



GREAT LAKES COUNCIL

Boomerang Beach and Blueys Beach Coastal Processes and Hazard Definition Study

301020-02334

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BOOMERANG BEACH AND BLUEYS BEACH COASTAL PROCESSES AND HAZARD DEFINITION STUDY

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PROJECT 301020-02334 - BOOMERANG BEACH AND BLUEYS BEACH

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1 INTRODUCTION

1.1 Background

The Great Lakes Local Government Area (LGA) is located on the mid-north coast of New South Wales (NSW). Boomerang Beach and Blueys Beach are two adjacent beaches, 1.5 km and 0.9 km long respectively, located within the LGA approximately 18 km south of Forster. A locality plan is shown in **Figure 1.1**.

The coastal frontage of the two beaches is predominantly residential development (post 1970). Significant redevelopment (residential and tourist) has recently occurred and may continue in the future. Property values along the beaches are amongst the highest in the LGA. Population growth and increasing residential and tourist development in the area place significant pressure on the natural resources of the coastline.

Coastal processes have threatened sections of Boomerang Beach and Blueys Beach in the past, impacting on assets and the recreational amenity of the beaches. The most recent technical advice relating to the extent of coastline hazards affecting the beaches remains the report prepared by the (then) Public Works Department (PWD) (1985) "*Boomerang Beach and Blueys Beach Coastal Engineering Advice*". While valuable, the PWD advice makes no allowances for climate change impacts. In particular, there is no allowance for predicted mean sea level rise and associated recession of sandy shorelines.

Council's DCP (GLC 2009) for the environmental hazard "Sea Level Rise and Coastal Erosion" requires the following for proposals on land subject to coastal hazards:

- a report from a suitably qualified geotechnical engineer to determine suitable measures for protection of the building against coastal erosion and sea level rise; and
- where native vegetation that currently protects the dune system from erosion processes will be affected, a Vegetation and Environmental Impact Assessment by a qualified ecologist.

Council's current policy - "Building Standard – Foreshore of Boomerang and Blueys Beaches" aims to minimise coastal erosion via a 15 m foreshore setback. The setback was based on a long term recessional trend of 0.3 m/year (identified in the 1985 PWD report referred to above) multiplied by the average life span of 50 years for a building.

Section 733 of the *Local Government Act 1993* provides exemption for liability for advice furnished by a Council which is substantially in accordance with the principles contained in *Coastline Management Manual* (NSW Government 1990). The *Coastline Management Manual* states that responsibility for management of the coastal zone should be discharged through the implementation of a coastline management plan based on the findings of a coastal processes/ hazard definition study (including consideration of climate change) and coastline management study.





In recognition of the issues outlined above, Council has resolved to prepare a comprehensive Coastline Management Plan for Boomerang and Blueys Beaches. This Plan would be prepared in accordance with the *Coastline Management Manual* (1990) and *NSW Coastal Policy* (1997) and the provisions of Part 4A of the *Coastal Protection Act 1979*. Such an action is considered consistent with the State Government's *Mid North Coast Regional Strategy* (NSW Department of Planning 2009) which identifies the minimisation of coastal hazards through land use planning.

1.2 Coastline Management Process and Policy Framework

The steps involved in formulating a Coastline Management Plan, in accordance with the NSW Government's Coastline Management Manual (1990), in broad terms include the following:

- 1. Formation of a Coastline Management Committee.
- 2. Preparation of a Coastal Processes and Hazard Definition Study identifying the type, nature and significance of the various coastal processes and hazards affecting the area.
- 3. Preparation of a Coastline Management Study to identify management options for the area.
- 4. Preparation of a Coastline Management Plan consisting of the best combination of options for the area.
- 5. Development of a Program to implement the Plan.
- 6. Approval of the Coastline Management Plan by the Minister for Climate Change and the Environment and then gazettal of the approved Plan by the Council.

Council has formed a Coast and Estuary Management Committee, representing the first step in the process outlined above. This report represents the second stage in the process, defining the hazards that affect Boomerang Beach and Blueys Beach and determine the landward limit of beach erosion escarpments, due to the cumulative effects of these hazards for various planning periods. Through studying the coastal processes that impact Boomerang Beach and Blueys Beach, a conceptual understanding is gained of how and why hazards arise. This is an important step in the overall sustainable management of the coastal Processes and Hazard Definition Study enables the preparation of the Coastal Processes and Plan.

1.3 Study Objectives/ Scope of this Report

The primary objective of this study is to develop a comprehensive Coastal Processes and Hazard Definition Study for Boomerang Beach and Blueys Beach. The report examines the coastal hazards that impact the coastline at the beaches and assesses these hazards to determine the immediate, 2060 and 2100 hazard lines taking into account the sea level rise planning benchmarks contained in the *NSW Sea Level Rise Policy Statement* (2009).





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The hazards examined in this report are generally those set out in the NSW Government's Coastline Management Manual (1990), as listed below:

- beach erosion;
- shoreline recession;
- sand drift;
- coastal inundation;
- stormwater erosion;
- slope instability; and
- climate change.

The information included in each report section is listed below:

Section 2 outlines the geographical and historical setting;

Section 3 outlines the data used in the preparation of this report;

Section 4 examines the coastal processes operating in the study area;

Section 5 discusses the coastline hazards affecting the study area, quantifying these hazards where possible;

Section 6 defines the coastline hazard zones; and

Section 7 provides a summary of the findings of the report.





BOOMERANG BEACH AND BLUEYS BEACH COASTAL PROCESSES AND HAZARD DEFINITION STUDY

2 STUDY AREA

Boomerang Beach and Blueys Beach are located on the mid-north coast of NSW, approximately 18 km south of Forster and 10 km north of Sugarloaf Point/ Seal Rocks. The study area is shown in **Figure 1.1**. These two embayments are located on the moderate to high energy, east Australian coastline and front the Tasman Sea (South Pacific Ocean). The width of the study area is variable and includes both marine and terrestrial areas (beaches, dunes, and nearshore waters) likely to be impacted by human activities and coastline hazards. While the marine area beyond the low water mark is not subject to Council's planning controls it is important to consider those waters and submerged lands in formulating the *Coastline Management Plan* where existing and proposed human activities may impact on the shoreline and its immediate environments

2.1.1 Regional Setting

Figure 1.1 (left panel) shows the study area's regional setting. The two beaches lie within a 25 km stretch of coastline, extending from Sugarloaf Point in the south to Cape Hawke in the north, that is predominately orientated in a north-south alignment. Sugarloaf Point marks an abrupt change in coastal alignment; south of Sugarloaf Point the coastline trends southwest whereas to the north of Sugarloaf Point the coastline trends northerly. Sugarloaf Point also marks an abrupt change in coastal geomorphology; to the southwest (towards Port Stephens) lie the massive sand barrier deposits of the Seal Rocks, Eurunderee and Fens embayments whereas to the north (towards Charlotte Head) the coastline is characteristically rocky. The sandy 2.8 km Sandbar Beach, which forms across the entrance to Smiths Lake is the exception.

North of Charlotte Head the coast turns west where Shelly Beach and Elizabeth Beach, both northfacing beaches, are found sheltered from the dominate southerly wave direction. Seven Mile Beach tends north then northeast and connects the Pacific Palms area to the Cape Hawke area. Further to the north, between Cape Hawke and Hallidays Point, lie the massive sand barrier deposits of the Forster/ Tuncurry embayment (PWD 1985).

Directly to the west of the two beaches lies the southern most section of Wallis Lake. Boomerang Beach, the closer of the two beaches, is separated from Wallis Lake by 1.7 km. A bedrock ridge separates the sediments of Blueys, Boomerang and Elizabeth beaches from the lake.

2.1.2 Definition of Coastal System

Although the beach is often perceived as the sandy stretch landward of the waterline the overall beach system extends from several kilometres offshore, in water depths of typically about 25-30 metres, to the back beach dune or barrier region. The beach itself includes the beach berm and any incipient dune formation. **Figure 2.1** illustrates the relevant features referred to in this study.





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Figure 2.1 Schematic illustration of Coastal System (source: PWD 1985)

2.1.3 Boomerang Beach

Morphology of Boomerang Beach

Figure 2.2 presents a digital terrain model of Boomerang Beach and Blueys Beach based on Council supplied LiDAR survey.

Boomerang Beach comprises a 1400 m long sandy barrier beach situated between the bedrock headlands of Charlotte Head and Boomerang Point (see **Figure 2.2**). Charlotte Head rises 96 m above Australian Height Datum (AHD) (which is approximately equal to mean sea level (MSL)) and Boomerang Point to 60 m AHD. The ocean/ shoreline interface is indented 300 to 600 m from the tip of the headlands at the southern and northern ends, respectively. The shoreline is slightly concave in shape but generally faces east-southeast. The beach berm width varies. Following calm conditions it can be up to 100 m wide and generally reduces in the southern corner of the beach. The beach berm is backed by a high foredune along its entire length, ranging in elevation from approximately 10 m to as high as 24 m AHD. Several large, stable dunes are found landward of the foredune along Boomerang Beach, these are visible in the digital terrain model (see **Figure 2.2**) reaching elevations of up to 28 m AHD. Landward on the barrier dune system the back beach area is dominated by teatree swamp of low relief (generally below 5 m AHD) and is drained northward by Elizabeth Creek which discharges to the ocean via Elizabeth Beach. As such very limited local drainage occurs across Boomerang Beach.





Boomerang Beach receives medium sized waves averaging 1.6 m which combine with the medium sized sand to maintain a single bar usually cut by five or six rips, together with a topographic rip against each head (Short 2007).

Built Environment of Boomerang Beach

Much of the frontage of Boomerang Beach consists of the one way coastal road, Boomerang Beach Road, that backs the foredune, with beach front houses directly landward of the road. At the northern end of the one way road there is a car park with picnic facilities, viewing platform and formal beach access. To the north of this is a single house with direct beach frontage. North of this house the beach is backed by a steep vegetated slope. A second car park with formal beach access is located at the southern end of the one way road. To the south of this, is a 230 m stretch of beach with 13 beach front properties. South of these properties is a steep and narrow area that separates the beach from Boomerang Drive. This area also contains a formal beach access.

2.1.4 Blueys Beach

Morphology of Blueys Beach

Blueys Beach is a 900 m long sandy barrier beach situated between Boomerang Point and Blueys Head (**Figure 2.2**). **Figure 2.2** presents a digital terrain model that includes Blueys Beach. The shoreline is straight and faces approximately east-southeast. The northern end of the beach is indented 400 m from Boomerang Point and the southern end is only slightly set in from Blueys Head. Blueys Head is backed by steep, vegetated slopes rising to 216 m AHD. South of Blueys Head the coastline is steep and rocky.

After long periods of beach building conditions, the beach berm and incipient dunes are typically 100 m wide. Much of the beach is backed by a small dune escarpment at about 3 m AHD that is loosely vegetated with sand binding grasses. Behind this barrier, dunes rise to 12 to 15 m above AHD and are generally lightly vegetated. In the centre of the beach the dune rises steeply and its height exceeds 18 m above AHD. This dune is thickly vegetated. The dune at the southern end of the beach drops to less than 4 m above AHD, marking the entrance of a small creek that drains the small coastal catchment behind Blueys Beach. Landward of the barrier dunes the land initially falls before rising again sharply as forested hills surrounding Blueys Beach.

Built Environment of Blueys Beach

Blueys Beach frontage is dominated by residential development, with 44 properties located along the rear of the foredune. At the northern end of the beach Banksia Street terminates at a cul-de-sac with beach views. A formal car park with beach access is located at the seaward end of Blueys Way. Between Banksia Street and Blueys Way, three properties, (two properties located on Banksia Street and a third property located on Blueys Way) front the beach. Along Newman Avenue there are:

- 15 beach front properties between Blueys Way and View Street;
- 13 beach front properties between View Street and Samuel Street; and





• 13 beach front properties between Samuel Street and the car park and beach access located adjacent to Ampat Place.

South of the car park and beach access is the entrance of an unnamed creek. There is one property with beach frontage at the very southern end of Blueys Beach and Newman Avenue.

2.2 Historical Setting

2.2.1 General

The study brief outlines a summary of the historical development of the area which is reproduced below.

"Boomerang and Blueys beaches were relatively undeveloped until the early 1970s when heavy mineral sand mining took place. According to the PWD (1985), "Some of this residential development is very close to the back beach erosion escarpments and has raised questions relating to beach stability, shoreline recession and hence the threat to the dwellings. Further, such questions arise whenever new developments and re-developments are proposed."

Available information shows that the development of Boomerang Beach for residential purposes and the evolution of the setback policy began with a subdivision in 1961, when 110 lots were created at the southern end of the beach (*DP 200167*). Subsequent large subdivisions were carried out in 1974 (*DP 248650*), 1975 (*DP 250863*) and 1977 (*DP 253875*). By 1964 only one dwelling had been erected within the village and at that time applications were made to mine the frontal dune and beach berm for heavy mineral sands (*rutile, zircon and ilmenite*). Considerable development took place subsequent to sand mining partly in response to the improved access. By September 1972 there were eight dwellings and by 1981 there were approximately 50 dwellings.

PWD (1985) indicates that residential development commenced at Blueys Beach earlier than at Boomerang Beach. The 1956 aerial photography indicated only a track running behind the frontal dune; this track eventually became Newman Avenue. By 1964, five dwellings had been constructed east of Newman Avenue, in 1972 there were twenty dwellings and by 1981, 32 dwellings existed between Newman Avenue and the beach (PWD 1985).

2.2.2 Sand Mining

Mining of the northern two-thirds of Boomerang Beach was carried out between July 1970 and January 1972. The mining lease covered the frontal dune and beach berm (**Figure 2.3** reproduced from PWD 1985). Associated with this mining was the development of a camping area and caravan park at the southern end of the beach.

Sand mining was carried out on Blueys Beach between March 1973 and January 1974. The mining progressed northwards from the creek outlets at the southern end of the beach and included the beach berm and incipient foredunes (**Figure 2.3**). At the end of mining works, the company constructed a car park at the northern end of the beach. However, as the car park was established seaward of the natural dune alignment, it was eroded away during storms in 1975 (PWD 1985).





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Figure 2.3 Location of historical sand mining activities at Boomerang and Blueys Beaches (Source: PWD, 1985)

2.2.3 The Establishment of Development Setbacks

In 1976, responding to a perceived need to implement a beach management program, Council sought advice from the Soil Conservation Service. The service recommended the construction of fencing, board and chain walkways, sowing of bare areas with Spinifex, fertilising of fenced areas and closure of the public road along the northern section of Boomerang Beach. In 1978 Council obtained a grant under an Unemployment Relief Program to construct fencing and walkways (Andrews 2007).

In 1981, following a proposal to lower the dune adjacent to Coast Avenue to facilitate the erection of dwellings on the dune, the PWD advised Council that there was evidence that Boomerang Beach was undergoing long term recession. PWD considered that any development located on the frontal dune could be under threat from coastal processes in the future. This led to the adoption of a policy in February 1983 in respect to development on the southern end of the beach, requiring development applications (DAs) to be supported by a report certifying that the land and buildings are not liable to be affected by coastal processes during the economic life of the building. In 1987, the policy was amended to permit the erection of new buildings subject to a minimum 15 m setback (based on a long term recessional trend of 0.3 m/year multiplied by the average life span of 50 years for a building) with the exception of Lots 112 to 124 (these required DAs to be accompanied by detailed geotechnical





investigation and analysis). In 1989 the policy was simplified to restrict development to a minimum 15 m setback. However, the overwhelming majority of developments along Boomerang and Blueys Beaches are sited less than 15 m from the eastern boundary, having been approved prior to the 1989 Policy adoption or more recently, after receiving engineering advice (Andrews 2007).

2.3 Conservation Values

An *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* Protected Matters Report was generated for an area of 2 km radius around Boomerang Point in May 2010. In summary, the report identified the following Matters of Environmental Significance in the study area:

- Wetlands of International Significance (Ramsar Sites) Myall Lakes Within 10 km of the study area.
- Threatened Ecological Communities Littoral Rainforest and Coastal Vine Thickets of Eastern Australia Community is likely to occur within the area.
- 40 threatened species of birds, frogs, mammals, reptiles, sharks and plants.
- 44 migratory species of birds (terrestrial, wetland and marine), marine mammals, marine reptile and sharks.
- 56 listed marine species.
- 13 whales and other cetaceans.

No Aboriginal sites of historical importance listed under the NPWS Aboriginal Sites Register are known in the Boomerang Beach area. However, officers of the Forster Local Aboriginal Lands Council are aware of several midden sites in the locality (Great Lakes Council 2006).





3 DATA ACQUISITION

3.1 Previous Studies/ Literature Review

As part of this study a comprehensive search and review of previous literature was undertaken. The reports most relevant to the current study are outlined below.

3.1.1 Coastal Engineering Advice (Public Works Department 1985)

Boomerang Beach and Blueys Beach - Coastal Engineering Advice was prepared by the then NSW Public Works Department (PWD, 1985) in response to ongoing concerns of Council regarding coastal hazards and development controls at Blueys Beach and Boomerang Beach. The study contained:

- an historical review of the region;
- a geological/ geomorphological assessment of the area;
- coastal processes;
- photogrammetric analysis of aerial photography; and
- wave and storm surge analysis.

From these assessments a conceptual coastal processes model for the two beaches was put forward. The main report findings, with regard to coastal processes, are summarised below:

- Boomerang Beach and Blueys Beach are two small sandy embayments lying on a coastal littoral drift system that extends from Sugarloaf Point to Black Head. The net rate of littoral drift is in the order of 30,000 m³ per year and is directed northerly.
- Both beaches show evidence of foreshore recession over the period encompassing the present high sea level stand, that is, over the past 6,000 years.
- Mechanisms exist whereby further sand losses from these beaches can occur. These mechanisms include the inland loss of sand under onshore wind action and the removal of sand from the littoral zone of the beaches by longshore littoral drift mechanisms.
- The present-day rate of loss of sediment from these beaches is considered to be small. Foreshore recession of Blueys Beach is considered to be negligible and the rate of sediment loss from Boomerang Beach is estimated to be in the order of 5,000 m³/year. This loss rate is reflected in the measured annual, averaged rate of recession over the central portion of Boomerang Beach of 0.3 m/year for the period 1956 to 1981.
- Preliminary slope stability analysis of the dune escarpment at the southern end of Boomerang Beach, south of Boomerang Beach Road, indicate that for fair weather conditions the factor of safety against escarpment slumping may be on the limit of, or lower than, those acceptable for normal good engineering practice. The factor of safety is considerably lower when storm





erosion removes a portion of the toe of the embankment and the dune water table is raised through surcharging caused by heavy rainfall and high oceanic run-up levels. The report noted that to confidently assess the safety of development along this portion of the frontal dune, more detailed geotechnical investigations and analysis are warranted.

• Apart from the section of development described in the above dot point, existing development generally along the frontal dunes of Boomerang Beach and Blueys Beach will not be at risk from coastal hazards in the foreseeable future provided that sound beach management practices, as currently being implemented by Council, are continued.

3.1.2 Boomerang Beach Dune Care

The Boomerang Beach Regeneration Project (a joint venture between Great Lakes Council and Boomerang Beach Dunecare (formed 2004)) was aimed at the "ecological restoration of plant communities along Boomerang Beach... to enhance the resilience of the landscape and plant community, therefore ensuring the long term stabilisation of the dune". The associated Bushland Volunteers Site Assessment and Work Plan – Boomerang Beach, was prepared by Great Lakes Council in 2006. The findings of the report are listed below.

Ecosystem/ Habitat Features of the Dune

- 1.5 km of incipient and foredune vegetated by species including Spinifex, Beach Fan Flower, Coastal Pig Face, Coastal Banksia, Coastal Wattle and invasive weeds.
- Littoral Rainforest is present at Charlotte Head and Boomerang Point (highly modified in this location).
- Patches of Themeda Grassland occur on the northern side of Boomerang Point.
- Rocky shores are present at the north and south ends of the beach.
- The dune vegetation forms part of a corridor linking Booti Booti and Myall Lakes National Parks.
- Habitat features of the sand dunes include dead trees, nectar plants, roosting sites, crab holes and rocky shelves.

Dune Erosion Issues

- The dune system has been damaged by historical sand mining, urbanisation, impacts of human recreational use (litter, foot traffic causing erosion, informal access tracks, tree vandalism etc.), dieback of native vegetation, boundary encroachment and weed invasion (including garden escapees).
- Small blowouts are present along most of the dune.





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Dunecare Current Activities/ Future Action Plans

- **Historical actions** Coastal Tea Tree and Golden Wreath Wattle were introduced as stabilisers following sand mining operations in the 1970s which severely reduced the natural extent of the fore and hind dunes. It is suspected that Bitou Bush invaded from nearby areas after sand mining ceased.
- **Current Actions** Weed reduction, litter control, vegetation protection (through erection of fencing to provide protection from strong winds), erosion control (dune access, fencing, brush matting), facilitated regeneration and community education (e.g. erection of signs, provision of information pertaining to illegal clearing and beach access), maintenance of formal accessways, addressing informal private access through dunes, defining property boundaries through use of bollards. The group targets Bitou Bush utilising hand pull, hand spray and cut and paint methods.
- **Future Actions** liaison with schools, seed collection and propagation, education campaigns, community field days.

3.2 Review of Historical Aerial Photographs

Aerial photography is available for the Boomerang Beach and Blueys Beach coastline dating back to 1937. To assist in gaining an understanding of the coastal processes and to assist in photogrammetric analysis (identifying anthropogenic influences such as sand mining activities, beach reshaping and beach accessway construction) a review of the aerial photographs was undertaken. A summary of some of the distinctive features of various dates of photography is provided in **Appendix B**.

PWD (1985) determined the history of shoreline movements of the two beaches using available aerial photography spanning the period September 1956 to March 1981. The depth of the analysis which could be undertaken on these photos was restricted by the short time period over which the photography spanned and the small photo scales. In addition, heavy sand mining operations at both beaches complicated interpretation of the natural sand movements. The major findings of the PWD review of aerial photography and photogrammetry are provided in **Section 4.7.1**.

3.3 Photogrammetry

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

The photogrammetry data consisted of 48 cross-shore profiles in 3 blocks covering a total coastline length of approximately 2.3 km from Blueys Head to Charlotte Head. The data covered the period from 1956 to 2006. **Appendix A** provides further information regarding the photogrammetry including:

• details of the dates of photography and the locations of photogrammetric profiles;





- a description of the methodology used in the analysis of the photogrammetric data; and
- tables and plots of analysis results.

3.4 Survey Data

An Airborne Laser Survey (ALS) of the LGA was conducted on behalf of Council in 2007. Council supplied the processed point data based on this survey information. The accuracy of this data is +/- 0.15 m. Based on the supplied survey data a Digital Terrain Model (DTM) of the study area was created using the 12D software package. This was used to assist in identifying low lying areas subject to coastal inundation and in developing a Conceptual Coastal Processes Model (see **Section 4.12**).

Hydrographic survey data of the nearshore area is limited to Hydrographic Charts. PWD (1985) provides information on sediment sampling including depths along a number of offshore profiles. This is further discussed in **Section 4.8.2**.





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4 COASTAL PROCESSES

In this Section, the coastal processes prevalent along the study area coastline are outlined. In particular, details are provided on:

- wave climate (Section 4.1);
- elevated water levels (Section 4.2);
- wave runup (Section 4.3);
- coastal storms (Section 4.4);
- wave induced currents (Section 4.5);
- short term onshore/ offshore sediment transport (Section 4.6);
- longer term sand movement (Section 4.7);
- geotechnical conditions (Section 4.8);
- climate change (Section 4.9); and
- aeolian (wind) sand transport (Section 4.10).

4.1 Wave Climate

Manly Hydraulics Laboratory (MHL), part of the NSW Department of Commerce, operates a network of Waverider buoys in deep water along the NSW coast. Waverider buoys are spherical floating accelerometers which determine sea level surface displacement based on the double integration of measured vertical accelerations. Analysis of the collected data allows, amongst other things, the significant wave height (H_s) and peak spectral wave period (T_p) to be determined. For the NSW network, records are collected for 2048 s bursts (about 34 minutes) every hour at 0.5 s intervals (Lord and Kulmar 2001). Waverider buoys can be non-directional or directional. Directional buoys allow the predominant wave direction to be determined.

In the vicinity of the study area, a Waverider buoy is located offshore about 65 km north east of the site at Crowdy Head. The Crowdy Head Waverider buoy is a non-directional buoy that has been operating since 10 October 1985. Hourly wave data from this wave buoy was sourced from MHL. The data covered the period from 10 October 1985 to 30 April 2008 with an 86% capture rate. The data consisted of H_s , H_{max} , T_z , and T_p for this period where H_{max} is the maximum wave height and T_z is the zero crossing wave period. Wave directions have been hindcast by MHL for the period 10 October 1985 to 31 December 1996 based on interpretation of historical synoptic chart information. Limitations in the accuracy of this hindcast method need to be considered in the analysis.





BOOMERANG BEACH AND BLUEYS BEACH COASTAL PROCESSES AND HAZARD DEFINITION STUDY

Based on analysis of the H_s data at Crowdy Head to 30 April 2008, the probability of exceedance of a particular offshore deepwater significant wave height (H_s) is as shown in **Figure 4.1**. From the analysis it was calculated that:

- the average wave height is 1.6 m, the median or 50th percentile wave height is 1.5 m;
- *H*_s exceeds 3 m for about 5% of the time;
- *H*_s values exceeding 4 m occur less than 1% of the time;
- storm conditions with H_s exceeding 5 m occur on average once or twice a year;
- the one day per year (i.e. 1/365.25=0.274% Probability of Exceedance) wave height is 4.8 m, the 12-hour per year (i.e. 12/(365.25x24)=0.137% Probability of Exceedance) wave height is 5.0 m;
- the largest H_s was 7.35 m recorded on 4 March 1995 at 13:00hrs with a T_p of 13.5 s, the corresponding H_{max} was 11 m;
- for a storm duration of 6 hours the 100 year Average Recurrence Interval (ARI) wave height is 7.8 m; and
- the average T_p at Crowdy Head is 9.7 s, with about 92% of records having a T_p between 6 s and 14 s.









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Beach erosion is strongly linked to the occurrence of high wave conditions with elevated ocean water levels (the latter are discussed in **Section 4.2**). Therefore, inclusion of duration is likely to more accurately describe the severity of a storm in terms of beach erosion, rather than using average recurrence interval (ARI) alone (Lawson and Youll 1977). Erosion is more likely to be significant when the large waves coincide with a high tide. In general, storms with a duration in excess of 6 hours are likely to coincide with a high tide on the NSW coast (Lord and Kulmar 2001). It is therefore considered that the 6 hour duration is the most appropriate to use for beach erosion and wave runup considerations, and as such has been adopted for use in this study.

Analysis of the available hindcast directional wave data from 1985 to 1997 is presented in the wave rose plot seen in **Figure 4.2**. In summary, this analysis indicates that deepwater waves approach the study area proportionally as follows:

- 6% from the NE;
- 11% from ENE;
- 17% from the E;
- 18% for ESE;
- 24% from SE;
- 13% from the SSE; and
- 11% from the S.



Figure 4.2 Wave rose for all hindcast directional Crowdy Head Waverider Buoy data (from October 1985 to December 1996)





Analysis of the hindcast directional wave data for Crowdy Head indicates the weighted (height and period) offshore directional average to be approximately from the SE at 134°N.

As previously discussed, the accuracy of this data is limited by the methodology employed to hindcast the wave direction. Nearshore coastal processes are highly sensitive to wave direction. The lack of high quality measured wave direction data in the local region is considered a significant data gap hindering the understanding of the processes in the study region.

Analysis of the Sydney directional data from 1992 to 1999 indicated that 34% of waves came from the south-southeast, with 17% of waves from the southeast and 14% of waves from the south. Furthermore, the south-southeast direction was dominant for larger waves (Lord and Kulmar 2001). Installation of directional Waverider buoys (since 1992 in Sydney) has indicated that the predominant wave climate along the NSW coast is from the south-southeast.

Comparison of the Crowdy Head hindcast directional wave data with the Sydney directional data suggests the possibility of a more easterly average offshore direction for the study region, although the limitations of the directional data derived for Crowdy Head must be recognised.

4.2 Elevated Water Levels

The factors potentially contributing to elevated still water levels on the NSW coast comprise:

- astronomical tide;
- storm surge (barometric setup and wind setup); and
- wave setup (caused by breaking waves).

Individual waves also cause temporary water level increases above the still water level due to the process of wave runup or uprush (see **Section 4.3**). Note that sea level is also predicted to rise due to climate change. This is discussed further in **Section 4.9**.

In NSW, open coast water levels (within the wave breaking zone) can increase by up to about 2.1 m above normal levels during storms due to storm surge and wave setup. The magnitude of these can be as large as:

- 0.6 m for storm surge (barometric setup of up to 0.3 to 0.4 m and wind setup of up to 0.2 to 0.3 m); and
- 1.5 m for wave setup (typically about 10-15% of the deepwater significant wave height).

This increase in water level is superimposed on the astronomical tide, which typically varies between about -1 m AHD (approximately equivalent to Indian Springs Low Water or Lowest Astronomical Tide, LAT) and 1 m AHD (approximately equivalent to Highest Astronomical Tide, HAT) along the NSW coast, with 0 m AHD close to mean sea level. On the NSW coast, Mean High Water Springs is about 0.6 m AHD, Mean High Water is about 0.5 m AHD, and Mean High Water Neaps is about 0.4 m AHD. If a severe storm continued for a day, it would be expected that two high tides would occur during this time. Ignoring wave effects, the highest absolute water level that might be experienced in a storm would be when the maximum storm surge occurred at the same time as the HAT.







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Water levels have been recorded at Fort Denison in Sydney Harbour for over 100 years, and are representative of NSW open coast water levels near Sydney (in the absence of waves). The data from 1914 onwards is considered to be reliable. Based on a joint probability analysis of tide and storm surge (assumed as independently occurring events), for the May 1914 to December 1991 data set, Manly Hydraulics Laboratory (MHL 1992) predicted that the 100 year, 50 year and 20 year ARI water levels at Fort Denison were 1.49 m, 1.46 m and 1.41 m AHD respectively. The highest recorded water level at Fort Denison was 1.48 m AHD in May 1974. These levels are representative of astronomical tide and storm surge, but exclude wave setup.

Assuming extreme water levels in Sydney were representative of conditions at Boomerang Beach and Blueys Beach, the 100 year ARI water level (including astronomical tide and storm surge) adopted was 1.5 m AHD. With a 100 year ARI offshore significant wave height of 7.8 m (**Section 4.1**), and assuming wave setup as 15% of this wave height, the 100 year ARI wave setup was determined as 1.2 m. Therefore, the 100 year ARI design storm elevated water level (astronomical tide plus storm surge and wave setup) of 2.7 m AHD has been adopted for this study. This design level does not include climate change considerations which are further discussed in **Section 4.9**.

4.3 Wave Runup

Wave runup is site specific, but typically is about 3 m to 6 m above the elevated still water level on the NSW open coast. The height of wave runup on beaches depends on many factors including (NSW Government 1990):

- wave height and period;
- the slope, shape and permeability of the beach;
- the roughness of the foreshore area; and
- wave regularity.

Wave runup can be difficult to predict accurately due to the many factors involved. Anecdotal evidence and the surveying of debris lines following a storm event usually provide the best information on wave runup levels.

Hanslow and Nielsen (1995) provide guidance on calculating wave runup. They found that the runup above the still water level was given by:

$$R = 0.9H_s \left(\frac{L_s}{H_s}\right)^{0.5} \tan\beta$$
⁽¹⁾

where *R* is the runup exceeded by 2% of waves, H_s is the significant wave height, L_s is the significant wave length, and $tan\beta$ is the beach slope.



 L_{s}



(2)

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The significant wave length is given by:

$$=\frac{gT_s^2}{2\pi}$$

where *g* is the gravitational acceleration (9.8 ms⁻²) and T_s is the significant wave period. Note: wave setup is implicitly included in this calculation of wave runup.

As noted earlier for Boomerang Beach and Blueys Beach the adopted 100 year ARI H_s is 7.8 m and T_s can be assumed to be 12 s, as is commonly used in coastal engineering design. Assuming that the beach face slope is equal to 1H:10V, as is common in an eroded profile, the predicted runup above the still water level is 3.8 m. With a still water level of 1.5 m AHD (**Section 4.2**), the predicted 100 year ARI wave runup level exceeded by 2% of waves is 5.3 m AHD. For planning purposes, it is considered that a runup level of 6.2 m AHD should be adopted for the study area. This includes the predicted sea level rise of 0.9 m by 2100 years. Refer to **Section 4.9** for a discussion on sea level rise.

Runup levels in the order of 6 m AHD would only be realised if the foreshore was at this runup height or higher. This would apply along much of the length of the two beaches where for the most part the dunes are well above 6 m AHD. The only exception is associated with the creek entrance area (an area approximately 50 m wide) in the southern section of Blueys Beach. In this area, wave runup would penetrate the creek channel as sheet flow at shallow depth, spreading out and infiltrating over landward areas. Accordingly a significant reduction in the velocity and depth of runup would be expected. If the peak of the storm event was associated with heavy rainfall, runoff water from the creek would exacerbate inundation.

In the long term, as a beach receded, it could be postulated that the present dunal barrier would disappear, with the new shoreline taking on the existing topography landward of the present dune. This is considered to be unlikely from an understanding of the morphological response of beaches. The existing dune crest levels are a complex response to a variety of factors including beach sand characteristics, exposure to wind and wave action, and local topographic controls, all of which are likely to be relatively constant irrespective of the shoreline position in the long term; i.e. it is considered more likely the existing dune profile would 'roll back' if there was no intervention to protect foreshore assets.

4.4 Coastal Storms

4.4.1 General

The NSW coastline is subject to intense tropical and non-tropical storms at irregular intervals. The drop in atmospheric pressure and the winds and waves that accompany these storms can cause the ocean to rise above its normal level (see **Section 4.2**).





If this occurs concurrently with high astronomical tides, there is the potential for:

- coastal erosion (in particular as the storm waves dissipate energy closer to the shoreline with the increased water levels); and/ or
- overwash into low-lying coastal areas (PWD 1985).

PWD (1985, 1986) categorised coastal storms to indicate the potential of a storm to generate abnormal water levels along the NSW coastline. The categories were discretised on the basis of offshore significant wave heights, as shown in **Table 4.1**.

Table 4.1.	Categorisation of coastal	storms in	NSW by PWD	(1985, 1986)
------------	---------------------------	-----------	-------------------	--------------

Category	Offshore significant wave height (<i>H_s</i>), m
Х	$H_s \ge 6$
А	$5 \le H_{\rm s} < 6$
В	$3.5 \le H_s < 5$
С	$2.5 \le H_{\rm s} < 3.5$

Category X and A storms were those expected to lead to coastal erosion and damage to coastal facilities. According to PWD (1985, 1986), Category X storms were characterised by damage to coastal installations, severe erosion, and serious disruption to shipping. Category A storms were characterised by erosion or other damage to coastal installations and disruption to shipping.

In PWD (1985), all Category X, A, B and C storms that were predicted to have occurred between 1880 and May 1980 were listed¹, along with a description of the storm generating mechanism and characteristics, and wave heights and periods (for selected storms). Estimates were given for each of four coastal sectors in NSW, namely North, Mid-North, Central and South. The Mid-North sector covered the NSW coastline north from Sugarloaf Point (near Seals Rocks) to Smoky Cape (near South West Rocks), placing the study area within this sector.

Similarly, in PWD (1986), all Category X, A, B and C storms that were predicted to have occurred between May 1980 and December 1985 were listed.

4.4.2 Storm Types

PWD (1985) recognised six different major storm types which impact on the NSW coast, namely:

- tropical cyclones;
- easterly trough lows;
- inland trough lows;

¹ However, the only reliable data for statistical analysis was from 1920 to 1944 and 1957 to 1980.





- continental lows;
- southern secondary lows; and
- anti-cyclonic intensification.

Typical synoptic patterns for tropical cyclones, easterly trough lows, inland trough/ continental lows, and southern secondary lows are shown in **Figure 4.3**.



Figure 4.3 Typical synoptic patterns for tropical cyclones, easterly trough lows, inland trough/ continental lows and southern secondary lows (source: NSW Government 1990)

Based on PWD (1985, 1986) it is evident that on average:

- the Mid-North Coast sector receives a relatively high rate of coastal storm incidents with only the Central Coast sector receiving significantly greater coastal storm incidents. This is due to these sectors being influenced by storms originating in both the tropical and southern area, as well as those developing locally;
- easterly trough lows and tropical cyclones are the dominant storm types on the Mid-North Coast², however southern secondary lows can also affect the area; and
- most storms on the Mid-North Coast occur in summer, autumn and winter, with June and March being the most prevalent months for storms (tropical cyclones generally only occur between January and April, with easterly trough lows dominating between April and July).

4.4.3 Storm History

As noted in **Section 4.4.1**, PWD (1985, 1986) listed all Category X, A, B and C storms that were predicted to have occurred between 1880 and 1985. Storm history information, derived from the offshore Crowdy Head wave buoy was also obtained from Manly Hydraulics Laboratory, NSW Department of Commerce (MHL 2008). DECCW is acknowledged as the owner of this data. The information was for events where the significant wave height exceeded 3 m since the commissioning of the Waverider buoy in 1985, up until the end of 2007. Information on this data was given in **Section 4.1**.

² These storm types are predominantly weather systems that come from the north.





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A listing of the predicted Category X storms from 1940 to 1985 is given in **Table 4.2**, including the storm type. The Category X storms measured at the Crowdy Head Waverider buoy from October 1985 to January 2008 are listed in **Table 4.3**, with the recorded H_s (at the peak of the storm) and T_s values also shown.

A total of 12 Category X events were recorded at the Crowdy Head Waverider buoy from October 1985 to January 2008. This represents an average of one Category X event every 1.9 years, in the 22 years of record. However, the time period between storms was not uniform. For example, there were no Category X storms from 1991 to 1994, and three Category X storms in 1990.

Date		Storm Type		
	12-15 October 1942	Easterly Trough Low		
	10-13 June 1945	Easterly Trough Low		
	18-19 January 1950	Inland Tough		
	8 June 1951	Easterly Trough Low		
	14-15 June 1952	Continental Low		
	19-22 February 1954	Tropical Cyclone		
	18-23 February 1957	Tropical Cyclone		
	20-24 January 1959	Tropical Cyclone		
	29-31 January 1967	Tropical Cyclone		
23-24 July 1968 24-25 August 1969 22-25 July 1971 18-20 March 1978		Southern Secondary Low		
		Easterly Trough Low		
		Continental Low		
		Easterly Trough Low		

Table 4.2 Mid-North Coast Category X storms, 1940 to 1985 (PWD 1985, 1986)





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Date	Peak <i>H</i> s (m)	Mean <i>T</i> s (s)
8-11 February 1988	6.5	10.6
7-10 March 1990	6.3	10.4
28-30 May 1990	6.7	9.2
12-15 October 1990	6.4	11.1
2-5 March 1995	7.4	9.9
6-8 March 1995	6.3	10.4
9-12 May 1997	6.3	10.1
22-25 April 1999	6.5	11.2
13-17 July 1999	6.8	10.5
28 -29 July 2001	6.3	11.9
29 June - 2 July 2002	6.3	11.7
13 -17 May 2005	6	9.2

Table 4.3: Category X storms measured at Crowdy Head from 1985 to 2008

Based on the available Crowdy Head Waverider data, as documented in MHL (2008), a total of 24 Category A events were recorded from October 1985 to January 2008. This represents an average of approximately 1.1 Category A events per year, in the 22 years of record. However, the time period between storms was not uniform. For example, there were no Category A storms in 1993, 1997-1998, 2000-2003 and 2006, and three Category A storms in 1989 and 2004.

4.5 Wave Induced Currents

The most common forms of wave induced currents are longshore currents and rip currents.

Longshore currents occur within the breaker zone and move essentially parallel to the shoreline, they are usually generated by waves breaking at an angle to the shoreline. These currents cause movement of sediment along the shoreline, commonly referred to as littoral drift. Due to the variability in wave approach direction at beaches, there may be times when the littoral drift is in one direction and at other times when it is in the opposite direction.

There is a strong net south to north longshore movement of littoral sand within the surf zone of most NSW beaches north of Newcastle. As such, Mid-North Coast beaches are generally supplied by sand from the south and are the source of sand for beaches to the north. This net northward movement of sand is caused by the dominant SSE wave climate (**Section 4.1**) in relation to the general NSW coast orientation of NNE to SSW, and is particularly pronounced in northern NSW as headlands are less prominent. Storm waves can also carry sand around headlands.









Where there is a longshore variation in the rate of longshore sand transport, there will be a net gain or loss of sand from the beach compartment. That is, where more sand is transported out of a beach area than is being brought in over an extended period of time, the beach will erode with the shoreline gradually realigning. The erosion will occur initially in the surf zone where sand transport is greatest, and manifest as beach retreat (recession) following onshore/ offshore readjustment of the nearshore profile.

On a dominant northwards longshore transport coastline, based on Stephens *et al.* (1981), shoreline evolution was predicted to occur as recession commencing at the southern end of the compartment forming an embayment between controlling headlands/ features. Within each embayment, recession was also expected to be highest in the southern hook, reducing northwards to negligible rates immediately south of each headland/ feature. The evolution of zeta form embayments³ between controlling headlands was considered to be the result of this longshore transport process.

As the shoreline realigned within each compartment, the longshore transport rate was expected by Stephens *et al.* (1981) to reduce, with an ultimate reduction in the supply of sand to the next compartment. This would induce a greater transport differential in the next compartment, and cause progressive recession from south to north. The increasing sediment transport rates moving north along the NSW North Coast are consistent with the compartmentalisation and zeta form model of Stephens *et al.* (1981).

Rip currents are strong currents which flow seaward from the shore. They comprise the return movement of water which is "piled up" on the shore by incoming waves and wind. The rip consists of three parts: the feeder currents flowing parallel to shore inside the breakers; the neck, where the feeder currents converge and flow through the breakers in a narrow band or "rip"; and the head where the current widens and slackens outside the breaker line.

As the "rip" is a locally deeper channel through the sand bars, larger waves can reach the shoreline opposite rip heads. Accordingly, it is common to distinguish the higher storm erosion demand which can occur at rip heads and the lower storm erosion demand which prevails away from rip locations.

Boomerang Beach is a rip dominated single bar beach. **Figure 4.4** shows six well developed beach rips visible in this photo. While both Boomerang Beach and Blueys Beach are both short pocket beaches with topographic rips typical adjacent to the headlands, there is no evidence to suggest that the rip locations are "fixed" elsewhere along the beaches. Rather rip locations are likely to be dependent on a number of factors including wave directions and preceding bar shape. Consequently, for the purposes of assessing the possibility of increased storm erosion demand at rip heads, it is necessary to assume that a rip could form at any location along the beach.

³ Many sections of coastline which are situated in the lee of a headland, feature a curved shoreline geometry. Where sections of coastline are situated between two headlands, and particularly when there is a single, dominant wave direction, the shoreline may likewise assume a curved or "scalloped" shape. In both cases, the curved portion of the shoreline related to the headland(s) is termed a crenulate or "spiral bay". Because of their geometries, these shorelines are also sometimes termed "parabolic," or "zeta-bay" shorelines. The shape results from longshore transport processes which move sediment in the downdrift direction along the down-wave section of the shoreline, and from processes associated with wave diffraction which move sediment in the opposite direction in the immediate lee of the up-wave headland (Rosati *et al*, 2002).





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Figure 4.4. Photograph of Boomerang Beach showing exposed rip dominated beach with six well developed rips visible (source: Short 2007).

4.6 Short Term Onshore/ Offshore Sediment Transport

Onshore/ offshore (also known as cross-shore) sand movement is caused by natural variations in wave climate and water level. The offshore movement of sand is usually referred to as storm erosion. This onshore/offshore movement of sand results in short term fluctuations in the width of the beach profile.

During storms, the beach is cut by storm waves with beach sand moving offshore to form bars in the surf zone. This process typically occurs over a period of hours to days. When extended periods of calmer waves occur, the material held in these bars migrates onshore to re-build the beach berm. Evidence of this process operating at Boomerang Beach and Blueys Beach is visible in historical aerial photographs where nearshore sand bars can be seen in both detached positions and attached to the beach. Depending on the magnitude of the preceding storm, this beach building process can occur over a time scale of days to years.

Onshore/ offshore sand movement can also be caused by wind, particularly manifested as landward sand drift into dune areas. See **Section 4.10** for further discussion on aeolian sand movement.





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4.6.1 Storm Demand

The amount of sand which can be removed from a beach during a storm event, and transported offshore, is referred to as the storm erosion demand or simply 'storm demand'. This quantity is generally measured above 0 m AHD (approximately mean sea level), and is usually expressed as a volume per m length of beach (m^3/m). Knowledge of the storm demand for a beach allows estimation of the amount of material required to be held in reserve for a storm in order to protect a given asset. It also allows estimation of the degree to which a beach would be eroded, or cut back, in a storm for a given pre-storm beach profile.

The reason that the storm demand is generally measured above 0 m AHD is a reflection of the manner in which the data to describe storm demand has been obtained. Storm demand estimates are typically derived from survey or photogrammetric techniques, where only that portion of the beach above mean sea level is either considered or is visible. The storm demand, or the extent of erosion along the beach, in any given event is based on a broad range of factors that include but are not limited to:

- wave height, period and direction of storm waves;
- tidal conditions (i.e. spring or neap tidal range and the phase of the tide at the peak of the storm);
- co-incidence with elevated ocean water levels (storm surge and wave setup);
- duration of the event;
- exposure and orientation of the beach;
- state of the beach and surf zone bars before the storm;
- presence of rip cells;
- topographic features (e.g. adjoining headlands), reefs and coastal structures that affect surf zone dynamics; and
- climatic influences such as El Niño and La Nina episodes.

Due to the lack of measured data on historical storm bite⁴ volumes it is difficult to assign a statistical design ARI value for storm demand. Several of the aforementioned factors have statistical ARI design values and have been used (e.g. waves and elevated water levels) as surrogates for estimating design storm demand. For example the use of 100 year wave heights and water levels have been used with numerical models as a surrogate to derive the 100 year ARI storm demand. In fact these approaches are unlikely to provide a 100 year ARI storm demand due to physical processes that are neglected in these models. As such it is typical to consider the largest measured storm bites at similar exposed locations and apply these as upper bound allowances for planning purposes in accordance with the precautionary principle.

⁴ Storm bite refers to the volume of sand eroded from the beach during a historical event





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Chapman *et al.* (1982) considered that major erosion generally occurred during a phase of erosive conditions, with a final culminating storm.

For most beaches the storm demand is likely to vary along the length of beach for any given storm event.

4.6.2 Estimate of Storm Demand

Gordon (1987) estimated that for the exposed NSW beaches the storm demand above 0 m AHD for a 100 year ARI event ranged from 140 m³/m to 220 m³/m for open beaches at low demand and rip head locations respectively. In practice, in any one storm, the most severe erosion would occur at discrete locations corresponding to the location of major rips.

As mentioned above numerical modelling techniques are limited in the estimation of storm demand. Typically, one dimensional cross-shore modelling is employed to estimate a storm bite during a synthesised simulation based on design forcing inputs, such as 100 year ARI wave heights and water levels. Previous experience has shown this to be misrepresentative of actual volumes. Complex three dimensional processes (particularly rip cells and hydrodynamic flows) and temporally varying conditions (e.g. a series of closely spaced storms) are not represented by this simplistic modelling.

No known measurements of storm bite are available for Boomerang Beach and Blueys Beach. **Figure 4.5** shows two photographs provided by a long term local resident, taken from the northern corner of Blueys Beach following the May 1974 storm event⁵. The storm erosion is clearly evident in this photo with an erosion scarp, estimated to be between 6 and 7 m in height, formed in the front of the foredune at the northern end of the beach. Based on the top photograph, 1972 photogrammetry profile 17 (see **Appendix A**) and an assumed post storm profile an approximation of the storm bite for this event was made. This crude estimation yielded storm bite volumes in the range 230 to 280 m³/m.

The bottom photograph in **Figure 4.5** appears to show that the storm bite for the 1974 events was greatest in the northern corner where the erosion escarpment appears highest, reducing toward the south end of Blueys Beach where the erosion escarpment seems to taper, reducing in height. This pattern of erosion is likely to reflect the nature of the May 1974 event, with south to south east waves. Despite this, no variation in storm demand along the beach is necessarily justifiable as storms with different wave directions may lead to different erosion patterns (although it is recognised that 100 year ARI wave heights from north of east are lower than those south of east).

In light of these findings, and given the uncertainties involved in estimating storm demand, a precautionary approach is deemed appropriate. It is therefore considered that a storm demand of $250 \text{ m}^3/\text{m}$ should be adopted for the entire length of both beaches.

⁵ The May 1974 storm event was the largest storm to occur on the NSW coast in observed history, based on the joint probability of the observed offshore wave height and elevated ocean water levels this event has been estimated as having an ARI of approximately 200 years (Burston, 2007).





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Figure 4.5. Two views showing erosion of Blueys Beach following the May 1974 storm event, photographs taken from northern corner looking south. (Source: Carl Dries, Blueys Beach)





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4.6.3 Recovery of Eroded Profiles

Evidence from photogrammetric data indicates that Boomerang Beach and Blueys Beach have the ability to recovery relatively quickly from major erosion events. **Figure 4.6** shows a comparison of the 1972 and 1975 photogrammetry profile 17 (see **Appendix A**). The 1975 profile was captured on 25 August, approximately 1.25 years after the May 1974 erosion event discussed above. Although not completely recovered it is evident that the much of the volume eroded by this event has returned to the beach berm. The steep slope evident in the 1975 profile between 6 and 9 m AHD is postulated to be a remnant of the May 1974 storm erosion scarp (see **Figure 4.6**).



Figure 4.6. Comparison of pre and post 1974 storm profiles.

4.7 Longer Term Sand Movement

Longer term sand movement on Boomerang Beach and Blueys Beach has been examined using photogrammetric data supplied by DECCW. By considering the trends in historical beach changes, such as the volume of sand within the active beach system, the dominant long term mode of shoreline change (i.e. accretion, recession or stability) can be estimated.

Caution needs to be exercised in the interpretation of the information due to a number of factors, for example:

- the relatively short period of historical data (it is implicitly assumed that coastal processes over this period are representative of the longer term situation);
- the frequency and severity of storms over the time span for which the volume changes were measured;
- the typically large fluctuations in sand volumes due to storms which can often mask longer term trends;
- the influence of sea level rise which causes a reduction in the volume of sand above AHD and which has been operative over the period of the photographic record; and





- both beaches were affected by heavy sand mining operations which can complicate the natural sand movements in the area.
- the limitations in the accuracy and relative infrequency of the photogrammetric data.

The longer term trends in sand movement are discussed below. The findings of a previous assessment are also outlined.

4.7.1 Previous Assessments of Longer Term Sand Movement

The only previous assessment of long term sediment movement completed for Boomerang Beach and Blueys Beach came as part of coastal engineering advice prepared for Council by PWD (1985). The history of shoreline movement was undertaken using photogrammetric data compiled for four dates in the years of 1956, 1964, 1972 and 1981.

Boomerang Beach

The findings of the analysis of the movement of the back beach erosion escarpment were as follows:

- At the southern end of the beach (south of Boomerang Beach Road) no discernable variation in the location of the top of the escarpment.
- Central section (from the start of the one way coast road to about 70 m north of Marilyn Place) a progressive shoreline recessional trend averaging 0.3 m/year, further this trend was apparent before and after sand mining operations in the area.
- Along the northern sections of Boomerang Beach no measurements of the location of the scarp could be made prior to sand mining because of extensive blowouts in the region.
 However, no measureable change to the escarpment was evident between 1975 and 1981.

The stability of the southern portion of the beach was attributed to the protection afforded by Boomerang Point and the possible presence of clay and weathered bedrock and indurated sands. Due to the short time span of the available photogrammetric data it was considered appropriate to adopt the 0.3 m/year recessional trend for the full length of the beach, including the southern portion.

Blueys Beach

Due to difficulties in obtaining the position of the back beach erosion scarp, examination of crosssectional beach profiles for Blueys Beach showed that while there were significant variations in the level of the beach berm and the development of incipient foredunes over the period of photography, there was no recessional trend in the location of the back beach erosion escarpment.

It is important to note that extensive sand mining and subsequent rehabilitation measures occurred along the two beaches in this period. Another complicating factor is the occurrence of the largest recorded erosion event during the analysed period. Due to the relatively short time frame of this assessment and the complication of sand mining and major storm erosion the conclusions of the PWD photogrammetry assessment are of questionable value.




PWD (1985) also developed a sediment budget model. The important implications for longer term sand movements include:

- Net northerly alongshore sand transport system (rate in the order of 25,000 to 30,000 m³/year).
- Aeolian sand transport losses are manifested in the large transgressive dune systems (rate of 340 m³/year and 270 m³/year over the last 6000 years for Boomerang Beach and Blueys Beach respectively). Present rate is considered negligible due to current dune management practices.
- Over the geological timeframe there has been a sand supply to the littoral system through foreshore recession of both beaches.

4.7.2 Interpretation of DECCW Photogrammetry

Based on the photogrammetric data provided by DECCW an assessment of the long term trends in beach volumes and shoreline position was completed. The aim of this assessment was to identify shoreline recession behaviour at Boomerang Beach and Blueys Beach. Trends in shoreline recession were estimated in two ways:

- by assessment of changes over time in the volume of sand contained within the beach and dune system above 0 m AHD (sediment budget approach); and
- by measurements over time of the position in plan of a certain "cut" level through the foredune taken in this study as 3 m AHD.

Both of these approaches have been used for Boomerang Beach and Blueys Beach. Details of the photogrammetry data, the analysis methodology and the results are presented in **Appendix A**. The findings of the photogrammetric analysis for each of the beaches are outlined below.

Boomerang Beach

An assessment of changes in the volume of sand contained within the active beach and dune system at Boomerang Beach revealed that there has been a net gain of sand within the beach compartment between 1956 and 2006 of approximately 561,000 m³. Based on regression analysis of beach volume in all years between 1956 and 2006 the rate of accretion is 2.4 m³/m/year or 3,440 m³/year over the length of the beach. Based on a profile by profile consideration of the average profile height this equates to a progradation of the shoreline of an average rate of approximately 0.6 m/year. Excluding years prior to sand mining operation, that is taking all years between 1975 and 2006, the rate of accretion was 4.4 m³/m/year, equating to a shoreline progradation of 1.1 m/year. The pattern of accretion has been generally uniform along the central sections of the beach approaching negligible levels at the northern and southern corners of the beach (see **Figure A.4**).

Similarly, assessment of position of the 3 m AHD contour shows that over the long term (1956 to 2006) the rate of progradation of the Boomerang Beach shoreface has been approximately 0.5 m/year and 0.7 m/year post sand mining (1975 to 2006).





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Blueys Beach

An assessment of changes in the volume of sand contained within the active beach and dune system at Blueys Beach revealed that there was a net gain of sand within the beach compartment between 1956 and 2006 of approximately 101,000 m³. Based on regression analysis of beach volume in all years between 1956 and 2006 the rate of accretion is 2.3 m³/m/year or 2,070 m³/year over the length of the beach. Based on a profile by profile consideration of the average profile height this equates to a progradation of the shoreline of an average rate of approximately 0.6 m/year. Excluding years prior to sand mining operation, that is taking all years from 1975 to 2006, the rate of shoreline accretion was 1.8 m³/m/year, equating to a shoreline progradation of 0.4 m/year. Over the long term rates of accretion have been reasonably uniform along the central portion of the beach and approaching negligible levels within 150 to 200 m of the northern and southern corners (see **Figure A.5**).

Similarly, assessment of the position of the 3 m AHD contour shows that over the long term (1956 to 2006) the rate of accretion of the Blueys Beach shoreface has been approximately 0.5 m/year and 0.3 m/year post sand mining (1975 to 2006).

4.8 Geotechnical Conditions

Targeted geotechnical information was previously gathered as part of the PWD (1985) coastal engineering assessment of Boomerang and Blueys Beaches. PWD (1985) reported on 11 boreholes from Boomerang Beach and four boreholes from Blueys Beach, each drilled to 7 m below mean sea level. This onshore drilling was more extensive than what would typically be allowed for in a modern geotechnical investigation. PWD (1985) also provided a summary of geotechnical and geological data gathered from previous investigations (for example undertaken by sand mining interests). In addition, PWD (1985) reported on:

- previous bathymetrical survey and sediment sampling of the nearshore and inner shelf sediments; and
- radiocarbon dating.

Based on the evidence present in the aforementioned data the authors developed a hypothetical geological model for Boomerang Beach and Blueys Beach. **Figure 4.7** reproduces this four stage model. The evolution is described as:

<u>Stage One</u>. Sea level around 120,000 years ago was a few metres higher than today. During this time the Pleistocene coastal barrier system was formed at Boomerang Beach and Blueys Beach. This coastal barrier is typical of that found along much of the NSW coastline. The Pleistocene barrier system is also identified in the *NSW Comprehensive Costal Assessment* (NSW DPI 2004) (refer to **Figure 4.8**). It is envisaged that this would have included a swampy rainforest back beach area in the warmer climate.





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<u>Stage Two.</u> Between 120,000 and 10,000 years ago sea levels fluctuated but were generally 20 to 70 m lower than present levels. During this time beach barrier systems would have formed at these lower levels. Cooler climate conditions are likely to have lead to lower water tables and the decline of the swampy rainforest, with organic material leached out through the old Pleistocene deposits. If this hypothesised scenario is an accurate description, it is likely that the indurated sands now found under Boomerang Beach and Blueys Beach were formed by the humate impregnation of the sand deposits.

<u>Stage Three.</u> From 10,000 to 5,000 years ago rapid sea level rise before stabilisation about 6,000 years ago. Following stabilisation of sea level initial shoreline accretion is hypothesised due to the large rate of onshore sand movement, when compared with the net effect of alongshore sediment drift.

<u>Stage Four.</u> Over the past 6,000 years or so sea levels have approximated present day levels. Sediment losses and foreshore recession have been due to aeolian sand transport `and littoral drift.





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Figure 4.7 Evolutionary model for Boomerang Beach (source: PWD, 1985)

In addition to the geological information provided in the PWD (1985) report, the *Comprehensive Coastal Assessment* project provided a map of Coastal Quaternary Geology for the north and south coasts of NSW. Geological information in these maps summarises the extensive record of the Department of Primary Industries (DPI) and can be used to supplement the geotechnical and geological information found in PWD (1985).





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Legend

Qhbb - Holocene Sandy Beach Qhbd - Holocene dune, marine sand Qhbf - Holocene backbarrier flat Qpbd - Pleistocene Dune, Marine sandy indurated sand Qpbf - Back barrier flat Qpbdr - Bedrock mantling dune D-Ct - Devonian to

D-Ct - Devonian to Carboniferous Sedimentary Rocks (Tamworth Belt)

Figure 4.8 Coastal Quaternary geology of study area (NSW DPI 2004)

4.8.1 Onshore Sediments

The sediment system comprising Blueys Beach, Boomerang Beach and Elizabeth Beach is separated from Wallis Lake sediments by a bedrock ridge. Dune sediments from Blueys Beach extend north-westerly behind Boomerang Point over the sandy back barrier deposit of Boomerang Beach. A large transgressive sand dune also exists toward the northern end of Boomerang Beach. The back barrier sand deposits have been classified as being of Pleistocene age (PWD 1985).





Figure 4.9 presents key borehole information data from the PWD 1985 geotechnical investigations. This includes the presence and level of substrate identified as indurated sands or rock.

4.8.2 Offshore Sediments

In May 1979 offshore sediments and seabed depths were collected by PWD in conjunction with the Geological Survey of NSW as part of an investigation into sand movements at the entrance to Wallis Lake and adjacent coastlines (PWD 1985). The data shows an offshore seabed slope constant at about 1:50. Across this slope the grain size varies from about 0.35 mm on the beach face, fining to 0.2 mm at a depth of 65 m at ISLW. **Figure 4.9** presents one of the transects and the depths and grain size of sediment samples collected.

4.9 Climate Change

4.9.1 Sea level Rise

The principal impact of climate change on coastal processes at Boomerang Beach and Blueys Beach will be associated with the predicted rise in mean sea level. The latest research on the evidence of global sea level rise indicates that we may be currently tracking at the upper end of the IPCC's predictions (DECCW, 2009b).

Ocean thermal expansion and melting of non-polar glaciers and ice caps are the largest contributors to recent sea level rise.

Sea level projections are reported in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) of 2007 for a range of future emissions scenarios. The range of AR4 model projections (with a 90% confidence range) are for a mean sea level rise of 18-59 cm in the decade from 2090 to 2099 relative to 1980 to 1999. The AR4 predicted range of sea level rise does not include the potential dynamic response of ice-sheets, however, qualifying statements in AR4 make an allowance of 10-20 cm to account for this possibility. Although this addition is not explicitly included in the AR4, the total projected range would be 18-79 cm, once allowance for dynamic ice sheet contribution was included. The AR4 specifically states: *"Larger values cannot be excluded, but understanding of these effects is too limited to assess their likelihood of providing a best estimate or an upper bound for sea level rise"*. It is noted that sea level projections for the 21st century from AR4 of 2007 are similar to the IPCC Third Assessment report (TAR) of 2001 when the qualifying statements in the AR4 are considered.

Increases in sea level will not occur uniformly across ocean basins with some regions experiencing higher levels of sea level rise and others lower. Variations in the mean sea level anomaly are the result of spatial variations in the thermal expansion of the ocean due to large scale atmospheric and oceanographic circulation patterns. A recent study predicted that the future sea level rise along the NSW coast will be slightly higher than the global averages, with an upper estimate of 12 cm by 2070.

The NSW Department of Environment and Climate Change and Water (DECCW) finalised the *Sea Level Rise Policy Statement* in 2009. The NSW Government guideline document adopts a sea level





rise planning benchmark for the NSW coastline based on the upper limits of the most credible national and international projections. The NSW sea level rise planning benchmark is an increase above 1990 mean sea levels of 0.40 m by 2050 and 0.90 m by 2100. The planning benchmark of 0.9 m increase by 2100 is similar to the high-range sea level rise estimate of 0.91 m previously adopted by DECCW. The benchmark's primary purpose is to provide guidance to support consistent consideration of sea level rise impacts, within applicable decision-making frameworks.

4.9.2 Other Climate Change Impacts

Another potential outcome of climate change is an increase in the frequency and intensity of storm events. Modest to moderate increases in average and maximum cyclone intensities are expected in the Australian region in a warmer world. However, cyclone frequency and intensity are strongly associated with the El Niño/ Southern Oscillation (ENSO) phenomenon. How this phenomenon will vary in a warmer world is currently unknown (CSIRO 2001; CSIRO Marine Research 2001).

Mid latitude storms have been predicted to increase in intensity but decrease in frequency with global warming (CSIRO 2002), due to a reduction in equator to pole temperature gradients. However as with tropical cyclones, climate modelling at present lacks the resolution to accurately predict changes associated with global warming.

If overall weather patterns change as a result of global warming, there is potential for changes in the angle of approach of the predominant wave climate (CSIRO 2007). For some beaches this may cause realignment of the shoreline, with resulting recession and accretion.

Given the above uncertainty and difficulty in quantitative prediction, no specific account was taken of any potential changes to storm frequency and intensity, or changes in wave directions. However, the potential for these effects to occur needs to be continually reviewed as more information develops in the scientific community.

Given the inherent difficulty in defining speculative climate changes impacts, such as the degree of beach rotation due to unknown changes in the wave climate, conservative 'precautionary principle' approaches have been applied in other areas. For example, instead of adopting ongoing accretion, as has been the trend for the past 50 years at Boomerang Beach and Blueys Beach, the definition of hazard lines neglect this in favour of a conservative zero change assumption.

4.10 Aeolian (Wind) Sand Transport

Aeolian sand transport can occur at beaches when dry sand is entrained by surface winds. Sand drift is the result of aeolian movement of beach sediment with the magnitude dependent on the density and extent of foredune vegetation. Sand drift can lead to a number of hazards depending on the volume of sand involved. Aeolian transport of high sand volumes can represent a permanent loss of sand from the active beach system, thereby causing shoreline recession (if the sand moves landward beyond the foredune⁶ into the hind dune), (NSW Government 1990).

⁶ The foredune is the larger and more mature dune lying between the incipient dune (generally characterised by grasses) and hind dune area (generally characterised by trees and understorey species). Foredune vegetation is characterised by grasses







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The presence of transgressive dunes in the back beach barrier at both Blueys Beach and Boomerang Beach is evidence of the loss of sand from the beach system through aeolian processes. There are three large transgressive dunes: a large system at the northern end of Boomerang Beach, a smaller dune at the southern end of the Boomerang Beach and a large transgressive dune extending northwest from behind Boomerang Point. Given the dominant south easterly wind direction this last system is likely to have been built with sediments from Blueys Beach. It is likely that these dunes have been established in their present form by aeolian transport over the period of present day sea levels (approximately the last 6,000 years).

Recent dune management activities and the construction of houses on these transgressive dune systems is likely to have slowed or halted the ongoing growth of these back barrier dunes.

It is important to recognise that dune vegetation is necessary to stabilise dune systems and protect them from wind erosion. Should human activities impact on the dunes at Boomerang Beach or Blueys Beach in the future, there is the potential for landward sand drift to occur, with resulting shoreline recession. As noted by the NSW Government (1990), the likely direction of sand drift (where it occurs) on the NSW North Coast is to the north-west.

4.11 River Entrances

There are no ocean entrances within the study area. The closest is the entrance of Smiths Lake located at Sandbar Beach, approximately 5 km south of Blueys Beach. Bald Head and a 3 km rocky coastline separate this entrance from the study area. It is possible that Smith's Lake and Sandbar Beach are a source of sediments to Boomerang Beach and Blueys Beach. It is postulated that longshore drift is active around the rocky coastline between Bald Head and Blueys Head. From examination of recent aerial photography (2003⁷) continuous sandy material along this stretch of rocky shoreline is evident. It is therefore assumed that wave and nearshore currents can actively transport this material. As such, the periodic opening of Smiths Lake by flood waters may act to discharge sandy material that is then transported north toward Boomerang Beach and Blueys Beach and Blueys Beach by the net northerly longshore drift.

4.12 Conceptual Coastal Processes Model

Boomerang Beach and Blueys Beach are situated at the northern end of a relatively small coastal compartment that extends from Sugarloaf Point in the south to Charlotte Head in the north. Sediment transport in this coastal compartment can be characterised by a net northerly littoral drift of relatively small magnitude. Others have quantified this sediment transport rate as in the order of 30,000 m³/year. In the absence of the required data (see **Section 7.5**) to further quantify this process this estimate cannot be discounted.

and shrubs. Foredunes provide an essential reserve of sand to meet erosion demand during storm conditions. During storm events, the foredune can be eroded back to produce a pronounced dune scarp (NSW Government 1990).

⁷ This aerial photography is used as the back drop to all large scale figures. Captured during extremely calm conditions, possibly at low tide, shallow bathymetric features (such as sand, reefs and bars) can be clearly seen.





Boomerang Beach and Blueys Beach are two beaches that are considered to be very similar in form and functionality. Volumetric analysis of photogrammetric data indicated that the long term trend on the sub-aerial (above 0 m AHD) beach is that of accretion. Modest annual net volume changes are in the order of 3440 m³ and 2030 m³ for Boomerang Beach and Blueys Beach, respectively. This rate of change is based on the 50 year period of available photogrammetric data. The long term progradation of Boomerang Beach and Blueys Beach is likely attributable to the following:

- both are relatively short pocket beaches with significant perturbing headlands that minimise alongshore transport;
- offshore losses during large events are expected to be negligible, these two beaches appear to respond favourably after large storms with offshore losses restored to the beach fairly rapidly (refer **Section 4.6.3**); and
- dune management practices are likely to have reduced aeolian loses that probably existed in the past.

Figure 4.10 summarises the conceptual coastal processes model for Boomerang Beach and Blueys Beach.

Sugarloaf Point is a significant feature at the end of Lighthouse Beach, Seal Rocks. A series of rocky reefs extend some 750 m from the shoreline of Lighthouse Beach. Sand by-passing of these features by littoral drift is considered to be extremely limited. As such, the net supply of sediment to this compartment from the south is considered to be limited.





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5 COASTLINE HAZARD ASSESSMENT

The *Coastline Management Manual* (NSW Government 1990) identifies a number of coastline hazards, including;

- beach erosion hazard;
- shoreline recession hazard;
- vegetation degradation and sand drift hazard;
- coastal inundation hazard;
- stormwater erosion hazard;
- climate change; and
- slope and cliff instability hazard.

Each of the above hazards is discussed in turn in the following sections. The assessment of the hazards often draws upon the information set out in the preceding sections.

5.1 Beach Erosion Hazard

During storms, large waves, elevated water levels and strong winds can cause severe erosion to sandy beaches (NSW Government 1990). The hazard of beach erosion relates to the limit of erosion that could be expected due to a severe storm or from the effects of a series of closely spaced storms.

The erosion can be measured in terms of the volume of sand transported offshore, or in terms of the landward movement of a significant beach feature. The volume is usually expressed in terms of cubic metres per metre run of beach (m³/m), as measured above Mean Sea Level (MSL) or Australian Height Datum (AHD). The significant beach feature is usually taken to be the back beach erosion escarpment.

The beach erosion hazard is analogous to the "storm demand" discussed in **Section 4.6.2**. It has previous been established, based on work by other researchers and experience, that the storm demand or beach erosion hazard for exposed beaches such as Boomerang Beach and Blueys Beach can be as high as 250 m³/m (Gordon, 1987). Anecdotal and photographic evidence also suggests that Boomerang Beach and Blueys Beach have experienced severe storm erosion in the past. Estimates of storm bite volumes in the range 230 to 280 m³/m were derived from the examination of photographs taken after the May 1974 storm event (see **Section 4.6.2**). Based on the precautionary principle the conservative value of 250 m³/m has been adopted for planning purposes at both beaches.

Beach erosion associated with stormwater outlets in discussed in **Section 5.5**.





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5.2 Shoreline Recession Hazard

The hazard of shoreline recession is the progressive landward shift in the average long term position of the coastline. The two causes of shoreline recession are sediment loss and an increase in sea level.

Sediment Loss - Recession of a sandy beach is the result of a long term and continuing net loss of sand from the beach system. Recession tends to occur when:

- the outgoing longshore transport from a beach compartment is greater than the incoming longshore transport;
- offshore transport processes move sand to offshore "sinks" from which it does not return to the beach; and
- there is a landward loss of sediment by windborne transport.

Sea Level Rise - A progressive rise in sea level will result in shoreline recession through two mechanisms: firstly, by drowning low lying coastal land, and secondly, by shoreline readjustment to the new coastal water levels. The second mechanism is probably the more important. Deeper offshore waters expose the coast to attack by larger waves; the nearshore refraction and diffraction behaviour of waves will change; and a significant volume of sediment will move offshore as the beach adjusts to a new equilibrium profile. Sea level rise is discussed in more detail under The Hazards of Climate Change in **Section 5.6**.

Shoreline recession is typically a long term process which in some cases is imperceptible. Its effect on a beach is often masked by the more rapid and dramatic erosion and accretion that accompanies storm events. Consequently it can be difficult to identify recession from historical data, even if it extends over many years.

The hazard of shoreline recession is the progressive landward shift in the average long term position of the coastline (NSW Government 1990). The two potential causes of shoreline recession identified above are discussed in **Sections 5.2.1** and **5.2.2** respectively. It is also appropriate to discount the historical recession due to net sediment loss, taking into account the actual sea level rise that occurred during the measurement period, as discussed in **Section 5.2.3**.

5.2.1 Long Term Recession Due to Net Sediment Loss

The analysis of photogrammetric data showed that there is no net sediment loss at Boomerang Beach and Blueys Beach. Rather, the shorelines at these two beaches are observed to be prograding at a rate of between 0.5 and 1.1 m/year, respectively. In this study a zero rate of long term recession for Boomerang Beach and Blueys Beach has been adopted for planning purposes.

Due to the limitations of the analysis completed for this study (see **Section 4.7.2**) it is not considered appropriate to include the prograding trend for planning purposes. Changes to the wave climate due to climate change or changes to sediment supply, a severe storm event or simply reaching an





equilibrium condition could see the current prograding tread cease or be reversed in the future. In addition, while the long term trend has been of progradation, there have been periods within the approximate 50 year record when recession of these two beaches has been observed. The additional effects of climate change, including sea level rise are discussed below.

Based on the above it is considered that regular reassessment of the long term recession due to sediment loss at Boomerang Beach and Blueys Beach be undertaken. This should be coordinated with the review cycle (5 year) undertaken in relation to State sea level rise benchmarks.

5.2.2 Long Term Recession Due to Sea Level Rise

Bruun (1962) proposed a methodology to estimate shoreline recession due to sea level rise, the so-called Bruun Rule. The Bruun Rule is based on the concept that sea level rise will lead to erosion of the upper shoreface and deposition of this sediment offshore, followed by re-establishment of the original equilibrium profile. This profile is re-established by shifting landward and upward. The concept is shown graphically in Bruun (1983), and can be described by the equation (Morang and Parson 2002):

$$R = \frac{S \times B}{h + d_c} \tag{3}$$

where *R* is the recession (m), *S* is the long term sea level rise (m), *h* is the dune height above the initial mean sea level (m), d_c is the depth of closure⁸ of the profile relative to the initial mean sea level (m), and *B* is the cross-shore width of the active beach profile, that is the cross-shore distance from the initial dune height to the depth of closure (m). This means that the recession due to sea level rise is equal to the sea level rise, multiplied by the average inverse slope of the active beach profile.

Nielsen (1994) found that, based on a synthesis of field and laboratory data and analytical studies (particularly offshore of SE Australia), there were consistent limits of sub-aqueous beach fluctuations, namely water depths (relative to AHD) of:

- 12 m \pm 4 m being the limit of significant wave breaking and beach fluctuations;
- 22 m \pm 4 m being the absolute limit of sand transport under cyclonic or extreme storm events; and
- 30 m \pm 5 m being the limit of reworking and onshore transport of beach sized sand under wave action.

⁸ The depth of closure is the water depth beyond which repetitive profile surveys (collected over several years) do not detect vertical sea bed changes, generally considered to be the seaward limit of littoral transport. The depth can be determined from repeated cross-shore profile surveys or estimated using formulas based on wave statistics. Note that this does not imply the lack of sediment motion beyond this depth (Szuwalski and Morang 2001).





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The 12 m \pm 4 m depth can be considered to be analogous to the depth of closure for use in the Bruun Rule, given that it is the limit of significant beach fluctuations, and is consistent with formulae for its prediction.

Rijkswaterstaat (1987), approximating the work of Hallermeier (1978, 1981 and 1983), found the following simplified equation for the effective depth of closure, d_c , namely:

 $d_{c} = 1.75 H_{e}$

(4)

where H_e is the effective significant wave height exceeded for 12 hours per year (that is, the significant wave height with a probability of exceedance of 0.137%).

Bruun (1988) suggested a depth of closure of $2H_b$, where H_b is actual breaker height of the highest waves within a certain time period, namely 50 to 100 years according to Dubois (1992).

Sedimentological data consistently shows distinct changes in the characteristics of sediments with water depth. These changes include variations in grain size, sorting, carbonate content and colour. The boundary between Inner and Outer Nearshore Sand is typically found at about 11 - 15 m depth (relative to AHD), while the boundary to Inner Shelf Sand (also known as Shelf Plain Relict or Palimpsest Sand) is usually at 18 - 26 m depth. The boundary between Nearshore (Inner and Outer) Sands and Inner Shelf Sands correspond to those parts of the seabed considered to be active and relict (Nielsen 1994).

Nielsen (1994) reported that three studies had identified the boundary between Inner and Outer Nearshore Sand at approximately 10 m depth (relative to AHD) in the Byron Bay area. Other investigations by Patterson Britton and Partners (2004) and others (Nielsen 1994, Stephens 2004) along the NSW mid-north and north coast indicated a depth of closure of 10 – 11 m relative to AHD.

It should however be noted that there are a number of limitations to the accuracy of the Bruun Rule, based on the location of the estimate of the depth of closure.

As described above, there are a broad range of techniques available for estimating the closure depth and several (Hallermeier, Birkmeier, Rijkswaterstaat, USACE, Bruun etc.) idealised formulae for estimating closure depth, based on offshore wave statistics. All formulae provide differing results.

The various techniques used for estimating the closure depth for application of the Bruun rule are generally dependent on wave data. Limited availability of complete local wave data sets and variations in wave statistics from year to year therefore also limit the accuracy of the Bruun rule results. The use of historical information to assume future wave statistics also limits the application of these techniques, particularly given postulated changes to wave climate due to climate change.

It is therefore appropriate to consider a sensitivity analysis for this element of the Bruun Rule. It is common for the active beach profile slope to fall in the order of 1:50 to 1:100 for the east coast of NSW. The range of recession due to sea level rise then becomes $R = 50 \times S$ to $100 \times S$. It is therefore possible for the recession due to sea level rise to be up to double the amount determined using the adopted active beach slope of 1:50. Measurements of the active beach and nearshore





slopes (to depths of 40 m at Boomerang Beach and Blueys Beach indicate that a slope of 1:50 is an appropriate value.

5.2.3 Discounting of Historical Recession Rates

Shoreline recession rates determined from historical data may be influenced by any sea level rise which occurred in the period of the historical record. As noted in **Section 5.2** if this contribution is significant, the historical recession rates should be adjusted (discounted) to represent recession due to sediment loss only. This is because, in the prediction of the future position of the coastline, shoreline recession due to net sediment loss and shoreline recession due to sea level rise are calculated separately.

Based on analysis of average annual water levels at Fort Denison in Sydney Harbour from 1887 to 1987, the NSW Government (1990) estimated that the mean sea level rise over the 101 years of record was 0.5 mm/year. More recent estimates by Church *et al.* (2001) indicated that for the two water level recording stations with the longest records in Australia (both in excess of 80 years), at Sydney and Fremantle, the observed rates of relative sea level rise were 0.86 ± 0.12 mm/year (from 1915 to 1998) and 1.38 ± 0.18 mm/year (from 1897 to 1998) respectively¹⁰. The Department of Defence (1999), cited in Nielsen *et al.* (2001a), estimated that the rate of relative sea level rise at Newcastle (on the NSW Central Coast), from 1967 to 1999, was 1.18 mm/year. Averaged around Australia, the relative sea level rise from 1920 to 2000 was about 1.2 mm/year (CSIRO Marine Research 2004).

Adopting a rate of relative sea level rise of 0.86 mm/year from 1965 to 2006, represents a sea level rise of 35 mm over this period. Using the adopted inverse slope of the active beach profile of 50 (**Section 5.2.2**), this is equivalent to a reduction in shoreline recession of about 1.8 m, that can be accounted for (that is, subtracted from the calculated total recession, or added to the calculated total progradation). This is equivalent to a recession of 0.04 m/year. Given the predicted low rate of recession due to historical sea level rise, together with the uncertainties in the Bruun analysis, no increase of measured progradation, to account for sea level influences, is considered warranted.

5.3 Sand Drift Hazard

As noted in **Section 4.10**, sand drift is a result of aeolian wind movement of beach sediment, and as such can be controlled to a large extent by the presence of a well vegetated foredune. Sand drift leads to a number of hazards depending on the volume of sand involved. For low sand volumes, sand drift is only of nuisance value. However, for high sand volumes it can represent a permanent loss of sand from the active beach system, thereby causing shoreline recession (if the sand moves landward beyond the foredune into the hind dune), and can result in abrasion, burial, blockage and damage to coastal developments (NSW Government 1990).

¹⁰ Corrected for land movement, the absolute rates of sea level rise at Sydney and Fremantle were about 1.2 and 1.6 mm/year respectively.







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For pocket beaches, such as Boomerang and Blueys Beaches, net sediment loss from the active beach system through aeolian transport can be significant. PWD (1985) indicates that, over geological timeframes, aeolian sand transport can be a significant contributory mechanism to foreshore recession and could result in the formation of a small transgressive dune sheet at the rear of Boomerang Beach. However, recent dune management practices have increased the extent, density and quality of foredune vegetation cover with sand trapping fences and other techniques contributing to the stabilisation of the dune and beach sand. In term of the overall sediment budget, the current sediment losses through aeolian transport are expected to be negligible. However, strong wind events may still result in sand drift impacting on beach front properties and infrastructure. Blowouts of the dune cannot be discounted particularly at low points in the dune, such as beach access corridors. Ongoing dune management is required to reduce sand drift hazard. Informal private access tracks, common along the two beaches also need to be addressed.

5.4 Coastal Inundation Hazard

Coastal inundation is the flooding of coastal lands by ocean waters, which is generally caused by large waves and elevated water levels associated with severe storms. Severe inundation is an infrequent event and is normally of short duration, but it can result in significant damage to both public and private property (NSW Government 1990).

The components which give rise to elevated water levels at times of storms have been referred to in **Section 4.2** namely storm surge (wind setup and the barometric setup) and wave setup. This increased water level may persist for several hours to days and can inundate low lying coastal areas and creeks. A 100 year ARI design storm elevated water level of 2.7 m AHD has been adopted for this study. For long term planning purposes, sea level rise (as outlined in **Section 4.9**) is also included using the State Government's planning benchmark of a 0.9 m increase by 2100. This would bring the total design storm, elevated water level over 100 years to 3.6 m.

During storm events individual waves cause further temporary water level increases above the still water level due to the processes of wave setup, and runup or uprush (**Section 4.3**). The wave runup values adopted were given in **Section 4.3**, namely 6.2 m AHD (including an allowance of 0.9 m for sea level rise by 2100).

The areas potentially affected by coastal inundation have been illustrated in **Figure 5.1**. From this figure it is evident that the dune system is generally sufficiently high to prevent inundation due to elevated water levels and wave runup. This is the case for all of the Boomerang Beach frontage and most of the Blueys Beach frontage. The only exception is the creek entrance at the southern end of Blueys Beach. Here the beach berm is reduced to around 3 m AHD for a small distance, approximately 50 m. During extreme events there is potential for wave action to penetrate this low lying area potentially inundating a number of allotments on Ampat Place and Newman Avenue.

A zone of 'potential minor inundation due to wave action' for this area is shown by the pink hatching

in **Figure 5.1**. This zone is not intended to accurately describe the inland extent of the water flow, as this is a complex process with many variables, but rather indicates an area that is more vulnerable to inundation now, and into the future as sea level rises.





As discussed in **Section 4.3** runup levels in the order of 6 m AHD would only be realised if the foreshore was at this runup height or higher. In reality, any waves that overtopped dunes or creek banks would fold over the foreshore crest and travel as sheet flow at shallow depth, spreading out and infiltrating over landward areas. A significant reduction in the velocity and depth of runup would be expected within 10 m of the foreshore crest. In addition, wave runup and overtopping is generally episodic, occurring around the peak of the high tide. As such the duration of inundation would be expected to be less than 2 hours. The affected areas would, however, become more vulnerable to inundation in the longer term as sea level rises.

It should be noted that local catchment flooding has not been considered in determining the potential inundation hazard at the creek entrances, as this is outside of the scope of this study.

5.5 Stormwater Erosion Hazard

Stormwater outlets, usually located at the back of the beach, discharge during large rainfall events. During major rainfall events, stormwater discharges from pipes and creeks can cause significant scour of the beach berm and the nearshore area. This in turn can allow larger waves to attack the beach (NSW Government 1990), locally exacerbating erosion.

Stormwater discharges at Boomerang Beach and Blueys Beaches are limited due to the topography and geology of the local area. Much of the back beach catchment of Boomerang Beach drains to Elizabeth Beach via Elizabeth Creek. Blueys Beach has a small coastal catchment area that discharges to the ocean via the beach. The infiltration capacity of Pleistocene sand deposits in back beach areas reduces runoff from these catchments, particularly for smaller rainfall events. The infiltration capacity of the Pleistocene sand deposits is evident in the discontinuation of the blue stream lines on the topographic map of the area.

Figure 5.1 shows the location of stormwater infrastructure, as provided by Council. The only stormwater pipe that discharges directly to the beach is a 600 mm diameter pipe located at the northern end of Blueys Beach. A photograph of this outlet is shown in **Figure 5.2**. Some localised beach erosion was observed around this outlet. This erosion is not considered significant for the beach system as a whole. In the event of an extreme erosion event the impact of a local reduction in sand volume at this location is not expected to significantly increase the erosion hazard to nearby properties, as the presence of a significant boulder layer in the vicinity of this outlet is likely to limit further erosion (refer to the bottom photo in **Figure 4.5**). The stormwater outlet at the southern end of Blueys Beach discharges to the creek.





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Figure 5.2 Stormwater outlet pipe at northern corner of Blueys Beach

5.6 Climate Change

A discussion on sea level rise associated with climate change, was provided in **Section 4.9.1**. The possibility of other effects caused by climate change, such as increases in storm intensities, was discussed in **Section 4.9.2**

Under predicted accelerated sea level rise, it is expected that shoreline recession will occur. This issue was discussed in **Section 5.2.2**, as part of the discussion on shoreline recession.

5.7 Slope and Cliff Instability Hazard

Beach slope and cliff instability hazards relate to the possible structural incompetence of these features, and associated potential problems with the foundations of buildings, seawalls and other coastal works (NSW Government 1990).

The study area is composed largely of sandy beach and dune areas within the active coastal zone. For such areas, based on Nielsen *et al.* (1992), a number of coastline hazard zones can be delineated as shown in **Figure 5.3**.





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Figure 5.3: Schematic representation of coastline hazard zones (after Nielsen et al, 1992)

The *Zone of Wave Impact* delineates an area where any structure or its foundations would suffer direct wave attack during a severe coastal storm. It is that part of the beach which is seaward of the beach erosion escarpment.

A *Zone of Slope Adjustment* is delineated to encompass that portion of the seaward face of the beach that would slump to a natural angle of repose following removal by wave erosion of the design storm demand and is represented by the hazard lines in **Figure 5.4**). It represents the steepest stable beach profile under the conditions specified (as defined by the beach erosion hazard, see **Section 5.1**.

A Zone of Reduced Foundation Capacity for building foundations is delineated to take account of the reduced bearing capacity of the sand adjacent to the storm erosion escarpment. Nielsen *et al.* (1992) recommended that structural loads be transmitted to soil foundations outside this zone (i.e. landward or below), as the factor of safety within the zone is less than 1.5 during extreme scour conditions at the face of the escarpment. In general (without the protection of a terminal structure such as a seawall), dwellings/ structures not piled and located within the Zone of Reduced Foundation Capacity would be considered to have an inadequate factor of safety.

The coastline hazard zones for the study area are defined in **Section 6**, with the position of the Zone of Slope Adjustment defined for the immediate (2006), 2060 and 2100 planning periods.

Within the study there are also rocky headlands, which were visually assessed for stability. The rocky cliffs and headland were generally found to be of a stable nature and did not appear to pose a significant hazard in the immediate future. This should be confirmed by a geotechnical engineer. These areas should be monitored for changes to highlight any instability that may evolve as natural weathering and erosion processes continue.





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A site specific geotechnical investigation in conjunction with a coastal engineering assessment is recommended during the planning stage of any foreshore development or works in these areas.





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6 DEFINITION OF COASTAL HAZARDS

In this Section, coastline hazard zones are defined within the study area, based on the cumulative impacts of the coastline hazards outlined in **Section 5**, in relation to storm erosion and recession.

Two coastline hazard zones are defined, namely the Zone of Slope Adjustment and the Zone of Reduced Foundation Capacity (see **Figure 5.3**)¹¹ for the immediate, 50 year (2060) and 90 year (2100) planning timeframes. The immediate hazard lines represent an estimate of the predicted location of the escarpment following a major storm (such as a 100 year storm or storm with a 1% chance of occurring in each and every year) or series of storms focused off the Great Lakes coast.

For simplicity, the landward limit of the Zone of Slope Adjustment for each of the planning timeframes has been denoted as the "Hazard Line". The position of the 2010 Hazard Line, 2060 Hazard Line and 2100 Hazard Line is thus the predicted position of the back beach erosion escarpment after an extreme coastal storm in 2010, 2060 and 2100 respectively, including subsequent slumping to a stable angle of repose.¹² The location of the immediate (2010) Hazard Line was determined by removing the storm demand volume (250 m³/m) from an equilibrium profile. The photogrammetry year used to represent the equilibrium year was based on assessing the set of photogrammetric profiles which best fit the mean profile volumes along each beach, using a least square fitting technique. This was then found to be 1996 for Boomerang Beach and 1964 for Blueys Beach. The volumes were applied as per Nielsen *et al* (1992); see **Figure 5.3**, on a profile by profile basis. Thus, at each profile, a position on the 2010 Hazard Line was determined.

The Zone of Reduced Foundation Capacity was also derived for each profile. The Zone of Reduced Foundation Capacity (ZRFC) takes account of the reduced bearing capacity of the sand adjacent to the storm erosion escarpment. In general, structures not piled and located within the ZRFC would be considered to have an inadequate factor of safety.

Note that the ZRFC was derived assuming a beach profile composed entirely of sand. If there were layers of less erodible or inerodible material, such as stiff clays and/ or rock within the ZRFC, then the extent of the Zone could potentially be reduced. A specific geotechnical investigation was not undertaken as part of this study. The limited geotechnical borehole data available (refer **Figure 4.9**) indicates that there may be areas of indurated sands and/or underlying rock along the frontage and a more extensive and detailed geotechnical investigation may provide sufficient evidence for further refinement of the ZRFC. Geotechnical engineering advice is recommended if foundations within the ZRFC are proposed.

The immediate, 2060 and 2100 Hazard Lines are shown in **Figure 5.4.** The ZRFC Lines for the immediate condition and 2060 are shown in **Figure 5.5**. It is recommended that if any development is planned seaward of the ZRFC (for the immediate condition), consideration be given to placement of structures on piers (spread footings or piles) extending into the Stable Foundation Zone as defined by

¹¹ The Zone of Wave Impact was also defined as part of the calculations, but is not depicted in Figure 5.3.

¹² That is, the Hazard Lines do not represent future predicted shorelines, but future predicted erosion escarpments after a 100 year ARI coastal storm erosion event.





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Nielsen *et al* (1992), unless geotechnical conditions enable reduced foundation depths. A site specific geotechnical investigation in conjunction with a coastal engineering assessment is recommended during the planning stage of any individual lot redevelopment where piling is required.





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7 CONCLUSIONS

This study has found that the most significant hazards in the study area are beach erosion and shoreline recession from sea level rise. These, together with other hazards are summarised below. **Figure 5.4** illustrates the defined coastline hazard zones within the study area based on the cumulative impacts of the coastline hazards relating to erosion and recession. The determination of these zones was discussed in **Section 6**.

7.1 Beach Erosion and Shoreline Recession

The immediate hazard line was determined to predict the erosive impact of the representative 100 year ARI coastal storm event. The 50 and 100 year hazard lines were determined based on the cumulative effects of the representative 100 year ARI coastal storm erosion event and long term recession due to sea level rise (refer **Section 6**). Note that long term recession due to sediment loss was assumed to be zero. **Figure 5.4** indicates that a number of assets will be impacted by coastal recession. Assets impacted by the immediate, 50 year and 100 year planning periods are listed in **Table 7-1**.

The most vulnerable area currently at risk (i.e. seaward of the "immediate" hazard line) is located at Boomerang Beach south of Boomerang Beach Road.

7.2 Coastal Inundation

The creek entrance at the southern end of Blueys Beach has been identified as being particularly vulnerable to inundation due to low lying topography (as shown in **Figure 5.1**). As many as 16 properties could potentially be inundated due to wave action. While the duration of inundation is expected to be short, generally less than 2 hours, the likely extent is difficult to define given complicated overland wave propagation processes. The affected areas would become more vulnerable to inundation in the longer term as sea level rises.

This assessment has not considered catchment derived flooding impacts.

7.3 Stormwater Erosion

Some localised beach erosion was observed around the stormwater outlet in the northern corner of Blueys Beach. However, due to significant hard substrata (in the form of a boulder layer) no significant increase in the erosion hazard is expected for properties in this area.





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Table 7-1: Assets impacted by coastal erosion and shoreline recession

Location	Assets impacted in Planning Period			
	Immediate *	2060	2100	
Boomerang Beach	• Dwellings along seaward side of Boomerang Drive south of Carramatta Close (10)	 Part of Boomerang Drive near Redgum Rd All lots and dwellings along seaward side of Boomerang Drive south of Carramatta Close (14) Small part of Boomerang Beach Road 	 Most of Boomerang Drive south of Carramatta Close All dwellings and lots along seaward side of Boomerang Drive south of Carramatta Close (14) Car park and beach access opposite Carramatta Close Essentially all of Boomerang Beach Road Apartment blocks on landward side of Boomerang Beach Rd between Carramatta Close and Marilyn Place (8) Beach access ways 	





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	Assets impacted in Planning Period			
Location	Immediate *	2060	2100	
Blueys Beach		 Stormwater outlet at southern end of Blueys Beach Most lots and 2 dwellings along seaward side of Newman Ave, south of Ampat PI Beach access at southern end of Blueys Beach Lots along seaward side of Newman Ave, north of Ampat PI (6) 	 Part of Newman Rd south of Ampat PI Lots and dwellings (2) seaward side of Newman Ave, south of Ampat PI (1) Property and structure along western side of Newman Ave, south of Ampat PI (1) Stormwater outlet at south Blueys Beach Car park and beach access at southern end of Blueys Beach All lots and most dwellings/ structures on seaward side of Newman Ave, north of Ampat PI (39 dwellings) Part of Car park at northern end of Blueys Beach 	

* where 'Immediate' planning period is defined by the immediate hazard line which represents an estimate of the predicted location of the escarpment following a major storm (such as a 1 in 100 year storm or storm with a 1% chance of occurring in each and every year) or series of storms focused off the Great Lakes coast.





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7.4 Climate Change

The predicted future sea level rise associated with climate change will be associated with shoreline recession. The estimated predicted shoreline recession due to sea level rise for the study area is in the order of 22 m by 2060, and 42 m in the year 2100.

Another potential outcome of climate change is an increase in the frequency and intensity of storm events. If overall weather patterns change as a result of global warming, there is potential for changes in the angle of approach of the predominant wave climate (McInnes *et. al.*, 2007). For some beaches this may cause realignment of the shoreline, with resulting recession and accretion at different locations in the compartment.

Given the above uncertainty and difficulty in quantifying any change, potential changes to storm frequency and intensity, or changes in wave directions were not specifically addressed.¹³ However, this uncertainty should be taken into consideration when assessing the risk and consequences of recession occurring in the future. The potential for climate change related recession needs to be continually reviewed as more information becomes available.

7.5 Recommended Ongoing Data Collection

During this investigation a number of data gaps were identified. Measurement of the physical forcing mechanisms driving coastal processes and assessments of the impacts of individual storms events is critical to a greater understanding of beach dynamics. Such data forms the basis on which informed decisions should be made. Recommended data collation includes the following:

- Directional wave data at Crowdy Head to better appreciate the influence of wave energy direction on the erosion/ recession of the beaches in the study area. This will become increasingly important if the angle of approach of the predominant wave climate changes due to climate change.
- Pre and post storm beach profiling to enable the storm demand volume to be better estimated.
- Repeat bathymetric surveys of the surf zone of Boomerang Beach and Blueys Beach to allow comparative analysis to identify changes.
- Ongoing aerial photography and subsequent photogrammetry profiling and analysis.

¹³ A generally conservative approach was used in the estimation of other coastline hazards.





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Northerly bypassing of Charlotte Head

Negligible aeolian sand transport

Net volume increase of Boomerang Beach approx. +3,400 m3/yr

Regular onshore / offshore adjustment of beach / bar system in response to short term wave climate. Episodic (storm) onshore / offshore movement of bar with little net loss of sediment from system and rapid recovery.

Episodic (storm) bypassing with net northerly transport.

Negligible aeolian sand transport

Net volume increase of Blueys Beach approx. +2,000 m3/yr

metres

Episodic (storm) onshore / offshore movement of bar with little net loss of sediment from system and rapid recovery.

W

Net supply via Blueys Head and rocky coastline

> WorleyParsons resources & energy

> > Great Lakes

Boomerang Beach and Blueys Beach Coastline Hazard Definition Study Conceptual Coastal Processes Model

Figure 4.10







2100 hazard line (0.9m SLR)

iources & energy Great Lakes

Immediate, 2060 and 2100 Hazard Lines Figure 5.4






BOOMERANG BEACH AND BLUEYS BEACH COASTAL PROCESSES AND HAZARD DEFINITION STUDY

APPENDIX A – PHOTOGRAMMETRIC DATA ASSESSMENT

A1 Introduction

The aim of the photogrammetric data assessment was to detect and measure historical changes occurring at Boomerang Beach and Blueys Beach. DECCW archives of aerial photographs, taken at regular intervals since the 1940s form the basis for this quantitative assessment.

A2 Photogrammetry

Photogrammetry is the science of measurement and data acquisition from photographic and other remotely sensed images. This appendix describes the methodology used in the analysis of the photogrammetric data as well as providing the results. Interpretation of results is discussed in **Section 4.7.2** of the main report.

The photogrammetric data used in this study was supplied by DECCW (received via email, 27 January 2010, Robert Clout (DECCW) – Dan Messiter (WorleyParsons)). Using their AC3 stereo plotter, DECCW are able to deduce an elevation model from appropriately selected vertical aerial photographs. The supplied photogrammetry data consisted of 48 cross-shore profiles in 3 blocks covering the two beaches, a total coastline length of approximately 2.25 km. The data covered the period from 1956 to 2006, details of the dates of photography are outlined below in **Section A3**.

Figure A1 shows the location of each cross-shore profile within each of the blocks. A summary of each block is provided in **Table A.1**.

Block Number	Length of Coastline (m)	Number of Profiles	Profile Spacing (m)	Geographical Coverage
1	850	18	50	Blueys Beach
2	350	8	50	South Boomerang Beach
3	1050	22	50	North Boomerang Beach

 Table A.1 Summary of Photogrammetry Cross-shore Profile Blocks

A3 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 DECCW from their archives (see **Appendix B**). Ten aerial photographs were selected for this assessment, the first date used was in 1956 with the most recent year of analysed photography being 2006, a 60 year period.





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The photography was selected on the following basis:

- coverage of area;
- time between photography;
- photo quality; and
- scale.

A summary of the photography used in the analysis is provided below in **Table A.2.** Details on the quality of the photography used are also outlined. In this table 'Photo quality' refers to the definition of detail under magnification.

Year	Date	Photo scale (1:X)	Photo quality
1956	1 Sep	31,000	Poor (black & white)
1964	Jan	43,000	Fair (black & white)
1972	9 Sep	40,000	Fair (black & white)
1975	25 Aug	26,000	Fair (black & white)
1983	13 Mar	8,000	Fair (colour/ sepia)
1984	18 Jan	8,000	Good (full colour)
1991	6 Sept	10,000	Good (full colour)
1994	22 Jun	10,000	Good (full colour)
1996	14 Mar	10,000	Good (full colour)
2006	21 Apr	10,000	Good (full colour)

Table A.2 Summary of the Aerial Photography used in Photogrammetry

A4 Analysis Methodology

The data obtained from aerial photography primarily consists of cross-sections, or profiles, of the beach and dune at the selected locations shown on **Figure A.1**. Plots of the profile data have been produced and are included in **Figures A.2a** to **A.2e** for Blueys Beach and **Figures A.3a** to **A.3h** for Boomerang Beach. Each panel in these figures contains a plot of the available photogrammetric dates for each profile.





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Trends in historical beach change can be estimated in two ways:

- by assessment of the volume of sand contained within the beach and dune system above 0 m AHD; and
- 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.

Both of these approaches have been used for Boomerang Beach and Blueys Beach, the methods used for each technique are detailed below.

Volumetric Analysis

Volumetric analysis was conducted in the following manner:

- a portion of the back beach area was removed from the profile such that only what was considered to be the active beach was included;
- the area under the truncated profile was determined, this is expressed as a volume of material (assumed to be sand) per metre of alongshore shoreline (i.e. m³/m); and
- regression analysis was used to identify trends in historical beach volumes and net beach volume changes were quantified.

Plots showing the regression analysis of active beach volumes and deviation of beach volume from mean beach volume are shown in **Figures A.4** to **A.7**.

Position Analysis

No evidence of a consistent erosion scarp feature is present in the Boomerang Beach and Blueys Beach photogrammetric profiles. As such the position of the 3 m AHD contour has been used. Position analysis was conducted in the following manner:

- the chainage of the most seaward downward crossing of the 3 m AHD contour was identified in each beach profile; and
- regression analysis was used to identify trends in historical shoreline position based on the 3 m AHD contour.

Plots showing the results of the regression analysis for beach position change over the entire photogrammetry data set and years limited to post sand-mining, are shown in **Figures A.4** and **A.9**.

Negative values indicate a recession trend while positive values indicate an accretion trend.

A5 Results

The volumetric and position analysis of the photogrammetry data shown in **Figures A.4** to **A.9** shows an overall positive trend for both Boomerang Beaches and Blueys Beach.





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Figure A.4 Blueys Beach - annual rate of beach volume change.



Figure A.5 Boomerang Beach - annual rate of beach volume change.





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Figure A.6 Blueys Beach – Volume deviation from mean.



Figure A.7 Boomerang Beach – Volume deviation from mean.





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Figure A.8 Blueys Beach – Annual rate of shoreline position change.



Figure A.9 Boomerang Beach – Annual rate of shoreline position change









Figure A.2d - Photogrammetry Beach Profiles, Blueys Beach

Figure A.2e - Photogrammetry Beach Profiles, Blueys Beach

















Figure B.3h - Photogrammerty Beach Profiles, Boomerang Beach









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APPENDIX B – Review of Historical Aerial Photographs

Aerial photography is available for the Boomerang Beach and Blueys Beach coastline dating back to 1937. These photographs include those in the DECCW archives and aerial photography sourced from Great Lakes Council. A summary of some of the distinctive features of various dates of photography is set out below on a beach by beach basis (north to south).

B1 Boomerang Beach

<u>October 1937</u> – photo shows Boomerang Beach and surrounds in a largely natural state, no anthropogenic disturbance is evident apart from a walking track that terminates at Elizabeth Beach. The foredune appears to be vegetated, however, a number of blowouts are visible at the northern end of the beach. Extensive areas of sparsely vegetated back beach dunes are evident in the mid and northern sectors of the beach, possible evidence of shifting wind blown sands. The dunes/ hills at the southern end of the beach are well vegetated. The photo shows a south-east swell, wide surf zone with waves breaking across a nearshore bar, with possible exposure of a boulder beach at the southern end, although this is difficult to see clearly.

<u>September 1956</u> – similar to 1937, Boomerang Beach shows no development in the 1956 photo. The beach appears wider at the northern end.

<u>January 1964</u> – A meandering access road loops over to west of Charlotte Head to Boomerang Beach from Elizabeth Beach, continuing behind the fontal dune and eventually linking with access road to Blueys Beach. This road will ultimately form Boomerang Drive. The beginning of Headland Road is also evident on Boomerang Head. The beach appears essentially the same width.

March 1964 - as above.

<u>September 1971</u> –It is difficult to pick out any detail due to the scale of the photography, however, the track from Elizabeth Beach, later forming Lakeside Crescent, extends down to the Boomerang Beach. A section of dune in this area is unvegetated, as is the northern half of the track that will become Boomerang Beach Road where it is assumed sandmining is taking place.

<u>September 1972</u>–There is some clearing and development along the southern end of Boomerang Road, south of Boomerang Beach Road. The eastern end of Red Gum Road is visible. A small finger of reef on the northern side of Boomerang Point is visible.

<u>August 1975</u> – Subdivision development for the remainder of the present day Boomerang Beach has commenced.

<u>August 1977</u> – Development appears essentially as per 1972/1975, although the scale of the photograph makes identifying individual houses difficult. The beach appears slightly wider at the northern end.





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<u>March 1981</u> – The beach car parks are visible. There are four houses between Coast Avenue and Boomerang Beach Road, a residence which looks to be under construction a the end of Angela Place and a residence to the north of the northern carpark (in line with Boomerang Beach Road). Residential development and construction of the south-eastern unit block between Boomerang Drive and Boomerang Beach Road has commenced. There are about seven houses on the eastern side of Boomerang Drive, south of Carramatta Close. The beach is essentially the same width.

November 1981 – Development as above.

March 1983 - Development is as above. The beach is essentially the same width.

January 1984 – There are now five houses between Coast Avenue and Boomerang Beach Road.

<u>June 1986</u> – Construction of the present day unit developments and dwellings between Boomerang Drive and Boomerang Beach Road is continuing. There are now about eight dwellings on Boomerang Road, south of Carramatta Close.

<u>September 1991</u> – There are now 12 dwellings between Coast Avenue and Boomerang Beach Road. There are also some additional dwellings between Boomerang Drive and Boomerang Beach Road and in Angela Place and about 12 dwellings on Boomerang Drive, south of Carramatta Close. The beach width tapers from north (wider) to south. There is an attached bar covering the reef on the northern side of Boomerang Point.

<u>June 1994</u> – the beach width tapers from north (wider) to south. There is a sand bank over the eastward side of the reef on the northern side of Boomerang Point.

March 1996 – short offshore bars are visible along the Beach.

<u>February 1997</u> – two rip heads are visible offshore from Boomerang Beach Road, the largest almost in the centre of the beach.

<u>September 1999</u> – Boomerang Point reef is visible in front of the southern two-thirds of properties at the southern end of Boomerang Drive, with an offshore bar covering the seaward extent. Offshore bars are visible along the rest of the beach.

<u>April 2006</u> – Dune vegetation is more sparse around the track from the southern car park an narrower in the central section of the beach.

B2 Blueys Beach

October 1937 - not available.

<u>September 1956</u> – An unsealed access road and a second road running behind the frontal dune is evident in the 1956 aerial. This road will eventually become Newman Avenue, while the access road will become the western portion of Boomerang Drive. Although not clear, a number of dwellings are evident along this road, three or four at the northern end and two or three at the southern end of the





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beach. The foredune appears well vegetated, a number of what appear to be informal beach access tracks are evident. The beach is wider at the northern end.

<u>January 1964</u> – There are several tracks or clearings to the beach, which is essentially the same width. It is not possible to tell the number of dwellings due to the scale of the photography. The beach appears to be 'full' and in line with Blueys Head. There are more unsealed roads at the northern end of the beach, including Croll Street and View Street.

<u>March 1964</u> – Five dwellings have been constructed on the eastern side of Newman Ave, with several to the west, north of View Street.

<u>September 1971</u> – The scale of the photograph makes it difficult to pick out much detail, although there appear to be maybe around 10 dwellings along the eastern side of Newman Avenue.

<u>August 1977</u> - There are a few vacant lots along Newman Avenue, particularly at the northern end. The beach appears much wider at the northern end.

March 1981 - Development is as above. The beach is essentially the same width.

November 1981 – same as for March.

<u>March 1983</u> - the beach front along Newman Avenue is fully developed. The dune is poorly vegetated either side of the creek. The beach is essentially the same width.

<u>January 1984</u> – The beach is essentially the same width. Swell is from the south east, with two rips spaced essentially equidistant along the beach.

<u>June 1986</u>–beach width is consistent along the length of the beach. Water from the creek is ponding in front of the dune

<u>September 1972</u> - The foredune is unvegetated south of the beach front houses along Newman Street and an area west of the southern end of Newman Avenue has been cleared of vegetation for, or in preparation for, sand mining. Headland Road and Banksia Street have been constructed and a track to the northern side of Boomerang Point, with a branch to the southern end of Boomerang Beach is evident. The beach appears narrower in the south in the vicinity of the creek and it appears that there are sections of boulder beach exposed at the northern and southern ends.

<u>August 1975</u> – Development has commenced along Banksia Street and Headland Road. The cleared areas at the southern end of Newman Avenue have been vegetated. The creek is discharging across the back beach area and then appears to pond and turn south.

September 1991 - the beach width tapers from north (widest) to south.

June 1994 – the beach appears slightly wider at the northern end.

March 1996 – the beach width is similar along its entire length.





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<u>*February* 1997</u> – A series of rip heads are visible along the beach between offshore bars. The southern end of the beach is relatively wide, being attached to a bar. The incipient dune is visible and vegetation on the northern part of the foredune is not as dense as that at the southern end.

<u>September 1999</u> – A detached bar is visible at the northern end of the beach, with an attached/ semiattached bar at the southern end. As above, the foredune vegetation is less dense at the northern end of the beach due to informal access and dune blowouts.

<u>April 2006</u> – Development has continued along Boomerang Road and has occurred along Headland Road and Banksia Street as well as Ampat Place, Alamau Place and Samual Street. Blueys Beach appears to be a consistent width. A multitude of informal accessways are visible from individual houses, with dune vegetation still more sparse in the northern half of the beach.







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APPENDIX C – Consultation

Community members and stakeholders were kept informed of the progress of the study via webpage updates on the Councils website and media releases in the local paper.

The first media release was published on 31 March 2010 (refer attached) announcing the commencement of the Coastal Processes and Hazard Definition Study.

The second media release was published on 16 December 2010 (refer attached) announcing the opportunity for the community and stakeholders to review and discuss the findings of the Coastal Processes and Hazard Definition Study at a drop-in session on Saturday the 22 January 2011.

The drop-in session, held at Pacific Palms Community Centre, was attended by some 40 or so interested parties, and feedback on the draft study was forthcoming. The main issues raised related to the location of hazard lines at the ends of the beach (where rock is likely to be present) and the term "immediate" hazard line. The definition of the immediate hazard line was clarified at the session and has also been explained further in this report. It was also explained that conservative assumptions regarding the substrate have to be made in lieu of more detailed geotechnical information. It is noted these hazard lines could be subsequently reviewed if a more detailed geotechnical geotechnical investigation were to be undertaken in the future.

Five formal submissions were made to Council by community members and stakeholders. These have been considered in the finalisation of the Study.

Boomerang Beach & Blueys Beach Coastal Processes & Hazard Definition Study Public Exhibition of Draft

In December 2009 Great Lakes Council engaged Worley Parsons Pty Ltd to investigate coastal processes and associated hazards along the Boomerang and Blueys coastline. This work has been jointly funded by Council and DECCW as part of the NSW government Coastal & Estuary Management Program. The aim of the study is to update understandings of coastal erosion on these beaches, including projected sea level rise and climate change effects. The project is the first step in developing a comprehensive coastline risk management plan and as such represents an on-going commitment to responsible management along Great Lakes coast.

The draft "Boomerang Beach and Blueys Beach Coastal Processes and Hazard Definition Study" will be on public exhibition from 22 December 2010 until 4 February 2011 at the following locations during business hours:

- Great Lakes Council Administrative Centre, Breese Parade, Forster
- Blueys Beach Newsagency & Supa Mart, Boomerang Drive, Blueys Beach
- Great Lakes Library, Breese Parade, Forster

Extracts from the draft report can also be viewed on Council's web site at: <u>www.greatlakes.nsw.gov.au</u>

A public information 'Drop-In Session' has also been arranged for Saturday, 22 January 2011 (12:00pm to 4:00pm) at the Pacific Palms Community Centre. Consultants from Worley Parsons will be on hand to assist the public with technical questions relating to the study.

Great Lakes Council greatly values public input to coastal management. To date Council have received significant input from local residents. Interested parties are now invited to review the draft document, provide comments, and to share any additional information they may have. Written submissions commenting on the draft study can be made at any time during the exhibition period and should be clearly marked "Submission to Boomerang Beach & Blueys Beach Coastal Processes & Hazard Definition Study" and be addressed:

> The General Manager, Great Lakes Council, PO Box 450, FORSTER NSW 2428

Clearly marked submissions via e-mail will also be accepted during the exhibition period and should be sent to:

council@greatlakes.nsw.gov.au

Advertise in: Great Lakes Advocate

Boomerang Beach & Blueys Beach Coastal Study - Public Exhibition of Draft Report and Community Information Session

The draft "Boomerang Beach and Blueys Beach Coastal Processes and Hazard Definition Study" is now on public exhibition until 4 February 2011 at the following locations during the business hours:

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- Blueys Beach Newsagency & Supa Mart, Boomerang Drive, Blueys Beach
- Great Lakes Library, Breese Parade, Forster
- Pacific Palms Library, Community Centre, Pacific Palms

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This study aims to update understanding of coastal erosion on these beaches, including projected sea level rise and climate change effects. The project is the first step in developing a comprehensive coastline risk management plan.

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Advertise in: Great Lakes Advocate 12th and 19th Jan 2011.