# Tanilba Bay Foreshore Erosion Management Plan

# Coastal Processes, Concept Design Options and Foreshore Stabilisation Strategy

**Prepared for:**

Port Stephens Council

**27 JUNE, 2012**

Port Stephens Council contracted the preparation of this document with financial assistance from the NSW Government through the Office of the Environment and Heritage. This document does not necessarily represent the opnions of the NSW Government or the Office of Environment and Heritage.

| | |
|---|---|
| Opportunity Name: | Tanilba Bay Foreshore Erosion Management Plan |
| Opportunity Number: | 30011040 |
| Report for: | Port Stephens Council |

## PREPARATION, REVIEW AND AUTHORISATION

| Revision # | Date | Prepared by | Reviewed by | Approved for Issue by |
|---|---|---|---|---|
| A | 28/10/2011 | Tak Nose / Andrew Symonds | Dan Messiter | Not for Issue (Preliminary Draft for client review only) |
| B | 3/11/2011 | Evan Watterson | Dan Messiter | Not issued |
| Final Draft | 07/05/2012 | Evan Watterson / Dan Messiter | Dan Messiter | Not for Issue (Final Draft for client review only) |
| Final | 27/06/2012 | Evan Watterson / Tak Nose | Dan Messiter | Dan Messiter |

## SMEC COMPANY DETAILS


| |
|---|
| **SMEC Australia** |
| **74 Hunter Street, Newcastle, NSW 2300** |

**Tel:** **02 4925 9600**

**Fax:** **02 4925 3888**

**Email:** **evan.watterson@smec.com**

www.smec.com

# Executive Summary

The Snowy Mountains Engineering Corporation (SMEC) was commissioned to undertake the *Tanilba Bay Foreshore Erosion Management Plan* on behalf of Port Stephens Council.

Tanilba Bay is located within the NSW Central Coast region, on the southern shore of the inner estuary of Port Stephens. Previous studies indicated that the foreshore had been subject to retreat over the last twenty years. Review of these studies and analysis of the most recent photogrammetric data suggest that foreshore recession rates of up to 0.4m / year over the 15 year period between 1993 and 2008. Adjacent to the Tilligerry Habitat State Reserve there is evidence that recently, greater recession rates have occurred. However, the limited temporal coverage of photogrammetry and uncertainties in the data due to dense vegetation cover at the site does not allow accurate quantitative assessment.

*Ad hoc* protection works have been implemented in an attempt to address ongoing recession. Whilst in some areas these measures have been relatively successful in arresting recession, the failure of some of the less adequate engineering designs or lack of consideration for adjacent areas have locally exacerbated recession rates. Furthermore the degradation of some of these failed measures significantly reduces public safety and amenity values.

The foreshore is a high value area offering recreational opportunities and visual amenity and as such, there is a large degree of community interest in the foreshore. Furthermore, the section of Tilligerry Habitat State Reserve within Tanilba Bay possesses significant environmental values.

The underlying cause of the foreshore erosion at Tanilba Bay is due to a number of factors:

- Seasonal variability in the predominant wave climate (wind generated waves).
- Changes in the sediment supply within the bay.
- Anthropogenic influences:
  - historical landfilling and dredging practices
  - changes to the littoral processes resulting from stormwater drains.
  - degradation of existing *Ad hoc* defences.
  - non uniform *Ad hoc* defences exacerbating erosion processes.

Based on the outcomes of coastal processes investigations, four concept options were developed to manage the erosion hazard along the Tanilba Bay foreshore. These options were developed and assessed with regard to relative economic, environmental and social impacts. This relative assessment and consequent consultation was aimed at assisting Council's decision making process to select the most feasible option considering available funding for the proposed works, priorities in preserving environmental values, enhancing recreational and visual amenity and accommodating Tanilba Bay community requirements.

A brief summary of the conceptual management options and associated indicative order of magnitude construction cost are as follows:

- **Option 1, Bay Wide Holistic Concept** - a comprehensive strategy that aims to address the erosion mechanisms affecting the entire Tanilba Bay foreshore. **($3M - $4.5M**)
- **Option 2, Bay Wide Budget Concept** - a strategy incorporating reduced, more economically efficient foreshore stabilisation measures than Option 1. **($2 - $3M**)

- **Option 3, Property and Critical Infrastructure Concept** - a strategy that is limited to providing erosion mitigation measures in the foreshore areas backed by residential properties and infrastructure. **($ 1M - $1.5M**)
- **Option 4, Priority Area Concept** - a strategy that is limited to providing erosion mitigation measures in the foreshore area identified in Council's briefing documents as the "Priority Area". **($0.65 - $1.0M**)

Following consultation and community feedback, significant budgetary constraints were indentified. Accordingly, a staged, low-cost foreshore stabilisation strategy, that revised the preferred management options to meet budgetary constraints, was proposed that incorporates:

- Stage 1 – detailed design and construction of a low cost sloped rock revetment seawall along Zone C (incorporating pockets of vegetated revetment and utilising existing structures where possible).
- Stage 2 – detailed design of an optimised sloped rock revetment seawall with incorporated pocket beaches along Zone D for later construction.
- Stage 3 - sand nourishment concepts plans for Zone E, to be developed further and implemented by Council, if and when an appropriate sand source becomes available.
- Stage 4 - foreshore stabilisation concepts for Zone F for future reference, detailed design and implementation by Council when funding is available.

Note: Foreshore Zones are indicated in **Figure 24 - Figure 27** in **Section 7 .**

A concept plan indicating overall staging and proposed foreshore access points for Stage 1 is provided in **Figure E1**.


**Figure E1** Concept staging plan

The implementation of the staged foreshore erosion management measures aims to reduce foreshore recession rates on a prioritised basis. This will be achieved through the consolidation of *ad hoc* and failed protection works (replaced by engineered designs) and further Bay-wide measures which give consideration to the local coastal processes and environmental and social values of the area.

# TABLE OF CONTENTS

**LIST OF FIGURES**

## LIST OF TABLES



## LIST OF APPENDICES

# 1 INTRODUCTION

The foreshore of Tanilba Bay has been eroding over a period of many years. Shoreline recession is currently threatening the foreshore reserve and high value ecological habitat in the eastern end of the bay. Various forms of *Ad hoc* erosion control works have been implemented over the past decades. These are now in various stages of disrepair and are generally not functioning effectively, and/or exacerbating erosion. Complete failure of these structures would result in accelerated erosion and degradation of amenity and public safety.

Tanilba Bay is exposed to a long wind fetch and is subject to high energy wind waves relative to the majority of the upper estuary shoreline. Locally generated wind waves have impacted the shoreline stability, causing localised erosion and the loss of riparian vegetation. Furthermore, local stormwater drains have also been found to affect sediment distribution and local shoreline stability.

The foreshore area is a high value recreational area offering amenity and as such, there is a large degree of community interest in the foreshore.

In response to the issues being experienced at Tanilba Bay, Port Stephens Council (Council) has determined to consider stabilisation of the foreshore. Council commissioned SMEC to undertake an assessment which is aimed at establishing a number of foreshore stabilisation options and ultimately providing a recommended design that is cost and environmental effective, locally appropriate and community endorsed.

This report presents the findings of investigations encompassing the definition of coastal processes and development of conceptual foreshore management options, consultation and development of a staged foreshore stabilisation strategy.

## 1.1 Study Area

Tanilba Bay is located 43km north of Newcastle on the southern shore of Port Stephens. Port Stephens is made up of an upper and lower estuary, with Tanilba Bay being located within the upper estuary (refer **Figure 1**). The upper estuary is located to the west of Soldiers Point, and is dominated by fluvial processes and characterised by wide mud flats, mangroves and salt marsh.

Tanilba Bay is small embayment that is wider (approximately 1.7 km wide at it longest point) than it is deep (approximately 0.6 km). The entrance to the embayment is 1.3 km wide between Sunrise Point (west) and Rookes Point (east). The bay is shallow with water depths less than 3m at low tide. The foreshore of the bay (from point to point) has a length of approximately 2.9 km.

The study area for this investigation incorporates the 2.75km length of Tanilba Bay foreshore that would, in a natural state, be generally comprised of unconsolidated material. The wider area of the upper Port Stephens estuary in included in the study area in so much that it impacts on the erosion on the Tanilba Bay foreshore.

More details on the study area are provided in **Section 3** .

## 1.2 Study Objectives

This report documents components of the development of the plan for which the main objectives are:

- Identification of areas most at risk from foreshore erosion.
- Provide a review of coastal processes with a view to identifying the likely causes of foreshore erosion and provide the design criteria required for detail design.
- Concept design options to address foreshore erosion.
- A list of recommended, prioritised, site specific management options that have been assessed against ‘triple bottom line’ criteria.
- Community and Agency consultation to demonstrate feasible foreshore management options to the wider community and gain concurrence from the Port Stephens / Myall Lakes Coastal Zone Management Committee (PSMLCZMC).
- Development of a feasible foreshore stabilisation strategy considering available funding.

Subsequent work for the proposed implementation of the adopted foreshore stabilisation strategy to provide:

- Detailed design documentation for stages considered for immediate implementation and construction cost estimate.
- Concepts design documentation plans for future stages.


**Figure 1** Locations of key areas within Port Stephens.

# 2 PREVIOUS STUDIES

Previous studies relating to coastal and estuarine processes in the Port Stephens Estuary have been reviewed. The most relevant information from the available reports is summarised below.

*Tanilba Bay Erosion Management Study (Willing Partners Geomarine, 1997)*

This report relates directly to the present study it is frequently referred to throughout this report. Notwithstanding this, a brief summary is provided below.

The Tanilba Bay Erosion Management Study provides an assessment of the cause of shoreline erosion within the bay as well as a plan to manage this issue. The assessment involved a review of existing data in order to describe the local coastal processes. A site inspection was also undertaken to assess the foreshore erosion.

The report documents localised erosion (in middle, western and eastern sectors of the bay) and the global (or bay-wide) erosion issues. Local erosion issues were found to be greatest in the middle sector and associated with a stormwater outlet. The recommended treatment was a flow barrier to reduce discharge velocities and blow-out of the beach berm during flood discharge events. Global erosion was identified as natural shoreline recession and no single option was proposed. A number of foreshore treatments were suggested. Beach nourishment was recommended as the preferred option.

*Port Stephens/Myall Lakes Estuary Processes Study (Manly Hydraulics Laboratory (MHL), 1999)*

The estuary processes study was aimed at providing a 'first cut' understanding of Port Stephens/Myall Lakes estuary that would provide a benchmark for future management and appropriate planning and monitoring of the system. The study covered all aspects of the estuaries characteristics including ecology, coastal processes, catchment hydrology and land uses, water quality, estuary sediments, circulation and shoreline processes.

In relation to shoreline processes MHL noted that:

> *Foreshore recession has occurred historically along the sandy shorelines within Port Stephens. This erosion has mainly resulted from natural processes of beach realignment and fluctuations in response to winds, waves and currents. Changes to unconsolidated shorelines area natural process and have been undergoing over geological timeframes. Frequently, these changes are perceived as problems when development is located too close to the foreshore or within the zone of fluctuation of shoreline processes. No change to the coastal processes resulting in increases to rates of foreshore has occurred.*

At Tanilba Bay, MHL also noted the recession encroaching into the Tilligerry Habitat affecting the sensitive vegetation along the shoreline and the wetland behind the shore.

*Umwelt Management Plans*

Two recent management plans have been produced to guide estuary wide planning. These documents include:

- *Living on the Edge – A Foreshore Management Plan for Port Stephens* (Umwelt, 2009)
- *Port Stephens/Myall Lake Management Plan* (Umwelt, 2000)

These reports provide a planning framework to guide the use and development of the estuary and its surroundings to ensure that the environment, recreational, aesthetic, economic and cultural values are protected and enhanced.

In these reports the main issues noted for the Tanilba Bay areas were:

- The area is subject to relatively high energy wind waves which has affected shoreline stability and has cause the loss of riparian vegetation and is threatening koala habitat.
- The local stormwater drains are thought to affect shoreline stability and cause water quality concerns.
- Water of the inner estuary is frequently turbid as a result of both the re-suspension of fine grained sediments by wind waves as well as the effects of discharges from the Karuah River catchment during periods of wet weather.
- There are large areas of seagrass off Tanilba Bay.

The primary concern was shoreline recession at Tanilba Bay and the effects this has on the riparian vegetation, recreational amenity and the Koala habitat on the foreshore. The actions recommended to address this issue were to review and implement priority actions of the Tanilba shoreline erosion plan and to undertake a riparian vegetation assessment for the foreshore management plan.

# 3 FORESHORE ZONES AND ISSUES

A site inspection was undertaken by SMEC consultants, representatives of Council and local residents on 27 May 2011. The main objectives of this site visit/inception meeting were:

- Study team to gain on site understanding of the foreshore environment and relevant coastal processes
- Gain a better understanding of the issues and priorities along the Tanilba Bay foreshore from Council and local residents who are familiar with local area
- Insight into the historical changes (e.g. anecdotal accounts of storm conditions and damage)

A further site visit was conducted by SMEC personnel on 19 October 2011 to ground truth the location of foreshore structures and observe conditions during low tide. Observations and insights gained through site visits, including a selection of site visit photographs, are provided below for each of the foreshore zones defined below.

## 3.1 Foreshore Zones

Based on the natural and anthropogenic features the study area has been divided into 6 zones. These zones are used to delineate between significant features. It is proposed these zones form the basis of prioritising management options (see **Section 7** ).

**Figure 2** provides the proposed zones. Based on site visits, previous reports, aerial photography and other information the general environment and foreshore issues in each zone is discussed below.

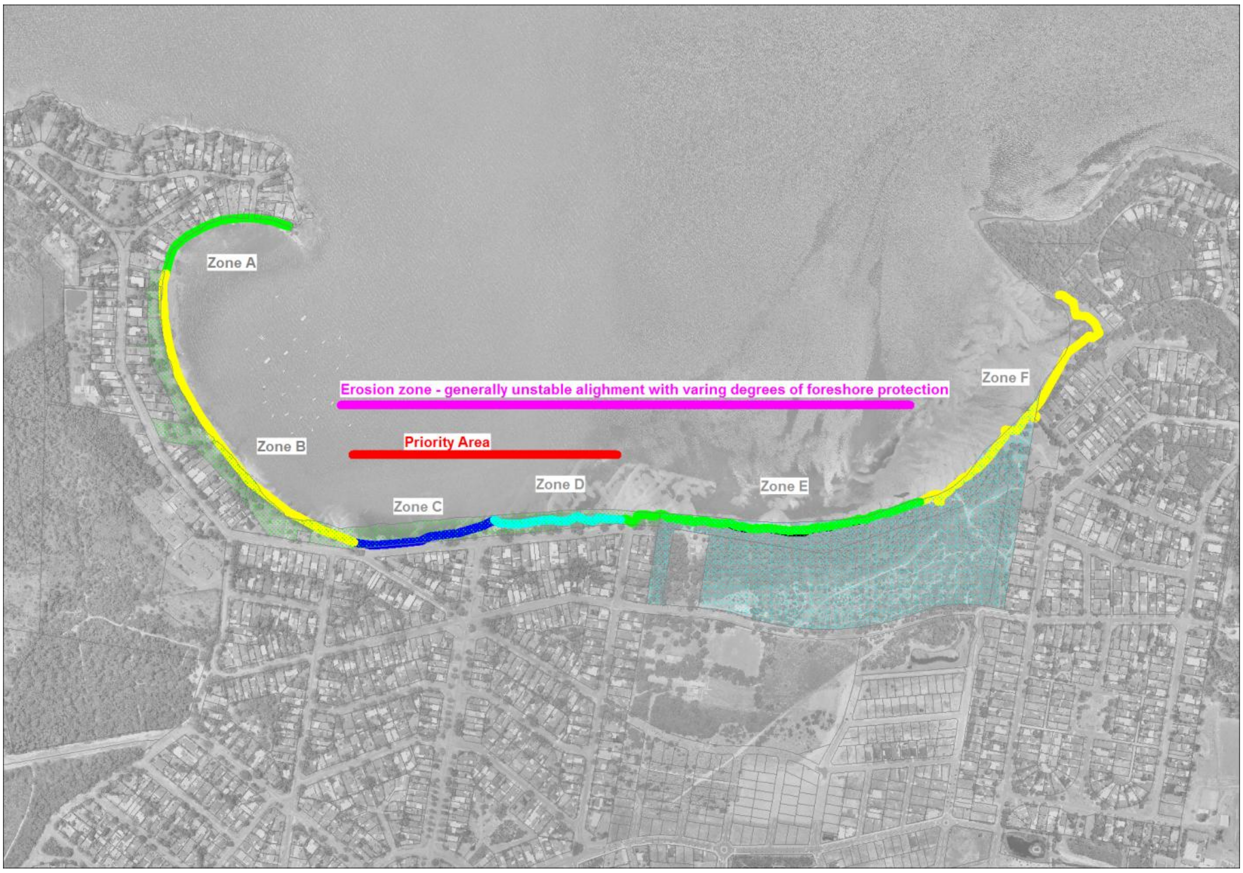



**Figure 2** Proposed foreshore management zones for Tanilba Bay

## *Zone A*

Extending from Sunrise Park to Tanilba Bay Foreshore Reserve, Zone A is mainly occupied by privately owned water front properties. The foreshore is composed of vertical seawalls punctuated by boat ramps that have been built by land owners.

Located in the north east corner of the bay the area is well protected from waves. The intertidal zone appears flatter, muddy and is largely covered by *Zostera* (seagrass) beds. It is observed that beach sand is not evident in front of the vertical seawalls.

Willing and Partners (1997) noted that the lack of sand was likely due to reflected wave energy from the vertical seawalls creating a system of short crested waves that makes sediment pass quickly from in front of the seawalls.

The end of Zone A is defined by both the last residential lot with direct water frontage (and vertical seawall) and by the beginning of the sand beach that forms Zone B.

Photographs 1 and 2 illustrate the conditions observed in Zone A.



## *Zone B*

A sandy beach characterises Zone B, the section of foreshore that fronts a series of parks (Swan Park, Tanilba Park and Forster Park – here referred to collectively as Tanilba Bay Foreshore Reserve).

The beach faces north east and is exposed a 7.5 km fetch to the north east. The beach is free from any significant natural or anthropogenic obstruction to littoral processes. There are a number of small drainage lines, in a quasi-natural condition, that discharge to the bay via the beach. The most significant of these creates an area of modified beach with beach sediments redistributed into a fan (or delta) on the lower beach profile.

The beach is backed by a grassed verge and a low-lying foreshore reserve with mature trees and recreational amenities. A public boat ramp transects the beach at Forster Park. Residential property boundaries are a minimum of approximately 30 meters from the back of the beach (i.e. the grass verge).

Willing and Partners (1997) did not recommend any treatment be applied to this section of the foreshore. The end of Zone B is defined by the area of disturbance created by the large stormwater outlet.

Photographs 3 and 4 illustrate the conditions observed in Zone B.



The stormwater outlet at the end of President Poincare Parade discharges directly to the beach at eastern end of Zone B.  The stormwater outlet consists of three barrel with wing walls (see Photo 5).  It drains a small residential catchment.  A persistent delta has formed from the beach sediment redistributed by the outlet.  At low tide, stormwater discharged cuts approximately 80 m width of beach.  Sand is likely to have smothered a small section of *Posidonia* seagrass beds.  It is also possible that sand is likely to have been transported beyond the depth of closure where the alongshore sediment transport typically occurs.

The grassed verge either side of the stormwater outlet structure is being undercut and eroded by wave action.  Evidence was observed that wave run-up had recently overtopped the grass verge in this location.

Willing and Partners (1997) recommend that a timber flow barrier be constructed around this outlet to redistribute the single jet flow and reduce discharge velocities.  However, priority was given to the stormwater drain further to the east, as discussed below.

The stormwater outlet at the eastern extremity of Zone B is effectively the beginning of Council's nominated "Priority Area" where foreshore erosion issues have been identified as urgently needing to be addressed.  The end of Council's approximate 600m "Priority Area" is a second stormwater outlet at the end of Zone D.

Photographs 5 and 6 illustrate the conditions observed at, and adjacent to the stormwater outlet at the eastern end of Zone B.


*Zone C*

Between President Poincare Parade and Avenue of the Allies, Zone C is characterised by various *Ad hoc* foreshore protection in various states of disrepair. There is very little sand on the beach and erosion along unprotected sections is observed into terrestrial material.

Willing and Partners stated that the issues relating to erosion along this section had existed for a long time before their 1997 report. Prior to that time various attempts by locals to control the problem by short rock groynes had not succeeded.

It appears that the various foreshore protection measures currently observed in Zone C have been constructed in a piece meal fashion and are not connected.

From west to east the condition of the foreshore is as follows:

- Unprotected section with very little beach undergoing back beach erosion into terrestrial soils (approximately 30m in length)

- Constructed pebble beach section (approximately 35 m in length) that has been effective in protecting a stand of trees (see Photo 7). Nearby signage suggests that this project was funded by a NSW Environment Trust grant and Council. Introduced rock material has been lost to surrounding nearshore area and this section is in need of maintenance/upgrade if existing trees are to be afforded ongoing protection.

- Largely unprotected section, erosion appears to be increase due to ineffective erosion control measures (approximately 95 m in length). Back beach erosion is into terrestrial soil and would not be providing sand size material to the system.

- Vertical seawall constructed from car tyres, concrete, steel, bricks and blocks (approximately 95 m in length). Appears to have been placed to save a stand of mature trees. Site visit Photo 9 and inspection of historical aerial photographs indicate that four mature trees that were behind this seawall in 25 November 2010 were not present on the 9 April 2011. A significant storm event on the 1 March 2011 (mentioned in the study brief) may have caused the loss of these trees. A single foreshore tree that remains at the end of the *ad hoc* vertical seawall, currently has its roots exposed where the wall has collapsed and would not be expected to last much longer (Photo 9).

- Approximately vertical seawall/revetment constructed of large rocks (approximately 85 m in length). This section of seawall is placed either side of a popular public boat ramp. This seawall appear to be recently constructed and in reasonable condition. However, the rocks are oversized and near vertical in nature. Without any underlayer of filter rock and failure of the geotextile fabric, material being washed out from behind the structure is evident compromising the wall's effectiveness and long term stability. The end of Zone C is defined by the termination of this rock wall (Photo 12).

The foreshore reserve in this zone is a popular section of Tanilba Bay and various beach amenities are provided. The reserve along this section is backed by Peace Parade before residential houses.

One of the main issues along this section of foreshore for residence is the loss of amenity and the compromise of public safety due failing non engineered protection works and associated debris on the foreshore. Access to the bay is limited as a result.

Willing and Partners (1997) recommended that this area be nourished with sand of appropriate size. A second layer of defence was recommended in the form of dumped rocks laid at an appropriate slope.

Photographs 7 to 12 illustrate the conditions observed in Zone C.


Photo 7


Photo 8


Photo 9


Photo 10


Photo 11


Photo 12

*<u>Zone D</u>*

Between Avenue of the Allies and President Wilson Walk, Zone D while in a badly eroded state is currently in better condition than Zone C. Similar to Zone C there is back beach erosion and undercutting of the bank and riparian vegetation (Photo 13). However, there is more sand on the beach profile in Zone D (Photo 14). Rubble, dumped rocks and failed timber groynes observed on the beaches provides evidence of failed and ineffective foreshore protection that is likely to be compounding natural shoreline recession (Photo 15). Isolated dump rock protection around foreshore trees has generally been unsuccessful (Photo 16). A number of dead trees were observed along the foreshore with some still resting in the nearshore area. A number of indicators observed suggested easterly directed alongshore drift at the time of the site visit, possibly seasonal.

The eastern end of Zone D is delineated by the relatively large stormwater outlet located in the middle section of Tanilba Bay. As mentioned above, this also delineates the eastern end of Councils “Priority Area”.

As with Zone C, Willing and Partners (1997) recommended that this area be nourished with dumped rocks forming a secondary defence.

Photographs 13 to 16 illustrate the conditions observed in Zone D.


Photo 13


Photo 14


Photo 15


Photo 16

The zone between Zone D and Zone E is defined by a rock revetment that appears to be in good condition. This rock revetment extends approximately 200m east from the stormwater outlet at the end of President Wilson Walk.

In the past the stormwater outlet within this area has been source of concern. Willing and Partners (1997) stated that a storm in November 1994 caused a ‘huge bite’, approximately 10 to 20 m wide and 7 m deep appeared in the bank west of the pipe. This storm damage was treated by the Tilligerry Habitat Committee (backed by Council) by filling the hole with sand and treating the banks to form a narrower channel and capping with tyres and geotextile. By the time of the Willing and Partners consultants site visit in 1996 the foreshore had dramatically improved.

The stormwater outlet is now rock-lined and a velocity dissipation structure in the form of gabion mattress has been installed (Photographs 17 and 18). Directly to the east informal protection in the form of dumped rock is present but is offering only limited foreshore protection (Photo 19).

Apart from the small section adjacent to the stormwater outlet, the majority of this area east of the outlet, has a good quality graded rock revetment constructed of appropriately sized rocks (Photo 20). This project was implemented around 2000/01 when grant funds to rehabilitate foreshore erosion and prevent further erosion became available. The revetment protects a small portion (western extremity) of the high value wetland and forest that provides koala habitat. This habitat area is comprised of Peace Park (Council owned foreshore land) and is backed by the Tilligerry Habitat State Reserve. The area is small but contains high value habitat such as, Swamp Oak Rushland Forest and Swamp Mahogany Paperbark Forest. A timber foreshore track is located along sections of this zone. A boat ramp is integrated into the revetment.

Historical evidence indicates that this section had experienced ongoing erosion and storm damage prior to the construction of the revetment. Erosion of the shoreline and salt water inundation threatened the whole swamp community. In response Council and the then NSW Department of Public Works renourished this section in 1994 (Willing and Partners, 1997). This nourishment was undertaken by *'pushing large quantities of sand off the tidal flats'*. At the time it was estimated that 25% of the placed sand had been washed away. This would seem to explain the two holes that appear in the intertidal in this area between 1992 and 1999 (see **Section 3.2.4** ). Willing and Partners subsequent (1996) observations of a healthy beach profile were taken as evidence that beach nourishment had been a successful, one of the main reasons it was recommended to address global (bay-wide) erosion issues. However, the 2000/2001 revetment construction indicates that erosion issues continued.

While details of the 2000/2001 revetment construction are not clear it would appear from examination of historical aerials that material used to renourishment the profile before 'capping' with rock was again borrowed from the western 'scrape' hole in the intertidal zone. The reasoning is that imagery from 1989 and 1999 showed a smaller borrow hole than in post 2001 images. Rough estimates place the total for this western borrow hole at around 1,000$m^3$ in total.

The two borrow holes appear have been colonised by seagrasses and are thus easily distinguished in aerial images. The apparent lack of change in the size and shape of these borrow holes in aerial images would suggest very little infilling has occurred.

Willing and Partners (1997) did not recommend any immediate actions for this area other than monitoring the success of the nourishment works already undertaken and emergency works should the need arise following storm damage.

Photographs 17 to 20 illustrate the conditions observed in the area between Zone D and Zone E.


Photo 17


Photo 18


Photo 19


Photo 20

*Zone E*

Zone E is defined by an eroding section of beach fronting the remainder of the ecological important habitat of Tilligerry Habitat State Reserve.  There is typically a sandy beach profile that is backed by natural vegetation (Swamp Oak Rushland Forest).  Significant back beach erosion was observed with undercutting of bank vegetation (Photo 21).  The area is susceptible to storm erosion and loss of trees during strong north westerly wind events (as occurred on the 1 March 2011).  Multiple dead and uprooted mature trees were observed during the site visit (Photographs 22 and 23).  Older weathered logs were evidence of the longer term erosion.

The existence of large trees lying at right angles to the beach and net easterly longshore sediment drift has exacerbated downdrift erosion (to the east) by limiting sediment bypassing. The timber foreshore boardwalk is located very close to the current shoreline along this section and it is at threat from the ongoing erosion.  At one location it is on the beach face (Photo 24).

In the eastern portion of Zone E, the foreshore aligns more to face the west (prevailing wave conditions).  Accordingly, erosion issues are less prevalent.  The Chorus Creek entrance in the east of the Zone is an area of amply beach sand of gradual slope with evidence of foreshore progradation due to deposition of sand from the western portion of Zone E (Photo 25). However, an offshore delta of indicates that during period of high rainfall sediment is scoured from the entrance compartment and deposited on the low tide terrace.  This sediment is lost from the nearshore area due to the lack of restoring mechanism (e.g. low swell wave energy).

A viewing platform is provided to the east of the creeks entrance (Photo 26).  East of the creek entrance, an indented shoreline position, fallen trees and weathered logs indicate historical recession due to natural erosion effects downdrift of a creek entrance and delta (Photo 26). The eastern end of Zone E is delineated by the boat ramp structure in Caswell Reserve.

Photographs 21 to 26 illustrate the conditions observed in Zone E.







*Zone F*

Extending from the boat ramp structure in Caswell Reserve to Rookes Point, Zone F covers the eastern most section of the bay. The foreshore is indented east of the boat ramp structure in Caswell Reserve due to shoreline recession downdrift of a hard structure. Similarly, the foreshore is further indented downdrift of the creek entrance in Caswell Reserve. Sediment character in this Zone becomes more estuarine in character and there is reduced longshore sediment transport of beach sized sediment at the foreshore.

Natural occurring erosion in the back beach area due to high energy wind waves occurring at elevated water levels during less frequent events is evident.  Residential properties front the foreshore reserve in the eastern portion of Zone F.  The foreshore adjacent to the majority of these properties has a reasonable back beach escarpment due to exacerbation of the erosion mechanism described above through historical vegetation clearing practices (the foreshore is generally a grass verge).  However, erosion in this zone is generally not significant.

Adjacent to some of these properties *ad hoc* foreshore protection measures have been put in place. (Photo 27).

Photographs 27 and 28 illustrate the conditions observed in Zone F.


## 3.2 Anthropogenic Features

In the assessment of coastal processes and management options, it is important to consider how the built anthropogenic environment impacts on the natural processes. Tanilba Bay has a number of these impacts which have affected the shoreline processes and contributed to the erosion of the foreshore. The most significant anthropogenic impacts present at Tanilba Bay are generally described below and summarise graphically in **Figure 3**.


**Figure 3** Tanilba Bay Anthropogenic Developments

### 3.2.1 Stormwater Discharge

The locations of the stormwater drains/natural outlets (creeks) are shown in **Figure 3**. As discussed above the larger stormwater outlets are associated with small deltas. Increased urbanisation in the catchment area is associated with increased rainfall runoff, peak flows and sediment loads and would have impacted on the formation of these deltas. These deltas represent a local instability to longshore transport, hindering, but not always preventing the longshore drift of sediment along the foreshore.

### 3.2.2 Hard Structures on Foreshore

Tanilba Bay has a number of constructed seawalls, many of these are not designed or constructed to accepted coastal engineering standards. Many are rigid vertical structures, current engineering and environmental standards do not favour these types of structures for a number of reasons:

- They restrict access across the foreshore and can pose a risk to public safety;
- They reflect wave energy, often causing the erosion and disappearance of the beach in front of the wall
- They can induce erosion on adjacent unprotected areas (and erosion around the ends of a seawall can lead to their collapse)
- Scour at the base of a seawall can result in its catastrophic failure
- They remove the natural intertidal habitat

- *Ad hoc* design, placement and materials can detract from visual amenity and may cause pollution of the adjacent estuarine waters

Existence of hard structures on sandy foreshores typically has significant impacts on local coastal processes.

### 3.2.3 Removal of Foreshore Vegetation

An adequately vegetated back beach and dune system with native plant species is one of the most effective and natural mitigation measures in the prevention of foreshore erosion (particularly in relatively low wave energy inshore waterways). The removal of native foreshore vegetation through anthropogenic influences since colonisation would have contributed to the existing eroded state of the Tanilba Bay foreshore.

### 3.2.4 Historical Land Filling Practices

The historical development of the foreshore area may have involved a degree of filling/levelling of some areas. Anecdotal evidence thorough discussions with long term local resident suggest that this may have been the case for the foreshore and adjacent landward areas at Tanilba Bay. Disturbance to the natural foreshore profile in this manner would lead to ongoing natural processes trying to restore the pre development condition through erosion.

### 3.2.5 Beach Scraping Borrow Sites

The borrow holes in the intertidal area offshore of Zones E (shown in yellow circle, refer to **Figure 3**) may have the impact of allowing greater wave energy to propagate to the foreshore, causing significant impacts to localised coastal processes. Detailed examination of historical aerial imagery and site inspection photographs revealed a large number of fallen trees and exposed tree roots immediately and to the lee side (with respect to the prevalent wave direction exposure) of the borrow holes. Furthermore, the most recent available aerial imagery of this area depicted that there is a significant increase in beach sediment accretion adjacent to the creek entrance to the east (down drift). This is evidence of an acceleration of longshore sediment transport adjacent to the holes. Accordingly, there is a localised exacerbation of the erosion hazard in this area of the foreshore.

# 4 METOCEAN DATA

Relevant existing metocean (meteorological and oceanographic) data collected in the Tanilba Bay area was utilised in this study to develop an understanding of coastal processes in the area and allow development of a conceptual coastal processes model. Analysis and interpretation of the existing metocean data assists in determination of key design parameters and an understanding of the effectiveness and impacts of foreshore stabilisation works.

A brief discussion on these data sets is provided in this section.

## 4.1 Wave Data

There is no measured wave data available within the inner estuary. However, numerous previous investigations have found that the wave climate within the inner estuary of Port Stephens is generated by the local wind climate with no offshore swell penetrating beyond Soldiers Point. As the waves are caused by the local winds, confidence in the numerical modelling of the waves is high despite the lack of calibration data as these wave processes can be accurately represented.

## 4.2 Wind Data

Wind data was sourced from the Bureau of Meteorology (BoM) for the station with long term wind records closest to the site. The closest station (61078) was located at Williamtown airport (E390998.5, N6371038.8: Zone 56), approximately 17km to the WSW of Tanilba Bay. Both locations also have a similar coastal exposure, being approximately the same distance from the coastline. Accordingly, wind data recorded at Williamtown Airport is considered similar to Tanilba Bay.

Approximately 22 years of wind data was provided from 01/01/1989 to 02/06/2011, with wind speed (km/hr) (10 minute averages) and wind direction (degrees) recorded at a range of temporal resolutions from half hourly to hourly. There were a number of data gaps in the wind dataset which have had to be excluded from the assessment; these are shown in **Table 1**.

**Table 1** Periods of no wind data excluded from wave modelling

| Wind Data Gap | | Duration (days) |
|---|---|---|
| Start Date | End Date | |
| 07/01/1997 | 03/02/1997 | 27 |
| 25/02/1997 | 11/03/1997 | 14 |
| 27/12/1997 | 18/01/1998 | 22 |

## 4.3 Water Levels

Tidal planes at Port Stephens are provided in **Table 2**.

**Table 2** Tidal planes at Port Stephens

| Tidal Plane | Elevation (m CD) |
|---|---|
| Mean High Water Springs (MHWS) | 1.6 |
| Mean High Water Neaps (MHWN) | 1.3 |
| Mean Sea Level (MSL) | 0.9 |
| Mean Low Water Neaps (MLWN) | 0.6 |
| Mean Low Water Springs (MLWS) | 0.3 |
| Lowest Astronomical Tide (LAT) | 0 |
| Correction to AHD (m) | -0.959 |

Source: Australian National Tide Tables 2011 (Australian Hydrographic Service, 2010)

Water level data has been provided by Manly Hydraulics Laboratory on behalf of NSW Office of Environment and Heritage (OEH) for Mallabula Point, located on the north side of the east headland of Tanilba Bay (E407770, N6379228: Zone 56). Data was provided from 08/07/1992 to 30/06/2010, with measurements recorded every hour. The gauge was decommissioned from July 2007 until March 2009.

## 4.4 Survey Data

A range of bathymetric data has been sourced for Tanilba Bay and the surrounding area of the inner estuary; the various sources are detailed in **Table 3**.

**Table 3** Available survey data.

| Area | Sampling Method | Source |
|---|---|---|
| Tanilba Bay – subtidal area | Hydrographic Survey | Office of Environment and Heritage (OEH) |
| Tanilba Bay – intertidal, supra-tidal areas and terrestrial | LiDAR Survey | Port Stephens Council |
| Inner estuary | Digitised Hydrographic Chart | Australian Hydrographic Service |

Bathymetric data was converted to Australian Height Datum (AHD) to ensure consistency. A Digital Terrain Model (DTM) of Tanilba Bay was generated using the bathymetric and topographic data available for the area (refer **Figure 4**).

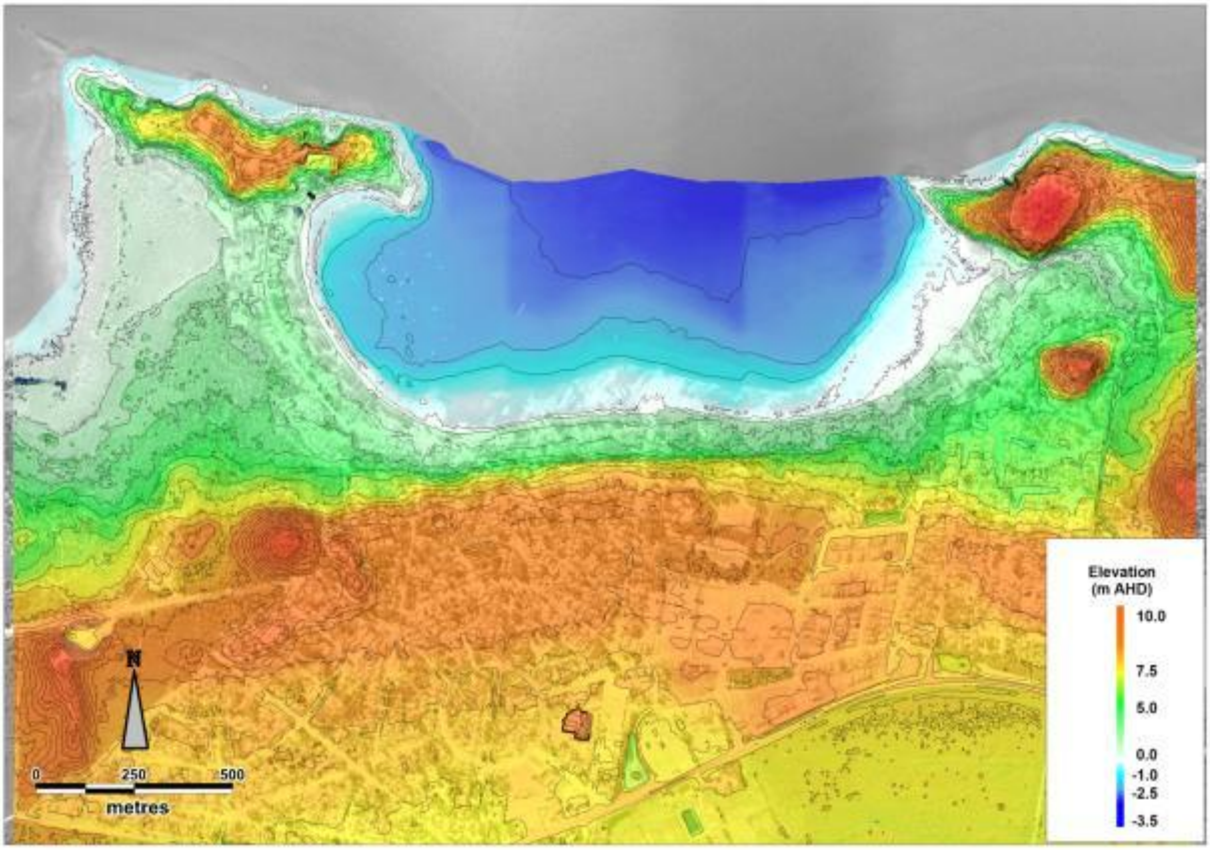



**Figure 4** Digital Terrain Model of Tanilba Bay.

# 5 REVIEW OF COASTAL PROCESSES

The dominant coastal processes prevalent at the Tanilba Bay site have been investigated to assist in the development and assessment of foreshore stabilisation concept design options. The understanding of physical processes occurring at Tanilba Bay informs the design process by enabling the selection of site specific foreshore stabilisation measures that suit the environment to maximise effectiveness and minimise adverse impacts. This information also defines various design parameters for mitigation works such as design rock armour sizing, toe and crest levels and saltmarsh berm levels.

These investigations have drawn on existing photographical and metocean data and utilised numerical modelling techniques. In addition, a site visit was undertaken to allow a detailed assessment of the site.

## 5.1 Geomorphology

Coastal Quaternary Geology maps of the Nelson Bay Area have been used to determine the geological properties of Tanilba Bay and the surrounding area (Hashimoto, T.R. & Troedson, A.L., 2008). The subtidal area surrounding Tanilba Bay consists of Holocene estuarine basin and bay sediments, consisting of clay, silt, shell and fluvial/marine sands. The intertidal area of Tanilba Bay is made up of Holocene estuarine in-channel bar and beach marine sand, silt, clay, shell and gravel. The land behind the intertidal zone (supratidal area) consists of Pleistocene dune made up of marine sand and indurated sand. Both the headlands at the Bay entrance are rock features, made up of Devonian to Carboniferous sedimentary rocks.

The sediments within the inner estuary are predominantly made up of muddy lithic sands that originate from the Karuah River (Umwelt, 2009). In Tanilba Bay a thin rim of sand and muddy sand has been reported along the bay which extends up to 200m from the shoreline (evident in the digital terrain model shown in **Figure 4)**. The inner estuary frequently consists of turbid waters as a result of re-suspension of fine grained material by wind waves as well as turbid discharges from the Karuah River catchment in wet weather (Umwelt, 2000). However, tidal currents are reported as being the dominant transport mechanism for any dispersal of sediment in this area (Thom et al, 1992).

### 5.1.1 Sediment Sampling

Sediment samples were collected in each zone and analysed for grain size distribution.

The analysis determined that collected samples were well sorted medium sand comprised predominantly of sub-angular to sub-rounded quartz. $D_{50}$ values (median) ranged between 0.32 – 0.39mm.

There was no discernible difference in the sediment samples. Accordingly, it can be inferred that sediment material is generally consistent along the entire bay foreshore.

The laboratory analysis results are compiled in **Appendix A**.

## 5.2 Review of Historical Aerials

A series of aerial photographs were provided by Council covering Tanilba Bay. Dates of the photographs which cover the entire bay are detailed in

**Table 4**; the photographs are shown in **Figure 5** to **Figure 8**.  The photographs were processed and compared to provide an indication of the changes which have occurred over these 17 years.

**Table 4** Aerial photograph dates

| Date of Aerial Photograph | Season |
|---|---|
| 28/05/1987 | Autumn |
| 21/09/1992 | Spring |
| 29/10/1999 | Spring |
| 23/05/2005 | Autumn |

Based on the review of these aerial photographs, a summary of fundamental coastal processes features prominent in Tanilba Bay are as follows:

- The crisscross sand wave feature is persistent for all the aerial photographs in the intertidal zone along the centre of the bay where the shoreline faces north.  This prominent feature would have formed as a result of bimodal sediment movement direction at the centre of the bay.  The crisscross feature gradually attenuates towards both east and west sides of the bay.
- The very wide intertidal zone on the eastern side of the bay indicates that the net longshore sediment transport direction is west to east.  Both sides of the bay present evidence of diminishing alongshore movement.  The sediment movement at the eastern extremity of the bay appears to be dominated by offshore - onshore transport driven by catchment outflows at the creek entrances.
- The geographic orientation of the bay, the prominent headland features at either ends , the narrow intertidal zone on the western side, the large intertidal zone at the eastern side and no evidence of a sediment pathway around either headland suggests that there is no influx or outflux of sediment from the Bay.  Essentially, the bay is a closed beach system (i.e. net zero change in sediment volume).  However, sediment loss from the nearshore (or littoral system) may occur near the edge of the intertidal zone through an imbalance between; offshore sediment movement from catchment flows at stormwater outlets and creek entrances, and onshore sediment movement from low energy wind waves.
- There was a noticeable change in the nearshore bathymetry (e.g. creation of 2 holes) between 1992 and 1999 in front of Tilligerry Habitat State Reserve.  The likely impacts on local coastal processes are discussed in detail in later sections.

It was found that that there was little change in the vegetation cover or residential developments adjacent to the foreshore between 1987 and 2005.  In addition, the photographs do not show any clear changes in the shoreline position or shape over this period.  However, there were changes in the intertidal area over this period.  These are described below:

- Between 1987 and 1992 there was a small change in the intertidal zone, with some infilling of the gaps (or smothering of stabilising vegetation) between the sand wave features.  There also appears to have been a slight increase in the width of the intertidal zone on the west side of the bay, with little change to the east side.

- Between 1992 and 1999 there was a significant reduction in both the width of the intertidal zone and the coverage of the intertidal zone (particularly adjacent to Tilligerry Habitat State Reserve). The gaps (or growth of stabilising vegetation) between the sand wave features on the intertidal zone increased and appear more widespread than they were in 1992. These gaps between the sand waves are predominantly focused around the centre of the bay where the shoreline faces north. The appearance of two large "borrow" holes adjacent to the foreshore fronting Tilligerry Habitat State Reserve is evident in the 1999 photograph.
- There was little change in the intertidal area between 1999 and 2005, with a slight reduction in the coverage in the eastern half of the central bay with no infilling of any gaps between sand waves features occurring. The western "borrow" hole increased in size in the 2005 photo.

There is a prominent ebb tidal delta feature at the southern end of the western foreshore which is present throughout all years. This is located adjacent to a stormwater drain and likely to be a result of accumulation of sediment from longshore transport in front of the outlet during period of low catchment flow; and offshore sediment movements in time of high catchment flow. To the east of this feature the growth of a hole in the intertidal zone (or stabilisation by seagrass colonisation) can be observed signifying low sediment passing of the delta in this direction. Similar ebb tide deltas are present at all other stormwater catchment outflow structures, or entrance features in the bay.

The photographs do not show any clear seasonal changes in the intertidal zone; the photograph take in 1999 soon after summer shows a very similar intertidal zone to the one take just after winter in 2005. However, as previously discussed, the ever present crisscross pattern of sand waves on the intertidal zone indicates bimodal sediment transport directions, most likely due to seasonal influences.

**Figure 5** Aerial photograph of Tanilba Bay (28/05/1987)

**Figure 6** Aerial photograph of Tanilba Bay (21/09/1992)

**Figure 7** Aerial photograph of Tanilba Bay (29/10/1999)

**Figure 8** Aerial photograph of Tanilba Bay (23/05/2005)

## 5.3 Photogrammetric and Other Survey Data

A detailed photogrammetric analysis of historical vertical aerial photography (photogrammetry) was undertaken by the NSW Office of Environment and Heritage (OEH) (formerly Department of Environment, Climate Change and Water). This enabled long term recession rates and storm erosion demand to be assessed.

The photogrammetric data consists of 52 cross-shore profiles in 4 blocks with the coverage extending the entire 2.6 km foreshore of Tanilba Bay. The data covered the period from 1951 to 2008. **Appendix B** provides detailed information regarding the photogrammetric analysis undertaken including:

- Details of the years of aerial photographs and the locations of photogrammetric profiles.
- A description of the methodology used in the analysis of the photogrammetric data.
- Plots of analysis results.

### 5.3.1 Interpretation of Photogrammetry

Based on the photogrammetric data provided by OEH, an assessment of the long-term trends in shoreline position was undertaken. The aim of this assessment was to identify and gain an improved understanding of the shoreline recession changes at Tanilba Bay. Trends in shoreline recession were estimated by measurement over time of the position in plan of a consistent erosion escarpment height, taken in this analysis as 1 m AHD.

The photogrammetric profile locations are shown in **Figure 9**. The findings of the photogrammetric analysis for Tanilba Bay are outlined below.

As discussed in **Appendix B**, Blocks 2 and 4 photogrammetric data were discarded from the analysis as anthropogenic influences interfere with the photogrammetric data.


**Figure 9** Photogrammetric Data Profile Locations

Block 2 incorporates a wide variety of foreshore protection measures (effective and otherwise) and unprotected foreshore. Accordingly, there is no erosion in some areas (foreshore fixed by protection) and significant erosion in unprotected areas due to the influence of adjacent protected areas. This is most significant along the foreshore fronting Tilligerry Habitat State Reserve where nourishment “borrow” holes in the nearshore zone have exacerbated erosion mechanisms and recent acceleration of erosion is evident from aerial photography.

The foreshore of Block 4 is typified by vertical seawalls that fix the shoreline position.

**<u>Block 1 (Eastern Foreshore)</u>**

Block 1 is approximately 480 m of the foreshore covering the eastern side of the bay where the shoreline faces north west. The Block 1 photogrammetric profile locations are presented in **Figure 9**.

The photogrammetric data analysis of Block 1 profiles determined that shoreline recession, rates ranging between 0.2 – 0.4 m/yr, occurred between 1951 and 2008. However, there was underlying decrease in recession rate during the most recent observation between 1993 and 2008. The recession rate during this period was typically around 0.1 m/yr.

Furthermore, the foreshore area immediately down drift of the boat ramp located on the eastern side of the bay located in Caswell Reserve (refer **Figure 3**) experienced the greatest recession in this area. The recession rate between 1951 and 2008, and 1993 and 2008 were 0.5 and 0.3 m/yr, respectively.

**<u>Block 3 (Western Foreshore)</u>**

Block 3 is approximately 680 m of the foreshore covering the west side of the bay where the shoreline faces north east. The Block 3 photogrammetric profile locations are presented in **Figure 9**.

The photogrammetric data analysis of Block 3 profiles suggests that the foreshore in this area was relatively stable over the analysis period between 1951 and 2008. Though, there is evidence of occasional shoreline movements, it is depicted in **Figure B.3d** (**Appendix B**) that there was no significant shoreline changes over the analysis period in this area. The recession rates were generally less than ±0.1 m / yr.

It should be noted that the photogrammetric data sets available for Tanilba Bay was very limited and that greatest interval between aerial photographs analysed was as long as 30 years. Accordingly, this photogrammetric analysis should be considered as limited to providing only indicative representation of the long-term shoreline trends at Tanilba Bay.

## 5.4 Wind Climate

The dominant wind directions at the site are from the west through to the north-west. Winds from this sector occur for the longest duration and tend to be of a higher speed (refer **Figure 10**). The wind rose plot also shows that strong winds can occur from the south, but these do not occur as frequently as those from the west to north-west. It is important to note that winds from the north-west to the north-east are generally relatively light (less than 5m/s) and also do not occur frequently. The largest fetch for Tanilba Bay is from the north through to north-east and as the winds are generally light from these directions the wave climate at Tanilba Bay is considerably less energetic than if these directions were dominant.

**Figure 11** shows how the wind climate varies seasonally in the area. This shows that there are clear seasonal changes in the wind climate, with predominant winds in the summer and winter being from different sectors and the winds in the autumn and spring being a mixture of the two. The wind direction which occurs most frequently in autumn, winter and spring is from the west north-west. While in the summer the most frequent wind direction is from the south, although winds from the east through to the north-east also frequently occur.

Additional joint frequency tables have been produced for all records and seasonal periods, these are provided in **Appendix C**.

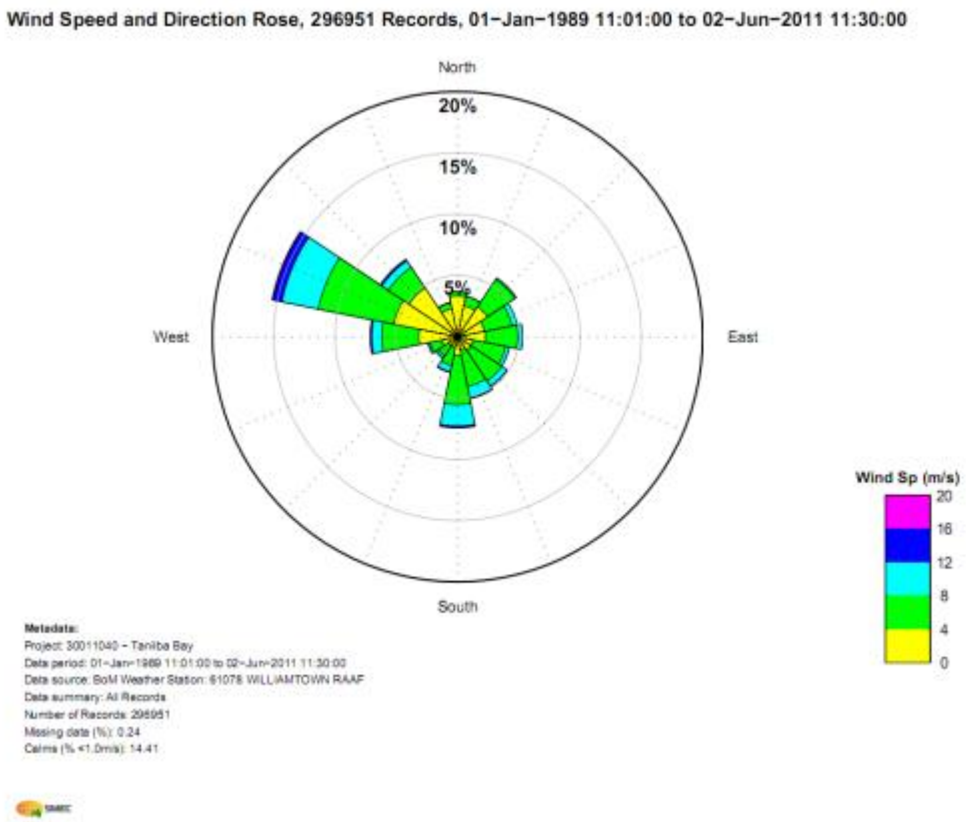



**Figure 10** Wind rose plot (BoM Williamtown Airport station. January 1989 - June 2011)

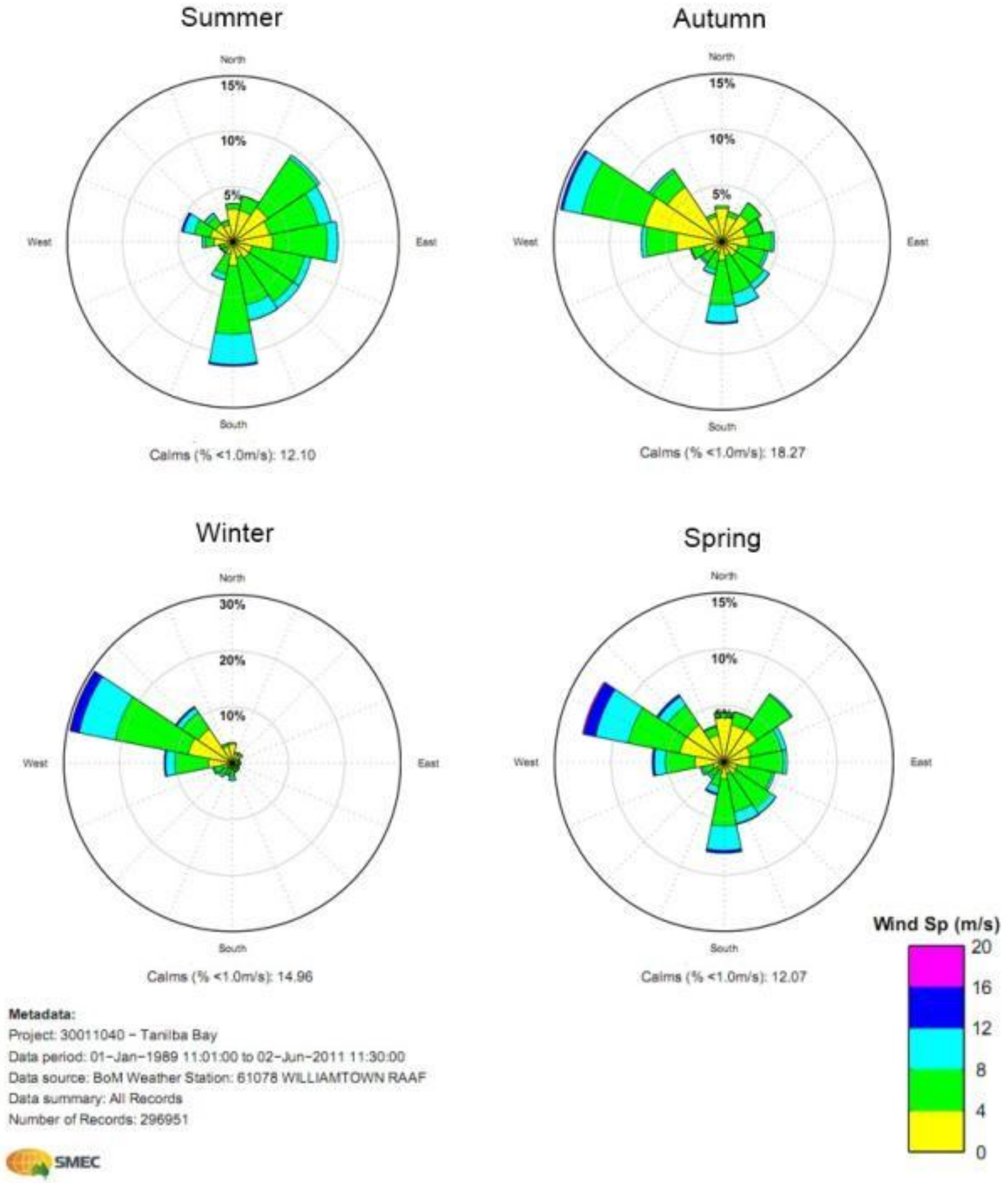



**Figure 11** Seasonal wind roses (BoM Williamtown Airport station. January 1989 - June 2011)

## 5.5 Wave Climate

No swell wave energy penetrates into the semi-enclosed bay surrounding Tanilba Bay. This is a result of the confined entrance from the sea to the Outer estuary (to east of Soldiers Point) at Shoal Bay, the shallow flood tide delta in the Outer estuary dissipating wave activity and the subsequent confined entrance to the Inner estuary (to the west of Soldiers Point), where Tanilba Bay is located. These constricted entrances combined with the relatively shallow water within the embayment prevent the propagation of any long period swell waves. Therefore, the wave climate at the site is a result of waves generated by winds within the inner part of the embayment.

Wave modelling was undertaken to predict the expected wave conditions at Tanilba Bay. Further detail on the wave modelling is provided in **Appendix D**. Based on results from the wave modelling a series of wave roses have been plotted around Tanilba Bay to demonstrate the variability in the wave climate (refer **Figure 12**). The wave rose at the entrance to the bay, Site 9, shows a bimodal distribution in the wave climate with dominant wave directions from the north-west and the north-east, this bimodal distribution is a result of the seasonal variations in the wind climate discussed in **Section 5.4** .

Waves from the north-west occur most frequently and also result in the occurrence of larger waves, indicating that the littoral drift within Tanilba Bay is expected to be from the west to the east. The wave climate at the points within the bay differs to the climate at the entrance owing to wave diffraction and refraction within the bay and the sheltering effects of the bay headlands. The central, area of the bay, sites 4 to 6, experiences the most energetic wave climate as it is exposed to the larger and more frequent waves from the north-west and also experiences wave activity as a result of waves from the east. The eastern parts of the bay, sites 7 and 8, are only subject to waves from the north-west while the western end of the bay, sites 1 to 3, is only subject to waves from the east.

To demonstrate how the wave climate varies with the seasons, wave roses have been plotted to show the wave climates for the summer and winter periods (refer **Figure 13** and **Figure 14**). Waves from the east north-east dominate in the summer, with Sites 2 to 6 being most exposed to these wave conditions. In contrast, in the winter months waves from the north-west dominate, with Sites 4 for 8 being the most exposed to these wave conditions. This seasonal variability in the wave climate is likely to be a very important aspect of the processes controlling the transport and distribution of sediment along the foreshore.

Percentile exceedance values of significant wave height ($H_s$) have been calculated for all the sites, these are shown for the 1% and 0.1% in **Table 5** indicating variability along the Tanilba Bay foreshore. The wave heights generally increase from west to east of the bay up to Site 6 which experiences the largest waves. The significant wave height which is exceeded for 1% and 0.1% of the year at Site 1 is almost half that at Site 6.

**Table 5** Percentile exceedance values for wind generated waves around Tanilba Bay.

| Site Number | $H_s$ (1% Exceedance) (m) | $H_s$ (0.1% Exceedance) (m) |
|---|---|---|
| 1 | 0.16 | 0.23 |
| 2 | 0.23 | 0.29 |
| 3 | 0.22 | 0.28 |
| 4 | 0.26 | 0.35 |
| 5 | 0.29 | 0.41 |
| 6 | 0.3 | 0.42 |
| 7 | 0.16 | 0.24 |
| 8 | 0.14 | 0.21 |
| 9 | 0.35 | 0.5 |

There have not been any specific studies to assess wave setup at Tanilba Bay and as such wave setup has been calculated based on results from the wave modelling. Wave setup is generally assumed to be in the order of 15% of the wave height directly offshore of the beach. The largest wave condition over the period the wave modelling was undertaken was used to calculate the wave setup values which are shown in **Table 6**.

Wave run-up is the vertical distance that a wave can reach when it breaks on the shore, this level is above maximum still water level and varies depending on the beach profile or structure slope. A beach slope of 0.1 (1 in 10 slope) has been assumed for all sites, however if a steeper slope is present in any areas then a much higher value will occur. The calculated wave run-up values are shown for the sites around Tanilba Bay in **Table 6**.

**Table 6** Wave setup and run-up values for the sites around Tanilba Bay

| Site Number | Wave Setup (m) | Wave Run-up (m) |
|---|---|---|
| 1 | 0.05 | 0.29 |
| 2 | 0.07 | 0.26 |
| 3 | 0.06 | 0.25 |
| 4 | 0.08 | 0.27 |
| 5 | 0.09 | 0.27 |
| 6 | 0.10 | 0.28 |
| 7 | 0.06 | 0.26 |
| 8 | 0.06 | 0.26 |

Based on 20 years of time series generated as part of the wave modelling, an extreme wave assessment has been undertaken to determine the design wave conditions around Tanilba Bay. Extreme wave heights ($H_s$) have been predicted at the 8 sites across Tanilba Bay; the 1 in 50 and 1 in 100 year Annual Return Intervals (ARI) of significant wave height ($H_s$) are shown in **Table 7**. The results show that extreme wave heights are smallest at the western end of the bay with a 100 year ARI wave height of 0.30m at Site 1, while they are largest towards the eastern end of the bay, with a 100 year ARI wave height of 0.71m at Site 6.

**Table 7** Extreme wave conditions for the sites around Tanilba Bay

| Site Number | 50 year ARI wave height ($H_s$) (m) | 100 year ARI wave height ($H_s$) (m) |
|---|---|---|
| 1 | 0.29 | 0.30 |
| 2 | 0.39 | 0.40 |
| 3 | 0.38 | 0.39 |
| 4 | 0.54 | 0.56 |
| 5 | 0.64 | 0.67 |
| 6 | 0.67 | 0.71 |
| 7 | 0.40 | 0.41 |
| 8 | 0.37 | 0.38 |

## All Seasons

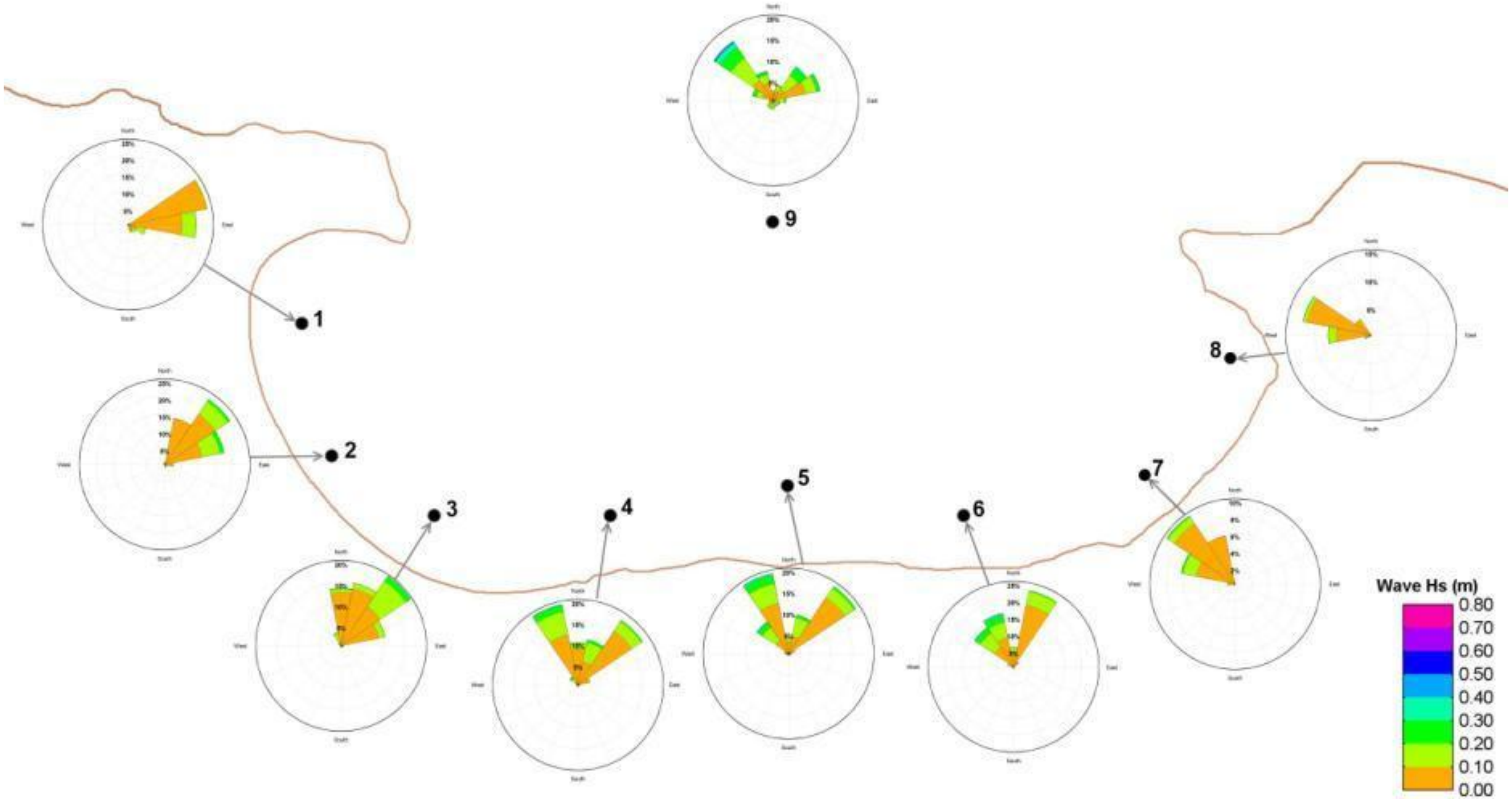



**Figure 12** Wave rose plots around Tanilba Bay (1991 to 2011)

## Summer

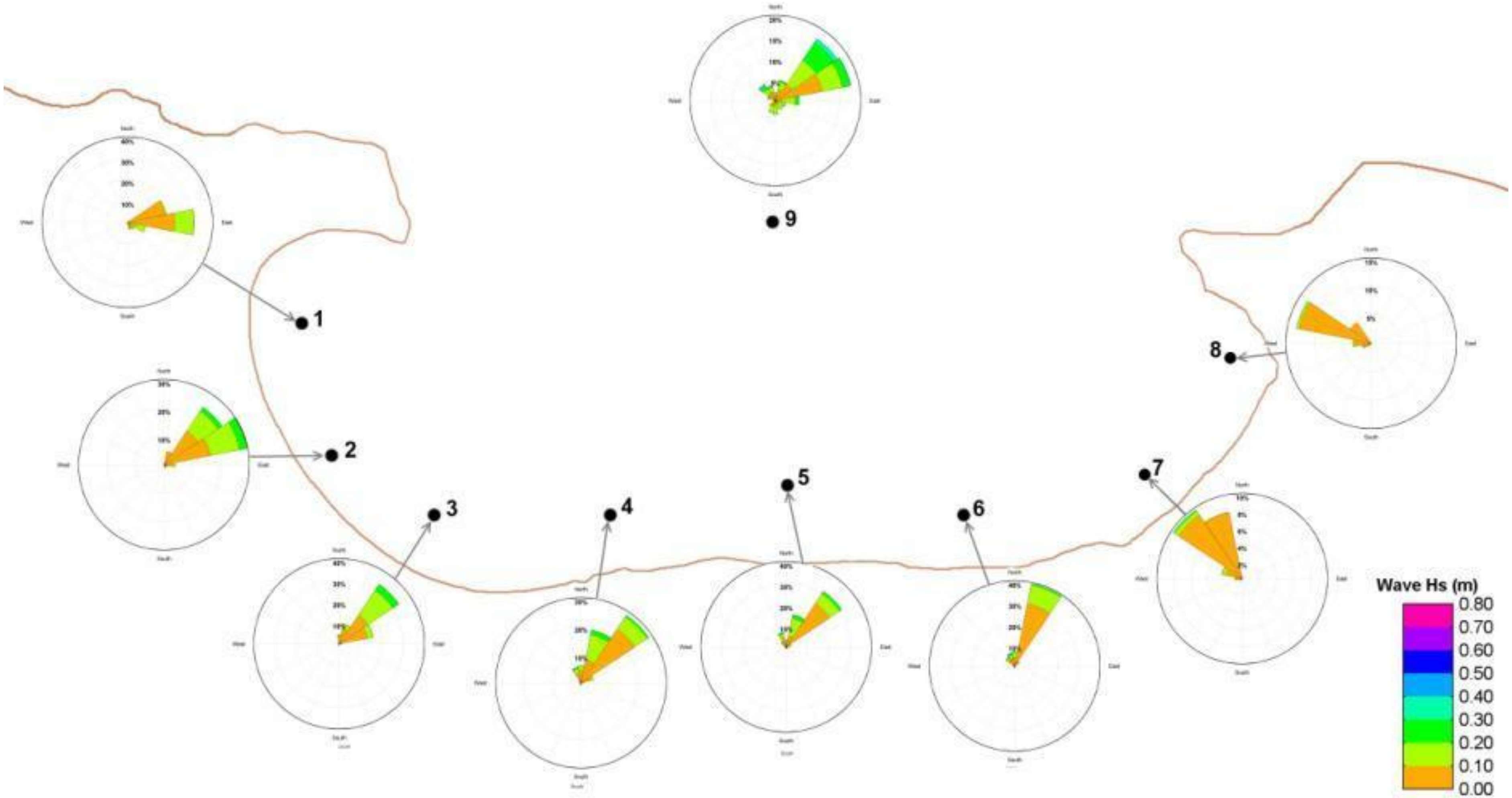



**Figure 13** Summer wave rose plots around Tanilba Bay (1991 to 2011)

Winter

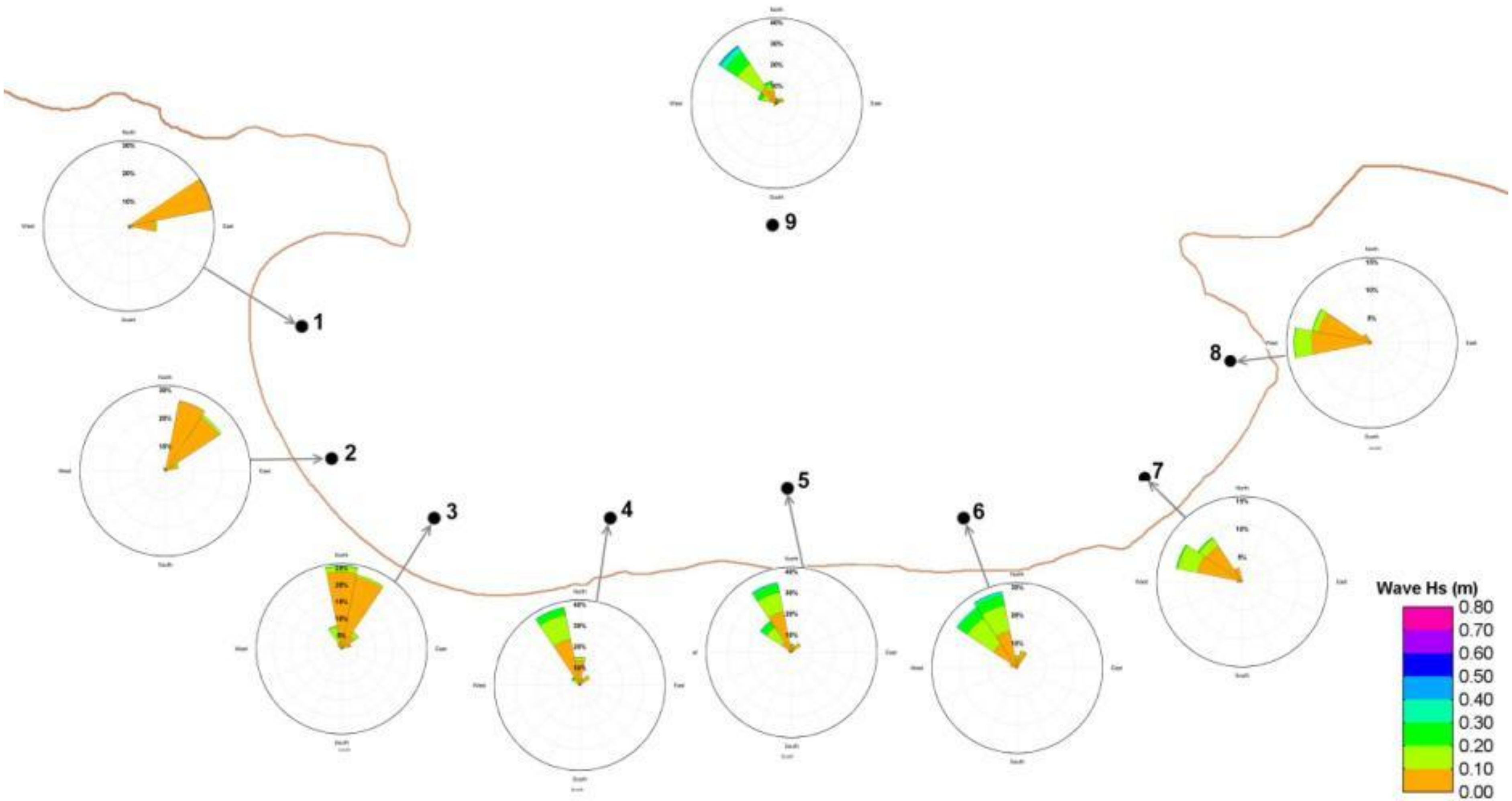



**Figure 14** Winter wave rose plots around Tanilba Bay (1991 to 2011)

## 5.6 Boat Wake

Waves generated by passing vessels have the potential to influence shoreline erosion within the study area. Anecdotal evidence from local residents and Council indicated that waves generated by boat wakes in the bay are not an issue in terms of shoreline recession. It was stated that waves resulting from boat wakes are generally not noticeable along the shoreline. Further investigations suggest that boat wakes would not have significant impact on the littoral processes along the Tanilba Bay foreshore.

## 5.7 Sediment Transport

The potential rate of longshore sediment transport has been calculated for Tanilba Bay, based on the modelled wind driven wave climate. The Kamphius (1991) longshore transport formula has been used to estimate the bulk transport rate. The formula used is based on extensive series of hydraulic model tests and accounts from the following variables:

- wave height, period and direction;
- beach slope; and
- typical sediment grain size ($D_{50}$)

Based on field observations and data from sediment cores collected by Willing Partners Geomarine (1997), the grain size ($D_{50}$) has been assumed to be a medium sand (0.38mm). The beach slope was calculated for each site within the bay based on the nearshore topography provided by Council, with slopes ranging from 1 in 10 to 1 in 20.

Potential sediment transport rates are shown in **Table 8,** these are indicative rates and assume an unlimited up drift supply. Rates are presented as summer and winter rates as well as a net annual rate in order to highlight the seasonal variability in the drift rates.

**Table 8** Net potential sediment transport rates based on modelled wave climate.

| Site Number | Net Potential Sediment Transport Rate; -ve = west, +ve = east | | |
|---|---|---|---|
| | Summer ($m^3$) | Winter ($m^3$) | Annual ($m^3$/year) |
| 1 | -55 | -7 | -163 |
| 2 | -67 | 17 | -66 |
| 3 | -246 | 89 | -92 |
| 4 | -198 | 279 | 23 |
| 5 | -104 | 294 | 282 |
| 6 | -12 | 350 | 605 |
| 7 | 10 | 73 | 170 |
| 8 | 13 | 58 | 146 |

Conceptual descriptions of the longshore drift results relative to Tanilba Bay for the net annual, summer and winter drift climates are shown in **Figure 15** to **Figure 17**. The summer and winter plots demonstrate how the longshore drift varies through the year depending on the dominant wave direction. In the summer months an easterly wave direction is dominant, resulting in a longshore drift from east to west while during the winter months a north-westerly wave is dominant, resulting in a longshore drift from west to east. The net annual drift shows that throughout the majority of the bay the dominant drift is from west to east. However, the western side of the bay, which is predominantly sheltered from the north-westerly waves, has a net annual longshore drift direction from east to west. This change in net annual drift directions results in a drift divide at the western side of the bay, where the dominant longshore drift changes from being to the west to being to the east. The annual net drift shows that the eastern end of the bay is an accumulating area with a gradual reduction in drift rates indicating that sediment would be deposited here.

In both the western and eastern ends of the bay there will also be some onshore and offshore transport of sediment resulting when wave directions are approximately perpendicular to the shoreline. Waves breaking on the shoreline act to erode sediment at high tide, while the low tide dissipation of wave energy will act to move sediment onshore.

It is important to note that there are a number of limitations associated with calculating potential sediment transport rates. The calculations assume an unlimited supply of sediment, whereas within Tanilba Bay there is limited sediment available along the western side of the bay which, combined with some areas of stabilised foreshore in the central areas of the bay is likely to limit the actual longshore transport rates. In addition, when sediment becomes eroded from the shoreline it ends up on the intertidal zone and as such there is a linkage between the two which cannot be accounted for in these calculations. It has been shown that throughout Tanilba Bay there can be both east to west and west to east littoral drift along the shoreline. Owing to this, combined with the relatively low energy wave conditions at the site, the net potential sediment transport rates for the area are relatively low in comparison to an open coastal environment (e.g. Jimmy's Beach with net potential sediment transport rates of 20,000m$^3$/yr). It is not possible to determine the quantity of sediment which is lost from the littoral zone by the cross-shore transport of sediment as a result of stormwater flows.


**Figure 15** Predominant directions of longshore drift within Tanilba Bay during the summer months.


**Figure 16** Predominant directions of longshore drift within Tanilba Bay during the winter months.

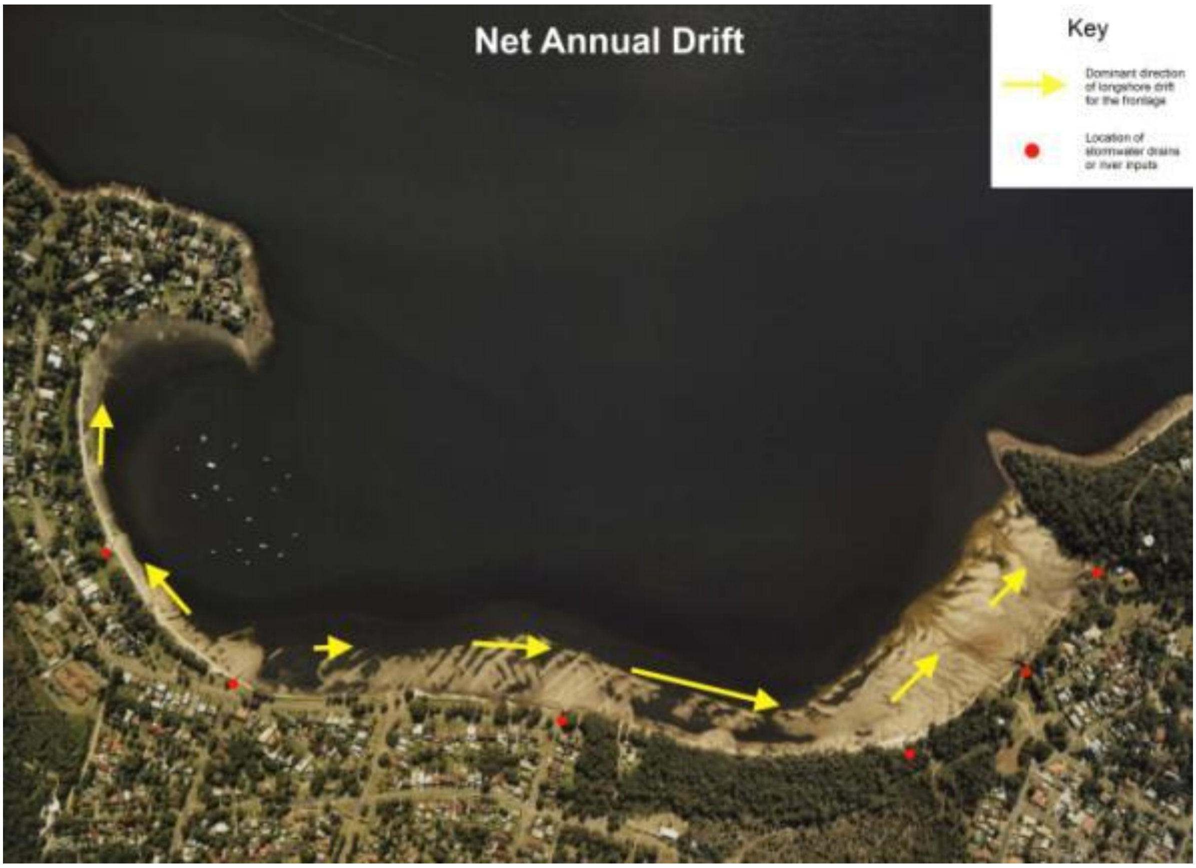



**Figure 17** Predominant directions of longshore drift within Tanilba Bay and the locations of stormwater drains within the bay.

## 5.8 Elevated Water Level Assessment

An assessment of historical elevated water levels due to residual surge/flood was undertaken using the water level data provided by Manly Hydraulics Laboratory (MHL) at Mallabula Point from 1992 to 2007. The primary objective of this assessment was to inform design criteria such as design crest levels and saltmarsh berm heights.

Tidal constituents for water levels at the site were calculated based on harmonic analysis on the measured water level data to determine the harmonic constituents which make up the tidal signal at Mallabula Point. The tidal level was predicted for the same period as the measured data and from this a residual surge/flood height was calculated for the period. Generally, the highest measured water levels over the 15.5 year period were shown to be the result of a high water much greater than MHWS coinciding with a medium sized residual surge/flood event (up to 0.25m); **Table 9** shows a list of the ten highest measured water levels.

The highest measured water level consisted of a predicted water level of 1.08m AHD combined with a residual surge/flood of 0.24m giving a total measured water level of 1.32m (refer

Figure **18**). The largest residual surge/flood events were shown to generally occur closer to MSL than to HW or LW; **Table 10** shows a list of the ten highest residual surge/flood events. The largest residual surge/flood event was 0.54m and coincided with a tidal level of 0.01m resulting in a measured water level of 0.55m AHD;

**Figure 19** shows the measured and predicted water levels and the residual surge/flood levels for this period.

The highest water level recorded at Mallabula Point between 1992 and 2007 correlate well with the Annual Return Interval (ARI) calculations for Fort Denison, Sydney which was used by WBM (2011) to represent Port Stephens. The ARI values for Fort Denison, Sydney, are therefore considered to be representative of the ARI water level events for Tanilba Bay, these are shown in **Table 11**.

A water level exceedance curve based on water level data from the Mallabula Point gauge provided by MHL for the period from 1992 to 2011 is shown in **Figure 20**. The mean high water spring (MHWS) level of 1.6m CD has a probability of exceedance of 10%. A water level of 2.1m CD (1.15m AHD) has a probability of exceedance of 0.01%. These levels coincide with previous assessments where it was found that a 100 year return period surge event would result in a water level of 1.5m AHD (Willing Partners Geomarine, 1997). It has also been indicated that an extreme flood event from the Karuah River could increase water levels by around 0.5m in the Inner estuary.

Based on the storm surge level, fresh water flood surcharge and wave setup (assumed to be 0.06m) a maximum still water level for Tanilba Bay of 2.06m AHD has previously been determined (Willing Partners Geomarine, 1997).

The sea level rise projected for the area is 0.4m above 1990 MSL by 2050 and 90cm above 1990 MSL by 2100. These sea level rises would increase the recession hazard along the sandy shorelines.

**Table 9** Ten highest water levels measured at Mallabula Point

| Date | Measured Water Level (m AHD) | Predicted Water Level (m AHD) | Residual Height (m) |
|---|---|---|---|
| 20/08/2001 22:00 | 1.32 | 1.08 | 0.24 |
| 19/08/2001 21:00 | 1.30 | 1.12 | 0.18 |
| 1/02/2006 11:00 | 1.30 | 1.04 | 0.26 |
| 13/06/1995 21:00 | 1.29 | 1.17 | 0.12 |
| 13/07/1995 22:00 | 1.29 | 1.14 | 0.15 |
| 1/01/2002 10:00 | 1.29 | 1.04 | 0.25 |
| 14/07/1999 22:00 | 1.27 | 1.09 | 0.18 |
| 2/06/2000 21:00 | 1.27 | 1.13 | 0.14 |
| 31/01/2006 10:00 | 1.26 | 1.10 | 0.16 |
| 10/08/2006 22:00 | 1.26 | 1.09 | 0.17 |

**Table 10** Ten highest surge/residual flood heights and the resultant measured water levels at Mallabula Point

| Date | Measured Water Level (m AHD) | Predicted Water Level (m AHD) | Residual Height (m) |
|---|---|---|---|
| 29/07/2001 6:00 | 0.55 | 0.01 | 0.54 |
| 29/07/2001 7:00 | 0.35 | -0.19 | 0.54 |
| 29/07/2001 5:00 | 0.71 | 0.18 | 0.53 |
| 11/05/1997 4:00 | 0.31 | -0.20 | 0.51 |
| 29/07/2001 8:00 | 0.14 | -0.37 | 0.51 |
| 11/05/1997 3:00 | 0.60 | 0.10 | 0.50 |
| 29/07/2001 4:00 | 0.76 | 0.27 | 0.49 |
| 29/07/2001 9:00 | -0.04 | -0.50 | 0.47 |
| 29/07/2001 3:00 | 0.71 | 0.25 | 0.46 |
| 11/05/1997 5:00 | 0.01 | -0.45 | 0.46 |

**Table 11** Extreme water levels predicted for Fort Denison, Sydney (WBM, 2011).

| Annual Recurrence Interval (years) | Extreme Water Level (Residual + Tide), Sydney (m AHD) |
|---|---|
| 10 | 1.35 |
| 20 | 1.38 |
| 50 | 1.42 |
| 100 | 1.44 |

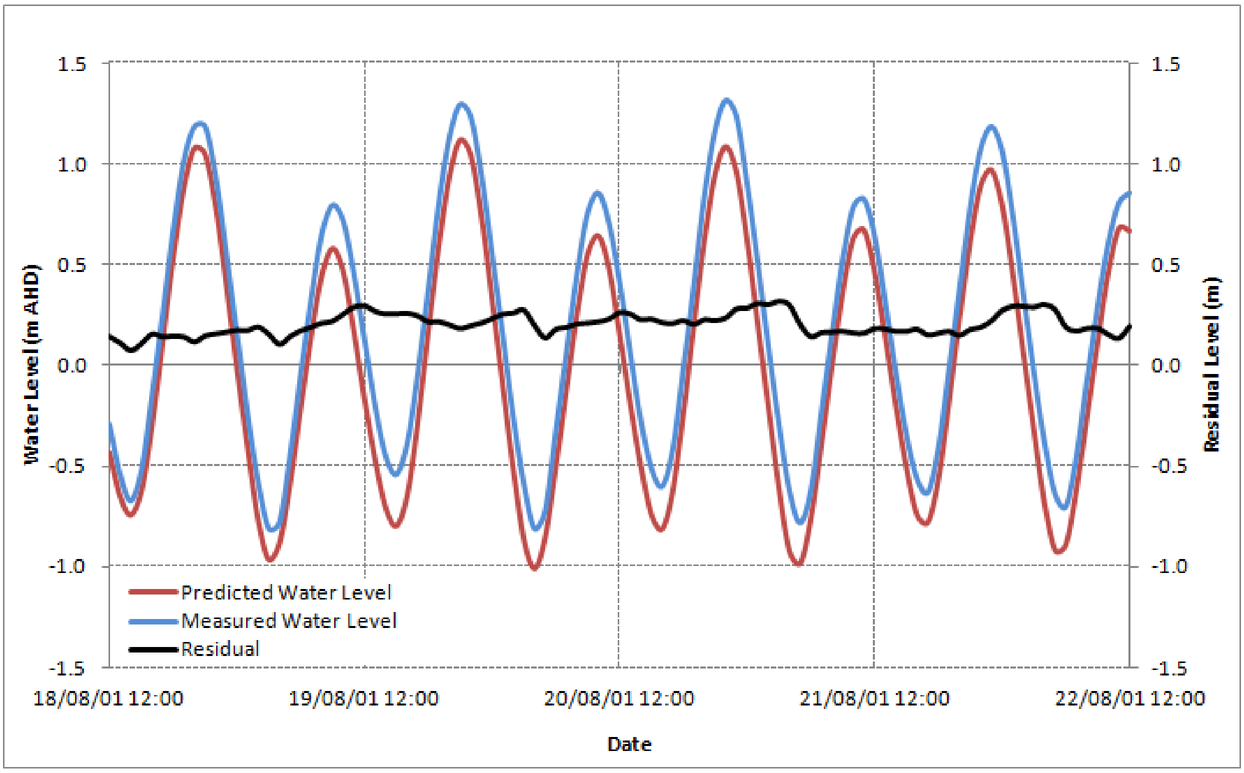



**Figure 18** Highest measured tidal level recorded Mullabula tide gauge (1992 to 2010).

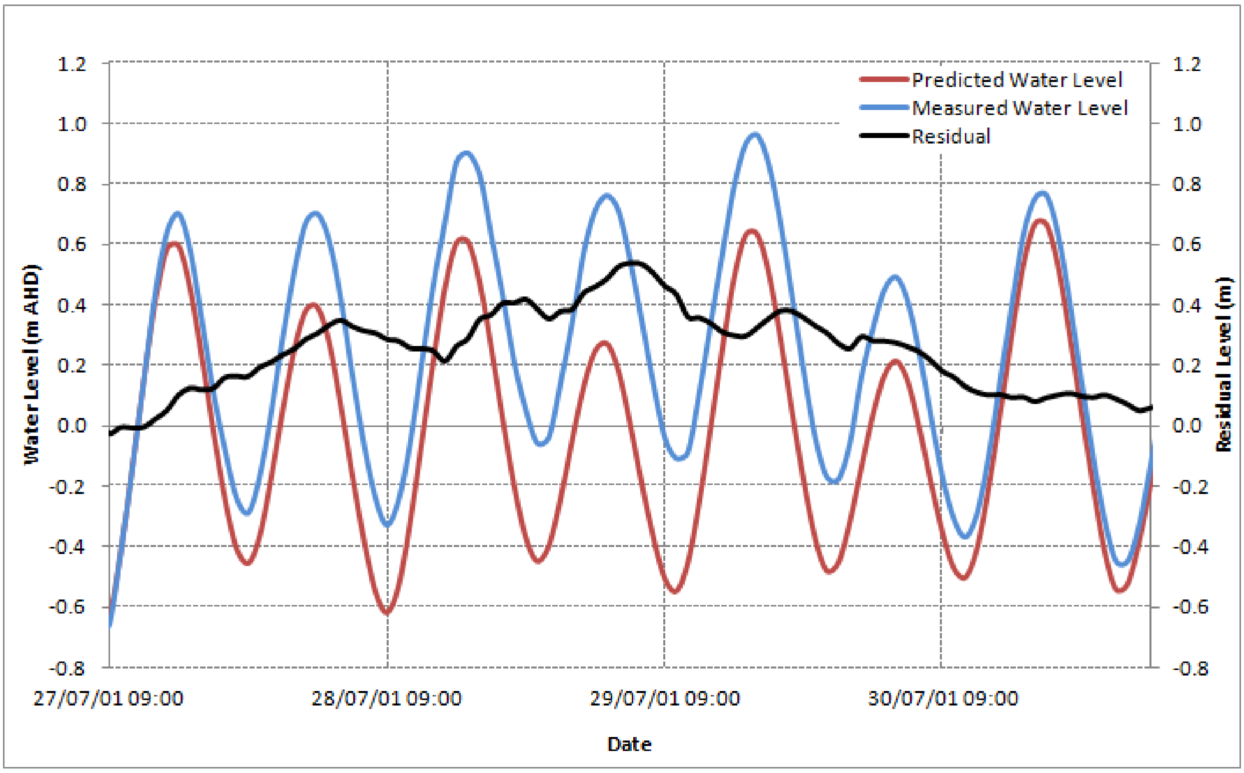



**Figure 19** Largest residual surge/flood event recorded. Mullabula tide gauge (1992 to 2010)

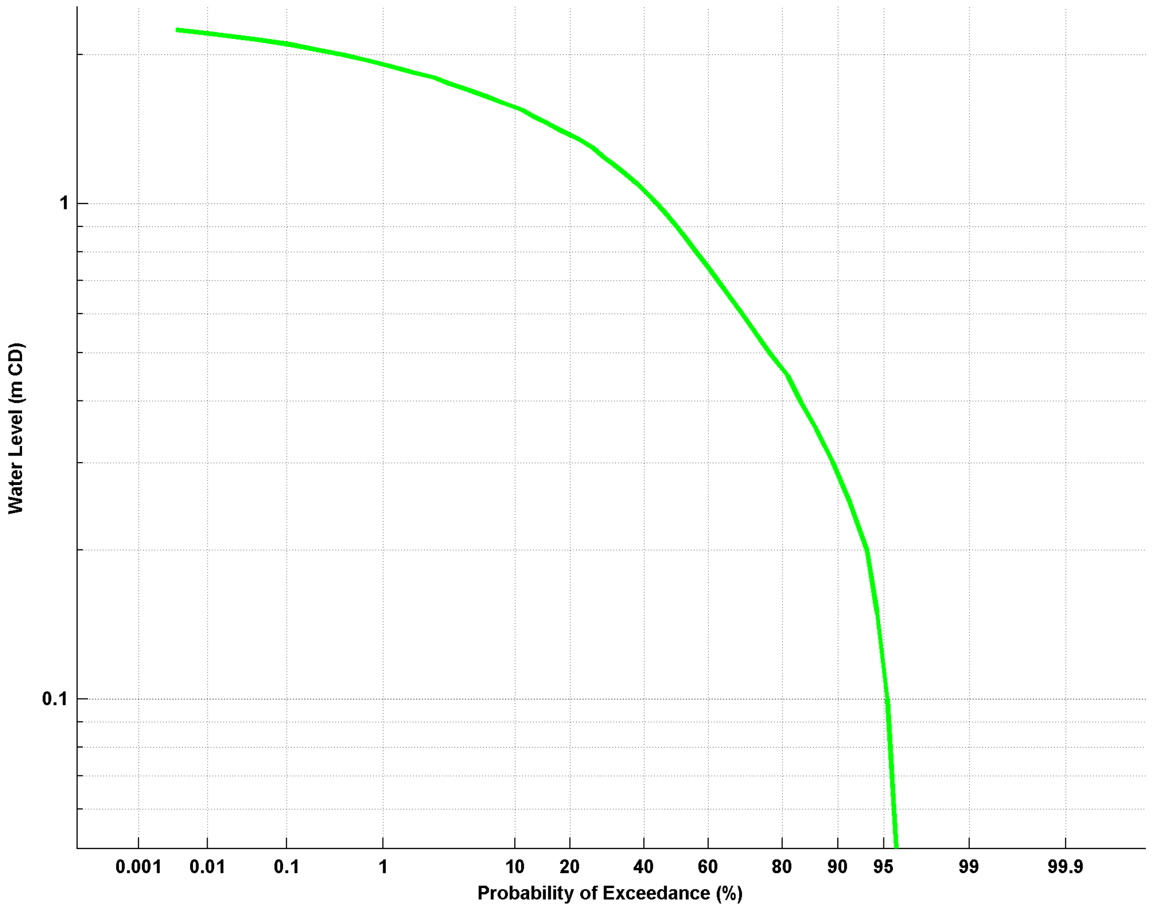



**Figure 20** Water level exceedance curve relative to chart datum (-0.959 for AHD) Mallabula Point (1992 to 2011).

# 6 CONCEPTUAL COASTAL PROCESSES MODEL

Implementation of successful protection measures requires a comprehensive appreciation of the coastal processes to ensure that a design is selected that can work within the constraints of the local environment. Therefore, based on the outcomes of the investigation detailed above, coastal processes have been summarised in a conceptual model.

The longshore drift of sediment within Tanilba Bay is driven primarily by the wave climate. The wave climate is locally generated by the wind conditions within the inner estuary which varies seasonally according to the dominant wind directions and strengths. During the autumn, winter and for some of the spring the dominant wind direction which produce waves within Tanilba Bay is from the north-west, resulting in a longshore drift from west to east. During the summer and for some of the spring the dominant wind direction producing waves within Tanilba Bay is from the north-east, this results in a longshore drift from east to west. The net direction of longshore drift through the central area of the bay is from west to east as winds from the north-west dominate through the year. Conceptual plots showing the governing physical processes during summer and winter months are shown in **Figure 21** and **Figure 22**.

The evolution of the shoreline within Tanilba Bay is currently controlled by both the dominant wave conditions and the positions of the headlands at either end of the bay. The headlands act to fix the entrance into the bay and therefore control the wave conditions which enter the bay. Owing to the location of the headlands combined with the seasonally varying dominant wave directions within the bay (from the north-east and the north-west) the bay has been unable to reach a dynamic equilibrium.

The wider area of intertidal zone present in the centre of the bay is a result of the bay trying to adapt to the wave conditions from both directions. The equilibrium response of the bay is to realign to attempt to form two embayments, indicated in **Figure 23**. However, this cannot be achieved due to the soft nature of the foreshore sediments. The areas of the bay where the shoreline is attempting to realign to be in equilibrium with the two dominant seasonal wave directions are located where erosion issues are greatest. The introduction of hard protection in some areas of this zone to stabilise the foreshore has starved the adjacent areas of sediment supply exacerbating erosion, particularly adjacent to Tilligerry Habitat State Reserve.

The wide intertidal zone at the eastern side of the bay is a result of the net drift transporting material in this direction.

Stormwater drains or natural outlets are located consistently along the entire foreshore of Tanilba Bay. Outflows from these result in the formation of small deltas, accumulating material. The formation of the deltas hinders longshore sediment bypassing of these point on the foreshore by acting to stabilise the material in the deltas through shallowing and realignment of the foreshore and intertidal bathymetry. During a large catchment flow event, stormwater flows result in material being scoured from the region in front of the outlet/entrance and transported offshore and out of the foreshore sediment transport system onto the low tide terrace. The resultant scour hole is subsequently filled in by longshore transport during the following low catchment flow period. This cycle is a significant sediment loss mechanism for the foreshore at Tanilba Bay due to the absence of low energy swell waves to return this sediment from the low tide terrace.

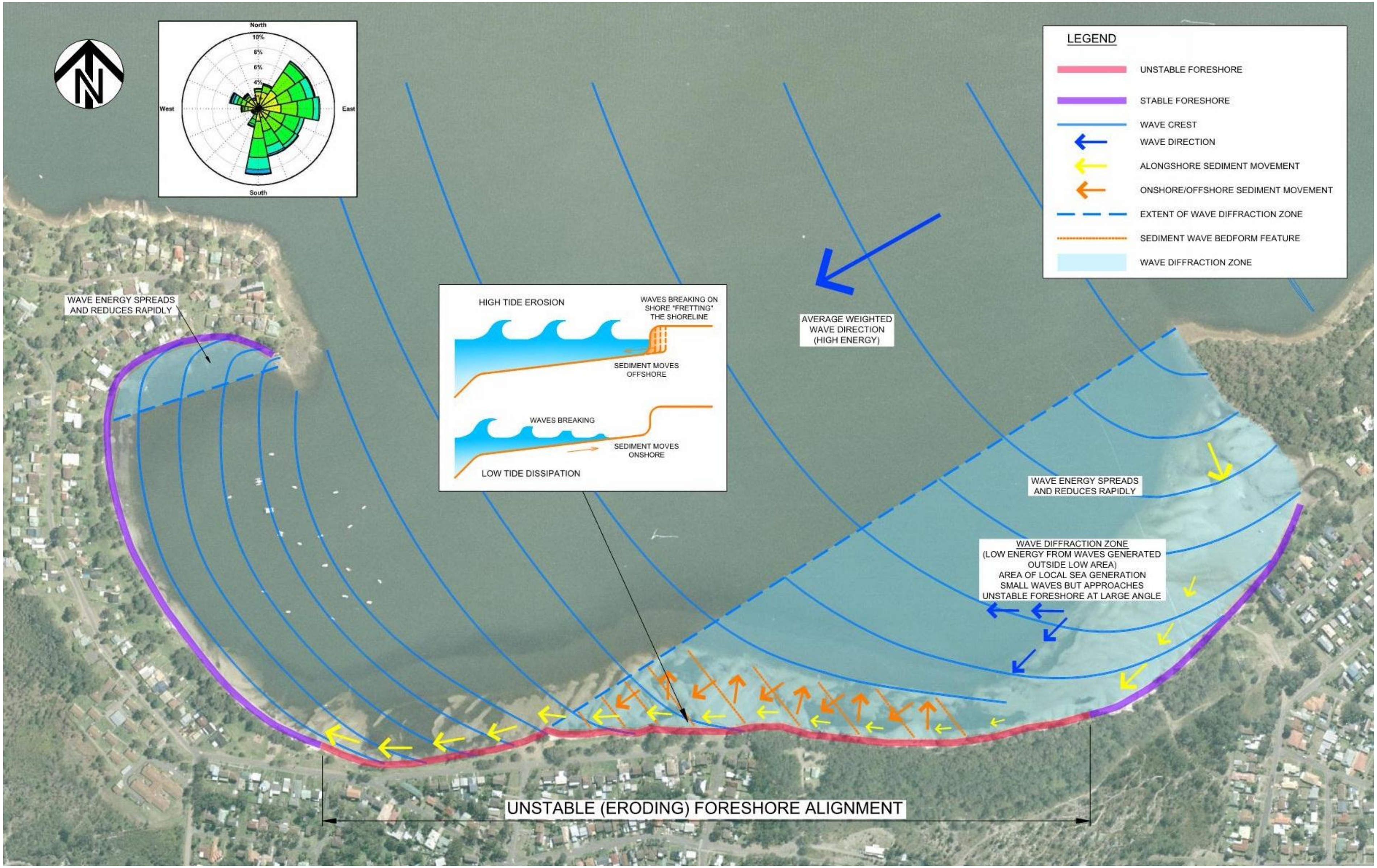



**Figure 21** Summer Conceptual Processes in Tanilba Bay

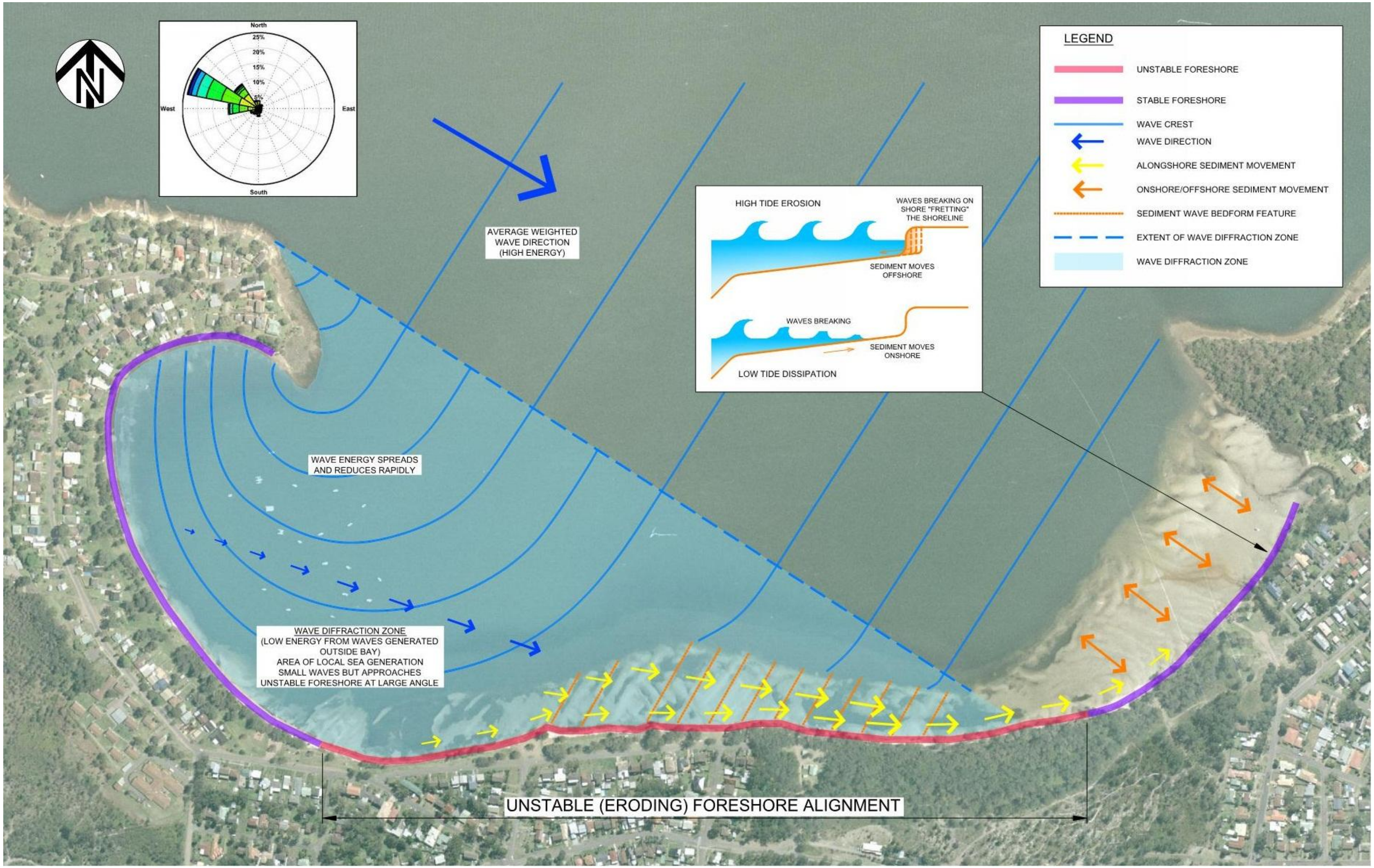



**Figure 22** Winter Conceptual Processes in Tanilba Bay

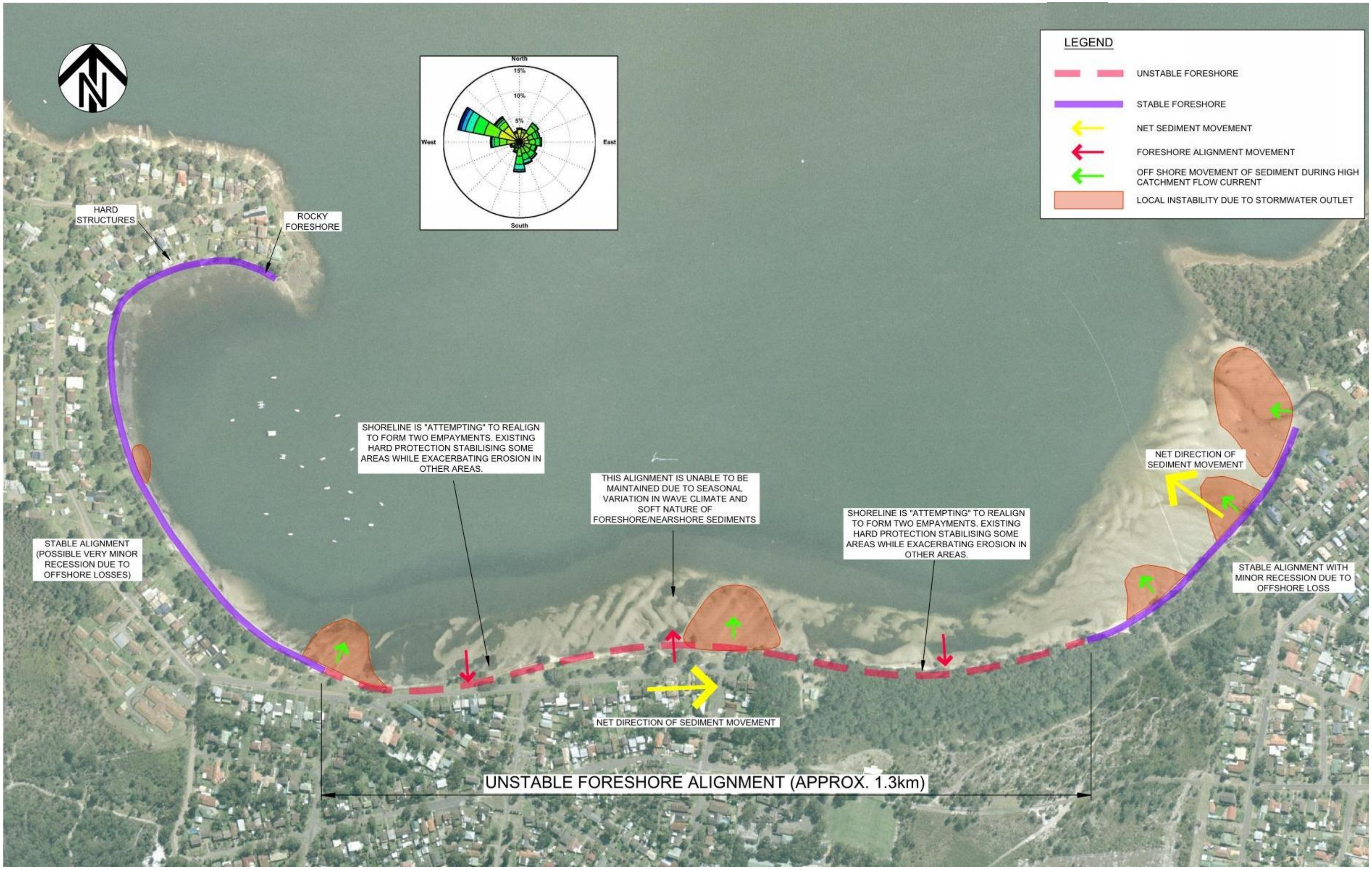



**Figure 23** Overall Conceptual Processes in Tanilba Bay

# 7 CONCEPT DESIGN OPTIONS

Based on review of existing information and data, coastal processes investigations and the subsequent development of a conceptual model; concept designs that are appropriate to manage the erosion mechanisms at the Tanilba Bay foreshore have been prepared. These concepts were developed taking into account the existing anthropogenic foreshore features, and where possible, using them as part of the erosion mitigation strategy.

## 7.1 Conceptual Design Options

Four conceptual management options, consisting of varying levels of environmental, social and economic implications were developed and are discussed in this section.

### 7.1.1 Option 1 – Bay Wide Holistic Concept

The Bay Wide Holistic Concept is a comprehensive management strategy that aims to address the erosion mechanisms of the entire Tanilba Bay foreshore. A combination of the following foreshore stabilisation approaches was included:

- restoration of vertical seawalls
- appropriately designed seawall (rock revetment) incorporating a vegetation berm
- periodic beach scraping and nourishment
- use of groynes to realign foreshore for increased stability of nourishment material
- low crested offshore breakwater and associated creation of tombolos to stabilise nourishment material

When viewing this section of the report**, Figure 24** should be referred to as it presents an overview plan of Option 1 and labels each erosion zone in an alphabetical order from west to east of the bay. Note that these zone labels remain consistent for all options.

Zone A - Foreshore stabilisation would involve placement of rock at a gradual slope immediately seaward of the existing seawall. The rock placement aims to dissipate wave energy and reduce wave reflection that may potentially pose erosion hazard to the adjacent foreshore. There are potential improvements to marine ecology habitat associated with the placement of the rock material.

Zone B –With the aim to manage stormwater related sediment loss mechanisms, a rock groyne up drift of the existing stormwater outlet, and beach scraping and nourishment of the foreshore to the west is proposed. It is expected that a groyne with a relatively small offshore extent would be sufficient to stabilise the nourishment material, thereby minimising the visual impact of the groyne.

In combination, the stormwater outlet could be formalised to include; hard protection of the foreshore to the east of the outlet (incorporated into the protection measures describe in Zone C), and modifying the location of the outlet. This may include setting it back in the foreshore reserve with an associated wider zone of spreading apron with rock energy dissipation (or settling basin).

Zone C - This is a priority area that exhibits evidence of significant erosion hazard, amenity and public safety degradation. Coastal processes investigation identified this area as having a naturally occurring net sediment deficit (see **Section 6**). Wave processes transport sediment away from this area either to the east or west (depending on the season) with minimal potential for replacement from updrift sources. Accordingly, recession of the foreshore is prevalent. Note: erosive mechanisms are mostly prevalent at higher water levels in the steeper portion of the foreshore profile.

Despite previous attempts of protection, erosion is ongoing in this area. Anthropogenic influences have exacerbated erosion in some locations. Piecemeal protection measures of various forms not designed or constructed to accepted coastal engineering standards, and the failure of these measures, has the impacted on foreshore areas behind and adjacent to degrading “structures”.

Proposed foreshore stabilisation would involve removal of the existing structures, regrading and development of a sloped revetment in the upper portion of the foreshore to mitigate erosion occurring at high water levels. This protection structure would incorporate a vegetation berm to enhance the aesthetic and environmental values of the area. A consolidated engineered design would stabilise the foreshore of this area and mitigate localised erosion where previous foreshore protection has been inadequate of non continuous.

Zone D - An approach that best manages the erosion mechanisms of this zone while significantly improving the recreational amenities in the foreshore area that is easily accessible by general public was required. The works would involve beach restoration including the removal of existing rocks, concrete rubble and fallen trees, regrading of the foreshore and construction of low crested breakwaters positioned in a strategic manner to dissipate wave energy and encourage formation and stabilisation of tombolo features. The formation of tombolos may need to be augmented by nourishment material and would realign the foreshore favourably to the incident wave climate and therefore reduce future erosion potential. The existing foreshore features such as a boat ramp and stormwater drain would be integrated into the design.

Based on the relatively low energy wave climate and shallow low tide terrace area of Tanilba Bay, it is expected that low crested breakwaters with relatively small footprint would achieve the design objectives, thereby minimising the visual and environmental impact of the breakwaters.

Zone E – This area of foreshore is backed by ecologically significant Tilligerry Habitat State Reserve (refer **Figure 24**). As discussed in **Section 6.4**, localised erosion is a significant issue in this area of the foreshore. In order to manage this, a similar low crested offshore breakwater approach to Zone D, combined with a series of groyne field down drift of the “borrow” holes discussed in **Section 3 and 5** is proposed. The groyne field would be designed such that it integrates the existing features such as a creek entrance and boat ramps, and would encourage realignment of the beach to a more favourable dynamic equilibrium. This would realign the foreshore favourably to the incident wave climate and therefore reduce future erosion potential An initial campaign of beach scraping and nourishment activities from the intertidal zone in Zone F would also be required to fill the created beach compartments and tombolo areas such that there is minimal foreshore readjustment to the structures.

Zone F –Erosion mitigation measures would involve a low crested rock revetment incorporating planting of littoral vegetation to stabilise the foreshore adjacent to public reserves areas (including those backed by residential properties). This would mitigate the high water level erosion of the foreshore escarpment.

### 7.1.2 Option 2 – Economised Bay Wide Concept

The Economised Bay Wide Budget Concept provides a management strategy adopting more economically efficient foreshore stabilisation measures than Option 1. A combination of the following foreshore stabilisation approaches was included:

- appropriately designed seawall (rock revetment) incorporating a vegetation berm
- periodic beach scraping and nourishment

- use of groynes to realign foreshore for increased stability of nourishment material (optional)

- low crested offshore breakwater and associated creation of tombolos to stabilise nourishment material

- regrading of the foreshore and stabilisation with cobble beach nourishment

When viewing this section of the report, **Figure 25** should be referred to as it presents an overview plan of Option 2.

Foreshore stabilisation measures for Zones C, D and E remain consistent with Option 1.

Zone E is included an optional in Option 2 considering there are no residential properties or critical infrastructure in this area (and has not been identified as a “Priority Area”), and the significant cost associated with implementing the concept option presented in Option 1. Implementation in this zone could be considered as part of a staged approach.

Zone F - Notwithstanding the high water level erosion occurring in this area, the wave energy driving the high tide erosion processes is relatively low and a very wide intertidal zone in front of this area may allow for implementation of a more softer management approach. As such, the revised proposed lower cost foreshore stabilisation for this zone involves foreshore restoration including regrading using a cobble stone beach and vegetation of the foreshore reserve areas.

Works in Zone A and B were omitted from Option 2 as the coastal processes investigation informed that this area has been relatively stable. This is likely due to the beach being favourably aligned to the summer wave energy environment of north easterly waves and protected from the winter north westerly energy. Furthermore the formation of the ebb tide delta at the outlet of the stormwater drain with subsequent realignment of the adjacent foreshore seems to be approaching a stable dynamic equilibrium providing stability to the foreshore to the west.

### 7.1.3 Option 3 – Property and Infrastructure Concept

The Property and Infrastructure Concept is a management strategy that is limited to providing erosion mitigation measures in the foreshore areas backed by residential property and critical infrastructure. A combination of the following foreshore stabilisation approaches was included:

- appropriately designed seawall (rock revetment) incorporating a vegetation berm

- artificial headlands and pocket beaches using existing material where possible

- regrading of the foreshore and stabilisation with cobble beach nourishment

When viewing this section of the report, **Figure 26** should be referred to as it presents an overview plan of Option 3.

Foreshore stabilisation measures for Zones C and F are consistent with Option 2.

It is proposed that Zone D erosion hazard be managed by adopting an economically efficient beach restoration approach. This involves removal of the existing rocks, concrete rubble and fallen trees, and compartmentalising several pocket beaches by formalising hard points (creation of artificial headlands) to contain the movement of sediment. The economic benefit of this approach is further enhanced by integrating the existing boat ramp and stormwater drain into the design strategy (e.g., these features would form the hard points). An initial campaign, as well as periodic, beach scraping and nourishment would be required if this approach was adopted.

Works in Zone A,B and E were omitted.

### 7.1.4 Option 4 – Priority Area Concept

The Priority Area Concept is a conceptual management strategy that is limited to providing erosion mitigation measures in the foreshore areas labelled “Priority Area” by Council’s Study Brief. A combination of the following foreshore stabilisation approaches was adopted:

- appropriately designed seawall (rock revetment)
- artificial headlands and pocket beaches using existing material where possible

When viewing this section of the report **Figure 27** should be referred to as it presents an overview plan of Option 4.

Foreshore stabilisation measure for Zones D is consistent with Option 3.

It is proposed that Zone C foreshore is stabilised adopting a typical seawall approach. This involves involve removal of the existing structures, regrading of the foreshore and a development of a formalised sloped rock revetment with backing vegetation landscaping.

Works in Zone A,B and E were omitted.

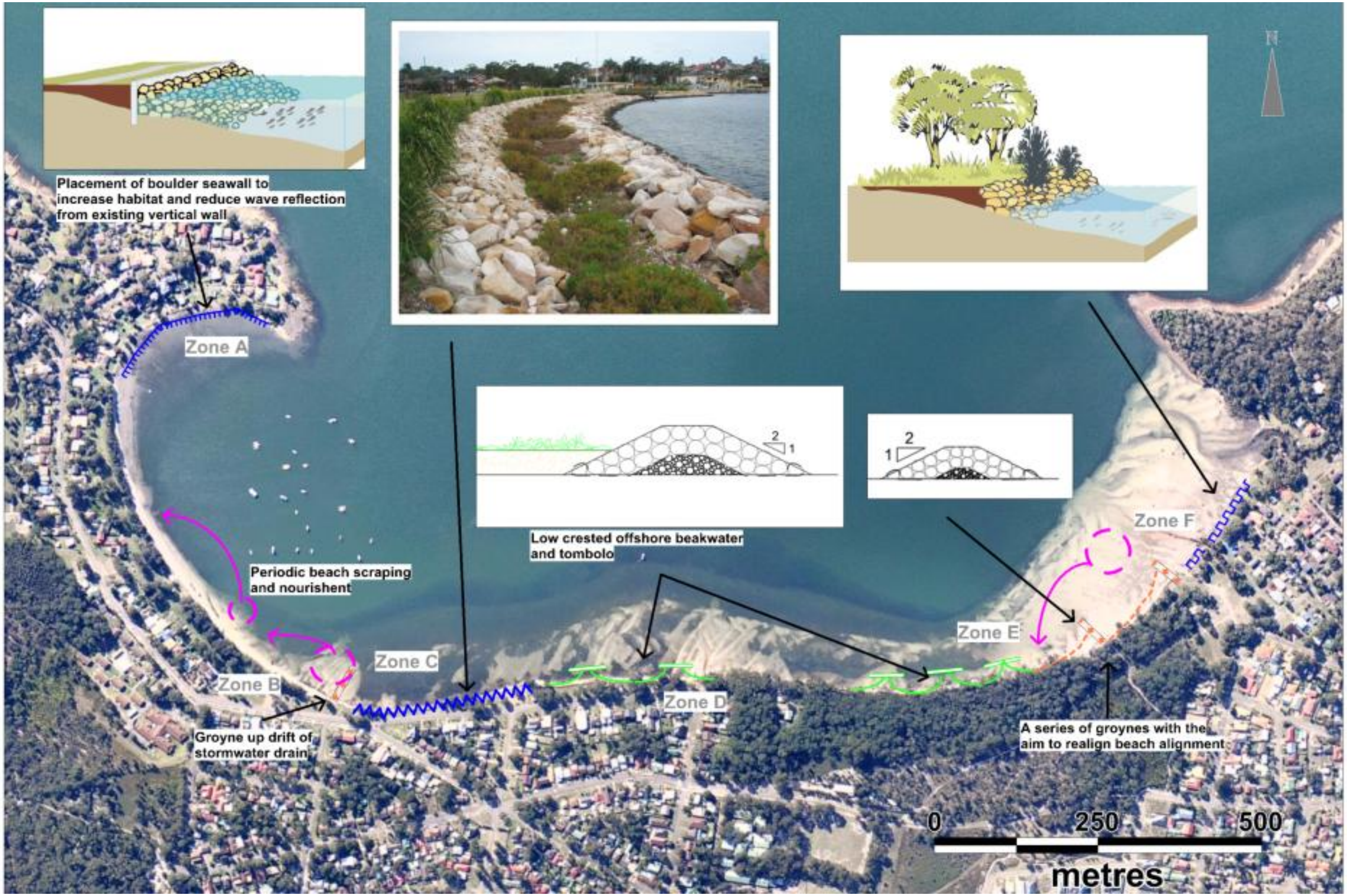



**Figure 24** Option 1, Bay Wide Holistic Concept (photograph/sketch source: DECCW 2009)

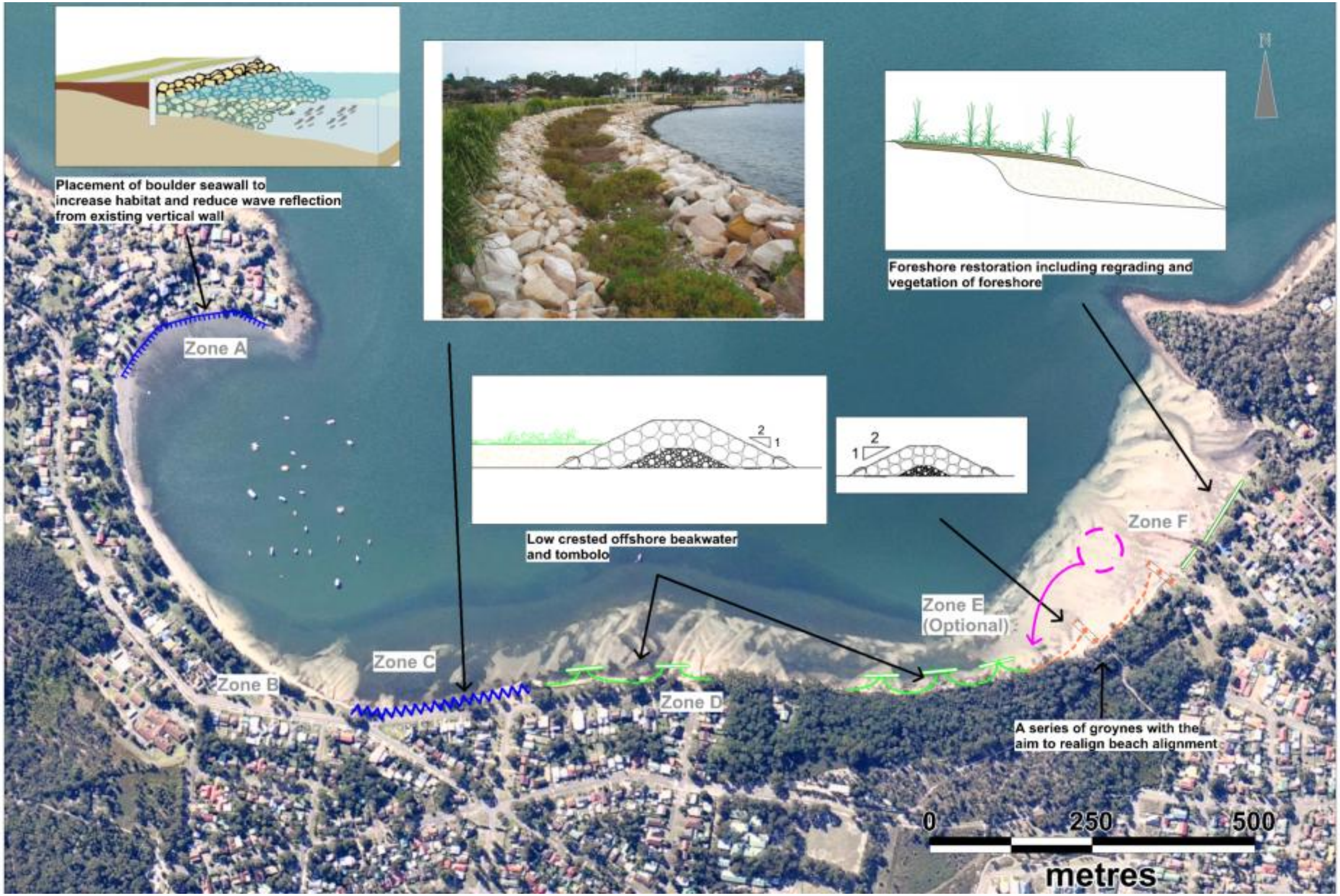



**Figure 25** Option 2, Bay Wide Budget Concept (photograph/sketch source: DECCW 2009)


**Figure 26** Option 3, Property & Infrastructure Concept (photo/sketch source: DECCW 2009)

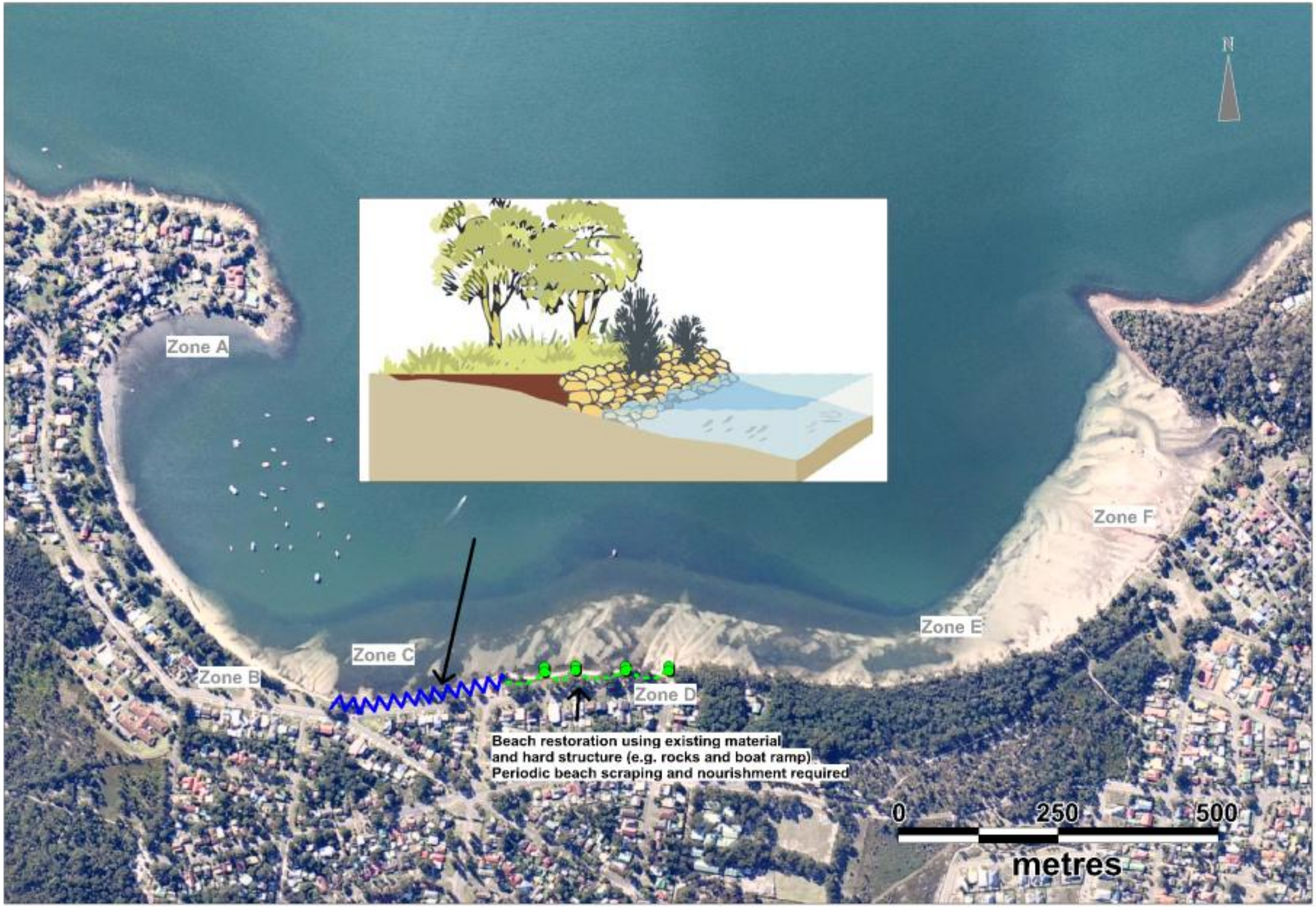



**Figure 27** Option 4, Priority Area Concept (photograph/sketch source: DECCW 2009)

## 7.2 Triple Bottom Line Assessment

To assist in the assessment and prioritising of management options **Table 12** presents a summary of each management option in terms of indicative construction costs and likely environmental and social outcomes.

A relative measure of social and environmental outcomes is provided.

For each zone, environmental and social implications are also described for the "do nothing" scenario for relative comparison.

**Table 12** Triple Bottom Line Assessment of Management Options

| Zone | Option | Indicative Cost (+/- 50%) | Environmental Implications (√ benefits and X impacts) | Social / recreational Implications (√ benefits and X impacts) |
|---|---|---|---|---|
| A | **1 (restoration of vertical seawall)** | $187,000 | √ Reduce wave reflections from vertical walls reducing scour and sediment movement from adjacent foreshore (moderate)<br>√ Potential improvement of marine ecology by providing habitat (low)<br>X Potential to adversely impact existing habitat muddy flats and seagrass (low) | √ Potential improvement in marine habitat (low)<br>√ Possible that sandy beach (similar to Zone B) would recover, providing some beach amenity (moderate)<br>X Placed rock may have adverse impacts on visual amenity particularly if movement occurs. (low)<br>X Private land owners may prefer to maintain the status quo and therefore opposed the plan. (moderate) |
| | **2, 3, 4 (do nothing)** | N/A | X Wave reflections from vertical walls continue to affect adjacent foreshore (moderate) | √ No public spending required (low)<br>√ Status quo is maintained and is unlikely to be opposed by private land owners (low)<br>X Vertical seawalls and mudflats provide no linkage between public spaces. (low) |
| B | **1 (groyne and nourishment)** | $149,000 | √ Prevent removal of sediment offshore during large stormwater flow events (significant)<br>X Disturbance during construction/nourishment works (low)<br>X Potential difficulties associated with approvals process due to negative perception of groyne structures (moderate) | √ Increase beach width adds to beach amenity (moderate)<br>√ Nourished beach would provide greater storm protection to foreshore reserve (moderate)<br>X Visual impact of groyne (low)<br>X Beach access around groyne structure (low)<br>X Disturbance during construction/nourishment works (low) |
| | **2, 3, 4 (do nothing)** | N/A | √ Status quo is retained with a relatively stable foreshore with no disturbance (low)<br>X Loss of beach sediment offshore during large stormwater flow events (significant) | √ No public spending required (low)<br>√ Existing level of foreshore protection remains (low) |
| C | **1, 2, 3 (seawall with vegetation berm and formalised access points)** | $690,000 | √ Improved terrestrial and intertidal habitat / ecology (significant)<br>√ Reduce toe scour relative to existing *Ad hoc* seawalls (low)<br>√ Removal of existing degraded structures (significant)<br>√ Consistent foreshore treatment (moderate)<br>√ Reduced turbidity (low)<br>X Possible end effects of seawall on the foreshore to the west (low – existing stormwater outlet already having this impact) | √ Stabilised foreshore could encourage public to access the amenities along the foreshore reserve (low)<br>√ Protection of critical infrastructure (significant)<br>√ Formalized safe access (moderate)<br>√ Removal of debris from intertidal area<br>X Disturbance during construction / nourishment works (moderate) |

| Zone | Option | Indicative Cost (+/- 50%) | Environmental Implications (√ benefits and X impacts) | Social / recreational Implications (√ benefits and X impacts) |
|---|---|---|---|---|
| C | **4 (typical seawall with formalised access points)** | $450,000 | √ Reduce toe scour relative to existing *Ad hoc* seawalls (low)<br>√ Improved terrestrial habitat / ecology (low)<br>√ Removal of existing degraded structures (significant)<br>√ Consistent foreshore treatment (moderate)<br>√ Reduced turbidity (low)<br><br>X Possible end effects of seawall on the foreshore to the west (low – existing stormwater outlet already having this impact) | √ Stabilised foreshore could encourage public to access the amenities along the foreshore reserve (low)<br>√ Protection of critical infrastructure (significant)<br>√ Formalized safe access (moderate)<br>√ Removal of debris from intertidal area<br><br>X Disturbance during construction / nourishment works (moderate) |
| | **(do nothing)** | N/A | √ No construction impacts (low)<br><br>X Scour of sandy sediment in front of existing structures (moderate)<br>X Loss of intertidal habitat/ecology (moderate)<br>X increased turbidity from erosion of terrestrial material (moderate) | √ No public spending required (moderate)<br><br>X Risk to critical infrastructure (sewer main, roads) due to localized erosion where *Ad hoc* protection works have impacted on adjacent foreshore areas (significant)<br>X Public safety concerns with unstable non engineered structures (moderate)<br>X Visual and recreational amenity impacted by debris and rocks from failing *Ad hoc* protection works (moderate)<br>X Impeded access (moderate)<br>X Visual amenity impacted by rubbish tip appearance of foreshore (moderate) |
| D | **1,2 (offshore breakwater and tombolo)** | $944,000 | √ Stabilised foreshore would mitigate erosion hazard and future threat to critical infrastructure (moderate)<br>√ Potential improvement of marine ecology by providing habitat (low)<br>√ Removal of existing degraded structures (moderate)<br><br>X Impacts on marine ecology (e.g. seagrass) (moderate)<br>X Visual impact of breakwaters (low)<br>X Potential difficulties associated with approvals process due to negative perception of structures within Marine Park (moderate) | √ Improved recreational amenities by providing additional vegetated foreshore reserve area (tombolos)<br><br>X High Cost – negative public appeal (moderate) |

| Zone | Option | Indicative Cost (+/- 50%) | Environmental Implications (√ benefits and X impacts) | Social / recreational Implications (√ benefits and X impacts) |
|---|---|---|---|---|
| D | **3, 4 (pocket beach/artificial headlands)** | $162,000 | √ Management of existing erosion hazard<br>√ Restore degraded foreshore condition<br>√ Lower cost option than offshore breakwaters<br><br>X Not as effective as offshore breakwaters<br>X Visual impact of artificial headlands<br>X Potential difficulties associated with approvals process due to negative perception of structures within Marine Park (moderate) | √ Pocket beaches would improve beach access for general public<br><br>X beaches may require periodic nourishment with ongoing costs (moderate)<br>X periodic nourishment and associated costs may be perceived by the public as failure of the works (moderate) |
| | **(do nothing)** | N/A | √ No construction impacts (low)<br><br>X Scour of sandy sediment in front of existing structures (moderate)<br>X Loss of intertidal habitat/ecology (moderate)<br>X increased turbidity from erosion of terrestrial material (moderate) | √ No public spending required (moderate)<br><br>X Risk to critical infrastructure (sewer main, roads) due to localized erosion where *Ad hoc* protection works have impacted on adjacent foreshore areas (significant)<br>X Public safety concerns with unstable non engineered structures (moderate)<br>X Visual and recreational amenity impacted by debris and rocks from failing *Ad hoc* protection works (moderate)<br>X Impeded access (moderate)<br>X Visual amenity impacted by rubbish tip appearance of foreshore (moderate) |
| E | **1 (offshore breakwater and groyne fields with associated beach scraping and foreshore nourishment)** | $1,050,000 | √ Mitigate existing erosion hazard to infrastructure (moderate)<br>√√ Prevent loss of mature trees and saltwater ingress at Tilligerry Habitat State Reserve (very significant)<br><br>X Impacts on marine ecology (e.g. seagrass)<br>X Visual impact of breakwaters and groynes (moderate)<br>X Possible difficulties associated with approvals process due to negative perception of structures and scraping/nourishment activities within the Marine Park (significant) | √/X Polarized views within the community regarding the spending of relatively significant amounts of public funds to protect environmental area (significant – both ways)<br><br>X High Cost – negative public appeal (moderate) |
| | **2,3,4 (do nothing)** | N/A | √ No work required in environmentally sensitive area<br><br>X Continued erosion of foreshore and risk to infrastructure (moderate)<br>XX Loss of mature trees and potential saltwater ingress at Tilligerry Habitat State Reserve (very significant) | √/X Polarized views within the community regarding **NOT** spending public funds to protect environmental area (significant – both ways)<br><br>√ No public spending required (moderate) |

| Zone | Option | Indicative Cost (+/- 50%) | Environmental Implications (√ benefits and X impacts) | Social / recreational Implications (√ benefits and X impacts) |
|---|---|---|---|---|
| F | **1 (typical seawall and vegetation)** | $225,000 | √ Mitigate high tide erosion (low)<br>√ Improve terrestrial and intertidal ecology (low)<br><br>X Potential loss of mature trees | √ Improve visual amenity (moderate)<br><br>X Reduced access to the intertidal zone moderate) |
| | **2, 3 (foreshore restoration)** | $45,000 | √ Manage high tide erosion (low)<br>√ Improve terrestrial and intertidal ecology (low)<br><br>X Potential loss of mature trees (moderate) | √ Improve visual amenity (moderate)<br>√ Restored foreshore would improve beach access (low)<br><br>X May require maintenance nourishment with associated ongoing costs and negative public perception (moderate) |
| | **4 (do nothing)** | N/A | X Continued recession due to high tide erosion (low) | √ No public spending required (low) |

## 7.3 Summary of Conceptual Options

The concept options for each zone are compared and assessed with respect to economic, environmental and social/recreational implications are presented in **Table 12**. A range of options were developed, to enable Council to assess and select the most feasible concept option that can be presented to the Tanilba Bay community. Selection of preferred option will take into account Council's funding requirements, priorities in preserving the environmental functions and accommodating for the needs of key stakeholders in Tanilba Bay.

A total indicative construction cost for each option is as follows:

- Option 1, Bay Wide Holistic - ($ 3,245,000)
- Option 2, Bay Wide Budget - ($ 1,866,000)
- Option 3, Property and Infrastructure Based - ($ 1,084,000)
- Option 4, Priority Area - ($ 610,000)

Note : this costs are based on conceptual designs only and should only be considered indicative of relative magnitude of costs. A contingency of +/- 50% should be considered. For budgetary purposes construction estimates should be undertaken based on higher level detailed designs, once developed.

# 8 CONSULTATION

Following development and assessment of the conceptual management options outlined in **Section 7 ,** targeted consultation with relevant stakeholders was undertaken to establish a preferred management strategy to proceed to the detailed design stage of the project.

## 8.1 Presentation to Committee

The existing erosion impacts, prevalent coastal processes and proposed conceptual management options were detailed in a presentation to the Port Stephens / Myall Lakes Coastal Zone Management Committee (PSMLCZMC) at the PSMLCZMC meeting on the 9th November 2011. This included discussion on the technical feasibility of all the options, the environmental impacts and/or benefits and the relative indicative costing (based on conceptual designs).

At this meeting it was indicated that the Committee concurred that the erosion required the implementation of management intervention and that the implementation of Option 4 with the variation of incorporating an “environmental” seawall was to be considered the priority.

## 8.2 Agency Workshop

Due to poor representation of key government agency stakeholders at the committee meeting on the 9th November 2011, an additional workshop was convened. This workshop included representation from the following organisations:

- NSW Marine Park Authority (MPA)
- NSW Office of Environment and Heritage (OEH)
- Council
- SMEC

At the meeting outcomes of the coastal processes investigation and concept design options study were discussed to obtain in principal government agency acceptance, or otherwise, of proposed management options. Key outcomes of this workshop included the following:

- Use of an environmental seawall concept gained in principle acceptance from MPA and OEH.
- Groyne, offshore breakwater structures and artificial headlands were not favoured by MPA on the basis of interrupting the natural flow of sediment in the Bay.
- Offshore low tide terrace sand scraping for nourishment was not favoured by MPA. However, gained in principle technical acceptance from OEH to be considered on its merits during the approval process, if required.
- Sand nourishment using sand from an external source gained in principle acceptance from MPA and OEH to be considered on its merit during the approval process, if an opportunistic source became available.
- MPA approval licences remain current for a period of one year only.
- Protection of habitat area behind the Zone E foreshore should be considered for protection through beach nourishment due to its high ecological value.

## 8.3 Local Community Information Session

A local community information session was held on the 9th February 2012. The information session was to present the outcomes of the coastal processes investigation and concept design options study and give local community members and opportunity to provide feedback. Key outcomes of this workshop included the following:

- Discussion regarding access across the proposed environmental seawall. Suggestions for the location of these access ways where requested by Council officers present and several feedback forms were received outlining community preferences.

- Concerns were raised about wave and tide action dispersing rocks from the seawall along the foreshore. Currently, small rocks from *Ad hoc* and community based protection works are strewn along the foreshore and low tide terrace area with negative aesthetic, recreational amenity and public safety impacts.

Outcomes of the local community information session are to be incorporated into detailed design of the final foreshore stabilisation strategy.

## 8.4 Preferred Management Option

On the basis of the outcomes of the coastal processes investigation and concept design options study in conjunction with subsequent consultation the following plan for progressing the design and implementation of the foreshore stabilisation strategy was agreed:

- Detailed design to be developed and documented for an environmental seawall along Zone C and pocket beaches for Zone D. Subsequent construction of designs.

- Sand nourishment concepts plans to be produced for Zone E, to be developed further by Council if and when an appropriate external sand source becomes available.

- Foreshore stabilisation concepts for Zone F to be produced for future reference and detailing by Council when funding available.

## 8.5 Grant Funding Application

To assist with project financial planning Council officers requested that SMEC produce a construction cost estimate based on more detailed designs of the preferred management option for Zone C and Zone D. SMEC developed detailed designs of the two foreshore stabilisation treatments to conduct the cost estimate for Council's grant application as requested.

The construction cost was estimated at $1.6M (including 30% contingency) and was provided to Council offices for use in a grant funding application.

The feedback received from Council following the delivery of this construction cost estimate was that Council was only able to provide $200,000 funding for implementation of the project. If Council where successful in its application for 50/50 grant funding for the project, the total proposed project budget for implementation would be $400,000.

## 8.6 Low Cost Alternative Design

The proposed project budget discussed in **Section 8.5** was significant less than the construction cost estimate for the first component of the proposed foreshore stabilisation strategy.  Accordingly, a low cost alternative design strategy was requested by Council.  To assist the development of alternative designs for Zone C and D a further site visit and agency discussion was conducted.  Key outcomes from discussion on site were:

- MPA representative reiterated that groynes or artificial headlands were not favoured. However, formalisation of the foreshore with a rock revetment where *Ad hoc* structures existed and where failing was considered acceptable.

- Existing features of attempted foreshore protection works were identified that could be incorporated into a retrofitted engineered seawall design.

- Staging of implementation to meet budget constraints would be necessary.

# 9 FORESHORE STABILISATION STRATEGY

A foreshore stabilisation strategy that revised the preferred management options discussed in **Section 8.4** due to budgetary constraints was developed.

Considering previous work which identified the cost breakdown of elements of the preferred option a staged foreshore stabilisation strategy was agreed.. General arragnements plans and typical cross sections for each stage were provided to Council.

The staged forshore stabilisation strategy incorporated:

- Stage 1 – To be put forward for funding and implementation. Detailed design to be developed and documented for a sloped rock revetment seawall (incorporating pockets of vegetated revetment and utilising existing structures where possible) along Zone C. This design would:
    - consider the use and/or modification of existing protection works and materials (where possible) to upgrade foreshore protection works to acceptable engineering standard.
    - be optimised to consider anticipated funding allocation
    - include a staging plan that prioritised work location to anticipate possible funding shortfall
    - include regular formalised access points along the protected foreshore to address community concerns (refer to **Section 8.3** )
- Stage 2 – To be considered for future funding. Detailed design to be developed and documented for an optimised sloped rock revetment seawall with incorporated pocket beaches along Zone D.
- Stage 3 - Sand nourishment concepts plans to be produced for Zone E, to be developed further by Council, if and when an appropriate external sand source becomes available.
- Stage 4 - Foreshore stabilisation concepts for Zone F to be produced for future reference, detailing and implementation by Council when funding is available.

## 9.1 Limitations

As a consequence of not being a holistic approach the revised foreshore stabilisation strategy described above has the following limitations:

- Potential end effects at the western end of Zone C (design has attempted to mitigate any increased impact by ending the sloped rock revetment structure at an existing hard point along the foreshore. i.e. the stormwater outlet). Further localised treatment may be required.
- Periodic maintenance nourishment of pocket beaches in Zone D may be necessary as the use of foreshore revetment in place of offshore breakwaters and/or groyne structures would be not as effective in containing sediment in the beach compartments.
- Nourishment of Zone E may be a short term fix as it does not address the cause of erosion, only treats the symptoms. Accordingly, regular maintenance nourishment may be required. (The use of offshore breakwaters to mitigate the impacts of increased wave climate resulting from “borrow” holes and groynes to realign the foreshore would increase the effectiveness of nourishment). The use of very coarse sand (larger than native) or cobbles with a backing low crested revetment may be an alternative if offshore/cross-shore structures are not to be used.

# 10 REFERENCES


Willing Partners Geomarine, 1997. Tanilba Bay Erosion Management Study. Project No. 3632

Umwelt, 2009. Living on the Edge – A Foreshore Management Plan for Port Stephens. Report No. 2034/R01/V4

Umwelt, 2000. Port Stephens and Myall Lakes Estuary Management Plan. Report No. 1287/R04/V2

Hashimoto, T.R. & Troedson, A.L., 2008. *Nelson Bay 1:100 000 and 1:25 000, Coastal Quaternary Geology Map Series.* Geological Survey of New South Wales, Maitland.

Glamore, W.C., 2008. A Decision Support Tool for Assessing the Impact of Boat Wake Waves on Inland Waterways. 20pp.

Kamphius, J.W., 1991. Alongshore sediment transport rate. *Journal of Waterways, Port, Coastal and Ocean Engineering,* ASCE, 117(6), 624-641

Thom, B.G. 1992. Coastal geomorphology and quaternary geology of the Port Stephens-Myall Lakes area. 407pp.

Department of Environment, Climate Change and Water (DECCW)., 2009. Environmentally Friendly Seawalls, A Guide to Improving the Environmental Value of Seawalls and Seawall-lined Foreshores in Estuaries

# APPENDIX A – SEDIMENT ANALYSIS RESULTS

## TANILBA BAY – SEDIMENT DESCRIPTION (optical estimations)

| SAMPLE | GRAVEL | SAND | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Rel. Size | Shape | Sorting | Shell % | Quartz % | Others# | $d_{50}$ microns |
| | | | | | | | | |
| TB01 | - | Fine | sa-sr | very well | - | 100 | - | 326 |
| TB02 | - | Fine | sa-sr | well | - | 100 | - | 333 |
| TB05 | - | Fine | sa-sr | Very well | - | 100 | - | 388 |
| TB07 | - | Fine | sr-r | well | - | 100 | - | 322 |
| TB08 | RF to10mm | Fine | sr-r | Very well | - | 100 | - | 322 |
| TB11 | - | Fine | sa-sr | well | | 100 | - | 364 |

**LEGEND**
In all instances shape factors and to a certain extent size factors apply to the terrigenous fraction of the sands. Shell is usually found in the coarser fractions and is generally angular mollusc..

Q – quartz
Sh - shell
RF – rock fragment
fp – faecal pellet
sl – furnace? ash
anthro – anthropogenic material including glass, paint, metal, plastic, fibro etc
co - coal
a - angular
sa – sub-angular
sr – sub-rounded
r – rounded
mod – moderately
v – very
Fe – iron oxide stained
-CO3 – less shell (removed by dissolution with dilute hydrochloric acid)
* - samples that have been analysed for grain-size distribution, $\mathbf{d_{50}}$ has been calculated for these sediments
- - indicate absence of component

## SAMPLE STATISTICS

SAMPLE IDENTITY: **TB01** ANALYST & DATE: EF, May 2012

SAMPLE TYPE: Unimodal, Very Well Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Very Well Sorted Medium Sand

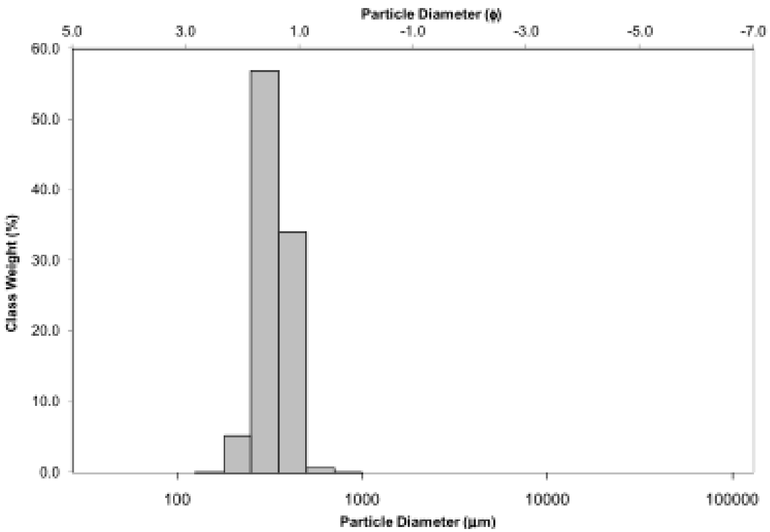
| | μm | φ |
|---|---|---|
| MODE 1: | 302.5 | 1.747 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 257.2 | 1.131 |
| MEDIAN or $D_{50}$: | 325.8 | 1.618 |
| $D_{90}$: | 456.6 | 1.959 |
| $(D_{90} / D_{10})$: | 1.776 | 1.732 |
| $(D_{90} - D_{10})$: | 199.5 | 0.828 |
| $(D_{75} / D_{25})$: | 1.401 | 1.362 |
| $(D_{75} - D_{25})$: | 112.7 | 0.487 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 0.8% |
| SAND: | 100.0% | MEDIUM SAND: | 94.0% |
| MUD: | 0.0% | FINE SAND: | 5.2% |
| | | V FINE SAND: | 0.0% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic μm | Geometric μm | Logarithmic φ | Geometric μm | Logarithmic φ | Description |
| MEAN ($\bar{x}$): | 343.9 | 331.9 | 1.591 | 334.3 | 1.581 | Medium Sand |
| SORTING ($\sigma$): | 71.08 | 1.224 | 0.291 | 1.247 | 0.319 | Very Well Sorted |
| SKEWNESS ($Sk$): | 0.815 | 0.130 | -0.130 | 0.161 | -0.161 | Coarse Skewed |
| KURTOSIS ($K$): | 5.054 | 3.098 | 3.098 | 0.809 | 0.809 | Platykurtic |

## GRAIN SIZE DISTRIBUTION




## SAMPLE STATISTICS

SAMPLE IDENTITY: **TB02** ANALYST & DATE: EF, May 2012

SAMPLE TYPE: Unimodal, Well Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Well Sorted Medium Sand

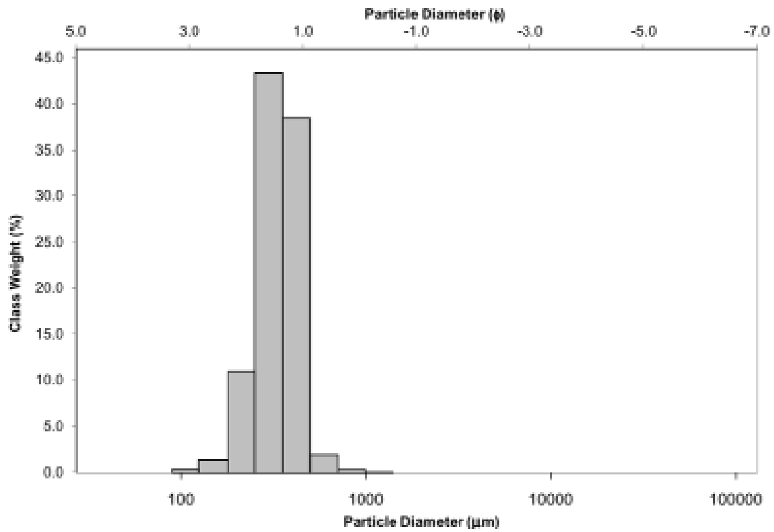
| | μm | φ |
|---|---|---|
| MODE 1: | 302.5 | 1.747 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 230.0 | 1.094 |
| MEDIAN or $D_{50}$: | 333.4 | 1.585 |
| $D_{90}$: | 468.5 | 2.120 |
| $(D_{90} / D_{10})$: | 2.036 | 1.938 |
| $(D_{90} - D_{10})$: | 238.4 | 1.026 |
| $(D_{75} / D_{25})$: | 1.496 | 1.453 |
| $(D_{75} - D_{25})$: | 136.3 | 0.581 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 2.4% |
| SAND: | 100.0% | MEDIUM SAND: | 84.8% |
| MUD: | 0.0% | FINE SAND: | 12.3% |
| | | V FINE SAND: | 0.4% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.1% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic μm | Geometric μm | Logarithmic φ | Geometric μm | Logarithmic φ | Description |
| MEAN ($\bar{x}$): | 348.2 | 330.7 | 1.597 | 336.2 | 1.573 | Medium Sand |
| SORTING ($\sigma$): | 95.33 | 1.317 | 0.398 | 1.317 | 0.397 | Well Sorted |
| SKEWNESS ($Sk$): | 1.233 | -0.423 | 0.423 | -0.054 | 0.054 | Symmetrical |
| KURTOSIS ($K$): | 10.28 | 4.479 | 4.479 | 0.923 | 0.923 | Mesokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **TB05** ANALYST & DATE: EF, May 2012

SAMPLE TYPE: Unimodal, Very Well Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Very Well Sorted Medium Sand

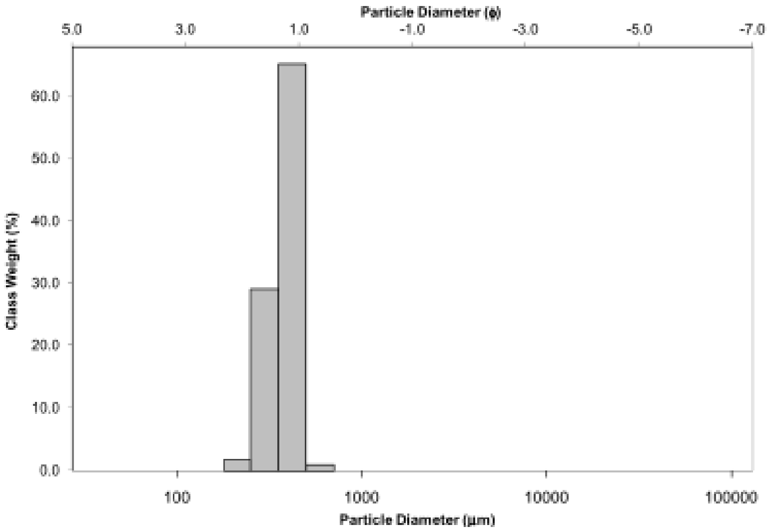
| | μm | φ |
|---|---|---|
| MODE 1: | 427.5 | 1.247 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 274.8 | 1.066 |
| MEDIAN or $D_{50}$: | 388.9 | 1.363 |
| $D_{90}$: | 477.5 | 1.864 |
| ($D_{90}$ / $D_{10}$): | 1.738 | 1.748 |
| ($D_{90}$ - $D_{10}$): | 202.7 | 0.797 |
| ($D_{75}$ / $D_{25}$): | 1.354 | 1.371 |
| ($D_{75}$ - $D_{25}$): | 115.5 | 0.437 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 1.0% |
| SAND: | 100.0% | MEDIUM SAND: | 97.2% |
| MUD: | 0.0% | FINE SAND: | 1.8% |
| | | V FINE SAND: | 0.0% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic μm | Geometric μm | Logarithmic φ | Geometric μm | Logarithmic φ | Description |
| MEAN ($\bar{x}$): | 387.5 | 375.8 | 1.412 | 375.7 | 1.412 | Medium Sand |
| SORTING ($\sigma$): | 65.52 | 1.200 | 0.263 | 1.233 | 0.302 | Very Well Sorted |
| SKEWNESS ($Sk$): | -0.459 | -0.854 | 0.854 | -0.251 | 0.251 | Fine Skewed |
| KURTOSIS ($K$): | 3.080 | 3.073 | 3.073 | 0.861 | 0.861 | Platykurtic |

## GRAIN SIZE DISTRIBUTION




## SAMPLE STATISTICS

SAMPLE IDENTITY: **TB07** ANALYST & DATE: EF, May 2012

SAMPLE TYPE: Unimodal, Well Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Well Sorted Medium Sand

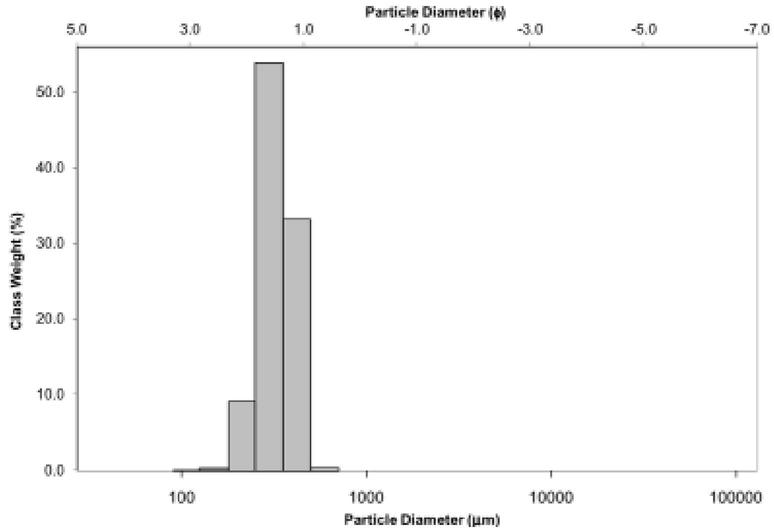
| | μm | φ |
|---|---|---|
| MODE 1: | 302.5 | 1.747 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 250.9 | 1.139 |
| MEDIAN or $D_{50}$: | 322.0 | 1.635 |
| $D_{90}$: | 453.9 | 1.995 |
| ($D_{90}$ / $D_{10}$): | 1.809 | 1.751 |
| ($D_{90}$ - $D_{10}$): | 203.0 | 0.855 |
| ($D_{75}$ / $D_{25}$): | 1.416 | 1.369 |
| ($D_{75}$ - $D_{25}$): | 114.6 | 0.502 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 0.4% |
| SAND: | 100.0% | MEDIUM SAND: | 90.2% |
| MUD: | 0.0% | FINE SAND: | 9.3% |
| | | V FINE SAND: | 0.1% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic μm | Geometric μm | Logarithmic φ | Geometric μm | Logarithmic φ | Description |
| MEAN ($\bar{x}$): | 337.7 | 324.9 | 1.622 | 329.7 | 1.601 | Medium Sand |
| SORTING ($\sigma$): | 72.49 | 1.245 | 0.317 | 1.279 | 0.355 | Well Sorted |
| SKEWNESS ($Sk$): | 0.278 | -0.305 | 0.305 | 0.059 | -0.059 | Symmetrical |
| KURTOSIS ($K$): | 2.600 | 3.325 | 3.325 | 0.952 | 0.952 | Mesokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **TB08** ANALYST & DATE: EF, May 2012

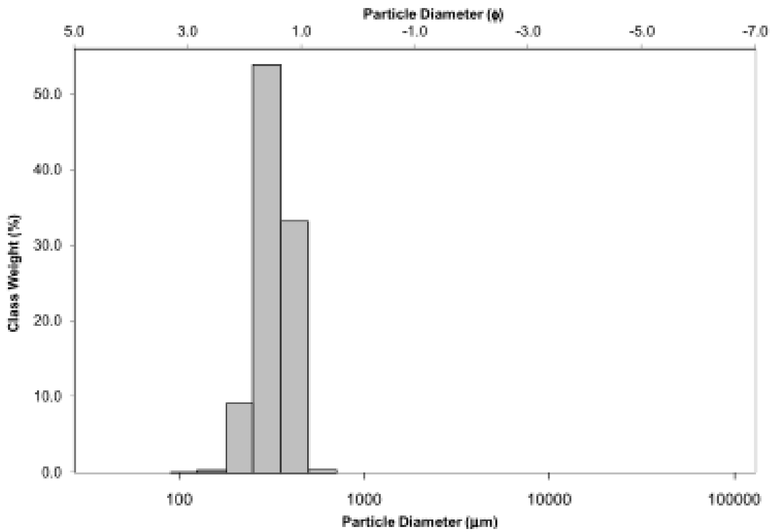
SAMPLE TYPE: Unimodal, Well Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Well Sorted Medium Sand

| | μm | φ | GRAIN SIZE DISTRIBUTION | | | |
|---|---|---|---|---|---|---|
| MODE 1: | 302.5 | 1.747 | GRAVEL: | 0.0% | COARSE SAND: | 0.4% |
| MODE 2: | | | SAND: | 100.0% | MEDIUM SAND: | 90.2% |
| MODE 3: | | | MUD: | 0.0% | FINE SAND: | 9.3% |
| $D_{10}$: | 250.9 | 1.139 | | | V FINE SAND: | 0.1% |
| MEDIAN or $D_{50}$: | 322.0 | 1.635 | V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| $D_{90}$: | 453.9 | 1.995 | COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| $(D_{90} / D_{10})$: | 1.809 | 1.751 | MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| $(D_{90} - D_{10})$: | 203.0 | 0.855 | FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| $(D_{75} / D_{25})$: | 1.416 | 1.369 | V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| $(D_{75} - D_{25})$: | 114.6 | 0.502 | V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic μm | Geometric μm | Logarithmic φ | Geometric μm | Logarithmic φ | Description |
| MEAN ($\bar{x}$): | 337.7 | 324.9 | 1.622 | 329.7 | 1.601 | Medium Sand |
| SORTING ($\sigma$): | 72.49 | 1.245 | 0.317 | 1.279 | 0.355 | Well Sorted |
| SKEWNESS ($Sk$): | 0.278 | -0.305 | 0.305 | 0.059 | -0.059 | Symmetrical |
| KURTOSIS ($K$): | 2.600 | 3.325 | 3.325 | 0.952 | 0.952 | Mesokurtic |

## GRAIN SIZE DISTRIBUTION




## SAMPLE STATISTICS

SAMPLE IDENTITY: **TB011** ANALYST & DATE: EF, Feb 2012

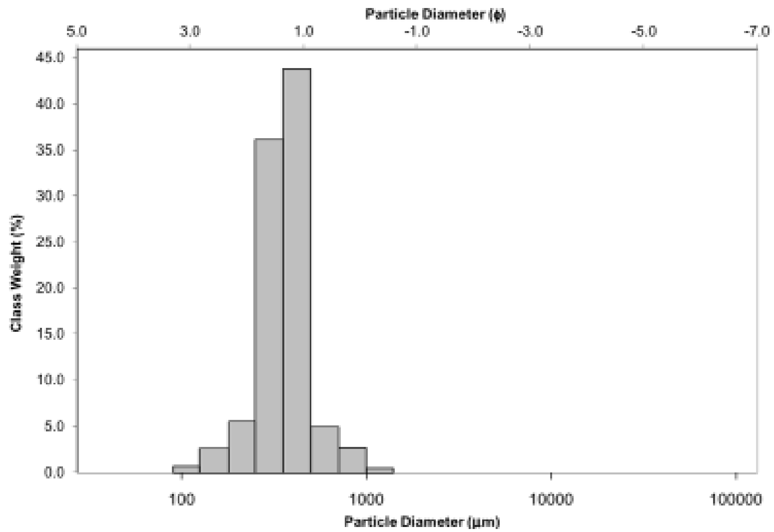
SAMPLE TYPE: Unimodal, Well Sorted TEXTURAL GROUP: Sand

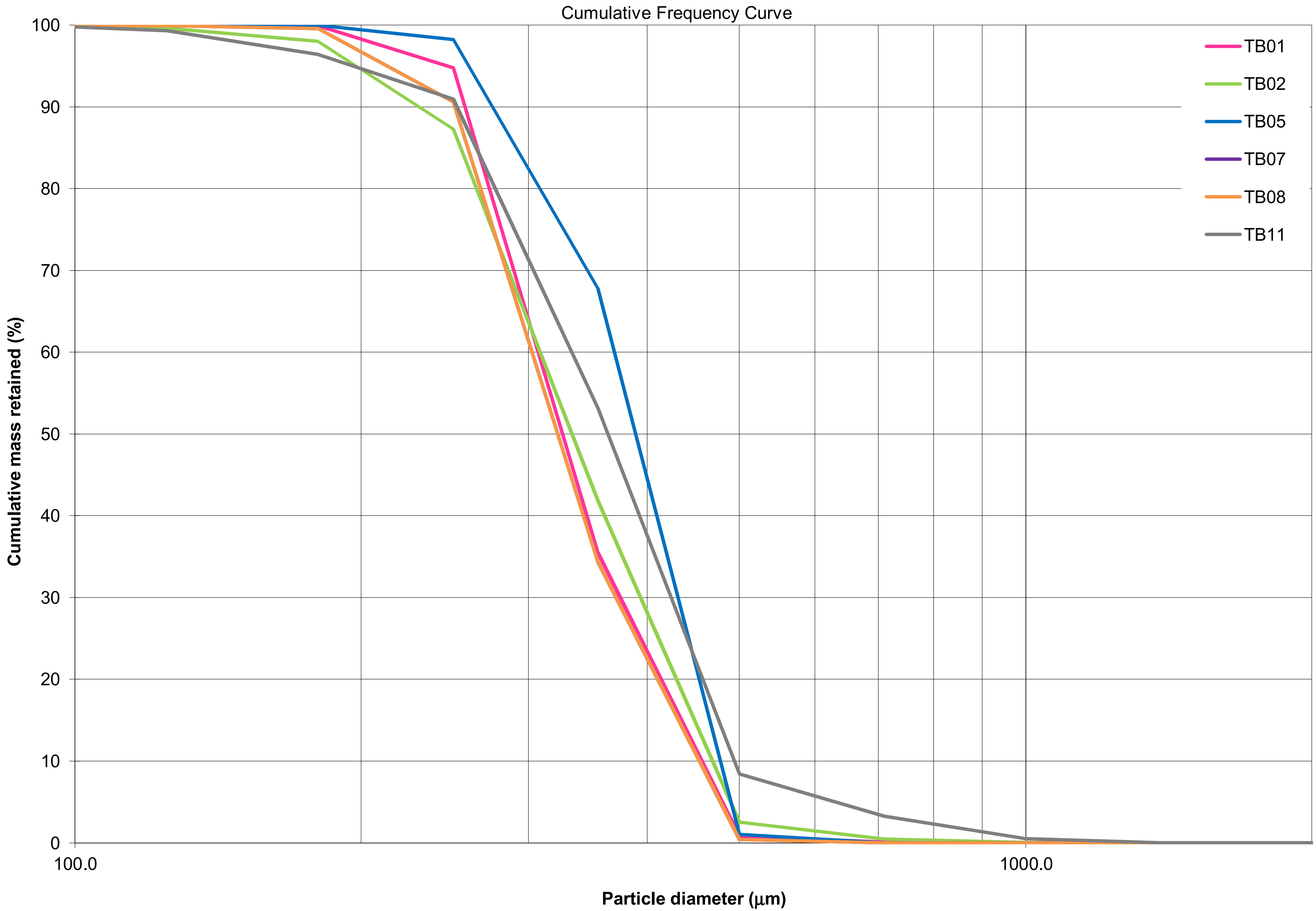
SEDIMENT NAME: Well Sorted Medium Sand

| | μm | φ | GRAIN SIZE DISTRIBUTION | | | |
|---|---|---|---|---|---|---|
| MODE 1: | 427.5 | 1.247 | GRAVEL: | 0.0% | COARSE SAND: | 8.0% |
| MODE 2: | | | SAND: | 100.0% | MEDIUM SAND: | 82.5% |
| MODE 3: | | | MUD: | 0.0% | FINE SAND: | 8.3% |
| $D_{10}$: | 252.2 | 1.017 | | | V FINE SAND: | 0.7% |
| MEDIAN or $D_{50}$: | 363.8 | 1.459 | V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| $D_{90}$: | 494.1 | 1.987 | COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| $(D_{90} / D_{10})$: | 1.959 | 1.954 | MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| $(D_{90} - D_{10})$: | 241.9 | 0.970 | FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| $(D_{75} / D_{25})$: | 1.519 | 1.510 | V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| $(D_{75} - D_{25})$: | 150.6 | 0.604 | V COARSE SAND: | 0.5% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic μm | Geometric μm | Logarithmic φ | Geometric μm | Logarithmic φ | Description |
| MEAN ($\bar{x}$): | 383.4 | 357.1 | 1.486 | 357.7 | 1.483 | Medium Sand |
| SORTING ($\sigma$): | 137.8 | 1.399 | 0.484 | 1.377 | 0.462 | Well Sorted |
| SKEWNESS ($Sk$): | 2.009 | -0.161 | 0.161 | -0.072 | 0.072 | Symmetrical |
| KURTOSIS ($K$): | 10.79 | 5.134 | 5.134 | 1.147 | 1.147 | Leptokurtic |

## GRAIN SIZE DISTRIBUTION





Cumulative Frequency Curve
TB01
TB02
TB05
TB07
TB08
TB11
Cumulative mass retained (%)
100
90
80
70
60
50
40
30
20
10
0
100.0
1000.0
Particle diameter (µm)

# APPENDIX B – PHOTOGRAMMETRIC DATA ASSESSMENT

### B1 Introduction

The aim of the photogrammetric data assessment is to detect and measure historical changes occurring at Tanilba Bay. The OEH archives of aerial photography, typically taken at regular intervals since the 1940's, form the basis for this quantitative assessment. However, as Tanilba Bay is located in the inner estuary (i.e. not located on the open coast), there were a limited number of aerial photographs available for analysis, namely 1951, 1963, 1999 and 2008.

### B2 Photogrammetry

Photogrammetry is a science of measurement and data acquisition from photographic and other remotely sensed images. A description of the methodology adopted for the analysis of the photogrammetric data and graphical representations of the results are provided in this Appendix.

The photogrammetric data used in this study was supplied by OEH (received by email, 8 September 2011, Robert Clout (OEH) – Takehiko Nose (SMEC)). Using their AC3 stereo plotter, OEH were able to deduce an elevation model from appropriately selected vertical aerials.

**Figure B.1** represents the cross-shore profile locations for each block. A summary of each block is provided in **Table B.1**.

Table B.1. Summary of Photogrammetric data profile locations

| Block Number | Length of Coastline (m) | Number of Profiles | Profile Spacing (m) | Geographical Coverage |
|---|---|---|---|---|
| 1 | 480 | 10 | 50 | Eastern end of the bay |
| 2 | 1170 | 24 | 50 | Southern foreshore of the bay |
| 3 | 680 | 13 | 50 | Western end of the bay |
| 4 | 270 | 5 | 50 | North western extent of the bay |

*Limitations of photogrammetric analysis at Tanilba Bay*

As discussed in **Section 2.1**, Tanilba Bay consists of a number of formally constructed seawalls. It is evident from **Figure B.1** that these seawalls significantly interfere with the Block 2 photogrammetric data, while the vertical seawall coverage extends the entire Block 4 foreshore. As such, the photogrammetric data for Blocks 2 and 4 were discarded from this study.

### B3 Aerial Photography

The accuracy of photogrammetric data depends on several factors including the quality of the image, the flying height, the focal length of the camera lens, lens aberrations and the expertise of the operator. Aerial photographs used in the photogrammetric analysis were selected by OEH from their achieved photographs. As Tanilba Bay is located in the inner estuary, there were a limited number of aerial photographs available for the analysis. Accordingly, aerial photographs from 1951, 1963, 1993 and 2008 were assessed.

## B4 Analysis Methodology

The data obtained from aerial photography primarily consists of cross-sectional profiles of the beach and dune at the selected location shown on **Figure B.1**. Plots of each profile data are identified in the title and presented in **Figures B.2a** to **B.2f**.

Trends in historical beach change are typically estimated in two ways:

- *volumetric analysis* - by assessment of the volume of sand contained within the beach and dune system above 0m AHD; and
- *position analysis* - by measurements of the position of various beach features, such as the position of the back beach erosion escarpment or the position in plan of a certain "cut" level through the foredune.

Based on the Tanilba Bay features consisting of very narrow beach and dune system, and the presence of distinct erosion escarpment, the position analysis approach was considered most suitable for the Tanilba Bay photogrammetric analysis.

<u>*Position Analysis*</u>

Based on visual examination of profiles in each block (refer **Figure B.1**), a consistent erosion escarpment height of 1 m AHD contour was utilised to conduct the position analysis to assess trends in historical beach change at Tanilba Bay.

Plots showing the outputs of the regression analysis for erosion escarpment changes over the analysis period are provided in **Figures B.3a** to **B.3d**.

Negative values indicate a recessive/erosion trend while positive values indicate a prograding trend.


Figure B.1 Photogrammetric Data Profile Locations

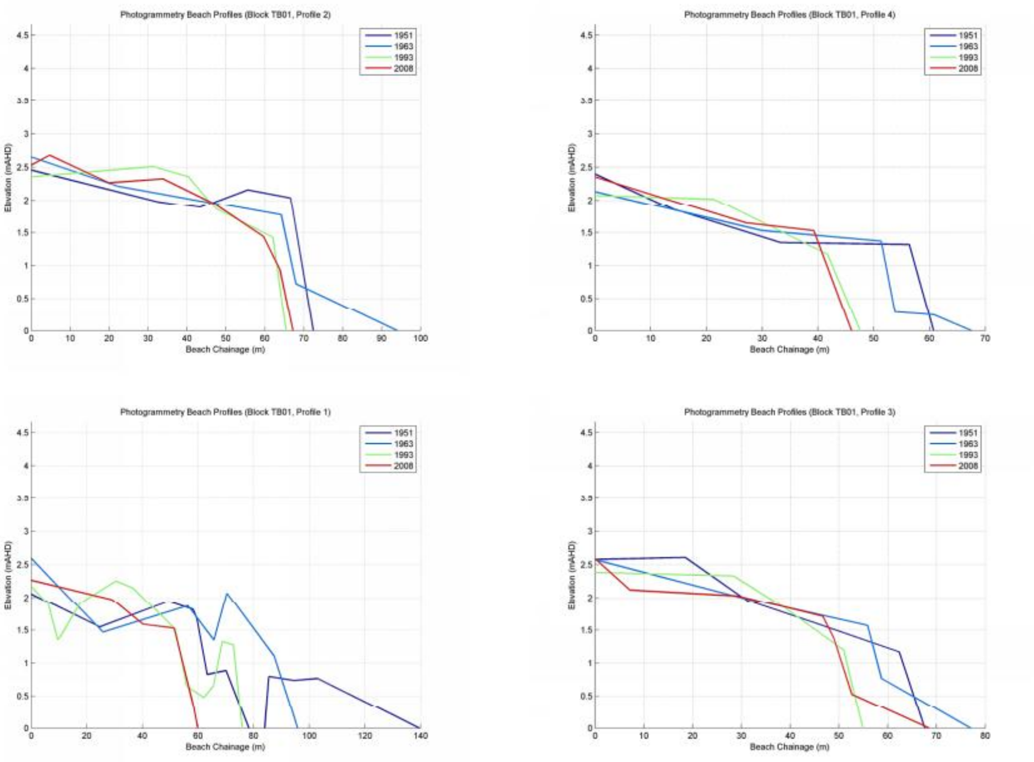



Figure B.2a: Photogrammetric beach profile, Tanilba Bay

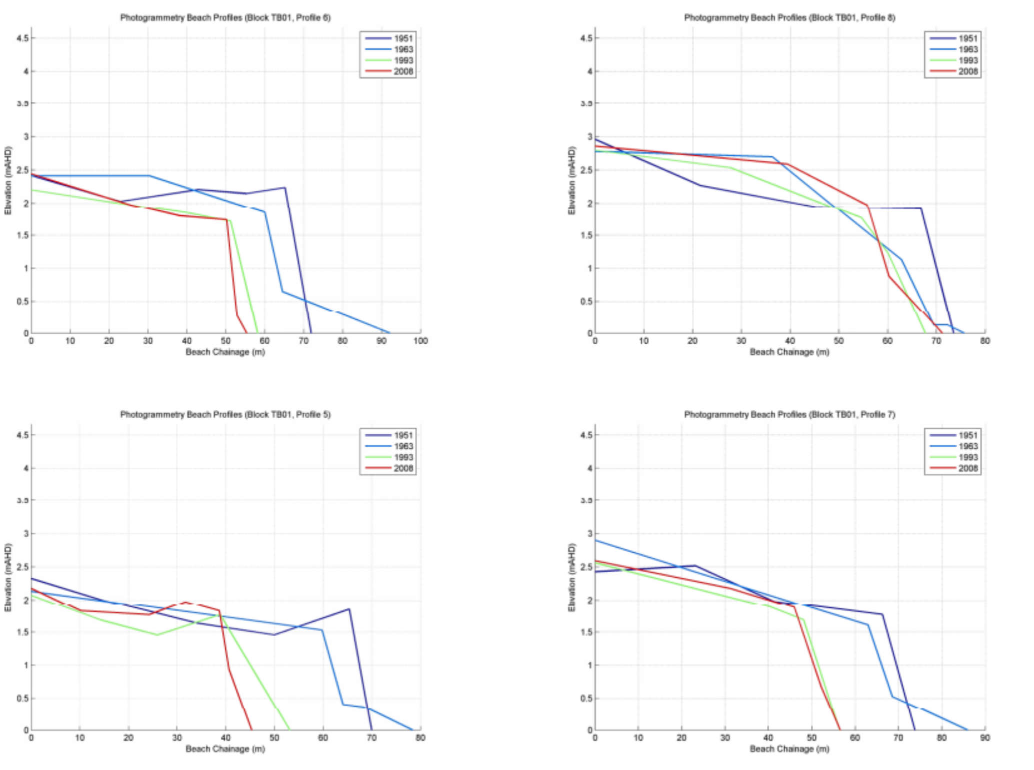



Figure B.2b: Photogrammetric beach profile, Tanilba Bay

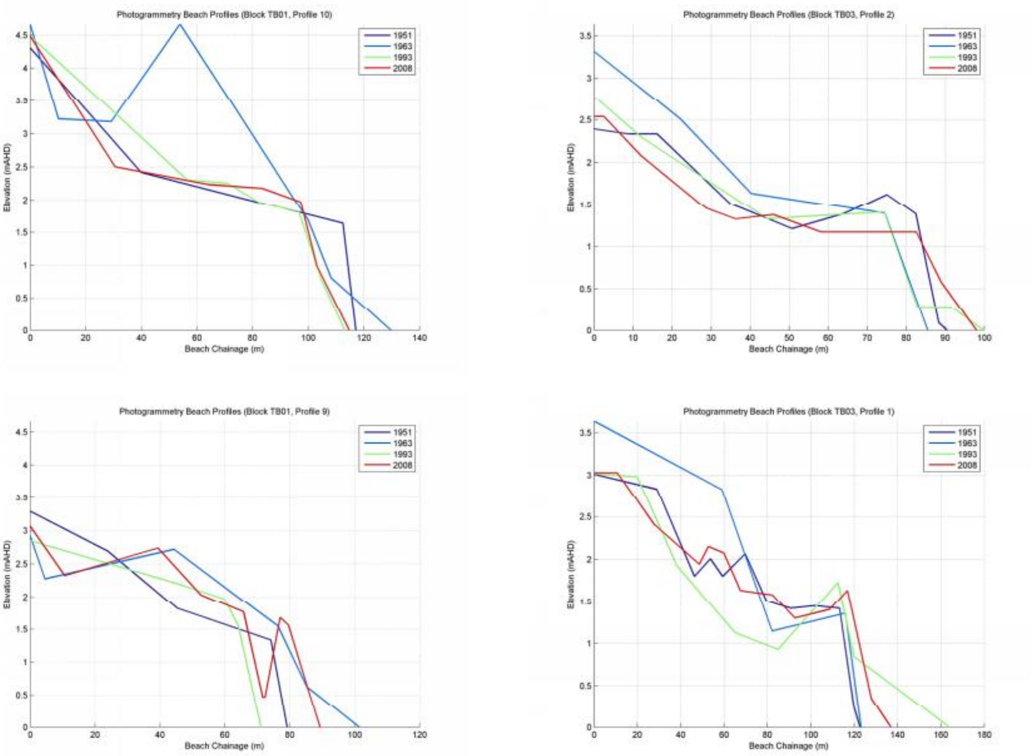



Figure B.2c: Photogrammetric beach profile, Tanilba Bay

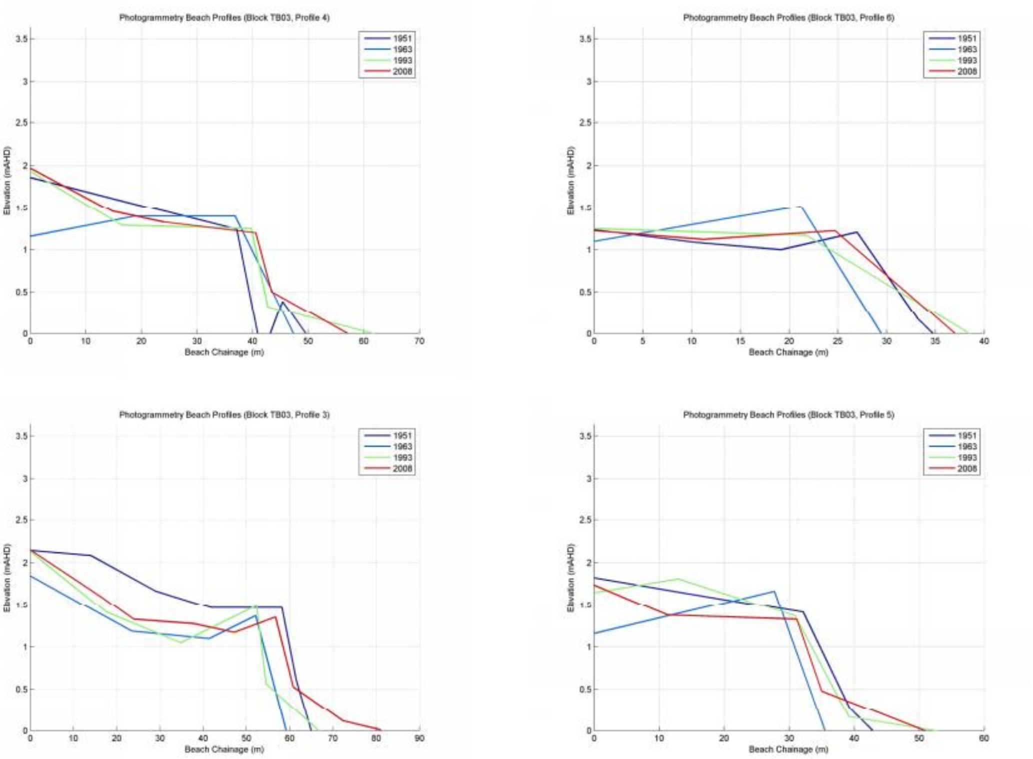



Figure B.2d: Photogrammetric beach profile, Tanilba Bay

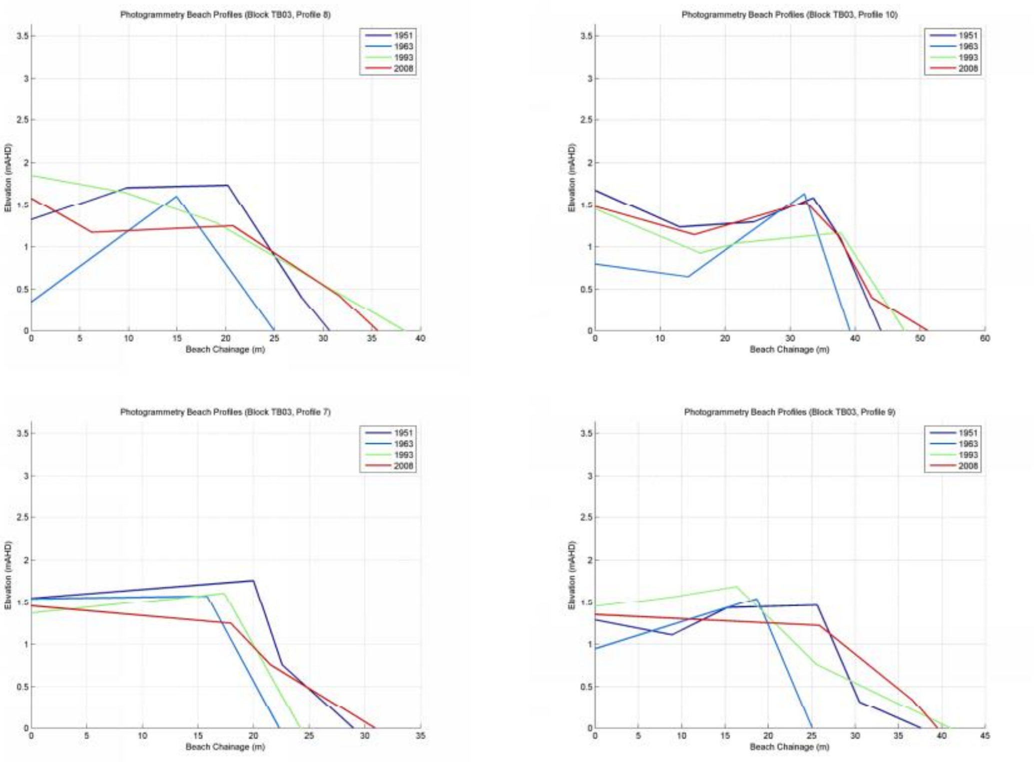



Figure B.2e: Photogrammetric beach profile, Tanilba Bay

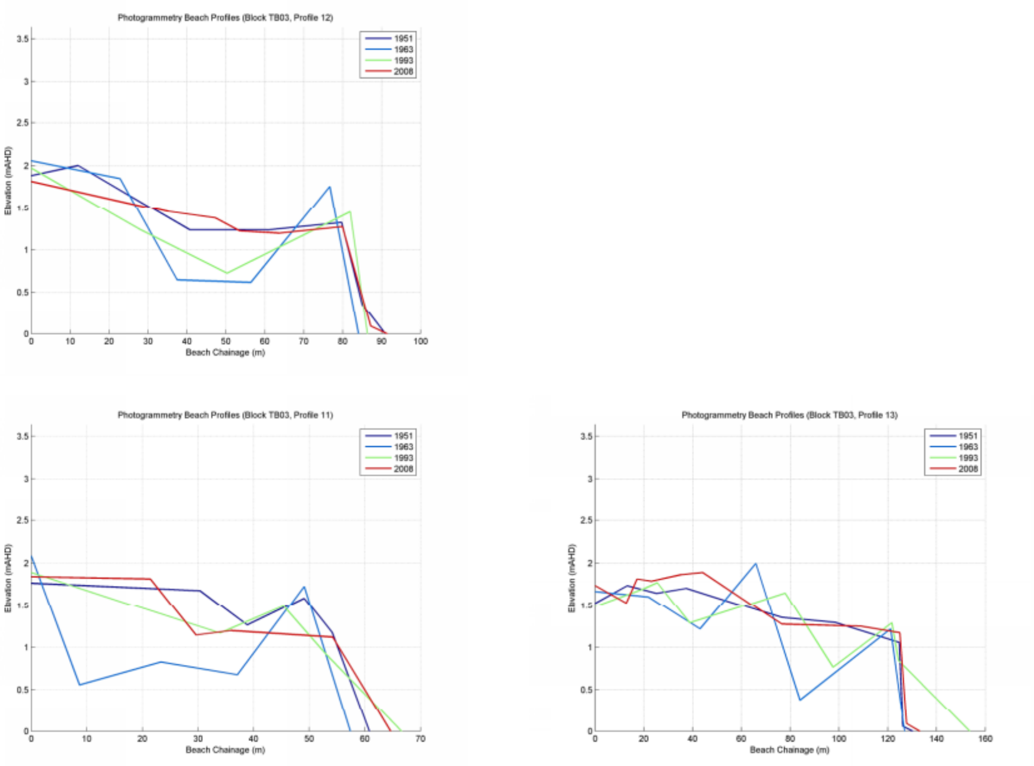



Figure B.2f: Photogrammetric beach profile, Tanilba Bay

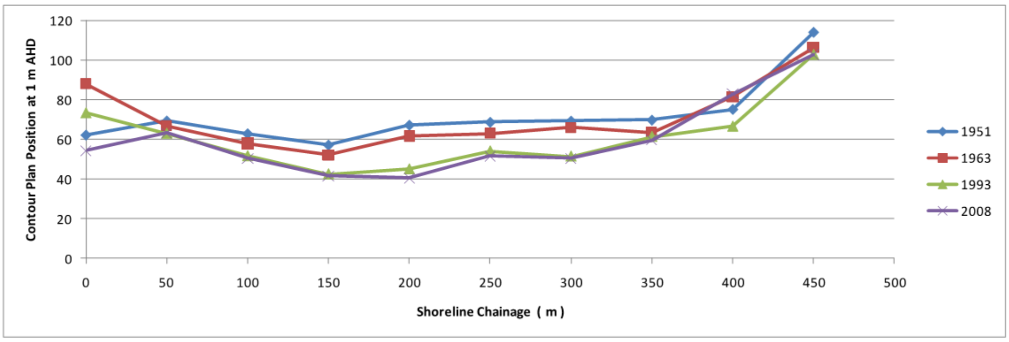



**Figure B.3a: Tanilba Bay, Block 1 – Contour plan position at 1 m AHD for 1951, 1963, 1993 and 2008**

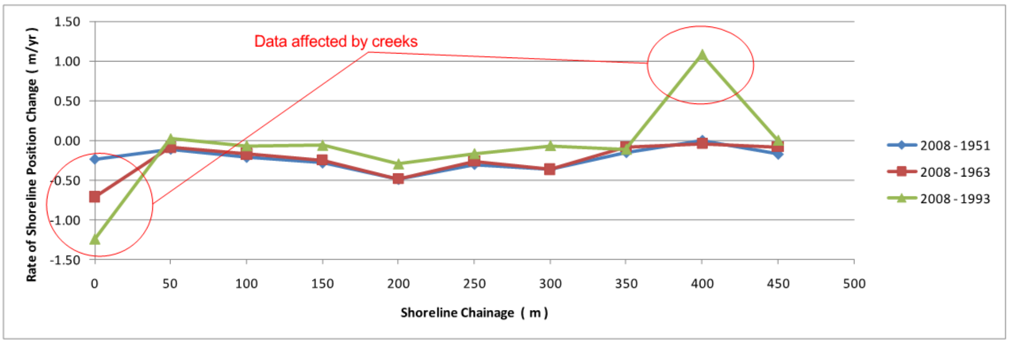



**Figure B.3b: Tanilba Bay, Block 1 – Annual rate of shoreline position change at 1 m AHD**

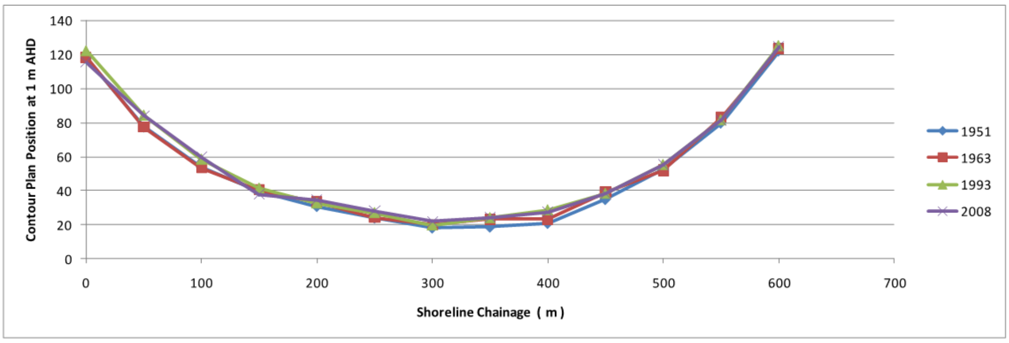



**Figure B.3c: Tanilba Bay, Block 3 – Contour plan position at 1 m AHD for 1951, 1963, 1993 and 2008**

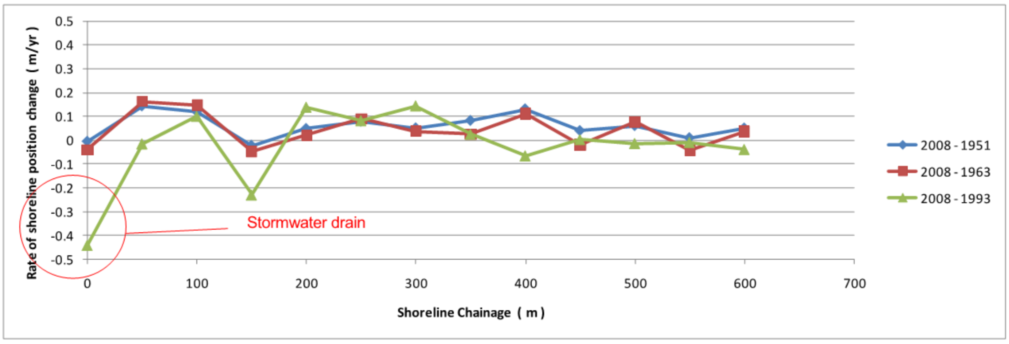



**Figure B.3d: Tanilba Bay, Block 1 – Annual rate of shoreline position change at 1 m AHD**

# APPENDIX C – PROCESSED WIND DATA

Table C.1 Joint frequency table for all the data from the BoM Williamtown Airport station between January 1989 and June 2011.

**Joint Frequency Table (%) Showing Wind Sp Against Direction for the Period 01–Jan–1989 11:01:00 to 02–Jun–2011 11:30:00**

| N=296951 | N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW | Total | Cumul. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0–2** | 0.88 | 0.53 | 0.49 | 0.41 | 0.42 | 0.20 | 0.22 | 0.19 | 0.26 | 0.15 | 0.18 | 0.25 | 0.60 | 0.88 | 0.77 | 0.53 | 6.95 | 6.95 |
| **2–4** | 2.43 | 2.04 | 2.44 | 1.84 | 1.85 | 1.06 | 1.09 | 0.89 | 1.27 | 0.74 | 0.73 | 1.02 | 2.55 | 4.43 | 4.01 | 1.80 | 30.20 | 37.15 |
| **4–6** | 0.31 | 0.67 | 2.00 | 1.27 | 1.53 | 1.57 | 1.71 | 1.59 | 1.97 | 0.78 | 0.58 | 0.73 | 1.88 | 3.68 | 1.45 | 0.39 | 22.12 | 59.27 |
| **6–8** | 0.04 | 0.11 | 0.69 | 1.00 | 1.10 | 1.17 | 1.32 | 1.46 | 2.02 | 0.72 | 0.39 | 0.30 | 1.14 | 2.60 | 0.58 | 0.09 | 14.72 | 73.99 |
| **8–10** | * | 0.01 | 0.11 | 0.38 | 0.35 | 0.28 | 0.42 | 0.78 | 1.31 | 0.38 | 0.19 | 0.12 | 0.58 | 1.94 | 0.41 | 0.04 | 7.28 | 81.27 |
| **10–12** | * | * | 0.01 | 0.04 | 0.04 | 0.02 | 0.09 | 0.19 | 0.45 | 0.13 | 0.04 | 0.04 | 0.24 | 1.09 | 0.22 | * | 2.63 | 83.90 |
| **12–14** | * | – | * | * | * | * | 0.02 | 0.04 | 0.12 | 0.05 | 0.01 | 0.01 | 0.10 | 0.56 | 0.11 | * | 1.04 | 84.94 |
| **14–16** | * | – | – | * | * | – | * | * | 0.02 | * | * | * | 0.03 | 0.20 | 0.04 | * | 0.31 | 85.25 |
| **16–18** | – | * | – | – | – | * | * | * | * | * | * | * | * | 0.05 | * | – | 0.07 | 85.32 |
| **18–20** | * | – | – | – | – | – | * | – | – | – | * | * | * | 0.02 | * | – | 0.02 | 85.34 |
| **Total** | 3.67 | 3.36 | 5.75 | 4.94 | 5.30 | 4.31 | 4.87 | 5.15 | 7.43 | 2.96 | 2.12 | 2.47 | 7.13 | 15.44 | 7.59 | 2.86 | | |
| **Cumul.** | 3.67 | 7.03 | 12.78 | 17.72 | 23.02 | 27.33 | 32.20 | 37.34 | 44.78 | 47.74 | 49.86 | 52.33 | 59.46 | 74.89 | 82.49 | 85.34 | | |

*** denotes values less than 0.01%** **– denotes no records in bin**

**Metadata:**
Project: 30011040 – Tanilba Bay
Data period: 01–Jan–1989 11:01:00 to 02–Jun–2011 11:30:00
Data source: BoM Weather Station: 61078 WILLIAMTOWN RAAF
Data summary: All Records
Number of Records: 296951
Mssing data (%): 0.24
Calms (% <1.0m/s): 14.41

SMEC

Table C.2 Joint frequency table for summer from the BoM Williamtown Airport station.

**Joint Frequency Table (%) Showing Wind Sp Against Direction for the Period 01–Jan–1989 11:01:00 to 28–Feb–2011 23:30:00**

| N=72947 | N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW | Total | Cumul. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0–2** | 0.71 | 0.52 | 0.52 | 0.50 | 0.58 | 0.24 | 0.28 | 0.23 | 0.34 | 0.17 | 0.13 | 0.18 | 0.35 | 0.38 | 0.32 | 0.32 | 5.77 | 5.77 |
| **2–4** | 2.25 | 2.37 | 3.22 | 2.85 | 2.96 | 1.50 | 1.48 | 1.18 | 1.78 | 0.95 | 0.63 | 0.64 | 1.38 | 1.71 | 1.58 | 1.24 | 27.72 | 33.50 |
| **4–6** | 0.43 | 1.12 | 3.76 | 2.29 | 2.68 | 2.47 | 2.47 | 2.15 | 2.97 | 0.99 | 0.30 | 0.28 | 0.51 | 0.80 | 0.58 | 0.33 | 24.12 | 57.62 |
| **6–8** | 0.07 | 0.19 | 1.62 | 2.23 | 2.30 | 2.36 | 2.29 | 2.24 | 3.24 | 0.86 | 0.13 | 0.14 | 0.27 | 0.69 | 0.30 | 0.07 | 19.01 | 76.63 |
| **8–10** | * | 0.03 | 0.29 | 1.05 | 0.88 | 0.58 | 0.60 | 1.17 | 2.06 | 0.40 | 0.04 | 0.05 | 0.15 | 0.63 | 0.23 | 0.03 | 8.21 | 84.84 |
| **10–12** | * | * | 0.03 | 0.12 | 0.08 | 0.03 | 0.11 | 0.27 | 0.69 | 0.14 | 0.01 | 0.03 | 0.10 | 0.35 | 0.09 | * | 2.08 | 86.91 |
| **12–14** | – | – | * | * | * | * | * | 0.03 | 0.13 | 0.04 | * | * | 0.03 | 0.16 | 0.04 | * | 0.47 | 87.38 |
| **14–16** | * | – | – | * | * | – | * | – | 0.02 | * | * | * | * | 0.03 | 0.02 | – | 0.09 | 87.47 |
| **16–18** | – | – | – | – | – | – | – | – | – | * | * | * | * | * | – | – | * | 87.48 |
| **18–20** | * | – | – | – | – | – | – | – | – | – | * | * | – | – | – | – | * | 87.49 |
| **Total** | 3.47 | 4.23 | 9.45 | 9.04 | 9.49 | 7.19 | 7.22 | 7.28 | 11.24 | 3.56 | 1.26 | 1.33 | 2.80 | 4.76 | 3.16 | 2.00 | | |
| **Cumul.** | 3.47 | 7.70 | 17.15 | 26.19 | 35.69 | 42.88 | 50.10 | 57.38 | 68.62 | 72.18 | 73.44 | 74.76 | 77.56 | 82.32 | 85.49 | 87.49 | | |

*** denotes values less than 0.01%** **– denotes no records in bin**

**Metadata:**
Project: 30011040 – Tanilba Bay
Data period: 01–Jan–1989 11:01:00 to 28–Feb–2011 23:30:00
Data source: BoM Weather Station: 61078 WILLIAMTOWN RAAF
Data summary: Summer
Number of Records: 72947
Mssing data (%): 0.40
Calms (% <1.0m/s): 12.10

SMEC

Table C.3 Joint frequency table for autumn from the BoM Williamtown Airport station.

**Joint Frequency Table (%) Showing Wind Sp Against Direction for the Period 01−Mar−1989 03:00:00 to 31−May−2011 23:30:00**

| N=77522 | N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW | Total | Cumul. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0−2 | 0.92 | 0.59 | 0.55 | 0.43 | 0.46 | 0.26 | 0.27 | 0.24 | 0.30 | 0.19 | 0.20 | 0.31 | 0.81 | 1.13 | 0.89 | 0.54 | 8.06 | 8.06 |
| 2−4 | 2.06 | 1.72 | 2.30 | 1.77 | 1.89 | 1.25 | 1.26 | 1.03 | 1.34 | 0.80 | 0.86 | 1.30 | 3.23 | 5.92 | 4.97 | 1.71 | 33.42 | 41.49 |
| 4−6 | 0.21 | 0.38 | 1.11 | 1.03 | 1.39 | 1.66 | 1.80 | 1.81 | 2.02 | 0.83 | 0.75 | 0.91 | 1.92 | 3.69 | 1.27 | 0.26 | 21.03 | 62.52 |
| 6−8 | * | 0.03 | 0.20 | 0.47 | 0.72 | 0.76 | 1.18 | 1.63 | 1.96 | 0.70 | 0.38 | 0.24 | 0.81 | 2.01 | 0.38 | 0.03 | 11.52 | 74.04 |
| 8−10 | * | * | 0.02 | 0.08 | 0.20 | 0.22 | 0.45 | 0.97 | 1.24 | 0.32 | 0.12 | 0.08 | 0.32 | 1.20 | 0.19 | * | 5.40 | 79.44 |
| 10−12 | − | * | * | 0.01 | 0.03 | 0.03 | 0.12 | 0.23 | 0.34 | 0.12 | 0.05 | 0.03 | 0.09 | 0.50 | 0.08 | − | 1.63 | 81.07 |
| 12−14 | − | − | * | − | * | * | 0.04 | 0.04 | 0.10 | 0.04 | 0.01 | * | 0.02 | 0.19 | 0.02 | − | 0.48 | 81.55 |
| 14−16 | − | − | − | − | * | − | * | * | 0.02 | * | * | * | * | 0.05 | * | − | 0.09 | 81.65 |
| 16−18 | − | − | − | − | − | * | − | * | * | − | − | − | * | * | * | − | 0.01 | 81.66 |
| 18−20 | − | − | − | − | − | − | − | − | − | − | − | − | − | − | − | − | − | 81.66 |
| Total | 3.20 | 2.73 | 4.19 | 3.79 | 4.69 | 4.19 | 5.12 | 5.94 | 7.32 | 3.00 | 2.38 | 2.87 | 7.20 | 14.68 | 7.81 | 2.54 | | |
| Cumul. | 3.20 | 5.93 | 10.13 | 13.92 | 18.61 | 22.80 | 27.92 | 33.86 | 41.19 | 44.18 | 46.56 | 49.43 | 56.63 | 71.31 | 79.12 | 81.66 | | |

* denotes values less than 0.01%     − denotes no records in bin

**Metadata:**
Project: 30011040 − Tanilba Bay
Data period: 01−Mar−1989 03:00:00 to 31−May−2011 23:30:00
Data source: BoM Weather Station: 61078 WILLIAMTOWN RAAF
Data summary: Autumn
Number of Records: 77522
Missing data (%): 0.07
Calms (% <1.0m/s): 18.27

SMEC

Table C.4 Joint frequency table for winter from the BoM Williamtown Airport station.

**Joint Frequency Table (%) Showing Wind Sp Against Direction for the Period 01−Jun−1989 03:00:00 to 02−Jun−2011 11:30:00**

| N=73436 | N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW | Total | Cumul. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0−2 | 0.96 | 0.40 | 0.36 | 0.25 | 0.22 | 0.13 | 0.12 | 0.14 | 0.18 | 0.12 | 0.18 | 0.31 | 0.71 | 1.23 | 1.19 | 0.68 | 7.18 | 7.18 |
| 2−4 | 2.43 | 1.34 | 1.32 | 0.81 | 0.70 | 0.47 | 0.52 | 0.47 | 0.72 | 0.53 | 0.83 | 1.31 | 3.51 | 6.75 | 6.13 | 2.38 | 30.22 | 37.39 |
| 4−6 | 0.21 | 0.22 | 0.46 | 0.26 | 0.33 | 0.43 | 0.48 | 0.61 | 0.90 | 0.61 | 0.87 | 1.14 | 3.45 | 7.49 | 2.60 | 0.41 | 20.48 | 57.87 |
| 6−8 | 0.02 | 0.02 | 0.06 | 0.06 | 0.17 | 0.17 | 0.20 | 0.27 | 0.73 | 0.62 | 0.71 | 0.49 | 2.50 | 5.77 | 0.93 | 0.09 | 12.82 | 70.69 |
| 8−10 | * | − | 0.01 | 0.02 | 0.06 | 0.08 | 0.18 | 0.11 | 0.39 | 0.34 | 0.37 | 0.20 | 1.19 | 4.21 | 0.63 | 0.03 | 7.81 | 78.50 |
| 10−12 | * | − | * | * | * | 0.02 | 0.07 | 0.08 | 0.15 | 0.10 | 0.06 | 0.06 | 0.49 | 2.31 | 0.37 | * | 3.72 | 82.23 |
| 12−14 | * | − | − | − | − | * | 0.01 | 0.02 | 0.04 | * | 0.01 | 0.01 | 0.20 | 1.18 | 0.20 | * | 1.69 | 83.92 |
| 14−16 | − | − | − | − | − | − | * | * | * | * | − | * | 0.05 | 0.42 | 0.09 | * | 0.59 | 84.50 |
| 16−18 | − | * | − | − | − | − | 0.01 | * | − | − | − | − | 0.01 | 0.10 | 0.02 | − | 0.15 | 84.65 |
| 18−20 | − | − | − | − | − | − | * | − | − | − | − | − | − | 0.02 | 0.01 | − | 0.04 | 84.69 |
| Total | 3.63 | 1.97 | 2.22 | 1.40 | 1.49 | 1.30 | 1.60 | 1.71 | 3.12 | 2.33 | 3.03 | 3.53 | 12.11 | 29.49 | 12.16 | 3.60 | | |
| Cumul. | 3.63 | 5.60 | 7.82 | 9.22 | 10.71 | 12.01 | 13.61 | 15.32 | 18.44 | 20.77 | 23.80 | 27.33 | 39.44 | 68.93 | 81.09 | 84.69 | | |

* denotes values less than 0.01%     − denotes no records in bin

**Metadata:**
Project: 30011040 − Tanilba Bay
Data period: 01−Jun−1989 03:00:00 to 02−Jun−2011 11:30:00
Data source: BoM Weather Station: 61078 WILLIAMTOWN RAAF
Data summary: Winter
Number of Records: 73436
Missing data (%): 0.35
Calms (% <1.0m/s): 14.96

SMEC

Table C.5 Joint frequency table for spring from the BoM Williamtown Airport station.

**Joint Frequency Table (%) Showing Wind Sp Against Direction for the Period 05−Sep−1989 03:00:00 to 30−Nov−2010 23:56:00**

| N=73046 | N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW | Total | Cumul. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0−2 | 0.91 | 0.60 | 0.54 | 0.45 | 0.41 | 0.18 | 0.20 | 0.15 | 0.21 | 0.14 | 0.21 | 0.20 | 0.53 | 0.75 | 0.66 | 0.56 | 6.70 | 6.70 |
| 2−4 | 3.01 | 2.74 | 2.95 | 1.94 | 1.86 | 1.02 | 1.10 | 0.88 | 1.26 | 0.66 | 0.58 | 0.81 | 2.03 | 3.24 | 3.28 | 1.88 | 29.23 | 35.93 |
| 4−6 | 0.40 | 0.97 | 2.75 | 1.54 | 1.75 | 1.74 | 2.09 | 1.77 | 2.01 | 0.69 | 0.37 | 0.56 | 1.64 | 2.73 | 1.36 | 0.56 | 22.94 | 58.87 |
| 6−8 | 0.06 | 0.18 | 0.90 | 1.27 | 1.25 | 1.41 | 1.62 | 1.70 | 2.17 | 0.70 | 0.34 | 0.32 | 0.99 | 1.93 | 0.72 | 0.18 | 15.75 | 74.62 |
| 8−10 | * | 0.03 | 0.12 | 0.38 | 0.28 | 0.22 | 0.44 | 0.86 | 1.54 | 0.44 | 0.22 | 0.14 | 0.66 | 1.74 | 0.62 | 0.09 | 7.80 | 82.42 |
| 10−12 | * | * | * | 0.04 | 0.03 | 0.02 | 0.07 | 0.19 | 0.63 | 0.19 | 0.05 | 0.06 | 0.31 | 1.20 | 0.33 | 0.02 | 3.15 | 85.57 |
| 12−14 | − | − | − | − | * | * | 0.03 | 0.07 | 0.20 | 0.13 | 0.01 | 0.03 | 0.14 | 0.73 | 0.18 | 0.01 | 1.54 | 87.11 |
| 14−16 | − | − | − | − | − | − | 0.01 | * | 0.04 | 0.02 | * | * | 0.04 | 0.31 | 0.03 | − | 0.48 | 87.59 |
| 16−18 | − | − | − | − | − | − | − | * | * | − | * | − | 0.01 | 0.10 | * | − | 0.12 | 87.71 |
| 18−20 | − | − | − | − | − | − | − | − | − | − | − | − | * | 0.05 | * | − | 0.05 | 87.77 |
| Total | 4.40 | 4.54 | 7.27 | 5.62 | 5.59 | 4.59 | 5.55 | 5.62 | 8.07 | 2.98 | 1.79 | 2.12 | 6.36 | 12.77 | 7.19 | 3.29 | | |
| Cumul. | 4.40 | 8.94 | 16.21 | 21.83 | 27.42 | 32.01 | 37.56 | 43.18 | 51.26 | 54.24 | 56.03 | 58.15 | 64.51 | 77.28 | 84.47 | 87.77 | | |

* denotes values less than 0.01% − denotes no records in bin

**Metadata:**
Project: 30011040 − Tanilba Bay
Data period: 05−Sep−1989 03:00:00 to 30−Nov−2010 23:56:00
Data source: BoM Weather Station: 61078 WILLIAMTOWN RAAF
Data summary: Spring
Number of Records: 73046
Missing data (%): 0.16
Calms (% <1.0m/s): 12.07

SMEC

# APPENDIX D – WAVE MODELLING

The location of Tanilba Bay is such that the narrow entrances between the open coast and the Outer estuary and between the Outer estuary and Inner estuary provide good protection from the prevailing ‘open coast’ conditions. As such, locally generated wind waves are of primary concern when assessing the likely wave climate at the proposed site.

### D.1 Approach and Objectives

As no recorded wave data is available at the site, a numerical wave hindcasting modelling approach was required to assess the wave climate. The general approach followed is outlined below:

- Determination of the most representative wind forcing and verification of wave modelling system
- Inclusion of key processes effecting wave climate including tidal water levels.
- Hindcasting simulation of the long-term wave climate using the Delft3D SWAN model.
- Statistical description of the representative wave climate.

This approach aims to produce a representative long-term record of waves at Tanilba Bay.

### D.2 Model Setup

A wave model has been setup using the Delft3D SWAN module. The third-generation **S**imulating **WA**ves **N**earshore (SWAN) model is designed to be used to simulate the evolution of random, short-crested wind-generated waves in estuaries, tidal inlets and coastal areas.

The SWAN model can account for refractive propagation due to current and depth and represents the processes of wave generation by wind, dissipation due to white capping, bottom friction and depth-induced wave breaking, wave blocking by flows, non-linear wave-wave interactions and transmission, diffraction, blockage and reflection due to obstacles explicitly using state-of-the-art formulations.

The SWAN model domain has been setup to include all wind fetches which are capable of generating waves within Tanilba Bay. Owing to the orientation of the bay, winds from west through north to east have the potential to result in waves within Tanilba Bay. The grid extends east up to the Soldiers Point, where the narrow entrance which separates the Inner estuary and the Outer estuary is assumed to prevent any residual wave conditions from the Outer estuary entering into the Inner estuary. The model has been setup using a rectilinear grid with a resolution of 25m.

Quality of wind data is a key factor for wave climate assessment at Tanilba Bay. The wave climate at Tanilba Bay is comprised of locally generated wind waves; wind is therefore the primary forcing mechanism. Theoretically, wind conditions over the Inner estuary may be different from wind measurements at the Williamtown BoM station as wind varies spatially with geographic features and different roughness over the water and land. Ideally, long term wind data measured at the site of wind generation (i.e. over the Inner estuary) would be used. However, no site specific data was available for this study and as such the Williamtown BoM station data has been used.

The wave model was driven by 3 hourly processed wind data and it included tidal level variations based on predicted levels from Mallabula Point. The model was setup to hindcast predict the wave conditions within Tanilba Bay from the start of 1991 to the end of June 2011.

There is no recorded wave data available within the Inner estuary and so it has not been possible to calibrate or validate the model. Without calibration the wave model is still capable of accurately representing how the wave heights within Tanilba Bay vary depending on wind speed and direction, but only limited certainty can be placed in the absolute wave heights and periods.

## D.3 Results

Results from the wave model have been extracted at a series of points around Tanilba Bay to demonstrate the variability in the wave climate. The extraction points are all in a depth of approximately -1m AHD and as such they are always submerged regardless of the tidal level. **Figure D.3** shows a series of wave rose plots across Tanilba Bay and demonstrates how the wave climate varies across the bay. The wave rose at the entrance to the bay, site 9, shows a bimodal distribution in the wave climate with dominant wave directions from the north-west and the north-east. Waves from the north-west occur most frequently and result in the more frequent occurrence of larger waves. The wave climate at the points within the bay differs to the climate at the entrance owing to wave refraction within the bay and the sheltering effects of the bay headlands. The eastern side of the bay, sites 7 and 8, experiences the most energetic wave climate as it is more exposed to the larger and more frequent waves from the north-west. The centre of the bay, sites 4 to 6, maintains a strong bimodal distribution in the wave climate as they are located in the centre of the bay and therefore exposed to waves coming from both the north-west and the north-east. The western end of the bay, sites 1 to 3, is predominantly sheltered from the larger waves from the north-west and as a result receives the least energetic wave climate within the bay.

To show how the significant wave height varies spatially around the bay, results showing the wave conditions resulting from winds from the north-west and north-east are plotted in **Figures D.1** and **D.2**. Both plots represent one of the largest events of the year from the direction, showing that a large event caused by winds from the north-west results in waves of between 0.2 and 0.3m larger than an event caused by winds from the north-east. Waves from the north-west do not refract into the western end of the bay, while waves from the north-east show a slight tendency to refract into the eastern end of the bay. This tendency for waves to refract at the eastern end of the bay is a caused by the wider intertidal zone in this area compared to the narrower intertidal at the western end of the bay.

Probability of exceedance curves have been generated for each site using the wave conditions predicted by the numerical modelling for the period from 1991 to 2011 (**Figures D.4** to **D.12**). Percentile exceedance values for the 1% and 0.1% are shown in **Table D.1**, these values highlight how the wave conditions vary along the Tanilba Bay foreshore. The wave heights generally increase from the west of the bay to the east of the bay, with the largest waves occurring at Site 7. The significant wave heights which are exceeded for 1% and 0.1% of the year at Site 1 are approximately half the value of those at Site 7.

Table D.1 Percentile exceedance values for wind generated waves at the 9 sites. Note: see Figure D.3 for site locations.

| Site Number | Hs (1% Exceedance) (m) | Hs (0.1% Exceedance) (m) |
|---|---|---|
| 1 | 0.16 | 0.23 |
| 2 | 0.23 | 0.29 |
| 3 | 0.22 | 0.28 |
| 4 | 0.26 | 0.35 |
| 5 | 0.29 | 0.41 |
| 6 | 0.3 | 0.42 |

| Site Number | Hs (1% Exceedance) (m) | Hs (0.1% Exceedance) (m) |
|---|---|---|
| 7 | 0.33 | 0.47 |
| 8 | 0.28 | 0.41 |
| 9 | 0.35 | 0.5 |

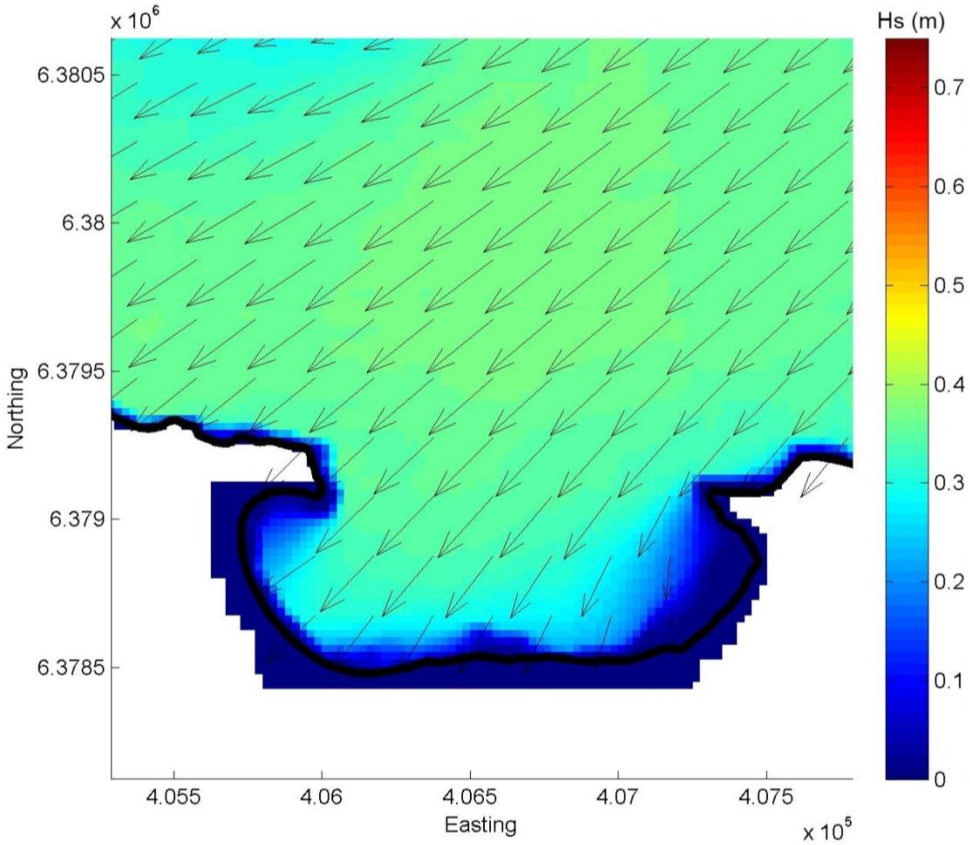



Figure D.1 Significant wave height and direction resulting from a wind coming from the NE.

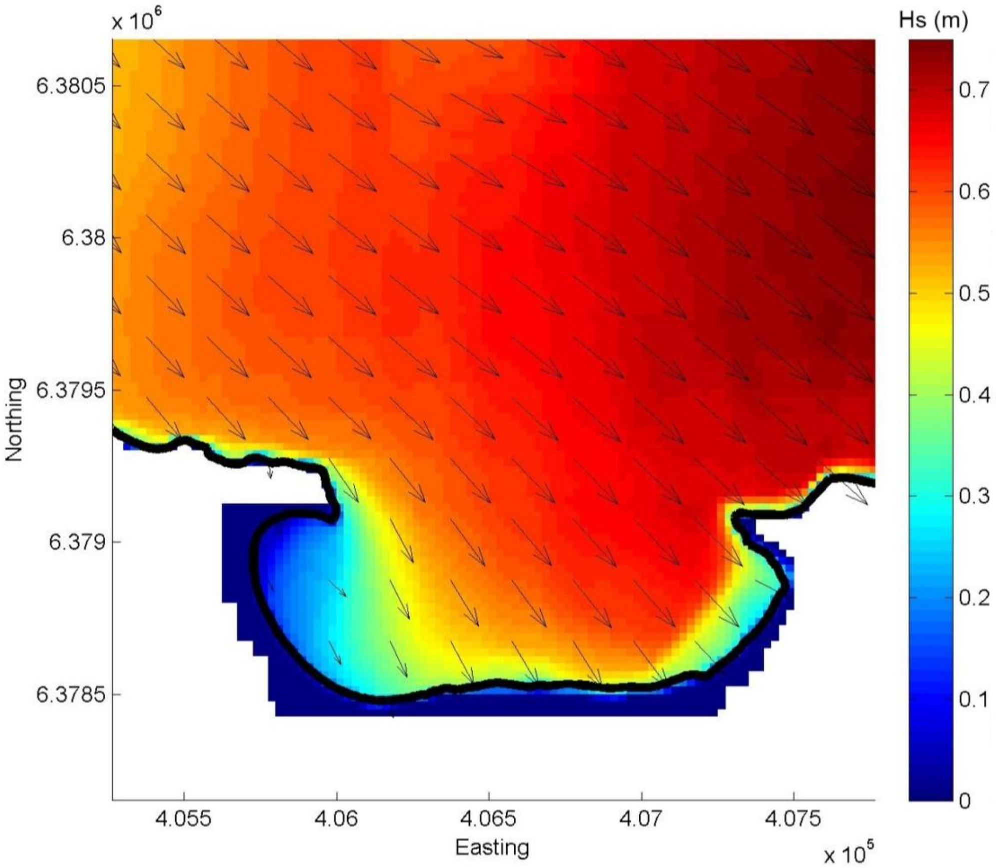



Figure D.2 Significant wave height and direction resulting from a wind coming from the NW.

## All Seasons

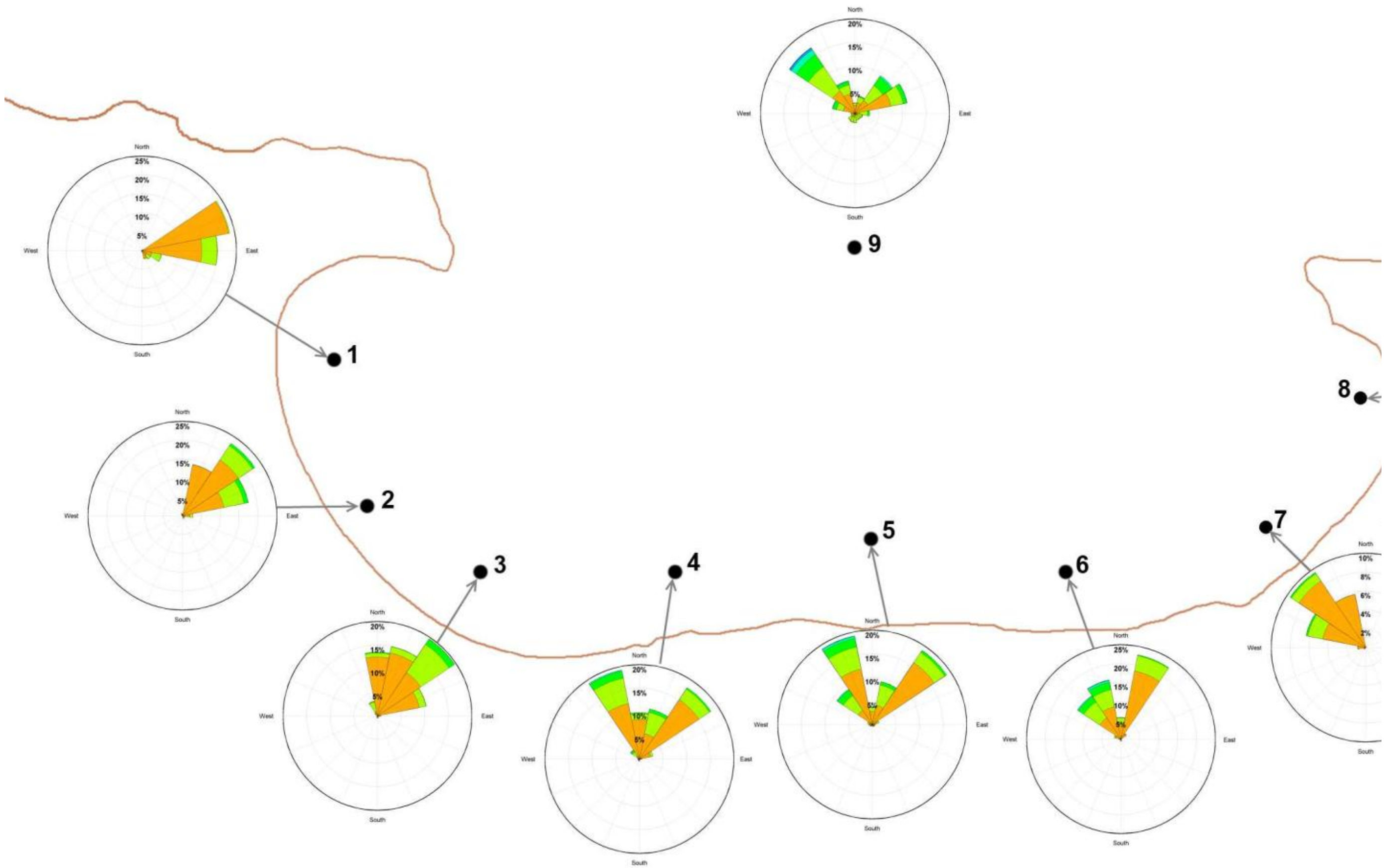



Figure D.3 Wave rose plots at a series of points around Tanilba Bay. The wave roses are based on wave conditions from 1991 to 2011.

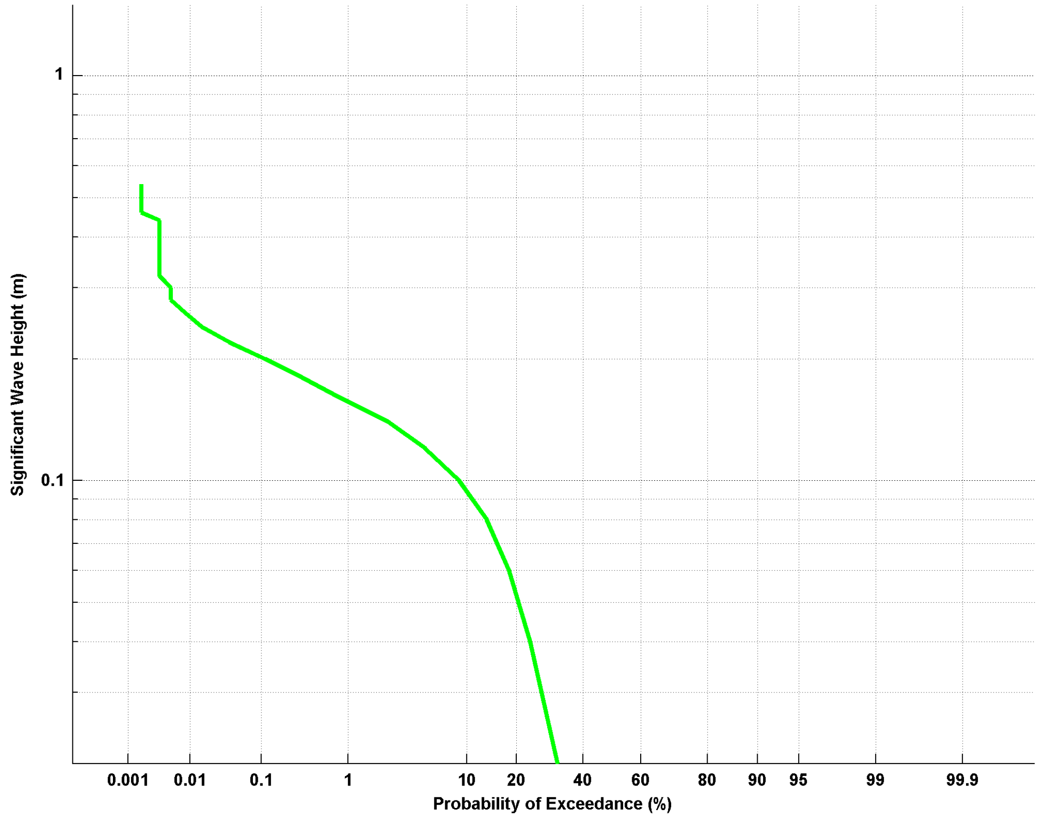



Figure D.4 Probability of exceedance curve for significant wave height at the site 1.

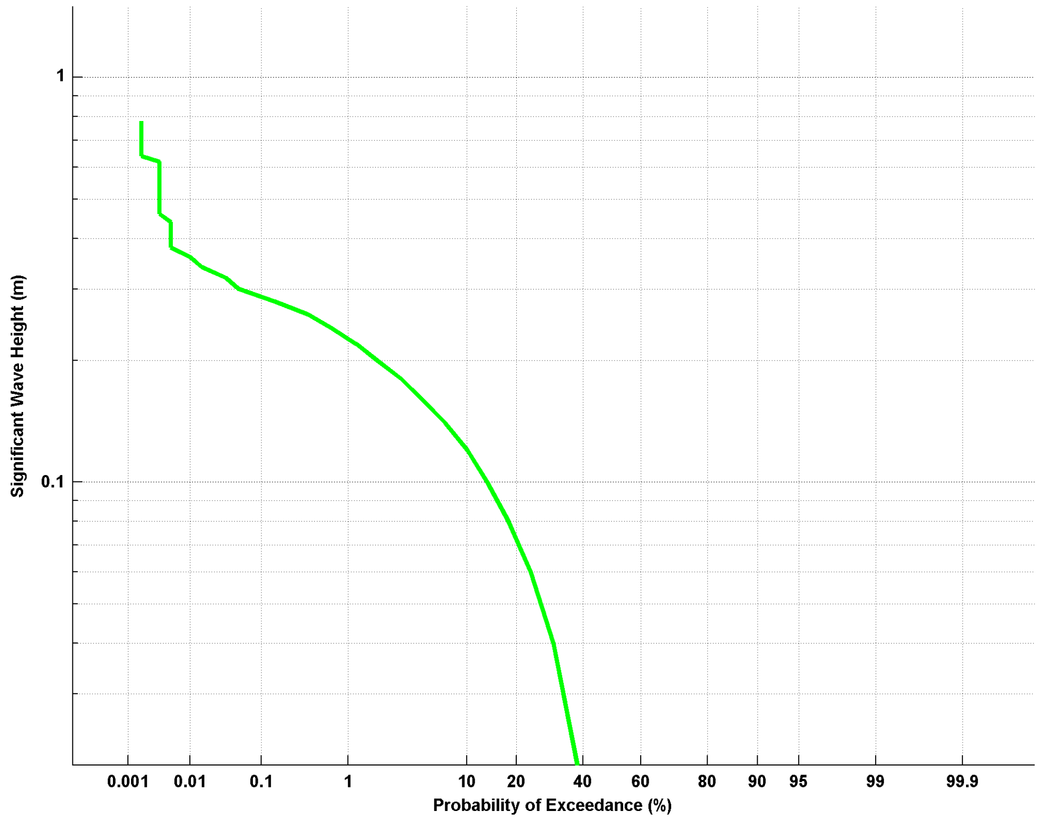



Figure D.5 Probability of exceedance curve for significant wave height at the site 2.

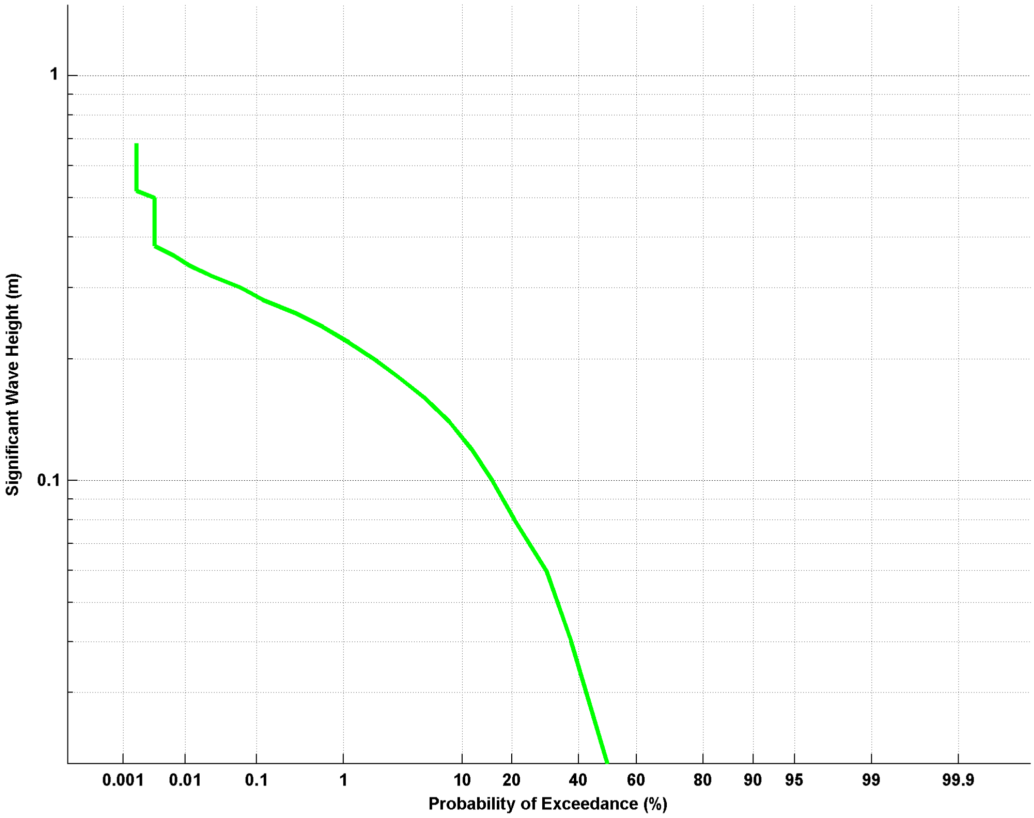



Figure D.6 Probability of exceedance curve for significant wave height at the site 3.

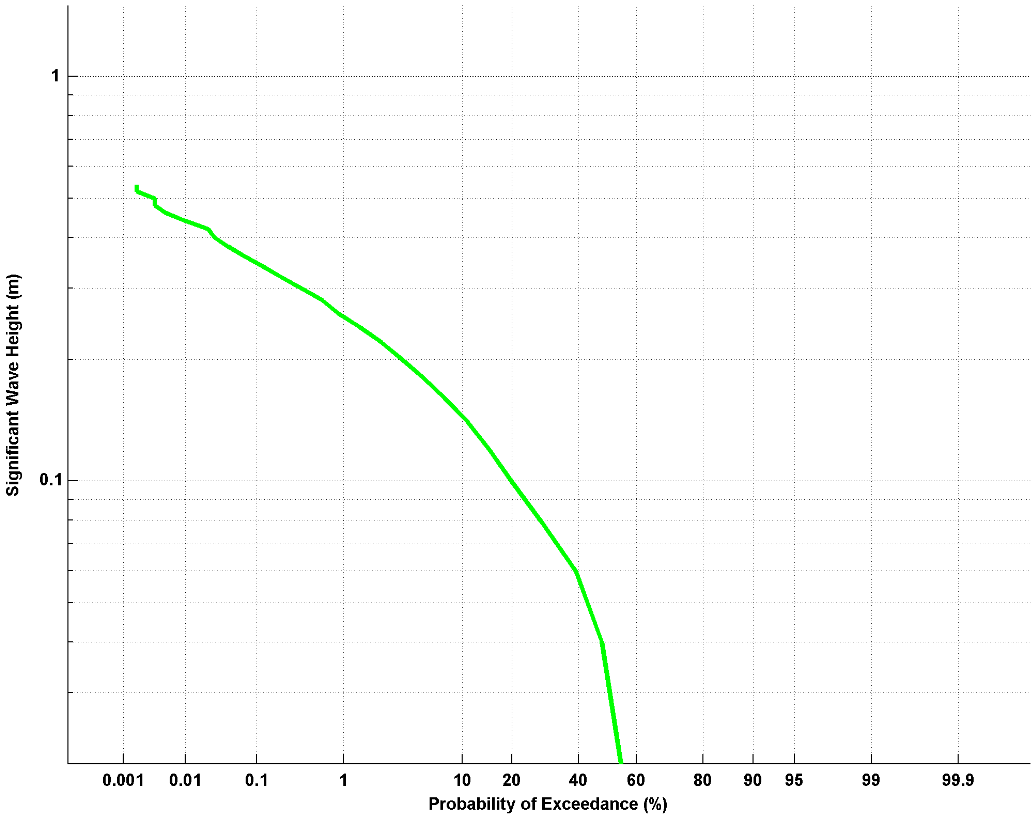



Figure D.7 Probability of exceedance curve for significant wave height at the site 4.

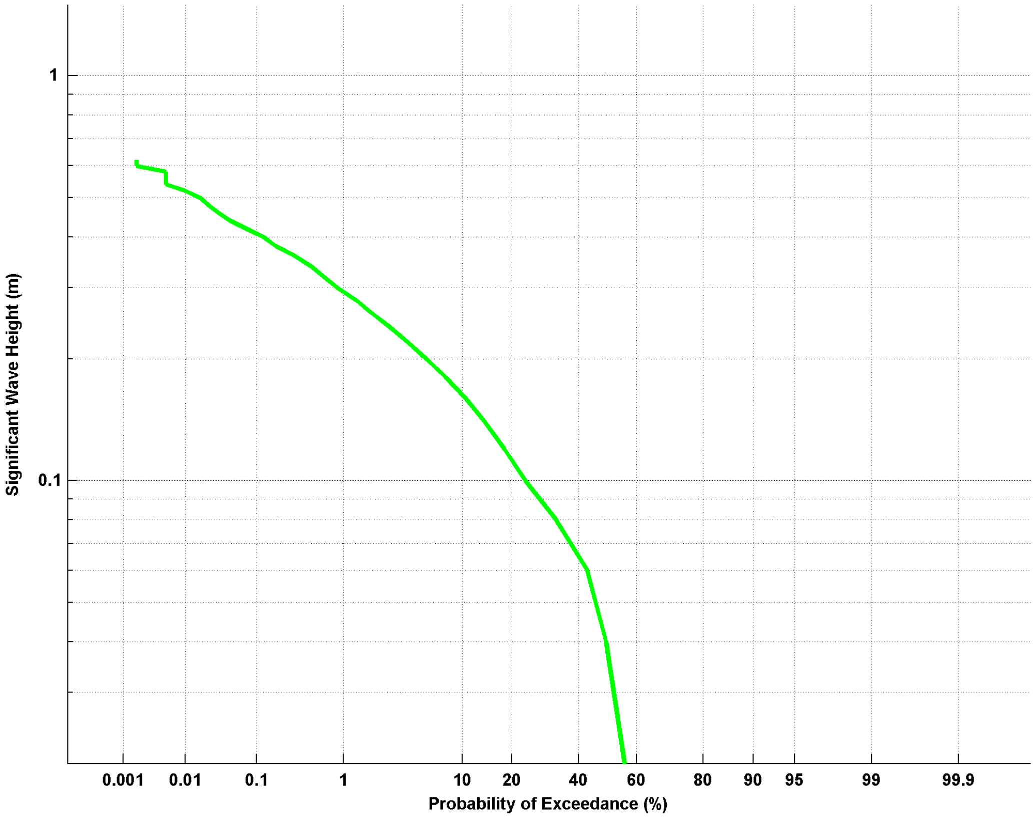



Figure D.8 Probability of exceedance curve for significant wave height at the site 5.

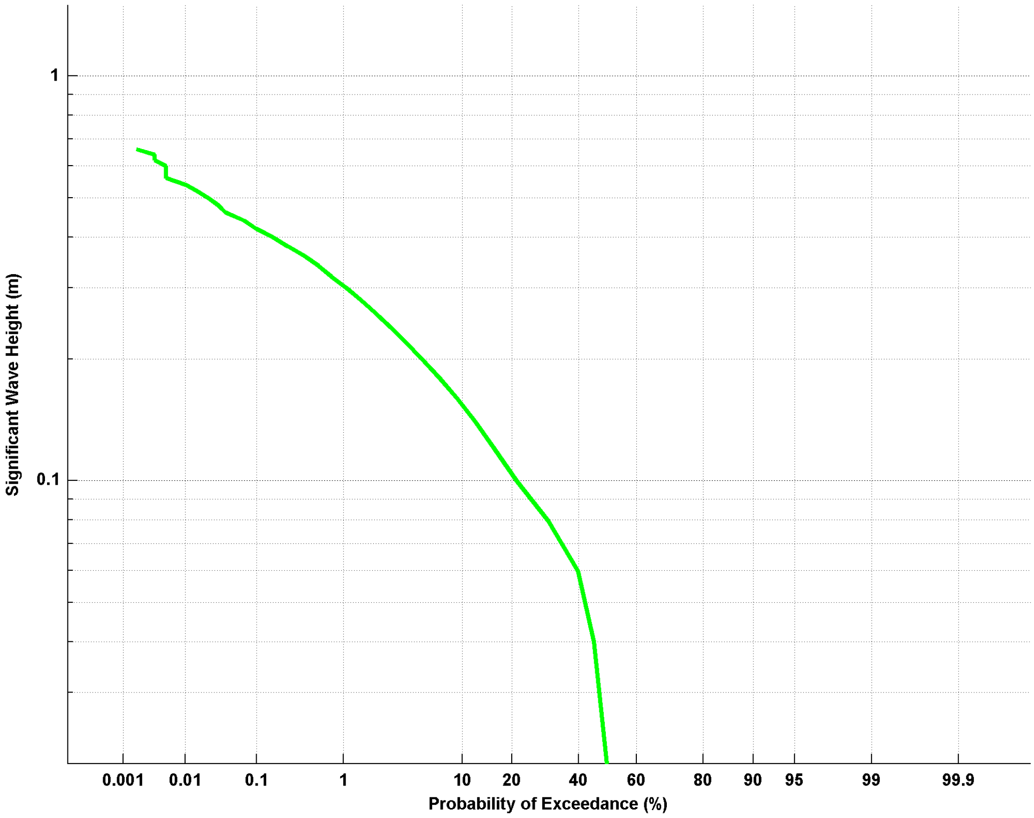



Figure D.9 Probability of exceedance curve for significant wave height at the site 6.

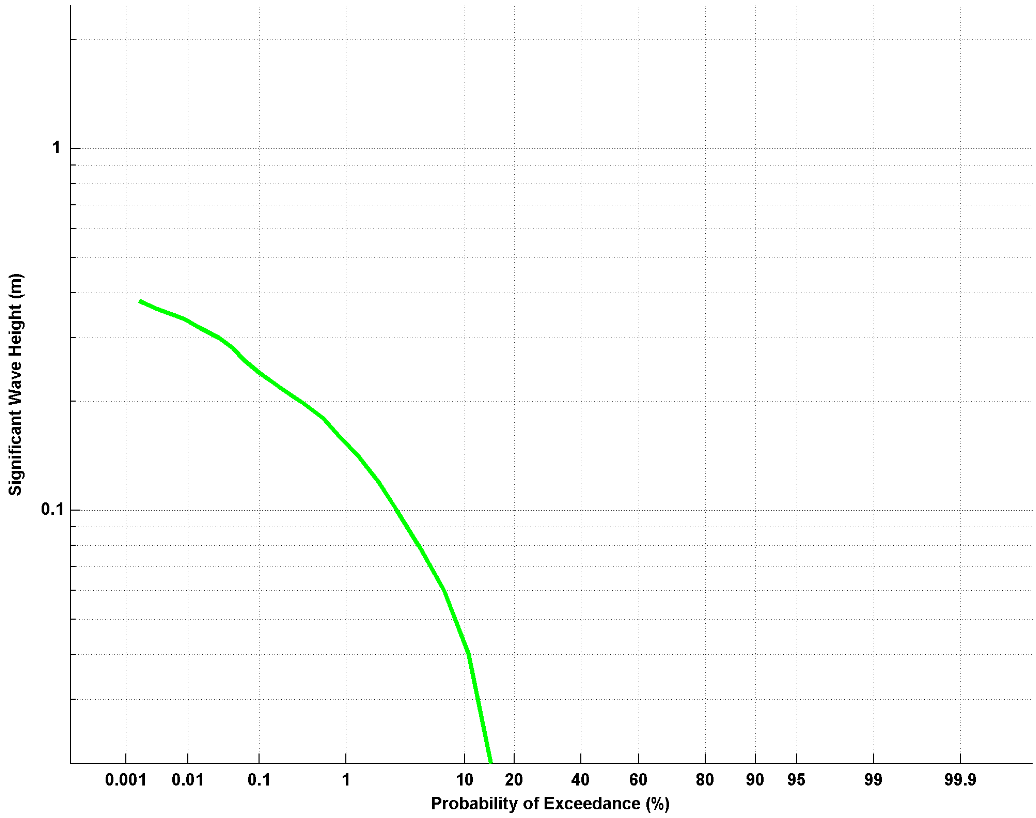



Figure D.10 Probability of exceedance curve for significant wave height at the site 7.

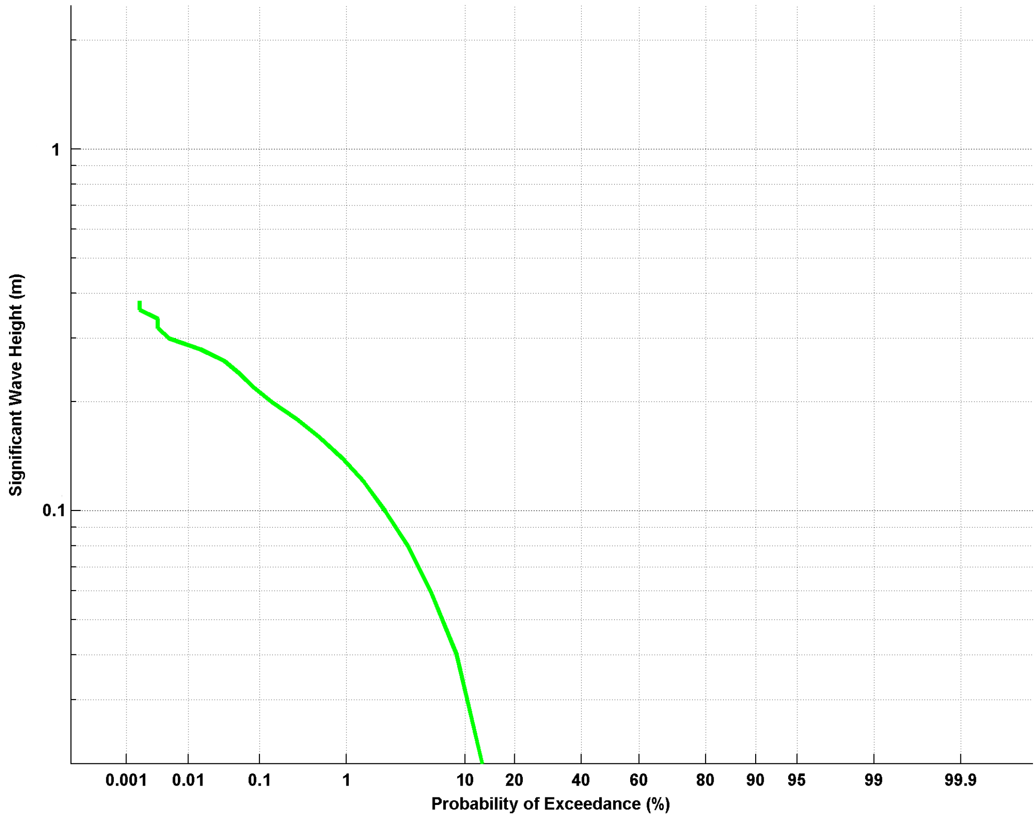



Figure D.11 Probability of exceedance curve for significant wave height at the site 8.

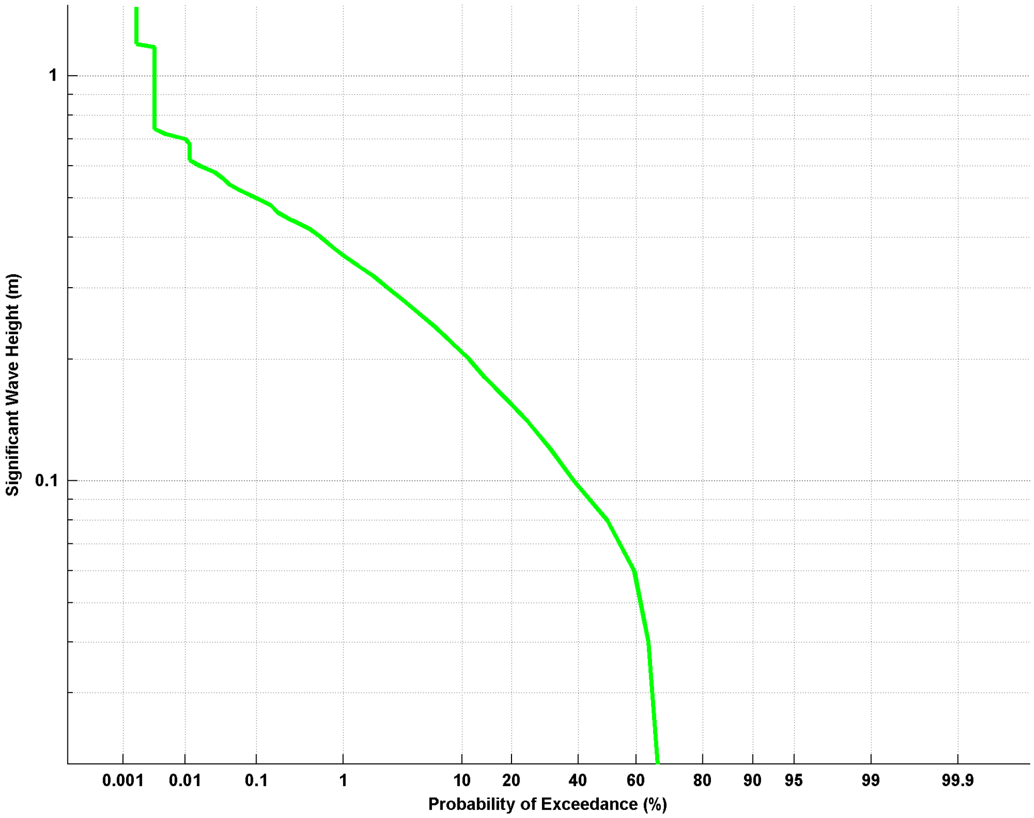



Figure D.12 Probability of exceedance curve for significant wave height at the site 9.