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Anketell Point Port

Coastal Processes Investigation of the Terminal 2 Port Layout

August 2011

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Prepared for

API Management

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In association with

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Cover

Main image: North-east coast of Dixon Island, looking north-west.

Minor images: Mangroves at Anketell Point; Anketell Point.

Contents

List of Figures

List of Tables

1. Introduction

API Management Pty Ltd (API) has proposed construction of a new multi-user port at Anketell Point for the export of iron ore. The initial port development (Stage 1) involving load-out facilities off Dixon Island (Terminal 1) was referred to the EPA on 26/6/2009, with a detailed impact assessment undertaken and presented within API's Anketell Point Public Environmental Review (PER) published on 24/12/2010. The potential impacts to coastal processes associated with the Terminal 1 layout have previously been assessed (refer to Oceanica & Damara 2010, & API 2010).

To achieve a capacity of ~350 Mt per year, a Stage 2 option (Terminal 2) is being considered, involving a tug harbour and tug harbour/materials offloading facility (MOF) off Anketell Point (Figure 1.1, Figure 1.2). This report presents a desktop assessment of coastal processes associated with the Terminal 2 facility, assuming this to be the sole facility emplaced. For the main part, this assessment is formed from an interpretation of available data. The assessment has focused on potential impacts to environmental factors, rather than on operational issues. However, in performing this work, some issues have arisen which may have broader implications, especially the nature of sedimentation around the facility, and these issues have been noted where appropriate.

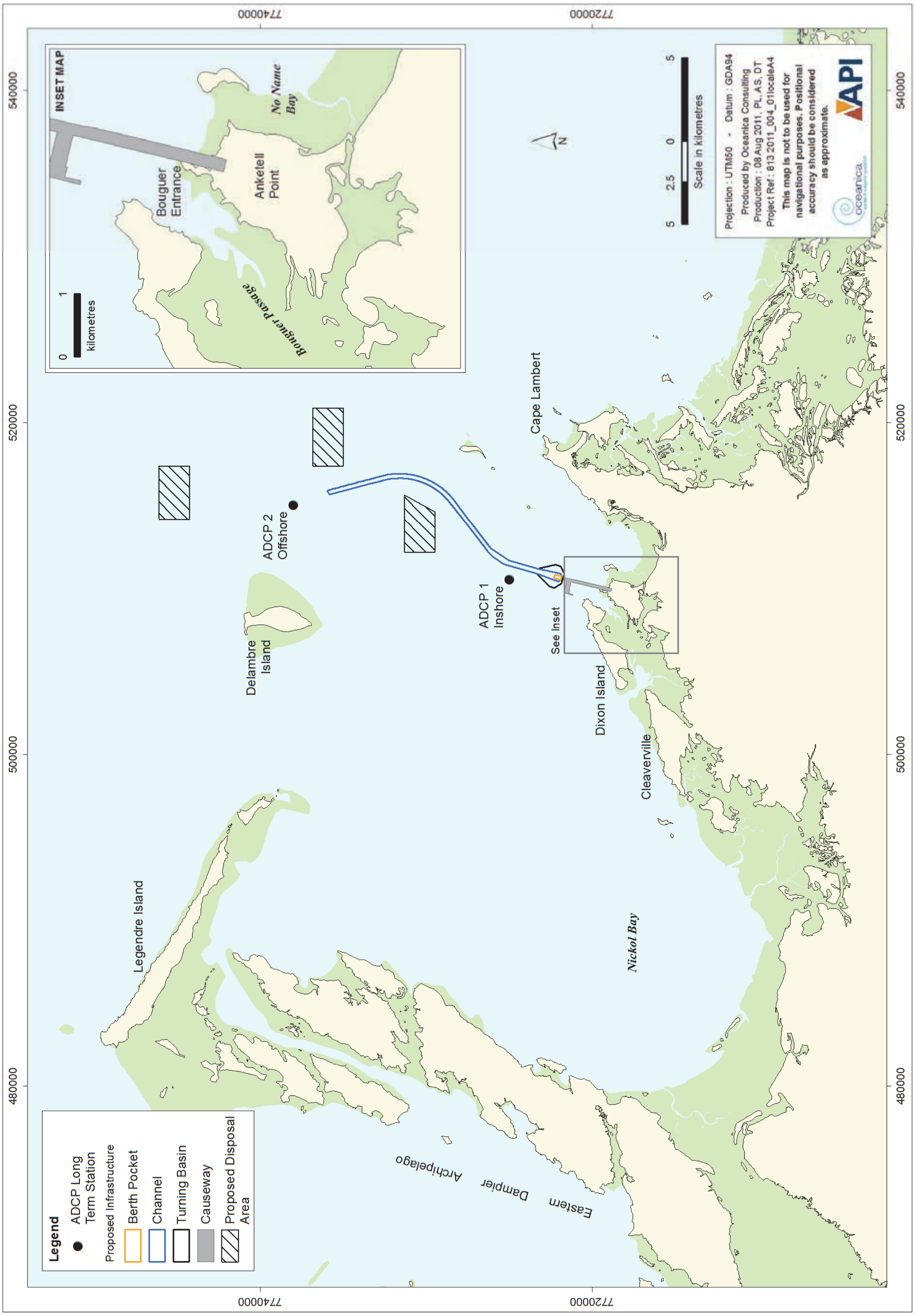


Figure 1.1 Location diagram

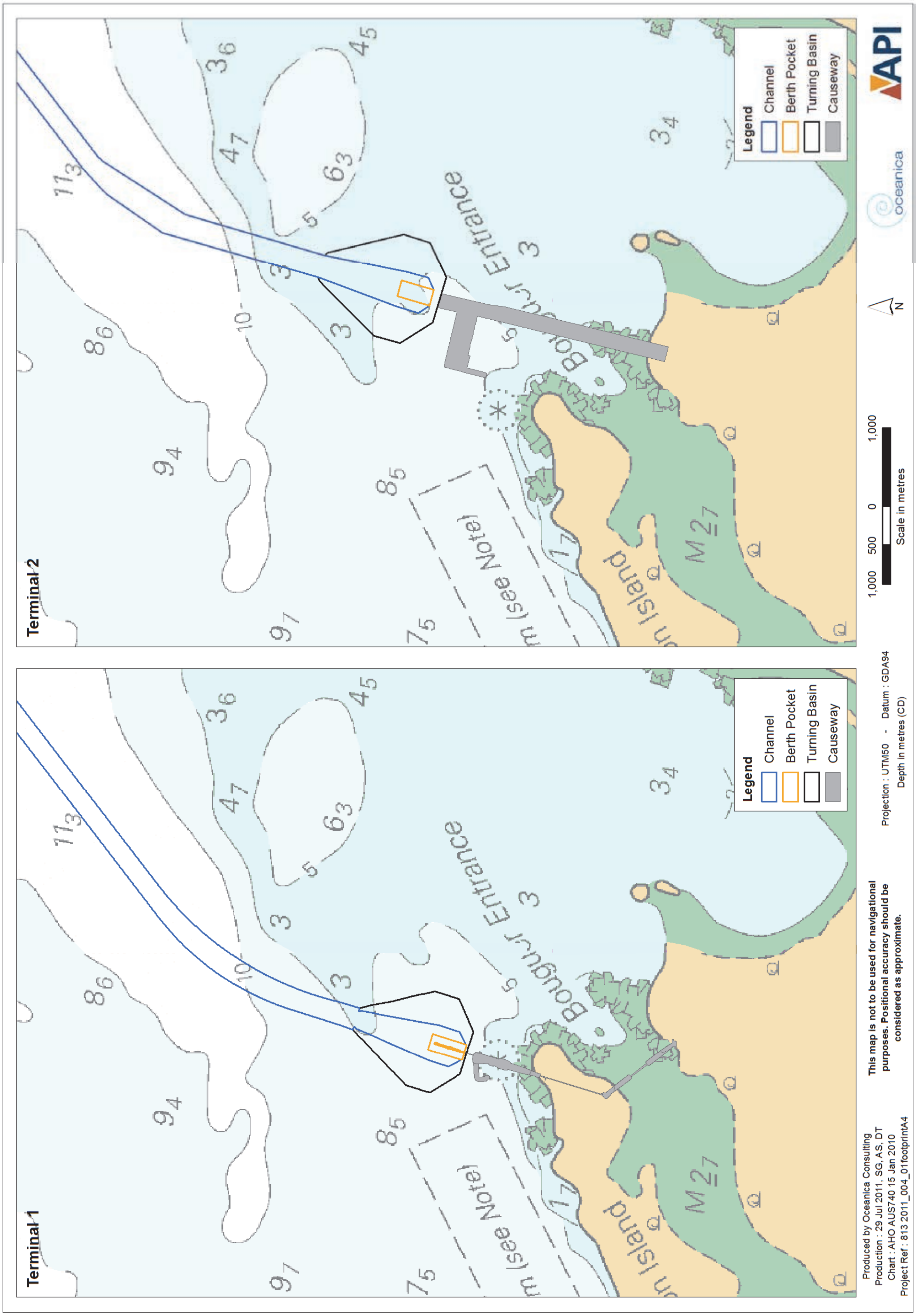


Figure 1.2 **Proposed Anketell Point Port Terminal 1 and Terminal 2 layouts**

2. Environmental Values

The key environmental values that may be impacted by modification to coastal processes at Anketell Point and Dixon Island are marine turtles, mangrove habitat and benthic habitats.

2.1 Marine turtles

Marine turtles rely on sandy beaches of suitable grain size and sediment depth for annual nesting. Changes to coastal processes which change the fundamental characteristics of a nesting beach may influence future nest success.

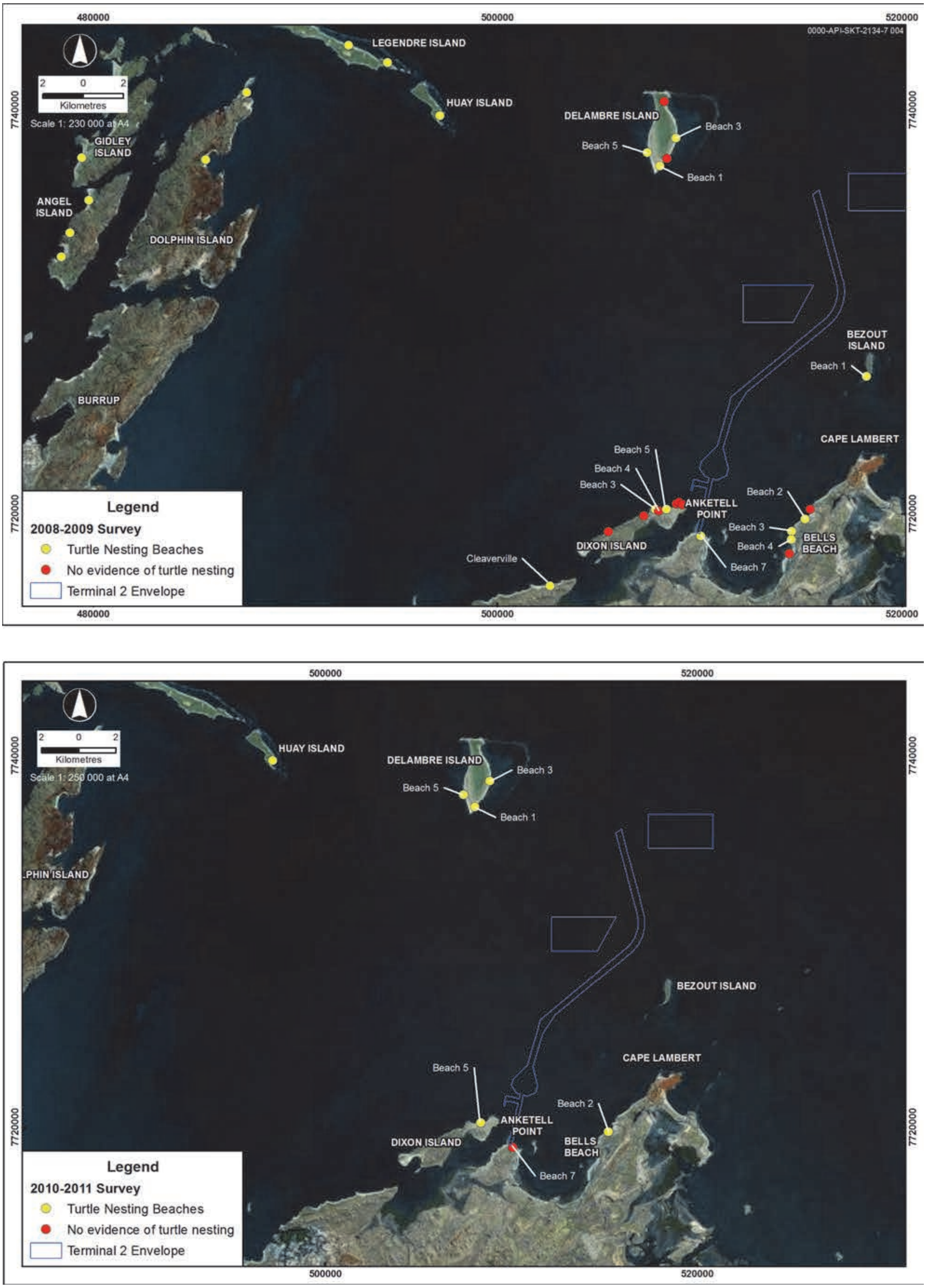
Three species of marine turtles routinely nest in the Dampier Archipelago; the green turtle (Chelonia *mydas*), hawksbill turtle (Eretmochelys *imbricata*) and the flatback turtle (*Natator depressus*). Loggerhead turtles (*Caretta caretta*) are occasionally observed. Marine turtle nesting on the mainland near Anketell Point and Dixon Island is predominantly of flatback turtles and these rookeries are not regionally significant within the Dampier Archipelago (Pendoley Environmental 2010).

Regionally significant marine turtle nesting beaches are found at Delambre and Legendre islands (Figure 2.1). Moderate density turtle nesting beaches are located at Angel and Gidley islands, and mainland beaches generally have low nesting density, with the exception of Bell's Beach (moderate density). Most marine turtle nesting on the mainland and Dixon Island beaches near Anketell Point is by flatback turtles (although there is some limited hawksbill activity).

At Anketell Point a small number of emerged nests were recorded (Beach 7) during the April 2009 survey, but no nesting activity was recorded during the 2010/11 nesting season (Pendoley Environmental 2011).

On Dixon Island flatback nesting activity has been recorded at two beaches ("turtle beaches") located along the eastern half of the north coast. In January 2009, up to 33 flatbacks and a small number of hawksbill turtles were found to visit Beach 5 each night, while in January 2011 only very low numbers of flatbacks (1-5 turtles per night) and no hawksbills were recorded on this beach. A very low level of nesting activity was recorded from Beach 3, to the west of Beach 5, in January 2009. This beach was visited again by turtle biologists in January 2011 and it was confirmed that there was no nesting at this site and that the habitat is considered unsuitable (Pendoley Environmental 2011).

At high tide, juvenile green turtles have been observed in the mangroves lining the north side of Bouguer Passage (API 2010). Flatback turtles are considered less likely to feed within the area adjacent to Dixon Island.



Data sources: Top - Pendoley 2010; Bottom - Pendoley 2011.

Figure 2.1 Turtle nesting survey observations

2.2 Mangroves

Mangrove stands are common in a wide variety of habitats, including on carbonate coral islands, sandy and muddy shores (Duke, 2006). On the margins of No Name Bay (Figure 1.1), mangroves colonise relatively sandy sediments with a mix of silt, and in the Bouguer Passage they grow in areas mud, mud overlying gravel or rock, and in places in sand, gravel and bedrock (AECOM, 2010b). A change in coastal processes which may change the characteristics of mangrove habitat substrate could result in changes to mangrove area.

A survey of mangroves surrounding Anketell Point and Dixon Island recorded mangroves along the mainland shoreline both east and west of Anketell Point and along the southern shore of Dixon Island (AECOM 2009a, Figure 2.2). *Avicennia marina*, the most abundant species, was widely distributed and in certain areas was observed to form extensive monospecific stands (AECOM 2008). *Avicennia marina* extended from the lower intertidal zone through to the upper intertidal zone. *Rhizophora stylosa* was the next most abundant species, restricted to the lower to mid-intertidal where it formed monospecific stands or co-existed with *Avicennia marina* (AECOM 2009a). Zonation of mangroves in the survey area was consistent with the pattern typically observed elsewhere in the Pilbara region.

2.3 Benthic Habitats

The benthic habitats in the area (Figure 2.2) include corals, seagrasses, macroalgae and turf algae, and have been described by AECOM (2010).

2.3.1 Corals

It has traditionally been understood that corals require warm, clear, well-oxygenated water (Rogers 1990). However, it is increasingly recognised that there are many different types of coral reef, evolved from a variety of Holocene environmental histories, which exist in conditions other than those traditionally considered 'ideal' (Larcombe et al. 1995; Perry & Larcombe 2003; Perry et al. 2008).

Gilmour et al. (2006) note that along the Pilbara coastline are hundreds of continental islands and small fringing and barrier reefs, which house coral communities that are distinct from those of the Kimberley to the north and Ningaloo Reef to the south. These coral communities are strongly influenced by regional weather patterns, and particularly by protracted periods of hot weather and episodic monsoonal storms and cyclones during the summer. Such weather patterns bring periods of high water temperatures and high levels of turbidity and sedimentation, which combined with the seasonal proliferation of macroalgae, are among the most important factors controlling the distribution and abundance of corals in this region (see also Blakeway & Radford 2005). This wide range of environmental conditions means that some corals exist in areas close to their physical limits, including inshore reefs. Nevertheless, there are a large range of habitats and coral communities within the Pilbara, which contain more species than elsewhere in Western Australia.

A total of 229 species from 57 genera of zooxanthellate corals have been recorded in the Dampier Archipelago (Griffith, 2004). In inshore areas, thin layers of coral form over rock platforms, often in patches. Further offshore, thicker reefs form distinct geomorphic features, such as Bezout Island and Delambre Island (MScience 2008). To the north-east of Anketell Point, close to the proposed causeway, there is a mixed coral assemblage, with a coral cover of greater than 15% (AECOM 2009b, Figure 2.2). As with other habitats, a sharp change in those coastal processes which control the key physical marine environmental conditions may result in changes to coral coverage or dominant species.

2.3.2 Seagrasses

Seagrasses are represented by isolated monospecific patches of *Halophila ovalis*, *Thalassia hemprichii* and *Thalassodendron sp.* (API 2010). The Anketell Point area is subject to frequent natural disturbance in the form of strong seasonal winds and relatively strong tidal currents that mobilise the seabed and influence seagrass survivorship and distribution. This is consistent with the predominance of *Halophila ovalis* which is a colonising species that is the first to establish after disturbances (Lanyon and Marsh, 1995).

2.3.3 Macroalgae

Most macroalgae require hard substrata to attach to and thus are found most commonly on rocky pavements. The most abundant macroalgae in the region are brown algae represented mostly by the genera *Sargassum*, *Dictyopteris* and *Padina* (API 2010). Macroalgae in this region are highly seasonal, being abundant over spring and summer and often disappearing in winter.

2.3.4 Turf algae

Turf algae are usually less than about 5 cm tall and are commonly fine, filamentous species, attached to rocks, coral or shell rubble. Turf algal communities are often characterised by fast-growing, ephemeral or rapid coloniser species, and they are widespread and abundant in the region (API 2010). Locally, areas of turf algae occur in Bouguer Passage and north-west of Dixon Island.

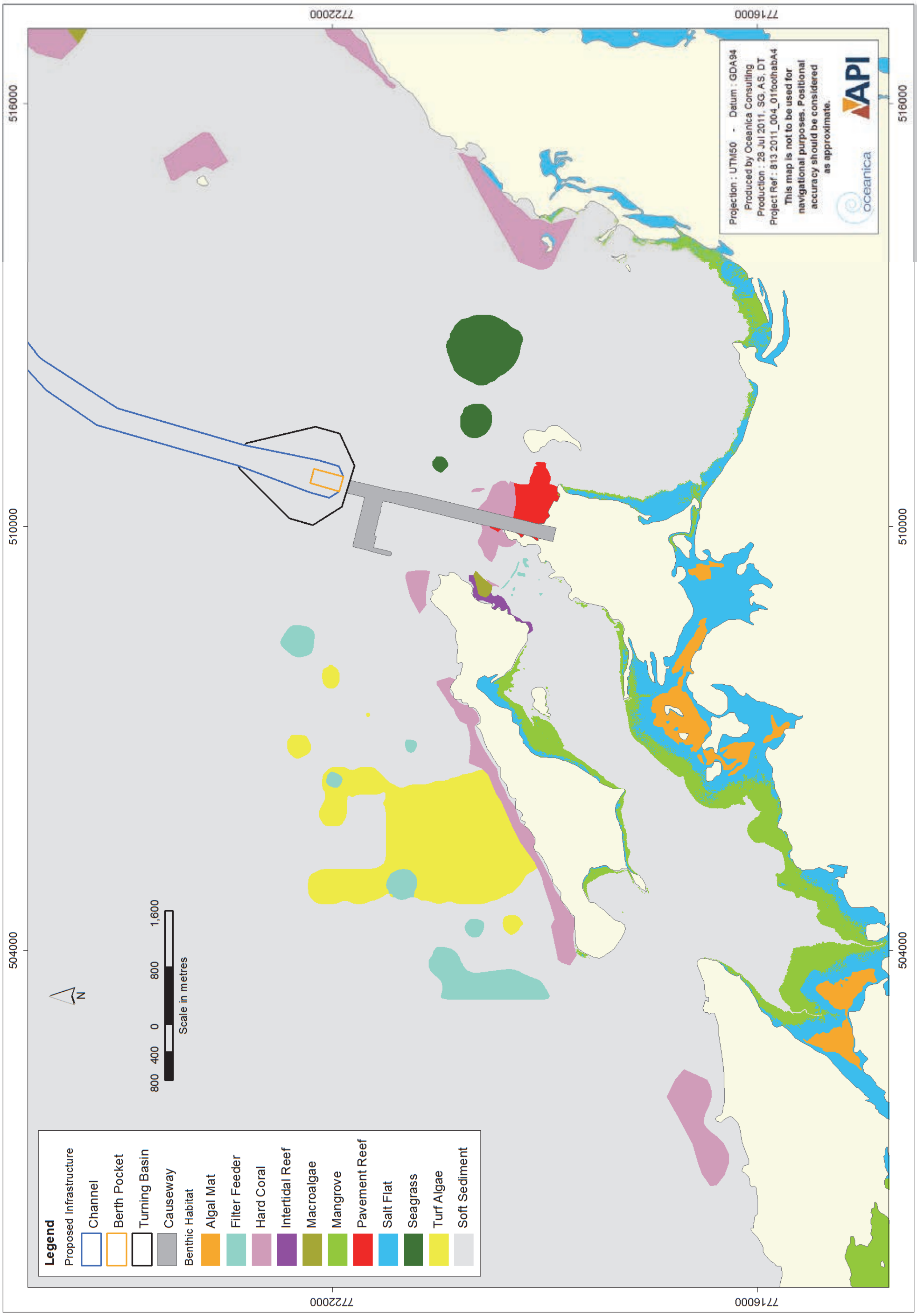


Figure 2.2 **Benthic habitats of the Anketell Point area**

3. Meteorology and Oceanography

3.1 Water levels

Long-term water level observations for the region are available since 1983 from the tide gauge at Cape Lambert, which is maintained by the Department of Transport. Cape Lambert experiences macrotidal semidiurnal conditions, with an astronomical tidal range of 6.2 m. Major tidal cycles include the fortnightly spring-neap cycle and the bi-annual tidal cycle, with peaks in March and September. Tidal planes, as defined in the Australian National Tide Tables (Department of Defence 2010) are given in Table 3.1.

Table 3.1 Tidal planes at Cape Lambert

Tidal Levels	Australian Height Datum (AHD)	Chart Datum (CD)	Percentage time inundated
Highest Astronomical Tide (HAT)	3.0 m	6.2 m	<1%
Mean High Water Springs (MHWS)	2.3 m	5.5 m	3%
Mean High Water Neaps (MHWN)	0.6 m	3.8 m	46%
Mean Sea Level (MSL)	0.0 m	3.2 m	50%
Mean Low Water Neap (MLWN)	-0.5 m	2.7 m	65%
Mean Low Water Springs (MHWS)	-2.4 m	0.8 m	97%
Lowest Astronomical Tide (LAT)	-3.2 m	0.0 m	>99%

Source: Department of Defence 2010

The conditions expected to generate extreme water levels have previously been modelled and show that tropical cyclones (TC) passing in a southward direction, to the west of Cape Lambert, will tend to produce the largest surges (Bureau of Meteorology 1998). Analysis of observed water levels confirms this general behaviour, but also highlights the fact that relatively few tropical cyclones generate water levels above HAT (Damara WA 2006). The highest recorded water level occurred during TC Orson (1989) with a level of 6.84 m CD, with TC Clare (2006) producing the highest individual surge event, estimated at 1.7 m. Notably, TC Vance (1999) produced the second highest observed water level, with only a moderate surge of 0.5 m, but it occurred coincident with the March equinoctial tidal peak (Damara WA 2009).

Extreme water levels modelled for Cape Lambert (Table 3.2; Bureau of Meteorology 1998) are generally larger than those derived from analysis of the tide gauge record, as they include allowance for nearshore processes, whereas the gauge is located near the head of Cape Lambert jetty.

Table 3.2 Return periods for extreme high water levels, modelled for Cape Lambert

10-year	25-year	50-year	100-year	1000-year
3.5 m AHD	4.3 m AHD	4.9 m AHD	5.3 m AHD	6.7 m AHD

(Department of Defence 2010)

3.2 Winds

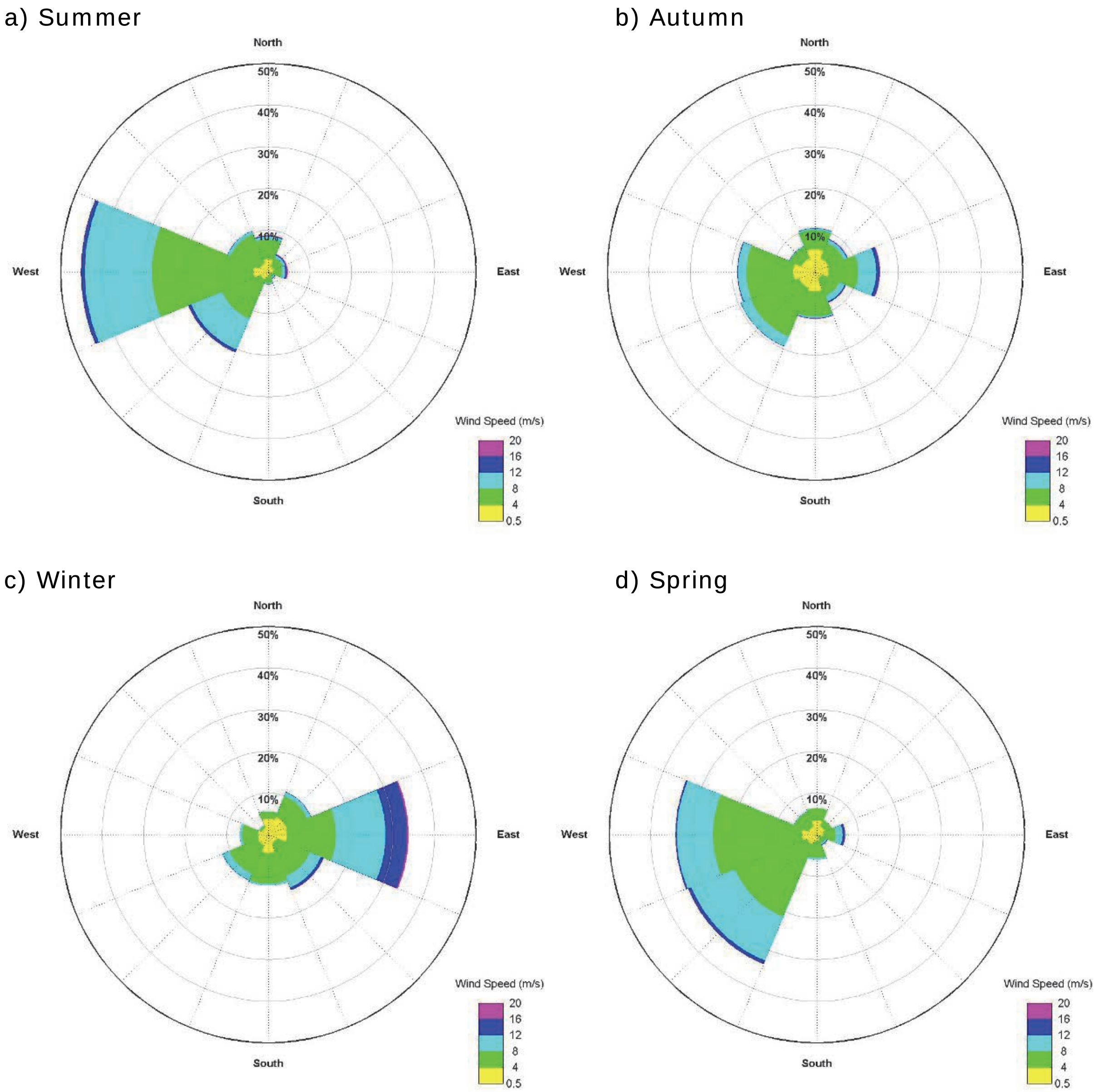
A weather station located on Legendre Island (BOM site 4095) has recorded wind from February 1992 (Table 3.3). Winds from a westerly direction[1] prevail from September to March and winds from an easterly direction prevail between May and July (Table 3.3, Table 3.2). April and August are transitional months between the two periods (Table 3.3, Figure 3.1).

[1] *Using the meteorological convention of the direction the winds are coming from.*

Table 3.3 Monthly occurrence (%) of wind directions at Legendre Island 1992-2010

Direction (°N)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
NNE	2.8	3.5	3.3	4.7	4.8	1.9	2.3	4.1	1.9	2.2	1.3	2.5	2.9
NE	2.6	3.3	3.7	4.4	6.2	4.8	5.1	4.4	2.1	1.5	1.1	2.1	3.4
ENE	2.5	3.0	3.9	4.5	8.3	9.1	8.5	4.9	2.1	1.6	1.1	2.1	4.3
E	3.0	4.0	7.0	11.5	21.1	27.4	21.8	12.7	4.9	3.3	1.8	2.4	10.1
ESE	1.1	2.5	4.3	6.8	12.4	17.5	13.4	9.4	3.2	2.4	1.1	1.0	6.3
SE	0.9	1.8	2.9	4.1	8.1	9.1	8.0	5.1	1.6	0.9	0.4	0.7	3.6
SSE	0.8	1.0	2.8	4.0	4.9	5.4	5.3	3.5	1.5	1.1	0.6	0.7	2.6
S	1.4	2.1	4.5	6.9	6.5	6.5	7.6	7.4	3.7	2.2	1.4	1.1	4.3
SSW	1.8	2.9	5.8	7.7	5.3	4.8	6.9	8.8	7.9	5.5	3.5	2.1	5.2
SW	6.5	8.0	11.1	9.9	5.3	4.1	5.7	10.7	18.0	17.7	14.6	9.8	10.1
WSW	17.5	15.4	14.3	9.1	4.5	2.4	4.1	9.4	21.6	22.5	25.9	21.6	14.0
W	29.7	24.0	15.7	10.0	3.5	2.1	2.9	7.8	18.6	23.4	31.5	33.8	16.9
WNW	11.2	8.5	5.6	3.3	1.4	0.7	0.9	2.0	3.9	4.9	6.3	7.0	4.6
NW	6.3	6.1	3.9	2.4	1.1	0.7	0.8	1.6	2.5	2.6	2.9	4.1	2.9
NNW	5.5	5.4	4.1	3.1	1.3	0.6	1.5	1.7	2.5	3.1	2.6	3.5	2.9
N	5.8	7.6	6.1	6.4	3.7	1.4	2.8	4.4	3.4	4.4	3.5	4.9	4.5

0.0
2.0
4.0
10.0
15.0
20.0
25.0
35.0



Source: APASA 2010

Figure 3.1 Wind Roses for Legendre Island

3.3 Currents

Currents in the Anketell region are determined by the regional shelf circulation patterns. There are four principal drivers affecting circulation: oceanographic (steric gradients and weather systems), tidal, wind-driven (local winds) and wave-driven; each of which is likely to be dominant in a different zone relative to the coast (Csanady 1997). In theory, there is a sequence of currents moving seawards that relates to the relative strength of the forcing mechanisms (Figure 3.2). However, these processes vary due to the relative strengths of the forcing mechanisms and are strongly modulated by shelf structure, including bathymetric influences.

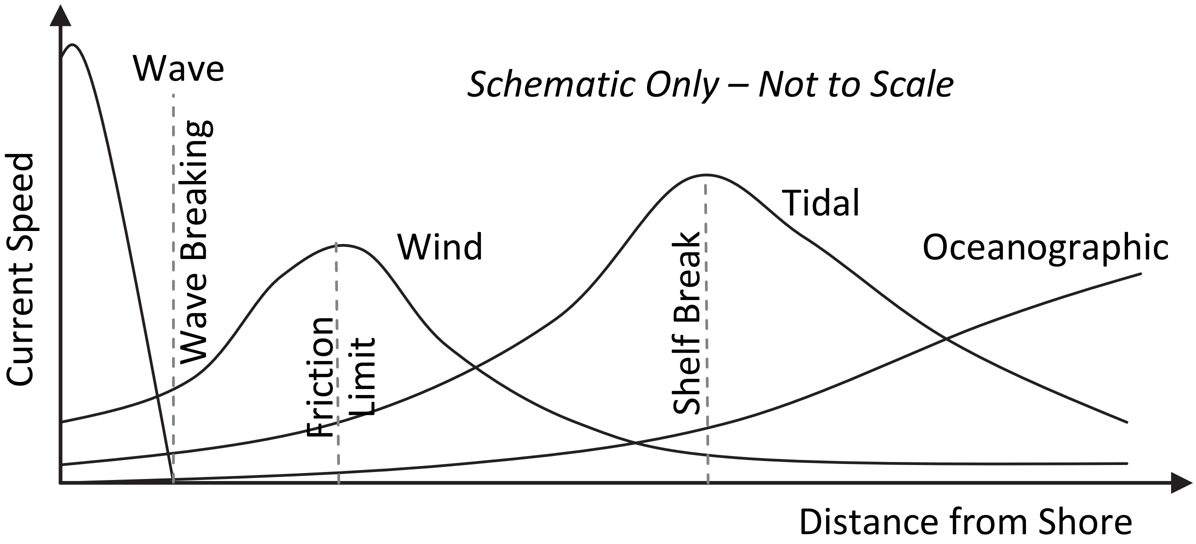
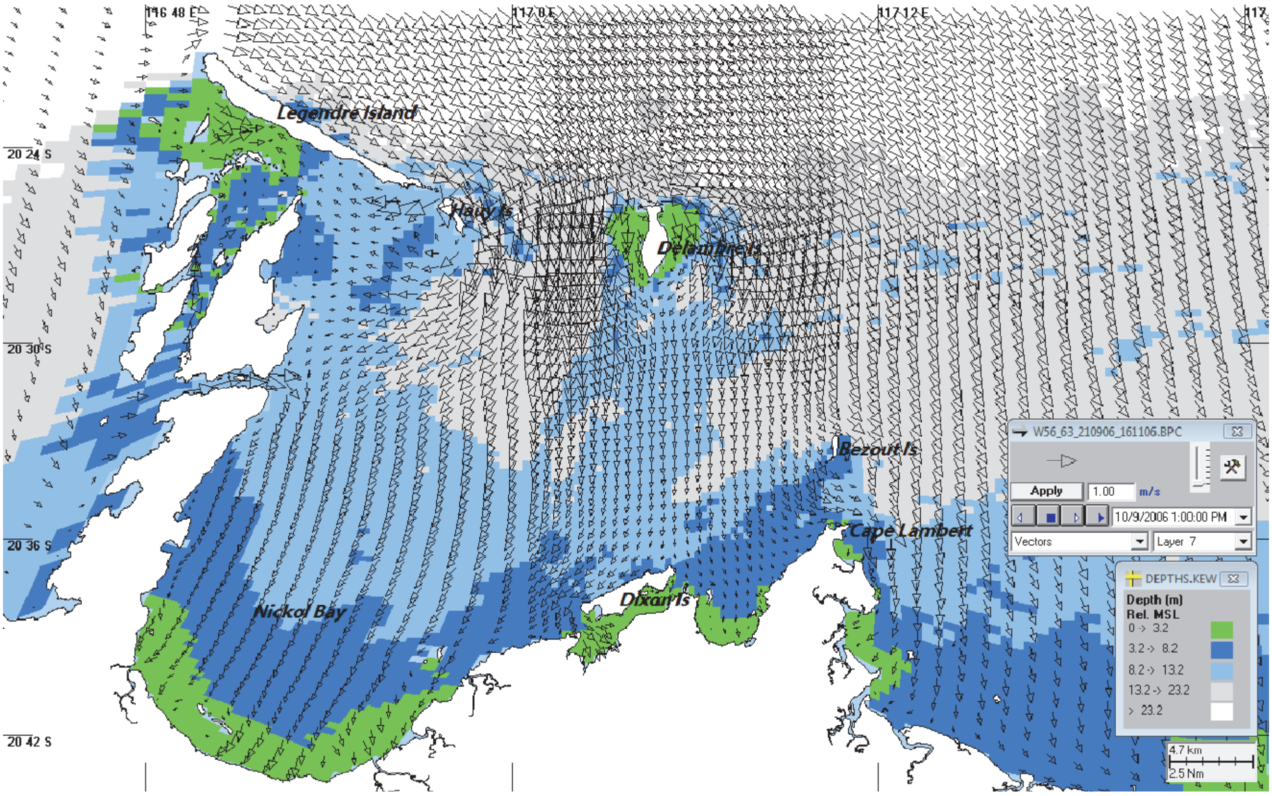


Figure 3.2 Cross-shelf distribution of the principal driving mechanisms of currents

There are few direct measurements of currents across the Northwest Shelf. However, available drifter deployments and moorings collectively indicate dominance by tidal currents due to the extensive shelf width and macrotidal conditions (Pearce et al. 2003). This dominance, along with the limited ability of moorings to resolve large-scale circulation patterns, has prompted the extensive use of numerical modelling to provide description of currents (Margvelashvilli et al. 2006; Condie & Andrewartha 2008).

Currents in the vicinity of Anketell Point and Dixon Island have been modelled using tidal forcing (Kerry 2009; APASA 2010), with measurements collected ~6 km north ('inshore') and 19 km north north-east ('offshore') from Anketell Point using two Acoustic Doppler Current Profilers (ADCPs) deployed by DHI for the 18-month period between October 2007 and April 2009 (Figure 1.1). Basic model validation has been undertaken, with the dominance of tidal currents limiting the validation for steric gradient or wind-driven circulation, including the effects of tropical-cyclone induced currents. Model results indicate significant influence of the shelf bathymetry (Figure 3.3), with tidal influx in and out of Nickol Bay producing a curved flow path that runs parallel with the coast along Dixon Island, but curves in a north-south direction towards Legendre and Delambre Islands.



Source: APASA (2010)

Figure 3.3 Typical flood tide surface current pattern overlain on model bathymetry.

The available ADCP records (Figure 3.4 to Figure 3.7) confirm the dominance of tidal forcing, showing almost bi-directional flow, with the same characteristic spring-neap cycle as the tide, with equinoctial peaks during March and September. The change in tidal current direction due to the influence of the coast between inshore and offshore is also confirmed, with the offshore modal flood tide direction of 180°N and a modal ebb flow direction of 0°N. The inshore site had a modal flood flow direction of 225°N and modal ebb flow direction of 45°N. Comparison with modelled currents indicates that the coastal influence has a greater spatial extent than may have been modelled.

The maximum observed current was 1.24 m/s and 0.68 m/s at the offshore (Figure 3.4, Figure 3.5) and inshore (Figure 3.6, Figure 3.7) locations respectively. At the offshore site, the flood tide is slightly stronger, but this is reversed at the inshore site, suggesting frictional influence. At times of high winds, directional scatter of the measured currents is evident, especially at times of relatively low tidal currents and at the inshore location. Wind-driven currents at the offshore site can also be of significant speed, with winds during the 8/11/2008 producing a wind-driven current of up to ~0.3 m/s (Figure 3.8 lower).

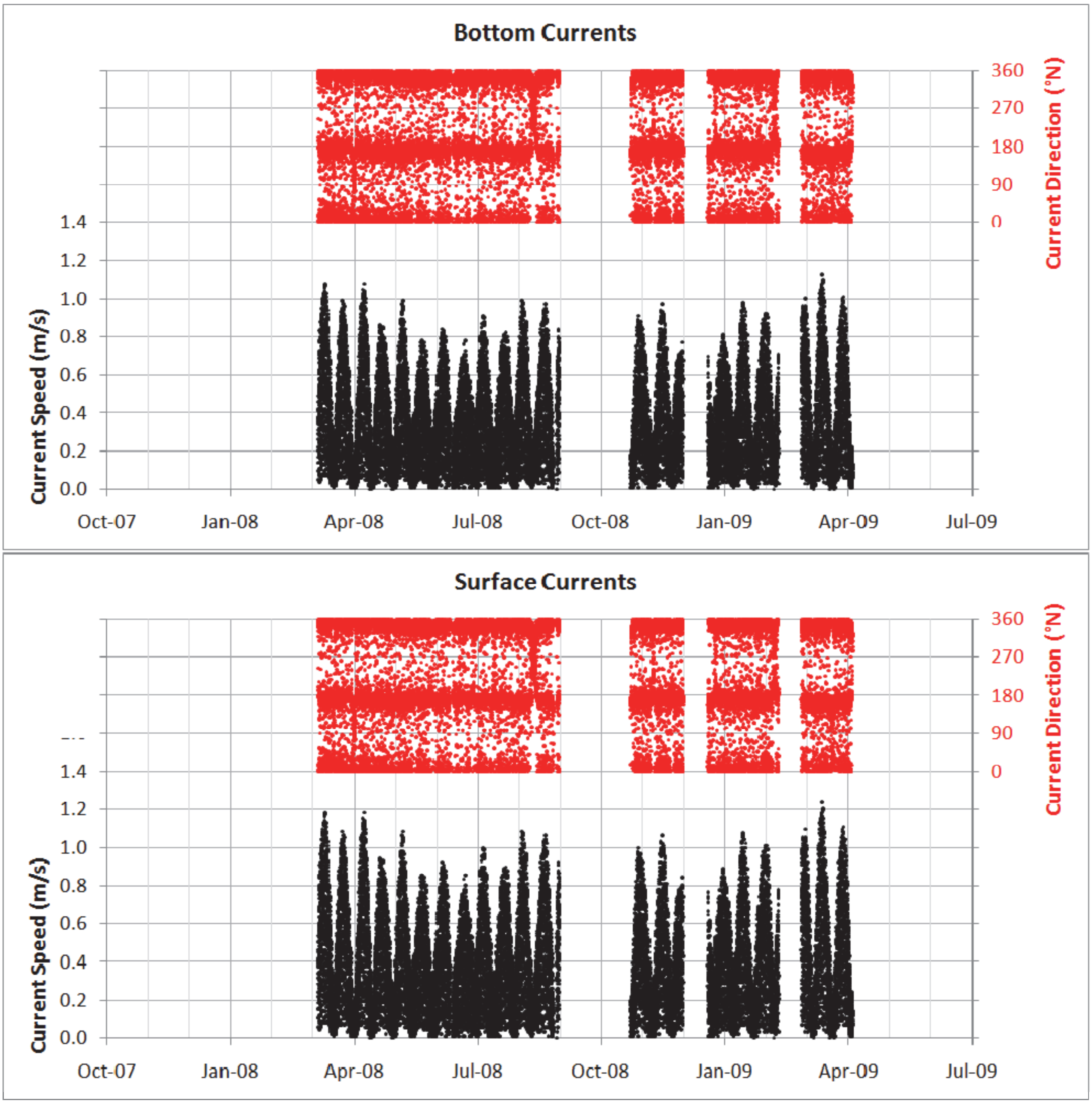


Figure 3.4 Observed Currents at the offshore ADCP site

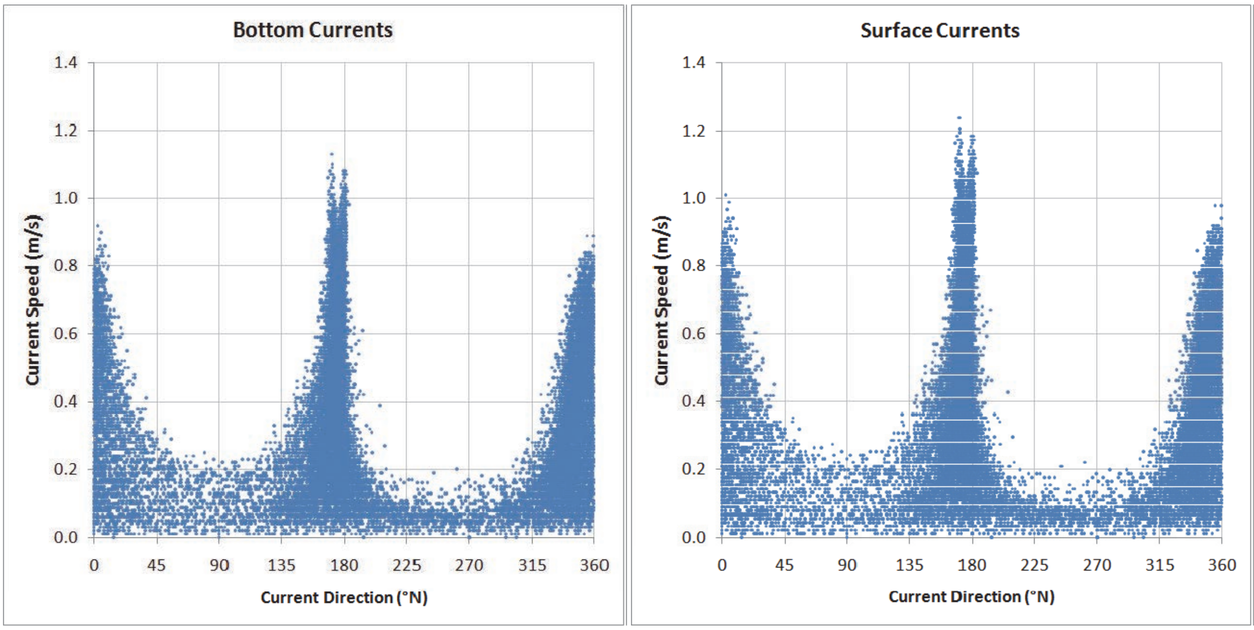


Figure 3.5 **Distributions of current speed and direction for the surface and bottom currents at the offshore ADCP site**

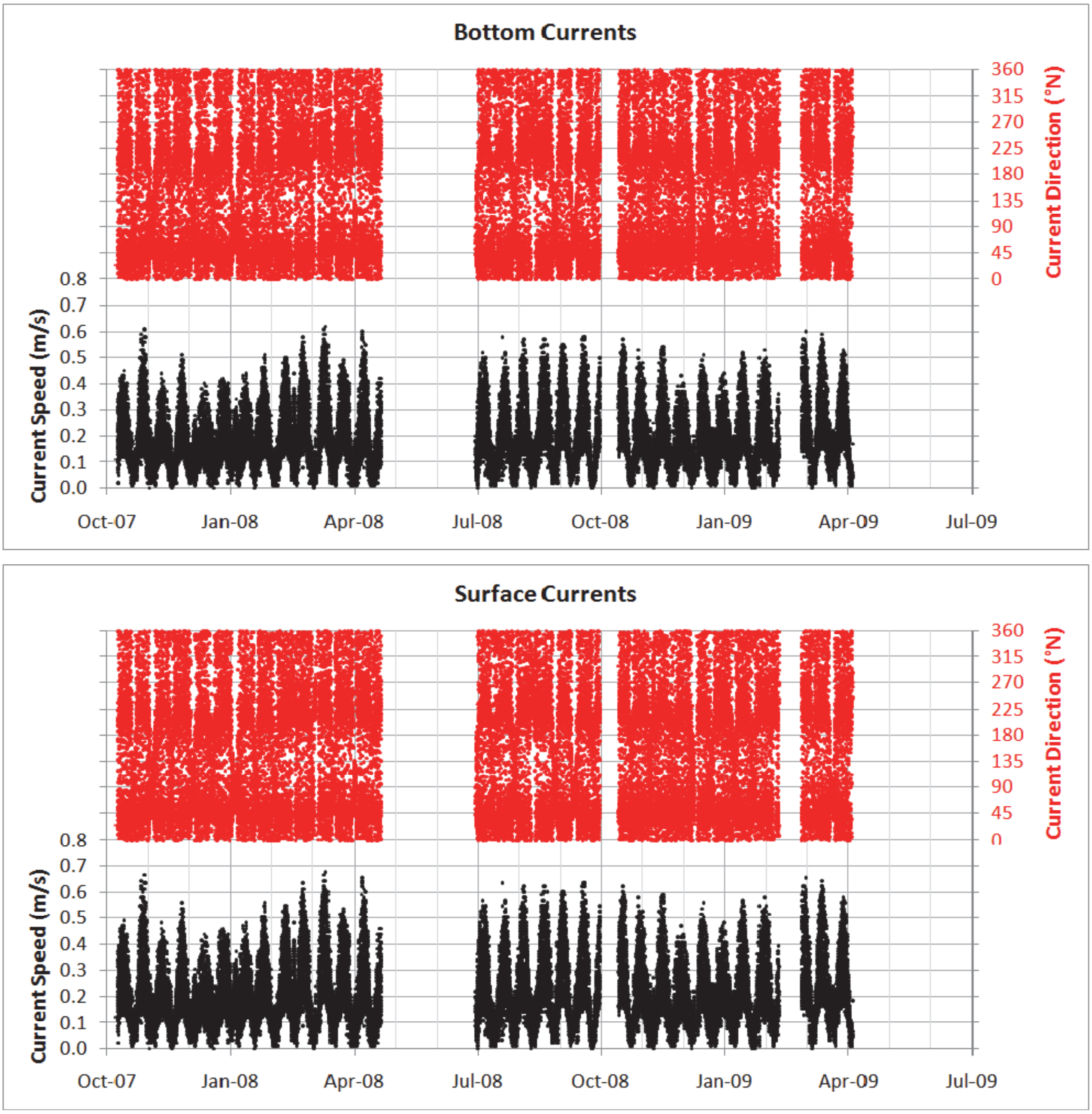


Figure 3.6 Observed Currents at the inshore ADCP site

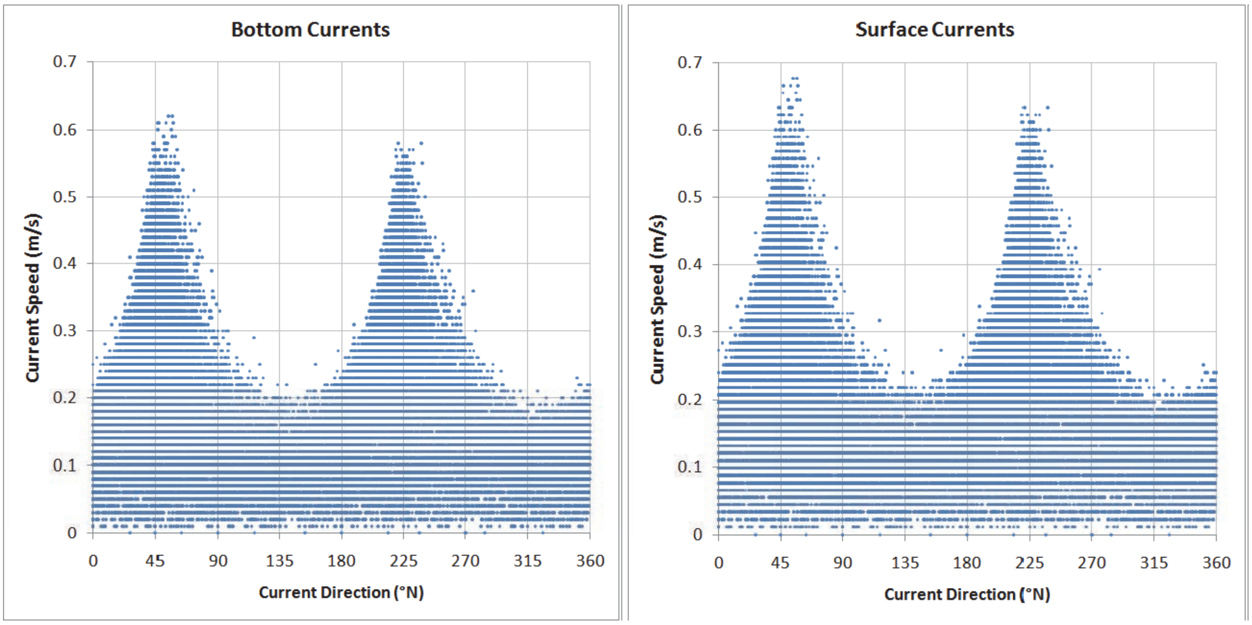


Figure 3.7 Distributions of current speed and direction for the surface and bottom currents at the inshore ADCP site.

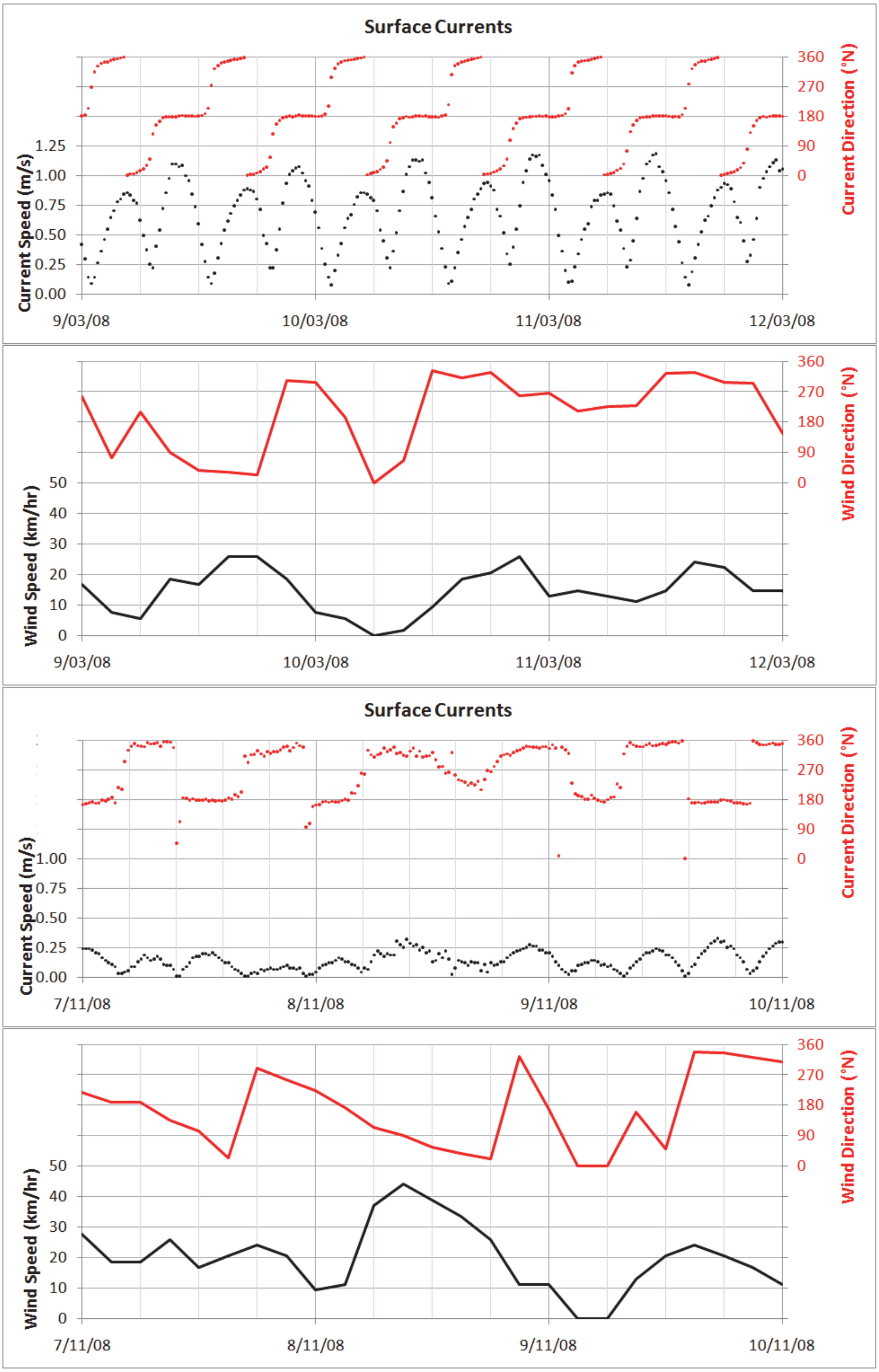


Figure 3.8 **Surface currents at the offshore site showing tidal characteristics without (upper) and with (lower) the influence of strong winds**

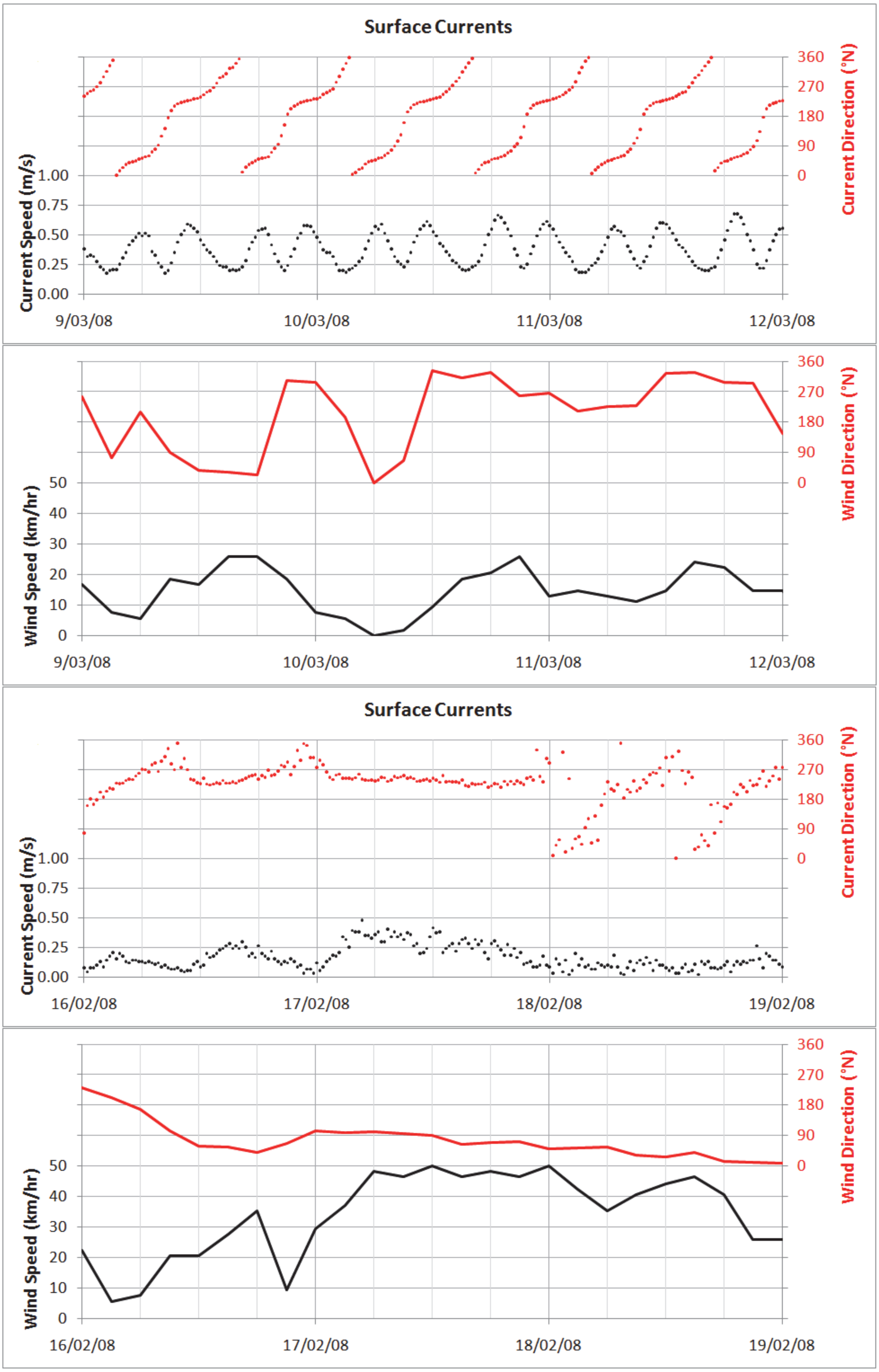


Figure 3.9 **Surface currents at the inshore site showing tidal characteristics without (upper) and with (lower) the influence of strong winds**

3.4 Waves

3.4.1 Available Data

Wave conditions in the Dixon Island region have been measured offshore from Anketell Point by DHI (2010) and AECOM (2011) and modelled by RPS MetOcean (2009) (Table 3.4). Two ADCPs were deployed by DHI at offshore locations between October 2007 and April 2009 (Figure 1.1) and an Acoustic Wave and Current sensor (AWAC) was deployed by AECOM from January to June 2011. RPS MetOcean modelled wave parameters in the region for the period July 1997 to April 2009 using the WAVEWATCH-III wave model (WW3) with data extracted from the nearest grid to the ADCP deployment locations (RPS 2009). These locations represent approximately the entrance (or offshore extent) of the dredge channel and mid-dredge channel (RPS MetOcean 2009).

For the purpose of this assessment, the RPS MetOcean modelled wave data has not been considered in detail due to the coarse scale (1 km x 1 km) of the model grid leading to low resolution of bathymetric data.

The short data length (5–6 weeks) of the AWAC did not enable integration with the ADCP and thus was not analysed in detail herein. Nonetheless, it is noted that during the period of AWAC deployment, a significant wave height of 3.12 m and maximum wave height of 5.22 m was recorded during TC Carlos on 22 February 2011.

Table 3.4 Available wave Information

Data	Company	Data Period	Method	Locations	Depth (m MSL)
Modelled	RPS MetOcean	July 1997 - April 2009	WW3	20° 35’ 47” S 117° 5’ 46” E	2.9
Modelled	RPS MetOcean	July 1997 - April 2009	WW3	20° 34’ 26” S 117° 5’ 53” E	5.1
Modelled	RPS MetOcean	July 1997 - April 2009	WW3	20° 25’ 13” S 117° 8’ 38” E	27.0
Measured	DHI	October 2007 - April 2009[1]	ADCP	20° 34’ 26.1’’ S 117° 6’ 4.8’’E	13.5
Measured	DHI	March 2008 - March 2009[1]	ADCP	20° 27’ 23.5’’ S 117°8’ 38.3’’E	22.3
Measured	AECOM	January 2011 - March 2011	AWAC	20°34.227’S 117°06.737’E	14.9

Notes: 1. These periods contain gaps in data due to instrument failure.

3.4.2 ADCP deployments

The ADCP instruments recorded relatively mild wave conditions with the offshore site (22.3 m depth) and inshore site (13.5 m depth) recording median significant wave heights of 0.61 m and 0.42 m respectively. Maximum significant wave heights recorded were 2.82 m and 2.20 m at the offshore and inshore locations respectively (Table 3.5). Wave directions were largely restricted between north and north-east for wave heights greater than 2.5 m at the offshore location and 1.5 m at the inshore location.

Analysis of the wave direction record from the ADCP deployments shows a broad directional range. At the offshore location, the median wave direction is north north-west with approximately 84% of waves occurring from north-west to east north-east. At the inshore location, wave direction is bimodal with high contributions from south-west to west south-west (22%) and north-west to east north-east (66%). The enhanced contribution of locally generated west south-west to south-west waves indicates the increased degree of sheltering, including the effects of friction, diffraction and refraction from the offshore to inshore location

Table 3.5 Wave height (m) and direction occurrence (%) from ADCPs

Offshore	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0.00-0.25 m	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.0	1.7
0.25-0.50	4.7	3.0	1.7	0.9	0.3	0.2	0.1	0.2	0.2	0.2	0.1	0.2	0.1	0.7	6.6	15.6	34.9
0.50-0.75	2.0	2.1	2.3	1.9	1.1	0.4	0.2	0.2	0.2	0.3	0.8	0.7	0.1	0.5	5.4	7.7	25.9
0.75-1.00	0.6	2.2	2.8	1.8	1.0	0.5	0.2	0.1	0.0	0.1	1.0	1.0	0.3	0.2	1.0	1.7	14.5
1.00-1.25	0.3	1.6	2.2	1.5	0.5	0.7	0.1	0.0	0.0	0.0	0.2	0.6	0.0	0.0	0.3	1.2	9.5
1.25-1.50	0.1	0.8	1.9	1.0	0.7	0.5	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.2	0.5	6.0
1.50-1.75	0.1	0.5	1.4	0.7	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	3.7
1.75-2.00	0.1	0.3	0.8	0.5	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.3
2.00-2.25	0.0	0.1	0.5	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
2.25-2.50	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
2.50-2.75	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
2.75-3.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	8.2	10.9	14.0	8.6	4.4	2.6	0.8	0.5	0.5	0.6	2.2	2.7	0.6	1.4	13.8	28.2	

0.0 %
1.0
3.0
5.0
8.0
16.0

Inshore	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0.00-0.25 m	5.9	4.3	3.1	1.1	0.4	0.2	0.1	0.1	0.2	0.1	0.2	0.4	0.4	0.5	1.5	3.6	22.2
0.25-0.50	4.2	4.4	6.7	2.6	1.4	0.5	0.4	0.5	0.3	0.3	0.9	4.9	3.2	1.5	2.9	4.5	39.2
0.50-0.75	0.8	1.1	4.6	1.1	0.6	0.1	0.0	0.1	0.1	0.2	0.9	4.9	3.8	1.6	2.0	1.1	22.8
0.75-1.00	0.2	0.6	3.9	0.5	0.1	0.0	0.0	0.0	0.0	0.1	0.4	2.3	1.4	0.5	0.5	0.3	10.6
1.00-1.25	0.1	0.2	1.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.3	0.1	0.1	0.1	3.3
1.25-1.50	0.0	0.3	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.1
1.50-1.75	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
1.75-2.00	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
2.00-2.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
2.25-2.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.50-2.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.75-3.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	11.3	11.3	20.8	5.7	2.5	0.8	0.5	0.7	0.6	0.7	2.4	12.9	9.1	4.2	7.0	9.7	

0.0 %
0.1
1.0
3.0
5.0
7.0

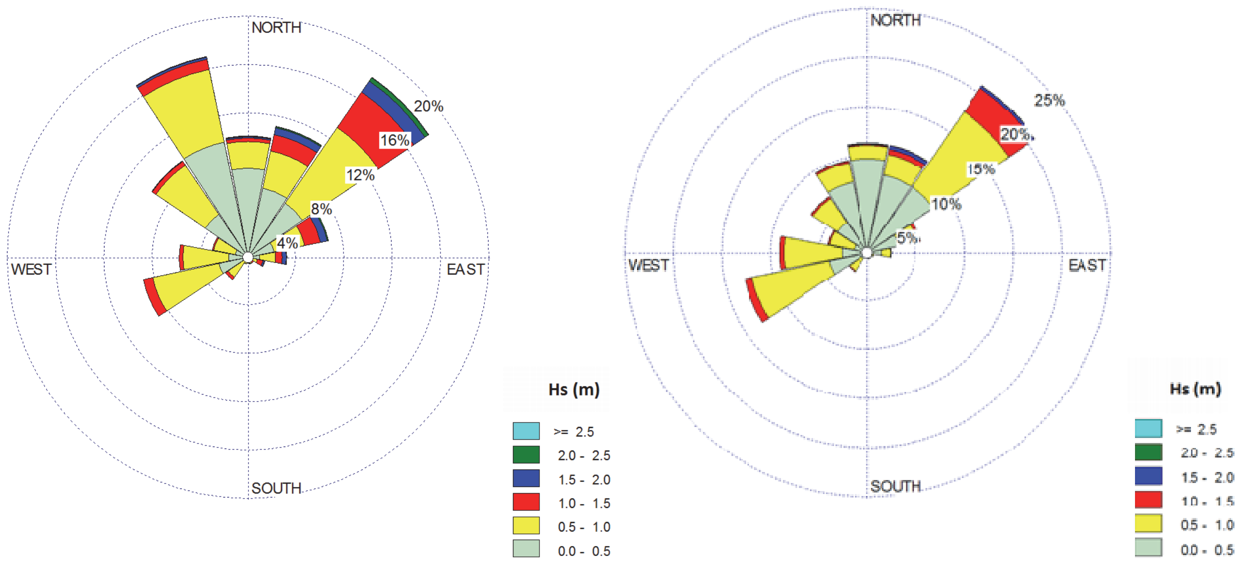


Figure 3.10 Wave roses from ADCP deployments (left) offshore and (right) inshore

Directional wave data measured from the offshore ADCP deployment indicate a distinct seasonal shift with the modal direction of north north-west from December to May and north north-east to east north-east in the winter months from June to August (Table 3.6). During the period from October to March waves generated by local winds over a restricted fetch from south-west to west south-west occasionally obscure the northerly swells.

As the inshore region is topographically protected from waves propagating out of west and north-western directions, the contribution from north north-west waves is significantly reduced. Hence, conditions where locally generated west south-west to west waves are dominant over northerly swells is significantly increased with respect to the offshore location. Additionally the contribution of swells is generally much larger during the winter months of July and August when it is propagating from the north-east.

Table 3.6 ADCP Measured monthly directional occurrence (%)

Offshore	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
N	12.4	3.1	9.4	11.9	5.4	4.7	7.5	4.6		7.0	7.2	10.6	7.9
NNE	4.0	1.3	3.8	14.1	19.0	19.4	13.3	16.9		4.8	2.6	3.2	10.2
NE	3.3	21.9	10.4	9.1	11.1	25.2	19.0	30.7		1.1	1.8	6.4	13.0
ENE	3.1	4.9	7.5	6.5	13.0	17.3	8.0	12.0		3.2	4.5	2.1	8.2
E	2.3	1.3	2.4	4.1	1.4	7.0	5.4	8.5		3.2	6.0	1.1	4.1
ESE	0.6	0.4	0.8	2.1	1.2	4.3	5.0	5.7		0.5	2.2	1.4	2.4
SE	0.6	0.0	0.4	0.9	0.2	1.4	0.5	1.2		0.5	1.2	0.7	0.7
SSE	1.0	0.9	0.8	0.6	0.2	0.5	0.0	0.3		0.0	0.5	1.1	0.5
S	0.1	0.0	0.9	0.2	0.2	0.0	0.4	0.3		0.5	2.2	0.4	0.5
SSW	0.3	0.4	0.9	0.3	0.0	0.0	0.3	0.1		2.7	2.0	0.0	0.5
SW	3.1	5.4	2.7	0.2	0.0	0.0	0.1	0.3		8.0	6.6	4.6	2.2
WSW	1.3	6.3	2.0	0.5	0.5	0.9	0.8	0.3		11.2	9.9	6.4	2.6
W	0.4	3.1	0.3	0.3	0.3	0.5	0.6	0.7		1.1	0.8	0.4	0.6
WNW	1.0	0.0	0.3	1.2	0.5	1.2	3.2	1.5		2.1	2.3	0.0	1.3
NW	12.8	7.1	21.6	9.4	12.2	6.4	15.7	6.6		14.4	19.6	13.1	13.3
NNW	53.8	43.8	36.0	38.6	35.1	11.2	20.1	10.3		39.6	30.7	48.8	31.9
No. Days	31	10	42	30	31	27	31	28	0	9	30	13	

0.0
1.0
2.0
6.0
10.0
20.0
30.0
40.0
55.0

Inshore	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
N	12.3	13.6	17.1	22.5			5.9	5.5	9.3	10.9	7.8	5.4	11.8
NNE	13.2	10.6	9.8	15.5			15.4	12.3	13.4	12.3	5.2	6.7	11.5
NE	10.1	23.2	20.6	18.1			46.1	59.6	13.3	12.1	7.9	10.0	24.8
ENE	2.8	2.3	5.7	12.1			11.7	8.4	7.5	4.0	3.3	3.3	6.6
E	1.0	0.5	1.8	4.4			2.8	3.4	5.1	1.9	3.0	2.3	2.5
ESE	0.3	0.1	0.7	2.5			0.1	0.5	1.6	0.9	0.8	0.8	0.8
SE	0.4	0.7	0.3	0.9			0.4	0.3	1.1	0.7	0.7	0.1	0.5
SSE	0.8	0.6	0.4	1.2			0.1	0.5	1.7	0.7	1.0	0.1	0.6
S	0.2	0.0	0.6	1.9			0.0	0.8	1.3	0.2	0.7	0.4	0.6
SSW	0.7	0.0	0.2	0.5			0.3	0.0	2.5	0.9	0.7	0.7	0.4
SW	1.6	0.9	1.4	0.5			0.1	0.3	2.7	2.1	3.2	6.8	1.5
WSW	13.6	10.7	8.9	3.3			1.6	0.9	10.1	18.3	19.9	21.1	9.4
W	9.5	4.4	5.9	1.1			1.8	0.4	10.4	10.1	16.2	15.1	6.5
WNW	5.3	1.6	3.2	1.1			0.4	0.5	4.5	3.9	8.4	5.5	3.2
NW	11.3	10.8	6.7	4.0			3.0	1.5	4.0	1.7	7.5	9.7	6.1
NNW	17.1	19.9	16.8	10.2			10.2	5.0	11.5	19.4	13.6	12.1	13.1
No. Days	62	37	58	25	0	0	31	31	30	40	61	55	

0.0
1.0
2.0
6.0
10.0
20.0
40.0
60.0

Extreme wave conditions are recognised to occur almost exclusively during tropical cyclones, and, as might be expected for any episodic event, are generally not amenable to analysis using relatively brief periods of wave measurements. Ideally, around 30 years of data are required to enable effective analysis. Instead, cyclonic wave conditions have been hindcast using several different modelling approaches. Buchanan & Treloar (2002) undertook a hindcast of observed tropical cyclones, and generated the corresponding extreme parameters. GEMS (2008, 2009) used a Monte Carlo approach to cyclone modelling, with a synthetic tropical cyclone database.

Table 3.7 Modelled extreme wave conditions

Recurrence Interval	Wave Hs (m)	Wave Hmax (m)	Period Tz (sec)	Water Level (m CD)	Surge η (m)	Wind Uw (m/s)
1 year	2.0	3.7	6.0	5.7	0.20	14
2 years	2.5	4.7	8.0	5.8	0.55	23
5 years	3.5	6.5	11.0	5.9	0.75	35
10 years	4.5	8.4	12.5	6.0	0.90	43
20 years	5.0	9.3	13.5	6.2	1.00	51
50 years	5.5	10.2	14.0	6.4	1.15	60
100 years	6.0	11.2	14.5	6.7	1.25	66

Summarised from Buchanan & Treloar (2002) and Damara (2006)

4. Geomorphology

Coastal geomorphic features of the Anketell Point area have been identified from aerial photography and during two separate site visits (29 April 2010 and 12 to 14 April 2011).

The main coastal geomorphic features of Dixon Island include (Figure 4.1):

1. A broad, intertidal rock platform along the northern coast;
2. A series of perched sandy beaches with headland control, on the north-east of the island;
3. An overwash plain, indicative of landward transport of marine sediments during periods of extreme high water-levels;
4. Four rock ramparts, north-east Dixon Island (one modern, three relict), possibly indicative of tsunami events or extreme cyclones; and,
5. A high tide lagoon located behind an established stand of mangroves.

The main coastal geomorphic features at Anketell Point include (Figure 4.1):

6. A sand spit (southern margin of central Bouguer Passage);
7. A narrow northward projecting rocky peninsula, located at the northern tip of Anketell Point; and,
8. A rock platform immediately east of Anketell Point.

The site visits did not include an inspection of No Name Bay; however, review of aerial imagery indicates that the nearshore area is likely to consist of sandy and silty tidal flats, rather than rock platform. During extreme high water levels, No Name Bay is joined to Bouguer Passage by a narrow salt flat.

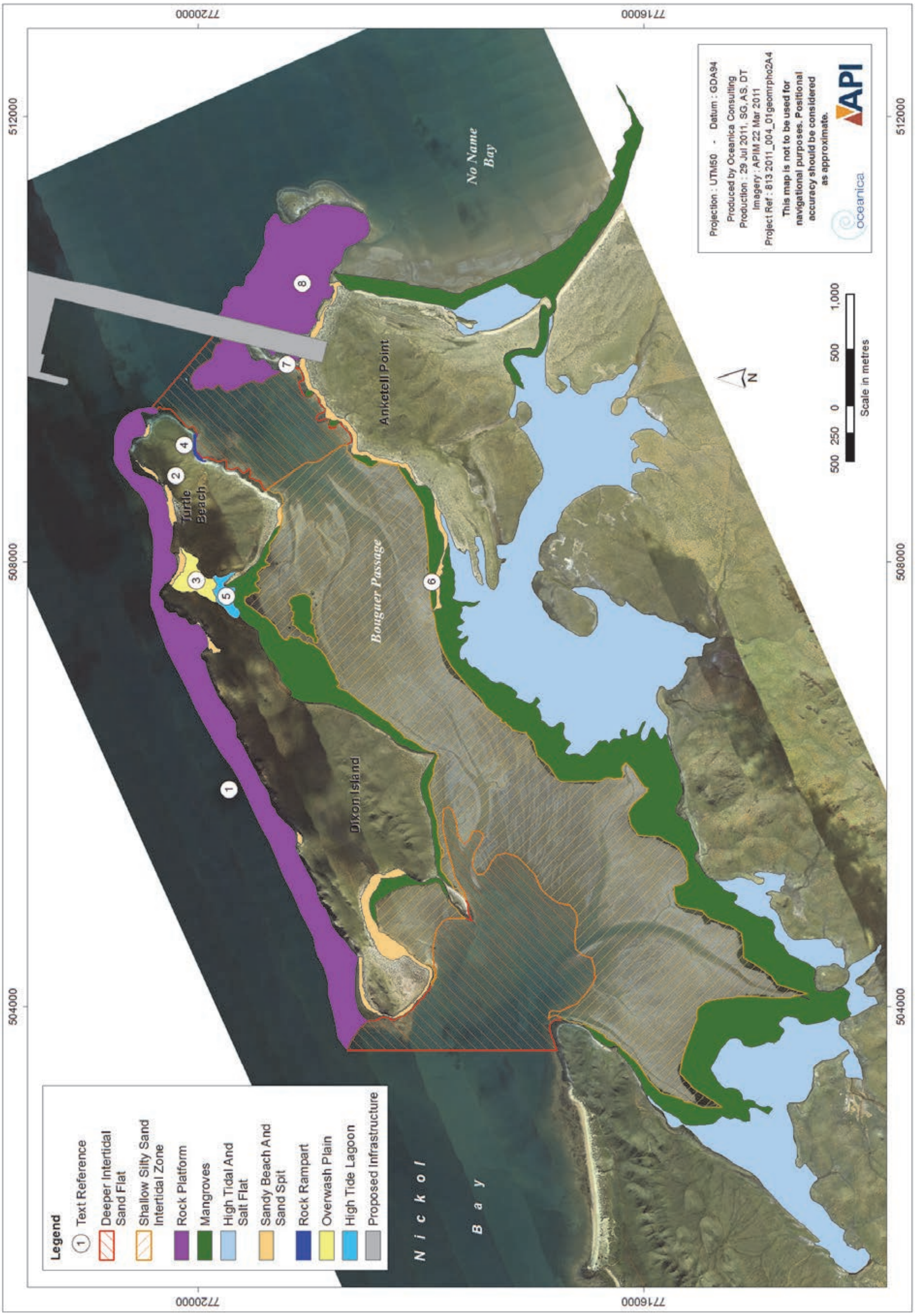


Figure 4.1 Coastal geomorphic features of Dixon Island and Anketell Point

The existing geomorphic features within Bouguer Passage include (from east to west and labelled on Figure 4.2):

1. A rock sill across the eastern end of Bouguer Passage (Bouguer Entrance), approximately corresponding to the alignment of the rock platform at Anketell Point itself (AECOM, 2010b)[2];
2. A flat sandy zone, which experiences active sediment transport on the bed;
3. A broad area of sand splays and tidal channels;
4. A small high tide lagoon (presumably saline), on the north side of central Bouguer Passage, fringed by a dense growth of mangroves (Figure 4.1)). This is presently linked to the main passage through a tidal channel running to the east, although the structure at its western end suggests that it previously may have had two channels to the westward;
5. A sandy zone, approximately 900 m wide, in the centre of Bouguer Passage, marking a separation between the east- and west-draining tidal channels;
6. The western ends of the west-draining tidal channels broaden significantly, without an apparent increase in area contributing to tidal flows; and
7. The western end of the channel connects to a sub-tidal basin between Cleaverville and the south-west end of Dixon Island.

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[2] *Jet probing along the proposed causeway alignment of Stage 1 encountered a consolidated layer between 0.01 m and 0.4 m below the seabed level (AECOM 2010b)*

Figure 4.2 Geomorphic features of Bouguer Passage

5. Sediment particle size

Particle size distribution data in the Anketell Point region were obtained from a number of sources and analysed for trends. Particle size distributions of 56 sediment samples were available from: along the proposed channel; within the proposed turning basin; within the proposed dredge material disposal areas; adjacent to the proposed Terminal 2 causeway; in Bouguer Passage; and, along the shoreline of north-east Dixon Island and north-east Anketell Point (Figure 5.1).

There is a range of available particle size data, deriving from five sediment sampling campaigns (Table 5.1). Each campaign has used a subtly different range of analytical methods, and the resulting particle size distributions are not directly comparable. The differences limit the comparisons able to be made between samples and the interpreted results are therefore described in isolation below. The material below is thus an interpretation of those datasets, containing some uncertainties. It is noteworthy that, should any future sampling be undertaken for the purpose of coastal process investigations, we would recommend that sediment samples be analysed using a laser-sizer across the fullest possible spectrum of particle sizes (e.g. 0.1—2000 µm), with any necessary screening of the coarse particles (to be wet sieved) done using a 2000 µm sieve. This will ensures data consistency across the key sand and silt size ranges and reduce the uncertainties produced by the interpretation of merged laser-sizer and wet sieve datasets.

The analysis of the available particle size data helps to: increase the understanding of the key controlling sedimentary processes; examine sedimentary linkages between different areas; and, provide a firm basis upon which to identify potential sediment transport pathways. Therefore the particle size data are presented as frequency curves, as used in the scientific literature for such purposes (e.g. Larcombe et al. 2001, Woolfe et al. 2000, Bryce et al. 2003).

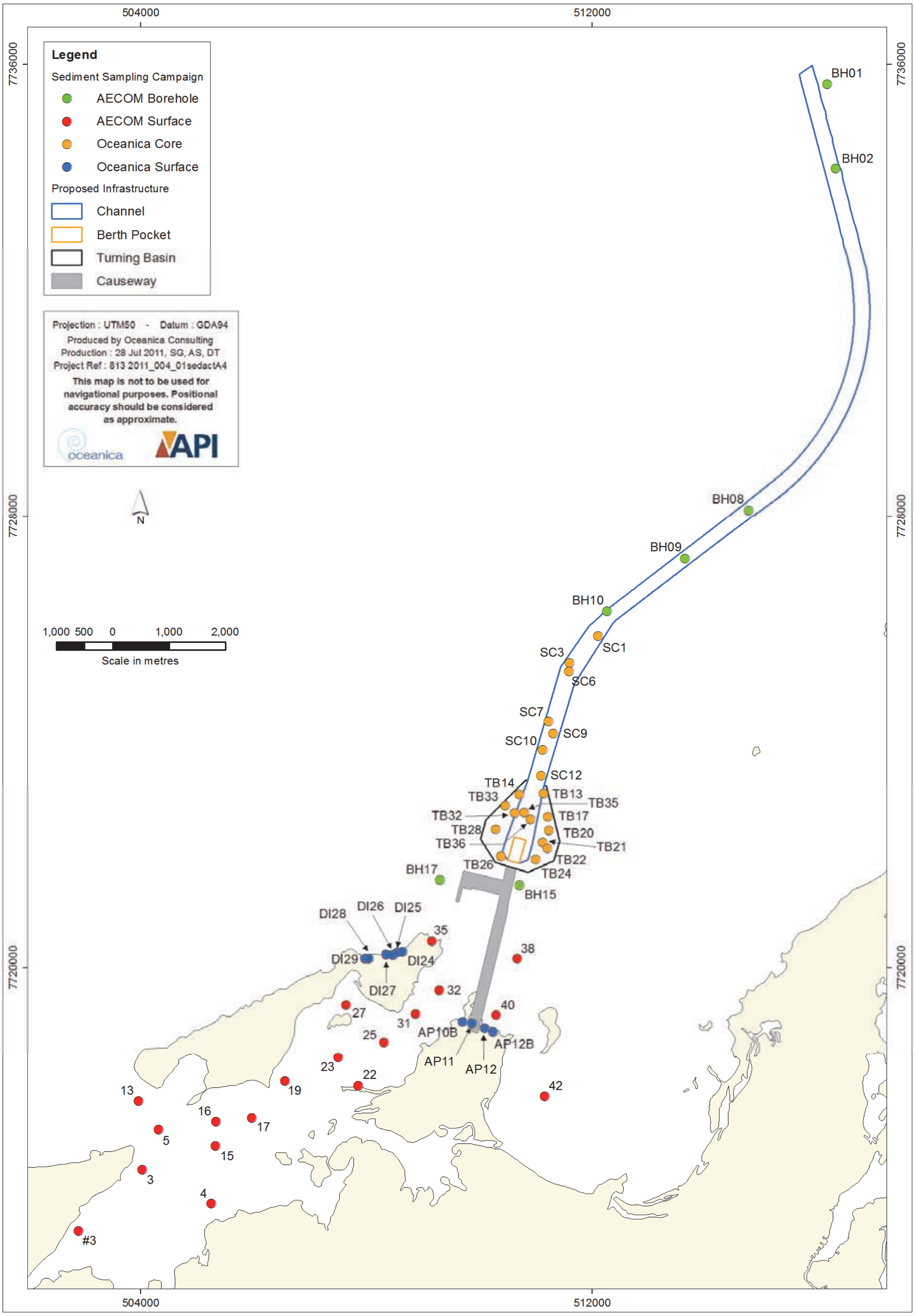

Figure 5.1 Sediment samples reviewed in this study

Table 5.1 Summary of particle size data

Sampling Campaign	Source	Text section number	Analysis method	Max. measured size (µm)	Min. measured size (µm)	Measure of grain size	Data resolution	Interpretation uncertainty
AECOM boreholes	AECOM 2009c	Section 5.1	Sieve	28,250	37.5	Median grain diameter	11 data bins	Low–Medium
AECOM surface	AECOM 2009c	Section 5.2	Wet sieving for >106 µm fraction, Sedigraph for finer fraction	1,500	0.26	Combination: 1) median diameter; and 2) mean settling velocity converted to size	51 data bins. Resolution good for 27-106 µm range, none finer and less resolution for coarser fraction	Low-Medium
Oceanica Cores	Oceanica DRAFT	Section 5.3	Wet sieving for >106 µm fraction, Sedigraph for finer fraction	1,500	0.29	Combination: 1) median diameter; and 2) mean settling velocity converted to size	29 data bins. Resolution good for silt fraction, less so for sand fraction	(Little interpretation made)
Oceanica Surface	Oceanica[1]	Section 5.4	Wet sieving for >500 µm fraction, laser diffraction for finer fraction	6,000	0.26	Combination: 1) median diameter; and 2) volume equivalent spherical diameter	51 data bins. Arithmetic mean of bin range	Medium–High
API disposal sites[2]	API 2010b	n/a	Wet sieving for 500–3,150 µm, laser diffraction for <500 µm. Method for coarser fraction not stated, assumed to be dry sieve	1,000,000	<4	Mix - Median diameter and volume/area equivalent spherical diameter	10 data bins	Insufficient data resolution to enable interpretation

Notes:

1. Sediment samples were collected by Oceanica and analysed for particle size distribution as part of the baseline beach profiles surveys (April 2010).

5.1 AECOM boreholes

The tops of the borehole samples along the proposed dredged channel indicate the presence of sands, which overall appear to fine landward (Figure 5.2). There are relatively well-sorted fine sands (112.5 µm size class) to the west and east of the proposed Tug Harbour (sites BH15 & BH17) and 8 km further offshore (at BH10). These give way to medium sands (225 µm size class; BH09 and BH08) and then to coarser sands further offshore (BH02 and BH01). All samples show relatively few particles around the 500 µm class (i.e. medium sand).

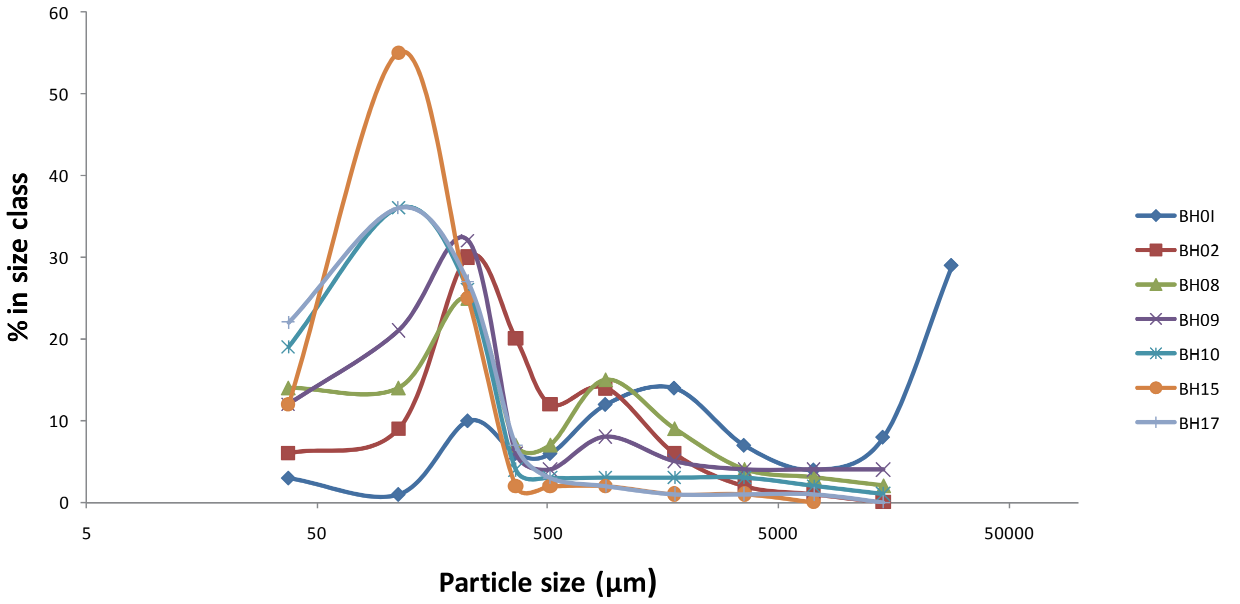

Figure 5.2 Grain size curves from AECOM borehole sediments

5.1.1 Interpretation

There is relatively little resolution in these data but overall they are consistent with a shelf which, in geological terms, is accumulating sediment near the coast.

5.2 AECOM surface

These samples are from Bouguer Passage and No Name Bay, and are all sands, with almost all their grains within the medium sand size class. It is notable that almost no sediment was recorded which was finer than 101 µm, except for a small proportion of very fine sand and silt in Sample 23. Most of the samples along the passage have a very similar grain size curve (Figure 5.3) but Samples 35 and 32, located off north-east Dixon Island and at Bouguer Entrance, are notably coarser.

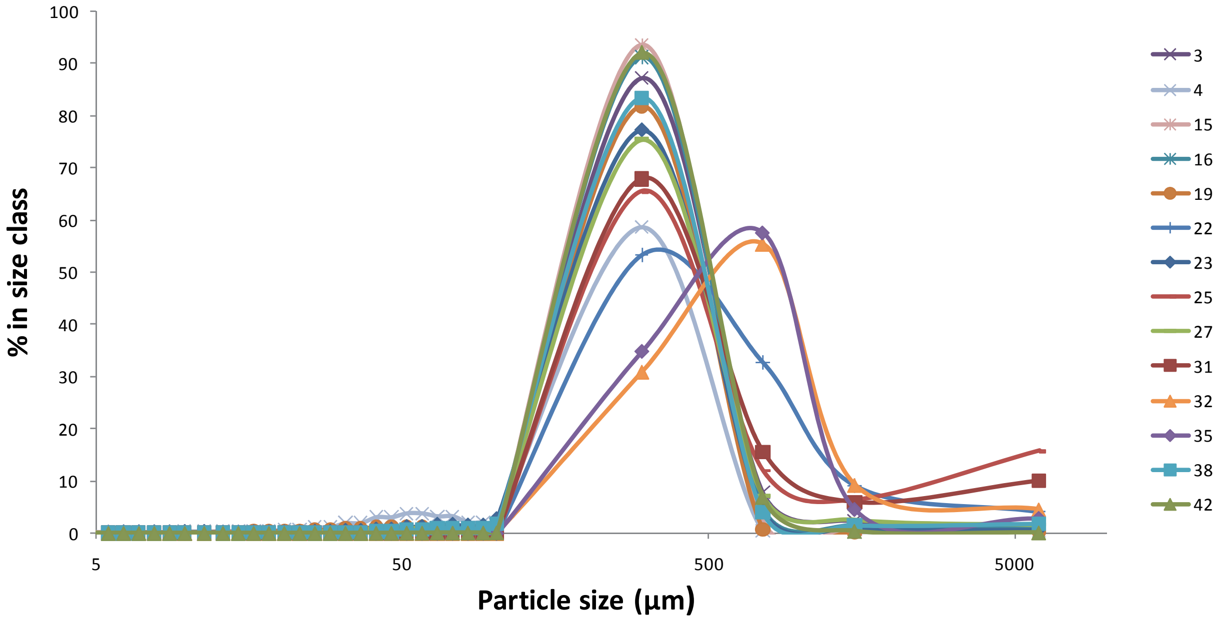

Figure 5.3 Grain size curves from AECOM surface sediments

5.2.1 Interpretation

In generic terms, the clean nature of these sediments (no silt fraction) is consistent with a sedimentary environment which generally lacks significant periods of quiescence. This is consistent with the observed strong tidal currents and the predominance of the stronger winds (see Sections 3.2 and 3.3) which provide little opportunity for silts to settle out on the sea bed. In addition, noting the relative uniform bathymetry across the area, it is likely that there is a continuous link between sediments in the passage and those to the east.

5.3 Oceanica cores

These samples are from the proposed turning basin and inner dredged channel, and are all sands, with a series of particle size modes within the sand fraction (Figure 5.4). Resolution in the silt fraction is good and indicates a small silt content in most samples, with a broad silt size mode of ~30-55 µm. There is an apparent absence of particle sizes immediately below 106 µm; this is the point where the sieve and sedigraph datasets merge. While the relative lack of silt compared to the sand is consistent with the other samples in the region, the drop in the curves around the 106 µm size class is considered to be an artefact of the merging of the analysis methods and not an indication of real particle size variation.

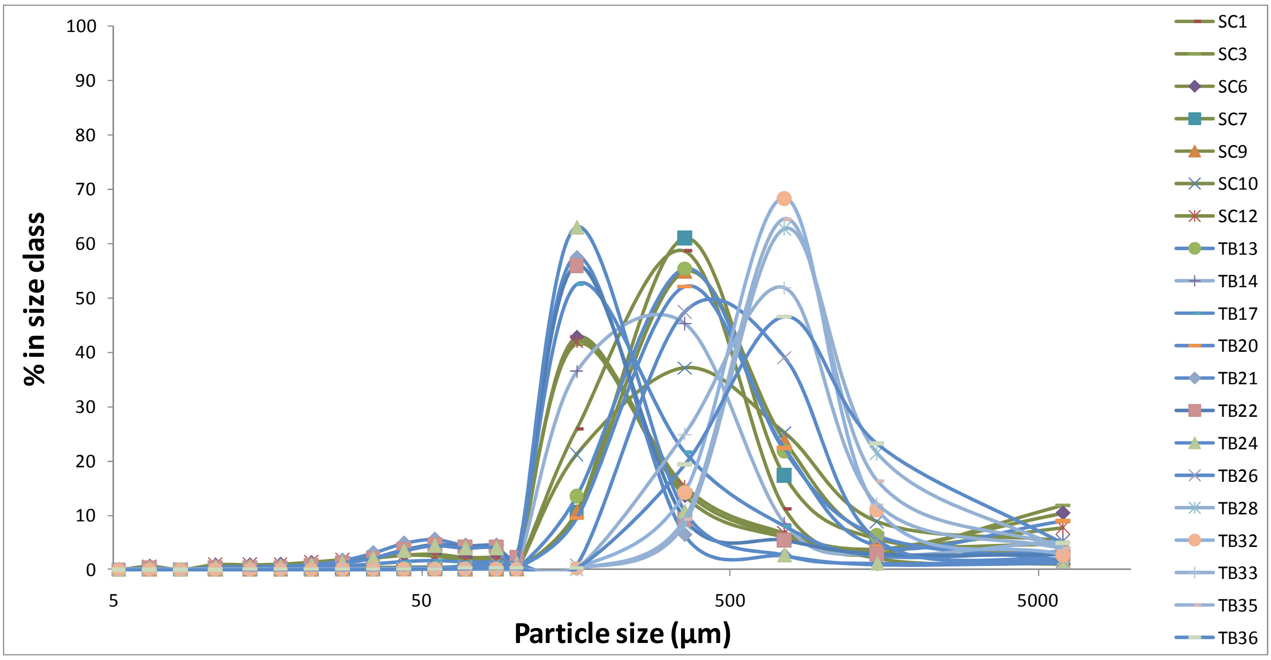

Figure 5.4 Grain size curves from Oceanica core sediments

5.3.1 Interpretation

There is no clear spatial pattern regarding the primary size mode of these sands, but the size ranges are consistent with those from surface borehole samples reported above (Section 5.1).

5.4 Oceanica shoreline

These samples are from the shoreline at Anketell Point and north-east Dixon Island. Samples from the north coast of Dixon Island are generally silty sands, and the data show a clear decrease in the relative abundance of the 450 µm size class towards the west along the turtle beach and beyond (Samples D124-D129, Figure 5.5). The samples from Anketell Point and the coastline are (in relative terms) very poorly sorted, with a wide range of grain sizes present, varying from silty sands to sandy silts.

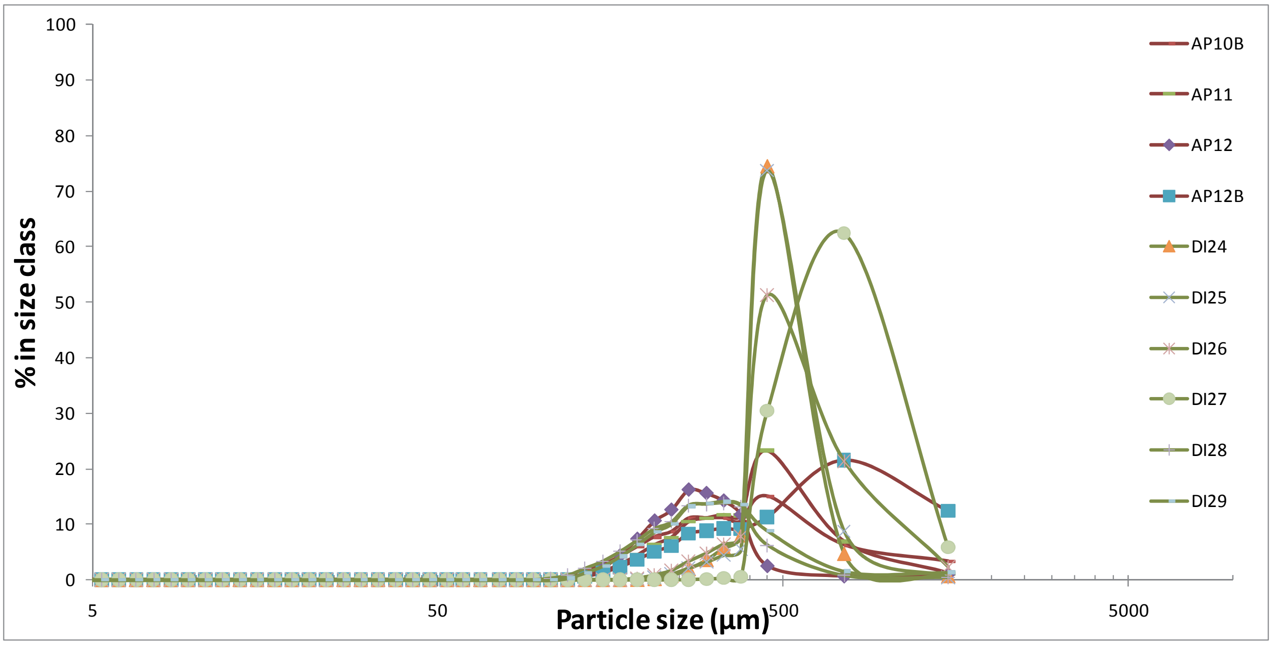

Figure 5.5 Grain size curves from Oceanica shoreline sediments

5.4.1 Interpretation

The trend in abundance of the medium sand mode is consistent with a westerly transport direction along the Dixon Island north coast.

5.5 Summary

The similarity in medium sand modes in the proposed tug harbour and Bouguer Passage with those along the north coast of Dixon Island indicate that it is likely that over timescales of months to decades, offshore sediments are exchanged between Dixon Island and Bouguer Passage. Further, the sediments, in conjunction with an understanding of the hydrodynamics of the region (Sections 3.3 and 3.4) and the proximity of the sites in question indicate that it is likely that a sedimentary link exists between Bouguer Passage and the sea bed to the east and north.

6. Coastal Processes

Coastal processes in the Anketell Point region can be inferred from the general dynamics of the continental shelf, geomorphology, historical information, metocean information, particle size trends, aerial photography and modelling simulations.

6.1 North Dixon Island

The northern side of Dixon Island experiences a moderate energy wave and current regime, which transports material alongshore, with direction varying between seasons (net north-eastward in summer and south-westward in winter) related to the metocean regime (Section 3). Over a period of one or more decades, the dominant effect of cyclones on sediment transport will almost certainly be to transport bed sediments strongly to the south-west. An extensive intertidal rock platform limits the capacity for this transport regime to directly affect the coast, leaving a broad, bare rocky intertidal area, the subtidal continuation of which is colonised by corals (Figure 4.1). The shoreline on the north side of the island is consequently sediment deficient, with the majority of mobile coastal material being comprised of coral rubble fragments. Rock outcrops provide shoreline control, with small pocket beaches forming in between.

During north-westerly storms, it is possible that sandy sediment on the inner shelf off north-east Dixon Island is transported towards No Name Bay. Once sandy sediments have been transported into No Name Bay they are likely to remain there, because there are few mechanisms for its removal.

Towards the north-east end of Dixon Island small, perched beaches have formed (Figure 4.1) in areas where there is a slight concave section of the shoreline (in plan view) and a broader intertidal platform. Although this alone is sufficient to enable accumulation of a perched beach, it is potentially further encouraged by a local weakening of alongshore tidal currents (DHI 2009) caused by the concave shoreline. This provides capacity for sediment to preferentially accumulate in front of the platform. This sediment can be mobilised and transported on to the shore during suitable combinations of wave and water level, forming a perched beach. The dynamics of perched beaches do not follow a simple model, as the beach stability is often a complex function of sediment supply, waves, tides, surges and rock platform structure.

The rates and magnitudes of beach erosion and recovery may be very high at times, as a perched beach at high elevation is only susceptible to major change (erosion or accretion) under elevated water levels. In contrast, the intertidal rock platform at the turtle beach is inundated by water levels around mean high water spring (MHWS) tides, which allows this platform to rapidly accumulate sediment under moderate conditions[3]. It is expected that the turtle beach will largely remain stable due to its exchange with subtidal sediments, except under extreme water level conditions, most commonly associated with tropical cyclones.

6.1.1 Historical shoreline change

Visual comparison of historic aerial photographs of Dixon Island (1968 to 2009) indicates that there have been no significant changes in coastal morphology or shoreline position in the last 40 years (AECOM 2009c). For most of the beaches along northern Dixon Island, there is also little evidence of seasonal shoreline changes. The exceptions are the turtle beaches, where sediments shift towards the east in summer and towards the west in winter as a result of seasonal changes in the wind regime.

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[3] *Should sediments be available locally and the specific hydrodynamics favour it.*

6.2 Bouguer Passage

Several aspects regarding the hydrodynamics and sediment dynamics of Bouguer Passage (including the coast of south Dixon Island and Anketell Point) can be inferred from the morphology (Figure 4.2):

- In the long term, most of the sediment in Bouguer Passage is likely sourced from the sea bed north-east of Dixon Island and transported into the passage during flood tides and cyclones.
- The sandy sill (Point 5, Figure 4.2) separating the tidal channels, indicates that during low tides, water flows in opposite directions from this point.
- Broadening of the channel towards the central eastern side of the Passage presents a natural area of deposition. This is supported by the presence of sand splays (Point 3, Figure 4.2), indicative of deposition.
- Sand splays (Point 3, Figure 4.2) just west of the eastern pinch point of the channel part way along the Passage appear to be active, and are likely to reflect a seasonal or episodic remobilisation of sediment.
- The rock sill (Point 1, Figure 4.2) provides a partial control on the seabed east of the sand splays and may be partly responsible for the absence of a distinct tidal channel structure in the eastern end of the Passage. Sediment mobility in this area is likely to be high.

Much of this interpretation is consistent with the patterns of tidal flow indicated by numerical modelling simulations (APASA 2010, APASA 2011). However, it is important to recognise that the modelling does not include variation of sediment size, and lacks the resolution to simulate tidal channel flows and dynamics. Nevertheless, the modelling indicates the potential for sediment accumulation towards the middle of the Passage, and relatively higher rates of tidal sediment transport between the sand splays and the rock sill. It is also important to note that extreme events have not been considered in the modelling. These play a large role in coastal processes of the region and will influence the development and nature of many of the coastal geomorphological features in the area.

7. Changes to coastal processes

7.1 Currents

Dredging of the berth pockets and shipping channel and construction of the tug harbour/MOF causeway have the potential to alter local wave and current patterns. The most important elements are the tug harbour/MOF and the causeway, because they prevent flow throughout the entire water column. Together, these are likely to act to narrow Bouguer Entrance, constricting tidal or cyclone-associated flows in and out of the passage.

During prevailing conditions, the flow constriction caused by Terminal 2 is likely to have three key effects (Figure 7.1):

- In broad terms, flow speeds through Bouguer Entrance and, to a lesser extent through Bouguer Passage will likely decrease (APASA 2011). This is likely to enhance both the rate and area of sediment accumulation within the Passage, including of silty sediments at the Passage margins.
- Locally, acceleration of flow across two narrow points at Bouguer Entrance: (1) between Dixon Island and the tip of the proposed tug harbour; and (2) between Dixon Island and the causeway. This is likely to act to scour and mobilise available sediment. This sediment will be deposited in adjacent areas with relatively less energy, including in the proposed tug harbour and directly between Dixon Island and Anketell Point.
- Flow between Bouguer Passage and No-Name Bay will be limited, encouraging local accumulation of sediment along the margins of the causeway, and in particular where it joins Anketell Point.

The proposed design of the tug harbour/ MOF, in particular the sheltered area to its south, is likely to act as a local sediment sink, fed by the regionally present silt and local sands. During summer, when prevailing winds are from the west, sediment from the sea bed north of Dixon Island may also be drawn into the proposed tug harbour.

During cyclones, there is likely to be a complex set of flows in the study area, associated with a complex and temporally varying flow field within Nickol Bay. The circulation patterns developed for each cyclone will be unique, although a degree of similarity will in part be imposed through the bathymetric and topographic structure. In this region of north-western Australia, the majority of tropical cyclones travel westward, passing north of Anketell Point (Gentilli 1972, Lourensz 1981, Damara WA Pty Ltd 2006). During such an approach, strong winds from the east through north-east will drive water south-westwards into Nickol Bay, raising water levels there, and potentially causing significant south-westerly transport of sandy sediment , driven by currents and waves on the inner shelf, and by waves at the coast. There may also be some return currents along the Bay's north-west and south-east flanks, but these will be relatively weak. Late in the passage of the cyclone, there is likely to be a general 'relaxation current' flowing north-eastwards between Delambre Island and Dixon Island, and also along Bouguer Passage. Given the design of the tug harbour/MOF and the causeway, this general pattern will be locally modified. The complexity of cyclone-associated flows means that it is not possible to confidently predict the coastal impacts of these effects.

7.2 Modification of waves

Given the prevailing wave regime, the presence of the proposed tug harbour and causeway has the potential to create significant changes in the wave climate experienced at Dixon Island, Bouguer Passage and No Name Bay.

Along the north coast of Dixon Island, exposure to waves from the eastern sector will be decreased so that waves reaching the shoreline and driving sediments westwards will be less frequent than at present. Exposure to waves from the western sector will be largely unchanged. Exposure to waves from the northern sector will be affected, such that some of these waves will be diffracted around the tip of the proposed tug harbour and may approach the north coast of Dixon Island at a smaller angle than at present, decreasing alongshore sediment transport. Overall, for waves alone, we would expect that any westward component of sand transport along the beaches of north Dixon Island would be decreased. Wave-driven erosion of these beaches is not likely to increase and indeed from a consideration of waves alone they may accumulate. Given that the turtle beach and other beaches to the west are perched beaches, if the sea bed between Dixon Island and the tug harbour deepens significantly, the potential for reduction in the beach volume is probably limited, although can't be entirely discounted.

For Bouguer Entrance, the wave regime would be significantly altered, such that the present exposure to waves from the north-east sector at high tide would be considerably reduced. This may increase the proportion of silt accumulated within the sediments there, especially along those parts of the passage's margins where tidal flows are also weak.

For No Name Bay, the structures effectively block north-westerly waves from entering the bay, lessening the wave energy reaching the beaches on the bay's eastern side. This is likely to enhance sediment accumulation within the southern portion of the bay, especially during the summer months.

7.3 Littoral drift interruption

The proposed causeway will provide a total barrier to alongshore littoral sediment transport, interrupting any exchange between the beaches to the east and west of Anketell Point. Presently, exchange across Anketell Point appears to occur occasionally at high water, but is probably not volumetrically significant. However, of greater significance is that the proposed causeway extends over 1500 m north of the present rocky promontory, and is liable to capture the sediments that would have otherwise been exchanged across the sea bed between No Name Bay and Bouguer Entrance.

As noted above, the changed wave climate may result in changes to the sediment transport regime at the beaches on the north side of Dixon Island. There may be exchanges of sediment between the north coast of Dixon Island and Anketell Point, but it isn't necessarily clear which way these might operate at present. Given the proposed design, the wave-driven component of transport might decrease, especially during cyclones. It is possible that, should cyclones occur which cause beaches to erode, this might decrease the rate of recovery of those beaches.

7.4 General changes to the sedimentary regime

In assessing coastal processes with a focus on potential environmental impacts of the proposed Terminal 2 facility, some issues have arisen which may have broader implications, especially the nature of sedimentation around the facility. There are likely to be a suite of general changes in sedimentation patterns (Figure 7.1):

- Sediments accumulate against both sides of the causeway, with a particular tendency to accumulate within the proposed tug harbour;
- A tendency for erosion at the narrow points between Dixon Island and the facility, with adjacent areas of accumulation; these changes may occur relatively rapidly;
- Deepening of a narrow tidal channel west of the facility into Bouguer Entrance; and
- Enhanced rates of sediment accumulation across Bouguer Passage generally, and likely most evident at its margins.

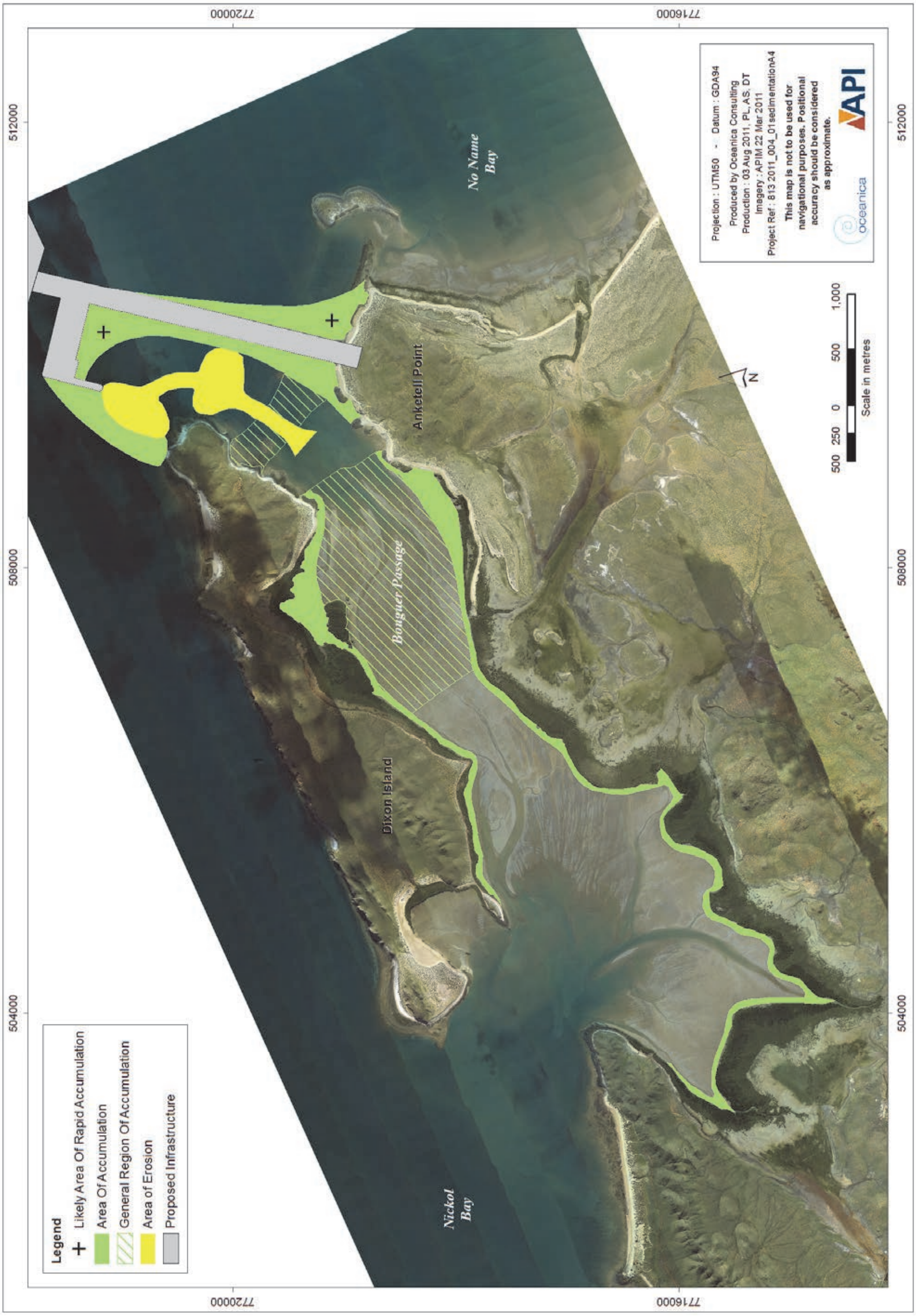

Figure 7.1 **Sedimentary changes predicted in the area associated with the proposed Terminal 2**

8. Impacts to Environmental Values

8.1 Marine turtles

The impacts on the turtle nesting beach from the proposed Terminal 2 Port layout are expected to be minor. The turtle beach may accrete as a result of the reduced wave-driven erosion and the relative reduction in westwards sand transport. No significant increased erosion is expected as a result of the development. A potential adverse impact to turtle nesting is that the nature of beach recovery after cyclonic erosion may change, because the presence of the causeway may alter the degree to which waves impact and are able to rebuild the beach; it is thus possible that beach recovery will be lagged (Figure 8.1).

8.1.1 Comparison to the Terminal 1 layout

The general nature of the impacts to the turtle beach from Terminal 1 and 2 are likely to be similar, but the closer proximity of Terminal 1 causeway suggests that the magnitude of impacts will be greater from the Terminal 1 layout.

8.2 Mangroves

The constriction of flow out of the Bouguer Entrance is expected to result in increased areas and rates of sediment accumulation in the passage. The sediments are expected to become slightly siltier, especially along the passage margins. Mangroves are known to grow in a wide range of substrates, and it is considered unlikely to be detrimental to the mangrove systems. Indeed, given that many of the mangroves along Bouguer Passage are in muddy substrates, there may be increased mangrove growth in these areas of sediment accumulation.

The sheltering of No Name Bay from the north-west by the causeway is likely to result in sediment accumulation in the south and east of the Bay. No adverse impacts on mangroves are expected.

8.2.1 Comparison to the Terminal 1 layout

The Terminal 1 option is expected to result in the relatively rapid accumulation of sandy beaches at both ends of the causeway, on its eastern and western sides. Sediment accumulation on the western side of the Terminal 1 causeway is likely to be more silty, and perhaps favourable for colonisation by mangroves. Accumulation of relatively silty sediments along the margins of the Bouguer Passage is also likely to be favourable to mangroves.

The Terminal 2 option has a broadly equivalent capacity to generate silty sediments along the margins of Bouguer Passage, but without the specific increased area of substrate near the causeway ends.

8.3 Benthic Habitats

Benthic habitats can be impacted by decreased light availability, increased turbidity and/or increased sediment accumulation. In waters east of Anketell Point, there are no significant increases in turbidity expected, except locally near the causeway as sediments accumulate. There is likely to be a slight reduction in wave energy and water flow from the north-west over the general area, and some minor changes in current speeds across the sea bed (APASA 2011), but this is not, in itself, expected to impact the health of benthic habitats.

However, permanent changes to adjacent benthic habitats may occur in association with the general changes in sedimentation patterns near the facility (Figure 7.1). It is likely that part of the rock platform east of Anketell Point will become overlain by a sand veneer (Figure 8.1), including those areas which support a coral community. Specifically, the physical barrier introduced by the causeway will result in accumulation of sandy sediment along the south-east margin of the causeway, including an area occupied by corals, east of Anketell Point. The bulk of this sediment will be derived from the sea bed north-east of Anketell Point. At present there is relatively little sediment accumulated along the edge of the rocky peninsula itself, but because the proposed causeway extends for a distance greater than 1,500 m north of the peninsula, it would block sediment transport at all stages of the tide and is liable to capture the sediments that would have otherwise been exchanged across the sea bed between No Name Bay and Bouguer Entrance. The precise rate and extent of likely accumulation against the causeway is unknown. However, preliminary borehole investigations "within 6 km of Anketell Point" (API 2010) indicate that the surface sediments are uncemented down to a depth of 5–7 m and contain an average of around 40% of fines, indicating that sediment supply is not likely to be a limiting factor upon sediment accumulation rate.

Given the capacity for sediment transport by fair-weather waves (Section 3.4) and episodically by cyclones, it is considered that accumulation along the causeway is likely to occur within several months to a few years rather than in decades. This change in sedimentation has the potential to smother some habitats and corals to the east of Anketell Point with a sandy veneer (Figure 8.1). This change is likely to be permanent and loss of coral habitat within the shaded area can be assumed.

8.3.1 Comparison to the Terminal 1 layout

The Terminal 1 option is not expected to have any major impacts on benthic habitats to the east of Anketell Point, but would have changed the sea bed to some extent near the tug harbour. The Terminal 2 option is likely to have a greater impact, on benthic habitats near the facility (through changed sedimentation patterns), and east of Anketell Point (due to the likely burial of a proportion of the area supporting corals).

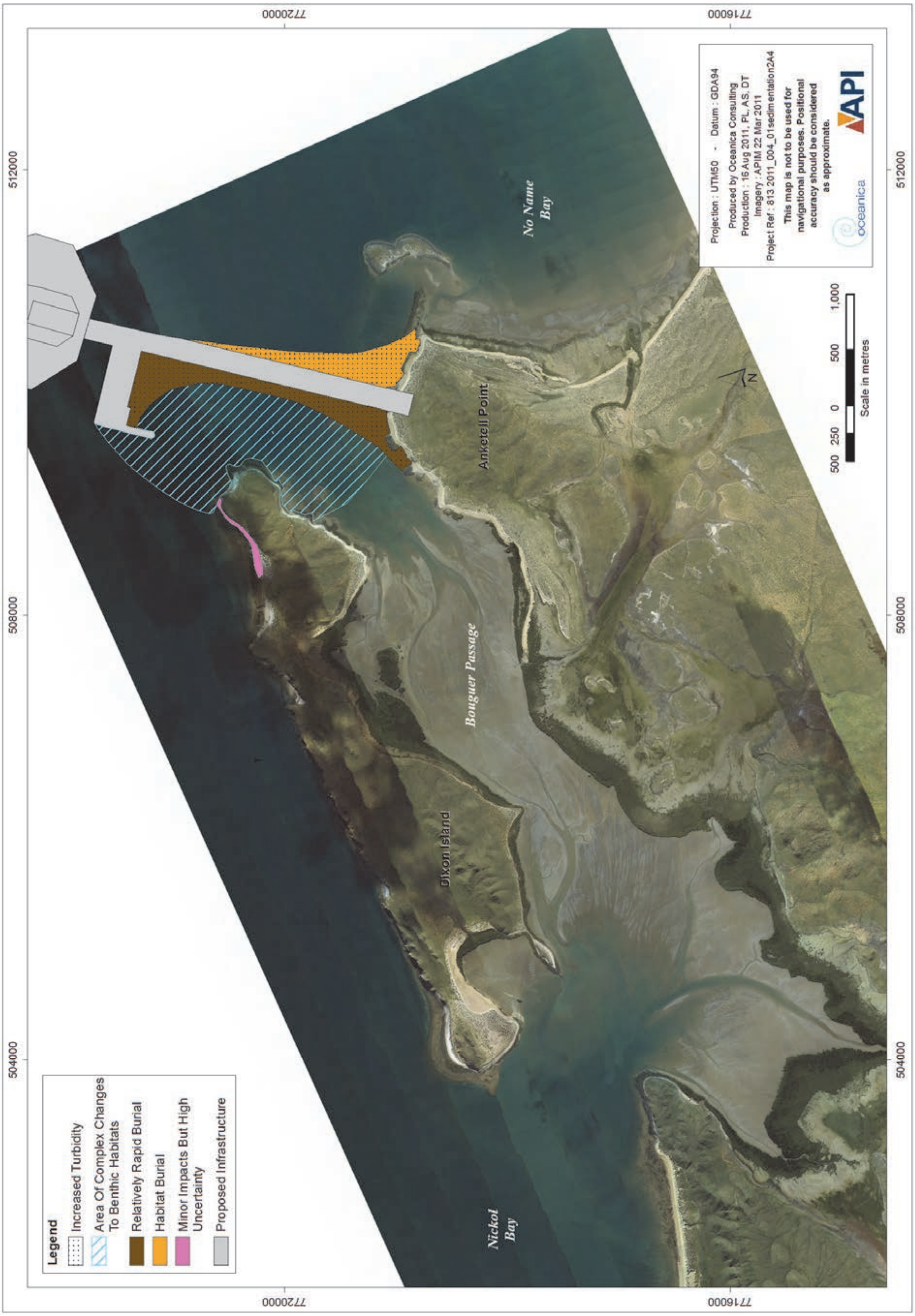

Figure 8.1 **Predicted impacts to environmental values in the area associated with the proposed Terminal 2**

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