ground has been in use for several years and the findings of Neil *et al.* (2003b) that the impacts of spoil disposal on benthic fauna over the last ten years have resulted in what could be described as subtle changes to diversity and composition of the benthic assemblage, no short-term monitoring for the impacts of smothering of benthic fauna and flora is recommended under this LTDSDMP.

8.4.5 Monitoring for Long-Term Impacts

a) *Sediment Contamination at the Spoil Ground*

Monitoring of sediment quality at the Spoil Ground will continue as a component of SAP assessments, as described in **Section 6.2.4**. There is no requirement to expand on the monitoring currently undertaken, however, it should continue as surveillance monitoring to validate the findings of on-going SAP assessments.

b) *Changes in Sediment Particle Size Distribution, Organic Content and Redox Conditions*

While these parameters are biologically important, detailed monitoring of sediment particle size distribution or organic content as part of monitoring at the Spoil Ground should only be considered if a SAP assessment reveals a significant shift in particle size or organic content. Although redox conditions are not currently monitored in SAP assessments, redox monitoring could be considered in the event of elevated organic carbon levels in the dredged material during a particular year. Such information would be beneficial in the interpretation of any changes over time in benthic fauna communities at the Spoil Ground.

c) *Spread of Dredged Material Beyond the Spoil Ground*

It is recommended that annual pre- and post-dredging hydrographic surveys contain sufficient data coverage of the Spoil Ground and its surrounds (for a distance0.5 nm from the boundary) to enable the plotting of transects running north-south and east-west across the Spoil Ground to provide a better indication of the direction and degree of dispersion of dredged material away from the Spoil Ground.

There is limited need for further benthic sampling to assess the effects of the spread of dredged material beyond the boundary of the Spoil Ground, as there is currently nothing about the physical or chemical nature of maintenance dredging material that is of ecological concern and according to the available information (Connell Wagner 1991), it is very unlikely that the amount of dredged material deposited beyond the Spoil Ground will pose any risk of sediment overburden.

If hydrographic surveys were to reveal that there was a significant sediment deposition beyond the Spoil Ground[24] over a large area, then the radial transect sampling method employed by Cruz-Motta (2000) could be used to assess how far the impact of dredge spoil disposal on benthic fauna extends outside of the Spoil Ground. The Cruz-Motta method is a form of gradient analysis and here the radial transects would be best positioned along major gradients (i.e. north-south and east-west, according to known sediment transport patterns). The value of this approach is that, not only can it be used to detect impacts, it can also be used to define the boundaries of where significant impacts occur (and where they do not). The latter cannot be determined using the discrete control locations (as was used by Neil *et al.* 2003b for their study).

d) *Increase in Turbidity Related to Decreasing Depths of Water at the Spoil Ground*

Ongoing pre- and post-dredging hydrographic surveys will allow a comparison of the rates of accumulation of dredged material at the Spoil Ground with the estimates made here (in **Section 2.6.2**). Should accumulation rates significantly exceed the low rates estimated here during the duration of the sought permit, then a more detailed assessment should be undertaken of minimum depths of water required at the Spoil Ground to prevent elevated/prolonged turbidity following placement of dredged material in water which is too shallow (i.e. in which bed shear stresses rapidly remobilise dredged material placed there).

Given the very limited decrease in depth of water expected at the Spoil Ground over the term of the permit sought (5 years), associated with the very gradual mounding of dredged material (as described in **Section 2.6.2**), monitoring for any increase in turbidity as a result of remobilisation of material placed at the Spoil Ground due to any minor increase in bed shear stresses is not believed necessary, particularly given the:

- current high rate of sediment dispersal from the Spoil Ground without any reported impact on turbidity levels,
- highly variable and often very high natural background turbidity levels in Trinity Bay, and
- low risk of increased turbidity to species or habitats of high conservation value, as:
  - hydrological conditions do not allow the spread of turbid plumes generated by dredge spoil disposal to reach offshore coral reefs (Carter *et al.* 2002), and
  - seagrasses only occur at low densities outside of the Spoil Ground and were not detected at the Spoil Ground at all during the survey by Neil *et al.* (2003b).

e) *Long-term Impacts*

The study by Neil *et al.* (2003b) has already provided some insight into the long-term impacts of dredge spoil disposal on the benthic assemblage of the current Spoil Ground, having been conducted some 10 years after its commissioning. However, it is considered important that long-term impacts be assessed again at the end of the 5-year permitting period as a guide to determining whether the existing Spoil Ground is at that juncture suitable for continued use. Although not considered likely, if the long-term impacts were found to be severe, then the chances of post-operation recovery may be reduced significantly. If this is the case, then cessation of sea

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[24] There is no currently accepted threshold for burial, so it would be up to resource managers to decide whether "significant" means a conservative mean burial depth of 3 cm (based on Norkko *et al.* 2002), or the figure of 15 cm cited from another study in Neil *et al.* (2003b), which might understate the impacts of burial at depths less than this.

disposal of dredge spoil and/or the introduction of impact reduction measures would need to be considered.

f) *Post-Operation Recovery*

As there is no intention to cease the operation of the current Spoil Ground during the term of the sought permit, no post-operation recovery monitoring of the benthic assemblage is proposed under the LTDSDMP. There may be benefits in undertaking a monitoring exercise at the previous Spoil Ground with reference to adjacent control sites in order to gain an understanding of how the benthic assemblages at the current or any future Spoil Grounds might respond once dredge spoil disposal ceases. The study by Carter *et al.* (2002) showed that natural processes had reduced the height of the spoil heap at the previous site to that of the surrounding seabed, so little detectable residual impacts of spoil disposal would be expected and benthic assemblages at this site should not be detectably different from those in surrounding areas. This monitoring would provide a clearer understanding of the rate of recovery of Spoil Grounds and therefore assist in weighing up the benefits of continuing to use the existing Spoil Ground versus moving to a new site.

Certain factors may reduce the viability or usefulness of this option and its cost, including:

- the previous Spoil Ground was in shallower water than, so the results obtained from such a study might not be relevant to deeper water sites,
- the low likelihood of gaining a precise understanding of how long it takes benthic communities to recover post-dredge spoil disposal activities, and
- the inability to use the same reference locations for both the current and previous spoil dumping sites due to differences in depth.

An opportunity exists to reuse the previous Spoil Ground in the future (beyond the 5 year horizon of the permit sought) should water depths significantly reduce at the current Spoil Ground, given that there is practically no evidence of change at the previous Spoil Ground through seismic survey and geochemical analyses undertaken by Carter *et al.* (2002). The spoil has apparently been redistributed to merge with the background seafloor sediment, since (i) no significant positive seafloor relief is now discernible at the site; and (ii) no geochemical difference was detected between far field Bay sediments and samples collected near the abandoned spoil site (Carter *et al.* 2002). Should such a need arise to cease placing dredged material at the current Spoil Ground, then the previous site could be reused for a duration, until water depths re-establish at the current Spoil Ground; with the on-going potential to use both sites in tandem. This tandem use of existing Spoil Grounds, rather than moving to new sites, would have particular merit in the unlikely event that an investigation of the previous Spoil Ground found a very low rate of recovery of benthic assemblages there.

g) *Introduction of Marine Pests*

The monitoring of the Spoil Ground post-placement for the Asian Green Mussel and the Caribbean Tube Worm is an annual condition of CPA's previous permit. This was carried out in 2003 by Neil *et al.* (2003b) and is again being performed by the same study team in 2004. These routine surveys should be continued as long as both target species are known to inhabit areas within the Port. If new introduced species are discovered within the Port and deemed a risk to ecology or economy if spread beyond the Port, they should be incorporated into the target monitoring. It is important, however, that the detection probabilities for the target species are known (i.e. that a degree of confidence can be assigned to absence of the species if they are not sampled during monitoring. If necessary, monitoring protocols should be modified to allow for a realistic degree of confidence (e.g. 0.90 or 0.95) that a target species is not present in the areas sampled if it is not picked up during monitoring.

The previous permit only requires monitoring for the Asian Green Mussel and the Caribbean Tube Worm. The long-term monitoring program should, however, cover the likelihood that new marine pests, (such as those detailed in **Table 7.2** may be introduced into Trinity Bay. This could be achieved by re-surveying the Port of Cairns using the methods described in Neil *et al.* (2003) every 3-5 years. This interval has been recommended as practical in the discovery of newly introduced species in commercial port areas (Hewitt and Martin 2001).

A key issue would be at what point management action should be launched should marine pests be identified at the Spoil Ground or in the dredger. An outline is provided below of the key steps in threat identification, monitoring, and abatement should this occur Recommendations for further reducing the chance of transporting introduced pests to the Port or Spoil Ground via the main dredging vessel, the *Brisbane*, are also provided below.

(1) Discovery of Marine Pests in the Port

Monitoring for known marine pests is undertaken in the areas to be dredged prior to dredging.

If marine pests (known target species or newly discovered species) are discovered in the Port, dredging and transport of dredged material should not take place until the distribution of the species has been established and expert advice on potential impacts has been obtained. A delimitation study of the pest should immediately be carried out and expert advice should be sought from specialist agencies such as the CSIRO Marine's Centre for Research on Introduced Marine Pests (CRIMP).

In the event of an outbreak of an introduced marine pest, the frequency of monitoring may have to be increased to enable finer-scale tracking of the species' distribution and abundance, and the efficacy of potential management efforts. Furthermore, emergency procedures should also include an interruption of any dredging that may be in process to prevent:

- disturbance of Port habitats that may increase the system's vulnerability to invasion by non-indigenous species (Davis *et al.* 2000), and
- transport of non-indigenous species or propagules from infested Port sites to the Spoil Ground.

The monitoring of marine pests is an expensive exercise and can only realistically be targeted at known species. It is recommended, however, that CPA continue to liaise with other port authorities and AQIS to keep abreast of developments in the proliferation of marine pests. New knowledge should be used to inform the recommended Marine Pest Contingency Plan.

(2) Vector Management by the *Brisbane*

If marine pests should be taken up into the hull of the dredge, they may survive the journey to the Spoil Ground as adult organisms (see **Section 7.4.3e**), planktonic propagules or cyst stages within the sediment. Survival of all of these has been documented in several cases (Carlton and Geller 1993; Hamer *et al.* 2001; Rigby and Hallegraeff 2001). In addition, because the principal dredge vessel used (the *Brisbane*) operates in a range of Queensland ports, other, unknown marine pests could reach the Spoil Ground as fouling assemblages on the ship's hull. Regular assessment of the dredge vessel's interior (principally the hopper) and exterior (hull section) are recommended as a prevention or early detection measure of marine pest invasion. The need for assessment of the hoppers might be negated by the fact that freshwater (deadly to the NIS) is used for ballast water and that no ballast water is exchanged between ports (therefore, little risk of translocation).

It is recommended that CPA liaise with the Port of Brisbane Corporation (the owner/operator of the *Brisbane*) in the development of an effective Marine Pest Contingency Plan as part of the Dredging

EMP. Precautions already undertaken to reduce the possibility of the *Brisbane* transporting marine pests and comments on the effectiveness of these, are as follows:

(a) The *Brisbane* is slipped every two years and antifouling is replaced. Experience with hull fouling communities suggests that this may not be sufficient. Dredge vessels move very slowly and are moored stationary for long periods of time. This tends to compromise the performance of antifouling paints that require frequent motion of the vessel. Especially hydrodynamically protected areas on the hull as well as ballast uptake recesses or other irregularities of the hull are susceptible to premature fouling. Dry-docking support strips (i.e. those area the vessels rests on while receiving new antifouling paint treatments) are usually not coated in antifouling paint and have been shown to contain fouling assemblages on vessels with relatively young antifouling paint. Furthermore, the recent ban of tributyl-tin (TBT) based antifouling paints is likely to increase the risk for hull fouling on most commercial ships. In addition to renewing the antifouling paint every two years, it is therefore recommended that diver searches for fouling species across the hull be undertaken every 6 months.

(b) All ballast tanks are filled with fresh water and not exchanged in any of the ports. The only reason water would be exchanged (by blowing) is in shallow dredging. In such circumstances, there would be a 125% ballast exchange as described in the ‘Australian Coastal Voyages’ subsection of CRIMP. This is sufficient to rule out any transfers of pests in the vessel’s ballast water.

(c) In addition to this, a thorough initial inspection and wash down is undertaken according to protocols on board before entering a new port. The *Brisbane* is currently not involved in dredging any international ports, reducing the possibility of introducing new pests. If this currently includes inspection and washing down of internal spaces (i.e. the areas where dredge spoil resides), then this is sufficient to rule out any risks. If this is not the case, then we recommend a complete emptying and/or sterilisation (followed by inspection) of those parts of the vessels that carry dredge spoil before commencing work in a new port.

(3) Discovery of Marine Pests at the Spoil Ground

The focus of the marine pests strategy is to identify them in areas to be dredged prior to dredging and to ensure that they do not infect the dredger. It is also prudent to periodically check for pests at the Spoil Ground.

If marine pests are detected at the Spoil Ground then it is likely that they were transported there by the dredging vessel during the previous dredging episode and that they originate from the Port.

If the pest species are present at the Spoil Ground but not in adjacent areas (or only over a small range), eradication can be attempted. Methods for that depend on the species concerned and could involve manual removal or smothering with sediments from a known un-infected site.

8.4.6 Initial Recommendations for Monitoring

Table 8.1 below provides a summary of the section above and outlines the initial recommendations for monitoring in relation to the impact hypotheses outlined above, based on the risk to resources and ability to distinguish the impacts of dredge spoil disposal over and above changes to the resource status brought about by natural processes.

a) *Tier 1 and Tier 2*

The Tier 1 / Tier 2 system is a stepwise approach that was put forward to help CPA reach decisions on the level of comprehensiveness of environmental monitoring they apply. This system is not only designed to help CPA avoid unnecessary costs, but also ensures that the level of comprehensiveness of any monitoring program CPA instigates is based on sound reasoning (comparison of data against stated or agreed thresholds, or the occurrences of particular scenarios).

It is recommended that the stepwise approach for the SAP outlined in the ODG process for sediment contaminants be used in conjunction with the Tier 1 and Tier 2 monitoring process outlined except that the four phases of the SAP, which is essentially a single process that leads to an assessment of sediment as benign or not, be considered jointly to be a Tier 1 response. Tier 2 in this case would cover the process to be followed if the SAP was not effective as a screening tool. If that is considered likely, then a Tier 2 response plan would need to be developed.

The criteria for going from Tier 1 to Tier 2 monitoring differ among the various types of impact hazards described in Tale 8.1 as noted by various footnotes.

For sediment contaminants and water quality related impacts, comparison of the results of Tier 1 monitoring with threshold values outlined in guidelines such as the ODG or the ANZECC / ARMCANZ water quality guidelines should be used to base this decision on (i.e. where results exceed these values, the Tier 2 monitoring is triggered).

For impacts of burial by deposited spoil, Tier 2 monitoring is only triggered if the burial depth outside the Spoil Ground recorded in Tier 1 monitoring exceeds an agreed burial threshold. As there are a number of possibly site-specific burial thresholds cited in the literature, ranging from 3 cm to 15 cm, an agreed threshold figure will need to be reached by the TACC members before this Tier system can be applied.

For changes in particle size, Tier 2 monitoring is triggered not by reference to threshold values in guidelines, but by the results of statistical analysis[25] on particle size distribution (PSD) data (before an after placement and between the Spoil Ground and reference areas. The significance of the interaction term (Time x Treatment) would be the appropriate term to use for assessing whether or not Tier 2 monitoring was required.

For NIS, Tier 2 monitoring is only triggered if new NIS are discovered in the area to be dredged. In this case the habitat requirements of these species are to be compared with the type and availability of habitats found at the Spoil Ground as part of a risk assessment.

b) *Explanation of Priority*

The final column in this table describes the study team's conclusions about the need for monitoring in terms of three categories:

- **Essential:** the monitoring is required for a number of reasons including:
  - the value of the parameter being monitored is expected to exceed established screening levels (i.e. is a stressor "of concern" – see **Section 6.3.6**)
  - the consequences of trigger exceedances of the parameter or effect being monitored are potentially severe.

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[25] Analysis of variance (ANOVA).

- **Desirable:** the monitoring is not essential for this permit application, but might be considered because:
    - regardless of whether risk to biota has been prescribed as low here, there is insufficient knowledge of the level or impact of the parameter or effect to verify our impact hypotheses
    - it may be a low cost option for data collection
    - it may be simply expedient to collect this information in order to address anticipated stakeholder concerns.
- **Not required:** Current knowledge is sufficient to rule out the parameter or effect either because there is a very low probability of the effect occurring, or the consequences are not likely to be severe. In some cases (e.g. disruption to feeding, breeding and spawning behaviour impacts) the logistical difficulties of implementing monitoring programs to test for impacts and the statistical confidence of results would further preclude monitoring being recommended.

c) *Future Gap Analysis*

The formulation of the final monitoring plan to be undertaken by CPA as part of the dredging and disposal process is beyond the scope of this report. However, it will be informed by a “gap analysis” that takes into account both the need for the monitoring and the extent to which the required monitoring is already taken place. This analysis should consider:

(a) what monitoring is needed but is not being done,

(b) what monitoring is needed and is currently being done, and

(c) what is currently being done but is not currently needed.

Table 8.1 Proposed Monitoring in Relation to the Impact Hypotheses Outlined Above.

POTENTIAL IMPACT	IMPACT HYPOTHESIS	PROPOSED MONITORING	COMMENTS	PRIORITY
Sediment dispersal /increased turbidity during dredging and/or disposal	(1) Plumes associated with dredging and/or the deposited material will not reach any sensitive areas, through dispersal of the dredge plume, in amounts sufficient to be of concern.	Tier 1: Monitoring of spatial extent and duration of plume during disposal under different hydrodynamic conditions to determine likelihood of reaching sensitive receptors. Tier 2: If there is indication that significant amounts of sediment could reach these areas[26]monitor concentrations of suspended sediment, duration of turbidity above ANZECC guidelines[27] and rates of sedimentation at relevant sites.	Tier 1 style monitoring already part of the range covered in section 1.5.2 of the Dredging EMP. In addition, Surveillance monitoring in the Entrance Channel and at the Spoil Ground has been carried out pre, during and post-maintenance dredging. Likely to be difficult to distinguish disposal-related from natural levels of suspended sediment and sedimentation. Monitoring unlikely to be effective unless there is indication of significant dispersal of sediment to sensitive areas, hence tiered approach. Necessity reduced if dredging and dredge spoil disposal are timed to coincide with naturally turbid periods and/or most disposal is carried out at night time. The former is not possible due to other commitments of the *Brisbane*.	Tier 1 monitoring **Essential** Tier 2 as required
Release of contaminants into the water column during disposal	(2) Disposal will not result in ecologically significant inputs of contaminants to the water column.	These steps are both incorporated into the existing SAP program.	Biological effects are considered very unlikely below trigger concentrations and, where trigger values are exceeded, assessment of potential effects requires consideration of case-specific factors affecting bioavailability, hence tiered approach. Tier 1 style monitoring is already part of the range covered in section 1.5.2 of the Dredging EMP. Current dredging EMP only has monthly water quality sampling in all areas to be dredged, not in areas of spoil placement. Elutriate tests rather than water quality sampling during placement is likely to yield more reliable results and is the approach advocated by the ODG guidelines.	SAP monitoring **essential**

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[26] For turbidity, significant = above current ANZECC /ARMCANZ guidelines for coastal waters, for bed level spread of sediment, significant = whatever the decided burial threshold is.

[27] Trigger values = values put forward in relevant guidelines (current ANZECC/ ARMCANZ) for water quality in coastal waters.

POTENTIAL IMPACT	IMPACT HYPOTHESIS	PROPOSED MONITORING	COMMENTS	PRIORITY
Reduction in dissolved oxygen during disposal	(3) Disposal will not result in ecologically significant reductions in dissolved oxygen in the water column.	Measurement of dissolved oxygen profiles during a disposal event to verify predicted low risk.	Section 1.4 of the current EMP highlights dissolved oxygen fluctuations as an environmental risk associated with dredging. Dissolved oxygen concentrations have been recorded in Trinity Inlet, the Entrance Channel and the inner port area. Limited need as predicted risk is very small and there is no past indication of any related impact. Although predicted to be a low risk, there is little data on dissolved oxygen fluctuations in association with spoil placement to confirm this.	**Desirable**
Release of nutrients into the water column during disposal	(4) Disposal will not result in ecologically significant inputs of nutrients to the water column.	Measurement of nutrient release during a disposal event to verify.	Very small predicted risk and it may be difficult to distinguish changes in concentrations related to disposal from natural variation. Hence monitoring of nutrient release might not be cost effective. CPA have undertaken monitoring of nutrient levels in the Entrance Channel and in the Inner Port Area at the same sites as for trace metals. The majority of nutrients measured in the Entrance Channel are sourced from within the Inlet from the sewage treatment plant and urban and agricultural run-off, and are therefore not Port-related. For this reason, it was concluded that continual monitoring of the nutrient status of the channel would not aid the development of an environmental management plan for the channel. Although predicted to be a low risk, there is little data on water column nutrient concentrations in association with dredge spoil disposal to confirm this prediction.	**Desirable**
Burial of seagrass by turbidity associated with dredging	(5) There will be no serious adverse impact from the dredging operation on seagrass beds adjacent to the dredged areas.	Tier 1 Compare results of monitoring with previous seagrass surveys and assess any changes in seagrass distribution and abundance in relation to natural events or anthropogenic port and catchment activities. Tier 2 Follow-up surveys and possible changes to management as required. Note that there is no Tier 2 currently associated with this monitoring.	Very small predicted risk based on the fact that so far the seagrass monitoring program indicates that there have been no adverse effects on seagrass meadows from the current dredging program since the beginning of monitoring in 2000. Current management of dredging (e.g. *Brisbane* EMP) is aimed at reducing impacts. It is expected that the DPI&F monitoring will continue for the life of the permit.	Tier 1 monitoring: **essential**

POTENTIAL IMPACT	IMPACT HYPOTHESIS	PROPOSED MONITORING	COMMENTS	PRIORITY
Burial by deposited spoil	(6) There will be loss of benthic assemblages at the disposal site once disposal commences, but this will not involve loss of any resources of special value. The deposited material will not reach any sensitive receptors through re-suspension and dispersal by water movement in amounts sufficient to be of concern.	Tier 1 Surveys of seabed height before and after disposal to determine whether or burial depth at or beyond the Spoil Ground exceed the agreed threshold for sediment overburden. Tier 2 Monitoring of benthic assemblages adjacent to the disposal site along environmental gradients (transects) related the predominant direction of sediment transport (north-south and east-west orientations).	Need for benthic monitoring limited as: • Burial impacts within the Spoil Ground are allowed under permit conditions. • Predicted depth of deposition beyond 1 km from the Spoil Ground is not sufficient to warrant concern. • There is variation in the range of deposition depths cited as causing significant impacts on benthic communities, so it would be difficult to interpret Tier 1 information as a trigger for Tier 2 monitoring. • There is likely to have been an increase in the resistance and resilience of the Spoil Ground benthic assemblage to burial, so it will be difficult to identify the most sensitive taxa for use as sentinel species as part of future monitoring approaches. • Understanding the mechanism of impact is not necessarily as important in informing CPA's management strategies as is the understanding of the magnitude of any impact and the ability of important resources to recover. Surveys of seabed height before and after disposal are already part of the range covered in section 1.5.2 of the Dredging EMP. However, to be meaningful, there needs to be further consideration of sediment overburden thresholds that have been cited in the literature (i.e. one of these needs to be selected as the threshold figure for relating hydrographic survey data to). Also to be considered is the accuracy / precision of the hydrographic survey in the context of the small thicknesses involved. Tier 2 monitoring should only be triggered if hydrographic surveys indicate that burial depths beyond the Spoil Ground exceed the agreed threshold, as burial impacts at the Spoil Ground are allowed under the current permit (and the one for which permission is currently being sought).	Tier 1 monitoring: **essential** Tier 2 monitoring **essential**

POTENTIAL IMPACT	IMPACT HYPOTHESIS	PROPOSED MONITORING	COMMENTS	PRIORITY
Disruption to feeding, breeding and spawning behaviour, mortality associated with dredging	(7) There will be no significant/ deleterious disruption to the feeding, breeding and spawning behaviour of dugongs, turtles, fish and prawns.	**No monitoring measures recommended**. Reporting conditions outlined in the current Dredging EMP will suffice as mitigation measures.	No severe impacts and difficult to monitor due to variations in timing of breeding and spawning, the short-lived and localised nature of dredging and spoil disposal plumes and the variety of methods needed to test this hypothesis. While any turtle or dugong mortality is a severe and significant event given their status, the expected low incidence of turtle and dugong mortalities associated with dredging would make it difficult to either infer a threshold level to trigger management intervention, or to devise a monitoring program capable of detecting significant increases in such incidences over time.	**Not required**
Changes in particle-size distribution, organic content and redox conditions	(8) There will be no significant changes in sediment particle-size distribution at the disposal site as a result of spoil disposal.	Tier 1: Monitoring of particle-size distribution and organic content of dredged material and at the Spoil Ground (and control locations) to determine level of change in sediments, as part of ongoing SAP assessments. Tier 2: If changes are significant[28], particularly if organic material increases, consider adding sediment and redox sampling to benthic monitoring program (but only if information on sediment-biota links is useful for resource management).	Tier 1 cost effective to include as part of SAP and would provide information as to whether or not CPA is consistently achieving 'like on like' spoil placement. The current EMP only recommends quarterly (more recently twice per annum) sediment samples from all areas to be dredged (reported bi-annually). Tier 2 cost effective, but developing an understanding of the mechanisms of impact are not necessarily a priority during the operational phase of the current Spoil Ground. In addition, changes in PSD at the Spoil Ground are more likely to result in shifts in taxonomic composition than the significant loss of benthic diversity (based on the findings of Neil et al. 2003b). From a resource management perspective. The most concerning shifts in taxonomic composition would be those that reduce the abundance or occurrence of species preferred by, turtles and commercially caught fish and prawns as food items. More data would be required to determine what those preferred food items are before such an assessment could be made.	Tier 1 monitoring **essential** Tier 2 **desirable**

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[28] No threshold values here, significant = If the changes in PSD at the Spoil Ground over time differ significantly from changes observed at reference sites (i.e. if the time x treatment term in the ANOVA is significant).

POTENTIAL IMPACT	IMPACT HYPOTHESIS	PROPOSED MONITORING	COMMENTS	PRIORITY
Accumulation of contaminants in sediments and biota	(9) There will be no ecologically significant accumulation of contaminants at the disposal site as a result of spoil disposal.	Stepwise approach from SAP.	Tiers 1 and 2 are part of the approach recommended in the NODGDM (2000) and Tier 1 monitoring is already part of Cairns Port Authority's licensing agreement. Approaches to bioavailability and/or direct toxicity assessment are described in **Section 8.4.2a** above.	**Not required** (follow stepwise approach from SAP)
Re-suspension of sediment from the disposal site as a result of increased re-suspension as water depth decreases	(10) There will be no significant increase in turbidity at the disposal site associated with increased exposure to wave-generated currents.	Surveys of seabed height before and after disposal with modelling of changes in current speed with depth.	Surveys of seabed height are already conducted by Cairns Port Authority prior to, and immediately after, spoil placement. Modelling is unlikely to be necessary during the 5-year permit period, as removal rates are high and significant increases in the height of the spoil heap are highly unlikely. However, modelling could be used to predict what height would be sufficient to allow regular re-suspension of dredged material/ turbid plumes above ANZECC (2000) trigger levels under normal hydrodynamic conditions. This, in turn, could be used to predict the lifespan of the current Spoil Ground or as a decision support tool for applying management measures (which might include sequential use of the current and previous Spoil Grounds).	Hydrographic surveys of the seabed: e**ssential** Modelling of spoil dispersal with changes in spoil mound height is **desirable**
Repeated burial by dredge spoil	(11) The Spoil Ground benthic assemblage will to recover between disposal events and, following cessation of disposal, will recover fully over time.	Monitoring of benthic assemblages (beyond 5-year permit period) at the current Spoil Ground and adjacent control locations. Monitoring of benthic assemblages at the Spoil Ground and adjacent control locations following cessation of disposal to assess post-operation recovery.	Monitoring during the operational life of the Spoil Ground is not essential, as continued impacts during operational phase are allowed under the permitting conditions and the frequency of re-burial is high. However, monitoring of the Spoil Ground at the end of the 5-year disposal campaign, for which a permit is sought should be adopted as an essential part of the monitoring for long-term effects of dredge spoil disposal if the existing Spoil Ground is considered for a further 5 years of use beyond the permit sought.	Monitoring of burial impacts at the Spoil Ground during next 5 years of operation is **not required** Monitoring of burial impacts outside the Spoil Ground during the operation phase is **essential**, triggered Tier 1 monitoring data as described for Burial by deposited spoil (5)

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[29] See earlier footnote comments regarding expected range of recovery period.

POTENTIAL IMPACT	IMPACT HYPOTHESIS	PROPOSED MONITORING	COMMENTS	PRIORITY
			Although not a requirement of this permit application, monitoring following the cessation of disposal activities at the current site is also considered to be **essential**, as the ability to recover during post-operation is a key assumption. Failure of post-operational recovery could lead to cumulative effects of dredge spoil disposal in Trinity Bay. Recovery is expected within a 2- year period.[29] Should this not be the case for the current Spoil Ground, then sea disposal of dredged material may need to cease/be reconsidered, or the impacts reduced (possibly by spreading it over proven sites such as previous Spoil Grounds if these were found to have recovered).	Monitoring repeated burial impacts at and outside the Spoil Ground at the end of this permit is **desirable** (is likely to become essential in support of applications for a future disposal site)
Introduction of marine pests, including Asian Green Mussel and Caribbean Tube Worm	(12) The lack of suitable habitat in both the dredged area and the Spoil Ground will prevent the development of significant populations of Asian Green Mussel or Caribbean Tube Worm at the Spoil Ground. (13) There will be no significant outbreaks of exotic species at the current Spoil Ground.	Tier 1: Surveillance for presence of exotic species at the source of dredged material and on vessels used to transport dredged material. Tier 2: Comparison of habitat requirements of any species discovered with those at the disposal ground. Surveillance at disposal site for any exotic species potentially able to colonise the site. Hull and hopper assessments may be warranted to further reduce likelihood of introducing NIS.	Target monitoring for known pest species should continue at the Spoil Ground as long as these species are known to inhabit areas within the Port. The detection probabilities of the current monitoring design should be identified and assessed for sufficiency. Tier 1. Not part of the current Dredging EMP, but has been carried out by CPA in conjunction with other organisations recently. For guidance on the recommended frequency of monitoring, see section 8.4.5g. More frequent targeted surveys would be required in the event of an outbreak. In the event of an outbreak of any introduced marine pest, the frequency of monitoring may have to be increased to assess the abundance of the species over time and the efficacy of management efforts that may be used. Periodic re-surveying of the Port should be carried out to detect new introduced marine species and revise monitoring methods depending on species targeted. If new introduced species are detected, this would trigger Tier 2 monitoring/evaluation. Periodic hull assessments are recommended. Hopper assessment is complex and costly and the current practices applied to the *Brisbane* appear to negate the need for this.	Tier 1 monitoring **essential** Tier 2 monitoring **essential** Hull and hopper monitoring **essential**

POTENTIAL IMPACT	IMPACT HYPOTHESIS	PROPOSED MONITORING	COMMENTS	PRIORITY
Impact on habitat for important fauna	(14) There will be no significant loss of dugong, turtle, wading bird, fish or prawn feeding and shelter habitat resulting from sea disposal activity at the Spoil Ground. (This will also be true for future Spoil Grounds, so long as their locations do not coincide too closely with dense stands of *Halophila* or *Halodule*).	Nil.	No monitoring proposed – refer to **Section 7.6.10.** The continuation of the QDPI&F long-term seagrass monitoring program in the shallow coastal region of Trinity Inlet is essential to allow the discrimination of dredging impacts on seagrasses. Monitoring of seagrasses at or near the current Spoil Ground is unlikely to yield data that could be interpreted meaningfully in relation to the degree of spoil placement-related impacts, as seagrass in this part of Trinity bay is too patchy and low in density and seasonally variable in occurrence. Therefore, monitoring of this sort is, in our belief, not essential. However, baseline monitoring of seagrasses is essential when assessing site suitability for placement of spoil at alternative sites (should alternative sites be considered in future).	**Not required**
Impact on indigenous cultural values	(15) There will be no significant impact on indigenous cultural values resulting from dredging, transport, or sea disposal activity at the Spoil Ground.	To be determined following additional indigenous consultation.	This issue is a current information gap.	**To be determined**

Source: Study team compilation.

8.4.7 Monitoring of Unscheduled Emergency Dredging

Unscheduled emergency dredging may, depending on the scale, require additional monitoring or modifications to the monitoring protocols described above. Monitoring would, however, likely be biased by the impacts of natural disturbance events such as cyclones, so is probably of little benefit as far as detecting impacts of un-scheduled dredge spoil disposal is concerned.

8.4.8 Study Design Considerations for Benthic Monitoring

The previous CPA dredging permit states that the sample design, timing and scope of reporting for all monitoring required be determined in consultation with GBRMPA. Therefore, a detailed outline of the study design will not be presented here. However, there are some considerations that might be pursued during such consultation (outlined below).

a) ***Choosing Appropriate Reference Sites***

The CPA's previous permit conditions for dredge spoil disposal in Trinity Bay advocate that sampling designs for benthic community monitoring should adhere to the ANZECC/ARMCANZ (2000) guidelines, from which, the Ocean Disposal Guidelines for the same have been derived. These guidelines outline a hypothesis testing approach to developing a study design for monitoring benthic communities, whereby ecologically relevant community measures are recorded at the Spoil Ground and at least two reference (non-impacted) locations. Where possible, sampling should occur at least once before dredge spoil disposal commences at a given site. Despite the assumption that disposal at a site will necessarily result in the loss of at least a part of the benthic assemblage at that site and that, where a site is used frequently or continuously, the impacts of dredge spoil disposal will be on-going. The Ocean Disposal Guidelines also recommend the following in terms of post-spoil disposal monitoring:

- sampling shortly after dredge spoil disposal to determine what the initial effects of disposal at the site are,
- sampling to determine whether benthic communities recover between dumping episodes, and
- sampling to determine whether there are any long-term changes to the community.

The study by Neil *et al.* (2003b) was consistent with the approach advocated in the Ocean Disposal Guidelines in that two reference locations were monitored in addition to the Spoil Ground and sampling was conducted at sites nested within each of these locations. Furthermore, a total of 18 samples were collected within the Spoil Ground, which exceeds the required minimum of 15 samples specified in these guidelines. However, the study design used assumed that the northern reference location was potentially impacted by resuspended dredge spoil transported northwards by along-shore drift. In effect, this meant that the northern reference location used was not a reference site as such, but a putative area of intermediate dredge spoil impact.

Carter *et al.* (2002) indicate that dredged material is removed from the site northwards via along-shore drift and offshore via tidal currents. Therefore an additional or replacement reference location would ideally be positioned to the south and west of the Spoil Ground, assuming that a western (landward) reference location could be found that was not too dissimilar to the Spoil Ground in terms of depth, hydrodynamics and sedimentology.

b) ***Maintaining Consistent Size of Sampling Unit***

While there are no *a priori* preferences for a particular sampling unit size or for benthic grabs over cores taken by divers, it is important that, once a sampling unit is chosen, it be used consistently in order to allow reliable between-site or between-survey comparisons. While it might be appropriate for abundance data to be converted to density data where different size sampling units are used, number of taxa collected and diversity measures related to a combination of this measure and abundance data are not directly proportional to the size of the sampling unit.

c) *Ecological Parameters and Analyses Used for Benthic Monitoring*

The study by Neil *et al.* (2003b) used a limited number of univariate community parameters to compare the status of the Spoil Ground assemblage with those of the two reference locations. Without prescribing what should be measured, a ‘multiple lines of evidence’ approach might give interpretations of results more surety. The derivation of diversity indices, such as Shannon-Wiener diversity and Gleeson diversity for instance, can be undertaken easily at no significant additional cost. Likewise, measures such as the densities of capitellid and spionid polychaete worms, which are advocated for use in benthic surveys in the ANZECC (2000) guidelines, can be easily obtained from survey data and could be used as part of future monitoring. Multivariate analyses were not performed in the study carried out by Neil *et al.* (2003b) and would have been of value, both in terms of visualising the degree of difference in taxonomic composition between the Spoil Ground and the two reference areas (e.g. using non-metric multidimensional scaling plots) and in a hypothesis testing framework (e.g. analysis of similarities – ANOSIM-tests). These sorts of analyses would ideally be included as part of future monitoring in addition to analysis of variance performed on univariate measures.

8.5 COMMUNITY AND AGENCY RELATIONS STRATEGY

It is recommended that a community and agency relations strategy be developed to formalise the relationship between CPA and the approving agencies and between CPA and the general community.

It is concluded that the existing arrangements are adequate, subject only to the preparation of a five year plan for communications. The following is an initial outline of future TACC involvement for consideration.

- 2005 meet as necessary to finalise this strategy (February 2005) and consider plans for 2005 dredging.
- 2006 meet to consider report on 2005 dredging and plans for 2006 work.
- 2007 meet to consider report on 2006 dredging and plans for 2007 work.
- 2008 meet to consider report on 2007 dredging and plans for 2008 work.
- 2009 meet to consider report on 2008 dredging and plans for 2009 work, and plans for new 5 year works and associated permit.

At some stage in this program it is recommended that consideration be given to the monitoring and other research required to identify the life of the Spoil Ground and commence the search for the next site. According to Carter *et al.* (2002) there is a suite of suitable sites with similar hydrographic properties in the vicinity of the current Spoil Ground. Some of these sites are closer to the port and may be selected for the next site as they will provide slight reductions in operational costs.

8.6 CORPORATE MANAGEMENT PROGRAM

Finally, the management and monitoring of dredging and spoil disposal needs to be integrated into CPA's overall corporate management program / structure to ensure that it receives the desired level of corporate governance.

This should include the continued concentration on management of the activities of lessees of CPA land to achieve improved environmental outcomes with respect to their own operations. The prevention of pollution by land-based activities is seen as the most effective way to improve the quality of dredged spoil.

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9. SUMMARY

The following is a brief summary of the matters described in this report:

- Sedimentation of the harbour and channel is a natural occurrence resulting from hydro-geomorphological processes.
- Comprehensive studies have confirmed that there is no practical alternative to sea dumping and that the current Spoil Ground is well-located.
- With respect to the dredged sediment and associated issues:
  - sediment quality complies with the sea disposal suitability criteria of the Ocean Disposal Guidelines,
  - there are tributyltin (TBT) and trace metal concentrations present in sediments in non-dredging areas which are of concern, and have the potential to mobilise into dredging areas,
  - TBT and some trace metals have, on occasion, been measured at elevated concentrations in the Inner Port Area,
  - the shipyards are considered to be an on-going source of TBT and trace metals associated with antifouling paints, and
  - no non-indigenous species (NIS) have been found in areas to be dredged, despite the availability of potentially suitable and vacant habitats.
- The marine environment appears to be relatively healthy and recent changes to seagrasses appear to be related to climate rather than any human activity occurring in the Harbour or Inlet. So far the seagrass monitoring program indicates that there have been no adverse effects on seagrass meadows from the current dredging program since the beginning of monitoring in 2000.
- The indigenous cultural values of the Spoil Ground and the dredged areas are unknown and further consultation is required on this matter.
- The current Spoil Ground has ample capacity to accommodate dredged spoil during the next five years and well beyond.
- Studies at the current spoil dump suggest that it is showing only small signs of adverse impacts. While it is likely that the area will recover following cessation of dumping, monitoring of the previous Spoil Ground is recommended to confirm this.
- Spoil quantity reduction is not considered practical.
- CPA currently meets the expectations of a Port Authority under the Ocean Disposal Guidelines to address polluting activities within the Port.
- A risk evaluation of potential impacts reveals that all impacts are in the low risk category except for introduction of marine pests to the Spoil Ground (low to medium risk). This evaluation is based on the current management regime that involves comprehensive pre-dredge testing of sediments via the Sediment Analysis Plan and associated water quality testing.
- A detailed monitoring program is recommended, both for the areas to be dredged and the Spoil Ground.
- It is recommended that a Marine Pest Contingency Plan should be developed as part of CPA’s Environmental Management System which currently includes dredging EMPs and other activities. This should integrate targeted monitoring of known pests and new knowledge obtained by other port authorities and AQIS on developments in the proliferation of marine pests.

- The initiatives and activities undertaken by CPA directly, or required of lessees, include wider catchment management efforts as well as site-specific environmental management. It is recommended that there be an increased level of stewardship by CPA of the activities undertaken at the shipyards, as potentially significant sources of TBT have been identified. This need relates to the vulnerability of the sea disposal suitability of sediments to TBT contamination. The increased stewardship by CPA should include:
  - raising awareness with shipyard management of the consequences of TBT contamination of sediments with regard to both environmental impact and the economic viability of the Port, should dredged material be deemed unsuitable for sea disposal,
  - review of the suitability and operational effectiveness of the pollutant discharge control measures at shipyards, under the EMPs required of lessees by CPA as property manager of Port land, and
  - an on-going program of audits of lessee operations, under CPA's Environmental Management System which is currently under development.
- With respect to existing leases where new conditions relating to EMPs cannot be introduced, it is recommended that CPA continue to take an advisory and liaison role to work with lessees, the Environmental Protection Agency, and Cairns City Council to develop practices aimed at achieving improved environmental outcomes for the Port.
- At some stage during the next five years it is recommended that consideration be given to the monitoring and other research required to identify the life of the Spoil Ground and commence the search for the next site. According to Carter *et al.* (2002) there is a suite of suitable sites with similar hydrographic properties in the vicinity of the current Spoil Ground. Some of these sites are closer to the port and may be selected for the next site as they will provide slight reductions in operational costs.

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