COCKATOO ISLAND MARINE CLOSURE KNOWLEDGE BASE AND COMPLETION CRITERIA

Report: MSA139R1

Report to:

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Document Information

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USAGE	This report describes works undertaken to address the remaining knowledge gaps in relation to closure planning for the Cockatoo Island mine.
PRECIS	Rehabilitation of the marine environment surrounding the Cockatoo Island Iron Ore mine involves stabilising the disturbed seabed. This document provides a knowledgebase for that activity and proposes working completion criteria and interim for the assessment of rehabilitation success.
KEYWORDS	Cockatoo, Closure, Planning, Knowledge Gaps

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V1 14/01/2010	DAA	Internal Review
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V4 10/12/2010	JAS	Final
V5 26/5/2011	DB	Final (revised water quality schedule)

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1.0 SUMMARY

The Cockatoo Mining Joint Venture (CMJV) has commenced planning for closure of the Cockatoo Island Iron Ore Mine. Part of that closure planning involves providing a sustainable and ecologically acceptable outcome for disturbed sections of the marine environment surrounding the Island.

The marine closure planning is based on the premise that if the marine substrate can be returned to a surface with an equivalent level of stability to that of surrounding natural habitats, then natural recruitment and community development processes should return a self-sustaining marine community. The nature of that community would be highly dependent on the post-closure configuration of the rehabilitated area, particularly its depth, slope and substrate type. Surveys of nearby undisturbed natural habitats will indicate appropriate target compositions of colonising flora and fauna for specific post-closure configurations.

A number of marine environmental completion criteria and interim completion criteria are proposed for the minesite, each one addressing an environmental quality objective within the Environmental Protection Authority's 'Environmental Quality Management Framework for the marine waters of Western Australia'. The primary threat to development of a healthy post-closure benthic community is continued high turbidity and sedimentation derived from resuspension of fine sediments from unstable surfaces or terrestrial runoff. Minimising long term turbidity and sedimentation is therefore an important goal of the rehabilitation process. Specific requirements for turbidity and sedimentation are proposed in the completion criteria.

2.0 INTRODUCTION

Cockatoo Island is located approximately 7 km off the Western Australian coast at 16° 06′ S and 123° 37′ E within Yampi Sound (Figure 1). The island lies within the Buccaneer Archipelago (Yampi Sound), approximately 130 km North West of Derby in Western Australia's southern Kimberley Region.

The island has a long history of mining of the high grade haematite deposit which occurs across the southern side of the island dipping steeply from the top of a ridge to well below the seabed. Mining and previous disturbance of the Island is described in Portman Limited (2002), and includes:

- Original mining of the main ore body by BHP between 1951 and 1985;
- Re-mining of low-grade stockpiles by Koolyanobbing Iron Pty Ltd between 1995 and 2000;
- Remnant mining from 2000 to 2002; and
- Mining below sea level by HWE Cockatoo Pty Ltd from 2002.

Current mining on Cockatoo Island was allowed under a Notice of Intent (Portman Limited, 2002) by the Department of Minerals and Petroleum Resources in May 2002, and tenement conditions require that a closure and decommissioning plan be developed (MScience, 2004). Closure obligations are presented in Appendix A.

The operational life of the Cockatoo Island mine is ending and Cockatoo Mining Joint Venture (CMJV) is developing plans for the closure of its Cockatoo Island operations. As part of the process, in April 2009 CMJV commissioned MScience Pty Ltd (MScience) to determine what key gaps exist in the knowledge of the marine environment of Cockatoo Island. MScience provided nine recommendations where further information was required, to assist in planning for closure or evaluating the progress of rehabilitation (MScience, 2009b).

CMJV subsequently requested MScience to progress several of the tasks identified in MScience Report MSA136R1 to a stage which was adequate to support closure planning design decisions and to develop performance criteria for rehabilitation works. The works consisted of:

- A literature review on the stabilisation of sediments in the Cockatoo Island region
- Definition of the environmental values of the Island;
- Establishment of environmental quality objectives;
- Development of interim completion criteria for rehabilitation efforts; and
- Mapping of intertidal communities around Cockatoo Island to provide community composition information for interim completion criteria.

This document presents the results of MScience works on the above.

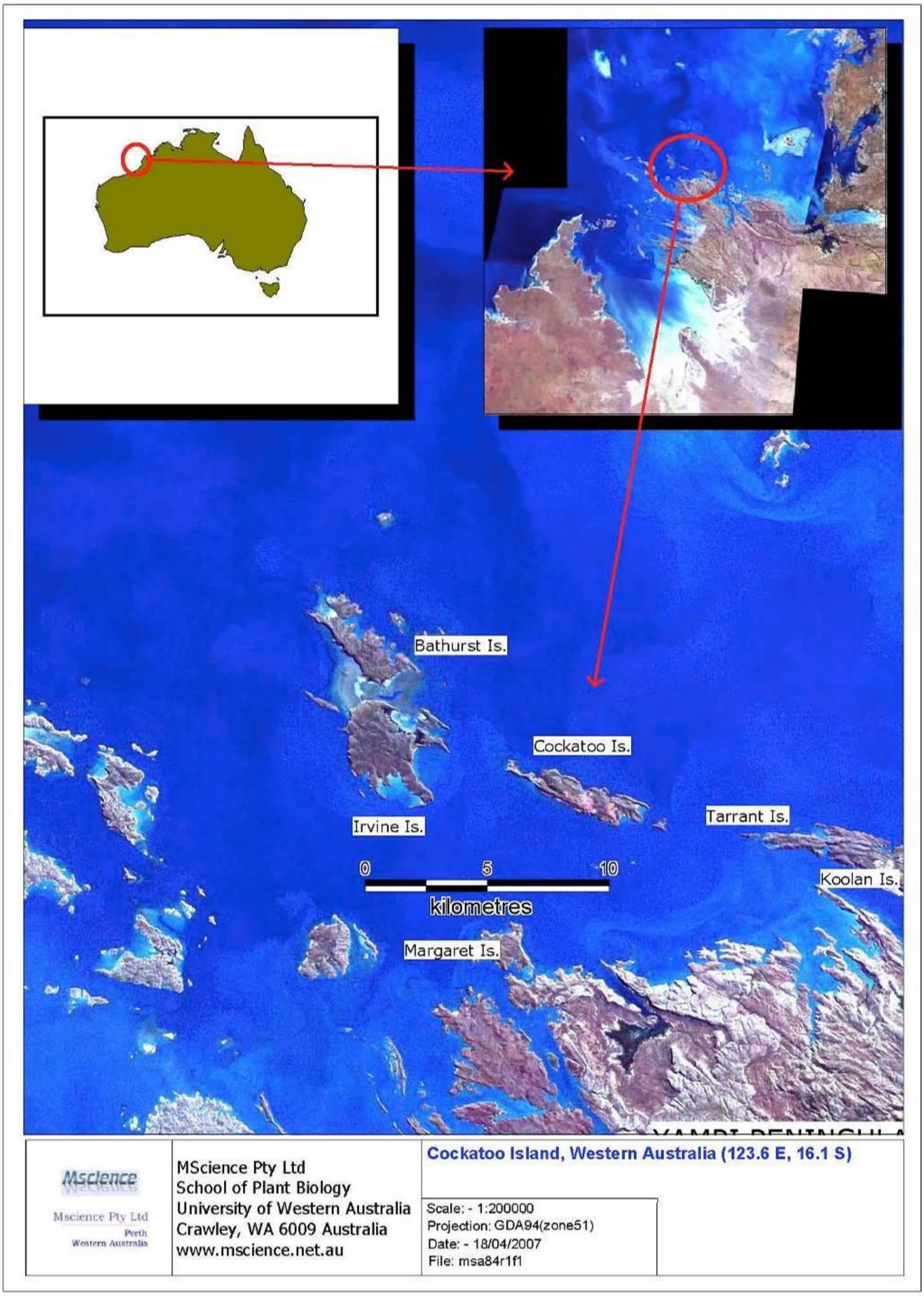


Figure 1. Cockatoo Island location map.

3.0 Stabilisation of Nearshore Sediments

3.1 Introduction

Marine environmental monitoring indicates that sedimentation is currently the main impact of mining on the marine environment of Cockatoo Island (MScience, 2010b). Ongoing sedimentation is also regarded as the main environmental risk of the mine decommissioning process (MScience 2004). Predicting the dynamics of nearshore marine sediments around the minesite is therefore an important component of mine closure planning at Cockatoo Island.

The main questions regarding the nature of the post-closure marine sedimentary environment adjacent to the minesite are:

- will it attain a stable equilibrium condition?
- what are the likely characteristics of equilibrium sediments (configuration, particle size, composition)?
- what is the likely timeframe for stable conditions to be attained?
- how will the different rehabilitation options under consideration affect the sedimentary environment?

The term equilibrium as employed above is not meant to imply there will be no change over time. Periodic resuspension and deposition events are expected even in undisturbed habitats. Thus 'stable' and 'equilibrium' criteria for rehabilitated areas must be judged by comparison against nearby undisturbed or minimally disturbed habitats. These habitats would represent rehabilitation targets for the disturbed areas.

Although the answers to the questions listed above will depend partially on the site's post-closure configuration, the existing literature provides some theoretical information and case studies that help inform predictions regarding sediment behaviour at Cockatoo Island.

This review presents a brief description of the general mechanisms controlling sediment erosion, transport and deposition, summarises current knowledge of sediment dynamics in the Kimberley and at Cockatoo Island, outlines the results of some relevant studies on post-disturbance sediment dynamics elsewhere, and attempts a preliminary evaluation of post-closure sedimentary processes at Cockatoo Island under the different proposed rehabilitation options.

3.2 MECHANISMS OF SEDIMENT EROSION, TRANSPORT AND DEPOSITION

Sediment erosion and deposition reflect a continual, dynamic adjustment between the fluid forces applied to the sediment bed and the condition of the bed itself. The most important descriptor of bed condition from this point of view is erodibility, a combination of resistance to initial motion and erosion rate once motion has begun (Schaaff et al., 2006).

While the essential physical balance that determines erosion rate is between fluid shear stress and bed shear strength, the factors that determine these two quantities are numerous, spatially heterogeneous, and temporally variable. Fluid shear stress is determined by water velocity, turbulence, depth, bottom roughness, ambient temperature-salinity stratification, and time dependence of the flow (Grant and Madsen, 1986, Wright, 1989). Bed shear strength depends on the physical and chemical composition of the sediment, the degree of consolidation, biogenic adhesion and bioturbation, and the time histories of deposition and resuspension (Grant and Madsen, 1986, Wright, 1989). These factors also determine the vertical structure of the deposit and the vertical variation in shear strength.

These factors may vary in space and time, depending on the characteristics of the local sediment, the local biota, and the local flow environment. The interactions can be summarised in the conceptual diagram in Figure 2.

Once sediment has begun to erode and the particles are entrained into suspension, they move with the water flow until the velocity drops enough for the particles to settle out from suspension. The velocity at which a particle will settle is lower than the velocity required to entrain it. In the case of silt and clay sediments the difference can be considerable (Figure 3). The degree of consolidation of the sediment has a large bearing on its erosion velocity; if fine sediment becomes highly consolidated it is very resistant to erosion.

3.3 COCKATOO ISLAND SETTING

Cockatoo Island is part of the Buccaneer Archipelago off Yampi Peninsula in the dry-subtropical south-western Kimberley Region of Western Australia. The Archipelago consists of numerous rocky islands usually surrounded by shallow shelves, channels and embayments, in a macro-tidal environment with generally low wave energy. The shallow marine environment surrounding islands contains a great diversity of fringing reefs, reef and intertidal mud flats, mangroves and sandy beaches.

The climate is typified by hot summers with occasional cyclonic rainfall and warm dry winters. Outside of cyclone-induced wind and swell, the wave climate is generally benign.

The tidal range at Cockatoo Island reaches approximately 10m. The tide has a major effect on the marine environment, creating currents which entrain and transport a large amount of suspended sediment, and also exposing the intertidal habitat to desiccation, UV radiation and high temperatures for up to 4 hours during spring low tides (Purcell, 2001).

Figure 2. Conceptual model of influences on sedimentation dynamics. Taken from: Sedimentary processes in the intertidal zone By Kevin S. Black, David M. Paterson, Adrian Cramp (1998) - 409 pages

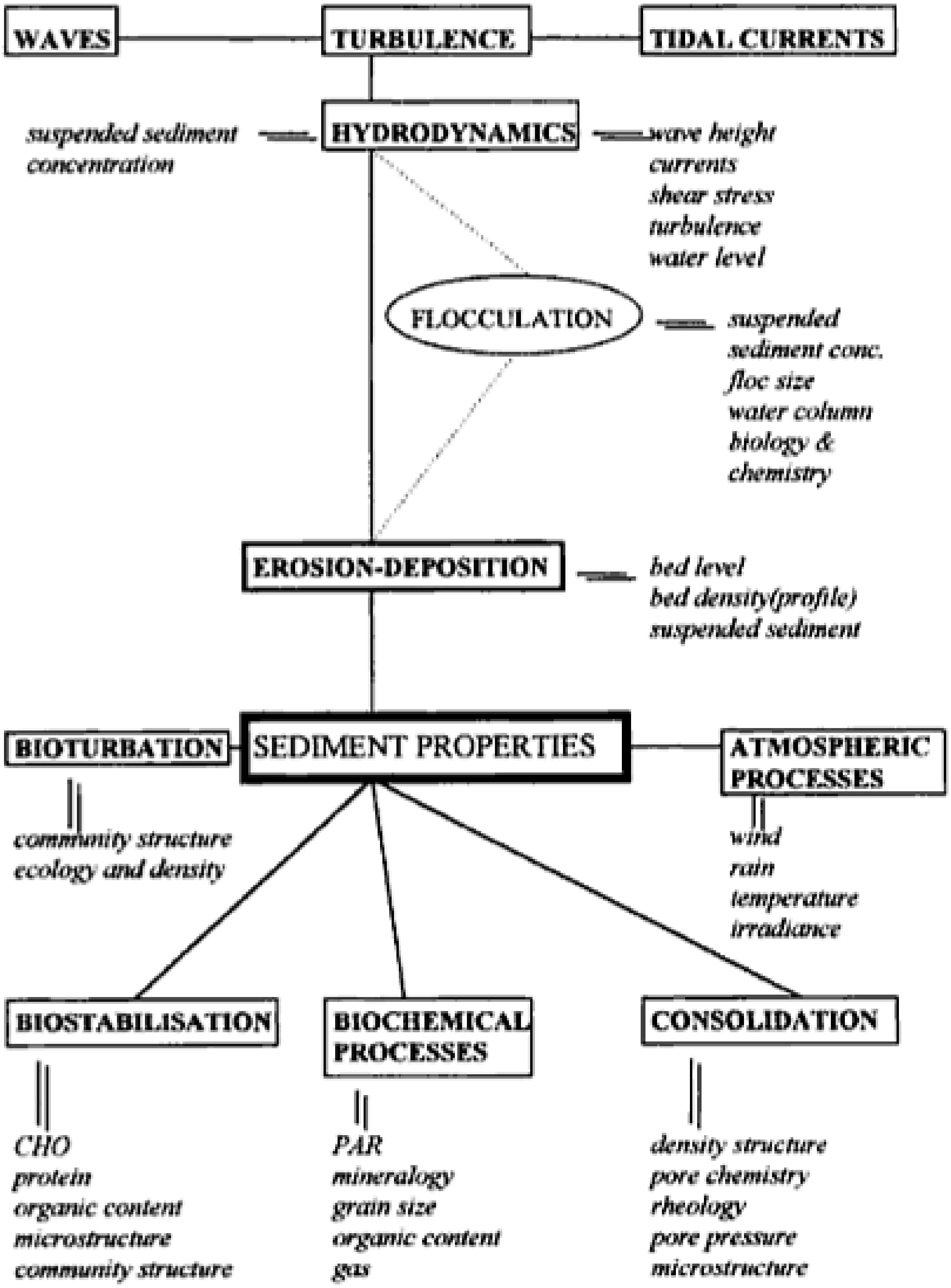
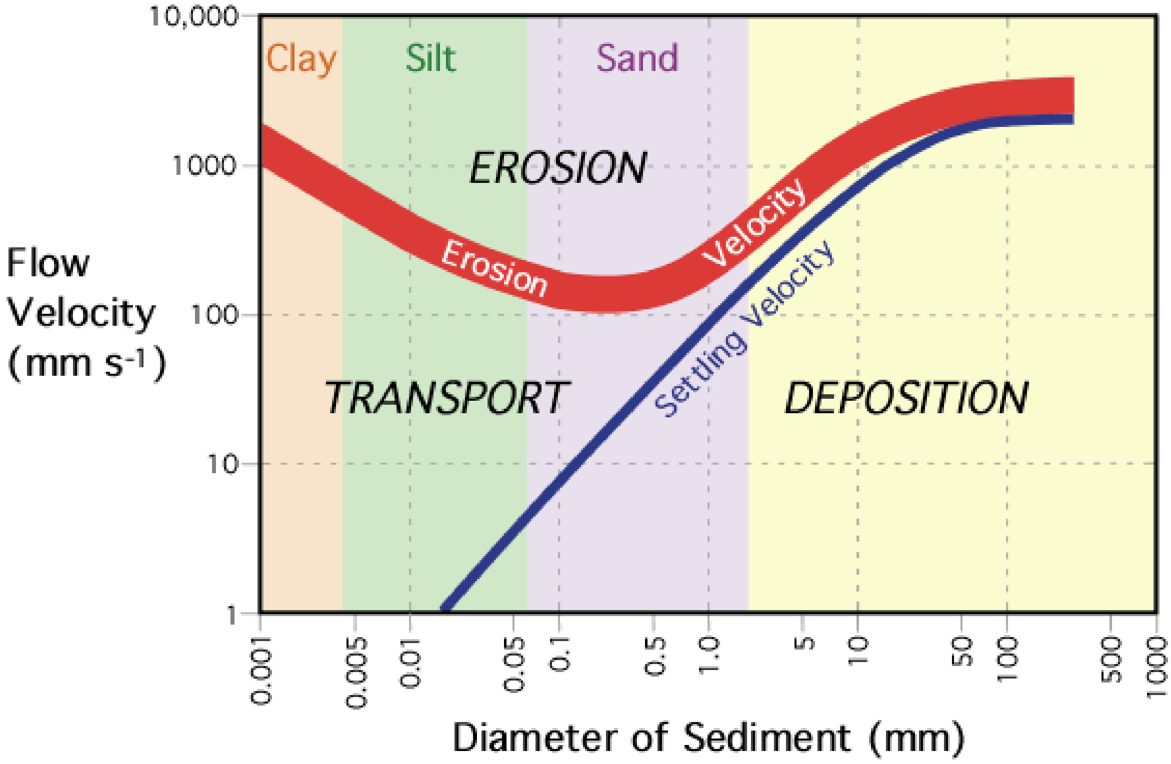


Figure 3. Relationship between flow velocity and particle behaviour for particles of different sizes (after (Hjulström, 1939).



3.4 Previous work

<u>King Sound</u>

Little information exists on the sediment dynamics of macro-tidal settings like the Kimberley coast, partially due to the challenges of working in these difficult to access and often highly turbid systems. The few studies that have been undertaken were based in King Sound.

Semeniuk (1980, 1981, 1982) differentiated intertidal zones and sediments of the inner King Sound into:

- lower intertidal—fine sands underlain by cleanly-washed sands shaped into shoals and ripples
- mid intertidal—interlayered sand and mud
- upper intertidal—laminated mud
- mangrove environment—mud, sandy mud or shelly mud, thoroughly mixed by crustaceans, worms, fish and plants

Semeniuk (1982) interpreted the mud flats and mangrove coastline of King Sound to be retreating, indicating that King Sound is providing sediment to the adjacent continental shelf. Semeniuk considered that net erosion produces high turbidity in King Sound and supplies mud to offshore deep water environments. Sand was thought to be trapped within the subtidal zone of King Sound, forming a vast residual sheet of sand and lithoclast gravel. Some sand may also be exported to the northern mouth of King Sound to form the subtidal sandbanks north of Sunday Strait.

Wolanski and Spagnol (2003) present a different interpretation. Their research determined that an asymmetric tidal current occurs in King Sound, with a stronger current at flood than at ebb. This is believed to trap fine sediment in the upper reaches of the Sound, resulting in extremely turbid conditions (suspended sediment concentration reaching 3 kgm^{-3}) and deposition of about 0.2cm $year^{-1}$. Wolanski and Spagnol's work was undertaken over two dry seasons (1997 and 1998). They acknowledge that some sediment may escape toward the central region of King Sound during wet seasons but suggest that it would be returned to the upper Sound in the dry season.

3.5 COCKATOO ISLAND

Because the King Sound coastline is primarily a mangrove environment, its zonation is not directly comparable to Cockatoo Island, which has a rocky coast surrounded by reef flat and indented by small sandy bays. The natural sediments around Cockatoo Island are coarser than those described by Semeniuk (1982), especially in the upper intertidal, which on Cockatoo Island consists of coarse sand, gravel and cobbles. Cockatoo Island's mid and lower intertidal zones generally consist of fine to medium grained sands. The nature of the original natural sediments beneath the seawall has not been determined. Based on characterstics of sediments on the less disturbed reef flat slightly further offshore, and also the nearshore sediment at the Reference site, they are likely to have been poorly sorted medium to fine grained sands with coral and shell fragments and a matrix of silt and clay.

Construction of the Seawall has modified the sedimentary regime of the adjacent reef flat. Marine environmental monitoring undertaken after construction found that turbidity, total suspended solids and sedimentation were greater near the seawall than at reference sites to the western end of the island (*ecologia*, 2003, 2004, 2005b, 2005a). Maximum values were obtained within 10m of the seawall, declining rapidly offshore along the 200m monitoring transects (*ecologia*, 2003, 2004, 2005b, 2005a). Factors contributing to this pattern include seawall construction activity, spring tides, cyclonic wave action, and rainfall/runoff events (Ecologia, 2005b, MScience, 2010a).

Turbid plumes generally remain close to the seawall and move eastward or westward (predominantly westward) depending on the tide (MScience, 2010). Sedimentation from these plumes has produced a band of red brown clay within approximately 10 to 20m from the Seawall, which may be locally up to 30cm deep (MScience, 2009a). Sediment smothering in this zone has reduced the abundance of the sessile benthic fauna, including corals (MScience, 2004, MScience, 2007). However the original natural community under the seawall footprint was probably relatively sparse, judging by the trend for increasing density offshore on all transects, including the Reference transect.

3.6 SEDIMENT DYNAMICS IN MACROTIDAL SETTINGS

Research into sediment dynamics in macrotidal settings in other parts of the world may provide some insights into the long term fate of the sediment deposits at Cockatoo Island. Of particular interest are studies of fine sediment mobility, which may help to determine whether natural processes could disperse and remove the clay deposit along the seawall.

One generalisation apparent in the literature is that, even in macrotidal settings, wave-forced suspension usually dominates over tidal currents in the erosion of fine grained sediments (e.g. (Christie et al., 1999, French et al., 2000, Sanford, 1994). Tidal currents only appear to dominate over wave action in relatively deep and/or calm macrotidal environments (Nittrouer and Richard, 1975).

Erosion rates can be relatively high in both tide and wave dominated macrotidal environments. For example a fine grained dredge spoil deposit in a tidally dominated environment, a 30m deep channel in Puget Sound, underwent an 84% reduction in volume of over four months (Nittrouer and Richard, 1975). A similar fine grained dredge spoil deposit in a wave dominated environment in northern Chesapeake Bay decreased in volume by approximately 10% after 1.5 months, 35% after 8 months and 52% after 19 months (Panageotou and Halka, 1989, Sanford, 1994). This pattern of initially rapid loss followed by gradual change reflects the approach to an equilibrium state; the finest sediments are rapidly winnowed from the deposit, leaving coarser particles which are more resistant to erosion. Such rapid changes are rare in natural sediments because they are usually in (dynamic) equilibrium with the prevailing conditions. Rapid, large scale sediment rearrangements usually only occur during infrequent high energy events such as storms and cyclones (e.g. Gagan and Chivas, 1990).

As mentioned in section 3.2, many processes can affect the erodibility of a fine sediment deposit. Two processes relevant to Cockatoo Island include exposure to the atmosphere at low tide and bioturbation (biological sediment disturbance). Exposure to the atmosphere generally increases cohesion and decreases erodibility, whereas bioturbation generally reduces the cohesion between particles and increases erodibility (Widdows et al., 2000). The relative balance between these two processes at Cockatoo Island is not known.

Another potentially major agent of erosion at Cockatoo Island is rainfall at low tide. If heavy rain were to fall during a spring low tide when the reef flat were exposed, large volumes of clay are likely to be washed into suspension (c.f. Pilditch et al., 2008).

3.7 Post-closure sedimentary processes at Cockatoo Island

The environment around the minesite can be broadly divided into areas where relatively little modification has occurred to the original substrate, including the reef flat outside the direct footprint of the mine, and areas where the original substrate has been highly modified, including the High Wall, Pit and Seawall. For the former, rehabilitation to a stable state resembling the pre-mining configuration is a viable aim. For the latter it is less likely, even if the original topography can be reproduced. However, alternatives to the original environment may represent acceptable substitutes, provided they can attain a stable state and support a natural benthic community.

3.7.1 Rehabilitation of the Reef Flat outside the mine footprint

The main impact of the mine on the reef flat outside the mine footprint has been the deposition and accumulation of fine sediment, predominantly red brown clay, as described above in section 3.5. The deposition and accumulation of fine sediment is harmful for most benthic organisms as it smothers their feeding and/or gas exchange mechanisms. Creating conditions that will erode and disperse the clay deposit, and prevent further fine sediment input, should be a primary aim of the rehabilitation effort. Some erosion does currently occur, through resuspension by waves during low spring tides. The suspended sediment is transported along the seawall by tidal currents. While much of the sediment appears to be redeposited further along the seawall, a proportion is carried beyond the reef flat and lost from the system. Judging by the net accumulation of fine sediment along the seawall at present, the amount lost is currently less than the amount entering the system via erosion and runoff from the island. If this situation can be reversed in the rehabilitation of the minesite, the clay deposit on the inner reef flat should eventually disperse and the sediments should evolve toward their original pre-mine state. The original sediment beneath the seawall has not yet been investigated, but may have been a medium to coarse grained carbonate and terrigenous sand, based on the appearance of the underlying sediment pushed up by the seawall subsidence (Figure 4).

A return to a natural state, assuming it occurs, could take years to decades, especially as the reef flat is in the lee of the island and rarely receives any direct swell to help erode the clay deposit. High energy events such as cyclonic winds and waves from the south, or heavy rainfall during low spring tides, would probably speed the process. However, unless effective measures are in place to prevent erosion of the seawall and/or disturbed areas of the island, such events could also increase the fine sediment input.

Depending on the seawall rehabilitation option undertaken, the rehabilitation process itself may generate substantial turbidity and sedimentation over the reef flat in the short to medium term (MScience 2004). While this has the potential to cause some damage to the reef flat communities, such short to medium term impacts may be acceptable if they allow the substrate to return to a stable natural state in the long term. If the substrate is not stabilised, and chronic fine sedimentation continues, the long term outcome for at least the inner reef flat community is likely to be poor.

Figure 4. Boundary between the sediment-affected inner reef flat (left) and the section of reef flat uplifted by the seawall subsidence (right) in September 2009.

3.7.2 Rehabilitation of the highly disturbed areas

Different rehabilitation options will produce different outcomes for the sedimentary environment. Options under consideration range from complete removal of the Seawall and infill of the Pit to the 'do nothing' option which would leave the Seawall and Pit to degrade naturally over time. The latter option is currently not favoured as modelling suggests the clay core would become exposed (MPR 2010). Instead the minimum rehabilitation option involves adding rock armouring to protect the clay core and cutting a channel through the seawall to allow tidal water exchange between the Pit and ocean.

As discussed in MScience (2004), evaluation of the rehabilitation options involves trade-offs between different goals. Goals include restricting the spatial extent of impacts, minimising the time required for the substrate to attain a stable state and minimising the visual evidence of mining. The relative importance of these goals would need to be assessed in consultation with government regulators. Below we provide an appraisal of the possible sedimentary and biological outcomes of the two rehabilitation options mentioned above ('removal/infill' and 'minimal rehabilitation'), with the expectation that intermediate options would have intermediate outcomes.

Removal/Infill

Full removal of the Seawall would involve cutting the Homer Dump and Seawall, and filling the Pit with clay and fines overlain by rocks and gravel. The final level of the rehabilitated ground would closely approximate the topography of the original reef flat. During the reconstruction, and possibly for several years after, a large amount of fine sediment would be exposed to suspension by waves and tidal currents. Deposition of at least some of this sediment on the high-value reef crest and outer reef flat is likely. Mortality of some reef organisms is also likely but, based on coral monitoring results at the current Impact sites, the majority would survive. Over time, perhaps a decade or so, the fine sediment would be removed from the system and the reef crest and outer reef flat communities would be expected to recover to a natural state.

The inner reef flat in the removal/infill option would comprise a relatively flat field of boulders and gravel, radically different to the (assumed) original medium to coarse grained carbonate and terrigenous sand. The sedimentary evolution of such a boulder field would depend to a large extent on its elevation relative to the original reef flat; possibly about 0.5m above datum sea level based on field observations at spring low tides. If the boulder field were lower than the original reef flat it would probably eventually be filled with sediment to approximately the height of the original reef flat, whereas if it were higher it would likely remain a projecting boulder field. The infill in the former scenario would probably be very slow, perhaps requiring several hundred years, primarily because much of the sediment would have to be generated in situ by carbonate producing organisms. In the latter scenario, the evolution of the boulder field would be dictated by its height relative to sea level and the stability of the boulders. Based on the current depth distribution of reef flat organisms, boulders lower than approximately 0.4m above datum sea level would be colonised by a diverse coral and encrusting invertebrate community while boulders above approximately 1m would only support sparse molluscs and chitons. Between those levels a relatively sparse community of corals, sponges and algae would develop. As the likely height of a projecting boulder field would be at least 0.5 to 1.5m above datum sea level, sparse colonisation is probably all that could be expected.

The initial high-turbidity environment of the rehabilitated boulder field may inhibit colonisation to some extent, but the colonisation rate would likely improve as the turbidity cleared. Any significant movement of the boulders would also set back the colonisation process, but selection of appropriate sized boulders would minimise this problem (e.g. GHD 2008).

'Minimal rehabilitation'

Under this option the topography of the minesite would remain essentially as it is at the cessation of mining. Some additional rock armouring would be strategically placed to protect the clay core of the Seawall, and may also be added as a protective berm around the seaward toe of the Seawall. A channel would be cut through the Seawall to allow tidal flushing. The post-closure substrates would comprise the rock slopes of the seawall/rock berm and the subtidal walls and benches of the flooded Pit.

GHD (2008) used the three-dimensional hydrodynamics model ELCOM to simulate the circulation within a flooded Cockatoo Island Pit and compare it to that of the Koolan Island Pit. The Koolan Pit is considered an acceptable benchmark as it is clear and well oxygenated and contains a variety of apparently healthy coral, invertebrates and fishes (MScience, 2008). The modelling indicates that, with a channel allowing tidal flushing, water quality within the Cockatoo Pit would be equivalent to or better than that of the Koolan Pit. It is therefore likely that the invertebrate and fish communities of the Cockatoo Pit would develop similarly to those of the Koolan Pit, i.e. sessile invertebrates would line the shallow subtidal walls and fishes would occupy all depths.

Runoff from the island after heavy rain would be expected to cause elevated turbidity and sedimentation in the Pit, but this would probably be short-lived as the suspended sediment would settle rapidly and, once deposited at the base of the Pit, is unlikely to be resuspended. In this regard the Pit may provide an effective sediment trap, preventing runoff reaching the reef flat.

The post-closure rock substrates of the Seawall and rock berm (if constructed) would probably develop along the lines described above for the boulder field habitat in the 'removal/infill' scenario. Due to the elevation of the rock substrates (upper intertidal to supratidal) colonisation by invertebrates and algae would be sparse at best.

A significant risk with the seawall retention approach is that the reservoir of potentially harmful clay and fine sediments remains on the reef flat, albeit shielded by rock armour. If the protective rock armour is breached, a long period of ongoing fine sediment release would result. While this is unlikely to have a catastrophic environmental effect, it would probably depress the colonisation, growth and diversity of benthic flora and fauna on the inner reef flat for an extended period.

GHD (2008) evaluate the stability of the seawall boulders under the predicted long term wind and wave climate, and recommend several measures of increasing stability to withstand at least a 1 in 50 year event.

4.0 ENVIRONMENTAL QUALITY VALUES

The environmental quality values (EQV) for Cockatoo Island closure planning should follow the guidelines of the Environmental Protection Authority's Environmental Quality Management Framework (EQMF) for the marine waters of Western Australia, which is consistent with the *National Water Quality Management System* and the Western Australian *State Water Quality Management Strategy*. The plan uses the framework shown in Table 1 to establish water quality objectives and targets.

Table 1. NWQMS framework elements.

ELEMENT	FUNCTION
Environmental Value (EV)	Establish a broad area of ecological or social importance to the stakeholders
Environmental Quality Objective (EQO)	Specify the specific management objectives for each Value
Environmental Quality Criteria (EQC)	Measurable benchmarks, developed in consultation with stakeholders and regulators, which will indicate the level of performance in meeting objectives – either as monitored outputs or measured inputs.

Four environmental values from the EQMF are relevant to closure planning for Cockatoo Island's marine environment:

- Ecosystem Health
- Recreation and Aesthetics
- Cultural and Spiritual Values
- Fishing and Aquaculture

Table 2 specifies the objectives relating to these four values. There are four levels of protection associated with objective 1, maintenance of ecosystem integrity (Table 3).

Waters surrounding Cockatoo Island fall within an area recommended for reservation as a multiple use marine park (WACALM, 1994), and therefore warrant a high level of protection. However, much of the southern shoreline of Cockatoo Island, and sections of the northern shoreline, have been substantially degraded by current and past mining activities. These areas may require a considerable length of time before sediment and water quality parameters stabilise and conform to natural variation. Hence the proposed levels of protection for Cockatoo Island marine environments are:

- High for undegraded marine ecosystems outside a 50m buffer from impacted areas (seawall footprint, discharge mixing zones)

- Moderate for marine ecosystems within a 50m buffer from impacted areas
- Low within impacted areas

To support the EQO of Table 4, a set of completion criteria have been derived, based on patterns of current and proposed use of the area (Table 4). These criteria will be subject to post-closure monitoring. As much of the social amenity of the area derives from the marine ecosystem, the social and cultural objectives can be largely met through the criteria designed to protect the marine ecosystem.

Table 2. Environmental Quality Objectives.

VALUE	OBJECTIVES
Value 1: Ecosystem health	1. Maintain ecosystem integrity.
Value 2: Recreation & Aesthetics	2. Water quality is safe for recreational activities in the water (e.g. swimming). 3. Water quality is safe for recreational activities on the water (e.g. boating). 4. Protect the aesthetic values of the marine environment
Value 3: Cultural & Spiritual	5. Cultural and spiritual values of the marine environment are protected. No reduction in populations of marine animals hunted by indigenous people.
Value 4: Fishing and Aquaculture	6. Seafood (caught or grown) is of a quality safe for eating. 7. Water quality is suitable for aquaculture purposes.

Table 3. Levels of ecological protection linked to EQO 1, maintenance of ecosystem integrity.

LEVEL OF PROTECTION	ENVIRONMENTAL QUALITY CONDITION	
	Contaminant Indicators	**Biological Indicators**
Maximum	no contaminants - pristine	no detectable change from natural variation
High	very low level of contaminants	no detectable change from natural variation
Moderate	elevated levels of contaminants	moderate changes from natural variation
Low	high levels of contaminants	large changes from natural variation

Table 4. Environmental quality criteria for each objective.

Objectives	Quality Criteria
1. Maintain ecosystem integrity: high level of protection for the marine ecosystem outside of degraded areas	1. Turbidity and light attenuation within the range of natural variability. 2. Marine sediments trend toward natural composition and particle size. 3. Colonisation of post-closure substrates by juvenile marine flora and fauna. 4. Mortality of sessile benthic community at rehabilitated sites within the range of natural variability
2. Water safe for contact recreational activity 3. Water safe for non-contact recreational activity 4. Aesthetic values protected	5. Waters meet the criteria applied for ecosystem protection. 6. No marine pollution (e.g. oil slicks or floating rubbish).
5. Cultural and spiritual values protected: no reduction in populations of marine animals hunted by indigenous people.	7. Avoid impacts on the amenity of the area for marine mammals & turtles. 8. No deaths of dugongs or turtles caused by the project.
6. Seafood (caught or grown) is of a quality safe for eating. 7. Water quality is suitable for aquaculture purposes.	9. Waters meet the criteria for ecosystem protection.

5.0 INTERIM AND COMPLETION CRITERIA

As the post-closure configuration of the Seawall and Pit has not yet been determined, some of the completion criteria presented in Table 4 are general in nature. Once the final configuration is determined, these criteria will be updated with specific conditions and sampling sites relevant to the selected option.

Criteria listed under Objective 1 of Table 4 represent long term aims. Some may not be immediately achievable, either because the processes involved are relatively slow (coral colonisation for example) or because the earthworks required in some of the rehabilitation options may increase turbidity and sedimentation in the short term. Hence final completion criteria are supplemented with interim criteria aimed at either minimising environmental harm during the necessary earthworks, or assessing the trends of the parameters in question. Interim criteria have been developed to provide strong indication that processes (physical or biological) are acting in a manner that will attain final completion criteria after a longer period. Where an interim criterion is met, it is highly likely that final completion criterion will be met. The completion criteria proposed in Table 4 are addressed individually in Table 5. Interim criteria listed in Table 5 are expected to be reached within 5 years post-closure.

Table 5. Suggested interim criteria relating to the completion criteria from Table 4.

Completion criteria	Interim criteria	Assessment method
1. Turbidity (NTU) and light attenuation within the range of natural variability.	Median NTU at the rehabilitated site to remain below the 80th percentile of selected Reference sites. Median light attenuation at the rehabilitated site to remain below the 80th percentile of selected Reference sites.	Periodic post-closure field surveys (suggested intervals 6 months, 12 months and annually thereafter for 4 years). Surveys to correlate with conditions sampled during monitoring program; i.e. spring tides to capture turbid conditions. Field surveys use hand-held instruments deployed from a boat to collect surface and bottom turbidity, total suspended solids (TSS), and light attenuation. NTU data to be gathered by long term in-situ loggers deployed 0.5m above the substrate at one of the current Impact subsites and one of the current Reference subsites* * Logger deployment would require a higher frequency of visits, possibly 3-monthly, to download data and replace batteries, or training of minesite staff to undertake the downloads.
2. Reef flat sediments attain an equilibrium composition and particle size, preferably those of the original natural sediment*. *Characteristics of the original natural sediment are to be determined by sampling with push cores at the Impact sites (through clay down to original substrate), supplemented by observations and sampling of original reef flat sedimentary strata within southern Pit wall.	The proportion of the fine particle component (<75µm) of sediment at the rehabilitated site is within +/-25% of that at the Reference sites. The proportion of Fe in sediments at the rehabilitated sites is within +/-25% of that at the Reference sites after normalisation with Al (representing particle size).	Undertaken during field surveys described above. Sediment sampling and analysis as per current program: collection of 250g surface sample to 4cm depth at each monitoring site. Analysis of particle size distribution by sieve. Analysis of total Iron by inductively coupled plasma atomic emission spectroscopy (ICP-AES). A subset of the current monitoring locations will be used, with additional locations to be decided based on post-closure configuration (i.e. if the Pit is infilled).
Completion criteria	**Interim criteria**	**Assessment method**
3. Re-establishment of natural benthic community on rehabilitated substrates.*	Colonisation of post-closure substrates by juvenile marine flora and fauna shares at least 50% of generic composition of equivalent undisturbed habitats.	Undertaken during periodic post-closure surveys as described above. Quantitative surveys of abundance of juvenile benthic flora and fauna in replicate 25 x 25cm grids on hard substrate at rehabilitated sites and reference sites.

* See Section 6, this report		
4. Mortality of sessile benthic community on rehabilitated substrates within the range of natural variability.	The mortality of juvenile fauna recruiting to the rehabilitated site is not statistically different to those recruiting to the Reference sites.	Undertaken during periodic post-closure surveys as described above. Quantitative surveys of abundance of juvenile benthic flora and fauna in replicate 25 x 25cm grids on hard substrate at rehabilitated sites and reference sites.
5. Waters meet the relevant ecological protection criteria (high, moderate, low).	As for criterion 1: Median NTU at the rehabilitated site to remain below the 80th percentile of selected Reference sites. Median light attenuation at the rehabilitated site to remain below the 80th percentile of selected Reference sites.	As for criterion 1: Periodic post-closure field surveys (suggested intervals 6 months, 12 months and annually thereafter for 4 years). Surveys to correlate with conditions sampled during monitoring program; i.e. spring tides to capture turbid conditions. Field surveys use hand-held instruments deployed from a boat to collect surface and bottom turbidity, total suspended solids (TSS), and light attenuation. NTU data to be gathered by long term in-situ loggers deployed 0.5m above the substrate at one of the current Impact subsites and one of the current Reference subsites* * Logger deployment would require a higher frequency of visits, possibly 3-monthly, to download data and replace batteries, or training of minesite staff to undertake the downloads.
6. No marine pollution (e.g. oil slicks or floating rubbish)	No marine pollution (e.g. oil slicks or floating rubbish)	high tide shoreline (southern shore) to be inspected during post-closure surveys.
7. Avoid impacts on the amenity of the area for marine mammals & turtles	No mine-derived sediment accumulation on seagrass area, west of Town Beach (dugong feeding area)	Seagrass area to be inspected for accumulation of mine-derived sediment during field surveys (mine-derived sediment can be distinguished by its red-brown colour, against the grey-green of the natural reef sediment).
Completion criteria	**Interim criteria**	**Assessment method**
8. No deaths of dugongs or turtles caused by the project	No deaths of dugongs or turtles caused by the project. Post-closure topography does not create traps that could strand dugong or turtles at low tide, minimal boat traffic.	Limited capacity for monitoring. Audit of the physical aspects of the post-closure landscape by marine biologist with experience in dugong and turtle management.
9. Waters meet the relevant ecological protection criteria (high, moderate,	As for criterion 1: Median NTU at the rehabilitated site to remain below the 80th percentile of	As for criterion 1: Periodic post-closure field surveys (suggested intervals 6 months, 12 months and annually thereafter for 4 years). Surveys to correlate with

low)	selected Reference sites. Median light attenuation at the rehabilitated site to remain below the 80th percentile of selected Reference sites.	conditions sampled during monitoring program; i.e. spring tides to capture turbid conditions. Field surveys use hand-held instruments deployed from a boat to collect surface and bottom turbidity, total suspended solids (TSS), and light attenuation. NTU data to be gathered by long term in-situ loggers deployed 0.5m above the substrate at one of the current Impact subsites and one of the current Reference subsites* * Logger deployment would require a higher frequency of visits, possibly 3-monthly, to download data and replace batteries, or training of minesite staff to undertake the downloads.

6.0 MAPPING INTERTIDAL COMMUNITIES

Documenting the benthic community composition of nearby natural intertidal habitats will help define appropriate target communities for the rehabilitated ground. The basic approach is to characterise the proposed post-closure substrate in terms of depth, slope and substrate type, then survey the benthic communities of undisturbed areas with those characteristics at Cockatoo Island, or further afield if necessary. The composition and density of these natural communities will provide guidelines for biological rehabilitation criteria (e.g. criterion 3 in Table 5).

This phase of work has been postponed until a preferred rehabilitation option has been identified and a general configuration can be specified for the rehabilitated area. While the broad categories of desirable natural flora and fauna can be estimated (e.g. hard and soft coral, sponges, coralline algae, macroalgae), the specific structure of an appropriate target community will be very sensitive to the post-closure configuration, particularly depth, slope and substrate type.

The proposed intertidal community mapping is to be based on classification of features from new aerial photographs and/or photographs taken from vantage points on the island. Photographs will be spatially registered by reference to existing registered images. Once the preferred rehabilitation option has been determined, target areas for field survey will be selected from the photos. Ground truthing will be undertaken by reef walking and boat-based drop-video surveys, recording substrate type, taxonomy and density of flora and fauna. Topographic detail will be obtained using surveying equipment.

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APPENDIX A – REGISTER OF CLOSURE COMMITMENTS

References to closure commitments currently effective.

Correspondence E2778/200304 30-Nov-2009	Internal Memo/Report from DMP regarding Cockatoo Island Sea Wall Failure Remediation Report.	6. At the time of decommissioning of the seawall embankment and prior to rehabilitation, a further review report by a geotechnical or engineering specialist shall be submitted to the DMP. This report should review the status of the structure and examine and address the implications of the physical and chemical characteristics of any materials contained (or to be contained) behind the embankment and present and review the results of all monitoring. The rehabilitation stabilisation works proposed and any on-going remedial requirements should also be addressed.	At decommissioning of seawall	Closure

Lease 04/137 Mineral Lease 9-Sep-2008	Department of Industry and Resources And Cockatoo Mining Pty Ltd	Mineral Lease	27(1) At the time of decommissioning of the seawall embankment and prior to rehabilitation, a further review report by a geotechnical or engineering specialist shall be submitted to DoIR. This report should view the status of the structure, and examine and address the implications with respect to site abandonment and operational issues associated with removal of the embankment.	Closure

Licence 04/49 Miscellaneous Licence 26-Sep-2006	Department of Industry and Resources And Cliffs Asia Pacific Iron Ore	Cockatoo Island Mining Project	4(1) At the completion of the mining operation of the Embankment Project the embankment, ROM Pad, settlement pond, and ancillary infrastructure are to be removed to the basement level which existed prior to construction of the embankment project with material placed in the completed mine void.	At the completion of mining	Closure
			5(1) Ensure that all operations for embankment project are kept within the boundary of the mining tenements and that any spillage of material outside this area as a result of construction of the embankment wall is cleaned up and contained with the tenements.		Construction; Operation; Closure
			6(1) The proponents are to provide a closure and decommissioning plan of the operations to the State Mining Engineer for his written approval 12 months prior to the scheduled closure/completion of the project.	12 months prior to closure	Closure

ENDS