LINDEMAN GREAT BARRIER REEF RESORT PROJECT

ENVIRONMENTAL IMPACT STATEMENT

APPENDIX Z- MARINE ECOLOGY ASSESSMENT

Addendum: *This EIS was initially prepared assuming that the safe harbour was to be part of the Lindeman Great Barrier Reef Resort Project. With the commencement of the Great Barrier Reef Marine Park Authority's (GBRMPA) Dredging Coral Reef Habitat Policy (2016), further impacts on Great Barrier Reef coral reef habitats from yet more bleaching, and the recent impacts from Tropical Cyclone Debbie, the proponent no longer seeks assessment and approval to construct a safe harbour at Lindeman Island. Instead the proponent seeks assessment and approval for upgrades to the existing jetty and additional moorings in sheltered locations around the island to enable the resort's marine craft to obtain safe shelter under a range of wind and wave conditions. Accordingly, remaining references to, and images of, a safe harbour on various figures and maps in the EIS are no longer current.*

Lindeman Great Barrier Reef Resort Project

Marine Ecology Assessment

HRP15078

Prepared for
White Horse Australia Lindeman Pty Ltd

2 March 2017

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Shaping the Future

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1 Introduction

White Horse Australia Lindeman Pty Ltd propose to redevelop the existing resort at Lindeman Island into a world class integrated resort comprising three resorts (spa, eco resort and beach resort), tourist villas, safe harbour and associated infrastructure.

This report describes the likely impacts of the proposed Lindeman Island Great Barrier Reef Resort project on beaches and intertidal areas, coral assemblages, aquatic vegetation and key marine species arising from the construction and operation activities. It proposes practicable measures for protecting or enhancing natural values (including coral and other marine species) and assesses how the nominated quantitative indicators and standards may be achieved for nature conservation management. The impact assessment focuses on the marine area in front of the existing resort in the vicinity of where the proposed safe harbour is to be located, as this would be where the majority of project activity (i.e. dredging and construction and ongoing operations of the upgraded resort and safe harbour) with potential to affect marine habitats and species would occur. In order to help determine the effects of the project on local habitats and biota, it is necessary to understand baseline conditions including the physical and chemical environment as well as the stressors that can cause changes to habitats and biota and whether the project activities could lead to these increasing from current (baseline levels).

This section is informed by modelling of waves, sediments and currents as reported in **Appendix H – Coastal Process Investigations.**

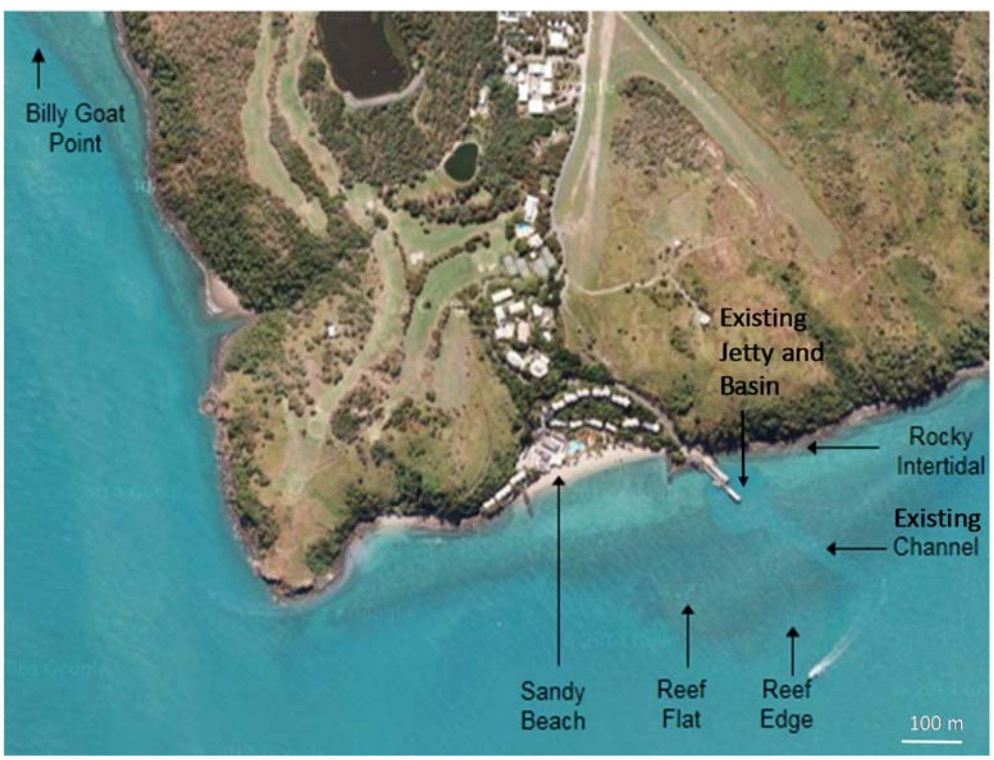
2 Existing Marine Environment

The marine habitats surrounding Lindeman Island have a high ecological value and recognised conservation significance (BMT WBM 2013). The project marine area (i.e. the south-western tip of the island) includes sandy beaches, rocky shores, fringing coral reef, soft bottom areas, sparse seagrass and macroalgae (Cardno Survey 2015, BMT WBM 2013). A search of marine matters of State Environmental Significance has identified that the proposed safe harbour includes areas located within the Great Barrier Reef Coast Marine Park (Conservation Park Zone). It does not include a Declared Fish Habitat Area, Dugong Protection Areas or High Ecological Significance Wetlands.

A sandy beach occurs in front of the existing resort on the southern coast of the island, bounded on both sides by rocky shore (**Figure 1**). A shallow rock platform occurs offshore from this, extending to a maximum distance of about 350 m directly offshore from the beach. A wooden jetty about 100 m long was built from the rocky shore to the right of the beach to service the existing resort. An existing 25 m wide man-made channel cut to a depth of about -3.0 m LAT runs through the reef platform and a turning basin cut to a similar depth occurs at the jetty.

The area for the proposed safe harbour is located in proximity to the existing jetty. The reef extends furthest from the shore adjacent to the existing jetty whereas the reef to the east and west of the jetty does not extend as far from the shore. The edge of the reef, which occurs in about -1 m LAT, drops quickly down a slope to deeper water (-4 m LAT) where the substratum is comprised of soft sediment (BMT WBM 2013). Seagrass habitat occurs further offshore from the fringing coral reef (BMT WBM 2013). The rocky shore further west of the proposed development is bordered by a narrow coral reef and some seagrass, as indicated by aerial imagery (**Figure 1**) and survey results south of Billy Goat Point (BMT WBM 2013).

Figure 1. Existing marine environment surrounding the proposed development (project marine area).



2.1 Coral Assemblages

Coral assemblages typically include hard corals mixed among soft corals, sponges, ascidians, gastropods, macroalgae and other invertebrate taxa. The most diverse coral communities generally occur in clear, offshore waters, however extensive coral communities, such as those adjacent to Lindeman Island can also be found in inshore tropical waters. The marine habitats surrounding Lindeman Island are within the Inner Shelf Lagoon Continental Island bioregion and Whitsunday region of the Great Barrier Reef (GBRMP) (Kerrigan et al. 2010). This bioregion is characterised by strong currents, some gorgonians and low reef sites, very turbid water and seagrass meadows in some bays. Within this area, there are scattered coastal fringing reefs that generally develop around the mainland and high continental islands and these can have high coverage of hard coral, soft coral and macroalgae, but generally low coral diversity (Kerrigan et al. 2010).

Key values of the Whitsunday region of the Great Barrier Reef Marine Park and issues are outlined in Great Barrier Reef Marine Park Authority's (GBRMPA) *Whitsundays Plan of Management 2008*. The Authority has identified the following values relating to corals and associated biota in the Whitsunday Planning Area:

(a) corals and associated biota are an integral part of the Marine Park and the Great Barrier Reef World Heritage Area;

(b) the relatively clear waters of the northern part of the Planning Area have allowed for the growth and development of extensive and diverse reef structures and corals that are relatively uncommon on fringing reefs;

(c) surveys of fringing reefs have identified a number of reefs of outstanding species richness, coral cover, uniqueness and aesthetic appeal;

(d) a previously undescribed coral species (*Goniastrea sp.)* has been recorded at Double Bay, and a species of sponge (*Rhabderemia sorokinae*) has been recorded at Deloraine Island reef.

The Authority has also identified the following issues relating to corals and associated biota in the Planning Area:

(a) fringing reefs are a limited resource throughout the Marine Park and especially in the Planning Area— this relatively scarce resource has important conservation and aesthetic values;

(b) the accessibility of fringing reefs make them vulnerable to degradation from excessive human use, particularly damage from anchoring, diving, reef walking and collecting;

(c) there is a higher risk that anchoring equipment associated with larger vessels will cause greater damage to coral and associated biota;

(d) coral and associated biota have the potential to be affected by run-off from adjacent coastal development;

(e) species of biota that are thought to have only limited geographic distribution (for example, *Goniastrea* sp., *Rhabderemia sorokinae*) require protection.

2.1.1 Water Quality

Ambient suspended solids (SS) varies in reef environments from only a few mg/L in clear waters to upwards of 200 mg/L in turbid waters (Fabricius and Wolanski 2000) with a variety of different coral assemblages adapted to ambient SS concentrations. Coral reefs in the Whitsundays are affected by turbid water from coastal runoff which can be influenced by erosion, poor drainage controls and increasing development within the coastal catchments. Records of SS from 12 of the 74 Whitsunday islands over many years of monitoring show SS ranging from 0.50 mg/L to 17.50 mg/L (**Table 1**). The SS at Lindeman Island and Seaforth Island from 2002 to 2015 ranged between 1.46-4.70 mg/L, with an average of 2.35 mg/L. This appears to be mid-range compared to the average ambient SS at other Whitsunday Islands (**Table 1**).

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Table 1. Water quality of the Whitsundays (source: AIMS, unpublished data).

Reef	Average SS (mg/L)	SS Range (mg/L)	Number of Records (n)	Data Date Range
Repulse Bay	4.05 ± 1.73	0.85-10.76	5	8/8/2004-6/3/2015
Shaw Island	2.33 ± 0.30	1.17-5.17	13	31/10/1992-26/8/2005
North Pine Island	4.14 ± 0.86	0.74-17.50	25	5/10/2007-6/3/2015
South Pine Island	3.61 ± 0.62	0.79-11.18	23	5/10/2007-6/3/2015
Dent and Henning Islands	2.87 ± 0.89	0.81-16.84	17	31/10/1992-15/1/2009
Border Island	1.25 ± 0.23	0.59-2.36	8	30/3/1994-8/1/2006
Edward Island	2.78 ±1.14	1.22-6.16	4	11/2/2007-27/2/2010
Deloraine Island	0.90 ± 0.20	0.61-1.50	4	11/2/2007-27/2/2010
Eastern Whitsunday Island	4.56 ± 0.94	0.50-11.75	14	10/2/1993-10/2/2007
Lindeman and Seaforth Islands	2.35 ± 0.24	1.46-4.70	11	28/10/2002-6/3/2015

2.1.2 Local Diversity and Cover of Coral

Aerial imagery indicates approximately 10 linear kms of reef fringes at Lindeman Island, extending variable distances from the shoreline between 10s to 100s of metres. BMT WBM conducted a marine ecology survey at four locations at Lindeman Island in August 2013 (BMT WBM 2013) and found that coral cover on these reefs was variable. Apart from the large bombora offshore from Plantation Beach on another part of the island where coral cover approached 100%, BMT WBM estimated living coral cover to be generally <25% with most of the reef area consisting of 5-10% cover. Although data were limited, it would appear that the largest area of high density of living coral assemblages occurred on the southern side of the island nearby to the existing jetty and channel (i.e. in the vicinity of the proposed safe harbour location).

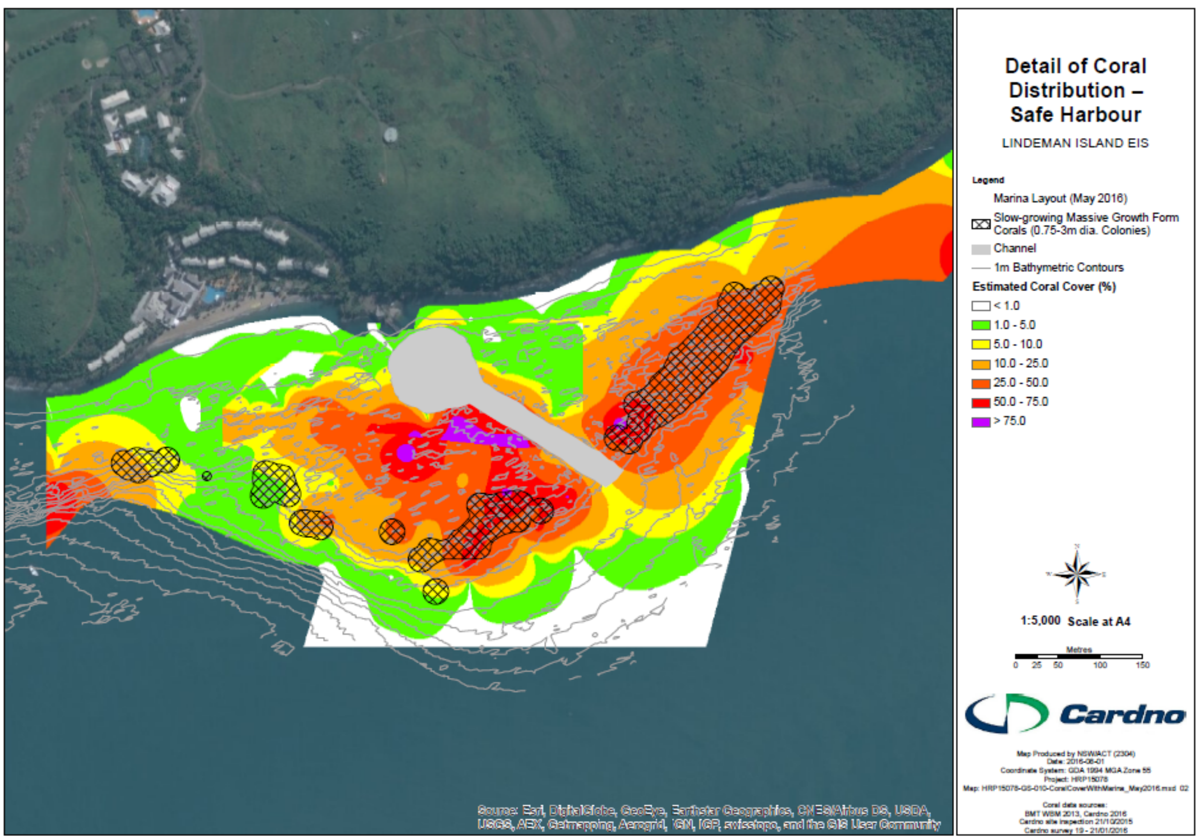
GBRMPA conducted a site visit in September 2015 that confirmed the findings (i.e. assemblage and percentage cover) of BMT WBM (2013) regarding the coral assemblage in the general vicinity of the proposed safe harbour location (GBRMPA 2015). Importantly, it would appear that coral cover had changed very little in the intervening two-year period between these two surveys. In the absence of large storms, cyclones, crown of thorns outbreaks or bleaching, temporal stability in coral assemblages over this time scale is normal (Cardno 2013). Further, given the large size and cover of the branching *Acropora*, it is likely that the assemblage has not experienced a major disturbance for at least five years.

Cardno conducted two additional surveys to assess the current condition of the coral assemblage in and adjacent to the proposed safe harbour location. The first, in October 2015, verified existing data on the assemblage and located large, old coral bomboras. The second, in January 2016, refined information about corals in relation to the footprint of the safe harbour. The characteristics of the coral assemblage at the location of the proposed safe harbour and in front of the existing resort (the Survey area) are shown in **Figure 2**. These data are based on data combined from the BMT WBM (2013), GBRMPA (2015) and the two additional Cardno surveys.

The existing resort at Lindeman Island is fronted by a fringing reef (a rock platform with coral growing upon it). The reefs extends about 350 m from the shore in the middle of the Survey area, and about 100 m from the shore on the eastern and western sides of the Survey area (Cardno Survey 2015, BMT WBM 2013). Generally, coral cover becomes greater with increasing depth in the Survey area in front of the existing resort, before a short transition into soft sediment habitat (i.e. with no hard substratum for coral) further offshore. The intertidal parts of the Survey area have a very low coral cover, with only some small hard coral colonies from a variety of taxa in front of the existing resort, as well as some soft coral belonging to the *Sinularia, Sarcophyton, Lobophytum* and *Cladiella* genera of the Alcyoniidae family.

Some areas within the Survey area in front of the existing resort have a dense cover of coral as well as massive *Porites* coral colonies (coral bomboras) (Cardno Survey 2015, BMT WBM 2013). An area located in the middle of the Survey area has more than 25% (and up to 100%) live coral cover (indicated by the red and purple areas on **Figure 2**). This area of dense coral cover begins at a distance of about 100 m from the shore and extends to the edge of the fringing reef. Dense coral cover is also found on the eastern side of the channel servicing the existing jetty. Another area of dense coral cover occurs on the western side of the Survey area to the south-west of the existing resort. This area is part of the reef edge and has a steeper depth profile compared to other parts of the Survey area (BMT WBM 2013). The dense coral cover in these areas is mostly due to large stands of bushy and branching coral (Acroporidae Family). Other common coral taxa are needle corals (G*enus Seriatopora, Family Pocilloporidae*), soft corals especially leather coral of the genus *Sinularia* and massive corals belonging to the Poritidae and Oculinidae Families (refer to **Figure 3, Table 2**). These areas of dense coral cover together represent the widest section of continuous fringing coral reef on the southern shore of Lindeman Island (Cardno Survey 2015, BMT WBM 2013). The morphology and characteristics of the reef in proximity of the existing jetty is variable with the area surrounding the channel having a steeper gradient and denser coral cover compared to the shoreward area of the reef which is flatter.

Figure 2. Coral distribution within the Survey area in front of the existing resort, estimated from Cardno Survey 2015/2016 and BMT WBM 2013.



Closer to the shore within the Survey area (i.e. <100 m), cover of coral is generally <25%, and typically much less than this (as indicated by green, yellow and orange colours on **Figure 2**). Here it consists of isolated small colonies of various growth forms. In front of the beach adjacent to the existing resort, the low coral cover extends from the shore all the way to the edge of the reef (Cardno Survey 2015).

The hatched areas in **Figure 2** indicate where colonies of the slow-growing, massive *Porites* genus were observed in the Survey area (Cardno Survey 2015). These colonies ranged in size between 0.75 and 3 m diameter, with the larger colonies potentially hundreds of years old (given an approximate growth rate of 10 mm per year, Lough and Barnes 1990). These colonies were mostly observed on the outer edge of the fringing reef or just beyond it. The short, outer fringing reef slope is manly inhabited by large colonies of the day coral *Alveopora* spp., sea whips (*Junceella* spp.) and soft corals such as branching *Nephthya* sp. growing in patches of rock interspersed among softer substratum. The dredged channel near the existing jetty has a low cover of hard and soft corals. The most common taxa are *Alveopora* spp., sea whips and few, small colonies of the Poritidae and Acroporidae families growing on rubble around the edges. The metal structure of the jetty provides substratum for numerous, very large soft coral colonies, mostly of the genus *Sarcophyton* (Cardno Survey 2015, BMT WBM 2015).

Figure 3. High density coral habitat within the Survey area: Stands of branching coral of the Acroporidae family (top left); Needle corals (*Seriatopora sp.*) and macroalgae (top right); Soft corals of the Alcyoniidae family (bottom left and right).

A complete list of coral taxa observed inside the footprint of the proposed safe harbour (Cardno 2016) and in the greater Survey area (BMT WBM 2013) is given in **Table 2.** The survey within the footprint did not identify notable additional taxa compared to the greater Survey area, indicating that coral taxa inside the footprint of the proposed safe harbour are generally similar to that of the greater area on the fringing reef outside of the footprint.

The *Whitsundays Plan of Management 2008* requires protection of species with a limited distribution and points to a new species of the coral *Goniastrea* sp., and the sponge *Rhabderemia sorokinae*, previously identified from fringing reefs in the region. Although targeted searches for these species were not undertaken at Lindeman Island for this EIS and individuals from the genus *Goniastrea* do occur in the Survey area, there are subtle differences in the habitats of these rare species that potentially indicate they would probably not occur in the direct footprint of the safe harbour. The new species of the coral, *Goniastrea* sp., was found at Double Bay on the Whitsunday mainland on a reef that is 0-2 m deep at low water (De Vantier et al. 1992). In the Survey area at Lindeman Island, the fringing reef at this similar depth occurs on the outer part of the fringing reef, well away from the safe harbour footprint. Further, the sponge, *Rhabderemia sorokinae*, collected at Deloraine Island (Hooper et al. 1990) was found on the edge of the reef, where there is a steep drop-off. Again, at Lindeman Island this habitat occurs on the outer parts of the fringing reef, well away from the safe harbour footprint. Notwithstanding this, video transects from the entire Survey were searched for possible specimens of *Rhabderemia sorokinae*. However, none were observed.

Table 2. Coral taxa recorded within the safe harbour footprint (Version 4).

Groups	Taxon	Safe Harbour Layout Version/Option 4 - May 2016 (Cardno 2016)	Survey Area (BMT WBM 2013)
SCLERACTINIAN CORALS			
Branching	*Acropora spp.*	✓	✓
	Seriatopora hystrix		✓
	Stylophora pistillata	✓	✓
	Pocillopora spp.	✓	✓
	Porites cylindrica	✓	✓
	Indeterminate	✓	✓
Massive	*Porites lobata*	✓	✓
	Moseleya latistellata		✓
	Favia spp.		✓
	Favites spp.	✓	✓
	Cyphastrea sp.		✓
	Goniastrea spp.	✓	✓
	Montastrea sp.		✓
	Lobophyllia spp.	✓	✓
	Platygyra spp.		
	Indeterminate	✓	✓
Submassive	*Porites spp.*	✓	✓
	Montipora spp.	✓	✓
	Pachyseris speciosa		✓
	Caulastrea furcata		✓
	Indeterminate	✓	✓
Columnar	*Galaxea fascicularis*	✓	✓
	Alveopora spp.	✓	✓
	Isopora palifera		✓
Plate or Lettuce like	*Turbinaria mesenterina*	✓	✓
	Platygyra spp.		✓
	Merulina ampliata		✓
	Merulina scabricula		✓
	Montipora spp.	✓	✓
	Indeterminate	✓	✓
Encrusting	Indeterminate	✓	✓

Groups	Taxon	Safe Harbour Layout Version/Option 4 - May 2016 (Cardno 2016)	Survey Area (BMT WBM 2013)
Lettuce	*Pavona cactus*		✓
Solitary	*Fungia sp.*		✓
	Polyphyllia talpina	✓	✓
	Indeterminate		✓
NON-SCLERACTINIAN CORALS			
Helioporacea (blue corals)	*Heliopora* spp.	✓	✓
Alcyonacea (soft corals)	*Nephthya* spp.	✓	✓
	Xenia spp.	✓	✓
	Sarcophyton spp.	✓	✓
	Sinularia spp.	✓	✓
	Lobophyton spp.	✓	✓
	Junceela spp. (Seawhip)		✓
No. scleractinian coral taxa		20	34
No. non-scleractinian coral taxa		6	7
No. all taxa		26	41

2.1.3 A Comparison with Coral Assemblages in the Region

There have been clear declines in the condition of inshore coral communities in many regions of the Great Barrier Reef for many years due to cumulative impacts from physical disturbance associated with tropical cyclones and storms along with elevated loads of nutrients and suspended sediment (Thompson et al. 2016). In the Mackay Whitsunday Region, however, coral communities have been the exception with average coral cover remaining at a similar level over the last decade. Further, in the Mackay Whitsunday Region the level of coral cover has been consistently ‘high’, even though turbidity in the area is considered to be relatively high compared to other regions (Thompson et al. 2016).

The high cover in the Mackay Whitsunday Region has been maintained due to a lack of acute disturbances in recent decades as well as the selection for species tolerance of high turbidity (Thompson et al. 2016). AIMS monitors inshore corals along transects at 2 and 5 m depths at 10 Whitsunday Islands and has recently published data from the 2014-15 surveys (Thompson et al. 2016). They indicated average hard coral cover among islands ranges between 13 and 68% at 5 m below LAT and between 19 and 59% at 2 m below LAT (**Table 3**). Data collected by BMT WBM (2015) and Cardno (2015 and 2016 Surveys) measured the average cover at Lindeman Island in front of the existing jetty to be 51% at 5 m below LAT and between 19 and 68% at 2 m below LAT (**Table 3, Figure 2)**. While there are definite patches of higher coral cover at Lindeman Island, these data indicate that average coral cover near the proposed safe harbour is comparable to other Whitsunday islands, although in the upper range of cover observed for the region. These data are also in contrast to statement made in a report by GBRMPA (2015) who considered the coral cover to be particularly high and unusual for the Whitsundays region, based on observations at a small number of spot dives.
GBRMPA’s (2015) report also considered that the large proportion of habitat forming corals (bushy and branching *Acroporidae* corals) on the south side of Lindeman Island on the fringing reef in front of the existing jetty to be uncommon for inner-shelf fringing reefs which are generally characterised by patches of massive corals and very low cover of branching corals. Bushy and branching corals are known to provide habitat for numerous reef fish (Wilson et al. 2008) and invertebrate species (Stella et al. 2011) by increasing the habitat complexity and providing food resources. Again, the recently published data presented in Thompson et al. (2016) indicates that the average cover of bushy and branching corals (*Acropora, Pocillopora* and *Seriatopora* combined) for Lindeman Island on the fringing reef in front of the existing jetty (totalling 33.8%) is at similar levels at 2 m LAT to many of the Whitsunday islands and much less at 5 m LAT (**Table 3**). Cover of massive

Porites corals at Lindeman was within the range seen at similar depths at the other Whitsunday islands. Given the differences between the lengths of transect used in Thompson's (2016) study with those used at Lindeman Island it is difficult to compare diversity of corals at Lindeman Island with that at other Whitsunday islands.

In summary, although the coral community on the fringing reef in front of the existing jetty appears to have flourished despite the majority of inshore reefs in much of the Great Barrier Reef suffering high levels of degradation, coral cover and growth form in the project area is not considered to be particularly high or unusual for the Whitsundays region.

Table 3. Coral cover (%) at two depth strata in the vicinity of the safe harbour at Lindeman Island and at other locations in the Whitsunday region.

Reef	Depth	Acropora	Alveopora	Caulastrea	Cyphastrea	Diploastrea	Echinophyllia	Echinopora	Favia	Favites	Fungia	Galaxea	Goniastrea	Goniopora	Hydnophora	Leptoseris	Lobophyllia	Merulina	Montipora	Mycedium	Oxypora	Pachyseris	Pavona	Pectinia	Platygyra	Pleisiastrea	Pocillopora	Podobacia	Porites	Psammocora	Seriatopora	Stylophora	Symphyllia	Turbinaria	Other	TOTAL HARD	Soft Coral
Hayman Is	5	3.8		0.1		1.9	0.2	1.3	0.9	0.5	*	0.1	0.6	0.2			0.6	2.3	11.6	0.8	0.5	3.1	0.2	0.7	0.5		0.2		2.1		1.8	*	0.2	0.2	0.5	35	3
Langford Is	5	2.7			0.1	0.8		1.5	1.3	0.4			0.5	6.1	0.2		0.7	0.2	1.1	0.1	*	0.1	3.0	0.4	0.1		0.1	*	4.1		0.2	*		0.1	1.2	25	3
Border Is	5	3.0			0.2	0.4	0.2	0.3	1.2	0.4	0.1	0.1	0.4	11.5	0.6		1.2	0.3	1.2	0.3	0.7	0.5	0.5	1.1	0.6		0.2		5.4		1.0	0.3	*	0.3	0.6	33	3
Hook Is	2	2.7				1.1		0.2	0.4	1.6	*	*	0.3	0.1		0.4		0.2	2.3		0.3	0.6			0.3		0.1		5.1			1.1		1.6	0.5	19	4
	5	2.6			0.2	0.2		0.3	1.3	0.2		0.2	0.5	5.6	*		0.5		3.7		0.1	1.0	0.8	0.1	0.5		0.1		8.8			0.1		1.3	1.8	30	3
Double Cone Is	2	34.3	0.4		*		0.1	1.3	*		*	5.4	0.3	4.0	0.3		0.9	1.8	5.6		0.1	0.3		0.8	0.3		0.3		0.6					1.2		58	6
	5	5.4	0.1		0.2	0.9		0.7	0.2	0.5	0.1	2.1		48.4			1.7	0.3	0.1		0.3	0.6	1.1	1.1		0.2	0.1	0.1	4.1						0.1	68	2
Daydream Is	2	16.6						0.3			*		*	0.1			0.7	0.1	0.9	0.3	0.7	0.3		0.4			0.4	0.1	1.4						0.3	23	1
	5	16.6						0.3	0.4		*	*	0.2				0.3		4.3	0.8	0.3		0.5	0.2			0.1	3.1		0.8	0.2				0.3	28	0
Dent Is	2	27.9			0.3			0.9	*			1.6	0.2	4.3		0.2	1.9	1.8	0.6			0.3	2.3	2.9	0.1				11.1	0.2		0.3		1.1	0.6	59	3
	5	18.7	0.2				0.1	0.8	0.4	0.3	*	1.7	0.2	12.6	0.2	1.2	1.5	1.4	0.8	0.3	2.9	2.1	0.4	.51	0.3		0.1	0.3	2.3			0.4		0.1	1.1	51	1
Shute Harbour	2	31.1		0.4	*				0.3	0.3		0.1		3.6	0.4		0.6	0.3	3.2	0.8	0.6	0.1	0.6	1	0.3		0.8		0.3	0.1	0.1	0.3		0.1	0.9	46	2
	5	8.0			0.1	*			*	0.2		0.4	0.3	3.2			1.4	0.6	3.1	0.7	1.6	0.3	0.1	2.1				0.3	1.2			0.4		0.1	1.4	26	1
Pine Is	2	6.8			*			*	0.2	0.2	0.1	21.6	*	0.3	0.5	*	1.4	0.7	7.6	0.1	1.3	0.9		3.1			0.8	0.3	2.6					0.1	0.4	49	1
	5	1.8					1.3	0.3	0.4	0.1	0.1	8.3	0.1	2.9	0.2	0.3	2.3	0.1	3.9	1.8	2.0	5.1		6.0				1.2	1.0					0.1	1.7	41	1
Seaforth Is	2	0.8	0.3					0.3	0.5	1.0	0.1	*	0.2	1.9	*		0.6	0.1	0.1			0.3	6.5		0.1		0.3	0.2	6.7					0.1	0.9	21	2
	5	0.3		0.3		0.5		*	0.3	0.1	*	*	0.6	5.7	*		0.2		0.7		0.1	0.1	0.7		0.3			0.1	1.8					0.4	0.8	13	2
Lindeman Is	2	13.3	20.5						1	1							3										8.5		4.7		11			3	2	68	14
	5	1.0	39.8										1.0				1.0												7.5						1.0	51	4

*data <0.1%

[1] Data estimated at each site from 5 x 20 m transects (Thompson et al. 2016)

[2] Data estimated from 7 x 5 m transects

2.2 Beaches and Intertidal Rocky Shores

There is limited information available regarding the beaches and intertidal rocky shores of Lindeman Island. Although there have been no studies of biota specifically occurring on the existing resort beach or adjacent rocky shores there have been many studies of biota on similar beaches and shores in other parts of Australia from which to draw inferences about biota at Lindeman Island.

2.2.1 Beaches

Lindeman Island has seven beaches, including the resort beach immediately west of the existing Jetty (refer to **Figure 1, Figure 4**); Plantation Beach in the southeast; Turtle Bay in the northeast, Gap Beach in the north; Boat Port in the northwest; and Coconut Beach on the western side of the Island. The existing resort beach consists of coarse sediment and extends for about 225 metres west of the existing jetty. The main structures of the existing resort are located directly behind the beach. Sandy beaches were once regarded as marine deserts by many ecologists because of their apparent lack of life (reviewed by McLachlan 1983). Although their ecology is not completely understood, they are now recognised as dynamic habitats that have great productivity and diversity.

There are four main groups of biota found in beach habitats: infauna and epifauna, plankton, fish and birds. Broad-scale studies of macroscopic infauna (macrofauna) have identified three major taxonomic groups (crustaceans, polychaetes and molluscs) but over 100 species can occur (Dexter 1983). Smaller animals (meiofauna) live in the interstices between sediment particles, and these have received less attention than the macrofauna. Meiofaunal assemblages are thought to be dominated by nematodes (Nicholas and Hodda 1999). The upper area of exposed sandy beaches (i.e. above the swash zone) is typically inhabited by several species of amphipods, isopods, insects and ghost crabs (Brown and McLachlan 1990, in Barros 2001). In times of rough weather, the upper area of exposed sandy beaches may have vast amounts of dislodged seaweed washed onto them. These depositions of seaweed, known as ‘wrack’, provide refugia by serving as food or shelter to numerous intertidal invertebrates or birds (Chown 1996 and Pennings et al. 2000, in Orr et al. 2005). They also release nutrients following bacterial decomposition. Very little is known of the plankton in beach habitats. Phytoplankton (planktonic plants) can occur in the water column and in beach sediment. Diatoms often dominate both groups. Zooplankton (planktonic animals) can also occur in beach habitat and provide food for fish and shore birds (see below). Fish, that would generally reside on the subtidal reef flat offshore from the resort beach, or in deeper water, would potentially forage on the lower parts of the beach at high tide.

Shore birds are one of the few large organisms that can occur on intertidal and dry sandy beach habitats and in waters adjacent to beaches. Shore bird foraging habitat typically includes shallow waters and sandflats and along open coasts. Roosting is common along sheltered and occasionally open coastlines on sandy beaches above the high tide mark, while some shore birds roost on elevated areas. Although the majority of the species are diurnal, some forage nocturnally as well (e.g. Eastern Curlew). Shorebirds are typically carnivorous or omnivorous, eating worms, molluscs, crustaceans, fish and insects.

Figure 4. The beach in front of the existing resort at Lindeman Island. Photo: Dr Marcus Lincoln Smith, 20/1/2016.

2.2.2 Intertidal Rocky Shores

Intertidal rocky shores generally support diverse floral and faunal assemblages, including gastropods, sponges, ascidians, soft and hard coral and macroalgae (e.g. Underwood and Denley 1984). Intertidal rock shores can be grouped broadly into two categories; rock platforms and boulder fields, and both of these occur in the south western tip of the island within the project marine area (refer to **Figure 1, Figure 5**).

The most general intertidal habitat is the broad expanse of a rock platform. Rock platforms occur in intertidal areas, seaward of the boulder fields and beaches of the south western tip of the island. The effects of waves and tide, which vary from low to high levels across the rock platform, influence the types of plants and animals in the intertidal habitat. As a result, assemblages on intertidal rock platforms are usually categorised within the low, mid and high shore. Although there is much overlap of species into each shore level, generally the low shore is dominated by foliose algae, ascidians and some corals, mid shore by gastropods and oysters and high shore by barnacles. Taxonomic richness is typically greater on the lower portions of rocky shores. Shore birds forage on intertidal boulder field and rock platforms. Intertidal habitats, particularly rock platforms, are subject to human disturbance. In populated areas, some people collect animals and plants for food or bait, overturn boulders for inspection, or step on organisms during their passage over the rock platform, causing damage to flora and fauna. Trampling, particularly where there are mats of algae present, can have localised impacts and may alter the abundance and composition of species in the intertidal zone (Povey and Keough 1991).

Boulder fields occur where large or small boulders accumulate on a shore, this occurs between the rock platforms and beaches of the south western tip of the island. Intertidal boulder fields are very important habitats in some parts of the world, although in this region, they are very scattered along the coastline. Intertidal boulder fields provide a habitat for a wide variety of animals and plants, which can live on the tops and sides of boulders, the underside of boulders and below boulders (Underwood and Chapman 1995). While many species living on the surface of boulders are generalists and are often found in other intertidal habitats (i.e. rock platforms) some species, are found only on the underside of boulders and can be considered habitat-specialists. The diversity and abundance of organisms living on intertidal boulders can vary between individual boulders, due to the size of boulders and different placements. Diversity is generally greater on the underside of boulders and this could be due to these areas providing refuge from abrasion (McGuiness and Underwood 1986).

Artificial structures in the project marine area, such as the existing jetty, also provide hard intertidal surfaces for sessile marine communities.

Figure 5. Boulder field (top) with the resort beach in background and intertidal rock platform (bottom) at Lindeman Island. Photo: Dr Marcus Lincoln Smith, 20/1/2016.

2.3 Aquatic Vegetation

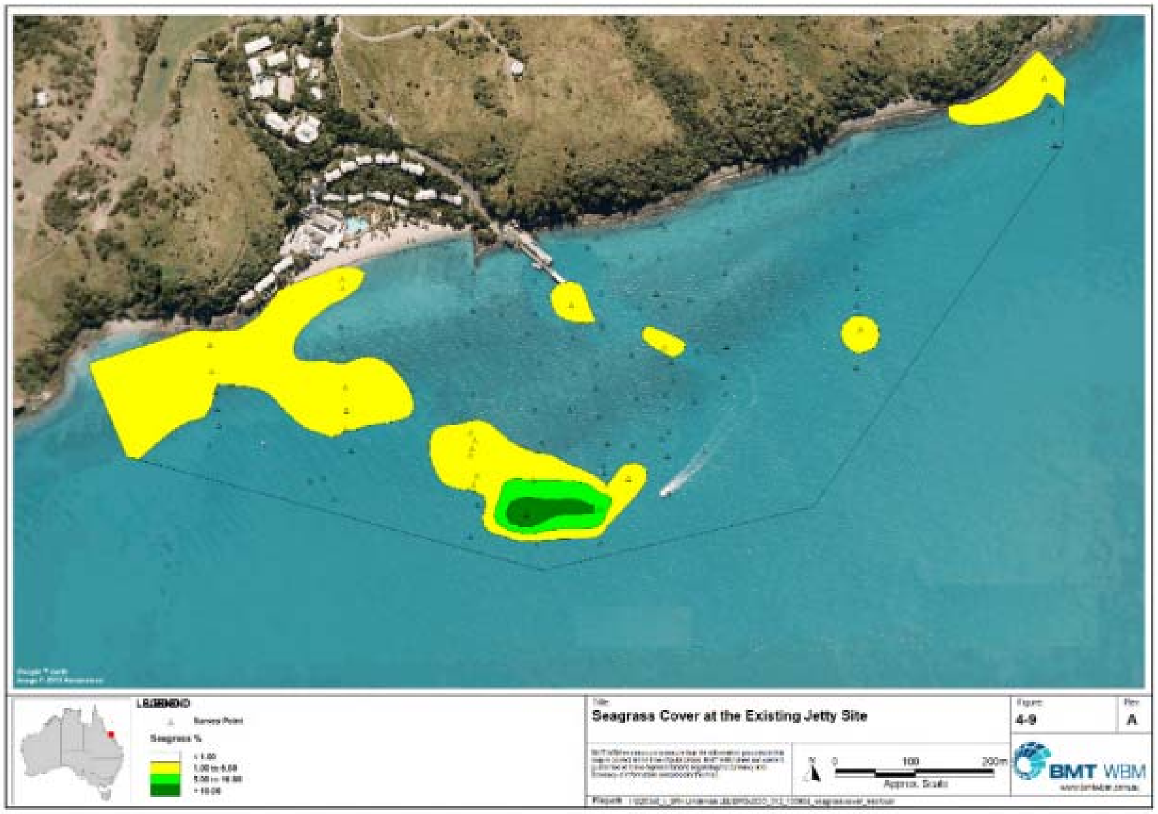
2.3.1 Seagrass

Seagrass assemblages are generally sparse throughout the shoreline around Lindeman Island (BMT WBM 2013). The densest seagrass meadows are located south of the existing jetty in soft sediment beyond the edge of the reef (BMT WBM 2013; refer to **Figure 6**) and, outside of the project marine area, at Boat Port and Coconut Beach. *Halophila* spp. (including *H. ovalis*, *H. decipiens* and *H. spinulosa*) and *Halodule uninervis* are the two most common seagrass taxa in the project marine area. These are fast growing, early colonising species that are known to survive well in unstable (shifting sediments) or depositional (subject to sedimentation) environments (Green and Short 2003). Both *Halophila* and *Halodule* are known to recover rapidly after disturbances, as they often establish large seed reserves in the sediment and/ or grow and expand rapidly from remaining patches (Short et al. 2010a, 2010b).

During a recent survey, seagrass meadows were generally sparse (mostly between 1% and 5% cover and one patch south of the existing jetty with cover > 10%), with a low above-ground biomass, with some soft and hard corals occurring in the same area (BMT WBM 2013). Some *Halophila spinulosa* was found in the dredged channel at the jetty site. A comparison of the distribution of seagrass in the latest available survey (BMT WBM 2013) with the survey undertook by Hyland et al. (1988) indicates that seagrass distribution did not change substantially over time.

Halophila and *Halodule* are a preferred seagrass food source sought by Dugongs (*Dugong dugon*) (Anderson 1998) and also a food source of Green Turtles (*Chelonia mydas*) (Lanyon et al. (1989).

Figure 6. Map of seagrass cover in the Survey area in the vicinity of the existing jetty (Source: BMT WBM).

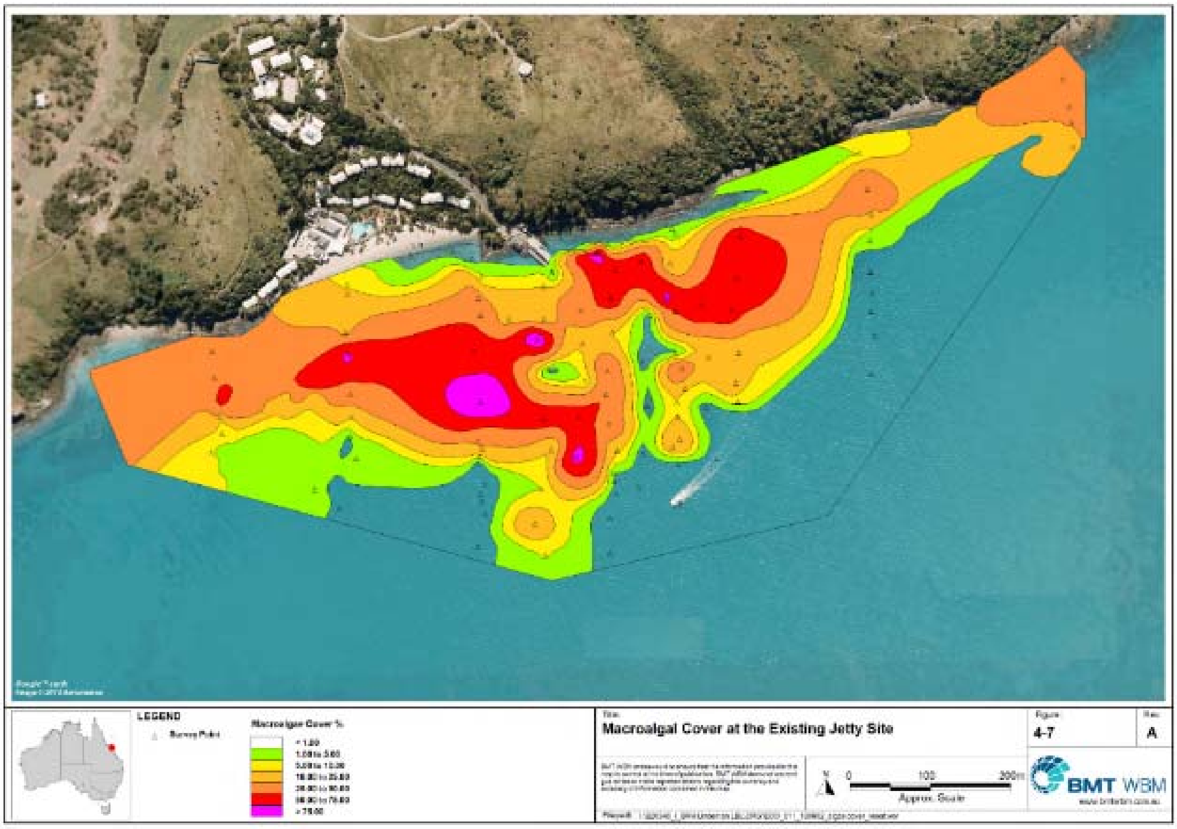


2.3.2 <u>Macroalgae</u>

Macroalgae generally requires hard, rocky reef for attachment and is common on the reef flat on the southern side of Lindeman Island (refer to **Figure 7**). Beds of macroalgae are highly productive (Biber et al. 2004) and may exert physical control over other attached benthic fauna, including corals (McCook et al. 2001, River and Edmunds 2001, McClanahan et al. 2002a, Box and Mumby 2007, Foster et al. 2008) and provide structural and functional integrity for macrofauna and fish (Tuya et al. 2008; Pérez-Matus et al. 2010). Detached, floating rafts of *Sargassum* also provide an important pelagic habitat and facilitate dispersal of biota among reefs, including juvenile sea turtles (Costen-Clements et al. 1991, Vandendriessche et al. 2006). Tropical *Sargassum* exhibits a seasonal growth pattern, where the biomass of individual plants is greater in summer than in winter, resulting in a larger standing crop during the summer months (Cribb 1990; Martin-Smith 1993; Vuki and Price 1994). Monitoring of algae is important as an increase in cover of algae of a particular type may indicate local nutrient enrichment or increased siltation or excess turbidity (Fabricius et al. 2005). *Sargassum* spp., in particular, may be an effective indicator of nutrient loads (Schaffelke and Klumpp 1998), as well as increases in filamentous algae (McClanahan et al. 2002b).

Macroalgae is common on intertidal and shallow subtidal reefs all around Lindeman Island (BMT WBM 2013). Macroalgae in the Survey area in the vicinity of the existing jetty occurs in amongst living and dead coral as well as on loose rocks in soft bottom substratum with a distribution and abundance pattern virtually complementary to that of corals. The main taxa characterising the assemblages found in the project marine area were *Padina, Sargassum, Dictyota, Laurencia* and *Lobophora*. Macroalgae were abundant west of the existing jetty and in the area in front of the resort beach. The high cover of coral-associated macroalgae within the Survey area is characteristic of many of Queensland's fringing reefs (McCook et al 1997).

Figure 7. Macroalgae cover in the vicinity of the existing jetty (Source: BMT WBM).



2.4 Subtidal Soft Sediment Fauna

Soft sediment habitat exists in the existing channel and turning basin and the benthic habitat beyond the edge of the reef flat fringing Lindeman Island is also soft sediment, which hosts infaunal and epifaunal assemblages. Tropical benthic infaunal assemblages generally contain burrowing organisms such as polychaete worms, amphipod crustaceans, bivalve and gastropod molluscs and other worm-like phyla such as nemerteans and nematodes (which are often abundant). These animals are generally found within the upper 30 cm of the sediment. Species richness and abundance are typically lowest in fine muddy sediment of intertidal areas, and highest in coarse sandy sediments. Benthic infaunal invertebrate communities of the region are typically dominated by filter feeders, which can account for more than 50% of the total abundance and nearly 30% of the species richness (FRC Environmental 2012). As well as being a source of food for organisms higher up the food chain, such as fish and large invertebrates, including some sharks, stingrays and Loggerhead Turtles (Kirkwood and Hooper 2004), they also drive nutrient cycling through reworking of the sediments (bioturbation), altering physical and chemical processes, excreting nutrient-rich wastes and feeding on phytoplankton (Pennifold and Davis 2001).

2.5 Fish, Sharks and Rays, Sea Snakes and Macrocrustaceans

The subtidal rock and reef habitat at Lindeman Island is used by a range of adult and juvenile fish species including cod, butterflyfish, damselfish, wrasses and parrotfish (Cardno Field Survey 2016, **Figure 8**). Over 48 taxa of fish were recorded from depths ranging from 2 to 4 m water depths in the vicinity of the proposed safe harbour (**Table 4**, Cardno Field Survey 2016).

Figure 8. Damsel and butterflyfish in branching corals near the navigation channel at Lindeman Island. Photo: Dr Marcus Lincoln Smith, 20/1/2016.

Fish assemblages of Lindeman Island are typical of inshore waters of the Great Barrier Reef and major reef fin-fish families are likely to be generally similar to those found on reefs located a comparable distance from the mainland. Generally, inshore reefs of the central Great Barrier Reef tend to host fewer fin-fish species compared to mid-shelf or outer-shelf reefs. The dominant fish species of inshore reefs are Pomacentrids, Lutjanids, Chaetodontids and Labrids, while Acanthurids and Scarids are generally found in lower numbers on inshore reefs compared to mid or outer-shelf reefs (Williams 1982, Williams and Hatcher 1983).

Table 4. Fish taxa observed in the Survey Area 19 to 21 January 2016. SJ (small juvenile), J (juvenile), A (adult). Occurrence represented as the number of sites where species was seen from a total of 42 sites visited.

Family	Genus	Species	Common name	Size class / Sex	Occurrence (No. sites)	Abundance (Range)
Clupeidae	-	-	Unidentified "baitfish"	SJ	5	> 50
Serranidae	*Epinephelus*	*merra*	Honeycomb cod	A	2	2 - 5
Serranidae	*Epinephelus*	*sp.*	Unidentified cod	A	1	1
Apogonidae	-	-	Unidentified cardinalfish	SJ	1	1
Plectropomidae	*Plectropomus*	*maculatus*	Bar-cheek trout	J; A	7	6 - 20
Lutjanidae	*Lutjanus*	*decussatus*	Checkered seaperch	J; A	12	6 - 20
Lutjanidae	*Lutjanus*	*quinquelineatus/kasmira*	Five-lined seaperch	J	5	2 - 5
Lutjanidae	*Paracaesio*	*xanthurus*	Yellowtail blue snapper	J	4	> 50
Lethrinidae	*Lethrinus*	*laticaudis?*	Grass emperor	J	11	21 - 50
Nemipteridae	*Nemipterus*	*sp. 1*	Unidentified threadfin bream	J	3	2 - 5
Nemipteridae	*Nemipterus*	*sp. 2*	Unidentified threadfin bream	A	1	1
Mullidae	*Upeneus*	*tragula*	Bar-tailed goatfish	A	2	6 - 20
Chaetodontidae	*Chaetodon*	*sp.*	Unidentified butterflyfish	A	7	6 - 20
Chaetodontidae	*Chaetodon*	*auriofasciatus?*	Golden-striped butterflyfish	J	10	6 - 20
Chaetodontidae	*Chaetodon*	*guentheri?*	Gunthers butterflyfish	A	2	2 - 5
Chaetodontidae	*Chaetodon*	*lineolatus*	Lined butterflyfish	A	2	2 - 5
Chaetodontidae	*Chaetodon*	*rostratus*	Beaked coralfish	A	4	2 - 5
Pomacanthidae	*Pomacanthus*	*sexstriatus*	Six-banded angelfish	A	3	2 - 5
Pomacanthidae	*Chaetodontoplus*	*duboulayi*	Scibbled anglefish	A	1	1
Pomacentridae	*Abudefduf*	*septemfasciatus*	Banded sergeant	A	11	6 - 20
Pomacentridae	*Abudefduf*	*sp. 1*	4-bar sergeant	A	1	1
Pomacentridae	*Chromis*	*margaritifer*	Bicolor chromis	A	25	> 50
Pomacentridae	*Chrysiptera*	*glauca*	Grey demoiselle	A	2	2 - 5
Pomacentridae	*Pomacentrus*	*moluccensis*	Lemon damsel	A	11	21 - 50
Pomacentridae	*Neoglyphidodon*	*melas*	Black damsel	A; J	3	2 - 5
Pomacentridae	*Pomacentrus*	*sp.*	Unid blue-lined head	J	5	6 - 20

Family	Genus	Species	Common name	Size class / Sex	Occurrence (No. sites)	Abundance (Range)
Pomacentridae	-	-	Unid grey+pale yellow throat	J	1	1
Pomacentridae	-	-	Unid translucent, yellow caudal ped	SJ	5	> 50
Pomacentridae	-	-	Light grey gregory	A	11	21 - 50
Pomacentridae	-	-	Unidentified dark grey damsel	J	4	2 - 5
Pomacentridae	-	-	Very pale grey/torquoise	SJ	1	2 - 5
Sphyraenidae	*Sphyraena*	*obtusata*	Striped seapike	J	1	6 - 20
Labridae	*Cheilinus*	*fasciatus*	Scarlet-brested maori wrasse	A	2	2 - 5
Labridae	*Cheilinus*	*undulatus*	Maori wrasse	J	3	2 - 5
Labridae	*Choerodon*	*schoenleinii*	Blackspot tuskfish	A; J	4	2 - 5
Labridae	*Choerodon*	*anchorago*	Anchor tuskfish	J	17	21 - 50
Labridae	*Epibulus*	*insidiator*	Slingjaw wrasse	A	3	2 - 5
Labridae	*Halicoeres*	*sp.*	Unidentified wrasse	J	2	2 - 5
Labridae	*Hemigymnus*	*fasciatus*	Thick-lipped wrasse	A	10	6 - 20
Labridae	-	-	Unidentified wrasses (sev. Spp.)	J	14	> 50
Scaridae	*Scarus*	*globiceps*	Violet-lined parrotfish?	J/Female	3	21 - 50
Scaridae	*Scarus*	*ghobban*	Blue-bar parrotfish	J; SA	8	21 - 50
Mullidae	*Upeneus*	*tragula*	Bar-tailed goatfish	J	2	2 - 5
Blenniidae	*Meiacanthus*	*grammistes*	Black-banded blenny	A	1	1
Blenniidae	*Plagiotremus*	*tapeinosoma*	Yellow sabretooth blenny	A	1	1
Gobiidae	-	-	Unidentified shrimpgoby	A	1	2 - 5
Siganidae	*Siganus*	*vulpinus*	Foxface rabbitfish	A	16	21 - 50
Acanthuridae	*Acanthurus*	*grammoptilus*	Ring-tailed surgeonfish	A	1	2 - 5

Fish species protected under Great Barrier Reef Marine Parks Regulations (1983) include Syngnathiforms (e.g. seahorses, pipefish, seadragons), all species of the *Pristidae* family (Sawfish), all species of the genus *Epinephelus* (greater than 100 cm in size), *Epinephelus lanceolatus* (Queensland Groper), *Epinephelus tukula* (Potato Rockcod), *Chelinus undulatus* (Humphead Maori Wrasse) and *Cromileptis altivelis* (Barramundi Cod).

Sharks and rays also occur in the project marine area. Black Tip Reef Sharks (*Carcharhinus melanopterus*) were observed over shallow subtidal reef by Cardno in October 2015. Many other sharks and rays would forage in the various nearshore and deeper habitats of the project marine area, including White Tip Reef Sharks (*Triaenodon obesus*), Grey Reef Sharks (*Carcharhinus amblyrhynchos*), as well some threatened or migratory species which would potentially be found on the edge of the reef or in deeper waters of the project marine area very occasionally (i.e. Great White Shark, *Carcharodon carcharias;* Whale Shark, *Rhincodon typus;* Giant Manta Ray, *Manta birostris*; Reef Manta Ray, *Manta alfredi*) (refer to **Chapter 26**).

Sea snakes are predatory marine reptiles that inhabit a range of habitats, including sandy bottom habitats, reef habitats and pelagic habitats (Stokes 2004). Sea snakes are likely to forage in all of the subtidal marine habitats in the project marine area. Sea snakes (family Hydrophiidae) are listed under the 'marine' schedule of the EPBC Act, and are consequently protected within Commonwealth Marine Waters such as the GBRMP. The highest diversity of taxa occurs in northern Australia and south-east Asia. Basic biological, distributional, and ecological information is limited for most Sea snakes (Lukloschek 2008), with the Olive Sea snake (*Aipysurus laevis*) one of the most studied species. The Olive Sea snake typically occurs at discrete reefs, with habitat preference related to reef location, exposure and area; their distribution does not appear to be related to the protection status of reefs (GBRMP zoning) (Lukoschek 2008). Factors driving spatial and temporal changes in abundances of Sea snakes are poorly understood (Lukoschek 2008 and references cited within).

The conservation status of Sea snakes is poorly known. Recent reports suggest declining abundances and loss of endemic species on protected Australian reefs. Threatening processes for reef-associated species, such as the Olive Sea snake, are unclear, but appear to include habitat degradation and loss and fisheries bycatch (Lukoschek 2008 and references cited within).

Artificial structures in the project marine area, such as the existing jetty, also provide hard surfaces for sessile marine communities. This structure is likely to provide habitat for several taxa including fishes, sea snakes, echinoderms, polychaetes and crustaceans.

There is limited information available regarding macrocrustacean communities of the region and in the waters around Lindeman Island. Communities are expected to be typical of other Queensland inshore waters and include (Queensland Museum 2011):

- Prawns and shrimps from the genera *Penaeus*, *Periclimenes*, *Stenopus* and *Thor;*
- Mantis shrimps from the genus *Odontodactylus*;
- Lobsters and crayfish from the genera *Allogalathea*, *Callianassa*, *Ibacus*, *Neaxius*, *Panulirus* and *Thenus*;
- Hermit crabs from the genera *Cilianarius* and *Dardanus*; and
- Crabs from several genera including *Uca*, *Mictyris*, *Trapezia*, *Charybdis*, *Portunus*, *Scylla* and *Ocypode*.

2.6 Marine Turtles

Four of the six species of marine turtles known to occur along Australian coasts would be common in the project marine area. These include Flatback (*Natator depressus*) and Green (*Chelonia mydas*) turtles, and less commonly the Loggerhead (*Caretta caretta*) and Hawksbill turtles (*Eretmochelys imbricata*). The Leatherback (*Dermochelys coriacea*) and Olive Ridley (*Lepidochelys olivacea*) turtles are less likely to occur in the project marine area but may occur there very occasionally. All of these turtles are listed threatened and migratory species under the EPBC Act.

Marine turtles are migratory and highly mobile species, moving between feeding grounds and rookeries, with males and females undertaking migrations of up to 3000 km. Marine turtles tend to nest on mainland or island beaches. Flatback and Loggerhead turtles nest on the mainland in the Mackay region but Lindeman Island is not a known nesting ground for any of the marine turtle species.

Marine turtle species are experiencing serious threats to their survival (Environment Australia 2003; EHP 2015). The main threats include:

- Habitat degradation and destruction, particularly nesting beaches, seagrass meadows, mangrove forests and coral reefs;
- Entanglement and drowning in fishing gear (e.g. trawler nets) and shark nets and drum lines;
- Ingestion of plastic bags;
- Pollution and declining water quality;
- Disease; and
- Indigenous over-harvesting of both turtles and eggs, and predation of eggs by native and introduced animals.

The threat posed by trawler nets has been substantially reduced with the implementation of the *Fisheries East Coast Trawl Management Plan 1999*, which requires trawlers to use approved turtle exclusion devices. Fibro-papillomatosis disease is a common disease amongst turtles in some areas, which may be related to high industrial or agricultural runoff (Kirkwood and Hooper 2004). There is limited information on the prevalence of this disease in the project marine area.

The number of marine turtle strandings (sick, injured or dead individuals) recorded in the GBRMP from 1999 to 2011 is presented in **Table 5**, giving an indication of the threats to these species. The most common species across all years is the Green Turtle *Chelonia mydas* with 73% of records, followed by the Hawksbill Turtle *Eretmochelys imbricata* with 6% of records (EHP 2011a). The major causes of marine turtle strandings along the Queensland coast from 1999 to 2011 included:

- Boat strike, propeller damage or fractures;
- Queensland coast shark safety program;
- Dredging;
- Ingestion of synthetic material;
- Hunting;
- Fisheries bycatch or entanglement in fishing gear;
- Predation (e.g. shark attack); and
- Disease not directly linked to anthropogenic sources.

Table 5. Summary of sick, injured or dead marine turtles by geographical location around the Queensland coast, January 1999 to 2011. Lindeman latitude is 20.5. From EHP 2011a.

Year	GOC	Qld (east coast in 1° latitude blocks)																				Total
		9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
1999*	18		2		2		4	1	7	1	9	37	8	21	4	31	51	110	39	203	6	554
2000*	4					1		1	9	7	10	44	18	15	11	36	26	71	38	197	7	495
2001*	8				1			2	12	4	21	64	28	20	15	24	43	62	31	192	6	533
2002*	30								15	5	8	54	12	14	4	46	31	61	25	229	9	543
2003*	6+ 11?							3	5+1?	6	4	36+3?	8+1?	25	10	68	26	57	55+ 1?	212+5?	6	527+22?
2004*	26							1	25	6	4	61+2?	13	10	2	53	25+ 1?	59+2?	53	225+3?	3	566+8?
2005*	73								21+2?	6+ 2?	6	40	9	11	2	29 +1?	16	43+1?	49	259$_{35}$+7?	1	563+14?
2006*	14							1	19	14	5	29	16+1?	24+ 7?	10	57	30+ 1?	69+1?	75	253$_{19}$+22?	3	617+32?
2007*	22	8	2						16	14 +1?	11 +1?	39 +2?	23 +4?	25 +1?	2	21 +5?	15	65+2?	126	352+29?	9	749+45?
2008*	19	1	3	1			2	1	26	7	6	35	25+1?	26+ 1?	9	55	20+1?	69+ 1?	111	368+33?	4	788+37?
2009*	1			7	1			2	16	7	10	44	21+1?	20	4	51	31	113	101	489+8?	4	918+9?
2010*	18						5	6+1?	16+1?	10	23+ 4?	147+3?	37+2?	14	19	52	28+1?	73+5?	78	328+2?	2	856+19?
2011	7		5				5	9	52+4?	35+ 1?	66+ 1?	308+16?	76+2?	84	43	323^{f}+ 1?	52	146	146	431+8?	5+1?	1793+34?

2.7 Marine Mammals

Several marine mammals (whales, dolphins and porpoises) listed under the 'cetaceans' schedule of the EPBC Act and the Sirenian *Dugong dugon* would occur in the project marine area. Several species are also listed as under the 'threatened' or 'migratory' schedule of the EPBC Act and NCWR, and in the IUCN Red List (refer to **Chapter 26**).

The number of marine mammal strandings in the region (latitudinal block 20°of the Queensland coast) from 1999 to 2011 is presented in **Table 6**. The major causes of marine mammal strandings along the Queensland coast give an indication of threats to these species. These were:

- The Queensland coast shark safety program;
- Hunting;
- Fisheries bycatch or entanglement in fishing gear;
- Boat strike, propeller damage or fractures; and
- Disease not directly linked to anthropogenic sources.

Table 6. Summary of cetaceans and pinniped strandings by year and identified sources of mortality (suspected or confirmed) for Queensland, from 2001 to 2011. Lindeman latitude is 20.5. From EHP 2011b.

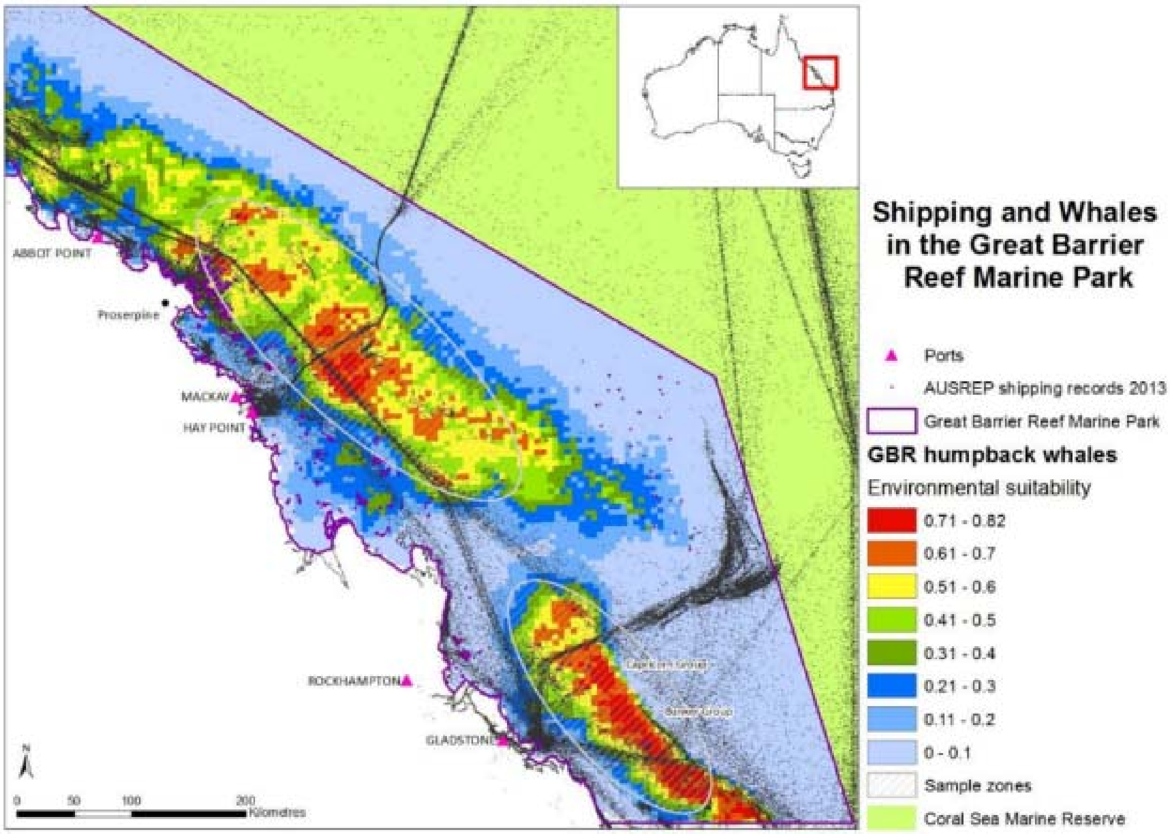
Cause of stranding and mortality	Year										
	2001*	2002*	2003*	2004*	2005*	2006*	2007*	2008	2009	2010	2011
Natural causes											
Disease and ill health	3	2				4	3	3	4	1	9
Trapped by natural event		1				(1)	(3)				
Stingray barb	1										
Predation/ predator attack				2	1				(1)		1
Other	3								1	2	
Anthropogenic causes											
Disease			1								
Boat strike/ fractures			1	3	2	(2)	(3)	(5)	1		(1)
Netting/crabbing/ entanglement in ropes or fishing line	4	1(1)	(2)	3(3)	1	1(5)	(11)	(2)	2 (1)+(1')		(5)
Non-permitted hunting											
Shark control program	10 (1)	8 (1)	14 (2)	12(7)	21 (9)	21 (6)	21 (4)	25 (8)	14 (7)+(1')	21 (1)	15 (5)
Ingested foreign material/fishing hooks									1		
Research											
Undetermined	1	1			2(1)	3	3	(1)	1		2
Undetermined cause	19(4)	22(6)	15(1)	28(1)	25(5)	20(4)	31(8)	20(10)	31(3)	34(3)	43(4)
Total	41(5)	35(8)+2?	31(5)+2?	47(8)+8?	52(15)+3?	49(18)+6?	52(29)+2?	48(26) +2?	55(12)+2'+3?	58(4)+6?	70(15) + 3?

The most common cause of mortality was ‘undetermined’. Of the known causes of mortality, the Queensland coast shark safety program was the most common known source of mortality, followed by commercial fishing and disease and ill health. Injury from boat strike was a small proportion of the reported strandings.

2.7.1 Whales

There are two core Humpback Whale habitat areas in the Southern Great Barrier Reef (refer **Figure 9**). One of these is located southeast of Lindeman Island, within the inner reef area and extending for approximately 100 km parallel to the coast. The ‘Whale Protection Area’ is designed to minimise disturbance to whales and is an important calving ground for humpback whales between May and September. Despite no sightings of marine mammals during a recent marine ecology survey at Lindeman Island, whale sounds were heard loudly and continuously underwater in a survey by BMT WBM (2013). Along with Humpbacks, Minke and Bryde’s whales are also likely to use deeper waters of the project marine area.

Figure 9. Model prediction of average environmental suitability for Humpback whales in the Great Barrier Reef Marine Park along the southern coast of Queensland. From Smith et al. 2012.



2.7.2 Dolphins

Indo-Pacific Humpback, Australian Snubfin, Bottlenose, Common and Risso's dolphins are likely to occur in all subtidal habitats of the project marine area where they would hunt, often in groups, for fish and cephalopods.

2.7.3 Dugongs

The dugong *(Dugong dugon)* is listed under the 'marine' and 'migratory' schedule of the EPBC Act and under the 'vulnerable' schedule of the NCWR Act (refer **Chapter 26**). Internationally, it is listed under the CMS and the CITES and as 'vulnerable' on the IUCN Red List. Dugongs feed almost exclusively on seagrass, particularly *H. uninervis*, *H. ovalis* and *H. spinulosa*, and principally inhabit seagrass meadows (Lanyon & Morris 1997). Their dependence on seagrass for food generally limits them to waters within 20 km of the coast, although individuals have been sighted further from the coast during aerial surveys (Marsh and Lawler 2002). While there is little scientific data on dugong within the project marine area, dugong may occur in the project marine area on occasion where seagrass occurs.

2.8 Marine Birds

Marine birds, including a number of threatened and migratory birds (refer **Chapter 26**), would occur in the project marine area. These can be grouped broadly into those found commonly on coastal shores, including beaches, rocky shores, mudflats, tidal wetlands and lagoons (shore birds) and those that spend most of their time at sea (sea birds).

2.8.1 Shore Birds

Shore bird foraging habitat typically includes shallow waters and mudflats/sandflats of estuaries, channels, coastal lagoons, harbours and along open coasts. Shorebirds are typically carnivorous or omnivorous, eating worms, molluscs, crustaceans, fish and insects. Although the majority of species are diurnal, some forage nocturnally as well (e.g. Eastern Curlew). For many shore birds, roosting occurs along sheltered and occasionally open coastlines on sandy beaches above the high tide mark, while some roost on elevated areas. Foraging and roosting habitats for shore birds occur in the project marine area. Life cycles of shore birds vary. Some nest in colonies while others are solitary nesters or nest amongst other birds. Many shore birds first breed from one year of age though some breed later. The nesting period is generally between 20 to 35 days with 2 to 5 eggs in each clutch. Ground nesting is common with the nest consisting of a scrape in the ground, sometimes lined by pebbles or seaweed. Nesting along exposed beaches, islands and spits, or among sparse vegetation is not uncommon; however, most of the threatened or migratory bird species potentially occurring in the project marine area do not breed in Australia.

Migratory shore birds travel up to 26,000 km and on these return journeys they may cross state boundaries, countries and oceans, linking the ecosystems, communities and governments responsible for providing suitable habitat to support the survival of these species.

2.8.2 Sea Birds

Sea birds can be found foraging and breeding across all Australian Commonwealth Waters. Potential foraging habitats for sea birds occur in the deeper waters of the project marine area. The lifestyle, behaviour and physiology of sea birds are varied but species exhibit similar feeding niches. Sea birds feed on the surface as well as dive for prey. They are mainly colonial, with nesting sites usually densely populated and on islands further south than Lindeman Island. Many species are highly dispersive or undertake long annual migrations both north-south and east-west, which can occur both after the breeding season for longer periods and to forage for chick provisioning.

3 Potential Impacts and Mitigation Measures

Note: A safe harbour is no longer proposed and as such the impacts associated with this structure are no longer relevant.

This section considers the potential impacts of proposed activities on the marine area. A qualitative risk analysis was carried out to identify potential risks associated with the project, to determine and evaluate the level of risk associated with activities and to assist in identifying appropriate options to mitigate these risks. The risk assessment process was adapted from the GBRMPA Environmental Assessment and Management (EAM) Risk Management Framework (GBRMPA 2009a), itself based on the *Australian and New Zealand Standard guidelines for risk management (AS/NZS 4360:2004)* and the *Handbook for Environmental Risk Management – Principles and Process (HB 203:2006)* (Standards Australia 2006) which are considered international benchmarks in standard risk management. Risk is defined as the chance of something happening that will have an impact on objectives. It is measured in terms of consequences and their likelihood. 'Risk' in the environmental context should be thought of as the environmental consequences of a given severity and the likelihood of that particular consequence occurring (AS/NZS 4360: 2004).

Note: Due to GBRMPA's framework, this section varies from the standard risk assessment adopted in other sections.

Potential impacts/hazards from the project in relation to the existing marine environment of the project marine area were identified through a combination of specialist advice, literature review, stakeholder consultation and from issues identified in the terms of reference for the EIS. The risk analysis identified the relative significance of hazards both before and after the treatment of risks (i.e. after consideration of proposed mitigation).

Potential impacts/hazards may be associated with construction of the safe harbour as well as operational activities of the safe harbour and the resort.

The following construction phase activities were considered to be potential hazards:

> Removal / relocation of corals in the safe harbour footprint;

> Initial dredging for construction of the safe harbour;

> Development of the safe harbour comprising **50 - 60** berths, ferry terminal, etc.;

> Transport to and from the island of construction workforce, equipment and materials;

> Increased presence and visitation to the island;

> Generation of construction and domestic waste; and

> Stormwater and waste water management from civil construction works.

The following operational phase activities were considered:

> Increased presence and visitation to the island;

> Increased vessel traffic;

> Transport to and from the island of guests and resort and maintenance personnel;

> Reef utilisation including, recreational fishing, diving, snorkelling;

> Utilisation of resort services including spa resort, golf course;

> Operations of the safe harbour.

These activities may result in the following potential impacts to the marine environment:

> Loss or gain of marine habitat;

> Increased turbidity and sediment deposition;

> Altered hydrodynamics;

> Degradation of water quality through spills of hydrocarbon and other contaminants, nutrient enrichment, littering and waste disposal;

> Vessel strikes on marine mammals;
> Disturbance to marine fauna from artificial lighting;
> Introduction of marine pests;
> Underwater noise; and
> Damage and disturbance from increased reef visitation.

A risk analysis was conducted to estimate the level of consequence of individual potential impact and the likelihood of the impact occurring, and a score was assigned to each consequence and likelihood. The product of the likelihood and consequence ratings of each potential impact was used to derive a risk level for individual natural values as shown in **Table 7.**

The rationale for scoring likelihood and consequence of a potential impact occurring is given in **Table 8** and **Table 9.** Scores of likelihood and consequence are then combined into a matrix to provide a qualitative assessment of risk. Based on this, each risk is identified as low, moderate, high or extreme. This does not mean that the project should not proceed (i.e. if the level of risk is high) or that an issue should be ignored if the level of risk is considered low, but rather that the issue may need greater or less effort in management and mitigation or that further research on the receiving environment is required. Consequence criteria were formulated based on the Significant Impact Guidelines for EPBC Act MNES and the EAM Risk Management Framework (GBRMPA 2009) and considered the potential for direct impacts (for example, loss of coral habitat) and indirect impacts (for example, altered community structure in response to altered water quality), and irreversible or temporary impacts.

Table 7. Qualitative measures of likelihood.

Level	Descriptor	Description
A	Almost Certain	Is expected to occur as a result of the project under most circumstances.
B	Likely	Will probably occur as a result of the project in most circumstances.
C	Possible	Could occur and has occurred in similar circumstances.
D	Unlikely	Could occur as a result of the project but is not expected.
E	Rare	Could occur only in exceptional circumstances.

Table 8. Qualitative measures of consequence, based on the EAM Risk Management Framework (GBRMPA 2009) and adjusted to the spatial scale of the project marine area.

Environment		
Level	**Descriptor**	**Description**
1	Catastrophic	Adverse impact to habitat/species throughout 'Conservation Park Zone' of Lindeman Island and potentially outside of this zone – recovery longer than 20 years.
2	Major	Significant local or widespread impact to habitat/species within the project marine area (nearshore areas of the southwestern side of Lindeman Island) – recovery over 10 to 20 years.
3	Moderate	Localised or widespread impact to habitat/species within the project marine area (nearshore areas of the southwestern side of Lindeman Island) - recovery over 5 – 10 years.
4	Minor	Localised impact to habitat/species within the project marine area (nearshore areas of the southwestern side of Lindeman Island) - recovery measurable within 1-5 years.
5	Insignificant	No impact on baseline environment (habitat/species) within the project marine area (nearshore areas of the southwestern side of Lindeman Island) - no additional mitigation required.

Table 9. Risk Matrix (After AS/NZS 4360:2004 and GBRMPA 2009).

			Consequence				
			5	4	3	2	1
			Insignificant	Minor	Moderate	Major	Catastrophic
Likelihood	A	Almost Certain	Moderate	Moderate	High	Extreme	Extreme
	B	Likely	Moderate	Moderate	High	High	Extreme
	C	Possible	Low	Moderate	High	High	Extreme
	D	Unlikely	Low	Low	Moderate	Moderate	High
	E	Rare	Low	Low	Moderate	Moderate	Moderate

E	Extreme risk	Risk is unmanageable and cannot be justified under any circumstances. Measures to reduce risk to a lower level are required.
H	High risk	Risk is significant and requires significant cost-effective measures for risk reduction and/or management.
M	Moderate risk	Routine and cost-effective measures required to reduce and/or manage risk. Risk may be acceptable.

L	Low risk	Risk can be managed by routine procedures and/or no further measures to manage the risk are required.

Key points that need to be recognised in relation to the general risk analysis:

- Potential impacts were identified through a combination of specialist advice, modelling, literature review and stakeholder consultation.
- The categories for environmental consequence are based on duration and spatial scale of potential impacts. Those that are localised but reversible in 1 - 5 years were considered minor, whereas those that would last longer and more widespread have a greater consequence.
- Detailed discussion of the potential impacts of the project and the rationale for the levels of risk are discussed in the following sections.
- The risk analysis identifies the relative significance of risks before mitigation (e.g. implementation of Construction and Operational EMPs for the safe harbour). Risks are re-evaluated with these construction plans in place assuming they include the given recommendations.
- Although some risks are considered to be 'low', further action may be recommended (through routine procedures) as appropriate.
- Risk analysis is an ongoing process and is a tool to help identify the appropriate level of management or mitigation required.

3.1.1 Key Mitigation Strategies

The key mitigation strategy for reducing potential for impacts is the development of an Environmental Management Plan (EMP) for the project (refer to **Chapter 28**). The EMP states the commitments and objectives that are relevant to controlling risk. The EMP contains specific, measurable targets to achieve the objectives. In turn, those targets necessitate the application of certain management actions. In order to continuously improve the effectiveness of the project's environmental management system, key performance indicators (KPIs) and monitoring activities are proposed to measure success in meeting the requirements and identify the need for corrective actions, for instance through proactive, responsive or contingency adaptive management. Reporting, terms and responsibilities complete the EMP which includes a number of supporting management plans such as the Construction EMP and Operational EMP.

Table 10 Overview of Monitoring Plans.

Program	Purpose
Water quality and sub-tidal sedimentation monitoring	Monitor for potential exceedances of water quality triggers and to inform assessment of the attribution of any observed change in sensitive receptor communities (i.e. corals, seagrass and macroalgae) to dredging and ongoing resort and safe harbour activities.
Coral Monitoring	Monitor coral health and regularly test the status of coral health against management trigger levels.
Dugong, cetacean and turtle monitoring	To minimise the risk of disturbance or injury to large marine vertebrates (dugongs, cetaceans and marine turtles) resulting from dredging and ongoing resort and safe harbour activities
Marine pest monitoring	To trigger and inform emergency response on detection of a marine pest species in the safe harbour

3.2 Coral Assemblages

The impact assessment provided here focuses on the coral assemblages currently located within and adjacent to the proposed safe harbour, as this would be where the majority of project activity with potential to affect corals would occur (i.e. dredging and construction and ongoing operations of the upgraded resort and safe harbour). In order to help determine the effects of the project on local coral assemblages, it is necessary to understand baseline conditions in the coral assemblage including the physical and chemical environment as well as the stressors that can cause change to coral assemblages and whether the project activities could lead to these increasing from current (baseline levels). Abundance and composition in coral assemblages are often controlled by abiotic factors, in particular salinity, turbidity, sedimentation, hydrodynamics and the availability of suitable substrata (Harriott and Banks 2002). Coral assemblages are generally considered to thrive in clear, warm waters that are well mixed with relatively low turbidity. Clear water promotes the photosynthetic activity of symbiotic algae hosted by most shallow water corals and these are required for the corals to survive. Coral assemblages of fringing reefs of continental islands, however, such as Lindeman Island, have adapted to less clear, more turbid water.

Biophysical and key ecological features of coral assemblages in the project marine area (i.e. coverage, growth form and taxonomic diversity). Further physical and chemical characteristics of the local environment are described in **Chapter 26** of the EIS. The coral assemblage in the project marine area in the vicinity of the proposed safe harbour location is diverse with areas of dense cover (particularly of branching corals). Turbidity in the Whitsunday islands is generally high and currents run longshore in both directions depending on the state of the tide. Potential impacts from the project to coral assemblages would be restricted to the footprint of the safe harbour and (because of dilution and dispersion) to nearby areas. These can be divided into direct impacts (removal of corals, damage from reef visitation and sedimentation) and indirect impacts (through changes in water quality and chemistry or hydrodynamics, and introductions of marine pests).

A complicating factor is the potential for cumulative effects of particular stressors. For example, degraded water quality may increase the susceptibility of corals to disturbance. Evidence from recent research into the interactions between water quality and climate change suggests that the tolerance to heat stress of corals is reduced by exposure to contaminants including nutrients, herbicides and suspended particulate matter (Wooldridge and Done 2004, Negri et al. 2011, Wiedenmann et al. 2013, Fabricius et al. 2013). Thompson et al. (2016) argues that any increase in susceptibility to disturbances as a result of local stressors will compound the pressures imposed on sensitive species and potentially lead to profound changes in inshore coral communities. At present, with a limited understanding of the cumulative impacts of these multiple pressures (e.g. assemblage shifts resulting from multiple stressors) the approach in this EIS has been to take a precautionary approach when assessing the potential impacts to corals from individual stressors given these could lead to cumulative impacts.

3.2.1 Predicting Zones of Impact to Corals

As described above, the level of risk (to corals) from potential hazards from the project has been determined from a qualitative risk analysis that considered the potential spatial and temporal scales of impacts. For the main hazards to corals (i.e. changes to hydrodynamics, sedimentation, turbidity and wave climate), modelling has been used to help interpret the spatial extent of (unmitigated) impacts, if any, in relation to tolerance limits for corals. Where applicable, impacts have been defined using the Western Australian Technical Guidance for Environmental Impact Assessment of Marine Dredging Proposals (EPA 2016) as follows:

> Zone of High Impact (ZoHI) is the area where impacts on benthic communities or habitats are predicted to be irreversible. The term irreversible means 'lacking a capacity to return or recover to a state resembling that prior to being impacted within a timeframe of five years or less'.

> Zone of Moderate Impact (ZoMI) is the area within which predicted impacts on benthic organisms are recoverable within a period of five years.

> Zone of Influence (ZoI) is the area within which changes in environmental quality are predicted and anticipated during construction or ongoing operations, but where these changes would not result in a detectible impact on benthic biota.

Although the zoning approach has been designed specifically for dredging, the approach has also been used in this case, (in addition to investigations of turbidity and sedimentation) to investigate potential spatial effects of the proposed safe harbour to hydrodynamics and wave climate. A review of literature was done to determine tolerances of corals to each particular stressor and to delineate boundaries between the ZoHI, ZoMI and ZoI (see below).

3.2.2 Turbidity and Light Attenuation

Turbidity refers to particles suspended in the water column including inorganic sediments, organic matter and plankton. Turbidity scatters and absorbs light rather than allow its transmission through the water column, which is known as light attenuation (Cooper et al. 2007, Jones et al. 2016). Turbidity can be highly variable over small spatial and temporal scales, and is influenced by a range of factors including terrestrial runoff, local waves and currents, and nutrient content which can result in plankton blooms (Cooper et al. 2007, Jones et al. 2016).

The majority of corals live in symbiosis with microalgal dinoflagelates known as *Symbiodinium*, which perform photosynthesis and provide energy to the host coral (Jones et al. 2016); consequently, corals require light for their survival. Therefore, increased turbidity and the associated reduction in light penetration over prolonged periods can have negative impacts on coral growth and survival. However, determining the potential effect of elevated turbidity on individual coral communities is complex, as it is dependent on a range of interrelated factors including the amount of turbidity, period of elevated levels, type of suspended material, depth range of coral as well as natural variation in tolerance to decreased light availability both between and within coral species.

Wide ranges of coral critical thresholds have been published, for example, within the Great Barrier Reef they can range from as little as 3.3 mg.L^{-1} for the Great Barrier Reef in general but up to 260 mg L^{-1} for nearshore fringing reefs such as Magnetic Island and Cape Tribulation (Erftmeijer et al. 2012). A similarly wide range of light (photosynthetically active radiation) requirements have been reported for different coral types, from 0.15% of surface irradiance (SI) for plate corals to up to 60% SI for branching corals (Erftmeijer et al. 2012). This clearly demonstrates the need to use information about local environmental conditions and reef composition when trying to determine any critical thresholds for a particular coral reef community.

A study of the coral reefs in the Whitsundays region (Cooper et al. 2007) used the maximal depth of coral development when not constrained by the availability of suitable hard substrata (i.e. Repulse, Whitsunday, Deloraine and Edward Islands), to determine that 6-8% SI represented the minimum light requirements of corals in the Whitsundays. However, Cooper et al. (2007) also notes that at this light level, coral cover and diversity is relatively low, suggesting that more light is required for active reef development. Similar light levels (10% SI) have been reported previously for coral survival (Achituv and Dubinsky 1990, in Erfmejier et al. 2012), however Achituv and Dubinsky (1990) also suggest that greater light levels (30-40% SI) are required to facilitate reef development. Cooper et al. (2007) estimated that 29% of surface irradiance reaches the lowest extent of corals at Lindeman Island (5 m LAT).

These responses of corals to light refer to ambient (permanent) conditions and it not clear as to how long it would take for changes to the amount of light reaching the seabed at Lindeman Island to have an effect. Although it is assumed that extremely high levels of turbidity can kill or injure corals after days of exposure (Gilmour et al. 2006), lower levels, such as that that would be expected during dredging for the safe harbour, would take weeks or even months to have an effect. The duration that corals can survive high turbidity ranges from several days (sensitive species) to at least 5-6 weeks (tolerant species) (Erfmejier et al. 2012). Given ambient turbidity for the Whitsunday islands is considered to be (relatively) high and sometimes variable compared to other regions (Thompson et al. 2016) it has been assumed that the corals at Lindeman are ‘tolerant’ rather than ‘sensitive’.

In summary, any increase in turbidity associated with dredging for the project or runoff will reduce the level of light reaching the seabed - a key factor limiting coral distribution (Cooper et al. 2007). The genus most susceptible to poor water quality is *Acropora*. This genus is also fragile and very susceptible to loss of cover during cyclones (Thompson et al. 2016).

Based on the above information, the Zones of effect have been defined for turbidity and its effect on light attenuation, as follows:

> ZoHI – Where light at the seabed is less than 8% of surface irradiance for more than one week, which is below the predicted minimum light requirement to maintain healthy coral.

> ZoMI – Where light at the seabed is between 8% and 30% of surface irradiance for more than one week, which is above the minimum light requirements to maintain healthy coral and up to the minimum light requirement for reef development. A benthic irradiance of 30% SI is the natural light levels at 5 m LAT at Lindeman Island, and as such represents the point at which benthic irradiance is similar to natural levels.

> ZoI – Where light at the seabed is greater than 30% of surface irradiance but still within the outermost extent of dredge plume.

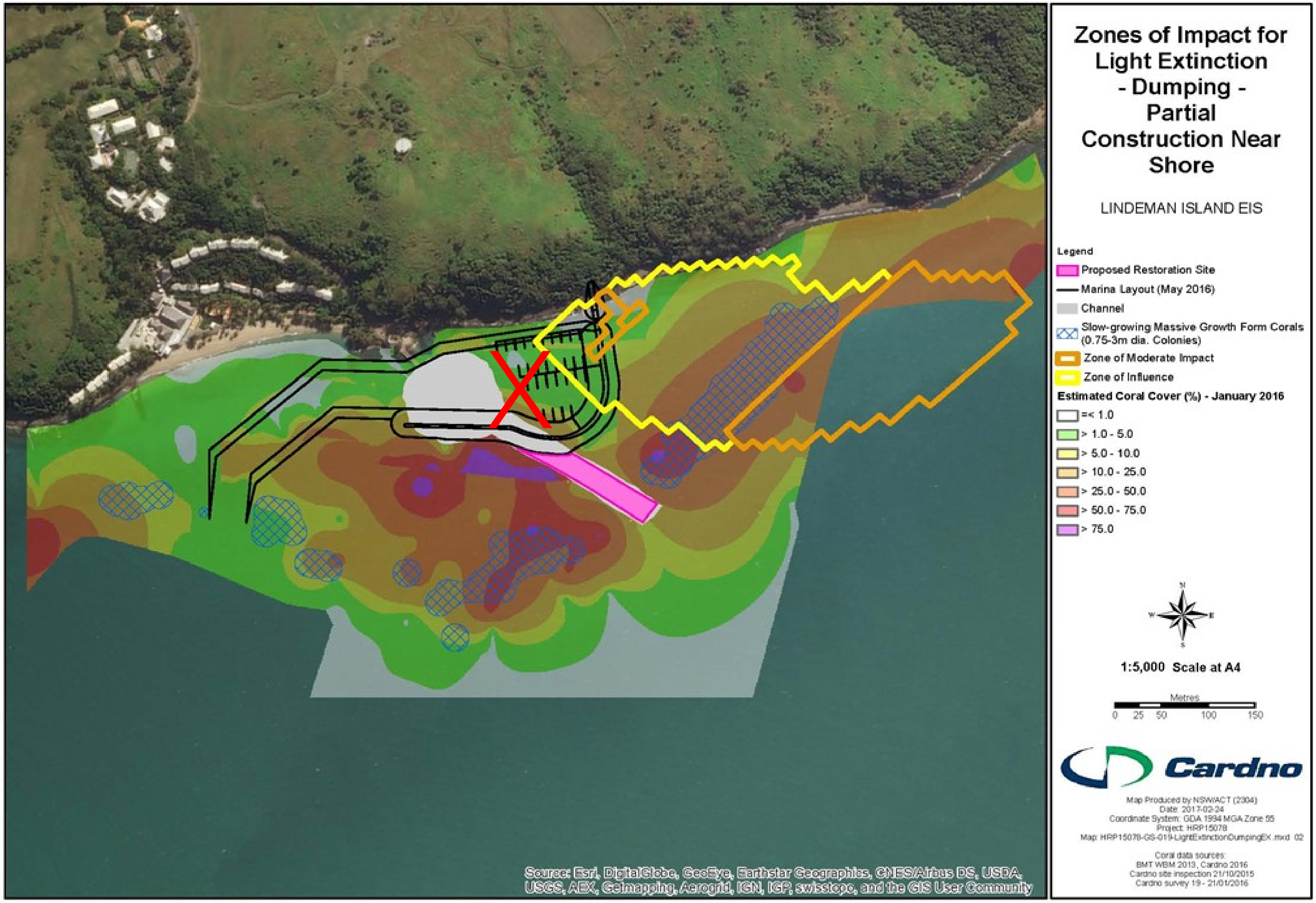
During construction of the proposed safe harbour, two activities would produce turbidity and hence potentially reduce light to the seabed and corals: construction of the breakwater followed by dredging of material within the safe harbour and the approach channel. The zones of effect were determined by modelling surface irradiance at the seabed, taking into account the relationship between concentrations of suspended sediment (SS) and light attenuation, depth, ambient SS in the water column and concentrations of SS and dispersion in plumes generated from construction (see **Chapter 26** for details of modelling). Scenarios were modelled that considered two areas during construction of the breakwater (i.e. near the shore and at its end) as well dredging at the end of the breakwater and at the end of the approach channel (refer **Figure 10 to 13**).

During construction of the breakwater, light at the seabed is predicted to be <8% of surface irradiance (SI) in small areas outside of the breakwater nearby construction. Placement of the rock core component (25,000m^3) of the breakwater would take 7 weeks followed by another 7 weeks to complete the rock-armouring. Hence, the small areas of very low light would be very temporary and would shift almost daily as construction progressed along the length of the breakwater. Due to their short durations the small areas of very low light would not be considered a ZoHI given they would not affect the same position for longer than a week at a time. However, SS in plumes and dispersion would be sufficient to reduce SI to places of the seabed so that a broad ZoMI and ZoI would be created. These would also shift as construction of the breakwater progressed.

During dredging, the increase in SS would not be sufficient to reduce SI at the seabed to <8% of surface irradiance but it would reduce light to between 8% and 30% (ZoMI) in some places.

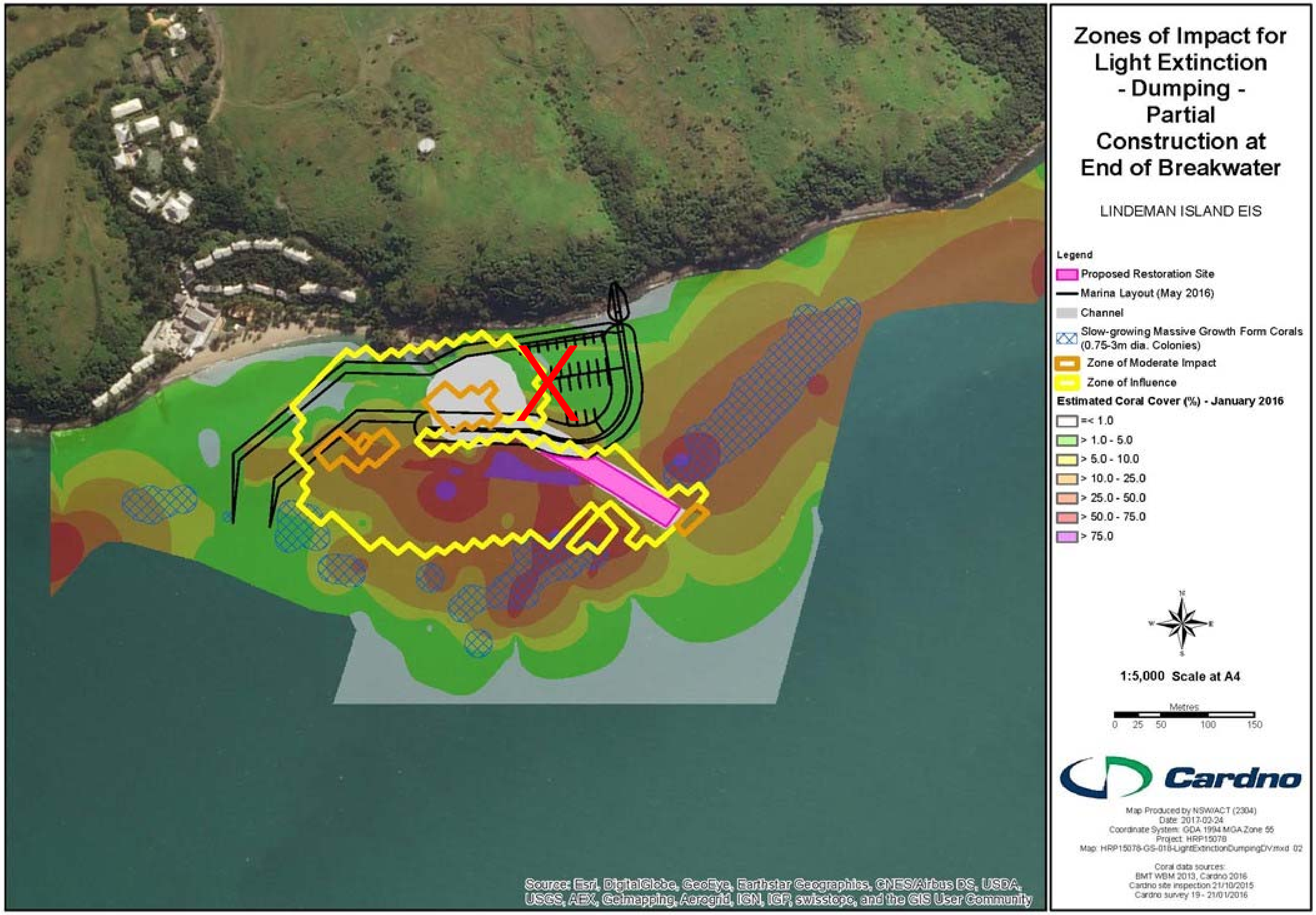
It is noteworthy that under some scenarios the ZoMI is seaward of the ZoI. In these instances, the concentration of SS in the ZoMI and ZoI may be similar, or may even be slightly less in the ZoMI, but the extra water depth further offshore means the amount of SI reaching the seabed in these areas is less.

Figure 10. Zones of effect for light extinction- construction of breakwater near



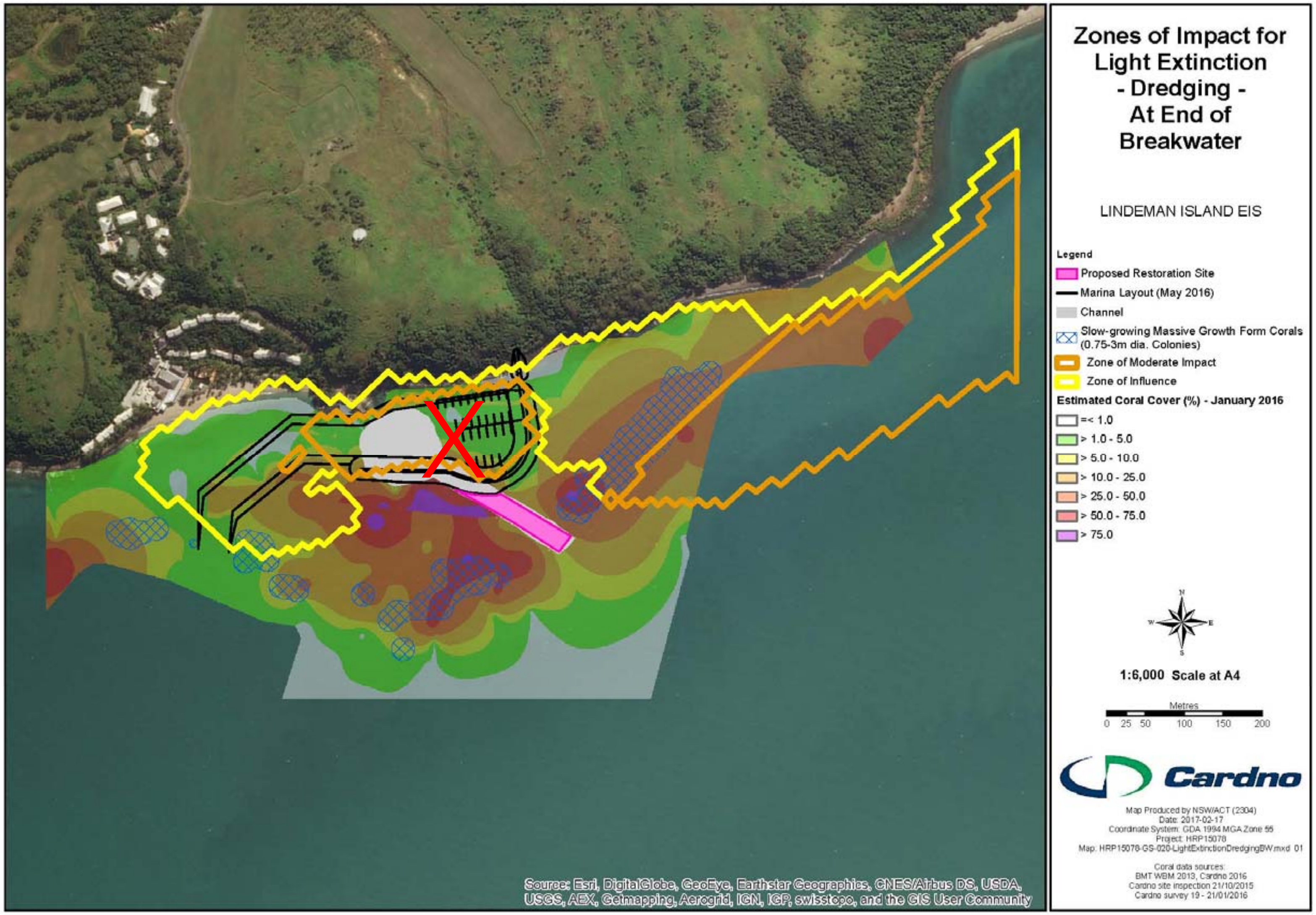
Note: A safe harbour is no longer proposed.

Figure 11. Zones of effect for light extinction- construction of breakwater at end of



Note: A safe harbour is no longer proposed.

Figure 12. Zones of effect for light extinction- dredging at end of breakwater.



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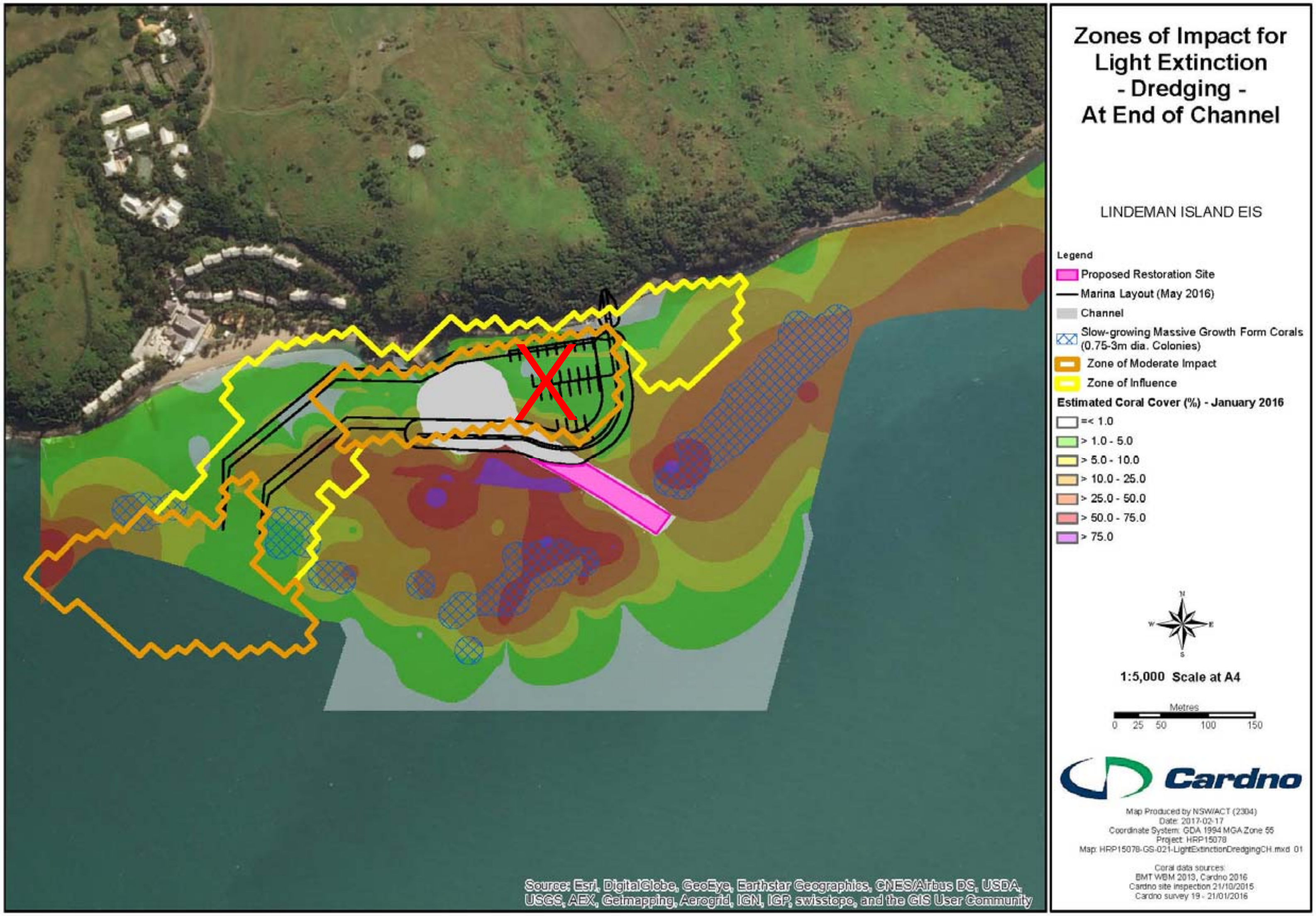
Note: A safe harbour is no longer proposed.

Figure 13. Zones of effect for light extinction- dredging at end of approach channel.



>

Note: A safe harbour is no longer proposed.

3.2.3 Sedimentation

Sedimentation is the settling of inorganic material and organic matter out of suspension in the water column and onto the seabed (Cooper et al. 2007). The rate of sedimentation varies temporally and spatially dependent on a range of factors including amount of suspended material in the water column, size of particles in suspension and wave and current regimes (Cooper et al. 2007).

Coral species have a variety of different mechanisms for removing sediments from their surfaces including mucus production and shedding, hydrostatic inflation, ciliary action and tentacle movement (R Jones et al. 2016). The ability to cope with sedimentation varies substantially between and within species due to differences in the removal mechanisms as well as differences in growth form (Erftmeijer et al. 2012). The active removal of sediment however, requires energy input from the coral, and hence causes stress (Cooper et al. 2007). If the rate of sediment deposition exceeds the rate of clearance, sediments will accumulate on coral surfaces. Alternatively, if sediment deposition occurs over a prolonged period, energy expenditure on sediment clearance may be greater than the corals energy production. These scenarios would both result in coral stress and potentially, mortality (Jones et al. 2016, Erftmeijer et al. 2012). A review by De'ath and Fabricius (2008) found several studies indicating that prolonged exposure to sedimentation rates in excess of 10 mg cm^{-2} d^{-1} can reduce coral cover, species diversity, growth rates and recruit survival while other studies have shown sedimentation rates greater than 3 mg cm^{-2} d^{-1} can cause mortality of coral recruits. De'ath and Fabricius (2008) also noted that many of the studies referred to above have been investigations of coarse grain sands, rather than finer silts, likely associated with dredging plumes. In addition, it has been demonstrated that fine grain sized sediments can have greater impact on corals than coarse sands (Weber et al. 2006). Where fine sediments are likely, De'ath and Fabricius (2008) suggests any impact threshold should be set at less than 10 $mg.cm^{-2}.d^{-1}$ as a conservative measure.

In summary, sedimentation from dredging and runoff constitute one of the biggest potential sources of reef degradation (Rogers 1990). Hence, any increase in sedimentation associated with dredging for the project or runoff may reduce the viability of coral communities.

Based on the above information, the Zones of effect have been defined for sedimentation as follows:

> ZoHI – Where sedimentation is greater than 10 $mg.cm^{-2}.d^{-1}$, which may have a negative effect on the established coral community. Recovery may take longer than 5 years.

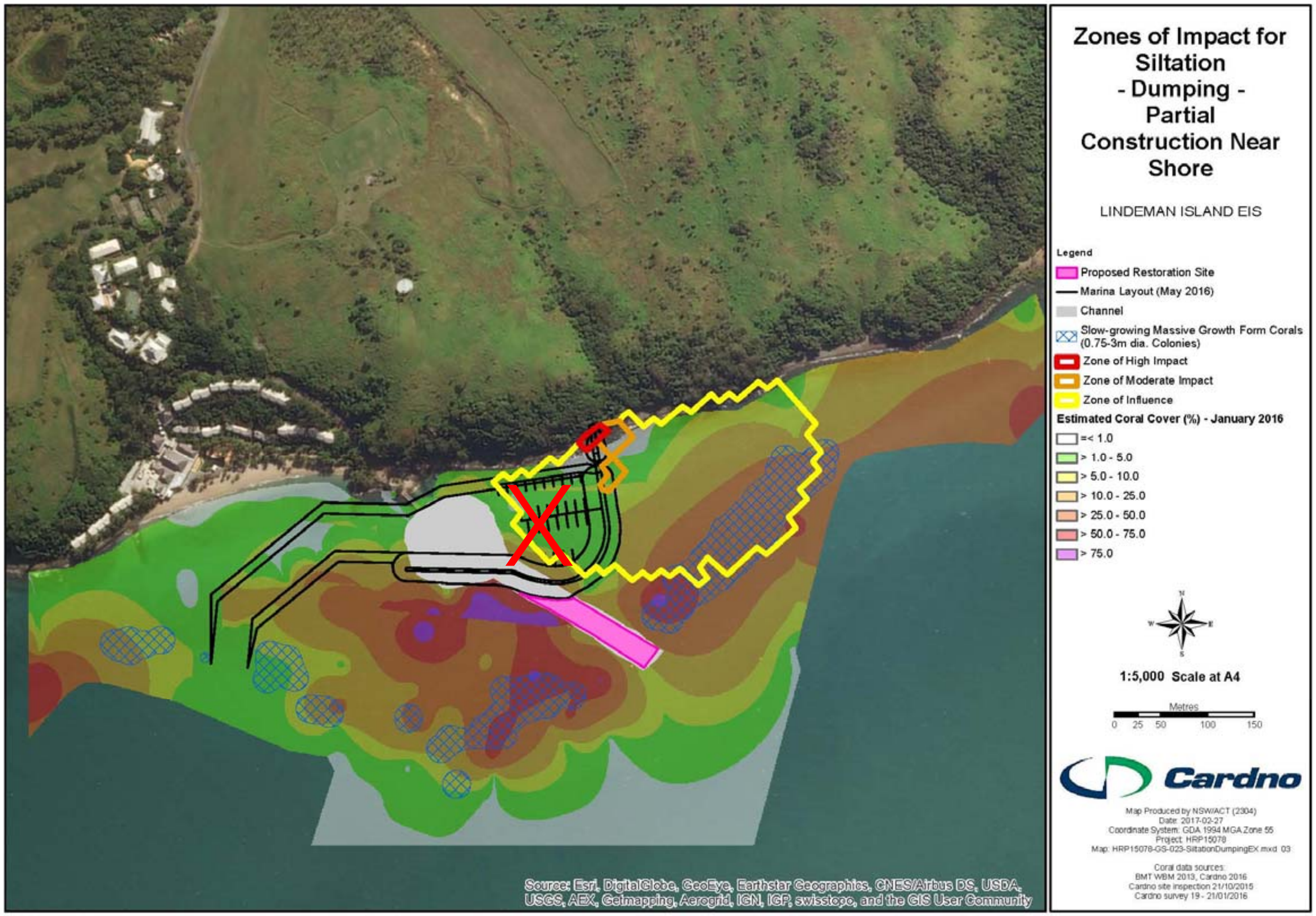
> ZoMI – Where sedimentation is between than 3 $mg.cm^{-2}.d^{-1}$ and 10 $mg.cm^{-2}.d^{-1}$, which may temporarily reduce recruitment, which is unlikely to have any prolonged effects on the coral community. Additionally, some effect on adult colonies may occur due to the fine grain size associated with the dredging plume.

> ZoI – Where sedimentation is less than 3 $mg.cm^{-2}.d^{-1}$ extending to the outermost extent of predicted dredge plume.

Two construction activities would produce suspended sediment (SS) that could lead to sediment being deposited on corals: construction of the breakwater followed by dredging of material within the safe harbour and approach channel. The zones of effect were determined by modelling deposition, taking into account concentrations of SS, ambient SS in the water column and concentrations of SS and dispersion in plumes generated from construction (see **Chapter 26** for details of modelling). Scenarios were modelled that considered construction of the breakwater near the shore and at its end and dredging at the end of the breakwater and at the end of the approach channel (**Figures 14** to **17**).

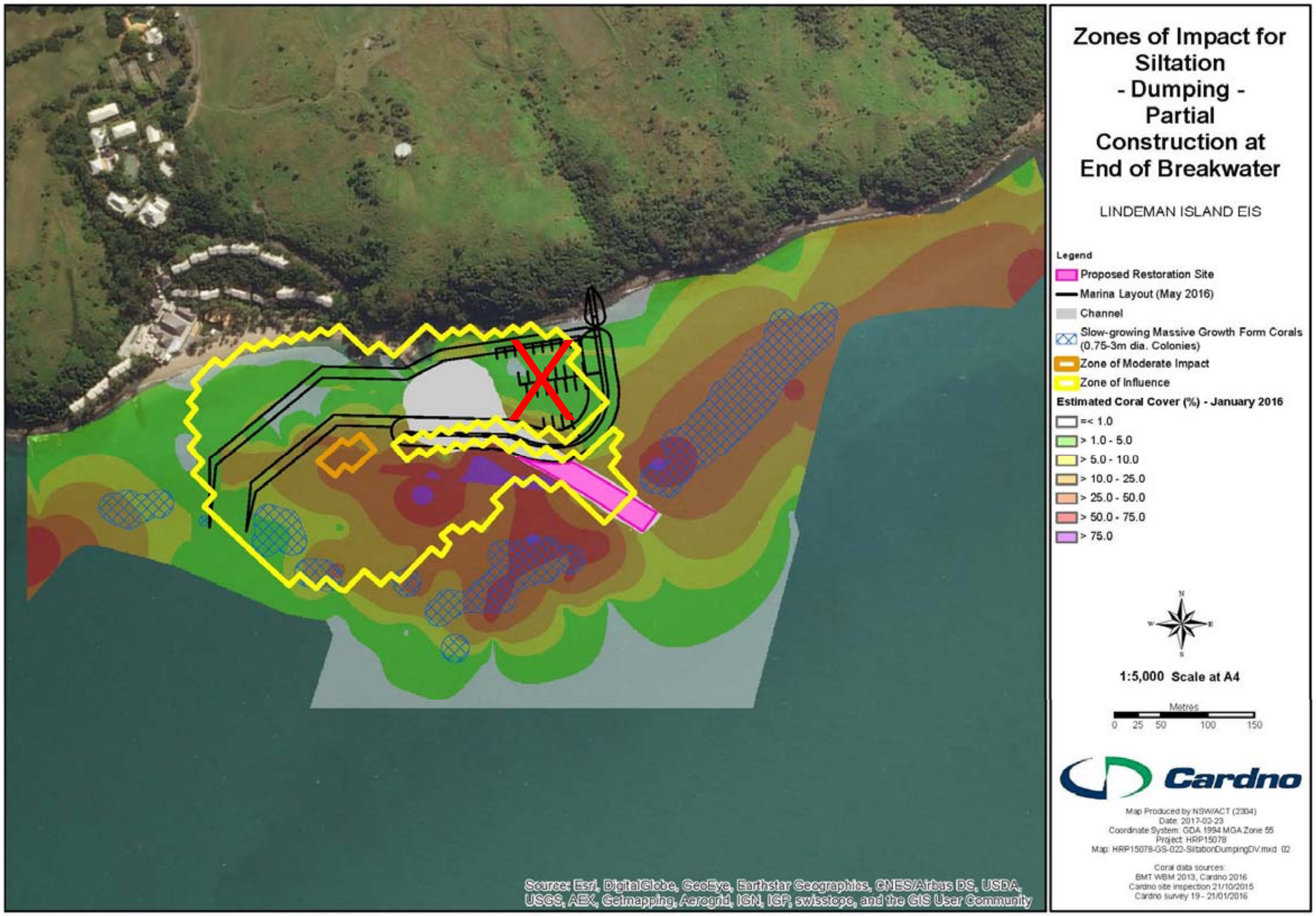
During construction of the breakwater, there would be a small area where sedimentation was predicted to be greater than 10 $mg.cm^{-2}.d^{-1}$ (i.e. ZoHI) close to shore and during dredging there would be a very small ZoHI near the end of the breakwater. Only the areas outside the breakwater are of concern given there would be no coral inside the breakwater after the area is dredged. The total area of the ZoHI would be 0.09 ha. In scenarios of dredging and breakwater construction, the ZoMI would be mostly contained within the safe harbour footprint but the ZoI would be extend across the reef for ~200 m to the west and ~500 m to the east of the proposed safe harbour.

Figure 14. Zones of effect for sedimentation - construction of breakwater near shore.



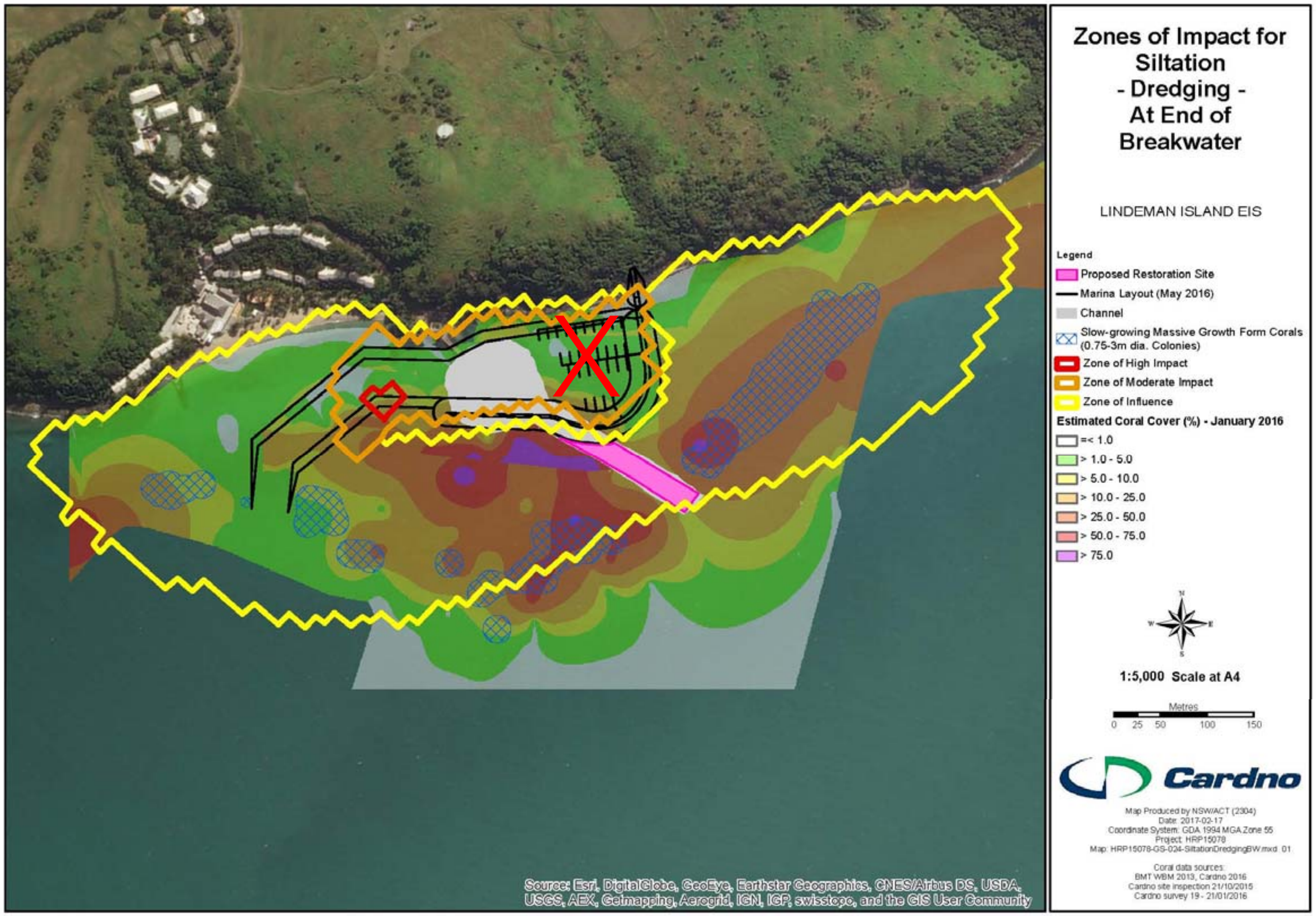
Note: A safe harbour is no longer proposed.

Figure 15. Zones of effect for sedimentation - construction of breakwater at end of breakwater.



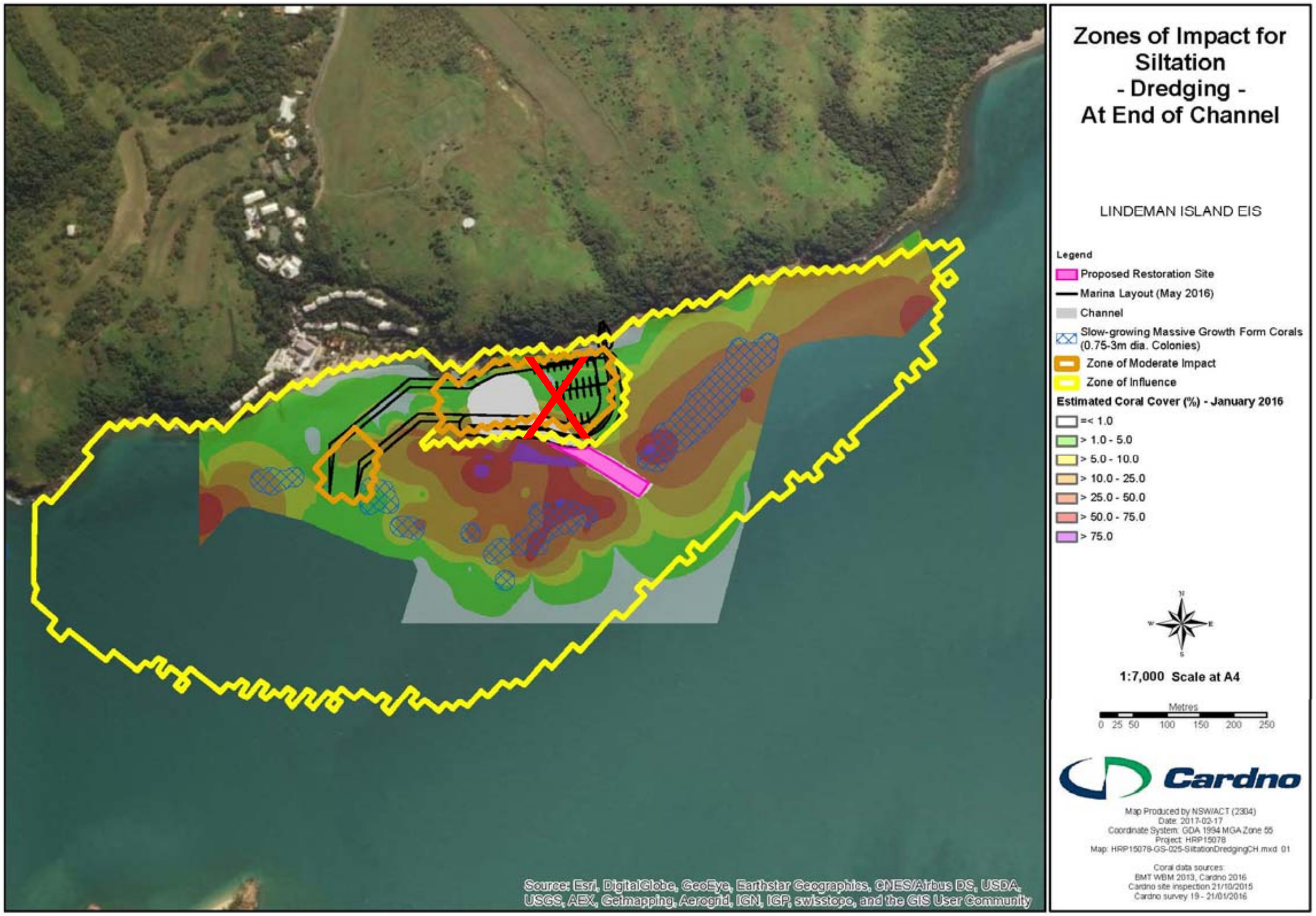
Note: A safe harbour is no longer proposed.

Figure 16. Zones of effect for sedimentation - dredging at end of breakwater.



Note: A safe harbour is no longer proposed.

Figure 17. Zones of effect for sedimentation - dredging at end of approach channel.



Note: A safe harbour is no longer proposed.

3.2.4 Change in Current Regime

In addition to short-term changes to the marine environment during construction, there may also be some long-term changes associated with the ongoing presence of the proposed breakwater. One consequence is that the safe harbour breakwater will change current velocities within some of the coral habitat.

Changes in current regime associated with the long-term presence of the proposed breakwater could have potential negative impacts to the coral community through a range of mechanisms. Although an extreme increase in currents could cause physical damage, this is only likely to occur under cyclonic conditions discussed above. Except for such extreme events, increased water movement may instead have positive impacts on coral health, through increasing the delivery of nutrients and planktonic food, as well as the removal of waste products (Lowe and Falter 2015, PIANC 2010). Conversely, localised reduction in currents could have negative effects on coral, through reduction in nutrient and plankton supply, reduction of waste removal as well as increases in sediment deposition (PIANC 2010).

The potential changes in current associated with the breakwater include areas of both slight increases and decreases in current velocity. There is limited published data on the effects of currents on which to establish thresholds for impact assessment, however, any change in currents, both increase and decreases, have the potential to alter the community composition, through favouring certain species. Due to the lack of information on critical velocities speeds, the chosen thresholds (that could result in a change to corals) were based on the minimum average current velocities in areas with presently thriving coral communities. .

Based on the above information, the zones of effect have been defined for current regime were as follows:

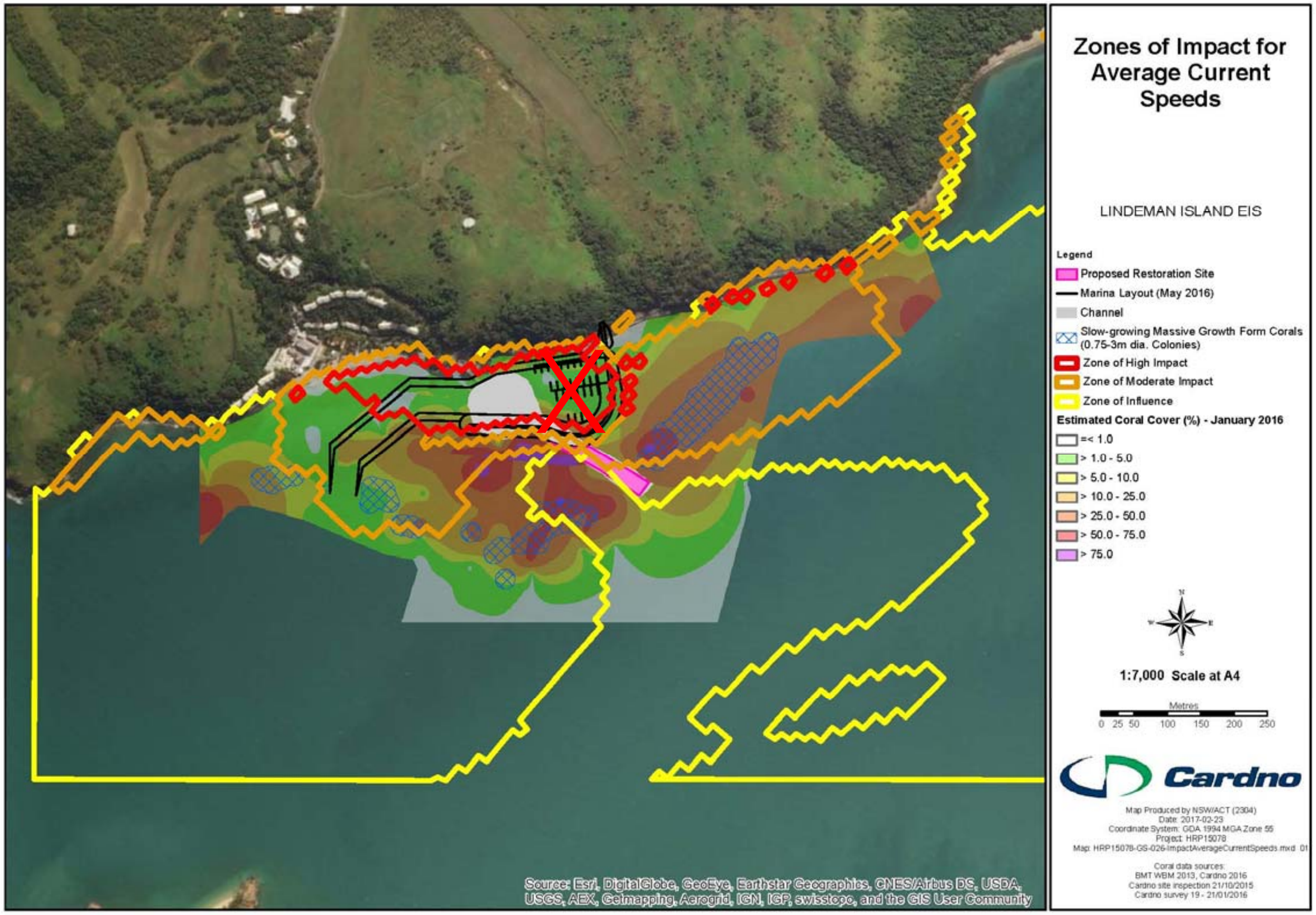
> ZoHI – Area where there was a decrease in average current velocity to less than the minimum average current velocity in areas where the cover of coral was >10% - the average current velocity was determined to be <0.03 ms^{-1}.

> ZoMI - Areas where current velocity has decreased by >10% but not to <0.03 ms^{-1}. Although changes of this magnitude are considered unlikely to have a significant ecological effect on coral cover, there is potential for slight long-term changes in coral community composition.

> ZoI – Areas where current velocity has decreased by 0% to 10% but not to <0.03 ms^{-1}.

The breakwater for the proposed safe harbour would alter currents. The zones of effect were determined by modelling average current velocities before and after construction of the breakwater and defining the locations where velocities had been reduced by particular magnitudes that could potentially affect coral (see **Chapter 26** for details of modelling). Outside of the safe harbour footprint average current velocities would be reduced to a level on the southern side of the breakwater that would potentially be detrimental to the coral community (ZoHI), but only in a small area very close to the breakwater (**Figure 18**). Another small ZoHI would also occur on the eastern side of the breakwater. The areas affected would be small and would amount to 1.01 ha. A ZoHI also occurs within most of the footprint of the safe harbour and near the shoreline close to the resort beach but as reef would be dredged for the safe harbour and there is very little, if any, coral very close to the shore this is not of concern. The safe harbour would result in small changes to average current velocities over healthy and dense coral communities close to the southern side of the breakwater but also to a large area of dense coral to the east. However, given velocities would not be reduced to levels below the minimum velocity observed for dense coral communities at Lindeman Island it was considered that although the composition of the communities in these areas may alter over time, there would be no change to coral cover. Hence, these areas were consider part of the ZoMI. The ZoI extended to some extent further to the east.

Figure 18. Zones of effect for altered current velocities.



Note: A safe harbour is no longer proposed.

3.2.5 Altered Wave Regime

Another long-term change potentially associated with the ongoing presence of the proposed breakwater would be that it will reflect waves and thereby increase wave energy within some of the coral habitat.

Spatial gradients in wave forcing can drive benthic community patterning and species zonation. For example, high wave forcing can reduce overall coral cover and favour wave-tolerant morphologies, and may even shift the entire benthic community to a dominance by low-lying algal species, such as turf algae and crustose coralline algae (Williams et al. 2013). Wave energy, and associated drag forces, can break and/or dislodge corals (PIANC 2010) and as such is an important determinant of coral community composition on both local and regional scales (Storlazzi et al. 2005). That is, areas with high wave energy are generally dominated by more robust coral growth forms such as encrusting and submassive type, while branching and more upright forms are more prevalent in lower energy areas (Storlazzi et al. 2005, PIANC 2010). In addition, high energy areas are often associated with lower overall coral cover and species diversity (Storlazzi et al. 2005). In contrast to encrusting and plating corals, the relative dominance of branching corals has been negatively related to the level of bed shear stress (BSS), with a dramatic decline occurring at a threshold of ~20 N.m^{-2} (Gove et al. 2015).

The wave regime associated with the proposed breakwater was investigated for BSS associated with a rare and extreme event (one in 100 years), and for a more frequent case (i.e. south-easterly wind wave conditions occurring once a year (peak H_s=0.8m)). Waves occurring on a day-to-day basis were disregarded given there would be no measureable change. Bed shear stress (BSS) was chosen over more traditional surface level wave metrics (e.g. wave height) because it specifically quantifies forcing at the depth of benthic organisms.

Based on the above information, the Zones of effect have been defined for wave regime as follows:

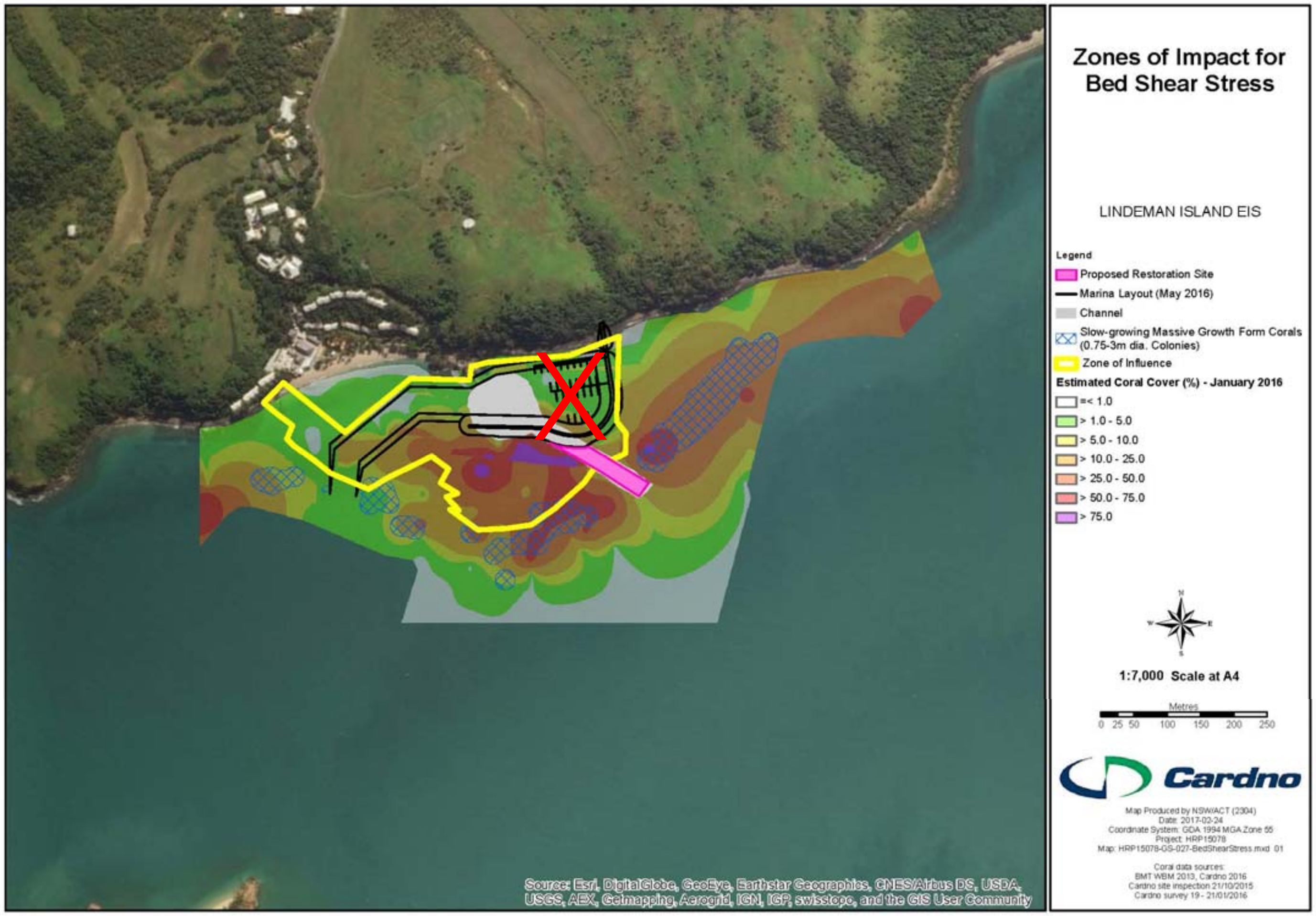
> ZoHI – Area where current wave energy bed shear stress increases from below 18 N m^{-2} to above 18 N m^{-2}. NB: the level was chosen as a precautionary level.

> ZoMI - No ZoMI, as any changes would be by definition irreversible.

> ZoI – The area which is predicted to experience a slight increase to bed shear stress.

The breakwater for the proposed safe harbour would alter BSS near the structure and also, within its confines given waves would no longer be able to penetrate past the structure. In the extreme event scenario, modelling determined that BSS would be above 18 N m^{-2} across the entire fringing reef under existing conditions. Hence, even though the breakwater would increase BSS close to the structure, it would not matter given the existing conditions would already be at a level that would cause severe damage to branching corals (see **Chapter 26** for details of modelling). Under the second, more frequent scenario (once a year event), BSS would be increased close to the breakwater, but not above 18 N m^{-2} anywhere. Hence, the would be no ZoHI or ZoMI, only a ZoI within the breakwater and on the southern side of the breakwater and between the proposed approach channel and the shore (refer **Figure 19**).

Figure 10. Zones of effect for altered wave regime.



Note: A safe harbour is no longer proposed.

3.2.6 Residual Risk to Corals

3.2.6.1 Change in Coral Habitat Extent

Construction of the safe harbour would have a direct impact on the coral assemblage, as it would require dredging of the seabed within the footprint.

The safe harbour location has been developed and refined based on findings from several marine habitat surveys, to specifically avoid large, old growth, coral bomboras and minimise impacts to areas supporting dense coral cover and the surrounding reef and benthic habitats (refer to **Figure 20**). The initial concept layout was aligned with the existing channel to include already modified habitat. The marine habitat survey conducted in 2013 revealed the presence of a dense coverage of habitat forming branching corals within the proposed footprint (BMT WBM 2013, refer to **Appendix Y**). The design was refined (Version 2, October 2015) to specifically avoid the large coral bomboras found in surveys done in September 2015 (GBRMPA 2015) and October 2015 (Cardno Survey 2015), and to minimise impacts (see below) on areas where coral cover was dense (Version 4, May 2016).

Coral Habitat Directly Affected by the Safe Harbour Footprint

The amount of directly affected coral reef impacted by the proposal (**Figure 20**) is presented in **Table 11**. The footprint of the safe harbour (+ 1.5 m buffer) would require removal (dredging) of 14.4% of the total area of 'coral habitat' in the 31.06 ha Survey area that stretched ~1 km along the coast of the southern side of Lindeman Island in the vicinity of the existing resort. However, most (i.e. 99%) of the total coral habitat in the safe harbour footprint (i.e. 4.46 ha) that would be removed has a cover of live coral of between 0 and 25%. This is because much of the area of reef in the footprint is intertidal or encompasses the existing turning basin and channel which has a sandy bottom and virtually no coral. Only 0.06 ha of the coral habitat to be removed (i.e. reef habitat in the safe harbour footprint) would have >25% live coral cover (refer to **Table 11**). This is a very small amount of the total area of coral habitat in the entire reef in the Survey area (31.06 ha) and only <1% of the total area of the entire reef in the Survey area where the cover of live coral is >25%. When the area of each category of coral cover is multiplied by the mean percentage cover of live coral in each category, the aggregate area of coral colonies (i.e. 'live coral') directly affected by the safe harbour footprint would be **0.23 ha.**

Coral Habitat Potentially Lost Due to Other Processes

The potential effects of turbidity and sedimentation from dredging for the safe harbour and construction of the breakwater and permanent changes to current velocities and reflected waves from the breakwater were identified through modelling. The results indicated that there would be potential for small pockets of irreversible damage (i.e. damage where recovery was considered unlikely within 5 years or not at all) to coral habitat on the reef outside of the safe harbour. Irreversible damage was considered to have potential to occur from changes to current velocities close to the breakwater, particularly to the east and from small areas where sediment would be deposited during construction of the breakwater. The areas affected were small and amounted to 0.02 ha from sedimentation and 0.92 ha from altered currents. Much of the area where currents would be reduced occurs in intertidal areas where the cover of live coral is very low (<1%) so the aggregate area of coral colonies (i.e. 'live coral') affected would be **0.02 ha**.

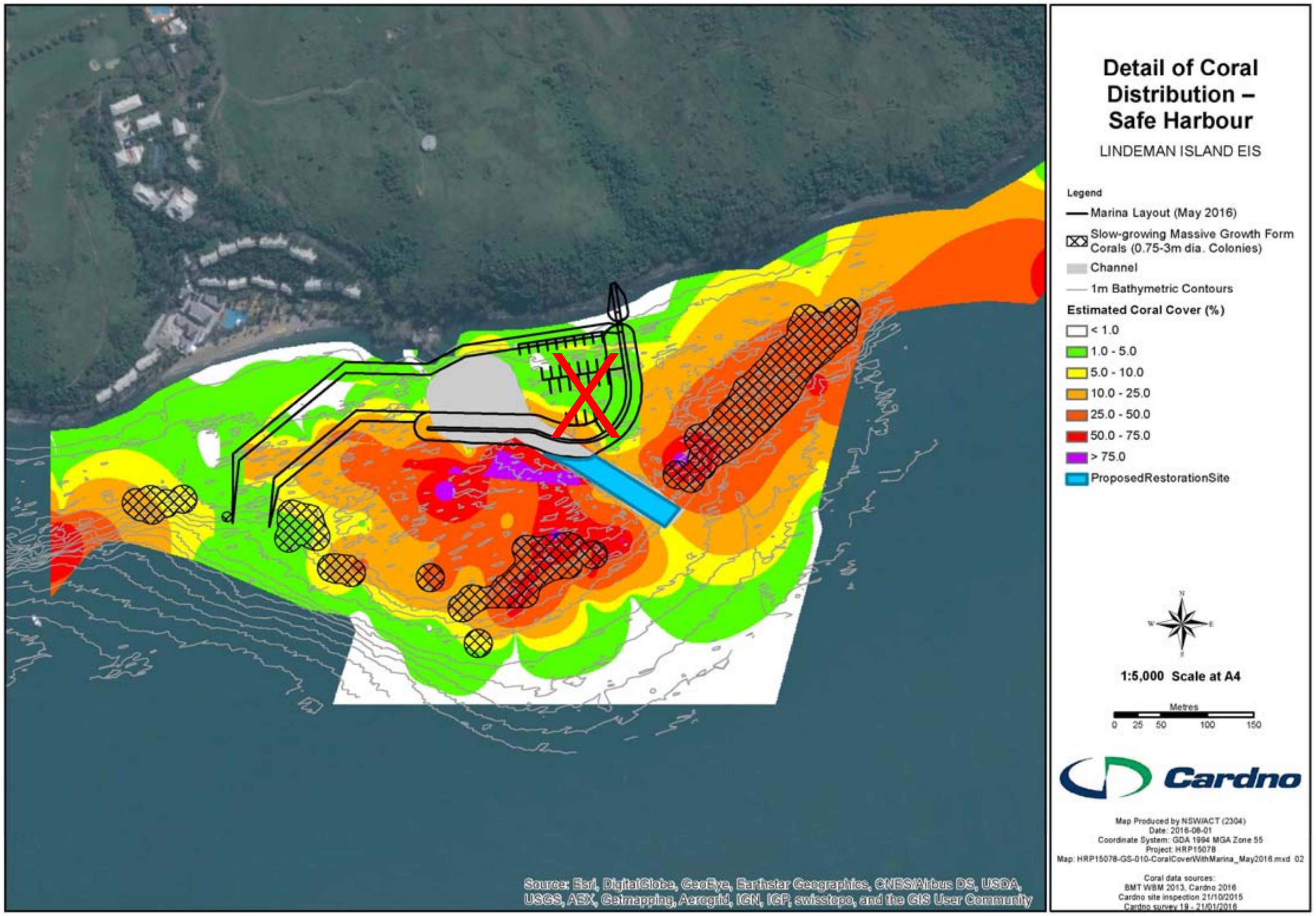
Overall, the total amount of coral habitat predicted to be lost is 5.4 ha and the aggregate area of coral colonies (i.e. 'live coral') affected would be **0.25 ha**

Table 11. Covers of coral in Version 4 of the Safe Harbour layout (+ 1.5 m buffer) and in the entire Survey area.

Cover of Coral (%)	Inside Footprint (ha)	Outside Footprint (ha)	Total Survey Area (ha)	Inside Footprint (%Survey Area)
≤ 1.0	1.32*	3.30	4.62	28.6
> 1.0 - 5.0	2.00	5.64	7.64	26.2
> 5.0 - 10.0	0.54	3.05	3.59	15.0
> 10.0 - 25.0	0.54	5.83	6.37	8.5
> 25.0 - 50.0	0.04	6.62	6.66	0.6
> 50.0 - 75.0	0.02	1.90	1.92	1.1
> 75.0	0.00	0.26	0.26	0.0
Total Cover Area (ha)	4.46	26.60	31.06	14.4

- *includes the existing turning basin and part of the existing channel

Figure 20. Location of the safe harbour in relation to coral distribution.



Note: A safe harbour is no longer proposed.

This direct impact would be long term and irreversible for some parts of the dredged area but corals would grow on some of the structure of the safe harbour. Using the risk analysis model, the risk to coral assemblages is considered to be high (refer to **Table 9**). This represents the greatest risk level identified among all potential project impacts to the marine ecology of the project marine area. According to the risk assessment matrix (refer to **Table 12**), the risk is considered 'significant and requires significant cost-effective measures for risk reduction and/or management'. These measures are described below and include like-for-like offsetting for lost coral habitat by creating new coral habitat and restoring previously removed coral habitat.

A key mitigation strategy for direct impacts of the Project on coral assemblages (i.e. resulting from direct removal of coral habitat for the safe harbour) is the proposed plan to create new coral habitat and restore existing habitat. Under the plan outlined below, the footprint of the proposed safe harbour that would remove 3.43 ha of existing coral habitat with generally low cover would be partially compensated for by the creation of new coral habitat on the breakwalls of the proposed safe harbour and the restoration of coral habitat in the existing channel. Although there would be less coral habitat at Lindeman Island due to the safe harbour, the proposal for creation of coral habitat (below) is estimated to create an equivalent amount of live coral (i.e. an aggregate area of 0.23 ha of live coral) as to what is estimated to directly affected within the safe harbour footprint.

3.2.7 Creation of Coral Habitat

Breakwalls, pontoons, piles and other intertidal and subtidal structures associated with the construction of the safe harbour would create a mosaic of potential new habitat. The hard surfaces of these structures would provide substrata for many species of hard and soft corals, as well as sponges, ascidians and a variety of other invertebrates. In turn, the sessile benthic community would provide shelter and food for a variety of fishes and other fauna. This gain of marine habitat is considered a positive long-term impact that may be realised within a 5-year timeframe, with the sessile benthic community expected to develop in line with ecological successional patterns recorded in other tropical Queensland marinas (The Ecology Lab 2008, **Figure 12**). A conservative estimate is that 0.3 ha of new coral habitat would be created on the margins of the safe harbour structures with 10% coral cover. This would equate to 0.03 ha of live coral.

3.2.8 Restoration of Coral Habitat

After construction of the proposed safe harbour, much of the 130 m long by 25 m wide existing channel (refer to **Figure 20)** would no longer be required to service Lindeman Island (although a portion of this would be reclaimed by the proposed safe harbour). Consequently, this presents an ideal opportunity for restoring coral habitat in this area. Restoration of coral habitat is proposed to be done in an approximately 130 m long by 25 m section of the remaining portion of the existing channel (refer to **Figure 20**) by first placing suitable substrata for corals on top of the sandy base of the channel, which is presently a couple of metres below the surrounding reef. The area of existing channel where coral habitat is planned to be restored would amount to ~0.29 ha. It is expected that coral in the channel could be restored to a similar coral assemblage to what occurs naturally on reef adjacent to the channel (i.e. coral cover ranging between 15-100%). If it is assumed that an average coral cover of 75% (the target of the 'Coral Restoration Plan' below) can be been achieved in the restored area, then this would equate to 0.22 ha of live coral. In combination with the new coral habitat created on the breakwall, the expected amount of 0.25 ha of live coral created or restored would be equivalent to the amount of live coral as is proposed to be removed for the safe harbour. Given that most of this would be high cover in the channel and would have the added ecological benefit of rejoining the fragmented coral reef around the existing channel, this would compensate for the lost low density coral habitat in the safe harbour footprint.

Chapman (1998) considers that restoration needs to be done with two components in mind: (1) construction of on-the-ground works which it is anticipated would restore the lost habitat or create new habitat; and (2) evaluation of the success or failure of these works with respect to improvement of the ecological structure and functioning of the restored/created habitat. Although component (1) of restoration is most important, component (2) is also important so that a measure of success is known throughout what can be a lengthy process and facilitate appropriate adaptive management where opportunities arise.

A Coral Restoration Plan has been developed for this EIS to mitigate direct impacts on coral habitat from construction of the safe harbour. It is considered that the Coral Restoration Plan developed is low risk and would be successful for the following reasons:

- The small size of the project. Successful restoration of coral habitat has been documented previously for other developments at similar scales to this project (i.e. up to a few hectares; Edwards and Gomez (2007));
- The nature of the restoration site. Prior to construction of the existing channel, coral cover at the proposed restoration site (i.e. the existing channel) is likely to have been high (50-100%) and similar to assemblages of surrounding coral. Some of the densest cover of live coral in the Project Marine Area occurs on either side of the existing channel and it includes branching corals, which are considered to be relatively uncommon in the declining southern inshore reefs of the GBR (De'ath et al. 2012). It is also likely to improve the ecological functioning of the outer parts of the reef area in the Project Marine Area, by joining areas currently separated by the existing channel.
- Given the existing channel is between complex coral reef it is likely that fish grazers will regularly visit the restoration site, and soon colonise, the restored area. Grazing of algae is a necessary part of maintenance during restoration so that the restored habitat is not able to switch to an alternate ‘algal-dominated’ assemblage in early stages of restoration (Edwards and Gomez (2007); and
- Indirect impacts to corals in the general area from construction of the safe harbour and ongoing operations of the resort are considered negligible or not sufficient to affect coral assemblages outside of the footprint of the safe harbour (see below).

Key aspects of the ‘Coral Restoration Plan’ are given below. Note that the ‘Plan has been developed in accordance with Reef Restoration Concepts and Guidelines as given in Edwards and Gomez (2007) but final details would be developed to the satisfaction of DoE and GBRMPA and consistent with the *EPBC Act environmental offsets policy* (2012). Although it is considered that the planned mitigation (offset) for direct loss of the small amount of coral and its habitat is appropriate to result in no net loss, achievement of a net benefit is sought to be achieved through other strategies (see **Appendix X** of the EIS).

3.2.8.1.1 The Coral Restoration Plan

(a) Aims

The overall aim of the plan is to restore coral habitat in the remainder of existing channel (after construction of the safe harbour) to a similar amount of coral cover as seen in adjacent assemblages after 10 years. The coral cover in assemblages adjacent to the proposed restored area is as much as 100% in some areas. A realistic target of 75% cover, on average, is proposed for the restoration area. As stated above, in combination with new coral habitat created by the safe harbour structure, this would compensate for the direct removal of coral habitat in the safe harbour by providing an equivalent amount of live coral.

(b) Physical Restoration

Before biological restoration is attempted, the need and requirements of physical restoration require careful consideration. For this restoration project, this is probably the aspect of the plan which will most likely determine success or failure. Key to success is covering the seabed of the existing channel between the breakwall of the proposed safe harbour and the seaward edge of the channel with suitable artificial substrata. The substrata units need to be of: sufficient size to remain stable in the environmental setting during storms; and a suitable height above the sandy base of the channel so that corals receive adequate light and our not affected by movement of sand. Given the sandy base is below the surrounding reef profile, artificial substrata units will need to be between 1 and 2 m in height so that the restored reef profile can be raised to close to the profile of surrounding reef. Artificial substrata could involve Reef Balls™ or other similar purpose built artificial surfaces for corals (Cummings et al. 2015, Meesters et al. 2015, Young et al. 2012) or simply large pieces of limestone rock (Edwards and Gomez 2007). The artificial substrata would vary in size according to the variation of topography in existing coral assemblages on either side of the channel. The final choice of restored substrata would be agreed to by GBRMPA.

(c) Biological Restoration

Restoring the coral habitat in the existing channel to exactly the same condition and functionality as its pre-disturbed condition is not possible because the original substratum has been cut away and removed, but it would be possible to restore an assemblage that would be similar to the surrounding assemblage in terms of the cover of coral and taxa. In terms of restoring living coral assemblages, the plan is not to rebuild the ecosystem in the existing channel piece by piece but to assist natural processes of development of the assemblage by transplanting corals and assisting natural recruitment to the new substratum.

i.Sourcing Transplants

To speed up the biological process of restoration, it is proposed that suitable colonies of coral would be transplanted from within the safe harbour footprint prior to its construction. Small coral colonies occur in the safe harbour footprint and those in the deeper sections would be transplanted as a priority given survival after transplanting can depend on the similarity of source and recipient environmental conditions. Coral taxa in the safe harbour are similar to the assemblages surrounding the existing channel and hence all taxa are candidates for transplanting. Only colonies greater than 5 cm would be transplanted to maximise survival (Edwards and Gomez 2007). Edwards and Gomez (2007) also recommend that colonies are not transplanted in summer to avoid the potential for additional seasonal stress (that could result in mortality) and detached corals should only be kept out of the water (prior to reattachment) for as little time as possible. Techniques are also available for transplanting larger colonies if required (Buckee at al., in prep).

ii.Attaching Transplants

Various epoxy adhesive, cements, cable-ties and wires have been used successfully for transplanting small colonies (Seguin 2008, Anmar et al. 2013, Edwards and Gomez 2007)) and expert advice would be sought as to the most appropriate method for detaching and re-attaching corals that would maximise survival in this instance.

(d) Schedule, Milestones and Adaptive Management

Given the cost of the proposed Restoration Plan, particularly associated with deployment of artificial substrata, and because construction vessels may need to use the access channel early during construction of the safe harbour, it is proposed that restoration is done in stages.

i.*Stage* 1.

A pilot study to evaluate the suitability and configuration of artificial substrata. Artificial substrata would be placed initially only in part of the channel. Different types of material would be used in different plots on only one side of the channel (to allow access of vessels during early stages of construction). Corals would be transplanted to each different configuration and type of substrata and the success of each plot would be evaluated after two years (Milestone 1). Some plots would also have no corals transplanted onto them so that a comparison could be made against natural recruitment of corals to the artificial substrata (i.e. against controls).

ii.*Stage* 2.

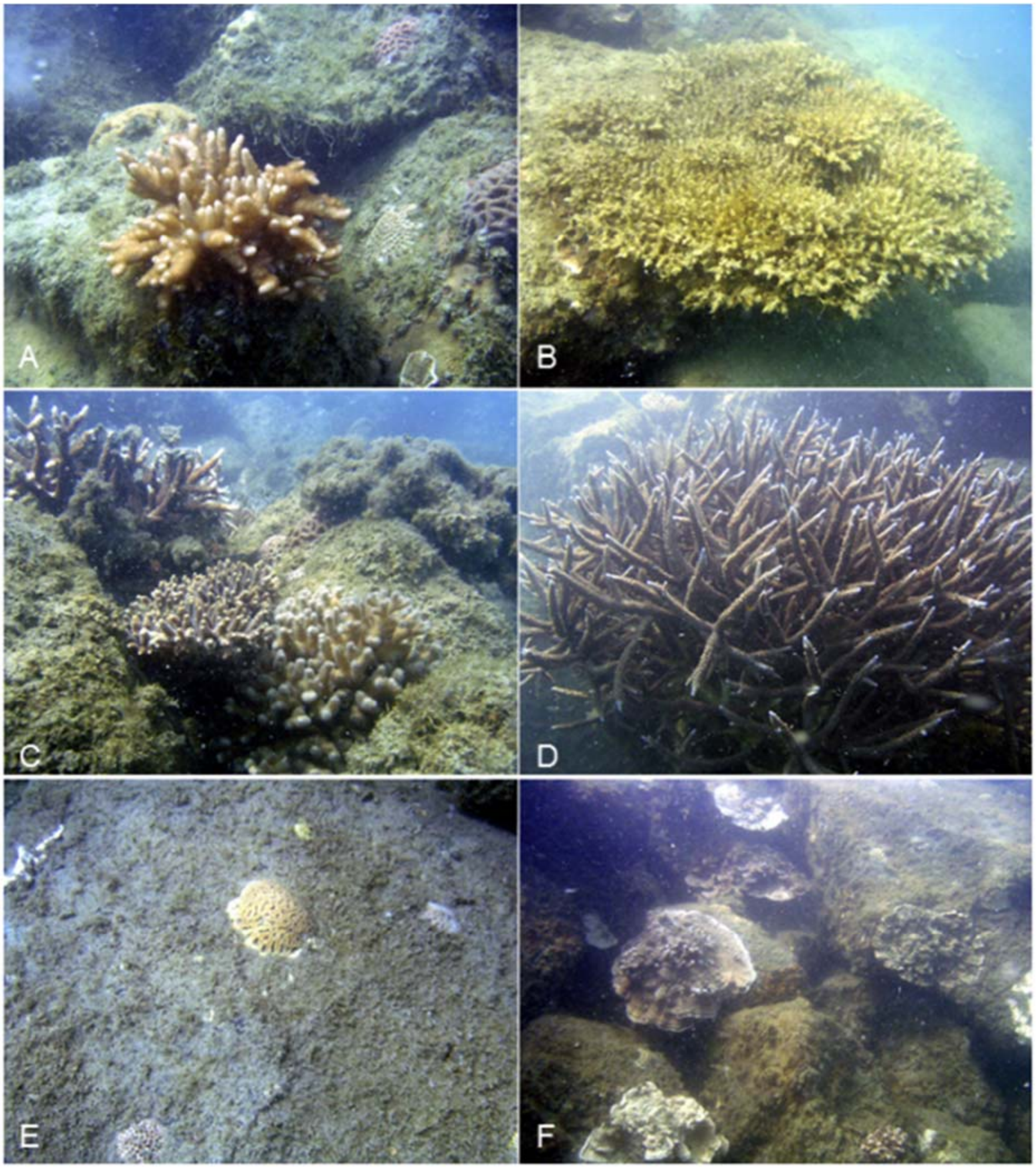
The most successful plot (after 2 years) would govern how physical and biological restoration was to proceed in the remaining area of the channel. At that point, substrata would be sourced for deployment in the remainder of the existing channel.

The exact details of the experimental design in Stage1, including monitoring (below) would need to be agreed to by GBRMPA.

(e) Monitoring and Maintenance

An appropriate monitoring strategy (see EMP) would be implemented so that the restored/newly created coral assemblages met the target ecological standard (i.e. an average cover of 75% live coral) after 10 years. Monitoring of the restored area would be done on a 3-month basis by marine scientists during Stages 1 and 2 and also include coral assemblages adjacent to the restored area for comparison. Maintenance would also be done on these quarterly visits. This would include removing excess algae (with a wire brush), if it appeared to be affecting transplants, and reattaching any transplanted colonies that had detached.

Figure 21. Underwater photographs of corals found to have colonized the inner break wall of Mackay safe harbour within a period of approximately 5-10 years (The Ecology Lab 2008). Branching Acropora spp (A, B, C); Branching *Stylophora pistillata and Pocillopora damicornis (C); Faviidae recruit (E); Encrusting Montipora sp.*



3.2.8.1.2 Increased Turbidity and Sediment Deposition from Dredging

Dredging to construct the safe harbour has potential to increase sediment mobilisation and turbidity in the surrounding marine environment. Increased sediment suspension from dredge plumes may result in increased turbidity and reduced light available for photosynthesis of corals and sediment deposition on corals. Reduction in light available for photosynthesis and partial or complete burial can lead to decreases in growth rate or loss of coral cover, bleaching and higher prevalence of diseases if it is above certain levels and for a long duration.

A turbidity and sedimentation study was undertaken to inform this EIS and this included an analysis of siltation in the existing boat channel and modelling of the dredge plume to determine zones of effect. Although modelling of the dredge plume indicated that, without mitigation, the dredge plume would disperse across the entire reef flat to the east (during flood tides) and west (during ebb tides), modelling indicates that suspended sediments (SS) quickly disperse from the site when the working-day ceases. The plumes are transported significant distances, but this process also reduces the concentrations. During dredging, the increase in SS would not be sufficient to reduce SI at the seabed to <8% of surface irradiance but it would reduce light to between 8% and 30% (ZoMI) in some places. During construction of the breakwater, light at the seabed is predicted to be <8% of surface irradiance (SI) in small areas outside of the breakwater nearby construction but given these areas would be very temporary there would be no ZoHI during breakwater construction.

There would be very little fine sediment settlement in the coral areas near the safe harbour because current speeds are often too high (>0.3m/s). During construction of the breakwater, sedimentation is predicted to be greater than 10 $mg.cm^{-2}.d^{-1}$ in some areas (ZoHI) outside and inside of the breakwater nearby construction. Only the areas outside the breakwater are of concern given there would be no coral inside the breakwater after the area is to be dredged. During dredging there would only be a very small ZoHI (i.e. when dredging occurred at the end of the breakwater) and this would be mostly retained in the approach channel. In scenarios of dredging and breakwater construction, the ZoMI would be mostly contained within the safe harbour footprint but the ZoI would be extend across the reef for ~200 m to the west and ~500 m to the east of the proposed safe harbour.

There would be potential for runoff and sedimentation from construction for the project occurring on the land. Best practice erosion and sediment control techniques will be used during construction. Sediment from runoff from land-based resort construction activities will be controlled as part of the Construction EMP.

Given the negligible increase to turbidity from the dredge plume would be short term and reversible, the risk to corals of increased turbidity and sediment deposition from dredging for the safe harbour would be low (refer to **Table 12**). Notwithstanding this, adaptive and contingency management of dredging operations must be applied to reduce turbidity below agreed turbidity trigger values if monitoring detects exceedances outside of the silt curtains. Best practice dredging would control the potential for turbid water from the dredge site moving onto the adjacent reef. Controls to dredging would include silt curtains and bunding and water quality monitoring of turbidity with triggers for adaptive and contingency dredge management.

3.2.9 Altered Hydrodynamics and Flushing Within and Outside the Proposed Safe Harbour

Water movement provides nutrients (food) and dissolved oxygen, removes wastes, and can reduce predation by coralivores. The construction of the safe harbour structures, including the breakwater, is expected to alter local hydrodynamics, and therefore has the potential to impact on the local marine ecosystem, however, the safe harbour has been designed to minimise such disturbances. Modelling indicated that the presence of the proposed safe harbour and its associated dredging will cause some change to current structure in the project marine area (refer to **Appendix H**). Following model calibration, however, it was shown that tidal forcing is the dominant current forcing mechanism. The changes observed on the reef flat either side of, and offshore from, the proposed safe harbour location are noticeable, but in most instances small enough as to not have consequences to the corals. The zones of effect were modelled by comparing average current velocities before and after construction of the breakwater and determining areas where average current velocities had been reduced to levels that could have permanent effects to coral cover or diversity. Small areas of dense coral would experience reduced current velocities resulting in permanent changes to coral cover close to the southern and eastern sides of the breakwater. Although velocities would be reduced in other areas, particularly to the east of the breakwater, this would probably not result in a change to coral cover although there may be a change to the composition of the communities.

With respect to the potential for reduced current velocities to result in an increase in the rate of siltation in the long-term, sediment sampling in October 2015 found that 90% of the material to be dredged would be comprised of reef rock, some scattered thin patches of coarse sand and only a very small proportion of fine sediments (**Appendix H**). It is understood that essentially no siltation had occurred in the channel over the past 23 years and no maintenance dredging has been required, indicating that existing sediment transport rates in the project marine area are very low. If there had been significant sediment transport along the reef shelf, this would have been trapped by the boat channel because it is approximately 3 m deeper than the natural reef shelf. The 2015 survey data has identified that such accretion has not occurred and as such it is likely that transport rates are very low. Hence longshore sediment transport on the reef shelf is likely to be very small, or negligible, and the construction of the safe harbour would not noticeably affect sediment transport and the reef environment that might be affected by such a change. Generally, peak reef shelf current speeds are too high for sediments to settle on the reef shelf.

Another consequence of constructing the safe harbour breakwater is that the structure would potentially reflect waves and thereby increase wave heights in the nearby areas of reef flat inhabited by coral. Some reflection from the beach currently occurs, but the wave reflection coefficient is low, ≈0.1 compared to ≈0.4 predicted from the breakwater, and further towards the shore (refer to **Appendix H**). It is clear that the safe harbour would provide significant wave sheltering and that the greatest changes in waves would occur immediately seaward of the breakwater, with smaller changes being caused by the new navigation channel.

Modelling of changes to bed shear stress associated with wave energy (see **Chapter 26** for details of modelling) indicated an effect on the southern side of the proposed breakwater. In both of the modelling scenarios (i.e. one in 100 year waves associated with a very powerful cyclone and every day waves) the effect was considered a ZoI (i.e. the area was predicted to experience a negligible increase to bed shear stress that would not affect coral). Under the one in 100 year waves scenario, the existing bed shear stress across the entire reef in the vicinity of the proposed safe harbour would be powerful (i.e. it would be equivalent to or above the threshold of 18 N m^{-2}) and likely to cause severe damage to corals, particularly branching corals. Given the threshold for damage is already exceeded under this scenario, the additional bed shear stress due to the breakwater is not relevant. Under the everyday waves scenario, the existing level of bed shear stress is well below the threshold for damage and the additive effect of the breakwater to bed shear stress would be negligible and unlikely to amount to any damage to corals. Hence, on a day-to-day basis there would be no identifiable change.

In summary, the impact to corals from changes to hydrodynamics can be considered long-term and irreversible but is not predicted to significantly alter the environmental values of the reef habitat. The risk to corals from this potential impact is considered to be moderate (refer to **Table 12**).

3.2.10 Acid Sulfate Soils

There is a low potential for potential acid sulfate soils in the intertidal areas of the safe harbour footprint. Notwithstanding this, there is potential for runoff from potential acid sulfate soils ((P)ASS) on the island during construction and from exposed soils in the intertidal areas to be dredged for the safe harbour. Within the safe harbour, a small quantity of intertidal sediment will be dredged. Holding PASS dredged material out of water increases the risk of oxidisation and acid sufate soils leaching material. Exposed (P)ASS leaching into the marine environment could reduce marine water quality and compromise the health of intertidal marine life.

The Dredge management plan will contain strategies and provisions to manage potential (P)ASS material encountered during the proposed dredging activities. The Dredge management plan will ensure no dredge material from the intertidal zone will be dewatered. There will be provision so that the Dredging Contractor minimises exposure of oxygen to (P)ASS materials and to ensure intertidal areas that have been dredged shall not be exposed to oxygen for more than 24 hours continuously. (P)ASS material loaded into containers for disposal is to remain hydrated (no dewatering) and dumped at the disposal site as soon as possible.

The Dredge management plan will include periodic pH monitoring in the safe harbour during dredging. The risk to coral habitats is moderate (refer to **Table 12**).

3.2.11 Degradation or Contamination of Water Quality from Hydrocarbons, Nutrients and Waste

Hydrocarbon spills in the safe harbour, pollutants and other waste associated with the safe harbour or resort and nutrients from the resort have the potential to contribute to the degradation of water quality within and adjacent to the safe harbour. Corals in particular could be directly impacted by changes in water quality. This may arise from a reduced flushing capacity for contaminants originating from the resort/island catchments that drain to this area, or from spills that may occur within the safe harbour. Contamination of marine environments or nutrient enrichment as a result of the dredging plume during construction of the safe harbour is likely to be low, based on sediment sampling undertaken in accordance with the National Assessment Guidelines for Dredging. Best practice site management can be expected to result in a negligible amount of other pollutant material from dredging and construction entering the marine environment. Where the spill is a ‘once off’ and no other cumulative impact occurs, recovery is likely and hence spills are considered to be short-term, reversible impacts.

Best-practice vessel management and site management will be used to minimise the risk of contaminant spillage. There will be no refuelling or vessel maintenance facilities at the safe harbour. Live-aboards will not be allowed nor emptying of waste-water or bilges in the harbour.

The Construction and Operational EMPs will establish and maintain personnel awareness of the importance of spill prevention and response management practices. Dredging and construction vessels and resort vessels are to provide sufficient spill response materials and locate those in close proximity to storage of hydrocarbons and chemicals as well as operational areas. During dredging and ongoing operations of the safe harbour there is to be sufficient oil absorptive and/or containment booms available.

During the construction of the resorts and safe harbour and ongoing operations, waste and sewage will be generated. Wastewater will be generated from the airstrip, safe harbour, pools, spa, restaurants, bars and the range of resort accommodation facilities. The Construction and Operational EMPs will contain criteria for disposing, managing, monitoring, minimising or avoiding the generation of different types of waste in line with applicable Acts, Regulations and International conventions.

Potential contamination of marine water has been assessed in terms of storm water contaminant concentrations and flushing times (described as e-folding times, refer to **Appendix H**). Model simulations were undertaken for the introduction of a conservative contaminant into the whole of the safe harbour (after two days of hydrodynamic warm-up). The simulations were run during a period of neap tides when flushing will be slowest and determined that the safe harbour will flush satisfactorily.

The risk of potential contamination or nutrient enrichment from wastewater and stormwater flowing into the marine environment is considered low given any spills will be of a temporary and reversible nature and the resort and safe harbour would use best practice filtering, storage and containment (refer to **Table 12**).

3.2.12 Introduction of Marine Pests or Diseases

Vessels and movement of offshore equipment have potential to act as vectors for introduced species. Introduced species may be translocated into the project marine area through the release of ballast water (in the case of planktonic larvae or species) or via reproduction from individuals attached to the hull of a vessel. Marine pests are considered to be a long-term, reversible impact to which marine communities have an existing level of exposure.

The resort and safe harbour will not service international routes although occasional yachts may visit, but there would be regular local vessel movement to and from the Island. The risk of vessel traffic introducing marine pests or disease to coral reefs would be moderate (refer to **Table 12**).

Mitigation measures include standard practice procedure such as compliance with Australia's mandatory ballast water management requirements, with the addition of regular inspection of niche areas of high risk vessels. The risk assessment process will consider the known transmission vectors and the vessels operational and maintenance history to assess the overall risk status of a vessel. High risk vessels will be inspected to determine the presence or absence of marine pests. These inspections will focus on confirming that the vessel (including any residual sediment) presents a low risk of introducing marine pests to the area.

3.2.13 Increased Reef Visitation Impacts

Damage to corals in the vicinity of the resort and safe harbour may result from increased vessel traffic and increased reef utilisation (e.g. boating, fishing, snorkelling, swimming and diving). This impact is considered long term but reversible and the risk of it occurring is low (refer to **Table 12**). As part of the Operational EMP there would be clear communication to skippers about approved anchor locations/areas and no-go areas, including clear indication of these areas on board resort vessels as well as visible signage.

If an underwater trail public education concept is adopted, the Operational EMP would include education material such as surface water signage to guide snorkelers and SCUBA divers and manage their behaviour on coral reef communities.

Table 12. Summary of project impact risk assessment on coral habitat in the project marine area.

Phase		Impacting Process	Potential Impact	Adopted Mitigation Strategies	Residual Risk Level		
C	O				L	C	Risk Level
●		Direct removal of coral habitat in the safe harbour footprint	Decrease in coral cover, loss of high-complexity coral reef habitat and potential loss of coral bomboras.	• The safe harbour footprint has been optimised based on coral surveys specifically to: o avoid the large slow growing coral bomboras present in the project marine area; and o minimise the footprint on coral reef habitat • Colonies amenable to transplant will be relocated and artificial habitat created. Other options that would result in a 'net benefit' are discussed in **Appendix X – Net Benefit Discussion Paper;** • Recovery expected over 5 -10 years through coral recruitment and growth on the breakwalls of the safe harbour and in section of navigation channel.	A (Almost Certain)	3	High
●		Increased turbidity and sediment deposition from dredging	Reduction in light available for photosynthesis and partial or complete burial can lead to decreases in growth rate or loss of coral cover, bleaching and higher prevalence of diseases. Ultimately, potential loss of high-complexity coral reef habitat and loss of coral bomboras in the project marine area.	• All dredging activities undertaken in accordance with GBRMPA's Dredging and Spoil Disposal Policy; • Best practice construction methods; • Isolation of the dredge and disturbance area using silt curtains, oil spill booms, bunding, trenching or similar technologies; • Monitoring of turbidity and use of trigger levels to control dredging activities and impact on ecologically sensitive areas.	D (Unlikely)	4	Low
●	●	Altered hydrodynamics and flushing within and outside the proposed safe harbour	Altered hydrodynamics may affect coral physiology through changes in the exchange of oxygen, nutrients and waste. Potential for reduced growth and decline in cover in the project marine area. Altered hydrodynamics may also affect sediment deposition patterns, potentially leading to smothering of corals and breakwater may cause an increase in reflected wave energy that could break coral.	• Sediment deposition study found virtually no siltation in the existing channel, indicating low risk of impact to sediment transport; • Hydrodynamic modelling indicates negligible change to water flow and wave height over majority of the reef in the project marine area apart from some small areas near the breakwater	B (Likely)	4	Moderate
●		Acid sulfate or potential acid sulfate sediment	Degradation of water quality, toxicity effect to corals	• Contain dredge plume through the use of silt curtains. Levels of acid sulfate likely to be low based on sampling done according to NAGD;	E (Rare)	3	Moderate

Phase		Impacting Process	Potential Impact	Adopted Mitigation Strategies	Residual Risk Level		
C	O				L	C	Risk Level
●	●	Degradation or Contamination of Water Quality from Hydrocarbons, Nutrients and Waste	Changes to water quality from contaminants, pollutants or nutrients may impact on coral health, reproduction, community composition and resilience to other stressors	• Fuel, oil and chemical storage and handling undertaken in accordance with AS1940. Minimised volume stored in a secure area; • A Spill Management Plan prepared in accordance with State Planning Policy requirements and to the satisfaction of DERM (Department of Environment and Resource Management); • No refuelling of guest vessels permitted in the Harbour; • Checking of vessel to prevent drips, leaks or failures; • Spill kits would be available and a register of Materials Safety Data Sheet relating to all hazardous substances on board maintained and audited; • Appropriate stormwater retention, filtering and treatment; • Golf course operations and maintenance including fertiliser application in accordance with Environmental Management Plan; • Waste material contained within the designed maintenance area and disposed of in designated bins to prevent contamination of water and soil; • All waste disposed lawfully and wastes listed as 'trackable wastes' handled or transferred in accordance with Environmental Protection Policy (Waste) (refer EPP Waste); • Waste removed from vessels and disposed of at an approved facility.	E (Rare)	4	Low
●	●	Introduction of Marine Pests	Pests can out-compete native species and result in loss of biodiversity	• Standard practice procedure such as compliance with Australia's mandatory ballast water management requirements; • Regular inspections of high risk vessels using the safe harbour.	E (Rare)	3	Moderate
	●	Increased Reef Visitation	Damage to coral colonies caused by resort activities and visitation and anchoring.	• Install appropriate signage regarding anchoring areas and no go area; • Underwater snorkel/SCUBA trail to restrict spatial scale of damage.	D (Unlikely)	4	Low

3.3 Beaches and Intertidal Rocky Shores

3.3.1 Change in Habitat Extent

Dredging and spoil disposal activities can affect beaches, intertidal rock platforms and boulder fields directly through physical removal or smothering. The footprint of the safe harbour intersects only a small area of mapped intertidal beaches or rocky shores (<0.2 ha) relative to its extent on the island. However, there is some potential for accretion and/or erosion of the present resort beach due to a slight change in wave direction as a result of the presence of the safe harbour. Because the present resort beach is held between headlands and groynes, loss by longshore transport may be negligible. From time-to-time sand may be lost by transport seaward beyond the reef edge, but that loss is not quantifiable. Some wind-blown sand loss may occur, but the new revetments at a crest level of 5.6 m AHD will generally prevent this process and resort management procedures will likely return any windblown sand to the beach. Modelling indicates that there would be slight change in mean-weighted wave direction due to the dredging, which increases depth locally causing waves to refract slightly in a counter-clockwise direction at the western end of the resort beach (refer to **Appendix H – Coastal Processes**). Over time, the beach at this end might show minor accretion in the order of a couple of metres. The opposite in terms of direction change occurs towards the eastern end of the beach, where dredging works as well as the presence of the breakwater would cause the mean-weighted wave direction to rotate in the clockwise direction. Hence there is some likelihood that there will be a reduction in mean beach width at the eastern end with some widening at the western end. The resulting accretion (at the western end) will be in the order of approximately 3 m. The overall volume of beach sand held within the headlands (groynes) won't change, but the shoreline in the centre of the beach will recede slightly (order of 2 m).

The residual risk to intertidal habitat from direct removal is considered low given the small amount of directly affected habitat. The overall volume of beach would not change and the accretion and erosion of the resort beach represents a very small proportion of the extent of this habitat in the project marine area and generally at Lindeman Island (refer to **Table 3-13**). In addition, breakwalls, pontoons, piles and other intertidal and subtidal structures associated with the construction of the safe harbour will provide substrata for many intertidal organisms so that there would be a net gain in intertidal rocky habitat.

3.3.2 Increased Turbidity and Sediment Deposition from Dredging

Dredging and spoil disposal activities could potentially impact beaches and intertidal rock platforms and boulder fields indirectly through the creation of turbid plumes and sedimentation. The level of response and rates of recovery are, however, likely to depend on several factors such as the timing, duration, intensity, and scale of the dredging works as well as the type of species affected. Under various dredging and core dumping scenarios, the highest concentration of sediment would be ≈3mg/L, but the increase in suspended solids above ambient generally would be very small (i.e. <1 mg/L) (refer to **Appendix H**). This would result in a negligible increase to the naturally high levels of turbidity in the project marine area. Although modelling of the dredge plume indicated that, without mitigation, the dredge plume would disperse across the entire reef flat to the east (during flood tides) and west (during ebb tides), modelling indicates that suspended sediments quickly disperse from the site when the working-day ceases. Moreover, there will be virtually no fine sediment settlement in the intertidal areas near the safe harbour because current speeds are often too high (>0.3m/s). The plumes are transported significant distances, but this process also reduces the concentrations. It is noted that concentrations below 5 mg/L would not be typically visible. Generally the results show that sediment concentrations in the immediate vicinity of the source are well below this limit and reduce rapidly as the plume moves away from the source.

Given the negligible increase to turbidity from the dredge plume, any impact to intertidal areas is expected to be short term and reversible and the risk would be low, as the species found in the area are resilient (see **Section 2.2**) to short-term disturbances and likely to recover full functionality. The risk to biota in these habitats would be low (refer to **Table 3-13)**. Notwithstanding this, adaptive and contingency management of dredging operations must be applied to reduce turbidity below agreed turbidity trigger values if monitoring detects exceedances outside of the silt curtains. Best practice dredging would control the potential for turbid water from the dredge site moving onto the adjacent reef. Controls to dredging would include silt curtains and bunding and water quality monitoring of turbidity with triggers for adaptive and contingency dredge management.

Altered Hydrodynamics and Flushing Within and Outside the Proposed Safe Harbour

Water movement provides nutrients (food) and dissolved oxygen to aquatic vegetation, removes wastes, and can reduce predation by herbivores. The construction of the safe harbour structures including breakwalls is expected to alter local hydrodynamics, and therefore has the potential to impact on the local marine ecosystem. The safe harbour has been designed to minimise disturbances to local hydrodynamic processes. Modelling indicates that the safe harbour would provide significant wave sheltering although the largest changes in significant wave height (H_s) would occur immediately seaward of the breakwater, away from the intertidal areas (refer to **Appendix H**). Wave direction would also change and this would affect deposition and erosion on the resort beach, although the overall volume of sand on the beach (and hence the area of this habitat) would not change.

The risk to beaches and intertidal rock platforms and boulder fields from this potential impact is moderate because of some physical changes to the ends of the resort beach. Although this impact can be considered long term and irreversible it is not predicted to significantly alter the environmental values of the resort beach given the area and volume of the beach habitat would not change.

Acid Sulfate Soils

There is a low potential for potential acid sulfate soils in the intertidal areas of the safe harbour footprint and the risk to marine habitats and biota is low (refer to **Table 3-13**). Notwithstanding this, there is potential for runoff from potential acid sulfate soils ((P)ASS) on the island during construction and from exposed soils in the intertidal areas to be dredged for the safe harbour. The Construction EMP will include periodic pH monitoring in the safe harbour during dredging.

Degradation or Contamination of Water Quality from Hydrocarbons, Nutrients and Waste

Hydrocarbon spills in the safe harbour, pollutants and other waste associated with the safe harbour or resort and nutrients from the resort have the potential to contribute to the degradation of water quality and may pose a direct hazard to intertidal biota. Contamination of marine environments as a result of the dredging plume during construction of the safe harbour is likely to be low (refer to **Table 3-13**), based on sediment sampling undertaken in accordance with the National Assessment Guidelines for Dredging. Best practice site management can be expected to result in a negligible amount of other pollutant material from dredging and construction to the marine environment. Contamination of marine water has been assessed in terms of storm water contaminant concentrations and flushing times described in terms of e-folding times (refer to **Appendix H**). Model simulations were undertaken for the introduction of a conservative contaminant into the whole of the marina (after two days of hydrodynamic warm-up). The simulations were run during a period of neap tides when flushing will be slowest and determined that the safe harbour will flush satisfactorily.

Contaminants, pollution and nutrient impacts on the intertidal biota are considered to be short term and reversible in nature and the risk is considered moderate. Best-practice vessel management and site management will be used to minimise the risk of contaminant spillage. There will be no refuelling or vessel maintenance facilities at the safe harbour. Live-aboards will not be allowed, nor emptying of waste-water or bilges in the harbour.

The Construction and Operational EMPs will establish and maintaining personnel awareness of the importance of good spill prevention and response management practices. Dredging and construction vessels and resort vessels are to provide sufficient spill response materials and locate those in close proximity to storage of hydrocarbons and chemicals as well as operational areas. During dredging and ongoing operations of the safe harbour there is to be sufficient oil absorptive and/or containment booms available.

During the construction of the resorts and safe harbour and ongoing operations, waste and sewage will be generated. The Construction and Operational EMP will contain criteria for disposing, managing, monitoring, minimising or avoiding the generation of different types of waste, in line with applicable Acts, Regulations and International conventions.

Introduction of Marine Pests or Diseases

Vessels and movement of offshore equipment have potential to act as vectors for introduced species. Introduced species may be translocated into the project marine area through the release of ballast water (in the case of planktonic larvae or species) or via reproduction from individuals attached to the hull of a vessel. Marine pests are considered to be a long-term, reversible impact to which marine communities have an existing level of exposure. However, given some intertidal pests with potential to be introduced could compete with intertidal biota, the risk is moderate (refer to **Table 3-13**).

Increased Reef Visitation Impacts

There is potential for damage to intertidal rock platform biota in the vicinity of the resort due to trampling and the risk of it occurring is moderate (refer to **Table 3-13**). Damage may occur on a small scale around the resort but it would not amount to an ecologically significant impact to intertidal biota in the project marine area. This risk could be managed through education and the delineation of walking trails on the reef flat.

Table 3-13. Summary of project impact risk assessment on beaches and intertidal rocky shore habitat in the project marine area.

Phase		Impacting Process	Potential Impact	Adopted Mitigation Strategies	Residual Risk Level		
C	O				L	C	Risk Level
●		Direct removal of rocky intertidal habitat the safe harbour footprint	Decrease in habitat and food resources for consumers, e.g. birds	• The safe harbour design has been optimised to minimise the footprint on marine habitat.	A (Almost Certain)	5	Moderate
●		Increased turbidity and sediment deposition from dredging	Reduction in light available for photosynthesis and partial or complete burial. Change in sediment grain size.	• All dredging activities undertaken in accordance with GBRMPA's Dredging and Spoil Disposal Policy. • Best practice construction methods. • Isolation of the dredge and disturbance area using silt curtains, oil spill booms, bunding, trenching or similar technologies • Monitoring of turbidity and use of trigger levels to control dredging activities and impact on ecologically sensitive areas.	D (Unlikely)	4	Low
●	●	Altered hydrodynamics and flushing within and outside the proposed safe harbour	Changes in sediment deposition patterns, potential erosion	• Hydrodynamic modelling indicates some changes to water flow and wave direction that would affect minor deposition and erosion at alternate ends of the resort beach but no change to beach volume.	B (Likely)	4	Moderate
●	●	Degradation or Contamination of Water Quality from Hydrocarbons, Nutrients and Waste	Toxicity effect to marine flora and fauna, including birds utilising the intertidal habitat	• Fuel, oil and chemical storage and handling undertaken in accordance with AS1940. Minimised volume stored in a secure area. • A Spill Management Plan prepared in accordance with State Planning Policy requirements and to the satisfaction of DERM (Department of Environment and Resource Management). • No refuelling of guest vessels permitted in the Harbour. • Checking of vessel to prevent drips, leaks or failures. • Spill kits would be available and a register of Materials Safety Data Sheet relating to all hazardous substances on board maintained and audited; • Appropriate stormwater retention and treatment. • Golf course operations and maintenance including fertiliser application in accordance with Irrigation Management Plan. • Waste material contained within the designed maintenance area and disposed of in designated bins to prevent contamination of water and soil.	E (Rare)	4	Low

Phase		Impacting Process	Potential Impact	Adopted Mitigation Strategies	Residual Risk Level		
C	O				L	C	Risk Level
				• All waste disposed lawfully and wastes listed as 'trackable wastes' handled or transferred in accordance with Environmental Protection Policy (Waste) (refer EPP Waste); • Waste removed from vessels and disposed of at an approved facility.			
●		Acid sulphate or potential acid sulphate sediment.	Degradation of water quality, toxicity effect to marine flora and fauna	• Contain dredge plume though the use of silt curtains. Levels of acid sulphate likely to be low based on sampling done according to NAGD guidelines.	E (Rare)	2	Moderate
●	●	Introduction of Marine Pests	Pests can out-compete native species and result in loss of biodiversity	• Standard practice procedure such as compliance with Australia's mandatory ballast water management requirements. • Regular inspection and cleaning of niche areas of commercial vessels before travelling to and from the Safe Harbour.	E (Rare) #N/A	3	Moderate
	●	Increased Visitation	Trampling of rock platform biota caused by resort activities and visitation.	• Walking trails and information signage.	B (Likely)	4	Moderate

3.4 Aquatic Vegetation

3.4.1 Change in Habitat Extent

Dredging and spoil disposal activities can impact seagrasses or macroalgae directly through physical removal or smothering. The footprint of the safe harbour intersects with part of the of mapped seagrass habitat (0.50 ha, and **Figure 22**). However, seagrass cover in the area directly affected is low (<5% cover, BMT WBM 2013) and the safe harbour has been designed to minimise the footprint on seagrass habitat, leaving a large area of seagrass (with much higher cover) unaffected outside of the proposed safe harbour. Tropical seagrasses of the type at Lindeman Island generally show a seasonality where there is a general expansion of distribution spatial extent and density (cover) during the dry season and reduction during the wet season (Cardno 2015). Importantly, the surveys done by BMT WBM were done in late August near the end of the dry season, when cover would have been approaching maximum. Further, given the small areas of suitable substratum in the footprint of the safe harbour there are unlikely to be any other areas of 'potential' seagrass habitat that could also be directly affected. The low cover in the small area of seagrass within the footprint suggests it would not be an important habitat for any species, including its potential for being an important food source to marine turtles or dugongs. As such the removal of seagrass in the footprint is not considered ecologically significant. Notwithstanding this, given it is benthic primary producer habitat, the loss should be compensated for in the offset program or net benefit strategy. The residual risk to seagrass habitat from direct removal is considered low (refer to **Table 14**).

The footprint of the safe harbour also intersects with macroalgae habitat (refer to **Figure 23**). This habitat is very common around the island and in the region. Breakwalls, pontoons, piles and other intertidal and subtidal structures associated with the proposed safe harbour will provide artificial substrata for many species of macroalgae to recruit to but there would still be a net loss in area of this habitat. Given this habitat is very common around the island and in the region, the net loss is considered a minor consequence and the residual risk to macroalgae habitat from direct removal is considered moderate (refer to **Table 3-14**). Notwithstanding this, this loss of general benthic primary producer habitat will be compensated for in the offset program through the creation of new benthic primary producer (coral) habitat.

3.4.2 Increased Turbidity and Sediment Deposition from Dredging

Dredging and spoil disposal activities could potentially impact seagrasses indirectly through the creation of turbid plumes and sedimentation. Although seagrasses are photosynthetic and reduction of light from increased turbidity may affect their growth and survival, the seagrass species found in the area are known to be resilient to short-term disturbances. The level of response and rates of recovery to any disturbance are likely to depend on several factors such as the timing, duration, intensity, and scale of the dredging works.

A turbidity and sedimentation study was undertaken to inform this EIS and this included an analysis of siltation in the existing boat channel and modelling of the dredge plume. The results of this study is given in **section 2.3**

Given the increase to turbidity from the dredge plume would be negligible, short term and reversible, the risk to seagrass of increased turbidity and sediment deposition from dredging for the safe harbour would be low (refer **Table 3-14**).

Macroalgae are expected to be highly resilient to turbidity and sedimentation and the risk to these biota would be low (refer **Table 3-14**).

3.4.3 Altered Hydrodynamics and Flushing Within and Outside the Proposed Safe harbour

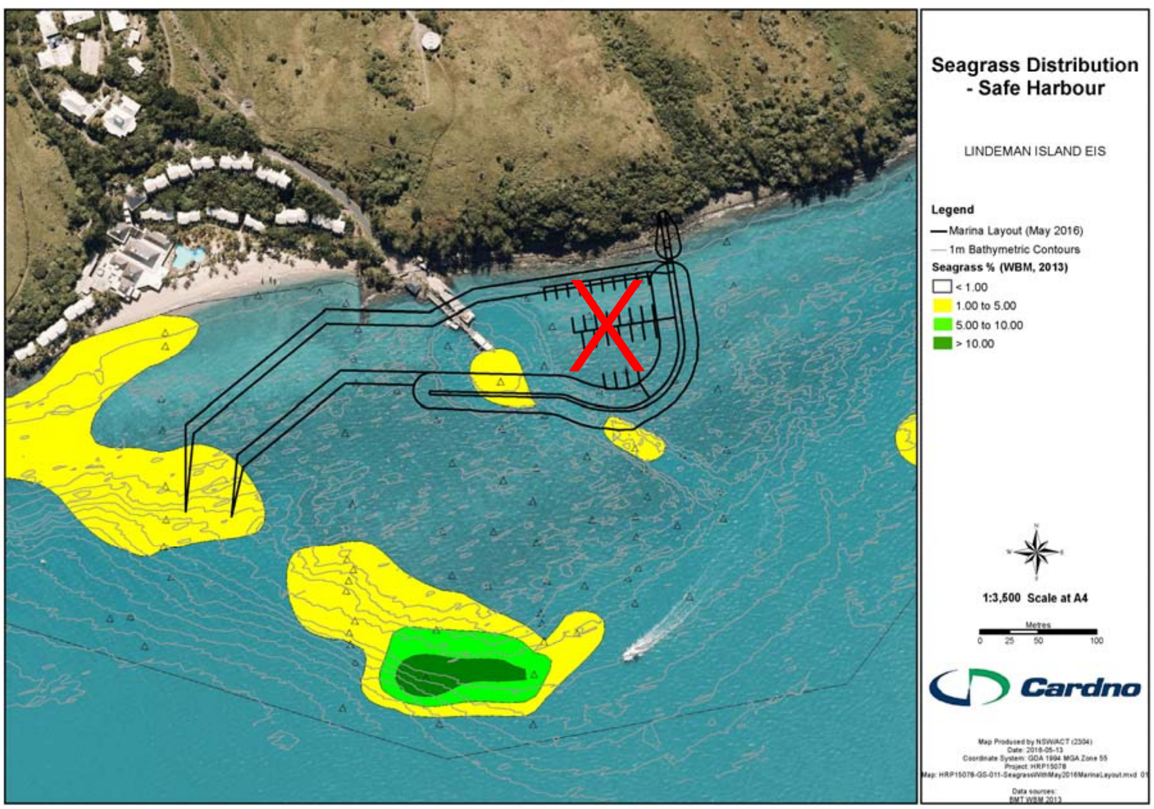
Water movement provides nutrients (food) and dissolved oxygen to aquatic vegetation, removes wastes, and can reduce predation by herbivores. The construction of the safe harbour structures including breakwalls is expected to alter local hydrodynamics, and therefore has the potential to impact on the local marine ecosystem. The safe harbour has been designed to minimise disturbances to local hydrodynamic processes.

The impact to marine vegetation from altered hydrodynamics is discussed above in relation to corals and can be considered long term and irreversible but is not predicted to significantly alter the environmental values of the reef or seagrass habitat. Seagrass closest to shore to the western end of the resort beach would be most affected but given the density of seagrass in this area is very low, it would not amount to ecologically significant impact to seagrass in the project marine area. The risk to seagrass and macroalgae from this potential impact is moderate (refer **Table 14**).

3.4.4 Acid Sulfate Soils

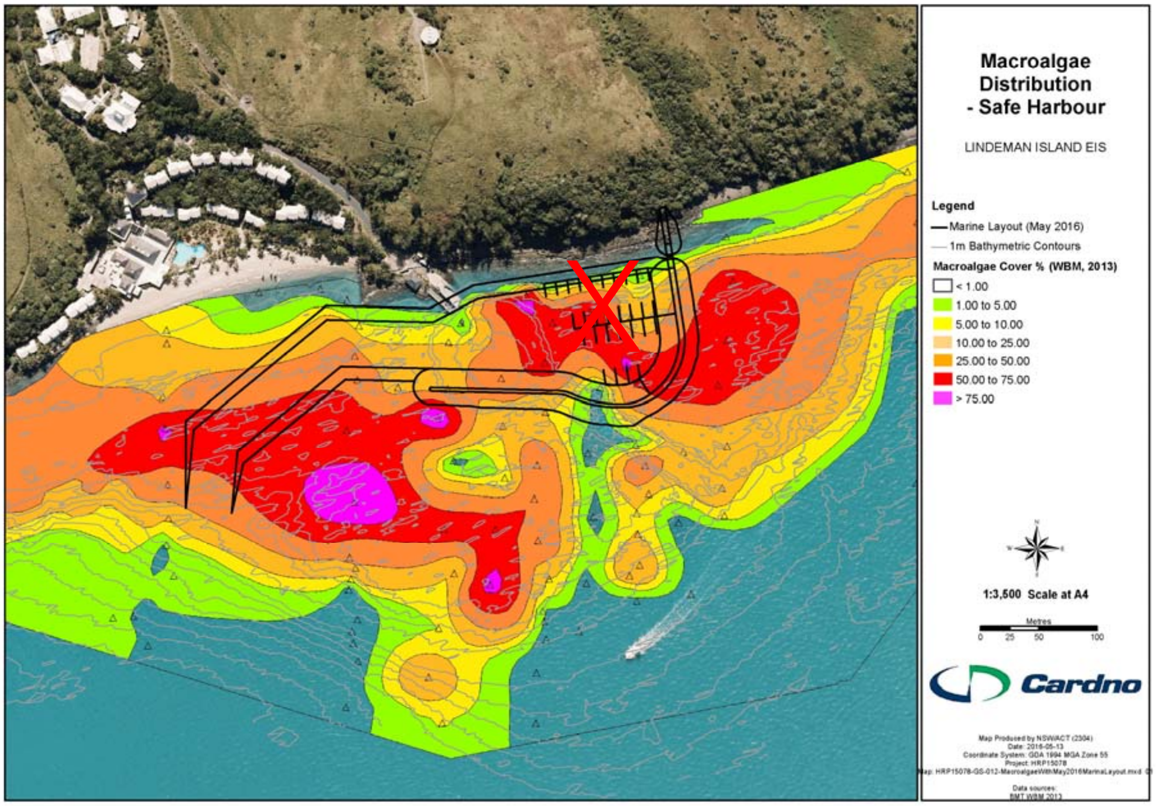
There is a low potential for potential acid sulfate soils in the intertidal areas of the safe harbour footprint and the risk to marine habitats and biota is low (refer **Table 14**). Notwithstanding this, there is potential for runoff from potential acid sulfate soils ((P)ASS) on the island during construction and from exposed soils in the intertidal areas to be dredged for the safe harbour. The Dredge management plan will include periodic pH monitoring in the safe harbour during dredging.

Figure 22. Footprint of the proposed safe harbour (Version 4) over seagrass distribution.



Note: A safe harbour is no longer proposed.

Figure 14. Footprint of the proposed safe harbour (Version 4) over macroalgae distribution.



Note: A safe harbour is no longer proposed.

3.4.5 Degradation or Contamination of Water Quality from Hydrocarbons, Nutrients and Waste

Hydrocarbon spills in the safe harbour, pollutants and other waste associated with the safe harbour or resort and nutrients from the resort have the potential to contribute to the degradation of water quality and may pose a direct hazard to marine vegetation, particularly if there is reduced flushing (refer to **Appendix H**). Model simulations were undertaken for the introduction of a conservative contaminant into the whole of the marina (after two days of hydrodynamic warm-up). The simulations were run during a period of neap tides when flushing will be slowest and determined that the safe harbour will flush satisfactorily.

Best practice site management can be expected to result in a negligible amount of other pollutant material from dredging and construction to the marine environment. Contaminants, pollution and nutrient impacts on the inshore marine vegetation are considered to be short term and reversible in nature and the risk is considered low (refer **Table 14**).

3.4.6 Introduction of Marine Pests or Diseases

Vessels and movement of offshore equipment have potential to act as vectors for introduced species. Introduced species may be translocated into the project marine area through the release of ballast water (in the case of planktonic larvae or species) or via reproduction from individuals attached to the hull of a vessel. Marine pests are considered to be a long-term, reversible impact to which marine communities have an existing level of exposure however, no pests are likely to be introduced that would affect seagrass or macroalagae and the risk to aquatic flora is low (refer **Table 14**).

3.4.7 Increased Reef Visitation Impacts

There is potential for damage to seagrass or macroalgae in the vicinity of the resort and safe harbour to result from increased vessel traffic and increased reef utilisation (e.g. boating, fishing, snorkelling, swimming and diving) but the risk of it occurring is low (refer Error! Reference source not found.). Seagrass closest to shore to the western end of the resort beach would be most affected due to its potential to be trampled but given it is unlikely that people would be walking in the area and the density of seagrass in this area is very low, any damage is unlikely and if it did occur, it would not amount to ecologically significant impact to seagrass in the project marine area.

Table 14. Summary of project impact risk assessment on seagrass and macroalgae habitat in the project marine area.

Phase		Impacting Process	Potential Impact	Adopted Mitigation Strategies	Residual Risk Level		
C	O				L	C	Risk Level
●		Direct removal of seagrass or macroalgae in the safe harbour footprint	Decrease in seagrass or macroalgal cover, loss of above- and below-ground biomass, habitat and food resources for consumers.	• Optimise the safe harbour design to minimise the footprint on seagrass patches, leaving large areas of unaffected seagrass habitat outside of the footprint; • Breakwalls create artificial habitat for macroalgae;	B (Likely)	4	Moderate
●		Increased turbidity and sediment deposition from dredging	Reduction in light available for photosynthesis and sediment burial.	• All dredging activities undertaken in accordance with GBRMPA's Dredging and Spoil Disposal Policy; • Best practice construction methods; • Isolation of the dredge and disturbance area using silt curtains, oil spill booms, bunding, trenching or similar technologies; • Monitoring of turbidity and use of trigger levels to control dredging activities and impact on ecologically sensitive areas.	D (Unlikely)	4	Low
●	●	Altered hydrodynamics and flushing within and outside the proposed safe harbour	Altered hydrodynamics may affect seagrass physiology through changes in the exchange of oxygen, nutrients and waste. Potential for reduced growth and decline in cover in the project marine area. Potential to affect sediment deposition patterns	• Safe harbour design guided by numerical modelling simulations to minimise impacts to hydrodynamics in the project marine area. • Sediment deposition study found virtually no siltation in the channel, indicating low risk of impact to sediment transport and deposition	B (Likely)	4	Moderate
●		Acid sulfate or potential acid sulfate sediment	Degradation of water quality, toxicity effect to marine flora and fauna	• Contain dredge plume. Levels of acid sulfate likely to be low based on sampling done according to NAGD guidelines.	E (Rare)	4	Low
●	●	Degradation or Contamination of Water Quality from Hydrocarbons, Nutrients and Waste	Toxicity effect of contaminants or pollutants to seagrass and algae Potential for overgrowth of seagrass/algae by epiphytes, limiting light available for photosynthesis and reducing productivity and growth	• Fuel, oil and chemical storage and handling undertaken in accordance with AS1940. Minimised volume stored in a secure area; • A Spill Management Plan prepared in accordance with State Planning Policy requirements and to the satisfaction of DERM (Department of Environment and Resource Management); • No refuelling of guest vessels permitted in the Harbour	E (Rare)	4	Low

Phase		Impacting Process	Potential Impact	Adopted Mitigation Strategies	Residual Risk Level		
C	O				L	C	Risk Level
				• Checking of vessel to prevent drips, leaks or failures; • Spill kits would be available and a register of Materials Safety Data Sheet relating to all hazardous substances on board maintained and audited • Appropriate stormwater retention and treatment • Golf course operations and maintenance including fertiliser application in accordance with Environmental Management Plan • Waste material contained within the designed maintenance area and disposed of in designated bins to prevent contamination of water and soil; • All waste disposed lawfully and wastes listed as 'trackable wastes' handled or transferred in accordance with Environmental Protection Policy (Waste) (refer EPP Waste); • Waste removed from vessels and disposed of at an approved facility;			
●	●	Introduction of Marine Pests	Pests can out-compete native species and result in loss of biodiversity	• Standard practice procedure such as compliance with Australia's mandatory ballast water management requirements • Regular inspections of high risk vessels using the safe harbour	E (Rare)	4	Low
	●	Increased Visitation	Trampling of seagrass caused by resort activities and visitation.	• No action necessary	D (Unlikely)	4	Low

3.5 Subtidal Soft Sediment Fauna

3.5.1 Change in Habitat Extent

Dredging for the safe harbour will create a new area of soft sediment within the footprint and approach channel. This habitat is very common around the island and in the region but nonetheless the newly created habitat would support infaunal and epifaunal assemblages. As well as being a source of food for organisms higher up the food chain, such as fish and large invertebrates, including some sharks, stingrays and loggerhead turtles, they would also drive nutrient cycling through reworking of the sediments (bioturbation) within the safe harbour

3.5.2 Increased Turbidity and Sediment Deposition from Dredging

The level of response of subtidal soft bottom benthos to a dredge plume and sedimentation, and rates of recovery, depend on several factors such as the timing, duration, intensity, and scale of the dredging works as well as the type of species affected. Turbid plumes and sedimentation from dredging could potentially impact assemblages of soft sediment fauna located at the entrance to the safe harbour and in deeper waters beyond the nearshore reef indirectly. However, the risk to biota in these habitats is considered to be low (refer to **Table 15**), given the dredging would be short-term and for a small volume of sediment, there is only a very small proportion of fine sediments in the dredge footprint and that modelling indicates a negligible increase to turbidity and potential sedimentation (refer to **Appendix H**). Were soft sediment biota affected, the impacts would be short term and reversible, as the species found in the area are likely to be resilient (see **Section 2.4**) to short-term disturbances and likely to recover full functionality.

3.5.3 Altered Hydrodynamics and Flushing Within and Outside the Proposed Safe harbour

Water movement provides nutrients (food) and dissolved oxygen to aquatic vegetation, removes wastes, and can reduce predation by herbivores. The construction of the safe harbour structures including breakwalls is expected to alter local hydrodynamics, and therefore has the potential to impact on the local marine ecosystem. The safe harbour has been designed to minimise disturbances to local hydrodynamic processes. The impacts of the proposed safe harbour to hydrodynamics are discussed above in relation to corals. The risk from this potential impact to soft sediment fauna (at the entrance to the safe harbour) in deeper waters beyond the nearshore reef is moderate (refer to **Table 15**). This impact can be considered long term and irreversible but is not predicted to significantly alter the environmental values of this habitat given the scale of impact is small and because the habitat is common in the region.

3.5.4 Acid Sulfate Soils

There is a low potential for potential acid sulfate soils in the intertidal areas of the safe harbour footprint and the risk to marine habitats and biota is low. Notwithstanding this, there is potential for runoff from potential acid sulfate soils ((P)ASS) on the island during construction and from exposed soils in the intertidal areas to be dredged for the safe harbour. The Dredge Management Plan will include periodic pH monitoring in the safe harbour during dredging.

3.5.5 Degradation or Contamination of Water Quality from Hydrocarbons, Nutrients and Waste

Hydrocarbon spills in the safe harbour, pollutants and other waste associated with the safe harbour or resort and nutrients from the resort have the potential to contribute to the degradation of water quality and may pose a direct hazard to soft sediment fauna (at the entrance to the safe harbour) in deeper waters beyond the nearshore reef. The risk of contamination of marine environments as a result of the dredging plume during construction of the safe harbour is likely to be low (refer to **Table 15**), based on sediment sampling undertaken in accordance with the National Assessment Guidelines for Dredging. Best practice site management can be expected to result in a negligible amount of other pollutant material from dredging and construction to the marine environment. Contaminants, pollution and nutrient impacts on the soft sediment fauna (at the entrance to the safe harbour) in deeper waters beyond the nearshore reef are considered to be short term and reversible in nature and the risk is considered moderate.

3.5.6 Introduction of Marine Pests or Diseases

Vessels and movement of offshore equipment have potential to act as vectors for introduced species. Introduced species may be translocated into the project marine area through the release of ballast water (in the case of planktonic larvae or species) or via reproduction from individuals attached to the hull of a vessel. Marine pests are considered to be a long-term, reversible impact to which marine communities have an existing level of exposure however, and given there are potential subtidal soft sediment pests with potential to be introduced that would compete with native biota the risk is moderate (refer to **Table 15**).

Table 3-15. Summary of project impact risk assessment on subtidal soft sediment fauna in the project marine area.

Phase		Impacting Process	Potential Impact	Adopted Mitigation Strategies	Residual Risk Level		
C	O				L	C	Risk Level
	●	Creation of habitat in safe harbour	Increase in extent of habitat	• N/a – positive impact of project	A (Almost Certain)	5	Low
●		Increased turbidity and sediment deposition from dredging	Partial or complete burial. Change in sediment grain size.	• All dredging activities undertaken in accordance with GBRMPA's Dredging and Spoil Disposal Policy; • Best practice construction methods; • Isolation of the dredge and disturbance area using silt curtains, oil spill booms, bunding, trenching or similar technologies; • Monitoring of turbidity and use of trigger levels to control dredging activities and impact on ecologically sensitive areas.	D (Unlikely)	4	Low
●	●	Altered hydrodynamics and flushing within and outside the proposed safe harbour	Changes in sediment deposition patterns, potential erosion	• Numerical modelling simulations to guide the design of the safe harbour • Sediment deposition study found virtually no siltation in the channel indicating low risk of impact to sediment transport and deposition	C (Possible)	4	Moderate
●	●	Degradation or Contamination of Water Quality from Hydrocarbons, Nutrients and Waste	Toxicity effect to marine flora and fauna, including fish utilising the subtidal soft sediment habitat	• Fuel, oil and chemical storage and handling undertaken in accordance with AS1940. Minimised volume stored in a secure area; • A Spill Management Plan prepared in accordance with State Planning Policy requirements and to the satisfaction of DERM (Department of Environment and Resource Management); • No refuelling of guest vessels permitted in the Harbour • Checking of vessel to prevent drips, leaks or failures; • Spill kits would be available and a register of Materials Safety Data Sheet relating to all hazardous substances on board maintained and audited • Appropriate stormwater retention and treatment • Golf course operations and maintenance including fertiliser application in accordance with an Irrigation Management Plan • Waste material contained within the designed maintenance area and disposed of in designated bins to prevent contamination of water and soil; • All waste disposed lawfully and wastes listed as 'trackable wastes' handled or transferred in accordance with Environmental Protection Policy (Waste) (refer EPP Waste); • Waste removed from vessels and disposed of at an approved facility;	E (Rare)	4	Low

Phase		Impacting Process	Potential Impact	Adopted Mitigation Strategies	Residual Risk Level		
C	**O**				**L**	**C**	**Risk Level**
●	●	Introduction of Marine Pests	Pests can out-compete native species and result in loss of biodiversity	• Standard practice procedure such as compliance with Australia's mandatory ballast water management requirements • Regular inspection and cleaning of niche areas of commercial vessels before travelling to and from the safe harbour	E (Rare)	3	Moderate

3.6 Fish, Sharks and Rays, Sea snakes and Macrocrustaceans

The following sections assess project impacts generally to Fish, Sharks and Rays, Sea snakes and Macrocrustaceans. For an assessment of impacts to Sharks and Rays listed as threatened or migratory under the EPBC Act refer to **Chapter 26.**

3.6.1 Increased Turbidity and Sediment Deposition from Dredging

Fish, Sharks and Rays, Sea snakes and Macrocrustaceans are found in all of the subtidal habitats in the project marine area. The very small increases to turbidity or sediment deposition due to dredging (**Section 2.5**) would not affect these mobile species who would move away from any potentially affected areas. The risk would be low (refer to **Table 16**).

3.6.2 Acid Sulfate Soils

There is a low potential for potential acid sulfate soils in the intertidal areas of the safe harbour footprint and the risk to marine habitats and biota is low (refer to **Table 16**). Notwithstanding this, there is potential for runoff from potential acid sulfate soils ((P)ASS) on the island during construction and from exposed soils in the intertidal areas to be dredged for the safe harbour.

The Dredge management plan will include periodic pH monitoring in the safe harbour during dredging.

3.6.3 Degradation or Contamination of Water Quality from Hydrocarbons, Nutrients and Waste

Hydrocarbon spills in the safe harbour, pollutants and other waste associated with the safe harbour or resort and nutrients from the resort have the potential to contribute to the degradation of water quality and may pose a direct hazard to soft sediment fauna (at the entrance to the safe harbour) in deeper waters beyond the nearshore reef. The risk to Fish, Sharks and Rays, Sea snakes and Macrocrustaceans would be low as these species would move away from any potentially affected areas**.**

3.6.4 Increased Reef Visitation Impacts

There is potential for fishing to affect the abundance of some fish species. Shark and Rays and Sea snakes wold not be affected by fishing given they would not be targeted. Some reef fish may be caught in the project marine area but the removal of some individuals would not amount to ecologically significant impact to fish assemblage in the project marine area and the risk is low (refer to **Table 16**).

Table 16. Summary of project impact risk assessment on fish, sharks and rays, sea snakes and macrocrustaceans in the project marine area

Phase		Impacting Process	Potential Impact	Adopted Mitigation Strategies	Residual Risk Level		
C	O				L	C	Risk Level
●		Increased turbidity and sediment deposition from dredging	Increased likelihood of contracting diseases and infections.	• All dredging activities undertaken in accordance with GBRMPA's Dredging and Spoil Disposal Policy; • Best practice construction methods; • Isolation of the dredge and disturbance area using silt curtains, oil spill booms, bunding, trenching or similar technologies; • Monitoring of turbidity and use of trigger levels to control dredging activities and impact on ecologically sensitive areas.	E (Rare)	4	Low
●	●	Degradation or Contamination of Water Quality from Hydrocarbons, Nutrients and Waste	Toxicity effect to marine fauna	• - Fuel, oil and chemical storage and handling undertaken in accordance with AS1940. Minimised volume stored in a secure area; • A Spill Management Plan prepared in accordance with State Planning Policy requirements and to the satisfaction of DERM (Department of Environment and Resource Management); • No refuelling of guest vessels permitted in the Harbour • Checking of vessel to prevent drips, leaks or failures; • Spill kits would be available and a register of Materials Safety Data Sheet relating to all hazardous substances on board maintained and audited • Appropriate stormwater retention and treatment • Golf course operations and maintenance including fertiliser application in accordance with Environmental Management Plan • - Waste material contained within the designed maintenance area and disposed of in designated bins to prevent contamination of water and soil; • All waste disposed lawfully and wastes listed as 'trackable wastes' handled or transferred in accordance with Environmental Protection Policy (Waste) (refer EPP Waste); • Waste removed from vessels and disposed of at an approved facility;	E (Rare)	4	Low
●		Acid sulfate or potential acid sulfate sediment	Degradation of water quality, toxicity effect to marine fauna	• Contain dredge plume. Levels of acid sulfate likely to be low based on sampling done according to NAGD guidelines.	E (Rare)	4	Low
	●	Increased Reef Visitation	Resort activities, fishing, visitation and fish feeding.	• Fishing locations and effort managed as part of the EMP • Install appropriate signage	E (Rare)	4	Low

3.7 Marine Turtles, Marine Mammals and Marine Birds

The following sections assess project impacts generally to Marine Turtles, Marine Mammals and Marine Birds. For an assessment of impacts to specific threatened or migratory species listed under the EPBC Act see **Chapter 26**.

3.7.1 Degradation or Contamination of Water Quality from Hydrocarbons, Nutrients and Waste

Hydrocarbon spills in the safe harbour, pollutants and other waste associated with the safe harbour or resort and nutrients from the resort have the potential to contribute to the degradation of water quality and may pose a direct hazard to Marine Turtles, Marine Mammals and Marine Birds temporarily foraging or resting in the habitats close to the safe harbour. The risk to Marine Turtles, Marine Mammals and Marine Birds would be low (refer to **Table 17**) as these species would move away from any potentially affected areas.

3.7.2 Litter and Waste Generated by Construction, Resort Activities and Recreational Fishing.

There is potential for accidental release of litter and other hard wastes by vessels used during construction of the safe harbour and those involved in ongoing operations of the new resort. There is also potential for litter and other hard wastes to enter the nearshore waters of the project marine area via resort stormwater outlets and from vessels, fishing and boating. Some marine debris have potential to entangle or harm marine mammals, marine turtles or marine birds. This type of threat is listed in the EPBC Act as the key threatening process 'Injury and fatality caused by ingestion of, or entanglement in harmful marine debris'. Given the following controls on the project regarding the release of litter and other hard waste, the risk of this impact, and consequently the key threatening process, is low (refer to **Table 17**).

- Monitor incidence of injury/fatalities and fishing effort and manage as appropriate;
- Education on responsible fishing;
- Waste material contained within the designed maintenance area and disposed of in designated bins to prevent contamination of water and soil;
- Allocated areas for solid and liquid waste storage on board of vessels;
- All waste disposed lawfully and wastes listed as 'trackable wastes' handled or transferred in accordance with Environmental Protection Policy (Waste) (refer EPP Waste);
- Waste removed from vessels and disposed of at an approved facility; and
- Housekeeping procedures implemented to minimise the generation of waste and all waste stored appropriately.

3.7.3 Acid Sulfate Soils

There is a low potential for potential acid sulfate soils in the intertidal areas of the safe harbour footprint and the risk to marine habitats is low. Notwithstanding this, there is potential for runoff from potential acid sulfate ((P)ASS) on the island during construction and from exposed soils in the intertidal areas to be dredged for the safe harbour. The risk to marine turtles, marine mammals and marine birds is considered moderate (refer to **Table 17**).

The Dredge Management Plan will include periodic pH monitoring in the safe harbour during dredging.

3.7.4 Vessel Strikes to Some Marine Fauna

Increased vessel traffic near the project marine area during both construction and resort operation has the potential to increase the risk of collision between vessels and marine fauna. Marine Turtles, Cetaceans and Dugongs are susceptible to harm from vessel strike.

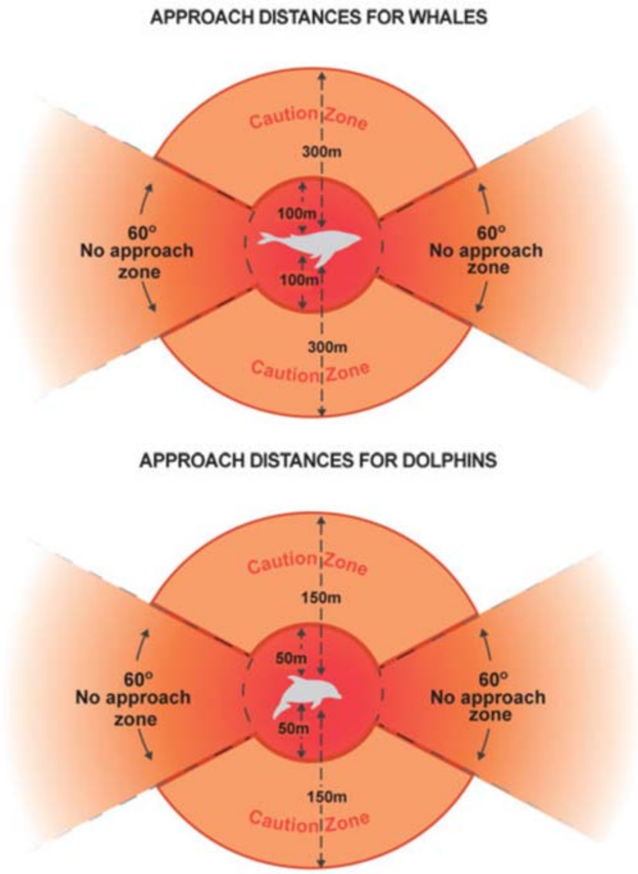
Mitigation measures include the establishment of ‘go slow’ zones around the safe harbour in line with Maritime Safety Queensland (MSQ) boating safety requirements, and signage for general best boating practice around the safe harbour. The Operational EMP would be prepared and actioned to educate skippers as to how best to avoid boat strikes and any boat strikes or stranding would be reported to management and relevant agencies. Skippers are to respond to whale observations in accordance with vessel interaction procedures including the application of 300 m observation zone and 100-m exclusion zone (refer to **Figure 24**). Skippers are to respond to dolphins and dugong observations in accordance with vessel interaction procedures including the application of 150 m observation zone and 50 m exclusion zone. Skippers are to respond to turtle observations in accordance with vessel interaction procedures including the application of 100 m observation zone and 50 m exclusion zone. Skippers are to respond to sightings in accordance with vessel interaction procedures outlined in **Figure 24** including application of a “no wash” speed for fauna approaching the vessel within the Observation Zone during operations

During construction of the safe harbour, construction vessels will abide by the following rules: As a minimum, one crew member trained as Marine Fauna Observer (MFO) to be on duty during daylight operations above deck with good visibility. All vessel masters must be competent in protected marine species interaction procedures. The construction Contractor is to ensure visual assessment are undertaken by trained MFO prior to dredging activities, while dredging, while construction vessels are on route to the island.

All reasonable efforts to reduce these impacts will be implemented as preventive management actions to manage the impact to protected marine species. In the unlikely event that vessel strikes occur, corrective actions will be considered and implemented on a case by case basis in order to adaptively respond and to prevent re-occurrence.

Vessel strike impacts are considered to be long term, but reversible if mitigated by slow boat speeds that minimise collisions or result in minor harm from which fauna may recover. The risk is moderate (refer to **Table 17**).

Figure 24. DoE guidelines on approach distances for whales and dolphins.



3.7.5 Artificial Lighting

Artificial lighting has potential to disturb species such as Marine Turtles or Marine Birds that are migrating, nesting or breeding. The project marine area is not a known turtle breeding or nesting area. Artificial lighting is considered a long-term impact with moderate risk on marine fauna (refer to **Table 17**), due to the current artificial lighting profile on the island, the lack of turtle nesting in the project marine area and the availability of alternate bird roosting sites on the island.

3.7.6 Underwater Noise

Vessel and dredging noise have the potential to modify species behaviour and result in avoidance of the area by Marine Turtles and Marine Mammals. This potential impact is considered short term and project activities are considered unlikely to generate noise of an intensity or duration that may result in physiological impacts on species. The risk is moderate (refer to **Table 17**).

Underwater sound from construction operations is not expected to exceed the underwater noise criteria. The observation that the sound generated by project activities could deter fauna away from the vicinity is considered advantageous to the species of interest. However, management measures will be applied to further reduce underwater noise impacts to protected marine species.

The Construction EMP will include procedures to limit physiological impact to marine megafauna as a result of sound and vibrations generated during dredging and construction activities. The construction Contractor is to ensure that all equipment is maintained in good operating condition and has proper sound control systems in place. The construction Contractor is to apply any of the following sound minimisation tools, where appropriate and practical:

- Mufflers;
- Use of special enclosures;
- Sound-insulation mounts;
- Propeller shrouds; and
- Tuned propellers and drive shafts.

The construction Contractor is to minimise the sound generation of equipment (thrusters and auxiliary plant) by switching them off when not used (e.g. avoid running on standby mode).

In the event that any sound- or noise-related incident takes place, the incident will be investigated and discussed to further improve awareness.

Table 17. Summary of project impact risk assessment on marine turtles, marine mammals and marine birds in the project marine area.

Phase		Impacting Process	Potential Impact	Adopted Mitigation Strategies	Residual Risk Level		
C	O				L	C	Risk Level
●	●	Degradation or Contamination of Water Quality from Hydrocarbons, Nutrients and Waste	Toxicity effect to marine fauna	• Fuel, oil and chemical storage and handling undertaken in accordance with AS1940. Minimised volume stored in a secure area; • A Spill Management Plan prepared in accordance with State Planning Policy requirements and to the satisfaction of DERM (Department of Environment and Resource Management); • No refuelling of vessels permitted in the safe harbour • Refuelling of other vessels in designated areas and by licensed suppliers in accordance with their Standard Operating Procedures; • Checking of vessel to prevent drips, leaks or failures; • Spill kits available and a register of Materials Safety Data Sheet relating to all hazardous substances on board maintained and audited • Education on responsible fishing. • Waste material contained within the designed maintenance area and disposed of in designated bins to prevent contamination of water and soil; • Waste removed from vessels and disposed of at an approved facility; • Housekeeping procedures implemented to minimise the generation of waste and all waste stored appropriately.	E (Rare)	4	Low
●	●	Litter and waste generated by construction, resort activities and recreational fishing.	Litter and waste from vessels, fishing and boating. Injury and fatality caused by ingestion of, or entanglement in harmful marine debris (EPBC Act)	• Monitor incidence of injury/fatalities and fishing effort and manage as appropriate; • Education on responsible fishing. • Waste material contained within the designed maintenance area and disposed of in designated bins to prevent contamination of water and soil; • Allocated areas for solid and liquid waste storage on board of vessels; • All waste disposed lawfully and wastes listed as 'trackable wastes' handled or transferred in accordance with Environmental Protection Policy (Waste) (refer EPP Waste); • Waste removed from vessels and disposed of at an approved facility;	E (Rare)	4	Low

Phase		Impacting Process	Potential Impact	Adopted Mitigation Strategies	Residual Risk Level		
C	O				L	C	Risk Level
				• Housekeeping procedures implemented to minimise the generation of waste and all waste stored appropriately.			
●		Acid sulfate or potential acid sulfate sediment.	Degradation of water quality, toxicity effect to marine flora and fauna	• Contain dredge plume. Levels of acid sulfate likely to be low based on sampling done according to NAGD guidelines.	E (Rare)	2	Moderate
●	●	Vessel Strike	Boat strikes to marine turtles and mammals (whales and dugong) due to increased marine traffic. Collisions may result in injuries or death.	• Designation of 'go slow' zones; • Resort Tours Management Plan prepared and actioned as part of the EMP; • Any boat strikes or strandings reported to management and relevant agencies.	E (Rare)	3	Moderate
●	●	Artificial Lighting	Disorientation and behavioural changes in adults and juvenile marine turtles, some birds; NB: turtle nesting not recorded on resort beach hence impacts on turtle hatchlings unlikely	• Sympathetic lighting strategies included in the design of resort and safe harbour infrastructure	C (Possible)	4	Moderate
●	●	Underwater Noise	Disorientation and behavioural changes in adults and juvenile marine turtles and marine mammals	• Sympathetic lighting strategies included in the design of resort and safe harbour infrastructure	C (Possible)	4	Moderate

4 Conclusion

The project's marine area includes sandy beaches, rocky shores, fringing coral reef, soft bottom areas, sparse seagrass and macroalgae. These marine habitats are important to mobile fauna including fish, shark, rays, sea snakes, macrocrustaceans, marine turtles, marine mammals and marine birds. Some of which are listed threatened or migratory species. Coral habitat, in particular, is considered carefully with respect to developments proposed in the Whitsunday region of the Great Barrier Reef Marine Park.

Key impacts associated with the development include:

- Change in habitat extent;
- Increased Turbidity and Sediment Deposition from Dredging;
- Altered Hydrodynamics and Flushing Within and Outside the Proposed Safe Harbour;
- Acid Sulfate Soils;
- Degradation or Contamination of Water Quality from Hydrocarbons, Nutrients and Waste;
- Introduction of Marine Pests or Diseases; and
- Increased Reef Visitation Impacts.

An assessment of the above impacts has indicated that they can be appropriately managed, with coral colonies amenable to transplanting being relocated and artificial habitat created. Other options that would result in a 'net benefit' are discussed in **Appendix X – Net Benefit Discussion Paper**. The key mitigation strategy for reducing potential for impacts will be the Environmental Management Plan for the project. The EMP states the commitments and objectives that are relevant to controlling risk. The EMP contains specific, measurable targets to achieve the objectives. In turn those targets necessitate the application of certain management actions.

4.1 Coral

Coral assemblages typically include hard corals mixed among soft corals, sponges, ascidians, gastropods, macroalgae and other invertebrate taxa. While the most diverse coral communities are in clear, offshore waters, extensive coral communities are also common in inshore tropical waters such as those adjacent to Lindeman Island. The coastal waters of Lindeman Island are within the Inner Shelf Lagoon Continental Island bioregion of the Great Barrier Reef (Kerrigan et al. 2010). This bioregion is characterised by strong currents, some gorgonians and low reef sites, very turbid water and seagrass meadows in some bays. Within this area, there are scattered coastal fringing reefs that generally develop around the mainland and high continental islands and these can have high coverage of hard coral, soft coral and macroalgae, but generally low coral diversity (Kerrigan et al. 2010).

The inshore coral habitats on fringing reefs in the Whitsundays are in very good condition, showing some of the highest coral cover for inshore corals the Great Barrier Reef, and in contrast to many areas, long-term stability. Indeed, GBRMPA's *Whitsundays Plan of Management 2008* indicates coral habitat in the Whitsunday region is valued for its extensive and diverse reef structures and corals that are relatively uncommon on fringing reefs in the Great Barrier Reef Marine Park and that there are a number of reefs of outstanding species richness, coral cover, uniqueness (e.g. a high cover of branching corals for inshore reefs) and aesthetic appeal. The *Whitsundays Plan of Management 2008* also indicates that given fringing reefs are a relatively scarce resource they have important conservation and aesthetic values, and are vulnerable to degradation.

Lindeman Island is one of 74 islands in the Whitsunday region and many of these islands have fringing reefs. A comparison of the coral cover and communities on the reef in the vicinity of the proposed safe harbour with coral habitat on other Whitsunday islands indicated it was not unique, but rather it shows characteristics typical of fringing reefs in the region.

Construction of the safe harbour would have a direct impact on the coral assemblage as it will require dredging of the seabed within the footprint. The safe harbour location has been developed and refined based on findings from several marine habitat surveys, to specifically avoid large, old growth, coral bomboras and minimise impacts to areas supporting dense coral cover and the surrounding reef and benthic habitats. The initial concept layout was aligned with the existing channel to include already modified habitat. The marine habitat survey conducted in 2013 revealed the presence of a dense coverage of habitat forming branching corals within the proposed footprint (BMT WBM 2013). The design was refined (Version 2, October 2015) to specifically avoid the large coral bomboras found in surveys done in September 2015 (GBRMPA 2015) and October 2015 (Cardno Survey 2015), and to minimise impacts on areas where coral cover was dense (Version 4, May 2016).

The footprint of the safe harbour (+ 1.5 m buffer) would require removal (dredging) of 14.4% of the total area of 'coral habitat' in the 31.06 ha Survey area that stretched ~1 km along the coast of the southern side of Lindeman Island in the vicinity of the existing resort. However, most (i.e. 99%) of the total coral habitat in the safe harbour footprint (i.e. 4.46 ha) that would be removed has a cover of live coral of between 0 and 25%. This is because much of the area of reef in the footprint is intertidal or encompasses the existing turning basin and channel which has a sandy bottom and virtually no coral. Only 0.06 ha of the coral habitat to be removed (i.e. reef habitat in the safe harbour footprint) would have >25% live coral cover. This is a very small amount of the total area of coral habitat in the entire reef in the Survey area (31.06 ha) and only <1% of the total area of where the cover of live coral is >25%. When the area of each category of coral cover is multiplied by the mean percentage cover of live coral in each category, the aggregate area of coral colonies (i.e. 'live coral') directly affected by the safe harbour footprint would be 0.23 ha.

Additional to habitats to be removed in the dredging footprint, the zones of effect were estimated for the main hazards to corals (i.e. sedimentation or turbidity associated with dredging and changes to hydrodynamics or wave climate associated with the proposed breakwater structure). The zones were based on modelling in relation to tolerance limits for corals and included zones where: impacts on benthic communities or habitats are predicted to be irreversible (Zone of High Impact- ZoHI); impacts are recoverable within a period of five years (Zone of Moderate Impact- ZoMI); and where changes occur but would not result in a detectible impact on benthic biota (Zone of Infleunce- ZoI). Modelling indicated that additional small areas of coral habitat outside of the dredging footprint would potentially be permanently lost due to excessive sedimentation resulting from plumes during construction of the safe harbour and reduced current velocities as a consequence of the permanent breakwater structure (ZoHI). The affected areas were small and amounted to 0.02 ha from sedimentation and 0.92 ha from altered currents. Much of the area where there would be excessive sedimentation or decreased currents would be in intertidal areas where the cover of live coral is very low (<1%) and the aggregate area of coral colonies (i.e. 'live coral') affected from sedimentation and altered currents would be 0.02 ha. Turbidity (from dredging) or altered wave climate (from the breakwater) was not predicted to cause a permanent change to coral habitat although there would be broad areas across much of the fringing reef where conditions would be changed slightly during dredging or as a consequence of the permanent structure (**Section 3.1**). Further, most indirect impacts to corals in general from construction of the safe harbour and ongoing operations of the resort are considered negligible or not sufficient to affect coral assemblages outside of the footprint of the safe harbour.

Where there was removal of the reef in the dredged area and where there was excessive sedimentation or changes to currents, the impact would be long term and irreversible, however corals would grow on some of the structure of the safe harbour. Using the risk analysis model, the risk to coral assemblages is considered to be high. This represents the greatest risk level identified among all potential Project impacts to the marine ecology of the Project Marine Area. According to the risk assessment matrix, the risk is considered 'significant and requires significant cost-effective measures for risk reduction and/or management'. These measures are described below and include like-for-like offsetting for lost coral habitat by creating new coral habitat and restoring previously removed coral habitat.

A key mitigation strategy for impacts of the project on coral assemblages (i.e. resulting from direct removal of coral habitat for the safe harbour, sedimentation or altered currents) is the proposed plan to create new coral habitat and restore existing habitat. Under the plan outlined below, the footprint of the proposed safe harbour that would remove 5.4 ha of existing coral habitat with generally low cover (equating to an aggregate area of 0.25 ha of live coral) would be compensated for by the creation of new coral habitat on the breakwalls of the proposed safe harbour and the restoration of coral habitat in the existing channel.

A Coral Restoration Plan has been developed for this EIS to mitigate direct impacts on coral habitat from construction of the safe harbour. It is considered that the Coral Restoration Plan developed is low risk and would be successful for the following reasons:

- The small size of the project. Successful restoration of coral habitat has been documented previously for other developments at similar scales to this project (i.e. up to a few hectares; Edwards and Gomez (2007));
- The nature of the restoration site. Prior to construction of the existing channel, coral cover at the proposed restoration site (i.e. the existing channel) is likely to have been high (50-100%) and similar to assemblages of surrounding coral. Some of the densest cover of live coral in the Project Marine Area occurs on either side of the existing channel and it includes branching corals, which are considered to be relatively uncommon in the declining southern inshore reefs of the GBR (De'ath et al. 2012). It is also likely to improve the ecological functioning of the outer parts of the reef area in the Project Marine Area, by joining areas currently separated by the existing channel.
- Given the existing channel is between complex coral reef it is likely that fish grazers will regularly visit the restoration site, and soon colonise, the restored area. Grazing of algae is a necessary part of maintenance during restoration so that the restored habitat is not able to switch to an alternate ‘algal-dominated’ assemblage in early stages of restoration (Edwards and Gomez (2007); and
- Indirect impacts to corals in the general area from construction of the safe harbour and ongoing operations of the resort are considered negligible or not sufficient to affect coral assemblages outside of the footprint of the safe harbour.

An appropriate monitoring strategy (see Environmental Management Plan in **Chapter 28**) would test the hypothesis that the restored/newly created coral assemblages met the target ecological standard (i.e. an average cover of 75% live coral) after 10 years. Monitoring of the restored area would be done on a 3-month basis by marine scientists during Stages 1 and 2 and also include coral assemblages adjacent to the restored area for comparison. Maintenance would also be done on these quarterly visits. This would include removing excess algae (with a wire brush), if it appeared to be affecting transplants, and reattaching any transplanted colonies that had detached.

4.2 Beaches and Intertidal Rocky Shores

Dredging and spoil disposal activities have potential to affect beaches, intertidal rock platforms and boulder fields directly through physical removal or smothering. The footprint of the safe harbour intersects with a very small amount of the mapped intertidal beaches or rocky shores (<0.2 ha) relative to its extent on the island. However, there is some potential for accretion and/or erosion of the present resort beach due to a slight change in wave direction would result from ongoing presence of the safe harbour. Because the present resort beach is held between headlands and groynes, loss by longshore transport may be negligible. From time-to-time sand may be lost by transport seaward beyond the reef edge, but that loss is not quantifiable. Some wind-blown sand loss may occur, but the new revetments at a crest level of 5.6 m AHD will generally prevent this process and resort management procedures will likely return any windblown sand to the beach. Modelling indicates that there would be slight change in mean-weighted wave direction due to the dredging, which increases depth locally causing waves to refract slightly in a counter-clockwise direction at the western end of the resort beach. The residual risk to intertidal habitat from direct removal is considered low given the amount of direct removal of intertidal habitat, the overall volume of beach won’t change and the accretion and erosion of the resort beach represents a very small proportion of the extent of this habitat in the project marine area and generally at Lindeman Island. In addition, breakwalls, pontoons, piles and other intertidal and subtidal structures associated with the construction of the safe harbour will provide substrata for many intertidal organisms so that there would be a net gain in intertidal rocky habitat.

4.3 Seagrass and Macroalgae

The footprint of the safe harbour intersects with seagrass and macroalgae habitat. Seagrass assemblages are generally sparse throughout the shoreline around Lindeman Island (BMT WBM 2013). The densest seagrass meadows are located south of the existing jetty in soft sediment beyond the edge of the reef and, outside of the project's marine area, at Boat Port and Coconut Beach. *Halophila spp.* (including *H. ovalis, H. decipiens and H. spinulosa*) and *Halodule uninervis* are the two most common seagrass taxa in the project marine area. These are fast growing, early colonising species that are known to survive well in unstable (shifting sediments) or depositional (subject to sedimentation) environments (Green and Short 2003). Both *Halophila* and *Halodule* are known to recover rapidly after disturbances, as they often establish large seed reserves in the sediment and/ or grow and expand rapidly from remaining patches. During a recent survey, seagrass meadows were generally sparse (mostly between 1% and 5% cover and one patch south of the existing jetty with cover > 10%), with a low above-ground biomass, with some soft and hard corals occurring in the same area (BMT WBM 2013). Some *Halophila spinulosa* was found in the dredged channel at the jetty site. A comparison of the distribution of the latest available survey (BMT WBM 2013) with the survey undertook by Hyland et al. (1988) indicates that seagrass distribution did not change substantially over time. The low cover in the small area of seagrass within the footprint suggests it would not be an important habitat for any species, including its potential for being an important food source to marine turtles or dugongs. As such the removal of seagrass in the footprint is not considered ecologically significant. Notwithstanding this, given it is benthic primary producer habitat, the loss should be compensated for in the offset program or net benefit strategy. The residual risk to seagrass habitat from direct removal is considered low.

Breakwalls, pontoons, piles and other intertidal and subtidal structures associated with the proposed safe harbour will provide artificial substrata for many species of macroalgae to recruit to but there would still be a net loss in area of this habitat. Given this habitat is very common around the island and in the region, the net loss is considered a minor consequence and the residual risk to macroalgae habitat from direct removal is considered moderate.

Indirect impacts to seagrass and macroalgae in general from construction of the safe harbour and ongoing operations of the resort are considered negligible or not sufficient to affect seagrass and macroalgae assemblages outside of the footprint of the safe harbour. Notwithstanding the manageable risks to these habitats, given seagrass and macroalgae are benthic primary producer habitats, the direct losses should be compensated for in the offset program or net benefit strategy.

4.4 Subtidal Soft Sediment Fauna

Soft sediment habitat exists in the existing channel and turning basin and the benthic habitat beyond the edge of the reef flat fringing Lindeman Island is also soft sediment benthic. Dredging for the safe harbour will also create a new area of soft sediment within the footprint and approach channel. Infaunal and epifaunal assemblages reside in soft sediment and would also recruit to the newly created habitat. Tropical benthic infaunal assemblages generally contain burrowing organisms such as polychaete worms, amphipod crustaceans, bivalve and gastropod molluscs and other worm-like phyla such as nemerteans and nematodes (which are often abundant). These animals are generally found within the upper 30 cm of the sediment. As well as being a source of food for organisms higher up the food chain, such as fish and large invertebrates, including some sharks, stingrays and loggerhead turtles, they also drive nutrient cycling through reworking of the sediments (bioturbation). Were soft sediment biota outside the safe harbour temporarily affected by sedimentation from dredging, the impacts would be short term and reversible, as the species found in the area are likely to be resilient to short-term disturbances and likely to recover full functionality.

4.5 Fish, Sharks and Rays, Sea snakes and Macrocrustaceans

The subtidal rock and reef habitat at Lindeman Island is used by a range of adult and juvenile fish species including cod, butterflyfish, damselfish, wrasses and parrotfish. Over 48 taxa of fish were recorded from depths ranging from 2 to 4 m water depths in the vicinity of the proposed safe harbour. Fish assemblages of Lindeman Island are typical of inshore waters of the Great Barrier Reef and major reef fin-fish families are likely to be generally similar to those found on reefs located a comparable distance from the mainland. Generally, inshore reefs of the central Great Barrier Reef tend to host fewer fin-fish species compared to mid-shelf or outer-shelf reefs. The dominant fish species of inshore reefs are Pomacentrids, Lutjanids and Chaetodontids, Labrids, while Acanthurids and Scarids are generally found in lower numbers on inshore reefs compared to mid or outer-shelf reefs (Williams 1982, Williams and Hatcher 1983). The risk to fish, sharks and rays, sea snakes and macrocrustaceans from dredging and construction of the safe harbour and ongoing operations would generally be low given only a negligible amount of their habitat would be affected (relative to the extent in entire region) and individuals would also be likely to move away from any temporarily affected areas**.**

4.6 Marine Turtles, Marine Mammals and Marine Birds

Marine turtles, marine mammals and marine birds would occasionally utlise the habitats in the project marine area and many of these are listed threatened and migratory species under the EPBC Act (see **Chapter 26**).

Four of the six species of marine turtles known to occur along Australian coasts would be common in the project marine area. These include Flatback (*Natator depressus*) and Green (*Chelonia mydas*) turtles, and less commonly the Loggerhead (*Caretta caretta*) and Hawksbill turtles (*Eretmochelys imbricata*). The Leatherback (*Dermochelys coriacea*) and Olive Ridley (*Lepidochelys olivacea*) turtles are less likely to occur in the project marine area but may occur there very occasionally. Marine turtles are migratory and highly mobile species, moving between feeding grounds and rookeries, with males and females undertaking migrations of up to 3,000 km. Marine turtles tend to nest on mainland or island beaches. Flatback and Loggerhead turtles nest on the mainland in the Mackay region but Lindeman Island is not a known nesting ground for any of the marine turtle species.

Several marine mammals (whales, dolphins and porpoises) listed under the ‘cetaceans’ schedule of the EPBC Act and the Sirenian Dugong dugon would occur in the project marine area. There are two core Humpback Whale habitat areas in the Southern Great Barrier Reef. One of them is located southeast of Lindeman Island, within the inner reef area and extending for approximately 100 km parallel to the coast. Along with Humpbacks, Minke and Bryde’s whales are also likely to use deeper waters of the project marine area. Indo-Pacific Humpback, Australian Snubfin, Bottlenose, Common and Risso’s dolphins are likely to occur in all subtidal habitats of the project marine area where they would hunt, often in groups, for fish and cephalopods. The dugong (*Dugong dugon*) is listed under the ‘marine’ and ‘migratory’ schedule of the EPBC Act and under the ‘vulnerable’ schedule of the NCWR Act. Dugongs feed almost exclusively on seagrass, particularly *H. uninervis, H. ovalis* and *H. spinulosa*, and principally inhabit seagrass meadows (Lanyon and Morris 1997). Their dependence on seagrass for food generally limits them to waters within 20 km of the coast, although individuals have been sighted further from the coast during aerial surveys (Marsh and Lawler 2002). While there is little scientific data on dugong within the project marine area, dugongs may occur in the area on occasion where seagrass occurs.

Marine birds, including a number of threatened and migratory birds, would occur in the project marine area. These can be grouped broadly into those found commonly on coastal shores, including beaches, rocky shores, mudflats, tidal wetlands and lagoons (shore birds) and those that spend most of their time at sea (sea birds).

For many shore birds, roosting occurs along sheltered and occasionally open coastlines on sandy beaches above the high tide mark, while some roost on elevated areas. Foraging and roosting habitats for shore birds occur in the project marine area. Ground nesting is common with the nest consisting of a scrape in the ground, sometimes lined by pebbles or seaweed. Nesting along exposed beaches, islands and spits, or among sparse vegetation is not uncommon; however, most of the threatened or migratory bird species occurring in the project marine area do not breed in Australia. Migratory shore birds travel up to 26,000 km and on these return journeys they may cross state boundaries, countries and oceans, linking the ecosystems, communities and governments responsible for providing suitable habitat to support the survival of these species.

Sea birds can be found foraging and breeding across all Australian Commonwealth Waters. Potential foraging habitats for sea birds occur in the deeper waters of the project marine area. Sea birds feed on the surface as well as dive for prey. They are mainly colonial, with nesting sites usually densely populated and on islands further south than Lindeman Island. Many species are highly dispersive or undertake long annual migrations both north-south and east-west, which can occur both after the breeding season for longer periods and to forage for chick provisioning.

All of the marine turtles, marine mammals and marine birds that could potentially utilise the marine habitats in the project marine area were considered temporary visitors and none were considered to reside permanently or breed in marine habitats on the foreshore or in waters in close proximity to Lindeman Island. As such, they do not rely implicitly on the marine habitats in the Project area, which account for only a very small proportion of the regional habitat potentially used by thes species. Hence, the potential impacts to marine turtles, marine mammals and marine birds would be limited to those associated with disturbance or injury to individuals visiting the island. It is considered that most marine turtles, marine mammals and marine birds visiting the foreshore or the waters in close proximity to Lindeman Island and that would be disturbed (during foraging, resting or while in transit between areas) by increased activity associated with Project construction or ongoing operations on the south-western corner on the island, would be able to move to other (undisturbed) parts of the island or to similar habitats within the region. This may be inconvenient to individuals but not harmful and would not be a significant impact to these species. In addition, given resort and marina operations would be best practice and include a comprehensive environmental management plan as part of the Resort EMP, the risks of water pollution, degradation of water quality and transmission of water borne diseases would be acceptably low as would the potential for the key threatening process to occur 'Injury and fatality caused by ingestion of, or entanglement in harmful marine debris'.

The greatest risk to marine turtles, marine mammals and marine birds would be vessel strike to marine mammals, marine turtles and possibly the Whale Shark given there would be increased vessel activity associated with ongoing operations of the Project. The risk would be greatest around the entrance to the proposed Safe Harbour where marine mammals or turtles could occasionally transit through or forage. Approach distances and interaction with marine mammals is regulated under State and Commonwealth regulations and the risks would be reduced further given marina operations would be best practice and include a management plan (as part of the Resort EMP) for vessels leaving and entering the harbour at slow speeds as well as education to skippers on behaviours when in the vicinity of marine mammals and turtles and keeping appropriate vigilance. These arrangements would make the risk of vessel strike acceptably low.

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