5. Coastal Processes

5.1 Existing Coastal Environment

5.1.1 Bathymetry

Boathaven Bay is a shallow embayment fronting onto the broad open waters of Pioneer Bay. The majority of the seabed in Boathaven Bay is above the lowest astronomical tide and it is only near its confluence with Pioneer Bay that the seabed slopes gradually away into deeper water.

The seabed approach slopes to Boathaven Bay are approximately 1,400. These flat approach slopes, in conjunction with the surrounding land features of Pioneer Point and Bluff Point, provide natural protection and wave energy attenuation for the site; particularly during cyclones.

5.1.2 Coastal Sediments

Extensive sampling and testing of seabed sediments throughout Boathaven Bay was undertaken for the earlier Impact Assessment Study (WBM, 1998). That work indicated that the seabed consists of very fine silts and muds. Typically the average size of the individual particles (i.e. the D_{50} size) was between 0.010 mm and 0.025 mm.

Where Campbell Creek and other natural drainage paths enter Boathaven Bay, coarser material is evident on the seabed. However these are primarily sediments brought down into the Bay from the surrounding catchments by surface runoff. The relatively mild wave climate which prevails locally cannot readily distribute these deposits into the wider areas of Boathaven Bay and Pioneer Bay.

Despite the majority of the seabed sediments being very fine, tidal currents alone will not initiate any significant sediment movement or re-suspension off the seabed into the water above. It is the additional shear stresses induced on the seabed by wave action which are necessary to mobilise the seabed material.

Waves therefore lift the fine seabed sediments up off the bottom and into suspension, where they are then transported by the prevailing tidal currents. In more sheltered waters, these particles settle out of suspension. Consequently there tends to be a natural accumulation of fine material in areas sheltered from wave action. These areas will include the proposed sheltered marina basin and access channel. This accumulation of sediments can present problems with respect to safe and convenient navigation of these areas, requiring periodic maintenance dredging of the deposits to alleviate the problem.

In order to appreciate the scale and frequency of the maintenance dredging requirement, it is first necessary to understand and quantify the transportation and deposition processes associated with the fine sediments.

During the earlier IAS (WBM, 1998) some field measurements of suspended sediment concentrations were used in conjunction with computer modelling techniques to predict possible siltation effects. This required the correlation of likely sediment mobilisation and suspended concentrations with the prevailing sea and weather

conditions. The data collection exercise for that study was undertaken during little or no wave action when suspended sediment concentrations were low.

In order to extrapolate that data to more active wave conditions, it was therefore necessary at that time to estimate the suspended sediment concentrations primarily on the basis of theoretical assessments, supplemented by experience from other areas. However since that work, the results of sediment sampling for a previous coastal engineering investigation in Boathaven Bay (Riedel & Byrne Consulting Engineers, 1988) has been obtained.

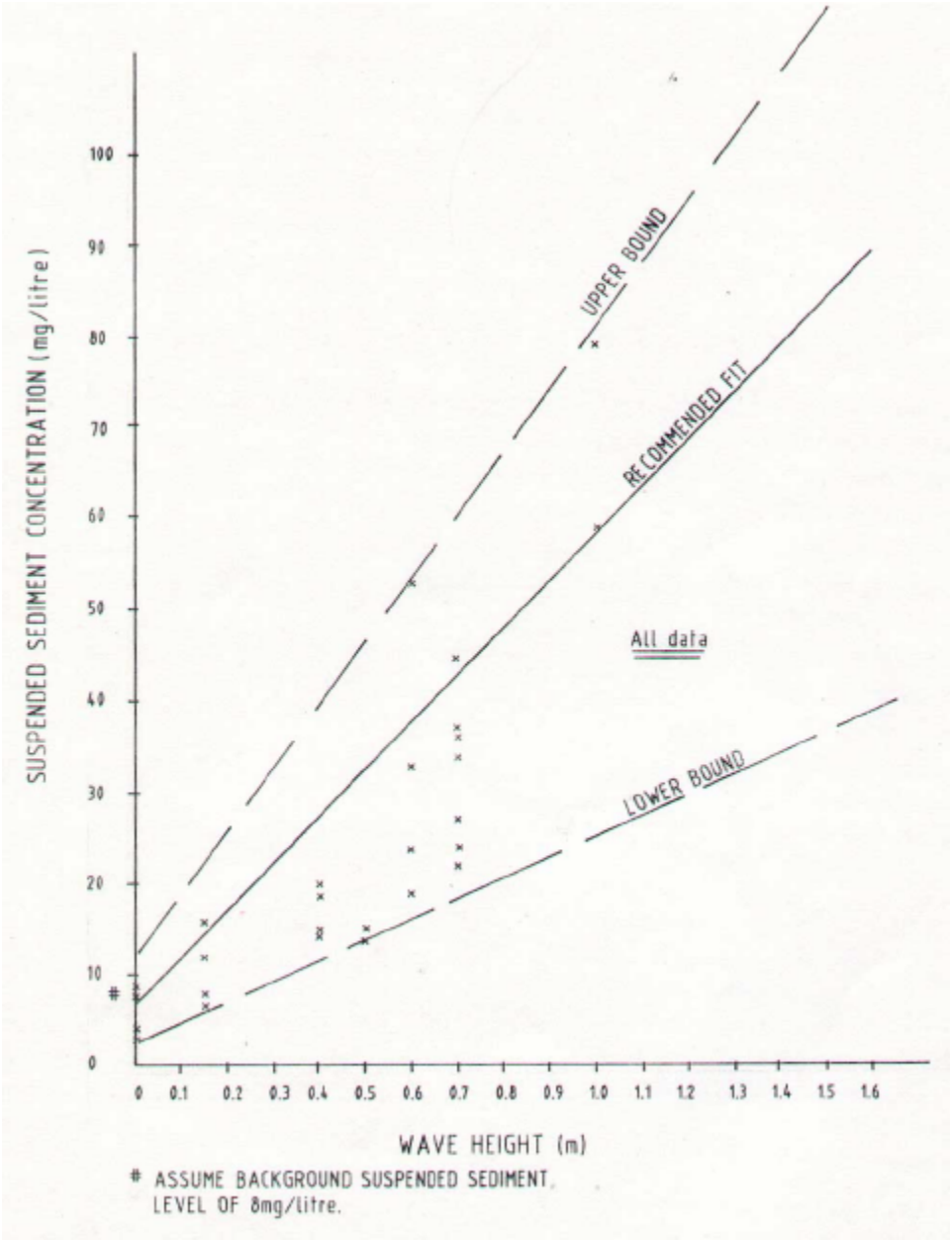
The Riedel & Byrne investigations obtained suspended sediment samples over a wide range of sea and weather conditions, in fact covering the likely range of conditions that can occur each year. Consequently this information represents a sound database of local suspended sediment characteristics and causative processes without the need to rely on information collected from other locations.

Data was obtained during Tropical Cyclone Charlie (March 1988). Due to safety concerns, sampling during the peak of the cyclone was not undertaken and the winds were 25 knots from the northeast at the time that the samples were taken. Nevertheless this sampling captured the strongest non-cyclone conditions that would occur normally in any year.

The results of the site specific sediment sampling is shown on the attached **Figure 5-1** (reproduced from Riedel & Byrne Consulting Engineers, 1988). It was noted that there was little difference in the concentration of suspended sediments throughout the depth of the water column. Typically the concentration near the surface was approximately 10% lower than that about 0.5 metres above the seabed. Consequently the data presented in **Figure 5-1** does not distinguish between sampling depths.

Some stratification in the suspended sediment concentrations was observed after heavy rainfall. This was a result of the runoff creating a freshwater lens on the surface of the Bay which contained concentrations of suspended sediment higher than in the receiving waters of Boathaven Bay. The fine material that is swept from the local catchments and brought into the Bay spreads within a thin layer of freshwater across the surface of the more dense seawater. This surface layer disperses quickly throughout and beyond the confines of Boathaven Bay.

Typically the concentration of suspended sediments was approximately 30 mg/litre in a freshwater layer estimated at 100 mm thickness. The annual rate of deposition from this source of sediment input is estimated at less than 0.5 mm. Consequently it is concluded that the sediment deposited by runoff from local catchments will have a negligible contribution to siltation within the waters of the proposed development.



■ **Figure 5-1 Suspended Sediment Rating Curve for Boathaven Bay**

(reproduced from Riedel & Byrne, 1988)

A background concentration of approximately 8 mg/litre was determined by the 1988 measurements. This compares well with those measured for the IAS (WBM, 1998).

5.1.3 Ocean Water Levels

As waves propagate shorewards into shallower water, they begin to “feel” the seabed. The decreasing depths cause the waves to shoal up until such time as they may break, dissipating their energy as they do so. The amount of wave energy reaching the shoreline is therefore determined by the depth of water over the seabed approaches. Consequently when planning and designing foreshore works, it is important to have an appreciation of the ocean water levels which occur from time to time.

This appreciation not only relates to the day-to-day tidal influences, but also to the storm surges which occur as a result of extreme weather conditions. The expected impacts of climate change also need to be accommodated in any new foreshore development.

Consequently it is necessary to consider the following phenomenon at Boathaven Bay:

- Astronomical Tide - which is the "normal" rising and falling of the oceans in response to the gravitational influences of the moon, sun and other astronomical bodies. These effects are predictable and consequently the astronomical tide levels can be forecast with confidence.
- Storm Tide - which is the combined action of the astronomical tide and any prevailing storm surge. Surge is the rise above normal water level as a consequence of surface wind stress and atmospheric pressure fluctuations induced by severe weather events (eg. cyclones).
- Climate change - which is the combined effect of environmental changes as a consequence of "Greenhouse" gas emissions into the atmosphere. One of these possible effects is an increase in ocean water levels.

Astronomical Tide

The tides at Airlie Beach are shown in **Table 5-1** below. This information has been derived from widely published information.

Table 5-1 Tidal Planes at Airlie Beach

Tidal Plane	to AHD (m)	to Chart Datum (m)
Highest Astronomical Tide	2.19	3.94
Mean High Water Springs	1.27	3.02
Mean High Water Neaps	0.61	2.36
Mean Sea Level	0.04	1.79
Mean Low Water Neaps	-0.53	1.22
Mean Low Water Springs	-1.19	0.56
Lowest Astronomical Tide	-1.75	0.00

The site has a maximum tidal range of 3.94 metres, with an average range during spring tides of 2.46 metres and 1.14 metres during neaps. Spring tides tend to be higher in mid-year (i.e. around June) and around the time of new year (i.e. December/January).

Storm Tide

The combination of astronomical tide and storm surge is known as storm tide. If the maximum surge should happen to coincide with a high spring tide, severe flooding of low lying coastal areas can occur and the upper sections of coastal structures can be subjected to the intense wave action.

A study of storm surge for Boathaven Bay was conducted previously (Riedel & Byrne Consulting Engineers, 1988) using a hydrodynamic mathematical model supplemented with Monte Carlo analyses so as to determine the recurrence intervals of various storm tide levels. The results of that earlier work is shown in **Table 5-2**.

■ **Table 5-2 Predicted Extreme Ocean Levels for Airlie Beach**

Average Recurrence Interval *(years)*	Storm Tide Level *(to AHD)*	Storm Tide Level *(to CD)*
50 years	2.5	4.2
100 years	2.6	4.3
250 years	2.8	4.5

These levels do not include the effects of wave set-up or wave run-up on the face of foreshore structures or natural slopes. An additional allowance of 0.2 metres is recommended for wave set-up. However, the level to which waves will run up a structure or natural foreshore depends significantly on the nature, slope and extent of the land boundary. Consequently this aspect needs to be considered separately during the design of each element of the foreshore protection system.

Climate Change

Climate change effects will cause environmental changes to ocean temperatures, rainfall, sea levels, wind speeds and storm systems. If climate changes develop as predicted, the foreshores of the Whitsunday Region will be subjected to potentially greater storm and cyclone activity, higher waves, stronger winds and increased water levels.

Of all potential impacts, only sea level has been quantified to the extent that some policy statements quote actual values. There are still significant uncertainties regarding predictions of the impact of climate change on sea level rise. At the present time, the best analytical data seems to suggest that the global mean sea-level could rise by about 30 cm (plus or minus approximately 20 cm) by 2050.

This recommendation by the *Intergovernmental Panel on Climate Change* (IPCC) was published in June 1996 and relates to average global sea level rise. More recent work by the Australian Bureau of Meteorology into regional (as opposed to global) fluctuations of sea level suggests that the predicted increases along the eastern seaboard of Australia are not significantly different to those predicted as global averages by the IPCC in 1996.

5.1.4 Hydrodynamic Processes

The earlier IAS (WBM, 1998) reported on a comprehensive computer modelling study of tidal currents. That model study also investigated the effects that winds might have on tidal circulation.

The model was calibrated against measured water levels and current speed and directions.

It was determined that tidal currents tend to flow directly into and out from Boathaven Bay at speeds typically no greater than approximately 0.15 m/sec. However under the influence of moderate south-easterly and north-easterly winds, the currents tend to set in a clockwise circulation in the Bay and strengthen to in excess of 0.2 m/sec. Nevertheless these currents are quite weak and are not sufficient to initiate significant movement of seabed sediments.

5.1.5 Wave Climate

The wave climate at Boathaven Bay is basically comprised of two quite distinct components, namely:

- an extreme climate (due to cyclone generated waves), and
- the ambient climate (i.e. those waves experienced on a "day-to-day" basis.

Extreme Wave Climate

An appreciation of the extreme wave conditions is necessary when considering the structural design of foreshore works.

The waves reaching the foreshores of Boathaven Bay are generated in the open water fetches between the mainland and the Great Barrier Reef. Previous studies of wave transformation in the waters of the Great Barrier Reef Marine Park have shown that there is negligible swell wave penetration of ocean swell from the Pacific Ocean to the north Queensland coastline.

Detailed investigations of the local wave climate have been documented in various previous studies associated with proposed developments and maritime works in the Airlie Beach region.

Those earlier wave studies determined the extreme wave heights and wave periods which can occur in the deep offshore waters of Whitsunday Passage due to a range of cyclone occurrences. These are summarised in **Table 5-3**. The wave periods have been appropriately adjusted to reflect peak periods (T_p) as is currently used in coastal engineering applications.

■ **Table 5-3 Extreme Wave Conditions in the Whitsunday Passage**

	Average Recurrence Interval		
	50 years	**100 years**	**500 years**
H_s *(metres)*	3.9	4.4	5.5
T_p *(secs)*	8.5	9.1	10.4

Those previous studies then proceeded to determine how such cyclone waves were transformed as they approach local foreshores, thereby computing design wave heights in the waters immediately offshore of Boathaven Bay. Such transformation occurs due to a complex combination of refraction, diffraction, seabed friction, shoaling and breaking.

The computed transformed wave characteristics are summarised in **Table 5-4** for a location near the proposed marina entrance, at the RL-1.0m depth contour (to Chart Datum).

■ **Table 5-4 Extreme Wave Conditions at Boathaven Bay**

	50 years	**100 years**	**500 years**
H_s *(metres)*	2.4	2.75	3.3
H_{max} *(metres)*	3.5	3.6	3.7
Tp (secs)	8.5	9.1	10.4
wave approach *(degrees)*	355° - 360°	356° - 360°	357° - 001°

The wave heights listed above as H_s are the "*significant wave heights*". This is a statistical term used to define the random nature of the sea state. The transmission of waves to the nearshore area is regulated by the water depth over the seabed approaches, consequently the maximum indicative wave height H_{max} which might arrive during the cyclonic sea state is also included.

The transformation of waves as they propagate from the deep water between the mainland and the Great Barrier Reef towards Pioneer Bay and into the Airlie Beach region has been investigated by Coastal Engineering Solutions during the design of the nearby Airlie Beach Lagoon precinct.

The reverse ray refraction model setup for that purpose has been used to determine the relationship between the offshore wave direction and the corresponding orientation of these waves as they arrive at a location near the head of the proposed breakwater. **Table 5-5** summarises this relationship.

■ **Table 5-5 Relationship Between Offshore & Inshore Wave Directions**

Offshore Wave Direction	Wave Period								
	2secs	3secs	4secs	5secs	6secs	7secs	8secs	9secs	10secs
310°	338 °	340 °	344°	347°	350°	352°	354°	356°	357°
320°	341 °	343°	345°	348°	351°	353°	355°	357°	358°
330°	344 °	345°	347°	350°	352°	354°	356°	358°	359°
340°	347 °	348°	350°	351°	353°	355°	357°	359°	360°
350°	350 °	351°	352°	353°	355°	356°	358°	359°	000°
360°	353 °	354°	354°	355°	356°	358°	359°	360°	000°
10°	356 °	357°	357°	357°	358°	359°	360°	001°	001°
20°	359 °	360°	359°	359°	359°	000°	001°	001°	001°
30°	002 °	002°	001°	001°	001°	002°	003°	003°	003°
40°	004 °	004°	003°	003°	004°	004°	004°	004°	004°

Of particular importance in the design of coastal structures is an understanding of the nature of the large design waves as they approach the foreshore. Calculations regarding the "Iribarren Number" for a location near the entrance to the marina, indicate that breaking waves will be spilling rather than plunging.

The wave forces produced by spilling breakers are similar to those of a non-breaking wave, with the rate of energy dissipation during breaking being gradual and milder than for plunging waves. This will have implications for the choice of criteria for the structural design of the proposed foreshore works in Boathaven Bay.

Ambient Wave Climate

An understanding of the day-to-day waves is required when considering such aspects as the design of new beach components, as well as when considering operational aspects of maritime facilities.

The ambient wave climate at Boathaven Bay is quite mild. This is due to its location on the southern shores of Pioneer Bay – where significant protection is afforded by the surrounding headlands. It is primarily the prevailing winds, which generate the ambient wave climate. The predominant regional winds come from the sector of northeast through to southeast. Boathaven Bay is sheltered significantly from these winds by the high topographical relief of Pioneer Point and Mandalay Point.

It is the waves generated by winds blowing across the open water fetches to the northwest, north and northeast of Boathaven Bay that primarily constitutes the ambient wave climate. As shown on the enclosed wind rose (reproduced from WBM, 1998) such northerly conditions occur for less than 25% of the time, and are typically associated with storm or cyclone events. This explains why there are frequently tranquil wave conditions in the Airlie Beach area.

The wave climate study completed by Riedel & Byrne in 1989 investigated ambient conditions by hindcasting waves for a year having sea and weather patterns typical of this region of the Whitsunday area, that year being 1975. A summary of the occurrence of wave heights for a location at the entrance to Boathaven Bay is presented in the **Table 5-6**. These ambient wave conditions do not include the effects of tropical cyclones.

■ **Table 5-6 Ambient Wave Height Occurrence at Entrance to Boathaven Bay**

Wave Height ***(metres)***	**% occurrence**
Calm	38.84
0.0 - 0.1	26.23
0.1 - 0.2	8.15
0.2 - 0.3	2.80
0.3 - 0.4	3.49
0.4 - 0.5	2.26
0.5 - 0.6	2.26
0.6 - 0.7	1.16
0.7 - 0.8	0.48
0.8 - 0.9	0.10
0.9 - 1.0	0.03
1.0 - 1.1	0.07
1.1 - 1.2	<0.01

5.1.6 Erosion Prone Area

The Queensland Beach Protection Authority has declared an Erosion Prone Area width of 55 metres (or to bedrock) along most of the foreshores of Boathaven Bay. An exception to this is the mangrove area at the mouth of Campbell Creek on the eastern shores of the Bay (opposite the proposed development) where a 400 metre wide Erosion Prone Area is nominated.

5.2 Maintenance Dredging

5.2.1 Siltation Rates

Figure 5-1 presents the sediment rating curve which correlates measured suspended sediment concentrations at the site and with the wave height prevailing at the time.

The frequency of occurrence of particular wave heights in the waters immediately offshore of Boathaven Bay is shown in **Table 5-6**.

These two aspects have been used to estimate the siltation rates in the confined waters of the proposed development. When doing so, some conservative assumptions have been made, namely:

- On each incoming tide, a volume of water equal to the tidal prism of the waterway enters the protected harbour and access channel. This water contains the suspended sediment concentration derived from the sediment rating curve of **Figure 5-1**.
- All of the suspended sediment in the tidal prism mixes with the water in the marina basin and entrance channel. Deposition occurs in this sheltered area during each tidal cycle such that the outgoing water carries only the background suspended sediment load of 8 mg/litre.

Given that the area of the marina basin is some 90,000 m^2, annual siltation is calculated as shown in **Table 5-7**.

Table 5-7 Annual Siltation Rates at Boathaven Bay Marina Basin

Wave Ht. range *metres*		incoming concentration *mg/l*	fully mixed concentration *mg/l*	excess concentration *mg/l*	occurrence of waves *%*	deposited per year *tonnes*
Calm		8.00	8.00	0.00	38.84	0.00
0.0	0.1	9.00	8.32	0.32	26.23	30.00
0.1	0.2	14.17	9.97	1.97	8.15	57.51
0.2	0.3	19.35	11.62	3.62	2.8	36.35
0.3	0.4	24.53	13.27	5.27	3.49	65.98
0.4	0.5	29.71	14.92	6.92	2.26	56.12
0.5	0.6	34.89	16.57	8.57	2.26	69.51
0.6	0.7	40.07	18.22	10.22	1.16	42.55
0.7	0.8	45.25	19.87	11.87	0.48	20.45
0.8	0.9	50.43	21.52	13.52	0.10	4.85
0.9	1.0	55.61	23.17	15.17	0.03	1.63
1.0	1.1	60.79	24.82	16.82	0.07	4.23
1.1	1.2	65.97	26.47	18.47	0.00	0.00
				Total weight deposited per year (tonnes)		*389.2*

This deposition of approximately 390 tonnes of fine sediments per year in the sheltered harbour area of the proposed marina is due primarily to the ambient wave climate rather than any changes induced by the proposed structure.

The sediment rating curve for Boathaven Bay (shown in **Figure 5-1**) does not extend into the wave conditions associated with cyclone conditions. Whilst this includes the effect of storms and strong wave action, it does not include the effects of cyclones. During these extreme events, the shear stress generated on the seabed is quite significant. Nevertheless even assuming that the 2.4 metre high waves arriving during the 50 year ARI cyclone event (refer **Table 5-4**) might initiate suspended sediment concentrations of around 200 mg/l, this equates to a deposition of approximately 30 tonnes of fine sediments for each tidal cycle during the peak of this severe cyclone event, less than 10% of the estimated annual deposition.

Given the build up and duration of the cyclone peak, it is conservatively estimated that the deposition during the total 50 year ARI cyclone event would be approximately 75 – 100 tonnes. In fact it could be much less due to the extreme turbulence in the water column during the cyclone inhibiting the deposition of suspended material,

thereby negating the already conservative assumption that all of the suspended sediment swept into the marina basin on the incoming tide will not be carried out on the ebb tide.

5.2.2 Frequency of Maintenance Dredging

As discussed above, it is conservatively estimated that approximately 390 tonnes of fine sediments will be deposited on the seabed within the confined waterways of the proposed development each year. A very severe cyclone may cause an additional 100 tonnes to be deposited during only a few days.

Assuming that the deposited material is laid down at an initial bulk density of 1.4tonnes/m^3, the calculated average annual siltation of 390 tonnes represents an average accretion of only some 3mm per year over the area of the marina basin. Actual depths of deposition will vary throughout the sheltered waters, with greater depths nearest the entrance and lesser depths further into the basin. An additional 1mm or less would be added during cyclones.

This estimated low rate of siltation is in accordance with the anecdotal experience of other sheltered marine facilities in the general area – namely the basins at the Abel Point Marina and the Whitsunday Sailing Club.

With initial over-dredging of say 0.5 metres, the buffer created will offset the need for maintenance dredging for a very considerable period. However the occurrence of cyclones will tend to reduce the effectiveness of this buffer.

5.3 Foreshore Protection Measures

The primary form of sea defence for the proposed development is the beach in front of the main breakwater. This is an appropriate foreshore protection mechanism since natural beach systems are particularly efficient at dissipating wave energy and will naturally rehabilitate themselves following extensive erosion. However it is important to design any new beach or beach nourishment in such a way that during severe cyclones the erosion does not compromise the infrastructure behind it.

The proposed arrangement for the beach/breakwater structure is to have a vertical sheet pile wall behind the beach as the “last line of defence”. Nevertheless the preliminary design for the beach has been prepared on the basis that during the 100 year ARI cyclone event the crest of the beach will not recede as far back as the structural wall. During subsequent detailed engineering design, this aspect could be reviewed and a more (or less) severe design event adopted. The selection of an appropriate Average Recurrence Interval for beach design would need to take account of the nature of any development on the breakwater itself.

In calculating the beach response to cyclone wave attack, the numerical model SBEACH has been applied. It is a dynamic computational model and therefore considers the transient nature of the beach profile adjustments. This system is used extensively throughout the world by the coastal engineering profession when investigating beach response to storm waves.

The physical characteristics of the sand in the beach itself play an important role in determining the response of the beach to erosion. When applying the SBEACH model, an average sand grain size (i.e. D_{50} value) of 1 mm has been adopted. This is typical of sand which has been provided on previous beach nourishment projects in the Whitsunday region.

The preliminary beach cross section is shown on **Figure 2-9**. This profile has been determined from consideration of the 100 year ARI storm tide level of RL+4.3 m (to Chart Datum) in conjunction with a 100 year ARI offshore wave event (with H_s = 2.75m and T_p = 9.1 seconds). This grouping of 100 year ARI coincident storm tide and wave events represents a situation well in excess of the 100 year ARI event – and is therefore a conservative scenario.

Figure 2-9 shows the buffer of sand necessary in the upper section of the beach profile to accommodate the recession of the beach. A 12 metre wide beach crest at a level of RL+5.25 m (to CD) would provide the necessary reservoir of sand to prevent recession of the beach back to the wall during the 100 year ARI cyclone event.

In addition to ensuring that the new beach cross section is adequate, it is important to ensure that the plan alignment of the beach is in equilibrium with the prevailing wave climate – both the extreme climate and the ambient climate. Otherwise the newly placed beach will be re-orientated by the incoming wave energy to a plan alignment which better represents the naturally preferred alignment.

The inshore wave climate at Boathaven Bay is dominated by waves having their peak spectral period between 4 seconds and 8 seconds. Wave periods outside of this range do occur, but they are either too infrequent (for periods greater than 8 seconds approximately) or of such limited influence that they would not strongly influence the equilibrium plan alignment of the new beach (for periods less than 4 seconds approximately).

Reference to the inshore wave angles listed in **Table 5.5** indicates that these dominant waves will arrive at the location of the new beach on bearings from approximately 344° to 004°.

The new beach should therefore be constructed on a plan alignment perpendicular to this preferred wave energy direction. An average incident wave alignment of 354° is considered appropriate for conceptual design – with the actual orientation to be determined by a detailed analysis of waves and longshore sediment transport during final engineering design. This preliminary alignment is shown on **Figure 1-1**.

The 10° fluctuations either side of this alignment are typical of what might happen on a natural beach in response to the changing seasonal sea conditions. However this aspect is essentially a design consideration and would be determined by a detailed wave and sediment transport study to be completed as part of the engineering design of the beach.

Given that the new beach will effectively be an isolated compartment, the plan fluctuations (in conjunction with changes to the cross section as a result of storm / cyclone activity) will need to be adequately contained by a “control structure”. This is

achieved by the spur breakwater at the end of the main breakwater. This feature acts to prevent sand moving eastward off the beach.

The crest level of the spur breakwater would be subject to confirmation during the engineering design process, nevertheless preliminary calculations suggest that this would be around RL+7.3 m (to CD).

Provided that the beach is designed and constructed in accordance with the detailed design specifications, experience in constructing breakwater beaches of this type indicates that this structure will remain stable without excessive loss of sand, even in storm events.

5.4 Potential Impacts on Coastal Environment

5.4.1 Sediment Processes and Maintenance Dredging

The movement of coastal sediments at the site is characterised by the fine sediments on the seabed being re-suspended by wave action and transported by the prevailing ocean currents. However it is the wave action which is the dominating mechanism for initiating sediment transport processes. The proposed development will not affect the wave climate in the outer regions of Boathaven Bay or on adjacent nearshore areas of Airlie Beach. Consequently the sediment processes in those areas will remain unaffected. In particular, turbid coral communities at Mandalay Point are not expected to be adversely affected.

The development will however shelter the inner section of Boathaven Bay from the action of waves - and to a lesser extent the tidal currents. This decreases the potential for re-suspension of the bed sediments in this region, but increases the potential for deposition. However, the extent of the deposition is minimal, being estimated at typically 3 mm per year on average. This can be managed by initially over-dredging the navigable waterways and adopting maintenance dredging as required. Given the low rates of siltation, such maintenance dredging deployments would be at very infrequent intervals, probably every 5 - 10 years.

The rate of siltation for the boat ramp will be essentially the same as for the rest of the marina and this has been factored into the maintenance dredging frequency.

Cyclone events are likely to contribute less than 25% (about 1 mm) of the annual sedimentation rate. Hence, cyclone events will not have a significant effect on the frequency of maintenance dredging.

The eastern and southern foreshores of Boathaven Bay are primarily mangrove fringed and rocky. The mild wave climate and benign tidal current regime on these currently sheltered foreshores results in very low rates of littoral transport. Given that the proposed development will provide further shelter, the local littoral processes on these foreshores will not be adversely affected by the proposed development.

It is not appropriate to compare maintenance dredging requirements for the proposed Port of Airlie Marina with other marinas or harbours as the coastal processes at different locations are unique.

5.4.2 Ocean Water Levels

The proposed development will not cause any changes to the frequency or severity of elevated ocean water levels as a consequence of storm tides. The frequency and the severity of storm tides are determined by regional meteorological phenomenon. The development itself will of course need to be designed to properly accommodate the anticipated extreme water levels.

The wave protection afforded by the development to the southern and south-eastern foreshores of Boathaven Bay will result in these areas experiencing lower wave set-up and wave run-up levels than at present. Therefore the extent of flooding in these areas during severe storm/cyclone events will be slightly reduced.

During the earlier IAS (WBM, 1998), extensive numerical modelling techniques defined the tidal regime in the waters of Boathaven Bay – for both the existing arrangement and for the then proposed development. That development involved a greater reclamation of Boathaven Bay and a greater constriction at its' confluence with Pioneer Bay than is now currently proposed.

That earlier modelling determined that there would be negligible impact on tide levels throughout Boathaven Bay, and no impact on the tidal characteristics of Campbell Creek. Given the reduced scale of the currently proposed development, it is appropriate to conclude that there will also be negligible impact on the tidal regime of Boathaven Bay and Campbell Creek for this smaller development.

Reference to **Table 5.2** indicates that ocean water levels can rise to RL+2.6 m (above AHD) during the 100 year ARI event. Consequently infrastructure associated with the development will need to accommodate such levels whilst still maintaining an appropriate freeboard and an allowance for climate change. This level of RL+2.6 m does not allow for wave set-up or wave runup effects. However the level to which waves will run up a structure or natural foreshore depends significantly on the nature, slope and extent of the land boundary. Consequently this aspect needs to be considered separately during the detailed engineering design of each element of the developed foreshore. Land and floor heights in response to these conditions are discussed in **Section 2.7.1.4**.

5.4.3 Hydrodynamic Processes

Again it is appropriate to draw on the findings of the detailed numerical modelling of the local hydrodynamic processes that was completed for the previously proposed marina development (WBM, 1998). That study determined that there was negligible impact on the structure of the ocean currents beyond the immediate area of the development, but some minor redistribution of currents within Boathaven Bay itself.

The redistribution of the Bay currents for that larger development was determined to result in a slight increase in currents along the eastern side of the Bay. However the increase was small and not above the threshold that would initiate re-suspension of the local seabed sediments.

Given that the currently proposed development is of a smaller scale than that earlier proposed, it is again appropriate to conclude that the effect on the local hydrodynamic processes would also be minimal. This conclusion is made after considering the nature of flows in Boathaven Bay and the surrounding area. Flows in Boathaven Bay

are largely tidally influenced with some additional influence from Campbells Creek and thus flows in and out of the bay are largely parallel to the north-south axis of the bay. Thus, a smaller development in the same location as the larger development originally modelled will have similar or lesser impact on overall flow patterns in the bay.

Some localised effects on flow patterns are expected, particular as the north-south tidal flows will shear slightly to flow in and out of the east facing harbour basin. However flows in mangrove systems adjacent to Campbell's Creek and other coastal ecosystems in Boathaven Bay will not be affected by changes in flow regimes. The exception to this is the strip of mangroves between the dredge spoil disposal area and Shute Harbour Road where circulation will be significantly inhibited by the dredge spoil disposal area. Channels will be created to allow tidal interchange in this area. This is discussed in more detail in **Section 2.7.1.5.**

Flushing efficiencies of Boathaven Bay are also not expected to be affected by the proposed marina and the effectiveness of diffusion of the discharge from Jubilee Pocket STP is not expected to be reduced.

5.4.4 Erosion Prone Area

The Queensland Government's Beach Protection Authority has designated a 55 metre Erosion Prone Area width along the foreshores of Boathaven Bay, except at the mouth of Campbell Creek where the width is defined as 400 metres. The permitting requirements for this are discussed in more detail in **Section 4.2.2.7**.

Given that the proposed development will not be adversely affecting the exposure of these foreshores to wave energy or to significant changes to local sediment transport processes, the width of the currently designated Erosion Prone Area will not be affected.

The Erosion Prone Area width at the location of the new beach / breakwater arrangement will depend upon the subsequent detailed design process, however it would likely extend inshore as far as the proposed buried sheet pile wall behind the beach.

The proposed marina development will not itself be subject to erosion. The land/water interface will either be:

- Armour rock
- Sandy beach (as described in **Section 2.7.1**)
- Sheet pile.

5.4.5 Natural Hazard Management

As with most of northern Australia, the marina is located in a cyclone prone area and it is necessary to develop management techniques to ensure that there is no risk to marina residents and users. Potential water levels due to storm events and storm surges are discussed in **Section 5.4.2** and **Section 2.7.1.4** describes the levels for various components of the development in response to this.

In addition to these safeguards, a Counter Disaster Plan will be developed for the project. It is envisaged that this will be incorporated into Whitsunday Shire Counter Disaster Plan (Whitsunday Shire Council, 2001). This Plan embodies all counter disaster arrangements as detailed under the provisions of the *State Counter Disaster*

Organisation Act 1975 as agreed to by the Whitsunday Shire Counter Disaster Committee. Specific Objectives of the Plan are:

a) to provide a coordinated response for all disasters within the Shire of Whitsunday;
b) to establish guidelines for the operation and liaison of all control authorities and support organisations in the event of a disaster within the Shire of Whitsunday;
c) to provide arrangements for the efficient coordination of local and external resources;
d) to regularly test, review and update the plan as required; and
e) to define activation arrangement

In addition to consultation with Whitsunday Shire Council, relevant emergency services and community stakeholders will be involved in development of the plan.

The Counter Disaster Plan will allow a coordinated response to cyclones and other severe weather conditions, in accordance with current best practice in this area.

The breakwater design will take into consideration realistic worst case scenario weather conditions and other hazards. Obviously, the risk of breakwater failure cannot be reduced to zero, however, it can be made extremely low by appropriate design. In the extremely unlikely event that the breakwater was to fail catastrophically, property and assets along the breakwater would probably be severely affected. Depending on the weather conditions at the time of failure, properties and assets inside the breakwater could also be at risk. Catastrophic failure would not occur without warning, if stabilisation works were unsuccessful in preventing failure, evacuation of the Port of Airlie would be possible.

A severe storm or cyclone during construction would expose the site to heavy rain and strong winds. Given that the excavation and reclamation activities are to take place within an area enclosed by sheet piles, and that sheet piles are to be sunk to depths suitable for the ultimate development, breach of the sheet piles is considered very unlikely and thus the risk to the environment is low. Delays to construction may occur due to the need to handle large volumes of water. In the event that a severe storm or cyclone occurs during dredging, there will be sufficient warning to cease dredging operations. Excavation, reclamation and dredging activities are to take place outside the usual cyclone season.

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