COCKATOO ISLAND MINE

ASSESSMENT OF ENVIRONMENTAL IMPACTS OF OPTIONS FOR DECOMMISSIONING THE COCKATOO ISLAND SEAWALL

JUNE 2011

Report: MSA139R2

Report to:

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Document Information

REPORT NO.	MSA139R2
TITLE	Cockatoo Island Mine Assessment of environmental impacts of options for decommissioning the Cockatoo Island seawall, May 2011
DATE	18 June 2011
JOB	MSA139
CLIENT	Cockatoo Mining Joint Venture Pty Ltd
USAGE	This report is an update of the MScience (2004) assessment of the potential impacts of removing the Cockatoo Island seawall, incorporating recent developments in closure planning. It should be read in conjunction with engineering studies undertaken for the Joint Venture in 2010 and 2011.
PRECIS	The reef flat along the south-western margin of Cockatoo Island comprises a well developed fringing coral reef, backed by an intertidal sand and mud flat. A 1.5 km long seawall has been constructed on the inner reef flat to allow mining below sea level. This study examines the likely environmental effects of two decommissioning options for the seawall: full removal of the seawall with infill of the mine void, versus retention and armouring of the seawall, with a channel allowing tidal exchange of seawater into the mining void. The former option would return the topography to something resembling its natural state in the long term, but would involve a long period of earthworks, causing turbidity and sedimentation. The latter option leaves the seawall structure in place with increased resilience, minimising sediment release, and creates a marine lagoon habitat in the mining void.
KEYWORDS	seawall sediment sedimentation turbidity coral reef

Version-Date	Released by	Purpose
V1 24 March 2011	DRB	Internal Review
V1 25 March 2011	JAS	Client Review
V3 25 May 2011	DRB	Client Review
V4 17 June 2011	DRB	Final

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1.0 SUMMARY

The Cockatoo Mining Pty Ltd Joint Venture (the JV), comprising HWE Mining Pty Ltd and Cliffs Asia Pacific Iron Ore Ltd, is conducting a feasibility study into the decommissioning of the mining seawall on Cockatoo Island in the nearshore area of Western Australia's Kimberley Region.

A 2004 report (MScience 2004) reviewing the potential environmental impacts during and following decommissioning of the seawall via full removal, suggested that the decommissioning option specified within the approvals documentation for the seawall was likely to produce a greater impact in the marine environment than practical alternatives. That option involved the total removal of the seawall and backfilling of the mine void within the reef flat. It was considered that option risked producing a sediment plume of such extent that it would negatively impact corals at the upper reef slope.

The 2004 review has been updated based on:

a) two engineering designs for decommissioning of the seawall progressed following a triple bottom line sustainability assessment;
b) surveys of the existing distribution of marine benthos around the reef flat conducted since the 2004 review; and
c) monitoring of waters and benthos off the seawall for the last 3 years.

Results of the update are presented here and reinforce the original findings that full removal of the seawall at the time of decommissioning is likely to cause a major impact to coral communities across the reef, due to the requirement for earthworks and earthmoving activity in the intertidal zone, and the exposure of clay core material to the ocean when the wall is breached during decommissioning.

Retaining the seawall involves some risk of future clay core exposure, but modelling indicates that the seawall can be armoured to withstand at least a one in 200 year event (MP Rogers & Associates 2011). Retention of the seawall also has the additional benefits of minimising runoff from the High Wall to the reef flat and providing a new marine lagoon habitat in the mining void. Based on this preliminary evaluation, retention of the seawall is likely to produce a better environmental outcome than removal. These findings will be updated as more details on engineering aspects of closure options and their potential impacts become available.

2.0 BACKGROUND

2.1 OVERVIEW

Cockatoo Island is located in 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 hematite 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 using a wet beneficiation process between 1995 and 2000;
- Remnant mining between 2000 and 2002;
- Mining below sea level by the JV under the Embankment Project of around 4M tonnes from 2002 to 2005; and
- Extension of the eastern seawall to extend mining at the landward edge of the reef flat (Stage 3 of the Embankment Project, proposed to continue until late 2012).

The Embankment Project was permitted under a Notice of Intent (Portman Limited, 2002) by the (now) Department of Mines and Petroleum in May 2002. The seawall constructed for the project is situated on Mining Lease 04/137 and is subject to the following tenement conditions:

Mo4/137 Condition 10 *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.*

Mo4/137 Condition 12 *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.*

Pursuant to those conditions, the Notice of Intent for the project (Portman Limited 2002) set out a number of Completion Criteria to be included in the Draft Cockatoo Island Closure Plan (Portman Limited, 2002). The two relevant to this study were:

- There should be no significant, physical off-site impacts; and
- The Embankment will be removed and disposed of within the mine pit below high water level.

Mining operations are currently conducted by the JV. As part of progressive closure planning for the operation, MScience Pty Ltd (MScience) was commissioned in 2004 by Cliffs' predecessor, Portman Limited, to carry out an assessment of the environmental aspects of various options for decommissioning the final seawall. That report was issued in 2004. The JV has now commenced intensive seawall closure planning to the stage of engineering options assessment and has commissioned MScience to update the 2004 report on the basis of:

- improved environmental knowledge derived from a number of marine habitat surveys and marine monitoring programs conducted by MScience in the period 2004 to 2011; and
- a more detailed evaluation of the likely engineering aspects of the seawall closure options.

This report presents that updated study, prior to a full evaluation of potential environmental impacts based on more definitive engineering.

3.0 THE ENVIRONMENT

3.1 REGIONAL SETTING

Most of the following information is drawn from a summary of reports in Wells et al. (1995).

Cockatoo Island is part of the Buccaneer Archipelago off Yampi Peninsula in the dry-subtropical south-western Kimberley Region of Western Australia (Figure 1). The Archipelago consists of numerous rocky islands usually surrounded by shallow shelves, channels and embayments, in a macrotidal 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, humid summers with heavy rainfall and occasional cyclones and warm dry winters. Riverine outflows during summer cause extensive nearshore sediment plumes that profoundly affect the water quality around many of the islands.

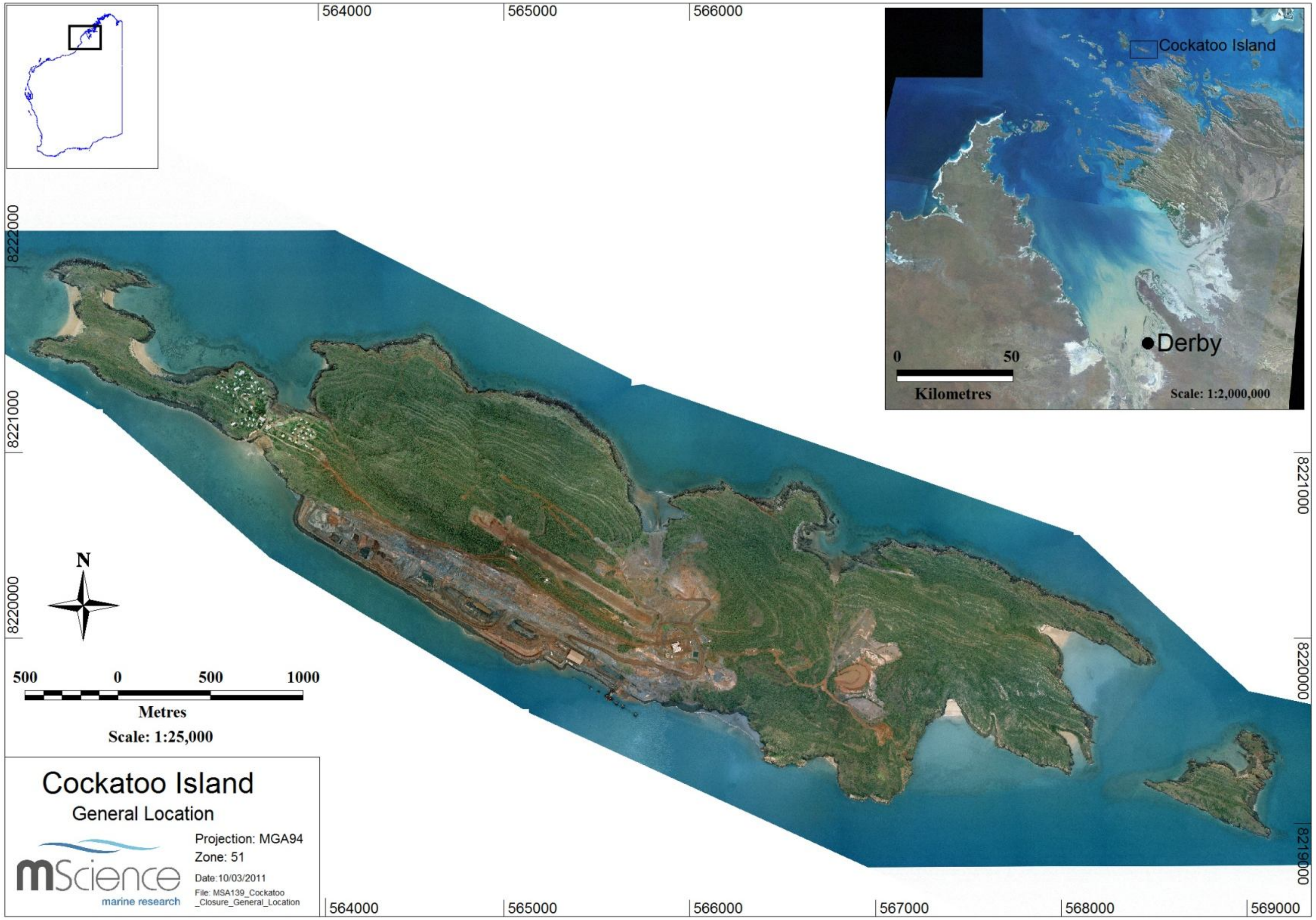
Outside of cyclone-induced wind and swell, the wave climate is generally benign, lacking the strong southerly or south-westerly swells typifying the rest of the exposed WA coastline. With most islands receiving some protection from nearby islands or the coast, the fetch for local waves is restricted and reefs do not show a typical windward/leeward development common for islands elsewhere. Wind energy during cyclones can be intense and waves capable of causing destruction of some reef communities can occur.

Tidal ranges are around 10m and tides cause strong local currents. Tidal currents, which are frequently above 10 knots, cause turbidity and deposit sediments during most high tides. Muddy intertidals are common, with mud derived from adjacent islands and the erosion of the King Sound coastline. Reef flats surrounding islands are also impacted strongly by the large tidal range, with low tides leaving biota exposed to very high temperatures for 3-4 hours (Purcell, 2001).

The islands of the Buccaneer Archipelago represent strike ridges and peneplains in a drowned coastline, where the original landform development occurred approximately 50m below current sea level. Thus, the present day shoreline evolution has been principally influenced by events of the late Holocene. Different islands show strikingly different shorelines, from cliffs to coral reefs, with widely varying degrees of sediment deposition.

Coral reefs occupy many of the outer flats surrounding islands and extend downslope. As for most fringing reefs (Hopley & Partain, 1986), these are constructional reefs, actively growing from their deeper margins while dying on their inner margins and being infilled with sediment. Many of the Buccaneer Reefs show strong terrace formation sloping mostly seaward, but occasionally with deeper margins on the landward edge (Purcell 2002).

Figure 1. Location of Cockatoo Island off the Western Australian Kimberley Region.



3.2 LOCAL SETTING

Cockatoo Island sits approximately 7km off the Western Australian coast at 16° 6’ S and 123° 37’ E within Yampi Sound (Figure 2). The island is a little over 6 km long and 1km in width, with a high ridge along the southern side, representing the top of the iron formation (Figure 3). The proximity to King Sound and the mainland coast means that waters around the island are subject to the higher turbidity influences from the erosional sediments around beaches and mangroves of the mainland coast.

The marine environment surrounding the island is structured principally by depth. Along the northern side of the island, the bottom drops rapidly into 30m of water and shallows are confined to the base of cliffs or within small embayments. Small coral bommies and patch reefs fringe much of the northern coast with sandy beaches in embayments.

A reef flat up to 400 m wide has developed along the south-western side of the island. The entire reef flat is exposed at extremely low tides. The seawall sits along the inner margin of this reef flat (Figure 3). The south-eastern margin of the island contains one small embayment and a larger, more open embayment. Both have sandy bottoms shelving to deeper water without reef formation.

While the south-western reef flat originally covered an area of approximately 1.5 sq km, and would have been between 200 m and 400 m in width, it is/was a relatively small fringing reef compared to those around many of the adjacent islands (Figure 2). A more detailed assessment of the south-western fringing reef appears in the next section.

In general, the inshore marine habitats around Cockatoo Island are typical of the Archipelago and are well represented around the fringes of other islands in the region. The major difference appears to be the scarcity of mangroves at Cockatoo Island, since most of the land-sea interface around Cockatoo Island comprises rocky cliffs or sandy beaches.

3.1 THE COCKATOO ISLAND REEF FLAT

The intertidal reef flat on the south western side of Cockatoo Island is the best developed reef flat around the island; those on the northern and western sides are much narrower (Figure 1, Figure 3).

Seven habitat units have been distinguished on the south western reef flat, based on field observations between 2004 and 2011 and recent aerial photographs. The habitats are described below and their spatial extents are illustrated in Figure 4.

1. Cliff shoreline with a lower zone of oysters and encrusting algae and an upper zone of grazing molluscs (note this habitat is not mapped in Figure 4 as it is extremely narrow).

2. Sand: medium to coarse clean sand with few macroscopic biota. Sparse *Halophila* seagrass in the western section.

3. Mine-derived fine sediment: Red-brown mud and fine black iron ore particles originating from the mine site and deposited adjacent to the seawall.

4. Low density coral and macroalgae: Sparse macroalgae, corals and sponges. Sparse *Halophila* seagrass in the western section. Within this unit, live coral cover increases from approximately 5% inshore to 10% offshore. The coral colonies are relatively small. The sedimentary matrix consists of fine to medium grained sand and mud, with coral rubble and shell fragments. Some deposition of mine-derived fine sediment is evident in this habitat, typically near the seawall.

5. Low density coral: As above, with fewer macroalgae and slightly greater coral density. Within this unit, live coral cover increases from approximately 10% inshore to 20% offshore.

6. Medium density coral: Approximately 20 to 50% live coral cover, coalescing to form a slightly elevated reef framework toward the outer edge of the reef. Relatively high coral diversity.

7. Upper reef slope: Approximately 50 to 100% live coral cover. Lower coral diversity than the adjacent ‘medium density coral’ unit, predominantly branching coral genera (*Acropora* and *Seriatopora*). Many corals exist here as relatively large colonies, suggesting rapid growth and low levels of disturbance.

Figure 2. Cockatoo Island in relation to King Sound and the Buccaneer Archipelago

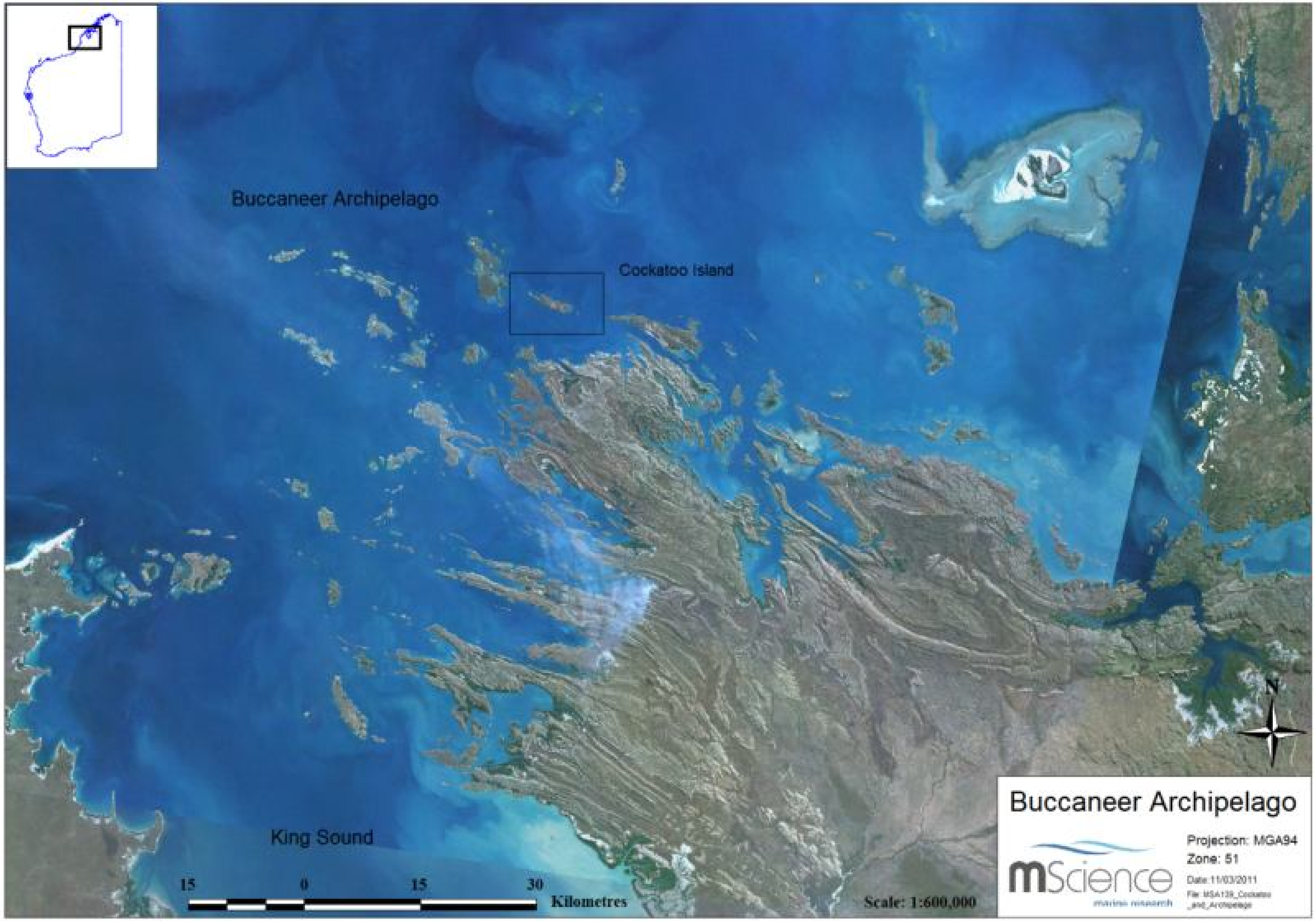


Figure 3. Cockatoo Island in September 2010, looking west. Image shows the High Wall, Pit, Seawall and reef flat exposed at a spring low tide. Image courtesy of John McFadyen.

3.2 REEF DEVELOPMENT

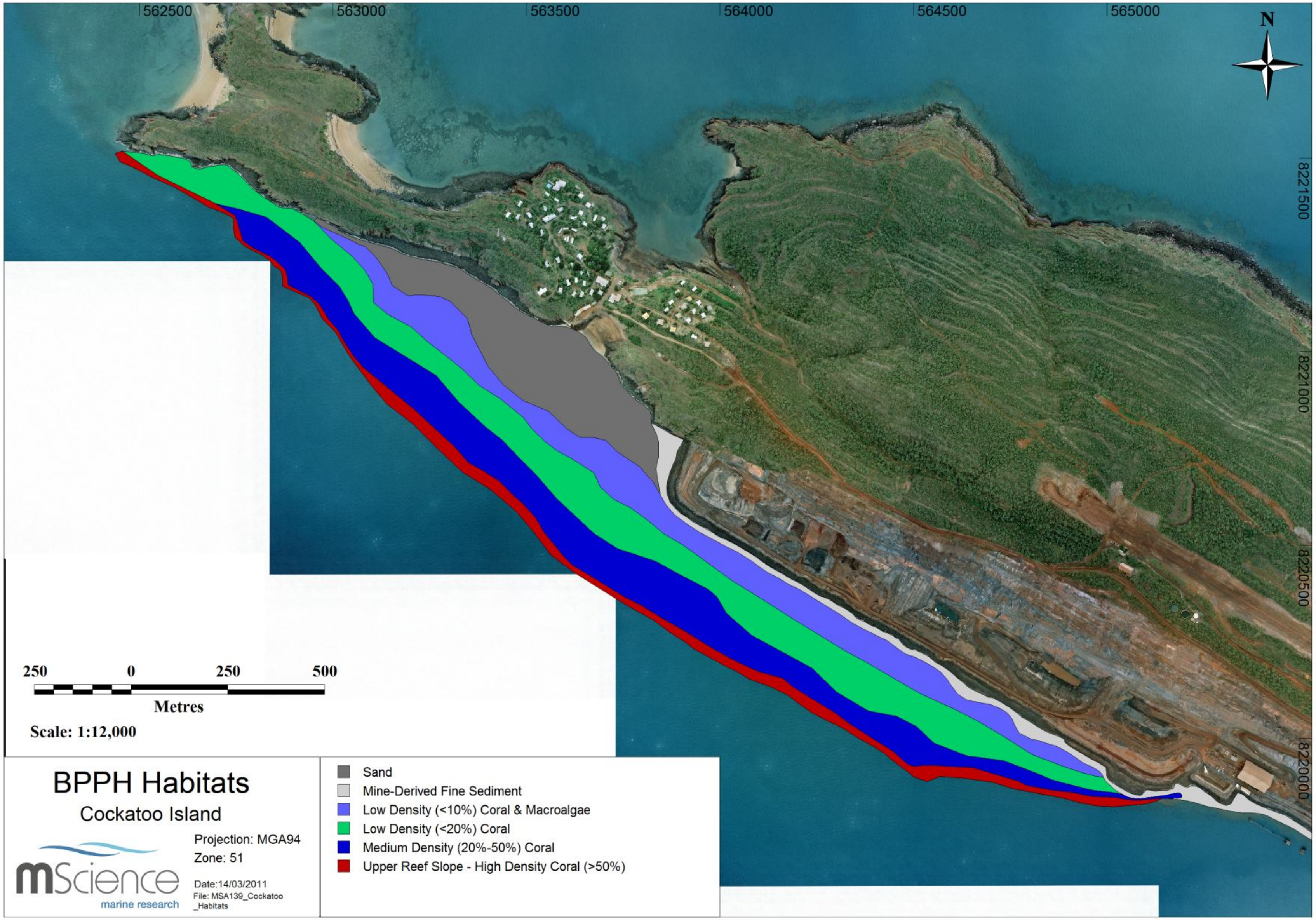
The south western reef flat of Cockatoo Island shows a pattern typical of the growth of fringing reefs throughout the world and consistent with descriptions of reef growth around the Buccaneer Archipelago islands (Brooke, 1995). Modern reefs in these areas probably initiated around 5 to 10 thousand years ago, when sea level rose onto the continental shelf and surrounded the islands. Corals, coralline algae and other calcifying organisms colonised hard substrate around the margins of the islands, growing outward and upward to eventually form reefs.

Upward growth of a coral reef ceases when the reef reaches sea level, because the reef building organisms cannot survive extended periods of exposure during low spring tides. On reaching sea level, live coral cover declines and the reef surface is infilled with sediment. Live coral cover on the outer margin of the reef remains high, and the reef continues to extend outward at its margin.

The current state of the Cockatoo Island reef flat reflects this typical sequence. The habitats depicted in Figure 4 represent a gradient from the outermost zones of high coral cover and rapid reef accretion to the sediment-dominated inner reef flat habitats representing the terminal stages of reef development.

Excavation around some of the fossil reef exposed in the foot wall of the western pit support this general pattern of reef development and suggest that the area may have passed through at least two periods of active reef growth. A well developed coral reef framework was evident and suggested two periods of reef growth separated by a sedimentary layer (possibly due to a different climatic period). The fossil reef was overlain by a layer of mud and coral sediment representing the pre-mining surface.

Figure 4. Benthic Primary Producer Habitat (BPPH) map of the Cockatoo Island reef flat, compiled from aerial photographs and field observations.



3.3 EFFECTS OF MINING

The main effects of the mine on the surrounding marine environment are related to increased turbidity and sedimentation. Observations and monitoring results during the Stage 3 seawall project indicate that these effects were greatest during the construction phase. The construction zone was located in the intertidal area and was therefore subject to regular tidal inundation. Tidal inundation suspended fine sediments and created sediment plumes, particularly on the incoming tides. Heavy rainfall during the construction phase had a similar effect, washing fine sediment from the construction zone into the ocean. Similar processes probably occurred during the earlier Stage 1 and 2 seawall construction programs.

Monitoring results during construction in the Stage 3 seawall zone showed that turbid plumes generally remained close to shore, rarely extending more than 100 m from the seawall, except during wet season runoff events or when waves disturbed the construction zone (as shown in Figure 5). The plumes generally moved along the seawall with tidal currents – westward during the incoming tide and eastward during the outgoing tide. Deposition from these plumes, and the earlier Stage 1 and 2 seawall developments, has created the nearshore mine-derived fine sediment unit depicted in Figure 4.

Figure 5. Plume from the Stage 3 seawall in windy conditions. Photo taken at 1615 29 August 2009.

Once the Stage 3 seawall was constructed above spring high tide level, it prevented tidal inundation and contained runoff from the island, greatly reducing fine sediment input to the reef flat. Large post-construction sediment plumes were generally only observed after heavy rainfall in the wet season.

Effects on the surrounding habitats documented in the monitoring program and observed during field surveys included:

- coral mortality due to sediment smothering in the zone of mine-derived sediment within approximately 20 m of the seawall, where sediment accumulations are locally up to 30 cm deep (MScience 2009);
- elevated sedimentation within approximately 20 to 100 m of the seawall, causing partial mortality of some corals and other benthic organisms, but rarely complete mortality;
- outside of a 100m radius from the seawall, invertebrate fauna appear unaffected and in similar condition to those examined on Irvine Island (a nearby pristine reef flat); and
- corals at the seaward margin of the reef flat and the upper reef slope appear unaffected.

The current state of the reef communities in the area can be described generally as highly disturbed within 20 m of the seawall, slightly to moderately disturbed within 20 to 100 m of the seawall, and essentially unaffected further than 100 m from the seawall. The spatial zonation of the reef flat places the habitats with the highest coral cover (upper reef slope) and the highest biodiversity (medium density coral) into the last (unaffected) category, except at the eastern extremity of the reef flat, where the reef zones curve toward the shore and intersect the rock berm constructed in 2009 to protect the corner of the seawall from further subsidence (Figure 4).

4.0 EVALUATION OF SEAWALL DECOMMISSIONING OPTIONS

4.1 SUSTAINABILITY ASSESSMENT

In 2009 the JV engaged specialist coastal and port engineers MP Rogers & Associates (MRA) to investigate options for decommissioning the Cockatoo Island seawall and associated infrastructure. Five options were investigated, including removing the wall and retaining all or some of the wall, with or without armouring.

A full-day sustainability workshop was held in September 2010 with environmental and mining staff from the JV, ENV Australia, MRA and MScience to investigate the decommissioning options and determine which offered the best economic, social and environmental outcome. At the workshop, the team of multi-disciplinary specialists evaluated and weighted a range of sustainability criteria against each option in the seawall decommissioning stage and post-decommissioning stage. The workshop considered Environmental (including marine, terrestrial and water quality factors), Social (including community safety, indigenous and aesthetic factors), Economic, as well as Engineering and Technical factors (such as construction impacts, climate change risk and resilience to severe events). The key outcomes of the workshop were:

- removing the wall (Option 1 of 5) was assessed as having the best environmental outcome in the longer term, since no seawall would be present, but had the greatest negative outcomes in the short term, during the decommissioning phase due to the risk of exposing the seawall's clay core; and

- retaining the wall with armouring (Option 4 of 5) was considered to be the most sustainable option due to the increased resilience of the structure left in situ and the lack of disturbance of the clay core, resulting in no major environmental risks during the decommissioning process.

The potential environmental outcomes of these two seawall decommissioning options are discussed further in the following sections.

4.2 OPTION 1: REMOVE SEAWALL AND BACKFILL

Scenario:

This option involves structured removal of each of the Embankment Project components, with the aim of returning the topography to approximately the pre mining state (+1 m RL) at the outer edge of the rehabilitation area, ramping up to +5 m RL to protect the base of the High Wall. This option involves removing the seawall, Homer Dump, sediment pond and ROM pad and placing the material in the mining void (Figure 6). The clay core material would be buried beneath a cap of coarser rock to prevent resuspension in the longer term. However, during the decommissioning process, which would take in the order of 11 months, exposure of the excavated clay to tidal currents and waves would likely lead to large scale suspension and consequently to large plumes. On completion of the works, rehabilitation would aim to maximise stability and minimise the long term release of fine sediment.

Predicted Environmental Outcomes:

Physical removal of the seawall into the current mining void is likely to generate a greater volume of suspended sediment, and more sedimentation, than the construction of the seawall. This is largely due to the fact that removal of the seawall and excavation of the clay core will allow the ocean to encroach into the mining void and entrain the fine sediments placed within the void. As a result, significant plumes are considered likely.

In addition to the above process, as excavation of the seawall and backfill of the mining void continues, earthmoving equipment will be required to operate on the surrounding flats at low tide and would operate essentially without any capacity to retain suspended sediments against the large tidal movements. Construction of a sediment retention structure around the works would be almost impossible due to the large tidal range and associated strong currents. It is likely that sediment would be deposited on the low and medium coral density zones of the reef flat and possibly also onto the upper reef slope, risking mortality to the actively growing outer reef edge.

Sedimentation should decrease significantly once the decommissioning earthworks are complete. The final extensive +1 m to +5 m sloping rehabilitation surface should be relatively stable, as it would consist of coarse material. Its coarse nature should also minimise sediment release, although, given the extent of the disturbance, some level of fine sediment release is likely to continue for several years. Presumably, waves and currents would eventually clear most of the mine-derived sediments and the site would attain a stable state, allowing recovery of the affected reef flat habitats. The outer, +1 m, section of the rehabilitation surface may return to the original sand/mud flat habitat, but this process would probably be very slow, perhaps requiring several hundred years, because much of the sediment would have to be generated in situ by carbonate producing organisms. Areas of the rehabilitation surface higher than +1 m above 0RL would probably remain as boulder fields and may develop mollusc/oyster/algae communities similar to those on the natural rocky high intertidal shorelines.

Runoff from the High Wall, and occasional failures of the High Wall, may cause sediment plumes, but these would not impact as widely as the initial decommissioning process.

4.1 Option 4: Retain and armour Seawall

Scenario:

This option involves retaining and stabilising the current seawall and mining void, creating a protected deep ‘lagoon’ habitat behind an armoured seawall (Figure 7). A channel would be cut into the seawall to allow tidal exchange of seawater. The channel would be a rock-armoured v-notch, 5 m above 0RL at its deepest point.

The seawall would be stabilised by constructing a berm on its seaward side using rock from borrow pits on the island. Simulations to date indicate the design will withstand at least 50 years of recorded cyclones followed by a one in 200 year event. It is estimated that the total works period would be less than three months for this option.

Predicted Environmental Outcomes:

Construction of the rock berm is unlikely to alter environmental conditions on the reef flat significantly. Little sedimentation or mechanical damage is expected during construction of the berm as the material would be coarse and would be placed from above. The proposed berm would be built mainly over the mine-derived fine sediment unit but would cover a small area of low density coral and macroalgae habitat at the eastern end of the seawall (Figure 7).

Option 4 has a lower risk of releasing clay than Option 1, since the only disturbance of the clay core would be during the construction of the v-notch through the seawall, which will temporarily expose some of the clay core (Figure 8). Armouring the edges of the channel will protect the core; however, it is possible that clay could be released from this section until sediments are stabilised. Clay release could be minimised by construction only taking place during low tides.

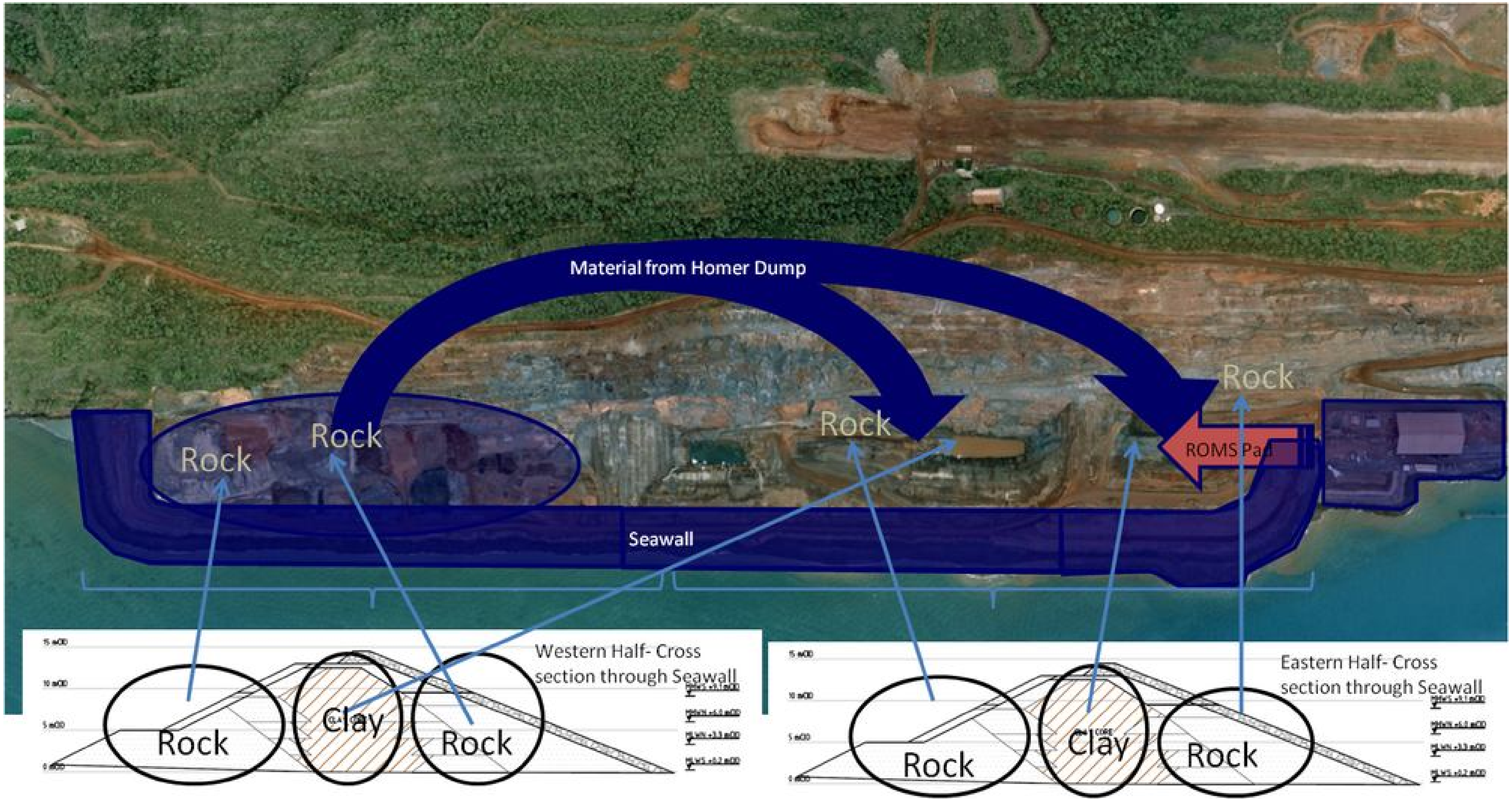
Post-decommissioning, there is still the risk that a storm greater than the design event (1 in 200 years) could breach the rock armour and allow some of the clay core to escape onto the surrounding reef flat. However, in this event the clay core release is likely to be gradual and would probably be dispersed by tidal currents. It is therefore unlikely to have a significant, irreversible impact on the marine environment.

GHD (2008) investigated the water quality considerations based on a limited opening to the existing pit and compared the water quality to the flooded mine pit at the adjacent Koolan Island. The Cockatoo Island mine void is smaller and shallower than the flooded mine pit at Koolan Island, which experiences 100% exchange over a fortnightly tidal cycle (GHD 2008). Modelling of tidal exchange through the Cockatoo Island seawall v-notch indicates that flushing rates should be up to 3 times greater than that of the flooded Koolan Island Pit (GHD 2008). A diverse coral and fish community would be expected to colonise the lagoon, similar to that of the Koolan Island Pit while it was open to the sea.

A major advantage of retaining the seawall is that it would act as a bund trapping runoff from the High Wall. Because the lagoon environment would be very calm, suspended sediment entering the lagoon would probably settle rapidly to the lagoon floor, with little being released through the channel. Sediment settling onto the lagoon floor is likely to remain in place as there would be no wave or tidal currents to resuspend it. At the expected rates of sedimentation, the lagoon would take many thousands of years to fill.

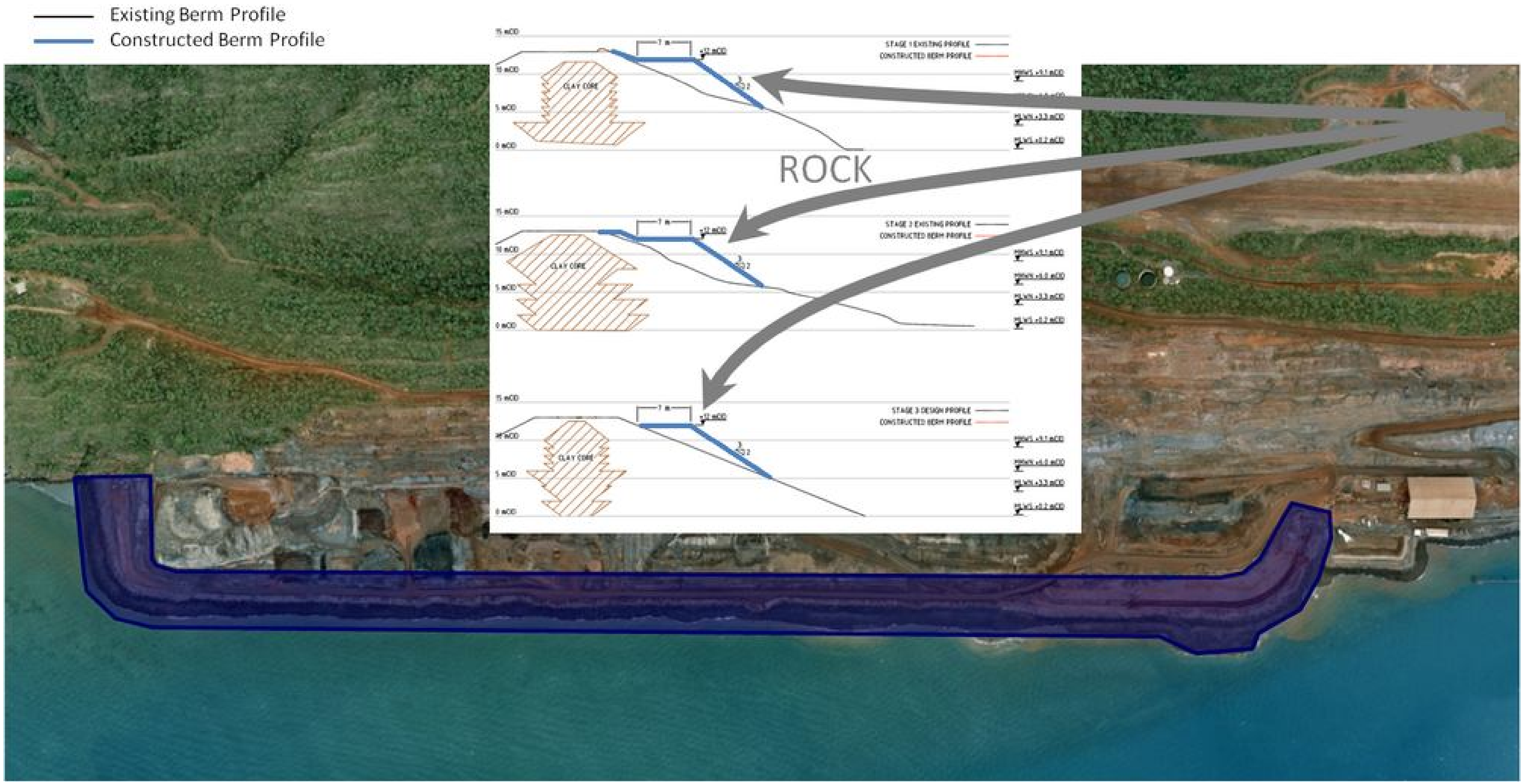
While turbid freshwater runoff into the lagoon could have some negative impacts on the developing marine community, the situation at Koolan Island indicates that runoff will not be a major impediment to growth.

Figure 6. Annotated image summarising Option 1. Note the coarser rock material will be dispersed along the base of the High Wall.



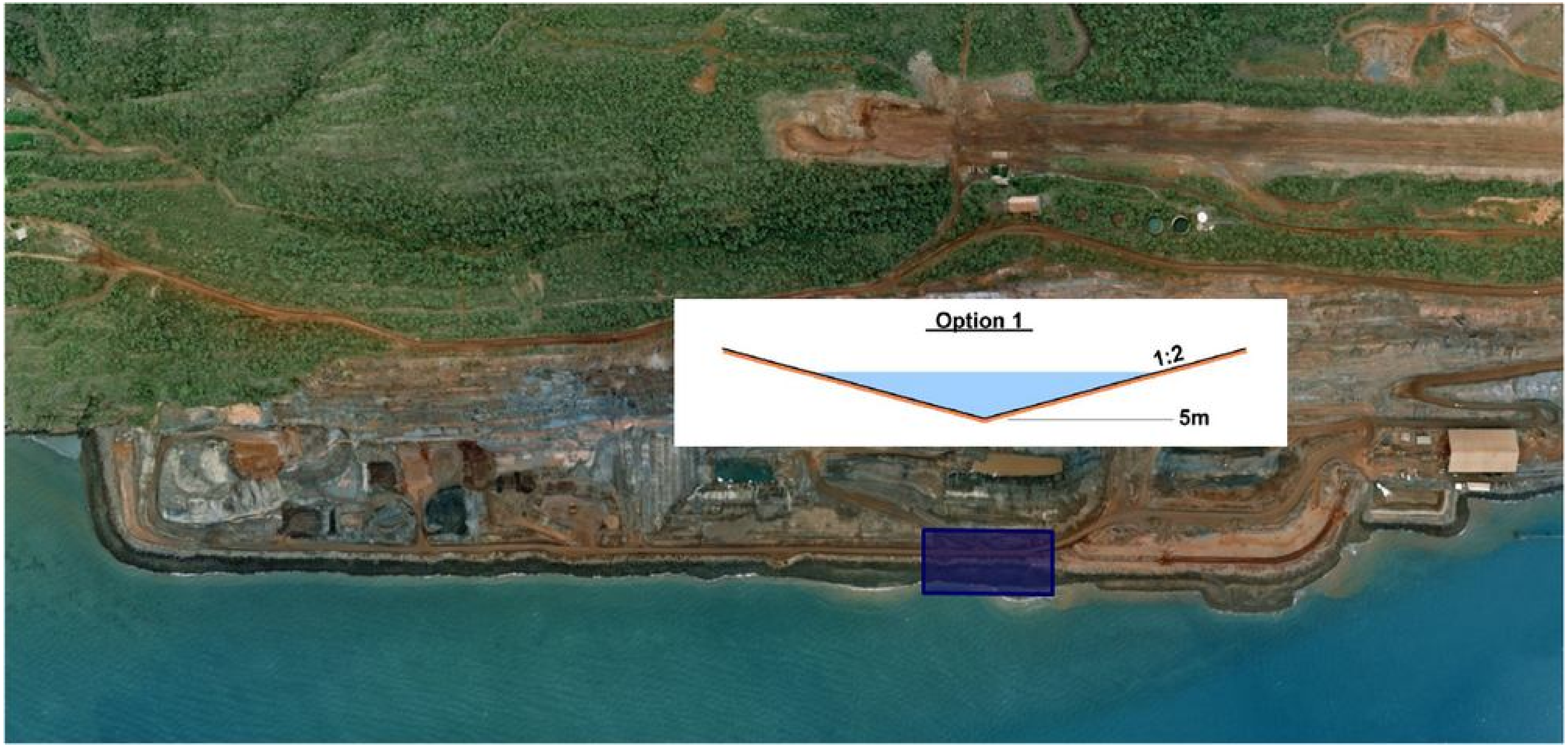
Modified from MP Rogers & Associates (2011)

Figure 7. Annotated image illustrating Option 4: The proposed constructed berm profile on seawall after rock armouring.



Modified from MP Rogers & Associates (2011)

Figure 8. Blue box shows proposed location and shape of the v-notch channel to be cut through the seawall (Option 4).



Modified from MP Rogers & Associates (2011)

5.0 DISCUSSION

The two options differ greatly in the amount of earthworks required and in their final configuration. Option 1 involves an extended period of earthworks and would return the topography to something resembling its original configuration, whereas Option 4 involves a relatively short period of earthworks and would leave a highly modified landform (the seawall and lagoon).

The main environmental advantages of Option 1 are that it would leave a more natural looking landscape post decommissioning and it would bury the clay core material to a level where it would not be disturbed. The main disadvantage is the potential for damage to the surrounding reef habitats from extreme and prolonged turbidity and sedimentation during the decommissioning works and possibly for several years after. The extent of this impact is likely to reach coral communities along the reef front, which have not been impacted by development activities thus far.

The main environmental advantage of Option 4 is that it minimises sediment release onto the reef flat, both through minimising earthworks and leaving the seawall 'bund' structure in place to trap runoff from the High Wall. It would also create a novel marine habitat (the deep protected lagoon behind the seawall), which is likely to support diverse coral and fish communities. The gradual decline of the seawall berm and associated dissipation of rock armour over a longer period of time is likely to result in less acute impacts, over a lesser area of the reef system.

The main environmental disadvantages of Option 4 are its unnatural appearance and that the clay core material remains above sea level, with the potential to be released onto the surrounding reef flat if the rock armour is breached by a storm greater than the design event (1 in 200 years). However, if this occurred the clay core is likely to be released gradually over time, resulting in a less significant impact on the marine environment than the large scale release during the proposed de-construction phase of Option 1. Option 4 would also involve some ground disturbance and quarrying on the island within the existing borrow pits.

The aesthetic issue regarding the natural versus unnatural appearance of Options 1 and 4, respectively, can arguably be downgraded in importance given that the adjacent, visually dominant, High Wall has undergone massive landscape modification and cannot be restored to a natural appearance. Furthermore, the concept of returning the inner reef flat area to its natural pre-mine state is arguably not critical given the indications that the pre-mine state was a sand and mud dominated habitat, supporting relatively few benthic primary producing organisms.

In this context, the issues of turbidity generation and sedimentation are primary. Option 4 presents a significantly lower risk from this point of view, provided the integrity of the seawall is maintained following the design event as the modelling predicts (MP Rogers & Associates 2011). As mentioned above, Option 4 also has the additional benefits of minimising runoff from the High Wall to the reef flat and providing new marine habitat. Retaining the seawall involves some risk of future clay core exposure, but modelling indicates that the seawall can be armoured to withstand at least a one in 200 year event (MP Rogers & Associates 2011).

In summary, the short-term decommissioning-time-scale impacts of Option 1 would be far more severe than those of Option 4 given the significantly greater works duration and the extent of earthworks and clay exposure that is required. These impacts would extend into areas of higher environmental value than those impacted by the mining development. In the longer term, the environmental performance of the two options is likely to be similar. Based on this preliminary evaluation, retention of the seawall is likely to produce a better environmental outcome than removal. These findings will be updated as more details on engineering aspects of closure options and their potential impacts become available.

6.0 REFERENCES

Brooke, B.P. (1995). Part 4. Geomorphology. In Marine Biota of The Southern Kimberley Islands (eds F.E. Wells, J.R. Hanley & D.I. Walker), pp. 21-57. Western Australian Museum, Perth WA.

ENV (2010), "Cockatoo Island, Seawall Decommissioning Options Sustainability Assessment," Technical, ENV Australia Pty Ltd unpublished report to Cliffs Natural Resources Pty Ltd, Perth WA.

GHD. (2008), "Cockatoo Island Seawall Retention, Design Aspects, November 2008," Technical.

Hopley, D. & Partain, B. (1986). The structure and development of fringing reefs off the Great Barrier Reef Province. In Fringing Reef Workshop: Science Industry and Management (ed C.L. Baldwin), pp. 13-33. Great Barrier Reef Marine Park Authority, Workshop Series 9., Townsville, Qld.

MP Rogers and Associates (2011), "Cockatoo Island Seawall Decommissioning," *Presentation by MP Rogers & Associates to Cliffs Asia Pacific Iron Ore Ltd , Perth, 4th March 2011*.

GHD. (2008), "Cockatoo Island Seawall Retention, Design Aspects, November 2008," Technical.

MScience. (2004), "Cockatoo Island Mine : Assessment of Enviromental Aspects of Options for Decommissioning the Sea Wall " Technical Report MSA21R1, Unpublished Report to Portman Limited by MScience Pty Ltd

MScience. (2009), "Cockatoo Island Marine Monitoring : Stage 3 Embankment Project : Sedimentation Assessment," Technical Report MSA113R11, Unpublished report to Cockatoo Mining Pty Ltd

Purcell, S. W. (2002), "Intertidal Reefs under Extreme Tidal Flux in Buccaneer Archipelago, Western Australia," *Coral Reefs*, 21, 191-192.

Wells, F.E., Hanley, J.R., & Walker, D.I. (1995) Marine Biological Survey of the Southern Kimberley, Western Australia. Western Australian Museum, Perth Western Australia.