16.0 Coastal Landforms and Processes

This section considers:

- The baseline for coastal processes and coastal landform condition in Wyong. By which indicators is it defined? How variable are coastal processes and coastal condition now? Detail is presented on:
    - coastal erosion processes that affect sandy beaches and dunes
    - coastal inundation
    - geotechnical processes that affect bluffs and cliffs along the coastline

This section provides information about the environmental factors that drive coastal processes. The historical variability of these processes and recently measured trends are discussed, together with information about how predicted climate change and sea level rise would affect coastal processes and their impacts on the coastal landscape.

- How good/reliable is the information about coastline condition?
- Who measures and manages the data?
- The opportunities and role of new spatial data and technology such as the LiDAR data set

Information about other aspects of baseline coastal condition, focusing on biodiversity, settlement patterns and use of the coastline, is in **Section 17.0**.

By establishing a reference point or benchmark for coastal management (**Section 15.0**) and coastal condition (**Sections 16.0** and **17.0**), council will be able to evaluate future achievements.

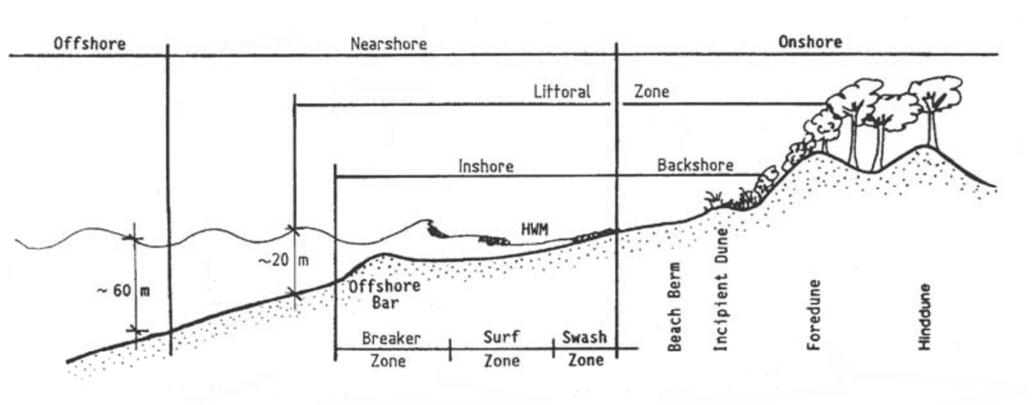
16.1 The diversity of the coastline

The coastline comprises diverse ‘soft’ sediment (offshore channels and sand bars, beaches and dunes) and rock based (headlands and bluffs, shore platforms) landforms which vary in their spatial scale, the extent of inherent variability and the timeframes over which they develop and change.

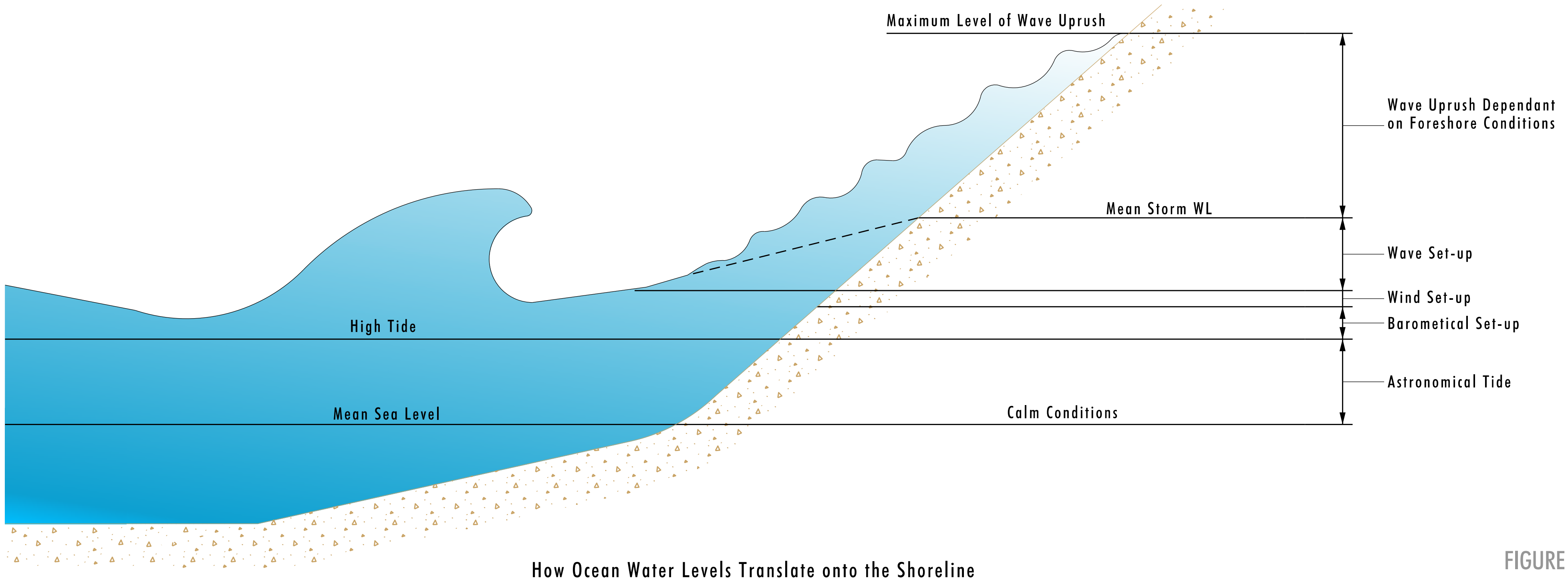
Sandy coastal landforms and features are shown schematically in **Figure 16.1**.

Coastal landscapes are dynamic environments where marine processes interface with terrestrial processes. People living in coastal communities are familiar with the systematic changing of the coastline in their local area at short time scales. This is the scale of the tidal cycle and frequently experienced wave climate (wave height, period and direction) that result in daily to monthly or annual patterns of rip currents and sand distribution on the beach, dunes and offshore bars.

Many communities have also experienced the impact of occasional extreme events on the coastline. **Figure 16.2** indicates the storm history of the NSW central coast over the last 60 years. For instance, the 1974 and 1978 storms that affected the NSW coastline resulted in well documented severe erosion of the beach and dunes at The Entrance North, Hargraves Beach and Soldiers Beach (see **Plates 1.1** and **1.2**) as well as reportedly overtopping of the Central Coast Highway at Lakes Beach.



Beach Definition Sketch



How Ocean Water Levels Translate onto the Shoreline

FIGURE 16.1

Coastal Features and
Water Levels

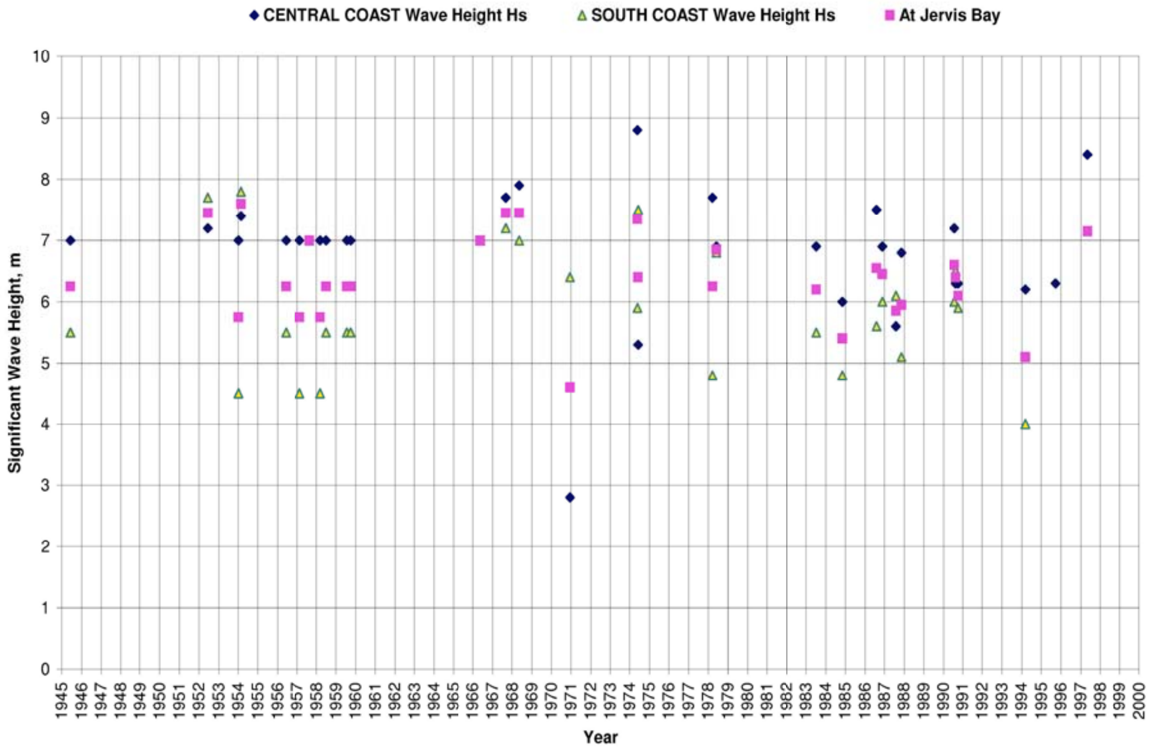


FIGURE 16.2

Storm History of Central and South Coast of NSW, 1945 - 2000

Source: SMEC Australia

File Name (A4): R03_V1/1869_014.dgn

On cliffs and bluffs, geotechnical instability events also recur at a time scale of decades. Examples include landslip (at Cabbage Tree Harbour) and rare rock topple events that cumulatively result in the accumulation of sandstone boulders and cobbles on intertidal rock platforms at the base of cliffs (**Plate 16.1**).

The diversity of process scale and timeframe means that there can be extended periods on the coast when coastal processes and landforms appear to be very much 'business as usual', with little evidence that change is occurring. Some long term processes and drivers of coastal erosion may be changing gradually, and be masked by shorter term processes. Episodic events such as major storms that coincide with all extreme water level factors bring together all the high risk variables for change in coastal landscapes. Coastal erosion processes associated with these events show the real extent of change in coastal process risks and erosion consequences occur as step changes.

This is why informed assessment and management of the full scope of risk is important, rather than relying on short to medium term observations.

16.2 The climate of the Central Coast – now and in the future

16.2.1 Wave climate

Physical aspects of the marine environment comprise the sea bed (sand or rocky reef), and water level made up of sea level, the wave climate, tidal variations, storm events and currents.

Water levels at the shoreline result from a combination of the astronomical tide, barometric water level set up (lower barometric pressure results in higher water levels), wind set up, wave set up and wave runup (see **Figure 16.3**). The amount of wave set up depends on many factors, including the type, size and period of the waves, the near shore bathymetry and the slope of the beach and foreshore. Typically wave set up on an open coast beach during severe storms is 1 to 2 metres. Wave runup depends on wave height and period, foreshore profile and slope, surface roughness and other shoreline features (such as rock outcrop or walls).

Oceanic flooding occurs when the dune height is lower than the ocean water level with wave runup. Elevated water levels also allow larger waves to cross offshore sand bars and reefs so that they break higher on the beach. Apart from overtopping low coastal landforms, elevated ocean water levels can cause flooding by increasing tail water control levels for discharges from the lake system.

In NSW the offshore swell wave climate has been recorded by the NSW government (Manly Hydraulics Laboratory) for many years.

SMEC (2010) (see **Appendix 4**) notes that the central coast of NSW experiences high wave energy. Lord and Kulmar (2000) show that the predominant wave direction is from the south-south-east, with 70 per cent of swell waves in this quadrant. The average deep water significant wave height is 1.5 metres, with a period of 9 seconds. During storms, much higher waves approach the coast. SMEC (2010) report that the erosion hazard analysis for the Wyong coast has adopted a one per cent storm event, with a significant wave height of 6.8 metres and a maximum wave height duration of 12 hours.

For more information about wave climate and extreme water level events affecting the Wyong coastline see **Appendix 4**.

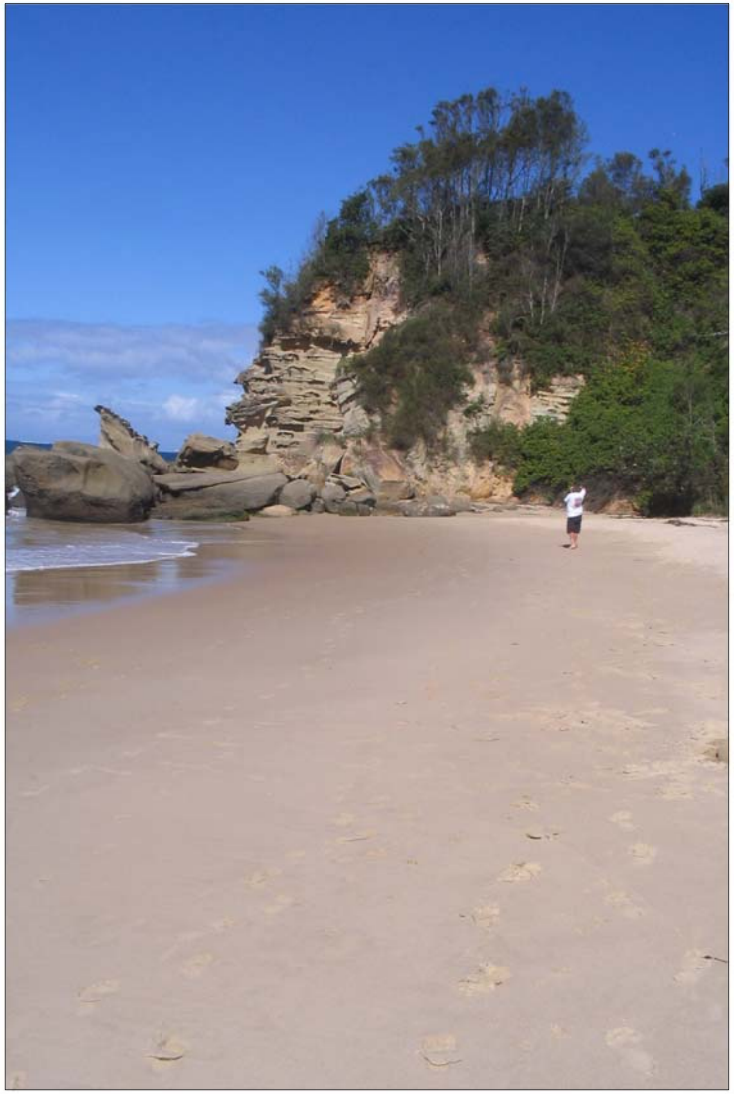


PLATE 16.1
Boulder and Cobbles accumulate at the base of cliffs after landslip/rockfall events

PLATE 16.2
Incipient foredune at Hargraves Beach

		Timeframe	Cause	Predictability
Net Extreme Event Hazard	Recurring extremes (Storm surge, storm tide)	Hours-days	Wave, wind storm strength coastal and offshore form	Moderate from observations; future very uncertain
	Tide ranges	Daily-yearly	Gravitational cycles	Very predicatble
	Regional sea level variability	Seasonal-decadal	Wave climates	Not well known
Net Regional Mean Sea-level Rise (SLR)	Regional net land movements	Decades-millennia	Tectonics and compression	Predictable once measured
	Regional eustatic SLR	Months-decades	Ocean warming, currents, climate	Existing effects observable, future effects uncertain
	Global mean SLR	Decades-centuries	Climate change (temperature, ice melt)	Short term extend current rates, future changes uncertain especially beyond 2100

FIGURE 16.3

Contributions to Sea Level Rise
and Extreme Water Level Hazards

Source: Jones et al. 2009, as reproduced in DCC 2009

16.2.2 Patterns of storm frequency and intensity

SMEC (2010) has analysed the storm history of the Wyong coastline for the period 1937 to 2007. Full details are included in Appendix A of their report. **Table 16.1** summarises the frequency of extreme storms by decade (see also **Figure 16.2**). An extreme storm is one which has a significant wave height of more than 6 metres. The effects of these extreme storms are magnified when the storm coincides with other high water level factors (such as high spring tides). This occurred in 1974.

Table 16.1 - Extreme storm frequency by decade

Decade	Number of Extreme Storms
1930-1940	1
1940-1950	1
1950-1960	10 Exact wave heights not available
1960-1970	3
1970-1980	3 (including 1974, considered to be the worst storm on record), significant wave height of 8.8 m
1980-1990	5 1997 significant wave height of 8.2 m
1990-2000	2
2000-2010	5 Significant wave heights all less than 7 m 2007 storm significant wave height 6.9 m

16.2.3 Sea level and sea level rise

16.2.3.1 Long term context

Sea level change is one element of climate change. The coastline of NSW has been shaped by major changes in sea level over a period of more than 100,000 years.

At the peak of the last interglacial period (about 120,000 years ago), sea level was 4 to 6 metres higher than the level we have experienced over the last thousand years.

During the coldest part of the last glacial period (about 17,000 years ago), sea level was approximately 130 metres lower than it is today, exposing the continental shelf. Beaches and estuaries were many kilometres east of where they are today and today's familiar coastline was part of the hilly hinterland. Sea level rose rapidly from about 15,000 years ago and reached approximately its current position by around 6000 years ago.

Research by Sloss, Murray-Wallace and Jones (2007) on the NSW south coast suggests that sea level fluctuated by +1 to 3 metres within the last 6000 years, falling to current levels about 2000 years ago. These fluctuations would have affected the stability of estuary entrances and may have periodically initiated mobile coastal dunes. **Figure 1.3** in **PART A** shows the pattern of sea level rise and fall along the east coast over the last 150,000 years. **Figure 1.3** also shows the indicative maximum extent of the Wyong ocean shoreline during that period.

The effects of past high sea levels can be seen in fossil shell deposits upstream of current tidal limits in estuaries, and in beach ridge sequences linked to higher base levels. Evidence of past lower sea levels is beneath the sea. On the continental shelf are multiple sand deposits that relate to former 'strand lines' or shorelines that were drowned by rising sea levels at the end of the last Glacial period.

16.2.3.2 Elements of sea level

Sea level rise is not a simple calculation, because actual sea level at any specific location is the result of complex interactions between many different factors, operating at different time frames and scales. For instance DCC&EE (from R Jones *et al.* 2009, see **Figure 16.4**), shows that sea level is the result of:

- Global mean sea level
- Regional eustatic sea level rise, affected by ocean temperature and land movements. Sharples *et al.* 2009 suggest that thermal expansion is responsible for about one third of the global sea level rise in the century to 1990. There is a significant time lag between ocean temperature and warmer air temperatures. CSIRO and Bureau of Meteorology (2010) report that sea surface temperatures around Australia have risen about 0.4 degrees C in the past 50 years. Whilst there is considerable variability ('noise') in the record year on year, the overall trend is clearly towards warmer ocean conditions.
- Regional net land movements. This takes into account that some coasts are affected by tectonism at a time sale of decades or more.
- Regional sea level variability. This is affected by wave climate; for instance, regional higher sea level occurs when persistent strong wave and current conditions push water towards the shore. This is also affected by the shape of the continental shelf.
- Tidal ranges
- Recurring extremes, such as occur with individual major storm events.

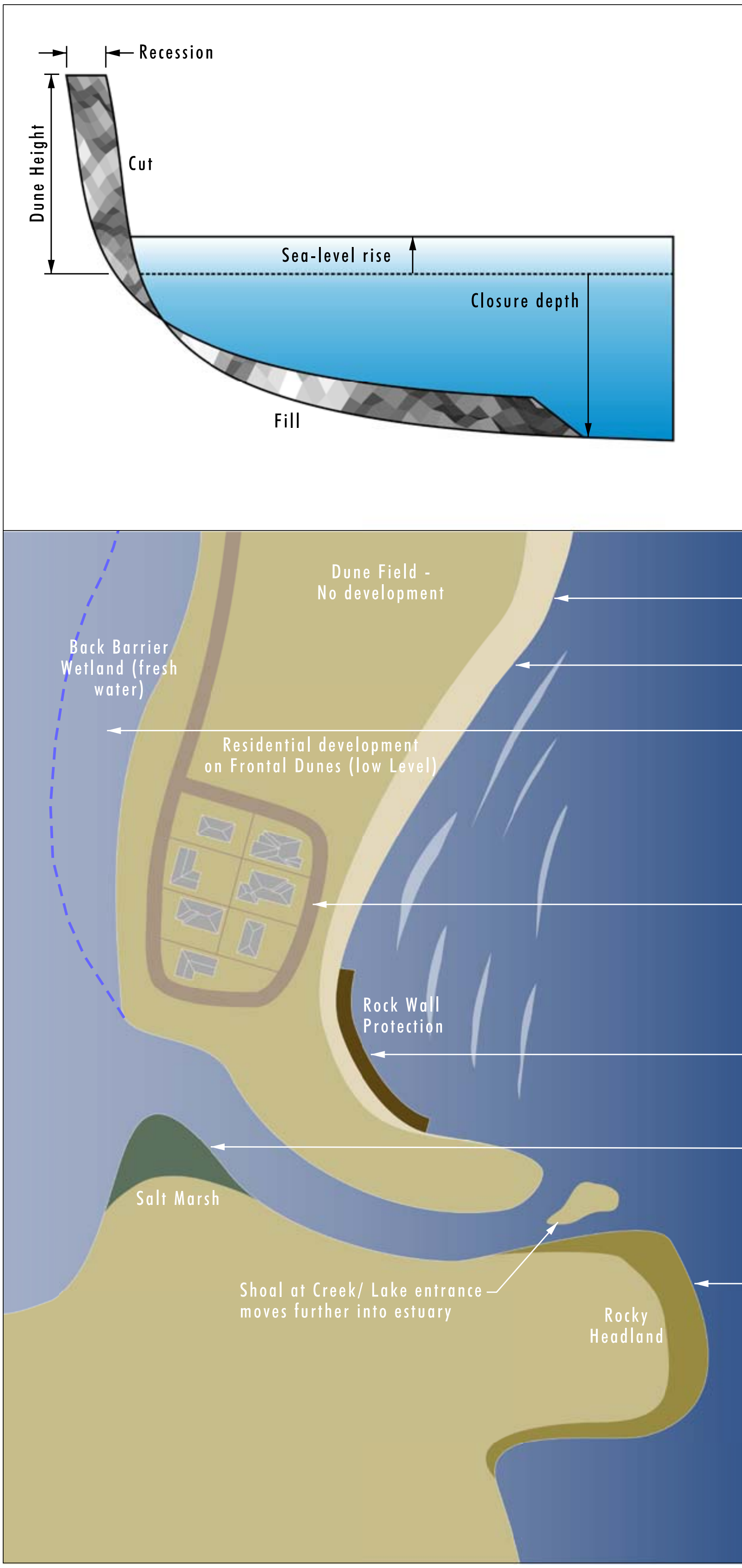
The highest sea level events will occur when maximum water levels from all of these sources coincide.

16.2.3.3 Recent evidence of sea level rise

Scientific evidence integrated and published by the Intergovernmental Panel on Climate Change (IPCC), most recently in 2007, shows that sea level has been rising over the last century. The amount of sea level rise measured at reliable gauging stations (and with high resolution satellite altimetry) is sufficient for change to be visible along the coast. Sea level rise has major implications for land use planning.

CSIRO and Bureau of Meteorology (BoM) (2010) and Church and White (2006) present evidence of sea level rise around Australia over the last century, based on measurements at stable, long term gauging stations, supplemented in recent years by satellite altimetry. **Figure 1.5** in **PART A** shows the sea level rise measurements reported by Church and White 2006.

On average, Church and White report a rise of 1.2 millimetres per year since 1842, varying from decade to decade. CSIRO and BoM (2010) report that since 1993, sea level rise in southern and eastern Australia has been at a rate of 1.5 to 3 millimetres per year. As for the sea temperature records, there is considerable variability in sea level the record over the last century, depending on the coincidence of various sea level rise factors. For instance, the measured slower rate of rise in the decade around 1980 is attributed to more frequent *El Nino* conditions through that period.



General

Bruun Rule Model for coastal response to sea level rise.
Note that the actual response will vary with the type of sandy coast - sediment supply, longshore drift, dunes or sea walls, wave energy and direction.

For NSW coast, Bruun Rule means approximate 1m coastline recession for every 1cm of sea level rise

Climate Change/Sea Level Rise Impact

Loss of beach width and amenity. Loss of dune buffer for storms.

Possible initiation of dune blowouts.

Possible saline intrusion into freshwater dependant ecology.

Residential Development on Frontal Dunes:
Potential overtopping or breaching of barrier. Erosion of dune, loss of erosion buffer for storms. Erosion impacts on development.

Loss of beach width and amenity. Possible undermining and collapse of hard protection.

Changes to entrance dynamics, increased risk of inundation for salt marsh and infrastructure.

Possible changes to stability of cliffs and bluffs, depending on stratigraphy and importance of surface/groundwater processes.

Source: Bruun (1962)

FIGURE 16.4

Sea Level Rise and the Bruun Rule

As noted in **Section 1.3** (**PART A**) and illustrated in **Figure 1.5** (from Department of Climate Change 2009a), the recent measured rates of sea level rise are at the upper part of the range predicted by IPCC in 2007. Because of the thermal inertia of the oceans, sea level will continue to rise after 2100.

As discussed in **Section 15.5**, in 2009 the NSW government released sea level rise benchmarks for application in coastal planning. These benchmarks take into account the findings of the IPCC Fourth Assessment Report (2007) and the best available measurements of how sea level has been changing on the Australian east coast and internationally.

16.2.3.4 How does a rising sea level affect coastal erosion?

Cooper and Pilkey (2004) provide a critical review of methods for evaluating the contribution of sea level rise and other factors to changing coastal morphology, including coastal recession. These factors include sediment supply, variations in wave energy, tidal currents, wind action, sediment type, tidal inlet dynamics, amongst others, as well as the effects of rising sea level. It is clear that local conditions will greatly influence the way in which sea level rise affects the coast and relationships and feedback between the various parameters are complex and three dimensional.

The Bruun Rule (Bruun 1954, Schwartz 1967) is a simple equation which has been used since the early 1960s to indicate the contribution of sea level rise to coastal recession on sandy coastlines. It takes into account the height of the berm (which reflects the amount of sand on the beach), the closure depth of the beach profile and the length of the active (shore normal) zone. It is based on specific assumptions about these parameters. **Figure 16.4** shows the erosion concepts applied by the Bruun Rule.

The depth of closure is the depth of water in which wave effects on the bed are negligible for each beach. It varies with wave exposure and with the nature of the beach – rocky sea beds produce a much shallower depth of closure. The length of the active zone reflects the beach and sea bed slope, to the offshore depth of closure.

The basic concept is that the beach and nearshore, out to the depth of closure, develop an equilibrium profile. As sea level rises, the form of the equilibrium profile remains unchanged, but moves upward and landward by redistributing sand from the beach face to the nearshore.

Woodroffe (2002), drawing on the work of Larson and Kraus (1995), Cowell and Thom (1997), and Cowell *et al.* (1995), suggests that the Bruun Rule should be used as a 'rule of thumb' for the direction of change of a coastline, but that it is a poor predictor of the details of the response of dunes. For instance, it struggles to predict gradual landward translation of dune forms. Landward translation of dune forms has been observed on coasts with rising sea levels. Cowell and Thom (1997) suggest that this will occur either by continuous roll over, or by more episodic barrier overstepping. It must be concluded at this stage that the details of coastal recession morphologies are not fully understood.

The Bruun Rule is still in widespread use, despite acknowledgement that its assumptions are not appropriate for all beaches. The Bruun Rule is recommended by the NSW Government for providing an indication of the amount of recession due to sea level rise. Researchers are working on new, more accurate methods of assessing how coasts respond to sea level rise and other variables.

In accordance with OEH specifications, SMEC (2010) (see **Appendix 4** for details of the method) have used the Bruun Rule in analysing the component of coastal recession hazard that is attributable to sea level rise. Wyong Council acknowledges that uncertainties remain about the exact response of different beaches along the Wyong coast to sea level rise, but has chosen to take a cautious approach until better models and better data (such as accurate measured changes to three dimensional beach and dune volume) are available.

Sea level rise also affects processes at the entrance to coastal lakes. It is expected to modify the balance between entrance open and entrance closed conditions and the volume of sand stored in the tidal delta, as well as the location of the tidal delta in lake entrances. Further information about how these changes could occur on the Wyong coastline is in **Section 16.4.4**.

Sea level rise can also change the exposure of cliffs and bluffs to wave action and the intensity of weathering of rocks in cliffs and bluffs. These changes are explored further in **Section 16.4.5**.

16.2.4 Regional scale climate change predictions

WSC is a member of Hunter Councils (HCCREMS). Hunter Councils (Blackmore & Goodwin 2009) has prepared a regional scale analysis of climate change impacts for the Hunter, Lower North Coast and Central Coast. The analysis considers a wide range of climate variables, including seasonal temperatures, rainfall spatial and seasonal distribution, water balance, wind and sea level. In particular, it considers the potential for changes to frequency of extreme events, such as high rainfall, heat wave, severe frost and extreme sea level. The 1970 to 2007 period is used as the baseline and anticipated changes are discussed for 20 year periods from 2020 to 2080.

Key findings of the regional scale study that are relevant to future conditions along the Wyong coastline are noted below. In many cases, much more substantial changes are expected in the inland parts of the Hunter region than on the coast.

Predicted climate change: Central Coast:

- A slight decrease in winter rainfall, but little overall change to water balance for the coast. A return to the type of rainfall conditions experienced in the region from 1948 to 1976 is suggested i.e. more like during a *La Nina* event and wetter than recent decades. Extreme rainfall events may become more frequent in summer.

- Small increases in average autumn and winter temperatures (up approximately 1.3 degrees) on the coast. Conversely, a very slight decrease in average summer temperatures is expected on the coast but the number of extreme heat days in summer may increase.

- A higher probability of east coast lows forming off the coast in autumn/winter, so that extreme storm events may occur more frequently. These storms will also drive extreme sea level conditions that can exacerbate inundation risk. Extreme sea level events are more likely to occur during *La Nina* years in the ENSO cycle. Wave climate predictions are much less advanced than other aspects of climate variability. Note, for instance that Hennessy *et al.* 2004 do not predict an increase in winter storm wind speeds for the NSW coast.

- Hunter Councils adopts the OEH sea level rise planning figures (40 centimetres by 2040 and 90 centimetres by 2100, but suggests small adjustments to allow for regional tectonic setting (to 37 centimetres and 84.5 centimetres respectively) over the 100 year planning period. WSC has adopted the slightly more conservative NSW government sea level rise planning benchmarks (DECCW 2010a).

Table 16.2 provides an indication of the ways in which these changes could influence management of the Wyong coastline.

Table 16.2 - Regional scale climate change predictions, implications for coastline management (based on Hunter Councils 2009)

Predicted change	Potential coastal impacts
Slight increase in winter rainfall	Little impact expected on beaches.
More extreme summer rainfall events	Changes to lake entrance processes with large discharges of fresh water from the catchment. This could affect the balance of sand distribution on the beach and in tidal delta deposits. Increase in the frequency of high volume stormwater discharges across cliffs and bluffs and across beaches in urban areas. May affect geotechnical hazards and local water quality
Overall slight decrease in summer temperatures but more extreme heat days	Beach usage affected by summer temperatures. Health warnings for beach users on extreme heat days. Possible lower success of dune revegetation programs, unless plant establishment planned around higher rainfall periods. Possibly dunes more vulnerable to erosion if vegetation cover is reduced. Possibly higher probability of extreme and catastrophic fire risk days in coastal bushland
Higher frequency of east coast low storms in autumn and winter; more frequent extreme water levels	May be multiple storm bites affecting dunes, with limited recovery time.
Gradually increasing oceanic water levels	Recession in accordance with the Bruun Rule (see **Section 16.2.3.4**) or as predicted by new models when they are approved. Landward translation of coastal dunes where sediment supply and costal development constraints permit. Where there is extensive development on frontal dune systems, there is little opportunity for dune landforms to roll landward and a higher probability that coastal protection works will be constructed, affecting beach sand volumes. Changes to sediment dynamics at The Entrance (such as extent and stability of entrance shoals and tidal delta)

16.3 Tsunami

Tsunami are long wave length and large amplitude progressive waves that travel very rapidly (C.D. Woodroffe 2002). They are created by submarine earthquakes or other major submarine seismic/geotechnical processes. Compared with all other ocean wave forms, tsunami are very rare. However, their power can be enormous. As a tsunami wave crosses the continental shelf it steepens and increases in height. There are multiple examples in recent history of tsunami waves completely overwhelming coastal landforms and development in southern and south-east Asia (e.g. 2006) and in the Pacific (2009 and 2010).

Because tsunami waves are likely to be much higher and more powerful than other wave types, their past occurrence can be inferred from otherwise anomalous positions and volumes of sediment, from sand deposits to boulders. On the NSW south coast, the past contribution of tsunami waves to the landscape has been suggested by researchers from Wollongong University (Young & Bryant 1992; Young & Bryant 1993; Young *et al.* 1996; Bryant & Nott 2001; Bryant 2008). In particular they point to the presence of imbricated and aligned boulders on coastal platforms and cliff tops on the Beecroft Peninsula (Jervis Bay on the NSW south coast), 15 metres to 30 metres above sea level. The authors argue that these boulders could not have been positioned by other subaerial, local seismic or marine processes. They suggest a link to a tsunami some 105,000 years ago.

Despite this potential evidence from the Pleistocene, in general, the NSW coast has a low exposure to tsunami hazards. Opper *et al.* (2006) suggest that about 34 tsunami events have been experienced along the NSW coast over the last 200 years. Most of these were so small as not to be noticed by the general public. Events in 1868 and 1960 were associated with tide gauge measurements of around 1 metre and created unusual wave, tide and current patterns along the coast.

Opper *et al.* (2006) quote two articles from the Sydney Morning Herald and Brisbane Courier Mail to show the magnitude of the impacts of these events. These are reproduced below, as many people would not have experienced a tsunami event in Australia.

> *Brisbane Courier Mail 25 May 1960*
> Freak currents tore away moored boats and upset shipping. The huge tide tore from their moorings about 30 launches and small craft and two barges at The Spit: Swirled the largest barges in among drifting launches, overturning several of them and damaging others: smashed one of the barges into the Spit Bridge. Set adrift 800 logs from moorings at Balmain shipping yard, which were then swept down the Parramatta River. Swept away a strip 100 yards by 60 yards from Clontarf Reserve Point Park and exposed a high tension submarine cable: In one tense moment a 30ft fishing trawler sank in Throsby Creek near Newcastle. Eight launches were ripped from their moorings in Throsby Creek and swept half a mile into Newcastle Harbour.

> *Sydney Morning Herald 17 August 1868*
> An extraordinary tidal disturbance has been experienced here this morning since about half past 6 o'clock – the vessels at the coal shoots broke from their moorings, one nearly losing her mass; the sand bank was suddenly uncovered to the extent of a foot and was rapidly covered again.
> At 8.30 the vessels in the harbour were thrown into great confusion. The Alexander broke from her moorings and had to anchor in the stream. The Planter was shaken so much by the action of the tides that the captain expected his masts to fall. The ship Lucibelle, 1000 tons, was swung round four times, although a strong ebb was running; and other vessels in the harbour swung round in all directions. The tide ran down sometimes at a rate of 12 knots, the same as if there was a strong fresh in the river.

Opper *et al.* (2006) note that the most vulnerable section of the east coast to tsunami impacts is the Newcastle to Wollongong region. The vulnerability of this region stems from possible exposure, low lying coastal land and very high population density and investment in critical community infrastructure.

Australia is part of the early warning network in the Pacific. Tsunami warnings have been issued for the NSW coast twice in the last 12 to 18 months. In each case, the actual tsunami wave was much smaller than initially considered possible, so that warnings could be quickly removed.

Advice from this network will inform Wyong Shire Council's emergency response protocols.

16.4 Sandy coast landforms and features

16.4.1 Sandy Beaches

For this project detailed assessments of coastal processes have been made at eight beaches, representing the diversity of wave energy and beach morphology that is experienced along the 35 kilometre coastline. The beaches assessed were:

- South Entrance
- North Entrance
- Shelly Beach
- Toowoon Bay
- Blue Bay
- Soldiers Beach
- Hargraves Beach
- Lakes Beach (including the southern part of Budgewoi Beach)

The location of each beach is shown in **Figure 1.1** (in **PART A**) and in the figures in **Sections 8.0** and **9.0** in **PART B**. Details of assessed beach profiles are in **Appendix 4**.

Beaches are accumulations of wave deposited sediment and in the Wyong area are almost exclusively sandy. The sand composition is primarily quartz and lithic grains and shell particles. The sand that is deposited on beaches is part of a larger coastal sediment compartment that includes the dunes, nearshore bars in the surf zone and bed sediments in deeper water offshore. Sand moves from one part of the compartment to another, depending on winds (onshore or offshore), wave height, period and angle of approach, length of time since major storm conditions and other factors.

It should be noted that whilst many beach goers have a concept of the 'beach' as the sand above low tide level, extending seaward to the where the waves break, the current statutory definition in NSW extends out to 10 metres water depth.

The morphology of the beach that is observed at any one time is a snapshot of the balance between different components of the coastal sediment budget. **Figure 16.5** shows the key features of the beach system during erosion and accretion cycles and **Figure 16.6** shows a model of the coastal sediment compartment, where sand can be deposited and stored in different locations at different times.

The Wyong coastline includes two long (7 to 10 kilometres) barrier beaches and several small 'pocket' beaches, bounded at either end by rock headlands or sandy cuspate forelands (often with a small rock bar offshore).

Tuggerah and Birdie Beaches are barrier beaches, north and south of Norah Head, which enclose the Tuggerah Lakes system. The sediment that forms these barrier beaches was swept landward from the continental shelf as sea level rose in the early Holocene, about 10,000 years ago. The sand was deposited after sea level stabilised at about 6500 years ago. The modern beaches are aligned approximately to the dominant south east swell direction and are backed by coastal dune systems, which widen northwards along the barrier. Old transgressive dunes occur on the northern part of both barriers, reflecting long term movement of sand from south to north along the beach systems.

Other beaches along the Wyong coast are short stretches of sand, against the base of a cliff or bluff. Several examples occur in Munmorah State Recreation Area. The small beach at Cabbage Tree Harbour is also an example, as are Shelly Beach, Bateau Bay, Blue Bay and Toowoon Bay. These beaches may have bedrock close to the surface both at the back of the beach and underlying the beach sand, so the sand volume is small. In major storm events, the bedrock is exposed.

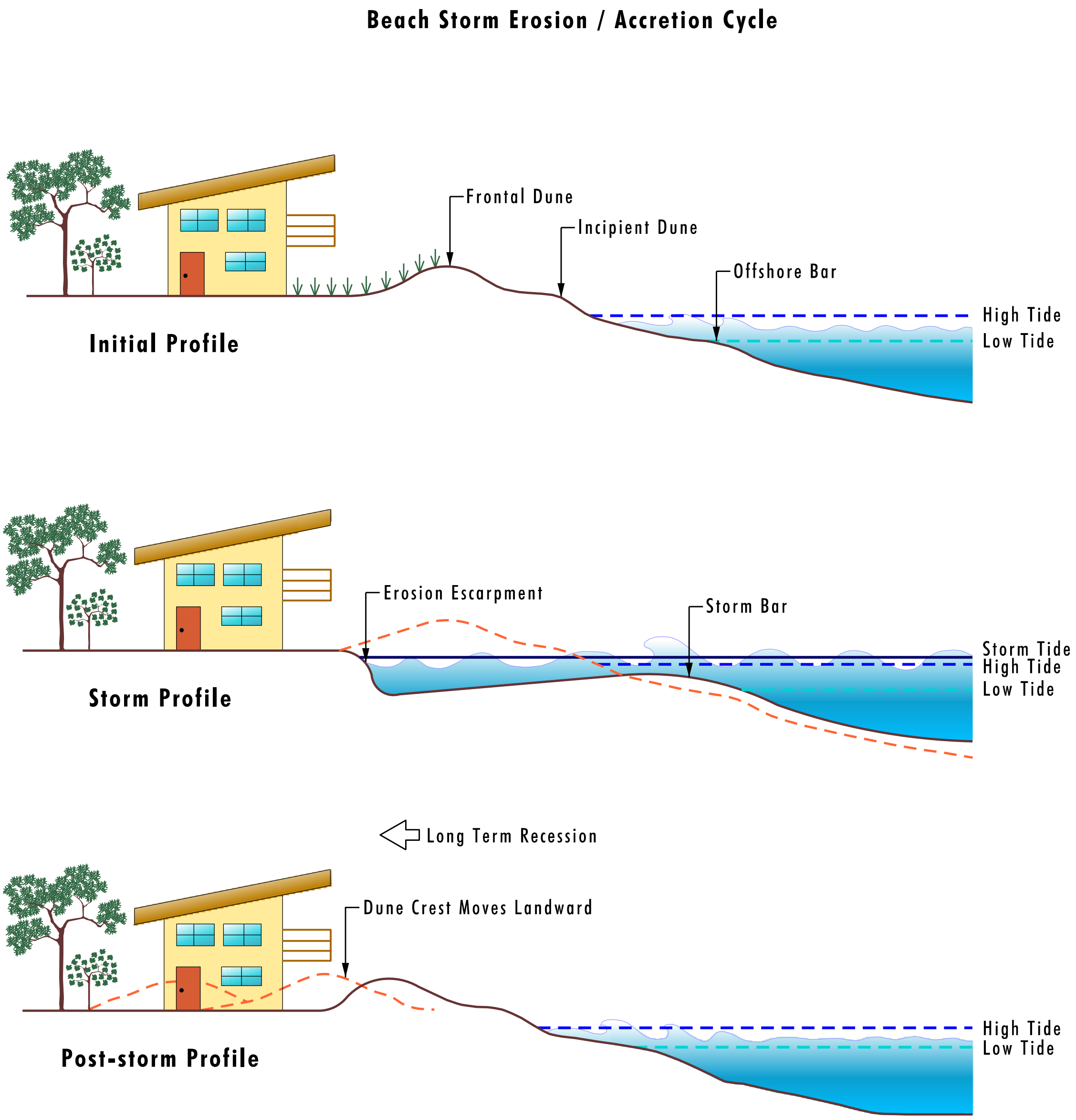


FIGURE 16.5

Erosion and Recession

Source: SMEC Australia

File Name (A4): R03_V1/1869_013.dgn

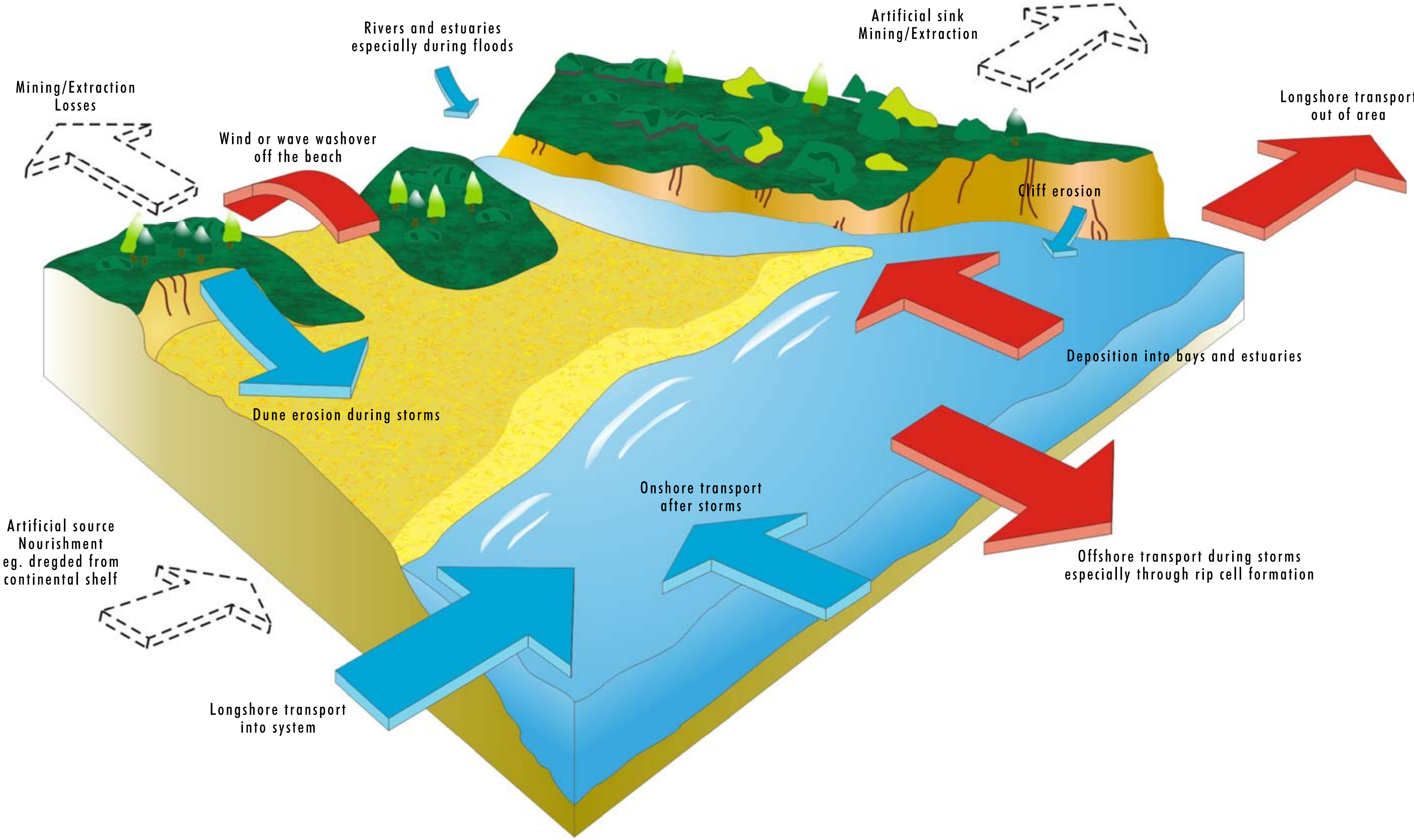


FIGURE 16.6

Sediment Budget in a
Coastal Sediment Compartment

Source: NSW Government Coastline Management Manual 1990

At some locations along the Wyong coast, such as Cabbage Tree Harbour, the ‘bedrock’ in several locations is not strong resistant rock, but Tertiary or Pleistocene indurated sands. For these pocket beaches, there are complex interactions between coastal erosion and coastal geotechnical processes (see **Section 16.6**).

The extent of rock under beach sand or dune sand is not definitively known for many of the beaches along the Wyong coast. This uncertainty has been taken into account in the erosion hazard studies and management proposals for areas where there is a transition from a bedrock to a sand landscape.

The pocket beaches (short embayments set within prominent rock headlands and/or reefs) are expected to respond to sea level rise in different ways to the long sandy barrier beaches. They have a smaller volume of sand available (for instance, as a thin mantle over bedrock) and because of the bedrock features landward of the beach there are constraints to the extent of dune roll back that is topographically feasible. In general there is less opportunity for long shore sediment transport to affect the alignment of pocket beaches (compared with long barrier beaches), because of the extent of rock protection.

Research by Brunel and Sabatier (2007) investigated the vulnerability of pocket beaches in southern France to sea level rise. Brunel and Sabatier (2007) note that in their study area, pocket beaches have historically narrowed, by 2 to 22 metres. They used a variety of modelling approaches (not the Bruun Rule, which they state could not be used because of difficulties with assumptions about offshore slope), to predict future shoreline positions. All models indicated that the pocket beaches would continue to narrow, by varying amounts. By 2100 the pocket beaches in their study area would disappear, as landward translation of each dune form is blocked by the break of slope to bedrock terrain.

16.4.2 Dunes

The coastal sediment compartment includes offshore sand, the beach and dunes. Coastal dunes are formed by wind-blown sand, often reworking wave deposited sand in beach ridges. Coastal dunes may be stable and vegetated, or may be actively migrating through blowouts, or may be eroding due to storm waves or sea level rise.

Examples of many different dune forms and processes can be seen along the Wyong coastline. For instance:

- Holocene transgressive dunes underlie the landscape in Wyrrabalong National Park, between Tuggerah Beach and Tuggerah Lake. These high vegetated dunes date to processes operating during the period 6000 to about 2000 years ago. The presence of extensive relic transgressive dune systems at the northern end of coastal embayments is evidence of the net dominance of south easterly wind and wave directions on the coast.

- Frontal or foredunes occur along most of the open ocean beaches and provide the main buffer for storm wave erosion. At North Entrance and Hargraves Beaches, houses have been constructed on the frontal dune system.

- At some locations, the foredune is subject to blow outs and other active windblown erosion. Soldiers Beach was an example of this dune process until stabilisation works were carried out in the 1980s. Aerial photographs of North Entrance Beach from the 1940s and 1960s show an active blow out dune extending from the beach (where Curtis Parade is now) across the barrier to the shore of Tuggerah Lake. This dune was stabilised in the 1970s.

- Incipient foredunes are low dunes seaward of the main frontal dune system. They tend to be removed during storm activity and rebuild after storms subside. Some may have colonising vegetation. **Plate 16.2** shows the incipient foredune at Hargraves Beach.

- Beaches, nearshore and frontal dunes are related parts of the coastal sediment compartment. However, the time scales of processes (and the nature of the processes themselves) operating in the beach system and dune system are quite different, with the transition occurring across the backshore area. Incipient foredunes and foredunes accrete as aeolian processes translate beach sand landward during low wave energy conditions. These dune forms provide a buffer for episodic erosion during major storm events.

- Dune erosion processes are episodic, not gradual. Storm wave cut into the frontal dunes will vary with storm intensity, direction of approach, period since the last storm and to a lesser extent, the binding of dune sand sources by established vegetation. Storm wave cut can initiate blowouts in the frontal dunes, and can overtop low frontal dunes.

- Whilst large dune fields can result when there is an abundant sand supply, there is some evidence that dunes can form even when there is a slightly negative sediment budget. Vegetation cover and wind strength will also strongly influence this process.

- Active landward sand movement in transgressive dunes is a cumulative process with positive feedback loops. Transgressive dunes will shift sand from the frontal dune system (as blowouts), reducing the volume of sand available to beach processes and, over time leading to beach recession. Large areas of destabilised sand, moving is a transgressive sheet, have the capacity to overwhelm landward well vegetated terrain, replacing stable back dune ecological communities with either bare sand or early colonisation communities. Active transgressive dunes existed at the northern end of Tuggerah Beach and Birdie Beach in the 1960s, 1970s and 1980s.

- The more landward elements of the dune system, which are protected from active coastal processes and tend to be well vegetated, slow or halt the movement of windblown sand. When the frontal dune buffer remains in place and good vegetation cover is maintained on the hind dunes, these dunes are decoupled from the beach system. Along the Wyong coastline, dune sand that is ‘decoupled’ from the beach sediment compartment is stored in forested transgressive dune fields at the northern end of Tuggerah Beach, at Soldiers Beach and Birdie Beach. Small volumes of sand are also stored in ‘decoupled’ (and now urbanised) dunes at Shelly Beach, Hargraves Beach and North Entrance Beach.

- As noted in **Section 16.2.3.1** interpretation of the behaviour of dunes with rising sea level has been confused in NSW because of a lack of clarity about how the coast responded to slightly higher sea level in the early Holocene and potentially during the Holocene (up to about 2000 years ago). In general, in NSW, the record of Holocene sea level patterns is poorly preserved. However, recent work by Goodwin and associates at Macquarie University (pers. comm.) suggests that some low sandy barriers along the NSW coast have only accreted over a period of hundreds of years.

- There is also relatively limited dating of the periods of active dune transgression (for instance, at Newcastle Bight). The dates that are available from Newcastle Bight suggest three periods of active dune transgression during the mid to late Holocene, the first of which pre dates 4500BP; a second period at around 2300BP and a final and continuing period, from about 500BP. No dated Holocene sequences are available for the Wyong coastline. Recent work from the Illawarra coast (Sloss *et al.* 2007) suggests that the early Holocene sea level was at least 1 to 2 metres higher than now, falling to current levels after 2000BP and that there may have been fluctuations of +/-1 to 2 metres during the mid to late Holocene. The stratigraphic record on most barrier systems does not have the resolution to identify local responses to these fluctuations.

Section 17.2.1 provides a brief overview of the history of land use along the Wyong coastline. Of particular note in relation to coastal dunes is the mineral sand mining industry that operated along parts of the Wyong coastline in the 1960s and early 1970s. Reconstruction and revegetation of coastal dunes after sand mining changed the location or alignment of the frontal dune system on some beaches, such as the central parts of Tuggerah Beach.

16.4.3 Creek and Lake Entrances

There is currently only one major estuary entrance along the Wyong coastline. This is the entrance to the Tuggerah Lakes system, at The Entrance. At the mouth, the channel into the estuary is normally set against the bedrock outcrop on the southern side. The northern side of the estuary entrance channel is the beach and dunes at the southern end of the North Entrance barrier beach.

The morphology and sedimentology of the sand deposit in Budgewoi Lake, behind the coastal barrier at Lakes Beach/Budgewoi Beach shows that there was formerly an entrance to Budgewoi Lake at this location. This entrance has not functioned in historical times and probably not for more than 500 to approximately 2000 years.

There are also a number of very small creek catchments along the Wyong coastline, principally along the rocky coast, which discharge directly to the ocean. Examples are in the Blue Bay and Shelly Beach area and in the Munmorah State Conservation Area.

The entrance processes of coastal lakes (such as the Tuggerah Lakes) affect the sediment dynamics of beaches.

As for all NSW ICOLLS (intermittently closed and open lakes and lagoons), the sand in the bed of the entrance channel is marine in origin and is part of a flood tide delta. In calm and low rainfall conditions, sand accumulates inside the mouth of the estuary in the tidal delta. Shoals may also close the mouth of the lake system and accumulate a sub-aerial berm or frontal dune system. The full extent of the tidal delta sand deposits includes at least partially stabilised shoals and islands upstream of The Entrance Bridge. More active sand which moves between the entrance channel and the adjoining North Entrance and The Entrance Beaches predominantly occurs downstream of the Entrance Bridge.

In high flood conditions, the head of water in the lake drives strong currents which scour out the entrance channel shoals and return marine sand to the near shore and adjoining beaches. The timeframes for this exchange process are unpredictable. The Entrance channel is untrained, other than natural rock along the southern shore at the entrance. Other channels (particularly upstream of the bridge) have been dredged, straightened and realigned in the past.

This intermittent sand accumulation and sand scour in the entrance channel means there is a relationship between entrance processes and sand supply on North Entrance Beach. When sand is held inside the entrance in the tidal delta, there is slightly less sand available on North Entrance Beach. When sand is scoured out of The Entrance channel, there is a slight increase in the amount of sand potentially available to accrete on North Entrance Beach.

WSC maintains a mobile dredge in The Entrance. Dredging of the active tidal delta shoals has been conducted since about 1990, to prevent the lake entrance from closing totally and to maintain tidal flushing of the entrance area which has high recreational value. More information about dredging process, sand volumes and impacts on sediment budget is in **Section 10.0** in **PART B**.

16.5 Sandy coast processes and hazards

Coastal processes are driven by ocean waves, currents, tides, water level and wind acting on the unconsolidated sediment of the beach, dunes and near shore sea bed. Geotechnical processes are also influenced by these variables but rainfall and local geological conditions are more important drivers.

For unconsolidated sediments on beaches and dunes, important coastal processes include:

- Storm bite or storm cut. This is the erosion of sand from the subaerial or visible part of the beach (above the swash zone) and usually results in a wave cut scarp
- Slope instability. When the sand dries after a storm, the wave cut scarp may slump, causing further recession of the dune face until it reaches a stable angle of repose.
- Longer term shoreline recession due to loss of sediment from the beach compartment. Sand may be lost from the beach due to:
    - Sand is trapped offshore, for instance on offshore reefs in deeper water, only active during major storms
    - Inland transport by on shore winds, particularly where the dunes are unstable and transgressing over other terrain
    - Sand moving along shore either as part of a medium term beach rotation process or bypassing around headlands
    - Sand moving into estuary entrances
    - Mineral sand extraction or construction sand mining. Many of the dunes in the northern part of Wyong Shire were mined in the mid twentieth century
- Longer term coastal recession due to sea level rise. Climate change may affect coastal processes in several ways, including:
    - Increasing ocean water levels as sea level rises. For planning purposes, the NSW government has adopted a long term sea level rise of 40 centimetres above 1990 levels by 2050 and 90 centimetres above 1990 levels by 2100.
    - Changes to storm frequency and intensity, affecting wave height and period, and wind strengths in individual storms
    - Changes to the dominant angle of wave approach

Variations in the angle of wave approach and dominant wave height also occur at time scales of seasonal to decadal periods, including *el nino* and *la nina* variations.

The real impacts of interactions between these processes that operate at different scales and timeframes are currently difficult to predict with any precision. However, the Bruun Rule has proven to be a robust predictor of shoreline retreat for systems that are consistent with the underlying assumptions of the model – such as underwater bed profile and offshore closure point. For the Wyong coastline, the assumptions of the Bruun Rule are appropriate for applications to sandy embayments, with no or very limited rock reef.

The Bruun Rule predicts that the shoreline will recede approximately one metre for every one centimetre of sea level rise. Research is continuing to allow other changes to be more accurately predicted.

Where there is abundant rock reef or rock underlies the beach and dune system, Bruun Rule predictions need to be examined closely. The analysis by SMEC (2010) (see **Section 16.6** and **Appendix 4**) takes underlying rock patterns into account to the extent that the distribution of this rock is known and recognises that for some small beaches, further work is necessary to better define the distribution of rock.

16.6 Results of sandy coast erosion hazard studies

SMEC (2010) reports the results of analysis of historical beach erosion (immediate coastal erosion hazard) and also predict coastal erosion for the planning periods of 2050 and 2100. Full details are in **Appendix 4** and the results are summarised below.

16.6.1 Immediate coastal erosion hazard

Immediate coastal erosion hazard is discussed in **Section 8.0**. Maps showing affected areas are in **Figures 8.3** to **8.9** in **PART B**.

Table 16.3 summarises the impact of immediate coastal erosion hazard on coastal development (private homes and public assets).

Table 16.3 - Development affected by coastal erosion, immediate planning period

Location	Wave impact and slope adjustment	Reduced foundation capacity
Shelly Beach	Part of southern caravan park	Narrow band of northern caravan park
Blue Bay	5 dwellings and 25 lots	19 dwellings and 2 lots
North Entrance	18 dwellings and 28 lots	Surf club and 1 lot
Soldiers Beach		Surf Club
Lakes Beach		Surf Club
Hargraves Beach	30 dwellings and 9 lots	5 dwellings and 4 lots

16.6.2 Beach recession over the last three decades

Based on analysis of digital aerial photogrammetry and LiDAR data, SMEC (2010) notes that most of the beaches in Wyong Shire have been stable in sand volume and form over the last three decades or so. Wyong beaches have generally not experienced recession over this period and some beaches have even accreted slightly, as the coast recovers from the period of severe storm activity in the 1970s. However, recession which would be noticeable to residents and beach users has occurred at North Entrance and Lakes Beach.

Measured recession results show that over the last 30 years, parts of North Entrance Beach have receded by 3 to 15 metres, and Lakes Beach has also receded by approximately 15 metres. For all other beaches, measured recession is less than three metres. For most beaches, it has been assumed that lack of evidence of recession, despite sea level rise, is due to a combination of a lack of major storms since the 1970s and the presence of a buffer of dune sand which provides resilience.

The recession over the last three decades could be due to several factors, including:

- Loss of sand from the active sediment compartment – for instance, to 'decoupled' dune systems, to offshore bars in deep water, or into a tidal delta. The interaction between North Entrance Beach and The Entrance channel may be an important factor at North Entrance.

- A response to sea level rise, in accordance with the Bruun Rule. **Figure 1.5** in **PART A** shows measured sea level rise of 100-150 mm at Fort Denison over the last three decades. In the absence of other factors, this should be sufficient to drive measurable recession, but it is clear that for many beaches, the frontal dune system has not receded.

  For recession to be limited to only two beaches, it would be expected that these beaches have a limited frontal dune buffer so that the threshold for recession has been passed at these two beaches, but not elsewhere in Wyong Shire. North Entrance Beach is the southern end of a long barrier beach and dune system, where there is clear evidence of long term, long shore transport to the north. Only a single narrow frontal dune remains.

Further examination of processes and impacts at North Entrance Beach is presented below.

16.6.2.1 North Entrance – 1974 and 2007 impacts

SMEC (2010) has examined the specific effects of the May 1974 storm and June 2007 storm at North Entrance Beach.

SMEC (2010) analysed storm bite erosion for several 'blocks' along the beach:

Block A	Sand spit at The Entrance
Block B	Residential development at Hutton Road
Block C	Surf Club vicinity
Block D	Residential development at Curtis Parade
Block E	Central beach, near Magenta Shores

The analysis shows that the 1974 storm had a greater erosive impact on the central part of the beach (Block E of the analysis, in front of the current Magenta Shores Resort), rather than the southern part of the beach (Blocks A, B, C and D of the analysis. In 1974, erosion of more than 150 m^3/m was experienced only in Block E, with the maximum erosion measured at 250 m^3/m. Erosion in Blocks A-D on this storm was less than 150 m^3/m. Photographs of the beach and residential development at the time show houses in Curtis Parade built on the mobile dune surface, approximately 10 to 15 metres landward of a 3 to 4 metre high erosion scarp.

In 2007, storm bite volumes of around 250 m^3/m were common in Block A (the sand spit at the southern end of the beach), with 150 to 200 m^3/m in Block B. Measured storm bite in Blocks C and D was less than 150 m^3/m. Photos of North Entrance Beach in Blocks B, C and D in 2007 show a 1.5 to 2.0 metre scarp impacting on domestic infrastructure such as fences. The storm bite impact in both storms was virtually the same; however, as discussed in **Section 16.6.2**, Blocks C and D had experienced recession of up to 15 metres in between these storms.

16.6.3 Predicted long term beach recession, with sea level rise

Figures 9.1 to **9.14** (all in **PART B**) show the coastal erosion hazard lines (i.e. the area affected by coastal hazards) for the 2050 and 2100 planning periods. Copies of these figures can also be viewed in **Appendix 4**.

Table 16.4 summarises the coastal recession findings for the 2050 and 2100 planning periods, applying the OEH sea level rise benchmarks and the Bruun Rule to the Wyong beaches. Note that SMEC (2010) has calculated recession rates for separate sections of long sandy beaches. See **Appendix 4** for full results.

Table 16.4 - Predicted beach erosion due to sea level rise

Beach	Beach recession 2050 (metres)	Beach recession 2100 (metres)	Beach erosion (volume of sand loss) m^3, 2050	Beach erosion (volume of sand loss) m^3, 2100
Shelly Beach (3 blocks)	14.8 to 17.4	33.3 to 39.2	72.9 to 189.8	164 to 426.9
Toowoon Bay (whole beach)	5.2	11.7	52.0	116.9
Blue Bay (whole beach)	4.4	9.8	39.5	88.8
South Entrance (whole beach)	n/a (on rock)	n/a (on rock)	n/a (on rock)	n/a (on rock)
North Entrance (8 blocks)	11.6 to 18.0	26.1 to 40.4	73.3 to 152.7	164.9 to 343.7
Soldiers Beach (5 blocks)	11.6 to 17.4	26.1 to 39.2	123.8 to 155.7	278.6 to 350.3
Lakes Beach (whole beach)	28.9	65.0	190.8	429.2
Budgewoi Lake (dune arm)	11.5	25.9	81.7	183.8
Hargraves Beach (2 blocks)	6.7 to 10.2	15.0 to 22.9	45.9 to 58.7	103.3 to 132.1

Tables 16.5 and **16.6** summarise the impacts of coastal erosion on coastal property for the 2050 and 2100 planning periods.

Table 16.5 - Existing development predicted to be affected by coastal erosion, 2050 planning period

Location	Zone of wave impact and slope adjustment	Zone of reduced foundation capacity
Shelly Beach	Larger section of southern caravan park	Surf Club
Toowoon Bay and Blue Bay	27 dwellings and 3 lots	1 dwelling and 5 lots
North Entrance	38 dwellings and 25 lots	21 dwellings and 6 lots
Soldiers Beach	Surf Club	
Lakes Beach	Surf Club	Central Coast Highway – dune likely to reach the road
Hargraves Beach	36 dwellings and 6 lots	3 dwellings

Table 16.6 - Existing development predicted to be affected by coastal erosion, 2100 planning period

Location	Zone of wave impact and slope adjustment	Zone of reduced foundation capacity
Shelly Beach	Larger section of southern caravan park, Surf Club	
Toowoon Bay and Blue Bay	27 dwellings and 6 lots (some of these houses may be on rock)	
North Entrance	Most dwellings and lots in Curtis Parade and most buildings seaward of Hutton Road, south the SLSC (additional 30 dwellings and 6 lots) Also wave overtopping to lake shore	20 buildings and 3 lots
Hargraves Beach	40 dwellings and 7 lots	6 dwellings and 4 lots
Budgewoi/Lakes Beach		Central Coast Highway Possible new entrance to Budgewoi Lake – combined overtopping, recession and high lake levels

16.7 Results of inundation hazard studies

Coastal inundation results when breaking waves run up over the beach and dune system and overtop the crest of the dune. Wave runup at any particular site is a function of wave height and period, the foreshore profile and slope, surface roughness and other shoreline features.

When storm waves overtop the dune crest, flooding and damage to structures behind the dune can occur. In the case of the Wyong coastline, wave overtopping of coastal dues is likely to occur at the same time as high water levels are experienced in the Tuggerah Lakes (due to extended rainfall). This means that inundation hazard at some sites on the narrow coastal barriers is influenced by both oceanic flooding and lake flooding.

SMEC (2010) has calculated the wave runup at eight Wyong beaches for a one per cent AEP storm event. As would be expected from the different morphology and exposure of the beaches, the maximum wave runup varies from beach to beach.

SMEC (2010) report that generally the maximum expected runup is 6 to 7 metres AHD, with runup of around 8.1 mAHD at north Entrance. By analysing the wave runup with detailed topography from aerial laser scan (ALS or LiDAR data), SMEC (2010) found that some overtopping can be expected at Blue Lagoon Resort, at the southern end of Blue Bay, at south Entrance swimming pool, along Curtis Parade at North Entrance and along Hargraves Beach.

Full details of the wave runup study are in **Appendix 4** and **Figures 9.22** to **9.29** show the extent of wave runup for each beach.

16.7.1 Long term estuary entrance processes

SMEC (2010) has considered how long term sea level rise will affect The Entrance to the Tuggerah Lakes system. They suggest several responses, including:

- Sea level rise will increase the tidal prism of Tuggerah Lakes. This would increase the amount of sand held in the tidal delta. Detailed sand volumes have not yet been calculated, but further empirical analysis of sand volumes and sediment dynamics in The Entrance channel is underway.

- An increased tidal prism would also tend to move the entrance bar (ebb tide delta) further offshore, increasing the wave energy that can reach the beach. This would tend to increase erosion hazard.

The full implications of changes to the tidal prism are not currently known, but there is some evidence from other estuaries where natural tidal processes have been altered by the construction of entrance training walls, that beach erosion around the entrance would increase around the entrance. The full extent of entrance process change depends on the coincidence of the various water level factors (such as *el nino* or *la nina* years, with storms and other factors.

SMEC (2010) has considered the interactions between inundation associated with higher lake levels and overtopping inundation and recession at North Entrance. It is likely that lake and ocean hazards will apply cumulatively to low lying land (back barrier flat) at North Entrance, after about 2050. There is extensive development in this area, including medium density residential, the Central Coast highway and other infrastructure which would be impacted by cumulative lake inundation and exposure to coastal recession.

SMEC (2010) has also considered the potential for a new estuary entrance to form at Budgewoi, in the vicinity of the relic tidal delta. The low barrier at this location is affected by coastal recession associated with sea level rise, and also by oceanic wave runup and extreme water levels in the Tuggerah Lakes system. SMEC (2010) found that there is potential for the old entrance to be reactivated, with the likelihood increasing from the 2050 to the 2100 planning periods.

By 2100, it is likely that the narrow dune at Budgewoi could be breached. Further detailed analysis is needed to clarify the exact conditions and the probability of the breach occurring. However, it is immediately apparent that the opening of a new entrance at Budgewoi would have major implications for Council and the Wyong community. It would greatly change the ecology of the lake system; it would affect road transport along the coast and other fundamental community infrastructure such as sewer lines.

These consequences are considered in the preliminary risk assessment in **PART C**, **Section 18.0**.

16.8 Geotechnical processes on cliffs and bluffs

This section describes the cliff and bluff landforms along the Wyong coastline, processes operating on those landforms and the hazards associated with geotechnical processes. Cliff and bluff landforms occupy about 20 per cent of the length of the Wyong coastline.

16.8.1 Cliffs, Bluffs and Rock Platforms along the coastline

The sandy beaches of the Wyong coastline are separated by:

- Cliffs (close to vertical forms with bedrock outcropping). Cliff heights vary from only a few metres to tens of metres.
- Bluffs (steep slopes, often formed on weathered rocks or indurated sand).

Some cliffs and bluffs have a small sandy beach at their base, often comprising only a thin layer of sand over a bedrock ramp. Other cliffs and bluffs have shore platforms at their base. **Plates 16.3** and **16.4** illustrate some rocky coast forms along the Wyong coastline.

Different assemblages of cliff, bluff, rock platform and narrow or pocket beach are distributed along the Wyong coastline, including:

- High plunging cliffs where no fallen debris is visible at the base above tide level
- High plunging cliffs with boulder size debris at the base
- Cliffs and bluffs which have rock shore platforms at their base
- Cliffs and bluffs which have offshore rock outcrop/reefs
- Cliffs and bluffs with narrow sandy beaches at their base, which may overlie a bedrock ramp
- Cliffs and bluffs where rock and soil debris of various sizes has accumulated as a ramp at the base of the slope.

These different morphological types hint at different processes that contribute to erosion and recession of the rocky coast. They also provide a preliminary indication of the likely vulnerability to process changes as climate changes and/or sea level rises in the future.

The geological character of the materials forming the cliffs, bluffs and shore platforms are clearly important factors influencing the landform and the rate at which cliffs erode. In particular, the strength of the rock influences the rate of cliff or bluff erosion at embayment scales and at local scales (creating, for instance, an uneven rock platform width where cliffs have high variable structure). The strength of rock units and their resistance to geotechnical processes is affected by factors such as:

- lithology (what types of particles and minerals are present)
- stratigraphy (the relationship of different layers of rock)
- presence of joints and faults
- presence of intrusions such as dykes and related fracture zones
- association with surface or groundwater flows.

Several distinctive geological units are present along the Wyong coastline. Both the nature of these units and their relationship to each other affect the geotechnical stability of the cliffs and bluffs. Important geological units are noted in **Table 16.7**. Details about geological units and geotechnical processes are in tables B1 to B3 of TAB B of **Appendix 4**.

Hargraves Beach/Noraville

Cabbage Tree Harbour

Cabbage Tree Harbour (Norah Head)

Plate 16.3

Rocky Coast Landforms, Wyong

Norah Head

The Entrance

Crackneck

Plate 16.4

Rocky Coast Landforms, Wyong

Table 16.7 - Geological units and characteristics, Wyong coastline (based on TAB A of SCE 2010, Appendix 4*)

Geological unit	Where it occurs	Important characteristics
Terrigal Formation (upper Narrabeen Group)	Outcrops only in upper parts of headlands at Crackneck and Yumbool Point.	Interbedded fine to medium grained sandstone and laminated siltstone, minor claystone. The interbedded character of the formation and its high lithic content make it relatively susceptible to weathering. Blocky Terrigal Formation sandstones can fail as block falls.
Patonga Claystone (Narrabeen Group, Early Triassic, approximately 240 to 250 million years old)	Overlies the Tuggerah Formation, and underlies the Terrigal Formation (both mostly sandstone); crops out south from Lake Macquarie and thickens southwards. Examples are at Noraville, Blue Bay, Bateau Bay and coastal slopes at Crackneck and Yumbool Point.	'Red beds' of interbedded sandstones, siltstones and claystones. Deeply weathered to red/brown mottled stiff clay with low load bearing capacity. Weathered strata are subject to landslip. Undercutting of interbedded sandstones can cause block fall. Strong seepage flows at the interface between the claystone and overlying Terrigal formation, forming springs and driving soil creep and landslip.
Tuggerah Formation	Overlies the Munmorah Conglomerate, exposed in headlands and cliffs at Norah Head, Noraville, Jenny Dixon Beach and Cabbage Tree Harbour; also in rock platforms at The Entrance, Blue Bay, Bateau Bay, Crackneck and Toowoon Point.	Principally lithic sandstone, with minor claystones, siltstones and pebbly bands. Where the claystone occurs at the level of the wave zone (at the base of the cliff) extensive undercutting can occur, creating unsupported rock overhangs which can fail suddenly. Large block failures can also occur because of weathering along the joints of the massive sandstones. This type of weathering leads to block failures. Large boulders accumulate on the rock platform; examples can be seen at the base of cliffs at Cabbage Tree Harbour and Noraville. The Tuggerah Formation is affected by multiple igneous dykes, which weather more rapidly than the massive sandstone, and change seepage patterns as well as opening up spaces for weathering of the sandstone.
Munmorah Conglomerate	This unit forms much of the elevated land in the Morisset area in Lake Macquarie (to the north of the study area). In the study area, it underlies the Tuggerah Formation and forms the rock platforms from Soldiers Point to Noraville.	Lithic to quartz lithic medium to very coarse sandstone and pebble conglomerate. Tends to be massive, usually medium strong to strong.

Geological unit	Where it occurs	Important characteristics
Cemented/indurated sands Pleistocene sand units (less than 2 million years; some sand units are less than 10,000 years old and are poorly consolidated)	Occurs in the northern Sydney Basin. In Wyong, cemented and indurated sands occur at Cabbage Tree Harbour and also at Bateau Bay, Jenny Dixon Beach, Shelley Beach, Toowoon Bay and Blue Bay. Some of these locations are not currently directly affected by coastal processes, but may be exposed to coastal processes in the future, as sea level rise causes recession of coastal dunes and other wind- blown sand deposits.	The sand grains were deposited in beach ridges or dunes, but over time the grains have been cemented and bonded by precipitation of iron and organic minerals leaching through the deposit. When exposed above the ground water table, these sands are friable and weak. Ground water flows create a series of pipes through the sand – making them extremely porous. Below the water table, the bonds between the sand grains weaken further.
Igneous dykes	There are many dykes passing through the lower Triassic rocks that occur along the Wyong coastline. Locations with multiple dykes include Norah Head, Cabbage Tree Harbour, Soldiers Point and Jenny Dixon Beach.	The dykes are igneous (usually basalt) intrusions. They weather more rapidly than the surrounding rocks, but the bedrock on either side of the dykes is also extensively fractured and altered. Seepage occurs along dykes and associated fracture planes. In combination these factors drive accelerated recession (e.g. see P9 in TAB B of **Appendix 4**)

*SCE 2010 refers to Chapman *et al.* 1982 and Uren, Herbert and Helby 1976

Rock platforms provide habitat for diverse marine species and the cliffs are dominated by coastal heath communities, including a range of Endangered Ecological Communities (see **Section 17.1**).

16.8.2 Processes on cliffs and bluffs

Processes acting on coastal cliffs and bluffs include:

- The structural integrity of rock (or other indurated or consolidated materials) is weakened by weathering or by undercutting. Weathering processes that can be observed along the Wyong coast include:
  - Chemical weathering which weakens the body of the rock or causes a hard case to form over soft rock.
  - Differential chemical weathering – of less resistant sedimentary rocks and along igneous intrusions (dykes), followed by rock fall of less weathered rock.
  - Weathering along joint planes and bedding planes of sedimentary rocks, which breaks the rock mass up into fragments of varying sizes.
- Different geological strata have different susceptibility to these weathering processes.
- Undercutting of strong rock by weathering and wave erosion of less resistant rocks is an important process along the coast.
- Mass movement (landslip, block falls or slumping) or fluvial erosion (such as gullying) moves the material downslope towards the bottom of the cliff of bluff, where it may

accumulate at the landward margin of the beach or rock platform. Material can also accumulate part way down the slope of the cliff of bluff, on small benches or bulges. The size of material accumulating at the base of the cliff varies from large rocks (>5 metre diameter), which are not further moved by any erosive agent, to sand and clay.

- Where cliffs plunge directly into the sea, most eroded material (other than large boulders) will be moved away from the base of the cliff very quickly by waves and currents.
- If it is not removed in the short term, material that has fallen, slumped or flowed to the base of the cliff or bluff (onto the beach or rock platform) may weather further and may be gradually removed or reworked by wind or by water. The water involved may be flowing down the cliff or it may be wave action at the base of the cliff.

Within this broader geomorphic context, SCE (2010) (see Table B1 and B2 of TAB B of **Appendix 4** for details and diagrams of different processes) describes and illustrates five main geotechnical or slope stability processes (mass movement processes such as rockfall or landslip) which cause cliffs and bluffs to gradually recede. These processes also affect the width of the rock platform and the extent to which boulders accumulate on the rock platform. The geotechnical processes are summarised in **Table 16.8**.

For many of the cliffs and bluffs along the Wyong coastline, the geotechnical hazard is the result of a combination of processes which affect the cumulative recession hazard. For instance, although the Patonga Claystone is a conspicuous claystone unit (claystone interbedded with sandstone) along the coast, other sandstone units are also interbedded with claystones/siltstones at several locations. In the Noraville area, cliffs and bluffs are affected by the presence of weathering along igneous dykes, weathering of massive sandstones along joint planes, differential weathering of claystones (beneath sandstone units) leading to block-fall and soil creep on weathering claystones.

Table 16.8 - Cliff and bluff recession processes
(from SCE 2010)**:** See Tables B1 and B2 in TAB B of **Appendix 4**)

Mechanism	Description
A: Indurated sand recession	Wave attack undermines the toe of the slope (high tide and during storms). Surficial slumping due to groundwater seepage, soil pipes and rainfall runoff. Cycles of progressive wave attack/erosion and slumping. Excavation near the toe of the slope exacerbates the processes. Cabbage Tree Harbour is the best example of this process. Indurated sands also occur at Toowoon Bay, Blue Bay and Bateau Bay, but at these southern sites are separated from the beach by Holocene sand deposits.
B: Soil and fill creep on slopes: shallow landslips	Landslip of an ‘over steep’ soil mantle in weak clay soils with groundwater seepage. Differential weathering of less resistant claystone bands within the massive, blocky sandstone. Placement of fill and/or poor drainage exacerbate the processes. Examples of this process are at Ocean Parade and Boondilla Road - The Entrance/South Entrance

Mechanism	Description
C: Rock and block differential weathering	Differential weathering of the Patonga claystone (and other minor claystone units); undercutting of more massive sandstone layers leading to rock fall. Block sizes are up to 1 to 2 metres. Where a wave cut platform is present, it may partially protect the toe of the cliff, except in storms. Wave cut platforms will offer less protection as sea level rises. Examples of rockfall due to differential weathering can be seen at Roslyn place and Ada Avenue at Noraville. Specific localities where the Patonga claystone is the cause of differential weathering include Toowoon Point, Bateau Bay headlands and Little Bay. Differential weathering is also illustrated on the northern side of Norah Head, where the Tuggerah Formation is exposed in the cliff face. Massive sandstone beds are separated by minor siltstones, which weather and undercut the sandstones. Failures (large rock topples) may be separated by long periods and may be linked to major storm events. Continuing undercutting of the sandstones also causes joints to open landward of the cliff face. Due to relief of horizontal stresses, the rock units are also affected by ongoing joint opening processes, extending landward from the cliff face.
D: Dyke influenced rock recession	Igneous dykes are common in the Tuggerah Formation and cause sandstone units to be heavily fractured. Differential weathering of dykes undermines sandstone blocks and also exposes joints, leading to block toppling. Where dykes are aligned parallel to the bluff face, the bluff may retreat in steps, set by dyke spacing. Examples of this type of recession can be seen at Soldiers Point, Jenny Dixon Beach, Noraville and Norah Head.
E: Instability of weathered rock/soil slope	Occurs when claystone units (Patonga claystone) overlie the Tuggerah Formation. Creep and slumping in the claystones interacts with collapse of the massive sandstone blocks below. Strong seepage flows occur at the interface of the claystone and underlying sandstones. Processes are exacerbated by wave action at the base of cliffs in the Tuggerah Formation. Examples of these processes can be seen at Henderson St above Jenny Dixon Beach and Noraville.

16.8.3 Results of geotechnical hazard studies

Rates of retreat (erosion) of coastal cliffs and bluffs can be calculated from a variety of field measurements and for NSW, about 100 to 150 years of historical mapping (using aerial photographs, ground level photographs, cadastral plans and historical survey data) is available to provide evidence of how, where and when geotechnical processes have contributed to coastal recession.

SCE (2010, **Appendix 4**) reviewed the evidence of historical cliff and bluff recession along the Wyong coastline (using evidence from local Parish Maps, orthophoto maps and aerial photography) and predicted the spatial extent of geotechnical hazards driven by each of the five mechanisms described in **Table 16.8**.

The study of historical recession makes it obvious that geotechnical processes have affected the Wyong coastline for hundreds if not thousands of years. Geotechnical instability is not a new process.

The rate of historical recession is not linear or gradual; rather slope instability events tend to occur episodically when local slope stability thresholds are exceeded. A cliff or bluff may appear to be stable for decades. The effects of major storms, including wave action, seepage, scouring and waterlogging may trigger a slope instability event.

Because of the long term episodic nature of slope instability processes and events, there is a level of uncertainty about whether measured historical rates are accurate estimates of long term rates of landscape change. Longer term processes affecting rock platforms and cliffs and bluffs are linked to sea level patterns and climate changes over the late Pleistocene and Holocene periods. These long term processes and rates of recession provide context for the measured (measured) recession along the Wyong coastline. However, although it is clear that the rates of recession have varied over geological time frames, there is not sufficient understanding of rock platform and bluff geomorphic relationships to apply the geological recession rates to predict recession rates in the study area over the next century.

Tables 16.9 (a) and **(b)** provide information about measured geotechnical recession and predicted recession (SCE 2010). The predicted recession for the planning periods 2050 and 2100 takes into account the NSW Government sea level rise policy and is also based on a number of assumptions about other aspects of climate change over the next century and beyond. Recession rates are expected to increase with sea level rise and other climate change aspects (such as changes to storm frequency and intensity) over the next century.

The predicted recession rates are considered to be relatively conservative. Conservative estimates of slope recession are necessary now, because of the uncertainty about long term process and recession rates, together with the imprecise nature of some available geological and terrain data (at the scale of individual allotments), uncertainty about actual future sea level rise and further uncertainty about exactly how slope instability processes will respond to a range of climate change scenarios (see also **Section 16.8.5** for analysis of how some recession scenarios might unfold).

Council will review the geotechnical hazard assessment on a regular basis, to take into account higher resolution information about geotechnical processes along the coast.

Council will also regularly review the hazard assessment and predicted rates of recession to take into account new and refined details of climate change, including new information about actual changes to storm frequency and intensity, rainfall and sea level rise. A new assessment of sea level rise is expected from IPCC in 2014.

Taking into consideration the above factors, SCE (2010) classified the hazards presented by the geotechnical mechanisms (see **Table 16.8**) within the coastline recession zone, for immediate to 2100 planning periods.

This information is also presented spatially in **Figures 11.1** to **11.18** and the analytical process is discussed in detail in **Appendix 4**.

Table 16.9 (a) - Measured historical recession due to geotechnical processes, by location (SCE 2010, see Appendix 4))

Location	Measured historical recession in metres, (over 20-130 years) – using best available maps and plans for a variety of locations along the coast	Historical recession rate, converted to metres/100 years
Jenny Dixon Beach	Measurement 1: 16-26 +/-3 metres, measured over 130 years Measurement 2: 5-10 metres over 21 years	12-20/100 years 23-48 metres/100 years
Henderson Street	Measurement 1: 10-15 +/-3 metres, over 30 years Site 2: 0 metres	8-12 metres/100 years 0
Cabbage Tree Harbour	Measurement 1: 34 +/-3 metres, over 130 years Measurement 2: 4-7 metres over 21 years	33 metres/100 years 19-33 metres/100 years
Norah Head	Measurement 1: 14-20 +/-3 metres over 130 years Measurement 2: 0 over 21 years	11-15 metres/100 years 0
Ocean Parade Headland	0 over 21 years	0
Crackneck Point	2-10 metres over 21 years	10 metres/100 years

Table 16.9(b) - Recorded historical recession by rock type (typical values) (SCE 2010, see **Appendix 4)**

Rock type	Measured recession and number of joint sets affected per 100 years
Indurated/cemented sands	30-33 metres
Patonga Claystone	5-7 joint sets or 10-15 metres
Tuggerah Formation	1-2 joint sets, or 4-8 metres
Tuggerah Formation (where affected by dykes)	3-4 joint sets, or 10-16 metres

16.8.4 Risks: existing development affected by geotechnical hazards, now and in the future

SCE (2010) (see **Appendix 4**) conclude that 69 lots are currently at least partly within the immediate high hazard zone for geotechnical hazards. Thirty eight buildings on these lots are affected.

By 2050, SCE (2010) estimate that 92 lots and 64 buildings would be affected by high geotechnical hazards and by 2100, the number of affected lots rises to 100, with 93 buildings affected.

It is clear that a large number of properties are or are potentially affected by geotechnical hazards which have the potential to restrict development on these properties.

A sound three dimensional understanding of geotechnical processes and how they can be properly managed through planning controls and engineering design is necessary to minimise risk along the Wyong coastline, without causing unnecessary hardship for land owners.

The Wyong LEP and DCP will include clauses which restrict new development in the immediate high hazard zone. Council is considering a requirement for detailed, three dimensional site specific assessments for any proposed new development between the immediate high hazard zone and the 2100 low hazard zone.

In addition, Council will regularly review land use zoning and controls in the LEP and DCP, to ensure that they reflect best available knowledge about recession processes, actual changes to local terrain and climate change.

16.8.5 Climate change and cliffs and bluffs

Climate change may affect the rocky coast in several different ways. The extent and significance of these process changes is complex and uncertain at the local scale. Predictions of changes to the rate of recession on cliffs and bluffs due to climate change will need to be revisited and revised as further information and new process studies become available.

SCE (2010) presents some possible impacts of sea level rise and climate change on geotechnical hazards, and further context is provided below.

The types of climate changes that may be experienced on the Central Coast over the next 50 and 100 years are discussed in **Section 16.2.4** (**Table 16.2**). **Table 16.10** presents a preliminary analysis of the interaction of these changes to process drivers with known geotechnical processes and with potential modifiers, such as the presence or absence of rock platforms.

Further development of spatial data bases is occurring in relation to coastal geological features, known locations where geotechnical processes operate, changes to process drivers for geotechnical hazards and the presence of features that modify the impacts of sea level rise. Interrogation of these data bases, when complete, will enable Council to better analyse risks associated with different climate change and geotechnical process scenarios. Figure D3 in TAB D of **Appendix 4** illustrates possible requirements for proponents to contribute geological information to Council's slope instability data base.

16.8.6 Indicative summary of changes to hazards with climate change and sea level rise

Based on the preliminary analysis in **Table 16.10**, which uses information from SCE (2010) (**Appendix 4**), climate change and sea level rise have the following broad implications for the rocky parts of the Wyong coastline.

Type A processes (Indurated sands)

Cabbage Tree Harbour: very vulnerable to both toe trimming and higher groundwater and surface water flows. Expect an increase in the rate of bluff retreat due to geotechnical/mass movement hazards

Toowoon Bay: in 2050 to 2100 timeframe, potential to pass a threshold of exposure as sea level rises and the Holocene and recent sands in the pocket embayment recede. Processes at Bateau Bay and Blue Lagoon are similar.

Type B processes (Soil creep)

Potential for more efficient toe trimming as sea level rises. Soil creep rates may increase, but overall rates of retreat would still be much less than the major episodic events on strongly jointed sandstone with multiple igneous dykes.

Type C processes (Rock/block differential weathering)

Potential for more aggressive toe trimming as sea level rises, but cliff stratigraphy means limited change to the intensity of other processes. Rock fall fragments up to 2 to 4 metres with limited accumulation at the toe.

Type D processes (Dyke influenced rock recession)

Potentially the most vulnerable to sea level rise aspects of climate change, and also to increased intensity of differential weathering processes (both dykes and claystones). Potential for step failure along shore parallel dykes, with joint opening and undercutting by weathered claystones near the base of the cliff or bluff. Generally in very exposed locations.

Type E processes (Instability of weathered rock/soil slope)

Very similar conditions to Type D processes and the two process types combine at some sites such as Noraville.

Table 16.10 - Factors influencing geotechnical hazards with climate change

Place and process			Key drivers and predicted changes				Modifiers		
Known process	**Location (type section)**	**Stratigraphy**	**Key driver**	**Predicted change to driver with climate change**	**Plunge cliff or bluff**	**Accumulated material at base**	**Aspect/ exposure**	**Vegetation**	**Drainage controls**
Type A Surficial slumping, piping in unconsolidated sand	Cabbage Tree Harbour Toowoon Bay area; also Bateau Bay and Blue Lagoon	Pleistocene indurated sand; weathered sandstone exposed at base Rock reef in near shore	Groundwater seepage. Toe trimming by waves – oversteepens unconsolidated material	Increased summer rainfall Sea level rise 40 cm and 90 cm More frequent east coast low storms	Bluff, no rock platform at base of slope (Cabbage Tree Harbour), but there are rock platforms nearby and in the nearshore in both locations	Cabbage Tree Harbour: Has occurred in the past, now largely removed (sand) No protection from accumulated material Toowoon Bay: Pleistocene sands are landward of a buffer of Holocene beach sand in pocket beach embayment. Toe trimming would not occur until the beach sands have receded.	Slightly north of east. Protected from SE storm waves by Norah Head Reduces exposure to storm waves	Invasive bitou and garden escapees Limited binding capacity	Previously installed at toe, now defunct

Place and process			Key drivers and predicted changes				Modifiers		
Known process	**Location (type section)**	**Stratigraphy**	**Key driver**	**Predicted change to driver with climate change**	**Plunge cliff or bluff**	**Accumulated material at base**	**Aspect/ exposure**	**Vegetation**	**Drainage controls**
Type B Soil and fill creep	The Entrance (south)	Patonga claystone; interbedded claystones and thin sandstone units	Soil creep on oversteep soil mantle Differential weathering of claystones and sandstones Wave trim of toe of slope Groundwater seepage and poor drainage when fill placed on slope.	Higher sea level increases height of wave trim and potentially affects weathering profile. Changes to seasonal groundwater flows.	Bluff Thin veneer of beach sand over rock. Limited rock platform development; overtopped by waves.	Generally not	East Affected by major east coast low storms	Introduced species and invasive species/grass. Very limited natural vegetation	Stormwater pipes from urban areas discharge within the clay soil on slopes – potential for further fluvial erosion and waterlogging.
Type C Rock/block fall due to differential weathering	Bateau Bay	Patonga claystone – interbedded claystone dominated and sandstone dominated sections (mostly beds less than 1m thick)	Differential weathering of claystones/ undercutting of sandstones - groundwater seepage and wave attack	Higher sea level would increase wave impacts on the base of cliffs – rock platforms overtopped more frequently, and thin veneer of beach sand stripped. Small rockfall debris broken down and removed – but larger debris would remain	Bluffs and stepped cliffs, with moderately wide wave cut platforms. No obvious stratigraphic thresholds (weathering) for rising sea level – similar interbedded sequence extends from base of cliff to top.	Moderate sized rock falls leave rock debris from 20 mm to 1-2 metres on the rock platform or beach	East and south east Exposed to high waves in east coast lows – but rock platforms on headlands at both ends of pocket beach.	Invasive species (bitou) with some coast woodland and heath at limited sites	Unchannelled surface runoff

Place and process			Key drivers and predicted changes				Modifiers		
Known process	**Location (type section)**	**Stratigraphy**	**Key driver**	**Predicted change to driver with climate change**	**Plunge cliff or bluff**	**Accumulated material at base**	**Aspect/ exposure**	**Vegetation**	**Drainage controls**
Type D processes Dyke influenced rock fracture and fall	Jenny Dixon Beach Soldiers Point	Tuggerah Formation Strong joint fractures, with weakness increased by wreathing along common igneous dykes	Differential weathering of dykes, groundwater effects. Extent of rock fall events determined by spacing of shore parallel dykes. Differential weathering of weaker strata interbedded with thick bedded but strongly jointed sandstone – Rock topple. Landslides in surficial sands may follow rock fall	Higher sea level would strip thin sand protection from base of cliffs, potential for more toe trimming where claystones are near the base of the slope, or where joint blocks are already vulnerable. Differential weathering may increase over time – major steps landward if failure occurs along weathered dykes.	Bluffs and cliffs Limited rock platform development, but some rock benches exposed on beach or underlying a thin veneer of beach sand	Rock falls include large blocks of massive sandstone; limited accumulation at base of slope – very limited protection.	South east and north east Exposed to high waves from both east coast lows and cyclones drifting south	Invasive species (bitou), grass	Unchannelled surface runoff

Place and process			Key drivers and predicted changes				Modifiers		
Known process	**Location (type section)**	**Stratigraphy**	**Key driver**	**Predicted change to driver with climate change**	**Plunge cliff or bluff**	**Accumulated material at base**	**Aspect/ exposure**	**Vegetation**	**Drainage controls**
Type E processes Soil creep/ slumping over massive rock fall (block topple)	Noraville, Henderson street	Tuggerah Formation Residual soils on Patonga Claystone, above sandstone cliffs	Wave attack on toe of sandstone cliff, beach sands Undercutting, joint opening Landslip and surficial slumping on clay soils at top of slope	Higher sea level would increase exposure of toe to wave erosion – but already affected. No rock platform threshold, but could change to wave impact even at low tide and calm conditions. Potentially groundwater changes at top of slope.	Bluffs and cliffs No rock platforms, thin veneer of beach sand at base of cliff	Rock fall material - 1-3 m size accumulates at base of slope; also debris slide material as thin layer over toe of slope – trimmed by waves	East, with limited protection from storm waves	Invasive species; some banksias woodland	Shallow gullies and unchannelled surface runoff

17.0 Baseline condition and status: biodiversity, settlement and land use

This section continues the description of the current condition of the Wyong coastline, and provides information about trends in the condition of the coastline. It supplements the information about coastal processes and the condition of the beaches and bluffs, presented in **Section 16.0**. **Section 17.0** considers coastal biodiversity (**Section 17.1**), cultural values (**Section 17.3**), settlement and coastal land uses (**Section 17.2**), to provide a picture of the coastal landscape that is valued by residents and visitors to Wyong Shire.

17.1 Biodiversity values

Biodiversity resilience is a key objective for coastal zone management, with and without the impacts of climate change on coastal vegetation communities and habitats.

17.1.1 Vegetation communities

Coastal biodiversity includes individual plant and animal species, communities and habitats occupying other terrestrial and marine pars of the landscape, as well as the connections between these species, habitats and communities and the ecosystem services that they provide. Ecosystem services include ecological functions that benefit other aspects of the physical, social and economic environment. For instance, vegetation on coastal dunes provides services such as sand trapping, dune stabilisation, provision of shade for recreational users and visual amenity.

Budgewoi Beach Dunecare 2010 reports the presence of four threatened flora species within the area of the group’s operations. These are Sand Spurge, Camfield’s Stringybark, Magenta Lilypilly and Black-eyed Susan. Of these, only the Sand Spurge is likely to occur within the area of coastal hazard impact.

Figures 17.1 and **17.2** show the distribution of vegetation communities along the Wyong coastline, based on mapping by HCCREMS (Blackmore & Goodwin 2009), mapping of Endangered Ecological Communities by Hunter Councils (McCauley *et al.* 2006) and the NSW Government SEPA14 maps of coastal wetlands.

Much of the coastline is developed for residential land uses. Much of the northern part of the coast was mined for mineral sands some 50 years ago, and has been broadly rehabilitated.

Coastal vegetation on dunes is dominated by coastal sand scrub and beach spinifex communities. Only very small areas of Endangered Ecological Communities are located within the area affected by coastal processes or its immediate landscape context, except in Munmorah State Conservation Area.

EECs in or close to the core area of interest for the WSCMP include:

- A small area of Swamp Oak Rushland Forest and a small area of littoral rainforest on the landward side of the dunes at Lake Munmorah
- A small area of littoral rainforest between Norah Head and Cabbage Tree Harbour. This patch is not gazetted under SEPA26.
- A small area of Littoral Rainforest at Little Bay, south of Toowoon Point. This patch is not gazetted under SEPA26.

Source: Department of Lands (2006), Hunter Councils (2003)

0 0.5 1.0 2.0km
1:40 000

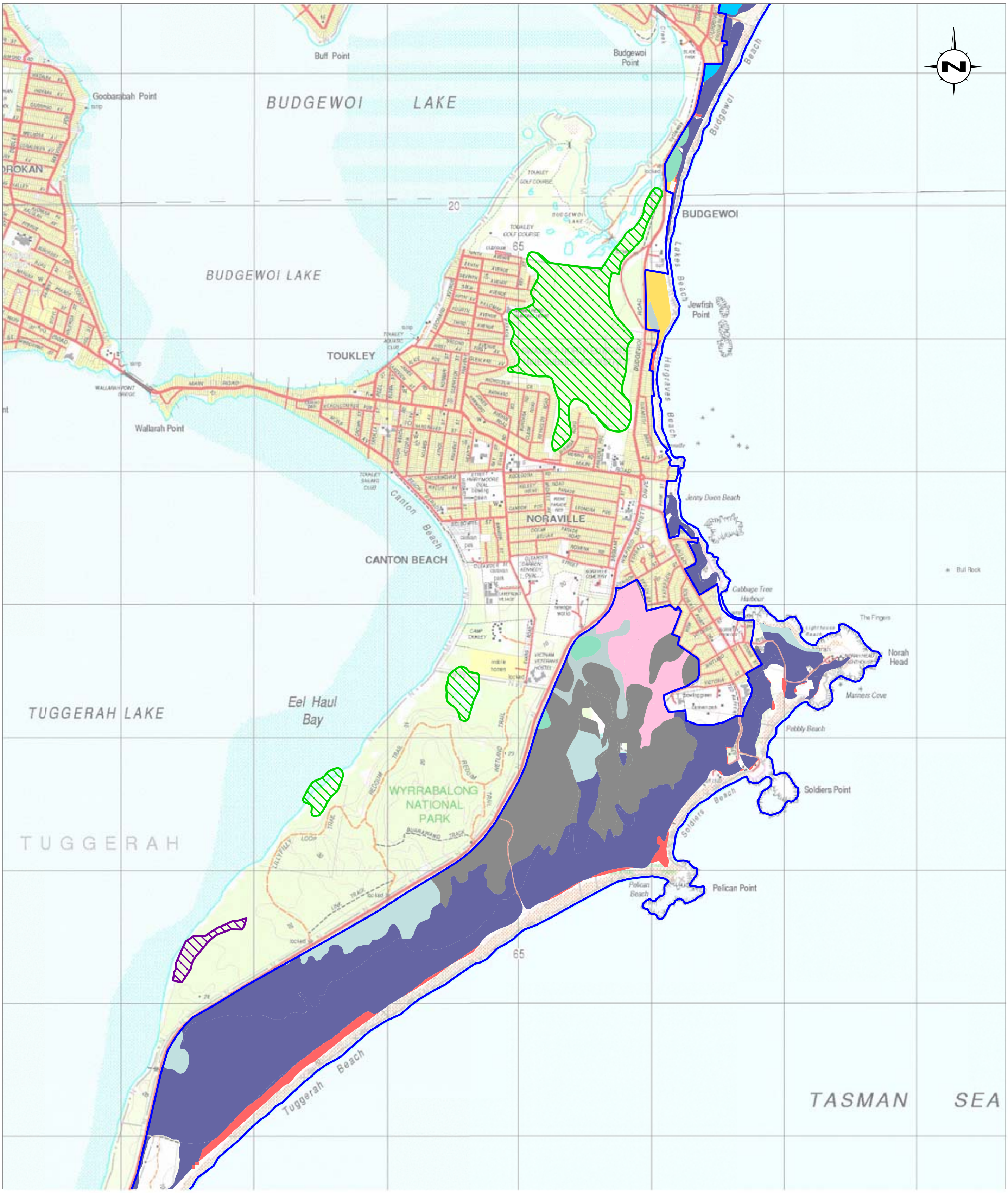
Legend

- Coastal Ecology Search Area
- SEPP 14
- Beach Spinifex
- Coastal Clay Heath
- Coastal Headland Complex
- Coastal Sand Apple Blackbutt Forest
- Coastal Sand Scrub
- Coastal Sand Wallum Woodland Heath
- Littoral Rainforest
- Mangrove Estuarine Complex
- Swamp Oak Rushland Forest

FIGURE 17.1a

Distribution of Coastal Vegetation Communities

File Name (A4): R03_V1/1869_020.dgn



Source: Department of Lands (2006), Hunter Councils (2003)

0 0.5 1.0 2.0km
1:40 000

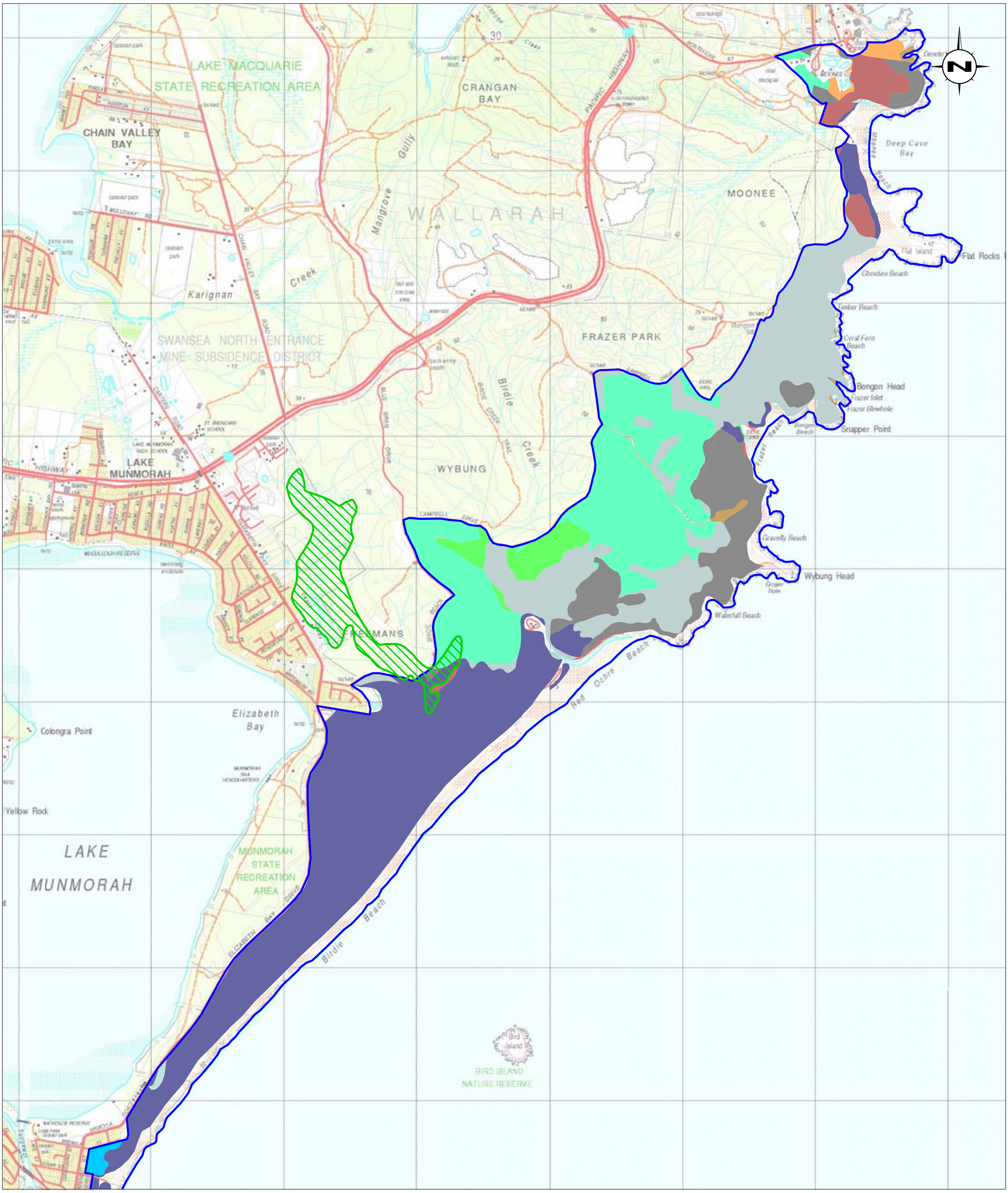
Legend

- Coastal Ecology Search Area
- SEPP 14
- SEPP 26
- Beach Spinifex
- Coastal Sand Apple Blackbutt Forest
- Coastal Sand Scrub
- Coastal Sand Wallum Woodland Heath
- Littoral Rainforest
- Nora Head Endangered Heath Woodland
- Riparian Melaleuca Swamp Woodland
- Swamp Mahogany Paperbark Forest
- Swamp Oak Rushland Forest

FIGURE 17.1b

Distribution of Coastal Vegetation Communities

File Name (A4): R03_V1/1869_021.dgn



Source: Department of Lands (2006), Hunter Councils (2003)

0 0.5 1.0 2.0km
1:40 000

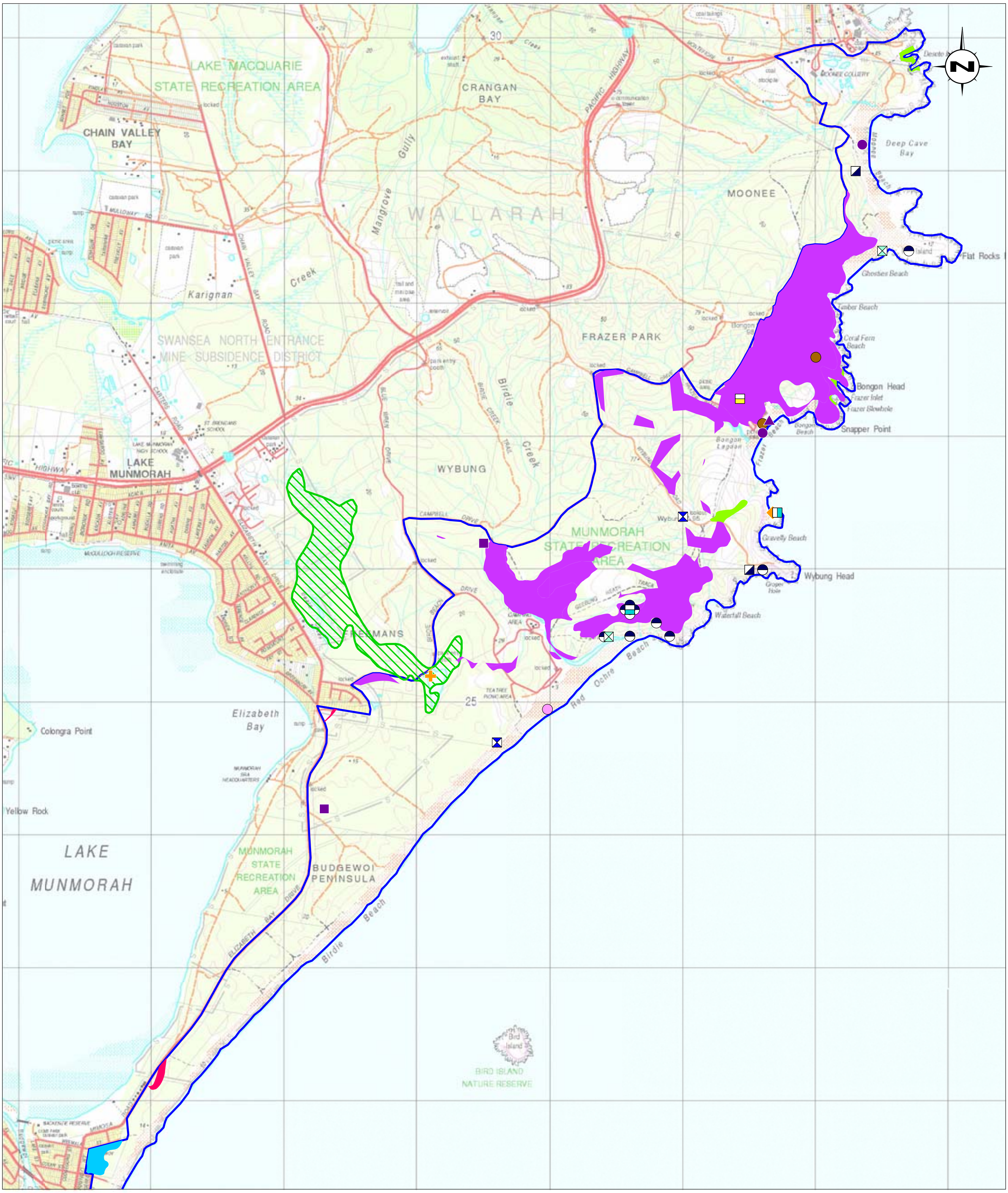
Legend

- Coastal Ecology Search Area
- SEPP 14
- Apple Palm Gully Forest
- Beach Spinifex
- Coastal Clay Heath
- Coastal Foothills Spotted Gum Ironbark Forest
- Coastal Headland Complex
- Riparian Melaleuca Swamp Woodland
- Coastal Plains Scribbly Gum Woodland
- Coastal Plains Smooth Barked Apple Woodland
- Coastal Sand Apple Blackbutt Forest
- Coastal Sand Scrub
- Coastal Sand Wallum Woodland Heath
- Coastal Wet Sand Cyperoid Heath
- Lepironia Swamp
- Swamp Mahogany Paperbark Forest
- Littoral Rainforest
- Swamp Oak Rushland Forest

FIGURE 17.1c

Distribution of Coastal Vegetation Communities

File Name (A4): R03_V1/1869_022.dgn



Source: Department of Lands (2006), Hunter Councils (2003)

Note: Overlapping records were moved slightly for display purposes. Some records, particularly those sourced from the DECC Atlas of NSW Wildlife, have variable accuracy.

0 0.5 1.0 2.0km
1:40 000

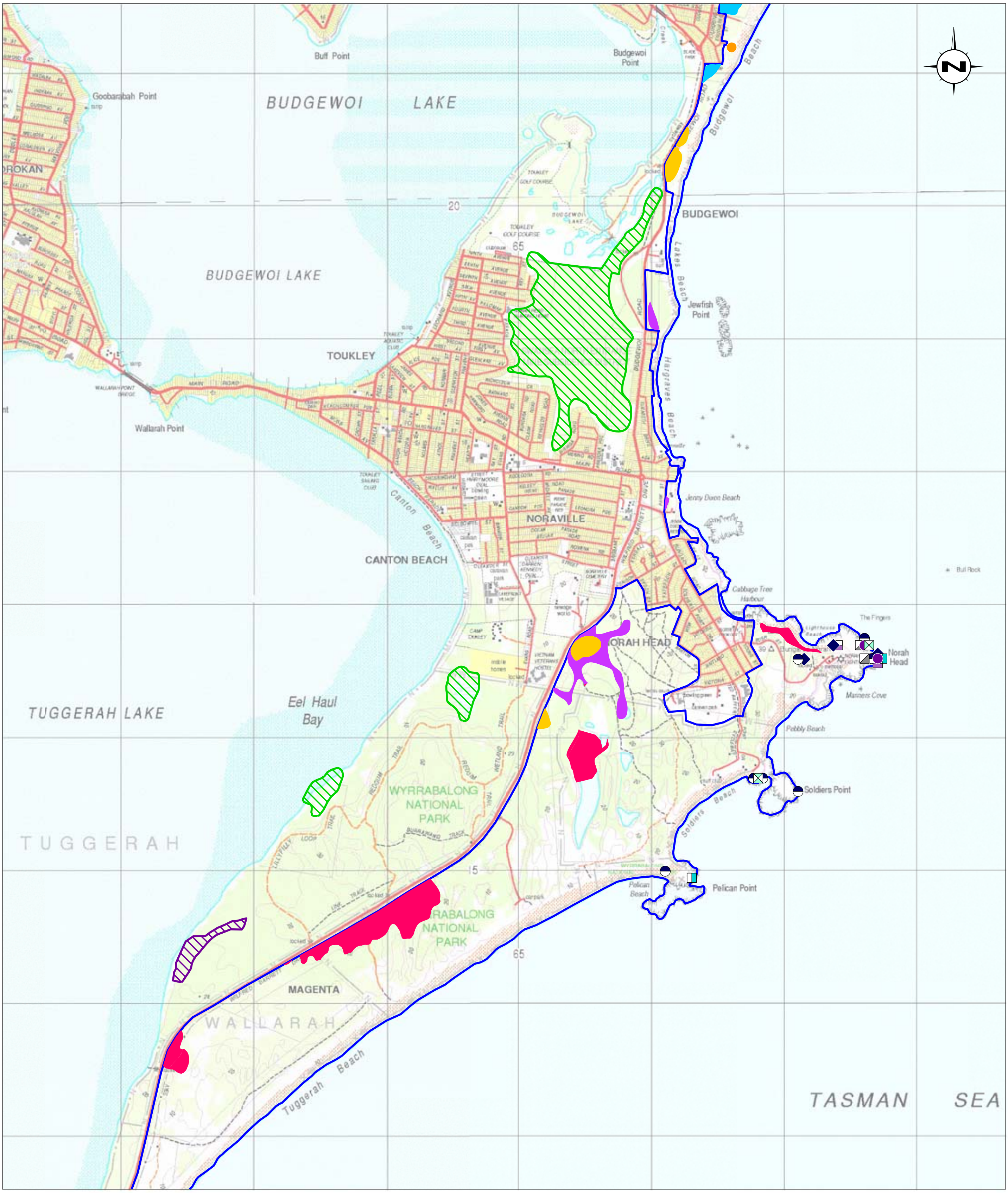
Legend

- Coastal Ecology Search Area
- SEPP 14
- EECs:
  - Coastal Headland Complex
  - Littoral Rainforest
  - Riparian Melaleuca Swamp Woodland
  - Swamp Mahogany Paperbark Forest
  - Swamp Oak Rushland Forest
- Grey-crowned Babbler
- Black-browed Albatross
- Grey-headed Flying-fox
- Little Shearwater
- Little Tern
- Osprey
- Pied Oystercatcher
- Sooty Oystercatcher
- Southern Giant Petrel
- Sperm Whale
- Wallum Froglet
- Eastern Pygmy-possum
- Flesh-footed Shearwater

FIGURE 17.2a

Locations of EECs, Protected Vegetation Communities and Threatened Fauna Sightings, with Coastal Risk Areas

File Name (A4): R03_V1/1869_023.dgn



Source: Department of Lands (2006), Hunter Councils (2003)

Note: Overlapping records were moved slightly for display purposes. Some records, particularly those sourced from the DECC Atlas of NSW Wildlife, have variable accuracy.

0 0.5 1.0 2.0km
1:40 000

Legend

Coastal Ecology Search Area
SEPP 14
SEPP 26
EECs:
Littoral Rainforest
Riparian Melaleuca Swamp Woodland
Swamp Mahogany Paperbark Forest
Swamp Oak Rushland Forest

Providence Petrel
Little Tern
Pied Oystercatcher
Providence Petrel
Sanderling
Sooty Oystercatcher
Southern Right Whale
White Tern

Pied Oystercatcher

FIGURE 17.2b

Locations of EECs, Protected Vegetation Communities and Threatened Fauna Sightings, with Coastal Risk Areas

File Name (A4): R03_V1/1869_024.dgn

Source: Department of Lands (2006), Hunter Councils (2003)

Note: Overlapping records were moved slightly for display purposes. Some records, particularly those sourced from the DECC Atlas of NSW Wildlife, have variable accuracy.

0 0.5 1.0 2.0km

1:40 000

Legend

- Coastal Ecology Search Area
- SEPP 14
- EECs:
  - Littoral Rainforest
  - Mangrove Estuarine Complex
  - Swamp Oak Rushland Forest
- Pied Oystercatcher
- Sooty Oystercatcher
- Southern Right Whale
- Australian Fur-seal
- Black-browed Albatross

FIGURE 17.2c

Locations of EECs, Protected Vegetation Communities and Threatened Fauna Sightings, with Coastal Risk Areas

File Name (A4): R03_V1/1869_025.dgn

Other EECs and/or larger areas of EEC are located in the broader coastal zone. For instance, the Budgewoi Beach Dunecare Group (2010) identifies areas of Swamp Sclerophyll Forest on Coastal Floodplains; Swamp Oak Floodplain Forest; Littoral Rainforest in the South East Corner, Sydney Basin and NSW North Coast Bioregions; Littoral Rainforest and Coastal Vine Thickets in Eastern Australia; and Sydney Freshwater Wetlands within the area of its operations.

SEPA14 wetlands are generally restricted to lake shore locations. At Budgewoi, where the coastal dune barrier is narrow and low lying, the SEPP 14 wetland comes to within 200 metres of the coastline.

17.1.2 Coastal Fauna

Table 17.1 lists shorebirds and wader species that have been reported (i.e. sighted) along the Wyong coastline, and are listed under either the Threatened Species Conservation Act or the Environment Protection and Biodiversity Conservation Act (subject to JAMBA, CAMBA or ROCKAMBA). Additional species (such as the Glossy Black Cockatoo) are known to occur within the broader coastal zone and may forage within the coastal hazard areas.

Table 17.1 - Protected and threatened bird species, Wyong coastline

Scientific name	Common name	Conservation Status		Known records
		TSC Act	EPBC Act	
Thalassarche melanophris	Black browed albatross	V	MAR and MIG	Red Ochre Beach
Pomatostomus temporalis temporalis	Grey-crowned Babbler (eastern subspecies)	V		Gravelly Beach Headland
Puffinus carneipes	Flesh footed shearwater	V	MAR & MIG JAMBA/ ROCKAMBA	Red Ochre Beach
Sterna albifrons	Little tern	E	MAR & MIG JAMBA/ CAMBA/ ROCKAMBA	Gravelly Beach Headland, Pelican Point, The Entrance North
Gygis alba	White tern	V	MAR	Norah Head
Puffinus assimilis	Little Shearwater	V	MAR	Birdie Lagoon/Birdie Beach Lookout
Pandion haliaetus	Osprey	V	MAR & MIG	Frazer Beach, Snapper Point road Lookout, inland from Coral Fern Beach
Haematopus longirostris	Pied oystercatcher	V		Birdie Lagoon, Ghosties Beach, Tuggerah Entrance, Norah Head, Soldiers Beach, Budgewoi
Pterodroma solandri	Providence Petrel	V	MAR & MIG JAMBA	Norah Head

Scientific name	Common name	Conservation Status		Known records
		TSC Act	EPBC Act	
Calidris alba	Sanderling	V	MAR &MIG JAMBA/ CAMBA/ ROCKAMBA	Norah Head
Haematopus fuliginosus	Sooty oystercatcher	V		Birdie Beach, Red Ochre Beach, Groper Hole, Flat Rocks Headland, Toowoon Point, Tuggerah Entrance, Soldiers Beach, Pelican Beach, Norah Head
Macronectes giganteus	Southern giant petrel	E	MAR & MIG	Groper Hole, Moonie Beach

Outside the Munmorah State Recreation Area, the most frequent sightings of these protected bird species have been on the sand flats at The Entrance and Toowoon Bay and at Norah Head.

Other threatened fauna which may be sighted along the Wyong coast from time to time include the New Zealand Fur Seal, Australo-African Fur Seal, Southern Right Whale, Humpback whale, Common Bentwing Bat and Squirrel Glider (Budgewoi Beach Dunecare, 2010)

17.1.3 Biodiversity assessment of rocky shores

In relation to its focus on the protection and enhancement of rocky shorelines, the HCRCMA has prepared a Central Coast Rocky Shore Biodiversity Assessment (Gladstone *et al.* 2007) and Discussion Paper: Management Planning for Coastal Rocky Shores (B-COS Consulting Services 2008).

The biodiversity assessment examined habitats at 26 rocky shore sites, including 11 in Wyong Shire (e.g. Blue Lagoon, Norah Head, Spoon Bay, The Entrance, Toowoon Point and Soldiers Reef). Results are summarised below.

Intertidal organisms

Species diversity: The smallest number of species (91) was recorded at Norah Head and Snapper Point.

Rare Species: the greatest number of rare species was recorded at Blue Lagoon (15 species, making it the most distinctive assemblage in the project area).

Conservation Value: The Entrance was rated as having the lowest conservation value

Birds

Species diversity: The largest number of species was recorded at Norah Head (10 species) and Blue Lagoon (7 species). Norah Head was regarded as a particularly important site for birds, being a high and low tide roost for gulls and terns, a significant low tide foraging site for migratory shore birds.

17.1.4 Ecosystem services

DECCW (2009), Eamus *et al.* (2005) and others identify a range of ecosystem services that are relevant to healthy, functioning coastal wetlands, dune and headland ecological communities along the coast. Examples of these include:

- Biological regulation – resisting or providing a buffer against invasive species; protection ecological functions of other communities.
- Erosion protection. Coastal dune communities provide some protection and buffering against storm bite erosion. Well established dune communities also help to maintain the sediment separation between beach and inland landforms. This ecosystem service is the rationale for investment in dune vegetation programs (such as by Landcare) which are included in **Section 9.0**.
- Hydrological regimes – vegetated landscapes moderate runoff during major rainfall events, by absorbing and detaining runoff; they also play a role in groundwater recharge and discharge and also have water filtering capabilities.
- Natural hazards. Well established headland vegetation can reduce the likelihood of mass movement events (land slip and creep) on terrain underlain by geotechnically unstable geology. Headland vegetation provides lesser services where the main geotechnical process is blockfall and can in fact exacerbate physical and chemical weathering along joint planes and other lines of weakness (see **Section 16.8**).
- Soil formation and nutrient recycling is dependent upon the functioning of ecosystems. In former mining sites along the Wyong coastline, soil formation on reconstructed dunes sis still limited.
- Recreation. The coastal landscapes of Wyong provide a major recreational asset for local communities and visitors. Valued activities that depend on functioning terrestrial and marine ecosystems at the local and regional scale include swimming and surfing, bird watching, walking, sight-seeing, photography and other art forms.
- Cultural services, including spiritual connectedness (Darkinjung traditional owners) and aesthetic appreciation. Apart from the spiritual attachment of local Aboriginal people to particular landscape features and species, intact and resilient landscapes also protect the physical evidence (archaeology) of past occupation of the coastal landscape by Aboriginal ancestors.
- Pollination and nectar supplies for species including commercial species or those used by humans.
- Genetic resources that can be drawn upon for commercialisation.
- Climate regulation and carbon sequestration. Carbon accumulation and storage in coastal ecosystems does occur and may be more efficient in relatively intact systems compared to disturbed systems.

Different assemblages of ecological communities on dune and headland terrain provide different combinations of these and other services. Consequently, threats which reduce the resilience of coastal ecological communities will have a differential impact on ecosystem services, depending on the spatial arrangement of impacted communities. The extent of loss of ecosystem services also varies with time frame. For instance, the effects of sea level rise have different impacts on ecosystem services over the 2050 and 2100 timeframes varies because a variety of thresholds for landform change will be passed at different times (see **Section 9.0** and **Section 16.6**).

17.1.5 Threats to biodiversity values

Biodiversity values, and particularly the maintenance of sustainable populations of threatened or endangered species are threatened by a wide range of natural processes and human activities.

In the Wyong coastline area, the most important threats to biodiversity are:

- Expansion of the development footprint on the coastline. In general, this is a threat that has already run its course on the Wyong. Coastal sand mining (see **Section 17.2.1.1**) and construction sand quarrying and expansion of urban areas occurred in the 1960s and 1970s in particular. These activities removed coastal heath and coastal woodland communities, many of which would now be considered to be Endangered Ecological Communities. Remaining areas of relatively undisturbed native vegetation along the Wyong coastline are now protected in conservation management, in National Park of State Conservation Area. Post mining dune vegetation rehabilitation has stabilised the dune surfaces, but has also resulted in lesser species diversity than the original vegetation (e.g. on the dunes at Budgewoi).

- Weed invasion. Lantana and Bitou are the most obvious species on coastal dunes and headlands, but other weeds are also present. Bitou is very widespread, as it was used as a coastal dune rehabilitation species at the time that the Wyong coastal dunes were mined for mineral sand.

- Urban edge effects. These impacts include predation by domestic animals, sources of weeds, additional clearing for views or fire control, clearing for tracks, introduction of pathogens and chemicals and increased nutrient levels in runoff.

- Heavy recreational usage of terrestrial habitats. Multiple, heavily used access ways reduce the ground cover of vegetation, encourage wind erosion and open opportunities for invasive species.

- On rock platforms and nearshore reef areas, heavy use by recreational anglers can impact on shellfish species and can also disturb migratory shorebirds.

- Climate change. For coastal dunes in coastal risk areas, climate change impacts over the next century are expected to include the erosion (recession) of the land surface occupied by remnant and restored dune vegetation. Whilst this will not necessarily reduce species diversity in the region, it does affect ecological connectivity (see **Section 17.1.5**) and loss of frontal dune vegetation communities will expose more landward communities to more aggressive coastal processes.

17.1.6 Trends in biodiversity resilience – what will climate change do?

Figures 17.1 and **17.2** show the locations of conservation reserves along the Wyong coastline and the locations of other patches of vegetation which provide connectivity between the principal vegetation reserves.

The lack of high conservation value ecological communities in the immediate coastal area means that coastline recession, by itself, is not a major threat to the biodiversity of the open sandy coast in Wyong. However, climate change has a number of other implications for biodiversity along the Wyong coastline, including the following:

- If coastal recession results in changes to the tidal processes in the Tuggerah Lakes, such as opening an entrance at Budgewoi, major biodiversity impacts would result
- Inundation of rock platform habitats so that they are permanently submerged rather than only at high tide. This will reduce the value of roosting habitat for a number of protected migratory species.
- Climate change (warmer and slightly wetter) may favour the expansion of some invasive plant species, particularly those whose range is currently restricted to further north than the central coast.
- Climate change driven coastal recession and dune mobilisation may further fragment coastal vegetation communities.
- The response of coastal dunes and associated vegetation to coastal recession clearly varies with the scale of the dune system and its landscape context (see **Section 16.4.1**). In general, pocket beaches (such as Cabbage Tree Harbour) are susceptible to coastal recession, because they have a limited buffer of sand, and landward translation of small dune forms is blocked by the break of slope to bedrock terrain.

17.2 Land use and assets

Other than the National Parks and State Conservation Areas in the far north and south of the coastline, the Wyong coastline is densely settled, particularly south of The Entrance.

This section provides background information about the population of the coastal area, trends in residential land values and the social values of the coastline, such as recreation, exercise, relaxation, views, meeting friends and family holidays.

Also in this section is information about the public built assets along the coastline. These include existing sea walls at The Entrance, surf club buildings, roads, pathways, sewerage and stormwater systems.

17.2.1 Evolution of settlement and coastal communities

The coastline of the Wyong Council area is the traditional home of the Awabakal and Darkinjung people. There is significant uncertainty about exact traditional tribal boundaries. Parts of the Central Coast were also occupied by the Guringgai people. It is believed that the name 'Wyong' derives from the traditional Aboriginal name for the area, meaning either 'running water' or 'place of yams'. More information about the Aboriginal heritage of the Wyong coastline is included in **Section 17.3.1**.

European settlement is believed to have commenced as early as 1796. Central Coast Tourism (Central Coast Tourism n.d.) reports:

> In 1796, some shipwrecked fishermen landed on the coast at The Entrance, thus marking the beginning of recorded European interest in the area. These seamen were safely guided most of the way to Sydney by some of the local Aborigines and upon their return they reported the existence of a white woman living amongst the Aboriginal peoples.
>
> Henry Holden became the first European to settle in the area at Picnic Point in 1828, then in the late 1820s, a group of Chinese fishermen set up a base at a place now known as Toowoon Bay.

> In 1889, the rail link from Sydney to Newcastle was completed and the first tourists began to visit the area. In the early 1890s a holiday camp began operating at Toowoon Bay and in 1895, the first guesthouse opened at North Entrance.
>
> Development of the area, however, was only gradual. A post office opened in 1911 under the name 'The Entrance' and thus the town's name was selected. It refers to the slender channel that connects Tuggerah Lake to the ocean.

Although there was some European settlement at several locations along the Wyong coastline from the 1830s onwards, increasing towards the end of the nineteenth century as the area became more accessible for tourism, significant expansion of the population of the Wyong Shire Council area did not occur until after the Second World War.

Up until the mid twentieth century, settlement of the coastal parts of the Wyong coastline was restricted to small fishing and holiday settlements, (e.g. see Scott 1998 or an oral history of the ecology of the Tuggerah Lakes). Holiday interest focused on the lakeside beaches (such as Canton Beach and Long Jetty) where there were popular camping grounds, and The Entrance and Toowoon Bay with both camping grounds and guest houses.

Rapid population growth occurred in the 1970s and 1980s, when Wyong Shire received a significant inflow of population from the Sydney Metropolitan Area. Much of the major growth in the 1970s and 1980s was concentrated in the eastern part of the Shire. More recent growth has focused on new estates west of the Pacific Highway. The pattern of settlement expansion in the coastal part of the Shire has resulted in areas that have transformed from small dune top or headland holiday cottages to major investment in residential property (see also **Section 17.2.4** for information about the value of coastal property).

This history, a transition from small scale rural settlement (forestry, fishing and later tourism) to small urban centres with low cost housing to major urban expansion to redevelopment of prime coastal sites, has influenced the distribution of risk along the coast (see **Section 18.0**).

The National Sea Change Taskforce (Gurran & Squires 2006) identifies five broad types of coastal community. Wyong Shire's coastal settlements have the characteristics of three of these types: coastal commuters, coastal getaways and coastal cities, and can be seen to be in transition from the commuter to the coastal city type, which also attracts weekend getaway settlement because of its proximity to Sydney. These settlement and community characteristics present particular challenges for managing the values of Wyong's coastline. There is a large and growing population, holiday peaks in occupation, high access and amenity expectations, historical inheritance of land use and pressure for redevelopment of 'prime' coastal sites.

17.2.1.1 Impacts of previous land uses

Coastal dunes are a traditional source of a range of heavy minerals, including rutile, zircon and ilmenite. From the 1950s to the 1970s, coastal dunes in Wyong Shire were mined for these mineral resources. For instance, mineral sand mining leases covered all of the North Entrance peninsula, east of Wilfred Drive (CCCEN Centre for Sustainability 2004; O'Dell 1980; Thom 2004). Mineral sand mining also occurred along the Budgewoi peninsula. Thom (2004) notes that the community environment groups fought for the conservation of red gum (*Angophora costata*) forest on the North Entrance peninsula in the 1970s, leading eventually to the dedication of part of the area to what is now Wyrrabalong National Park.

Thom (2004) notes the general adverse affects of historical mineral sand mining on the coastal environment, including:

- Mining opened up relatively inaccessible coastal land which was subsequently used for residential development (e.g. parts of North Entrance and Norah Head)

- Mineral sand mining creates hazardous waste (such as monazite), which requires careful remediation

- Mining disturbed soil, groundwater and vegetation in coastal dunes (beach ridges and transgressive dunes, such as were located at North Entrance). Initial post mining rehabilitation was poor, leaving some permanently degraded landscapes.

- Mining rehabilitation was the principal source of the invasive species bitou bush (*Chysanthemoides monifera*), which is now a major national weed, and is a primary target of Coastcare/Dunecare groups. Bitou is a major weed in remnant woodland on the North Entrance peninsula.

- Disturbance of frontal dunes may have exacerbated shoreline erosion during the 1970s, when a series of major coastal storms coincided with mining activity (see also **Section 16.0**). However, in some locations, the post mining dune profile moved dune sand seaward, increasing the sand buffer in frontal dune positions.

Part of the North Entrance peninsula, within the former mineral sand mining lease, was used as the Wyong shire landfill site prior to the mid 1990s. DCP 26 DCP 26 (Wyong Shire Council 1999) noted the potential for contaminated land to occur on the North Entrance Integrated Tourist Facility site, associated with past mineral sand mining and landfill activities. The DCP requires that no buildings are situated on land previously used for landfill.

Urban growth has occurred since mineral sand mining leases expired or were cancelled, as well as with the growing value of the central coast as a commuter residential area.

17.2.2 Coastal property values and ownership profile

The scenic and social amenity of ocean frontage or ocean view land has for decades provided premium pricing for these properties.

The Department of Lands (Office of NSW Valuer General) issued new land valuation notices for Wyong Shire in January 2009. The new valuations drew on an analysis of real estate sales during 2008. The NSW Valuer General (press release dated 12 January 2009) notes that the value of ocean waterfront land is significantly higher than all other property in the Shire. A waterfront residential property at Blue Bay, for instance, was valued at $1.8 million and property at Noraville and The Entrance North was also valued at around this amount.

The Commonwealth Bank publishes suburb by suburb information about demography, housing prices and recent sales (myrp.com.au n.d.). The reports use 2001 and 2006 census data and up to date information about median sale prices and trends. All suburbs which have some ocean frontage residential property are reported to have median sale prices well above the average for Wyong Shire. The median value in any suburb is greatly influenced by the size of the residential area and the relative portion of the residential area that has ocean frontage or ocean views as opposed to non waterfront (or waterfront reserve) land. Toowoon Bay, Norah Head and Blue Bay in particular have long term (over the last ten years) property values close to double the Shire average.

Information for suburbs with ocean frontage land is summarised in **Table 17.2**.

Table 17.2 - Residential property value in ocean frontage suburbs (source Commonwealth Bank data)

Suburb	Absolute waterfront or foreshore reserve	Proportion with ocean views/frontage?	Owner occupier or rental property?	Median price and trends (to 2009)
Budgewoi	The entire ocean frontage and lake frontage is reserve or open space.	Some residential property has lake views, but all residences east of the bridge are on low lying land, with no ocean views. Access to the beach across the dune field is good.	Total population in 2006 was 3191. 66% of the housing stock is owner occupied (42% owned outright), up from 55% in 2001.	Median house prices peaked in 2004 at approximately $300,000. Median prices in the two years to 2009 were in the $230,000 to $275,000 range, generally slightly less than the Shire wide median over this period, but have since increased to around $295,000.
Noraville	Absolute cliff top properties. No absolute beachfront or beach front reserve properties.	One street, plus short side streets, less than 10% of housing stock in the suburb	Total population in 2006 was 2,548. 67% owner occupied in 2006 (39% owned outright). 71% owner occupied in 2001.	Occasional recent property sales over $1.1 million. Median values of sales from 2003 to 2008 were generally over $300,000, but declined to less than $220,000 in 2009. This clearly in part reflects the locations of actual property sales as well as the volatility of the property market in the major economic downturn. The 2010 median house price in this area is $285,000 with occasional sales in the locality at over $1.1 million.

Suburb	Absolute waterfront or foreshore reserve	Proportion with ocean views/frontage?	Owner occupier or rental property?	Median price and trends (to 2009)
Norah Head	The entire cliff and beach frontage is reserve.	Properties along streets with cliff top ocean outlooks are common. Overall, properties with ocean reserve or ocean view account for approximately 30% of the housing stock.	Total population in 2006 was 1,136. 73% of homes were owner occupied in 2006 (47% owned outright), and 72% in 2001.	Median prices rose to approximately $600,000 in 2004 (with median unit prices at this level from 2003 to 2006), but have dropped to around $400,000 since then. Only one month in 2009 had a median house sale price above $600,000. The 2010 median house price in this area has increased to $465,000 with occasional sales over $1.3 million.
The Entrance North	About 250 metres of Curtis Pde has absolute ocean frontage; properties along Hutton road also have direct ocean access. A few other properties have ocean views from the ends of cross streets. Much of the development at The Entrance North is behind the frontal dune; some would have views west across Tuggerah Lake.	Ocean frontage streets account for approximately 5% of the housing stock in The Entrance North. All properties have easy access to the beach.	Total population in 2006 was 1,108. 55% of homes were owner occupied in 2006 (37% owned outright), 56% in 2001. This is consistent with a higher number of holiday properties in this beach front location.	The maximum median sale price per month in 2008 was $1,230,000. For most months the median sale price was less than $500,000 reflecting the diverse housing stock and terrain in the suburb. Overall median prices were $550,000 or more from 2003 to 2006, but declined in 2008/2009. The 2010 median house price is around $500,000 in this area.
The Entrance	The ocean frontage in The Entrance is all reserve (heavily used for tourism and community recreation), as is much of the frontage to the entrance area of Tuggerah Lake, particularly east of the bridge.	Properties along the street facing The Entrance channel and beach have ocean views.	Total population was 2633 in 2006. 38% of homes were owner occupied in 2006 (32% owned outright), and 41% were owner occupied in 2001.	Median house prices peaked at approximately $500,000 in 2004, but declined to around $350,000 in 2008/9. Unit prices are slightly lower than house prices.

Suburb	Absolute waterfront or foreshore reserve	Proportion with ocean views/frontage?	Owner occupier or rental property?	Median price and trends (to 2009)
Toowoon Bay	The foreshore is almost entirely reserve or caravan park.	Some properties landward of the reserve have ocean views, but many properties in this area have ocean proximity rather than ocean views.	Total population in 2006 was 490. 56% of homes were owner occupied in 2006 (46% owned outright). In 2001, 54% of homes were owner occupied.	Median house prices peaked at approximately $900,000 in 2007, although several properties sold for more than $1 million in early 2008. Since late 2008, median sale prices have been in the $450,000 to $620,000 range.
Shelly Beach	A small locality, which has parkland over approximately 72% of the area.		Total population in 2006 was 1343. 75% of homes were owner occupied in 2006 (49% owned outright), up from 68% in 2001.	Median house prices peaked at approximately $500,000 in 2004 and 2005, but fell to $400,000 to $450,000, with many sales under $400,000 in 2008. Unit prices are slightly lower, but fell dramatically in early 2008. As for other parts of the Shire, median prices have now recovered.
Blue Bay	The entire ocean frontage is in reserve.	Approximately 750 metres of properties with reserve frontage and/or ocean views. This represents about 25% of the housing stock in the locality	Total population in 2006 was 920. 50% of homes were owner occupied (38% owned outright) in 2006. In 2001, 51% of homes were owner occupied.	The median housing price peaked in 2003 and 2004 at approximately $700,000. However, sales of properties in the range $1.4 to $1.8 million occurred in several months in 2008. This reflects the split in property values between the ocean front and elsewhere in the locality. In 2009, the median price was more than double the average across the Shire and has been up to five times the Shire average.

Suburb	Absolute waterfront or foreshore reserve	Proportion with ocean views/frontage?	Owner occupier or rental property?	Median price and trends (to 2009)
Bateau Bay	The entire ocean frontage is reserve (or caravan park).	All houses are landward of the first street in from the ocean, although some would have filtered ocean views. Bateau Bay has a total population of 11,595 (2006). A very small proportion of the total housing stock has direct ocean amenity values, but there is good public access.	69% of homes were owner occupied in 2006 (39% outright owners), down from 72% in 2001.	Median house prices rose to approximately $400,000 in 2004, but remained at around $350,000 to $400,000 in 2008/2009.

17.2.3 Population trends

How will trends in demography and socioeconomic indicators increase or reduce vulnerability to coastal processes and to climate change?

The estimated total population of Wyong Shire Council in 2007 (based on 2006 Census data) was 143,951. Population data for the period 1996 to 2007 shows a period of rapid growth from 1996 to 2001, with significant slowing in the growth rate since then. Current population growth rates for the Shire as a whole are less than one per cent per annum. **Table 17.3** summarises demographic data for the Wyong coastline.

The narrow coastal strip of Wyong Shire Council includes six Census sub areas:

- Bateau Bay- Shelly Beach
- Long Jetty-Blue Bay-Toowoon Bay
- Noraville-Norah Head-Canton Beach
- The Entrance-North Entrance
- Budgewoi-Halekulani-Buff Point
- Lake Munmorah-Chain Valley Bay

Clearly the census data for these sub areas includes residents from streets outside the core area of interest for the WSCMP. However, a review of the demographic trends from these six areas reveals important population characteristics that Council has considered in its planning for coastal access and recreation facilities.

The total population of the six coastal sub areas remained quite stable between 2001 and 2006. The 2001 population was 42,849 and by 2006 the population had increased slightly to 42,923, a gain of less than 0.2 per cent.

The population of the Toowoon Bay-Blue Bay, Noraville and Budgewoi areas declined slightly between 2001 and 2006. Very small increases were experienced at The Entrance and Bateau Bay, with a slightly larger increase in the Lake Munmorah-Chain Bay area.

The three oldest settled coastal areas have a lower proportion of young people (population under 18 years) and a higher proportion of older adults than other parts of the coast and particularly than other parts of the Shire. However, all parts of the coast have more than 20 per cent of their population in the older age bracket (over 64 years)

Table 17.3 - Population statistics, coastal census sub districts

Sub area	**Total population, 2001 and 2006**		**% of coastal population 2006**	**Density**	**Number and % under 18 years**	**Number and % over 64 years**
Bateau Bay-Shelly Beach	12380	12569 (1343 in Shelly Beach)	29%	14.24/hectare	2865 23% 10-19 years age group is largest at Bateau Bay.	2868 23% 40-49 years age group is the largest at Shelly Beach.
Long Jetty-Blue Bay-Toowoon Bay	6784	6483 (920 in Blue Bay, 490 in Toowoon Bay)	15%	17.08/hectare	1244 18%	1614 24% The 60-69 years group is the largest in Toowoon Bay. 40-49 years age group is the largest at Blue Bay.
Noraville-Norah Head-Canton Beach	4841	4719 (1136 in Norah Head, 2548 in Noraville)	11%	No information	1020 21% 10-19 years age group is the largest at Noraville.	1186 24% 40-49 years age group is largest at Norah Head.
The Entrance-North Entrance	3839	3913 (2633 in The Entrance, 1108 in The Entrance North)	9%	No information	682 18% % Shire wide	956 25% 50-59 years age group is the largest at The Entrance North. % Shire wide

Sub area	**Total population, 2001 and 2006**		**% of coastal population 2006**	**Density**	**Number and % under 18 years**	**Number and % over 64 years**
Budgewoi-Halekulani-Buff Point	8670	8564 (3191 in Budgewoi)	20%	11.86/hectare	2070 24%	1847 22%
Lake Munmorah-Chain Valley Bay	5880	6675	16%	2.12/hectare	1654 25%	1439 22%

17.2.4 Commercial uses of Wyong coastline beaches

Beaches in Wyong Shire are used for the following commercial purposes:

- Commercial fishing (beach hauling)
- Surfing schools and board hire - Toowoon Bay Beach, Lakes and Soldiers Beaches
- Fitness training - Soldiers Beach

Other commercial events are occasionally held on beaches; however these are usually one off bookings

Several caravan parks (see **Section 17.2.7**) have ocean frontage locations, not extending onto the beach itself. Many other businesses, including accommodation and food businesses derive a significant portion of their income from visitors who come to the area because of its beaches and coastal recreation opportunities such as beach and rock platform fishing.

17.2.5 Recreation and tourism

Recreational uses of the Wyong coastline include:

- Recreational ocean fishing from beaches and rock platforms. Access is generally on foot, but four wheel drive vehicles use parts of Birdie Beach
- Ocean fishing from boats launched at Cabbage Tree Harbour or Toowoon Bay
- Swimming and general surfing
- Surf board riding – by locals and visitors
- Surf life saving and competitive surf life saving club activities such as surf boat rowing and surf ski paddling (see **Section 17.2.6**)
- Walking – see **Section 17.2.7** for information about paths and other access ways for walkers and swimmers
- Other fitness activities such as cycling and running
- Bird watching
- Picnics – on beaches, headlands and in foreshore reserves

- General sightseeing
- Kite surfing
- Whale watching
- Environmental activities such as weeding and planting
- Car parking access is required for all of these activities

The tourism uses of the coast include:

- Bed and breakfast accommodation
- Caravan parks and camping areas. **Table 17.4** indicates the locations of Caravan Parks in relation to the six patrolled beaches in the Shire.
- Restaurants and cafes
- Formal open spaces for large community events/festivals
- Surfing lessons
- General sightseeing
- All of the recreational uses noted above

Table 17.4 - Caravan Park locations
(Data from L&PMA and SGL 2010)

Shelly Beach and Shelly Beach North	Sun Valley Tourist Park (Crown lease) Blue Lagoon Beach Resort (Crown lease) Toowoon Bay Tourist Park (walking distance to beach for young families)
Toowoon Bay	Toowoon Bay Van Park
Blue Bay	Blue Bay Camping and Caravan Tourist Park (walking distance to beach for young families)
North Entrance	Dunleith Caravan Park Two Shores Caravan Park
Soldiers Beach	Norah Head Tourist Park
Budgewoi Beach (Ocean Street)	Budgewoi Tourist Park (walking distance to beach for young families)

17.2.6 Patrolled beaches and Surf Club activities

There are six surf clubs along the Wyong coastline (see **Section 15.2.1.4** of **PART C**).

Council provides lifeguards at six beaches for seven months of the year between the end of September and 25 April, excluding weekends and public holidays when the beaches are patrolled by Surf Life Saving volunteers.

Council also provides a contract service at Frazer Beach in Lake Munmorah State Recreation Area (Christmas, Easter and April School Holidays). Hours of patrol: are 8.30 am – 5.00 pm and 8.30 am – 6.00 pm (Christmas holidays)

17.2.6.1 Beach usage statistics

Lifeguards working at each of the six surf clubs in Wyong Shire have collected estimates of beach usage over the last twenty years (SGL Consulting Group 2010). **Table 17.5** summarises beach usage data for the patrolled beaches for 2004/2005. There are obvious inaccuracies/rounding in this data, but despite this, it is likely that more than 1.1 million people visited the Shire's beaches over that period. This is part of a trend of overall increasing beach usage in the Shire. **Table 17.5** also shows the number of rescue and first aid incidents at each of the beaches for 2004/2005.

Table 17.5 - Beach usage and incidents, 2004/2005 (data from SGL 2010)

Beach	Estimated attendance, weekdays	Estimated attendance weekends	Rescues/users per rescue	First aid
Soldiers	182,170	100,000	261 recues or 1081 users per rescue	138
Shelly	152,700	100,000	360 rescues or 702 users per rescue	258
Toowoon Bay	126,860	75,000	31 rescues or 6511 users per rescue	306
The Entrance	110,870	25,000	102 rescues or 1332 users per rescue	75
Lakes	92,450	25,000	28 rescues or 4194 users per rescue	135
North Entrance	90,030	25,000	14 rescues or 8216 users per rescue	185
Estimated total	755,080 (68%)	350,000 (32%)		

Soldiers, Shelly and Toowoon Bay beaches are the most popular, and slight declines in the usage of The Entrance, Lakes and North Entrance Beaches have been reported over the last decade. SGL (2010) do not provide information about the types of injuries treated at each of the beaches (e.g. stings, grazes on rocks, heat exhaustion are all likely reasons for first aid). However, it is apparent from this data that Soldiers and Shelly Beach require the highest resources for safe management of beach users. Both have high and increasing numbers of users, and high numbers of rescues/first aid incidents.

Based on these statistics, Shelly Beach has the lowest numbers of users per rescue incident – i.e. a higher likelihood of users requiring rescue than other beaches. Soldiers Beach has the next most frequent rescues relative to user numbers. In 2004/2005, North Entrance, Lakes Beach and Toowoon Bay had relatively low numbers of rescues relative to the estimated number of beach users.

17.2.6.2 Functions and services of surf club sites

Surf club buildings provide the following services and functions. Some of these services and functions require a location very close to the beach and with direct line of sight to areas used by people swimming or surfing (Beach Front BF). However, other activities/services are already delivered or could be delivered effectively from a building located further back from the beach (Near Beach NB, outside the immediate coastal risk area) and potentially outside the 2050 or 2100 coastal risk areas. See **Section 16.6** for more information about coastal risk areas.

- Beach lookouts for lifeguards (with high beach visibility, shade and power for announcements) (BF)
- Focal point for safety issues for beach users (BF)
- Main beach access to patrolled swimming areas (BF)
- Source of information to beach users, including about beach safety, beach access and protecting coastal environments (BF and NB)
- Storage of surf life saving equipment such as surf boats, rubber duckies, surf skis, buggies for towing etc. Larger pieces of equipment need a direct ramp access onto the beach (BF)
- Meeting rooms for life saving club members (NB)
- Function rooms for club members and general community hire – social values (NB)
- Public amenities such as toilets, change rooms and showers (NB). Showers may also be provided at beach access points near the club (BF)
- Disabled access points onto beaches (BF)
- Focal point for coastcare activities on dunes (NB)
- Kiosks and cafes (NB)
- Car parking (NB)
- Starting point for coastal walking paths (NB)
- Picnic areas (NB)
- Venues for major events such a State and National Surf Life Saving Championships bringing significant tourist revenue to the area (BF and NB)
- Some club buildings (such as The Entrance) have heritage value.

17.2.6.3 Environmental works and community development at surf club sites

Toowoon Bay Beach was awarded the title ‘Australia’s cleanest beach’ by the Keep Australia Beautiful program in 2007. The beach also won the ‘friendliest beach’ award in that year.

Toowoon Bay Surf Club, in partnership with Wyong Council and other community members, has implemented a number of innovative environmental and social programs to enhance the quality of the beach experience for all users. These initiatives include:

- Regular maintenance by Council maintenance crews, Council lifeguards, Surf lifesaving Club members and the local community mean that the beach and reserve area is virtually litter free.
- A ‘Talking sign’ system, which provides visual and audio information about visitor safety issues in multiple languages. The sign is solar powered.
- A double filtration storm water tank at the surf club collects water for use in equipment wash down and toilet flushing. In extended dry periods, council diverts recycled water to top up supply.

- The club area is fully accessible to people with disabilities and the Club works with the Disabled Surfers Association to run a surfers day for disabled people.
- Extensive landscaping has been conducted around the club, using local species, which attract birds and other local wildlife. Landcare groups look after foreshore vegetation with some assistance from surf club nippers.
- The club runs an education program for its junior members on the natural values of rock platforms, beaches and dunes.
- Seaweed collected from the beach is used as mulch/fertiliser on council reserves.

These programs are also relevant to the other surf clubs along the Wyong coastline.

17.2.7 Other community infrastructure and built assets

WSC has constructed and/or is responsible for the maintenance of the following community infrastructure and assets along the coast:

- Stormwater drainage systems and discharge points – onto beaches and headlands
- Water collection for desalination
- Water distribution (drinking water supply)
- Sewerage lines and sewerage pumping stations
- Sea walls at The Entrance
- Surf clubs (see **Section 17.2.6** for details).
- Boat ramp and fish cleaning facilities, such as at Cabbage Tree Harbour
- Beach access ways, including steps, ramps and viewing platforms
- Picnic facilities in foreshore reserves
- Pathways and cycleways

Council lists 156 parks developed for public recreation in Wyong Shire. Many parks contain recreation facilities such as picnic tables, seats, playground equipment, toilets, and community information about ecological or heritage values. A few parks are designated off lead dog exercise areas (see **Section 17.2.7.1**). Some parks and reserves provide valuable connecting coastal habitat as well as community recreation facilities. Coastal parks and facilities are listed below. The ecological values of coastal parks and reserves is considered in **Section 17.1**.

- Munmorah State Conservation Area (OEH), with facilities at:
  - Moonee Beach
  - Coral Fern Beach (road loop to informal look out),
  - Frazer Blowhole (road access to car park),
  - Frazer Park Beach (picnic area, camping area, parking and toilets)
  - Red Ochre Beach (picnic area, road access and toilets)

    - Podgewoy Reserve, Budgewoi Beach (walking tracks)
    - Other dune and beach access tracks along Budgewoi Beach and Lakes Beach
    - Lakes Beach Surf Life Saving Club (parking, toilets and beach access)
- Jenny Dixon Reserve at Noraville (parking, picnic area, playground equipment, beach access and toilets)
- Lions Park at Noraville (playground equipment)
- Cliff Street Reserve at Norah Head (picnic table)
- Mazlin Reserve at Cabbage Tree Harbour (Norah Head Search and Rescue area, boat launching ramp to ocean, picnic tables and playground equipment)
- Rossett Lookout and Bush Street Reserve (parking, toilets, playground equipment, picnic tables, lookout)
- Norah Head Lighthouse Reserve (Department of Lands)
- Pebbly Beach Reserve at Soldiers Point (parking area, picnic tables, surf life saving club, beach access, toilets)
- Wyrrabalong National Park North (DECC) (daytime beach access roads and parking area)
- Beach access to Tuggerah Beach fro Wilfred Barrett Drive
- Tuggerah Beach Recreation area (off lead dog exercise area)
- Matron Simpson Reserve, North Entrance (beach access, walking path, surf life saving club)
- North Entrance Foreshore Reserve (sensory garden), (disabled toilets)
- Karragi Point Reserve, North Entrance (sand spit) (beach access, parking, walking track, toilets, picnic tables, playground, links to caravan park)
- Memorial Park, The Entrance (on southern side of entrance channel) icon park with major tourist attractions and facilities, used for events and festivals.
- Shore Park (surf life saving club, lookout, ocean baths, walking tracks)
- Blue Bay foreshore reserve (beach access, toilets)
- Toowoon Beach Reserve and Swadling Reserve (boat launching ramp to ocean, surf life saving club, toilets, parking, lookout, picnic tables, playground equipment)
- Shelly Beach surf Club (parking, toilets, beach access)
- Naomi Honey Reserve (picnic tables)
- Bruce Burgis Park (playground equipment, picnic tables, community hall)
- Wyrrabalong National Park (South) (OEH), Bateau Bay (walking track to Crackneck Point, playground equipment, picnic tables, lookout, parking, toilets, access to Bateau Bay Beach)

17.2.7.1 Dog exercise areas

Dogs are not permitted on some beaches and foreshore reserves. Council has approved a number of on and off leash dog exercise areas. These are:

- Lakes Beach from 500 metres north of the Surf Club to Ocean Street
- North Shelly Beach from the northern beach access walkway off Shelly Beach Road (adjacent to the Golf Course) to the beach access stairs opposite Swadling Reserve
- North Entrance Beach from Wyuna Avenue to Stewart Street
- Bateau Bay Reserve, bounded by Avignon Avenue, Sabrina Avenue and Fishermans Bend

Unleashed dogs must not cause a nuisance to people on these beaches and owners remain responsible for the safety of other users (from dog attacks) and for cleaning up dog waste.

17.3 Cultural and heritage values

17.3.1 Indigenous places and values

Approximately 2700 Aboriginal people live in Wyong Shire. The Wyong coastline is part of the traditional country of the Darkinjung people and the coastal strip was occupied by the Kuringai clan (Wyong Shire Council 2005a). The Darkinjung Local Aboriginal Land Council is the representative body for Aboriginal people living in the Wyong area, some of whom are Darkinjung people, others people from other Aboriginal nations across NSW. The traditional Darkinjung country extends from the Hawkesbury River to Lake Macquarie and west through the Wollombi and Mount Yengo area, including the Wollombi, Colo and Macdonald Rivers. The whale is one of the totems of the Darkinjung people.

The Darkinjung Local Aboriginal Land Council (DLALC) is negotiating a Memorandum of Understanding with Wyong and Gosford Councils in relation to respecting cultural values.

As a Local Aboriginal Land Council, Darkinjung makes land claims under the Aboriginal Land Rights Act. Some 461 land claims across Darkinjung country are pending. In 2009, the DLALC completed a land assessment for land it has acquired under the Act, considering cultural significance, biodiversity significance and development significance. The DLALC also works with the HCRCMA and NSW Environmental Trust on land management projects to protect the natural and cultural values of its lands.

More than 270 Aboriginal sites (places with physical archaeological evidence of past occupation), listed in the OEH AHIMS register, are formally recorded in the Shire, but many more sites are undoubtedly present across the coastal landscape. Known (recorded and registered) sites are protected by the *National Parks and Wildlife Act 1974*, as are Aboriginal Places which have been gazetted by the Minister for the Environment.

The value of the landscape to the Darkinjung people and other Aboriginal people who have now made the Shire their home is much more than archaeological sites. The coastal landscape provided people with stone for tools, with a multitude of plants that could be used for food, medicines and fibres (e.g. for weaving), and with fish and shellfish as well as terrestrial animals. Coastal places are associated with traditional Darkinjung stories and with the totems of Darkinjung people. Some places are also important because they are associated with the early interactions between the Darkinjung owners and European settlers moving into the district. Rock art and engravings provide an important record of the association between Darkinjung people and their country. These sites are concentrated in the sandstone lands in the western part of Darkinjung country and in the Gosford council area, rather than along the Wyong coastline.

17.3.2 Heritage listings

A number of places and buildings along the Wyong coastline are identified in local, state and National heritage lists. **Table 17.6** lists heritage items listed in Schedule 1 of the Wyong LEP (1997).

Table 17.6 - Coastal historic heritage items, Wyong Shire

Location	Item	Why significant?	Significance
Bush Street **Norah Head**	Light house and building	The last NSW lighthouse to be built in the classical style of James Barnet, the lighthouse was established in 1903. The lighthouse is built of precast concrete blocks rather than stone. There are outstanding views from the top of the lighthouse (now accessible in tours). The complex also includes three keepers cottages.	Regional
Elizabeth Drive **Noraville**	Dwelling (Hargraves House)		State
Corner Wilfred Barrett Drive and Oleander Street **Noraville**	Noraville cemetery and Hargraves Grave		Regional
Marine Parade **The Entrance**	Surf Club building	Interwar architectural style, like other buildings along the sea front/lake front of the Entrance. Built in the early twentieth century, The Surf Club represents the beginning of The Entrance's heyday as a tourist destination and it has social significance to 'generations of early to mid twentieth century holiday makers and locals'.	Regional
Marine Parade, **The Entrance**	World War 1 Memorial	Situated in the waterfront reserve at the entrance to Tuggerah Lakes, the original memorial was dedicated in 1926 (this memorial has now been replaced). The site records the scale of participation of local people in World War 1.	Local

Location	Item	Why significant?	Significance
	The Entrance Ocean Baths	A complex of three outdoor ocean baths in the rock platform between The Entrance Beach and Blue Bay. Like the Surf Club building, the baths are linked to the importance of the Entrance as a holiday destination in mid twentieth century (from post WA1 to the 1960s). The local Swimming Club celebrated its Golden Jubilee in 2003.	State. Reported to have been listed in 2003.

17.3.3 Cultural landscapes – integrating physical, visual and social values

Culture incorporates many different aspects of human activity. This section considers only how human activities and values have interacted with the natural coastal landforms and processes, resulting in four main types of landscape along the Wyong coast.

17.3.3.1 Indigenous cultural landscape

The Indigenous cultural landscape reflects the attachment of the Darkinjung people to the coast, for spiritual reasons and associated ceremonies and obligations, as a reliable and abundant source of food medicines and other resources. The Darkinjung people would have experienced considerable change in the shape of the coastline, particularly the coastal dunes and lake entrance areas, over many generations. Naturalness is an important part of the Indigenous cultural landscape, because natural areas conserve the landscape features of cultural value.

17.3.3.2 Historic to modern recreation and tourism

Recreation/tourism and fishing were the key drivers of European settlement along the Wyong coast. The key precincts which reflect a transition from long standing recreation and holiday making to modern versions of these uses are The Entrance ocean channel (north and south shorelines), The Entrance Beach, Norah Head/Noraville and Toowoon Bay. Parts of Budgewoi illustrate a more recent transition from small holiday cottages to more permanent residences.

The Entrance Beach and lake entrance area is a heritage coastal recreation area, long recognised as a place for an escape to the seaside. Holiday camping was an established practice from 1901. The Entrance had only about 50 permanent residents, but there were 400 to 500 tents on Mr Taylors property at the Entrance (and on Rabbit Island) in the holiday season. The Entrance rock pool dates to 1919, with the 50 metre pool constructed in 1938 (NSW Ocean Baths n.d.).

> In the 1920s the Entrance was a popular holiday place with 15 guest houses and hordes of campers, including many rail and tramway men and their families. The holiday makers caught boats across the Tuggerah Lakes after travelling on the Sydney to Newcastle railway to Tuggerah or Wyong. Use of the ferry services started to decline after 1923, when the first bus services to the Entrance from Wyong and Gosford began.

Kims Resort on the beachfront at Toowoon Bay, which commenced as a campsite in the late nineteenth century, also grew to become a popular guesthouse from the 1920s, continuing to the present day.

The Entrance Surf Club is linked to an inter-war consolidation of the area as a significant tourist destination.

As a tourism and recreation destination, The Entrance includes not just the ocean beach and rock pools, but the recreational connection between the lake and ocean, extending as far into the Tuggerah Lakes as the Entrance Bridge and the nearby islands.

The Entrance foreshore has been developed as a premier tourist site for Wyong Council, designed to attract and cater for large numbers of visitors. A promenade and boardwalk extends along the estuary foreshore to The Entrance beach and the foreshore is backed by recent redevelopment to medium density residential/tourism accommodation.

The Entrance Peninsula Planning Strategy (2009) identifies some key elements of this landscape and how they will be taken forward in concepts for the future development of the area.

The Entrance Peninsula Vision is based on a clear and unique identity:

- Unique ocean channel with naturally forming mini beaches, shallow and deeper water providing for swimming, paddling, fishing and other water based activities
- Ocean beaches, providing for swimming, surfing, fishing, kite surfing, other water and beach based activities
- Islands providing scenic value, boating refuges, fishing and wildlife refuges (these islands are inside The Entrance Bridge)
- Shopping, including boutique style, restaurants, coffee shops, local convenience stores. Entertainment events.
- Heritage buildings and other places of historic value
- Biodiversity including various threatened species and environments

17.3.3.3 Expansive ocean beach and dunes

The Wyong coastline is dominated by two long classic ‘zeta curve’ beaches, which form the coastal barrier enclosing the Tuggerah Lakes. These are Tuggerah Beach (extending north from The Entrance) and Birdie Beach, extending north from the Hargreaves Beach/Lakes Beach area. Although both dune systems have been mined for sand in the past, there is residential development at North Entrance, and a coastal resort part way along Tuggerah Beach, these two long beach and dune systems present an open and almost remote feeling landscape for beach users.

For the expansive coastal dune areas, a further important cultural value is the commitment to and involvement of local residents in restoring and enhancing the natural environment. The work of the Budgewoi Dunecare group along Budgewoi Beach and dunes, since 1996, is an example of this community cultural value in action.

The cliffs and smaller beaches of the Wallarah Peninsula and the National Park at Crackneck are also part of this open, relatively natural landscape, used primarily for low key activities such as fishing and walking.

17.3.3.4 The residential coast

There is considerable overlap between the recreational and tourist landscapes of the Wyong coast and the residential coastline, as many of the residential areas also serve as tourist accommodation and attractions. The residential coast landscape is characterised by family homes set in a coastal landscape – and designed for enjoyment of the coastal lifestyle. As noted in **Section 17.2.2**, land values in these residential areas are significantly higher than in other parts of Wyong Shire. Permanent occupancy rates are also lower than many residential areas, because of the overlap with tourism uses and the historical inheritance of holiday homes.

The residential coast landscape includes:

- North Entrance: dune landscape, formerly with low key fishing and holiday houses – now significant residential redevelopment
- Noraville to Lakes Beach
- Shelly Beach, Toowoon Bay and Bateau Bay

In these areas, a narrow foreshore reserve provides for habitat protection, or recreation (including along shore public access) or a visual buffer.

18.0 Key Risks for the Wyong Coastline

This section reviews the range of risks within the Wyong coastal risk area. The assessment uses a standard risk assessment protocol that takes into account the likelihood of a threat (hazard) occurring and the consequence of the threat – what would be impacted if the hazard occurred and what values (economic, natural systems, social or cultural) would be modified or damaged?

Section 18.1 provides some more background on how risk is assessed and the planning implications of risk management (reducing unacceptable risks) in coastal areas.

Sections 18.3 to **18.4** apply the risk assessment and management process to the coastal erosion hazards and values associated with the Wyong coastline.

Council has previously conducted a Shire wide emergency risk assessment (WSC and Eschelon 2007, see **Section 15.3**). That risk assessment considered only the impact of individual coastal storms on coastal property and safety, in terms of emergency response requirements in the immediate coastal risk area. Compared with other natural hazards in the Shire (such as bushfire or flooding), which could impact on thousands of people and properties, coastal storm impacts were considered to present a low risk.

The scope and purpose of the current risk assessment is quite different. It considers not only one-off storm events in the immediate coastal risk area, but the longer term risks of poor planning systems and decisions for areas with a high probability of coastal recession, driven by climate change or other factors. Council's planning decisions now will affect future risk in these areas.

This risk assessment therefore informs Council's strategic planning direction for the coastline.

18.1 Assessing risk

Detailed assessments of coastal process hazards are reported in **Section 16.0**, and full hazard reports are in **Appendix 3** and **Appendix 4**. Risk assessment considers the assets and values that will be impacted by the coastal hazards the consequences of those hazards.

DECCW (2009) has defined 'coastal risk area' as areas that are affected by any coastal hazard within a specified time frame (by 2050 or 2100). Whilst many of the risks are associated with impacts on structures (such as sea walls), infrastructure (such as roads, sewerage systems) and private property (such as residences and businesses), risks can also derive from impacts on valuable natural assets such as Endangered Ecological Communities or on social or cultural values. For instance, the impact of a coastal erosion hazard on a surf club building includes both the value of the structure and the social values that the structure provides, such as a meeting place a place for community functions, or a place associated with long term recreation values. These non structural risks are more difficult to quantify, but should still be taken into account when identifying priorities for risk reduction and when assessing potential risk reduction options.

DCCEE (2009a) discusses the value of risk based planning for making sound decisions about land use in coastal landscapes that are, or are likely to be affected by erosion or inundation. DCCEE (2009a) provides qualitative descriptions of different risk levels, drawing particularly on the likelihood of an event occurring, and planning for new development. The four main risk classes used in the DCCEE (2009a) classification are shown in **Table 18.1**.

For the Wyong coastline, the coastal planning issues relate to both new development and extensive existing development. This means that risk needs to be considered not only in terms of decisions about where new development should be located, but also in terms of decisions about the extent of protection of other management measures that should be considered or provided for existing development.

Table 18.1 - Land use planning for new development, based on a hierarchy of risks (Source DCCEE 2009, p142)

Risk category	Application and planning response
Low risk areas	Defined by areas where there is little or no risk of erosion, flooding or long term inundation at less than 1 in 1,000 year return periods, under worse case climate change scenarios to 2100. **Planning response**: no constraint on land use planning because of physical climate processes
Medium risk areas	Defined as shorelines, tidal watercourses and low lying lands subject to erosion, inundation and flooding at 1 in 500 to 1 in 1,000 year return period. **Planning response**: no new construction of essential and critical infrastructure and public utilities unless designed to remain operational during extreme climate events (suitable for most other development)
High risk areas	Defines as coastal areas likely to be affected by erosion, inundation and flooding at a return interval of between 1 in 500 and 1 in 100 years. **Planning response**: approval only for development that can be relocated or designed to withstand the impacts of extreme events or flooding without causing adverse consequences for adjoining coastal areas.
Very high risk areas	Defined as areas subject to erosion, inundation and flooding at a return interval of greater than 1 in 100 years under worst case climate change scenarios. **Planning response**: approval only for developments that are compatible with a high degree of land surface disturbance. Existing high value assets in such areas should be subject to restrictions on new development and on the management of potential adverse consequences for adjoin areas, in the light of the ability of the community to protect these assets and support their relocation over time.

Note: current planning is generally based on assessing risks from a 1 in 100 year event. Events less frequent than this, i.e. a 1 in 1,000 year event, are significantly larger in magnitude.

18.1.1 Risk assessment protocols for geotechnical hazards

Much of the focus of recent policy and planning initiatives has been on addressing potential increases in risks associated with coastal erosion, exacerbated by climate change and sea level rise. The multiple policies, guidelines and codes of practice recently released by the NSW Government and discussed in **Section 15.0**, all relate to coastal erosion and recession.

Geotechnical hazards are driven by quite different processes and the consequences are also different. The Australian Geomechanics Society (2007) has prepared protocols for assessing risks associated with geotechnical hazards. These protocols consider potential damage to property, but also potential injury and loss of life associated with landslip and rock fall events. Full details of the assessment process for the Wyong coastline are in **Section 16.0** and **Appendix 4**.

Risks associated with geotechnical hazards are not further evaluated in this section. However, it should be noted that the geotechnical hazard assessment found some extreme risks associated with landslip risk in public reserves, and also in relation to some private property.

18.1.2 Standard risk assessment protocols – likelihood and consequence

Tables 18.2, **18.3** and **18.4** outline how likelihood and consequence are incorporated into risk and how different levels of risk are described. **Figure 18.1** is a risk matrix which shows how the likelihood and consequence scores contribute to the risk description. This qualitative risk matrix is consistent with the Australian Standard and the DCCEE 2009 framework.

Sea level rise predictions are not certain, but the sea level rise planning benchmarks set for the NSW coast (DECCW 2009) are considered likely to occur within the various time frames (immediate, 2050 and 2100). Because coastal erosion/recession hazards are considered likely to affect all development and sandy landforms within the hazard zone for a given time frame, all hazard impacts in the following tables are accorded the same probability. The probability of 'likely to occur' means that all assets within the hazard zone are likely to be affected at least once. Some assets may be affected many times. The time linked width of the hazard zones also means that the seaward parts of the zone will be impacted by erosion hazards sooner and more frequently than the landward margins of the hazard zone.

By applying the same probability of hazards occurring to the entire hazard zone, the risk score actually varies with the value of the asset that will be affected by erosion or coastal recession within that time period. The high likelihood of hazard impacts occurring within the hazard zone for each time period also means that even low consequence scores will lead to a moderate to high risk in the relevant time period. This is in fact the basis of the NSW Government planning response for coastal risk areas that are based on time frames.

Table 18.2 - Qualitative Measures of Likelihood

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

Table 18.3 - Qualitative Measures of Consequence

Level	Descriptor	Description
1	Catastrophic	Irreparable damage to highly valued structures/items or places with the coastline. This would include removal of entire landforms and associated ecological functions. It would also include destruction of major community infrastructure, such as highways, water and sewer links serving large populations, hospitals etc. Culturally, loss of paces of national heritage significance would be considered a catastrophic loss.
2	Major	Significant damage to structures/items or places or values associated with the coastline.
3	Moderate	Moderate repairable damage to structures/items or places or values associated with the coastline.

Level	Descriptor	Description
4	Minor	Minor repairable damage to structures/items or places or values associated with the coastline, or values are not considered important.
5	Insignificant	No impact to structures/items or places or values associated with the coastline, or the values impacted are very minor.
P	Positive	A benefit or enhancement to coastline places or values.

Table 18.4 - Risk Descriptions

Level	Risk	Description
E	Extreme	Risk is intolerable and cannot be justified under any circumstances. Measures to reduce risk to a lower level are required.
H	High	Risk is significant and requires cost effective measures for risk reduction.
M	Moderate	Routine and cost effective measures required to reduce risk.
L	Low	Risk can be managed by routine procedures and no further measures to manage risk are required.
P	Positive	Positive impact expected. No management required – except perhaps communication. May provide offset benefits for other losses?

Likelihood	Consequences				
	Insignificant	Minor	Moderate	Major	Severe
Almost certain	M	H	H	E	E
Likely	M	M	H	H	E
Possible	L	M	M	H	E
Unlikely	L	M	M	M	H
Rare	L	L	M	M	H

Figure 18.1 - Qualitative risk matrix, combining likelihood and consequence.

18.2 Immediate coastal erosion and inundation risks

Immediate risks are assessed in **Table 18.5**. The table considers assets located within the immediate hazard lines (wave impact and slope adjustment) to understand the consequences of storm erosion and wave runup.

Table 18.5 – Qualitative assessment of immediate coastal risks

Hazard	Impacts on	Likelihood	Consequence	Assessed risk
Immediate Coastal Risk Area, **North Entrance** (includes Curtis Parade and Hutton Road)	Dune vegetation	Likely to occur and could occur at any time.	Insignificant	Moderate
	Beach access ways (steps and ramps)		Minor	Moderate
	Surf Club buildings		Moderate	Moderate to High
	Residential buildings		Moderate to Major	High
	Residential landscaping		Minor	Moderate
	Infrastructure		Minor	Moderate
Immediate Coastal Risk Area, **Lakes Beach**	Dune vegetation	Likely to occur and could occur at any time	Insignificant	Moderate
	Beach access ways (steps and ramps)		Minor	Moderate
	Surf Club buildings		Minor	Moderate
	Beach access ways (steps and ramps)		Insignificant to Minor	Low to Moderate
	Surf Club buildings		Minor	Moderate
Immediate Coastal Risk Area, **Hargraves Beach**	Dune vegetation	Likely to occur and could occur at any time	Insignificant to Minor	Low to Moderate
	Residential property		Moderate	High
	Beach access ways		Minor	High
	Picnic areas		Minor	High
	Caravan park sites			
Immediate Coastal Risk Area, **Shelly Beach**	Dune vegetation	Likely to occur and could occur at any time	Insignificant	Low
	Beach access ways		Minor	Moderate
	Picnic areas		Insignificant	Low
	Surf club buildings		Minor	Moderate
	Parking area		Insignificant	Low
	Beach access ways		Minor	High
Immediate Coastal Risk Area, **Soldiers Beach**	Coastal dune vegetation	Likely to occur and could occur at any time	Minor, potential to destabilise dune field?	Moderate
	Beach access ways		Insignificant to Minor	Low to Moderate
	Surf club buildings		Moderate	Moderate

Hazard	Impacts on	Likelihood	Consequence	Assessed risk
Immediate wave runup (for a 1 in 100 year return interval storm), **North Entrance (Curtis Pde)* and South Entrance**	Houses along Curtis Pde South entrance surf club, boat shed and swimming pool	Possible	Minor	Moderate
Immediate wave runup (for a 1 in 100 year return interval storm), **Lakes Beach (north)***		Possible	Insignificant to Minor	Low to moderate
Immediate wave runup (for a 1 in 100 year return interval storm), **Hargraves Beach***	Most houses along the frontal dune system	Possible	Minor	Moderate
Immediate wave runup (for a 1 in 100 year return interval storm), **Blue Bay***	Caravan Park at Toowoon Bay Caravan Park south of Shelly Beach Low lying houses (southern half of Blue Bay)	Possible	Minor	Moderate

*these beaches were considered to be most at risk for wave runup inundation

18.3 Coastal erosion risks for the 2050 and 2100 planning periods

Table 18.6 provides a qualitative assessment of coastal erosion risks for the planning period to 2050. **Table 18.7** provides a qualitative risk assessment for the 2100 planning period.

Table 18.6 – Coastal erosion risks, for 2050

Hazard	Erosion impacts on assets	Likelihood (for this planning period, based on current predictions)	Consequence	Assessed Risk
2050 Coastal Risk Area, **North Entrance** Hutton Road and Curtis Parade	Dune terrain and vegetation	Likely to occur by 2050	Moderate – shoreline moves landward to crest of current dune form	High
	Beach access ways		Minor to Moderate	Low
	Surf club buildings		Major– surf club land will be in the sea	High

Hazard	Erosion impacts on assets	Likelihood (for this planning period, based on current predictions)	Consequence	Assessed Risk
	Car parking and road access		Moderate – some parking remains landward of old dune form	High
	Sewer and water infrastructure within coastal hazard area		Major disruption for infrastructure along Curtis Parade	High
	Private property (land and outdoor structures)		Minor	Moderate
	Private property, houses		Major (multiple houses affected)	High to Extreme
	Land tenure definition		Minor – moving boundary of crown and private land	Moderate
2050 Coastal Risk Area, **Hargraves Beach**	Residences	Likely to occur by 2050	Major	High to Extreme
	Infrastructure		Moderate	High
	Dune form and vegetation		Moderate	High
	Infrastructure		Major	High
2050 Coastal Risk Area, **Lakes Beach**	Dune form and vegetation	Likely to occur by 2050	Major – frontal dune system removed	High
	Beach access ways		Minor	Moderate
	Surf club buildings		Major	High
	Car parking		Minor to Moderate	Moderate
	Sewer and water infrastructure		Minor	Moderate
	Central Coast Highway		Major	High
2050 Coastal Risk Area, **Shelly Beach**	Dune vegetation	Likely to occur by 2050	Minor (dune form will be removed)	High
	Beach access ways		Insignificant to Minor	Moderate
	Picnic facilities		Insignificant to Minor	Moderate
	Beach safety (including life saver station)		Insignificant to Minor	High
	Car parking		Moderate	High
	Road access		Moderate (road impacted both sides of surf club)	High
2050 Coastal Risk Area, **Blue Bay and Toowoon**	Residences and commercial development	Likely to occur by 2050	Major	High

Hazard	Erosion impacts on assets	Likelihood (for this planning period, based on current predictions)	Consequence	Assessed Risk
Bay	Infrastructure		Moderate	Moderate to High
	Beach access and amenity		Major (these pocket beaches likely to disappear)	High
2050 Coastal Risk Area, **Soldiers Beach**	Dune vegetation and landform	Likely to occur by 2050	Moderate – likely to destabilise dune	High
	Beach access ways		Minor	Moderate
	Surf Club buildings		Major	High
	Car park		Moderate	Moderate to High
	Infrastructure such as Soldiers Point Drive and sewer and water lines		Moderate	High

Table 18.7 – Coastal erosion and recession risks for 2100 planning period

Hazard	Erosion impacts on assets	Likelihood (for this planning period, based on current predictions)	Consequence	Assessed Risk
2100 Coastal Risk Area, **North Entrance** Hutton Road and Curtis Parade	Dune terrain and vegetation	Likely to occur by 2100	Major to Catastrophic – dune form entirely removed/rolled back	Extreme
	Beach access ways		Major	High
	Surf club buildings		Major – existing surf club site eroded by 2050	High
	Car parking and road access		Major	High
	Sewer and water infrastructure within coastal hazard area		Major	High
	Hutton Road alignment (southern section) and Curtis Parade alignment		Moderate Major	High High
	Private property (land and outdoor structures)		Moderate	High

Hazard	Erosion impacts on assets	Likelihood (for this planning period, based on current predictions)	Consequence	Assessed Risk
	Private property, houses		Major (approximately 50 existing houses entirely removed)	Extreme
	Land tenure definition		Moderate	High
2100 Coastal Risk Area, **Lakes Beach**	Dune form and vegetation	Likely to occur by 2100	Moderate (dune will have been removed)	High
	Beach access ways		Minor to Moderate	Moderate
	Surf club buildings		Major	High
	Car parking		Moderate	Moderate to High
	Sewer and water infrastructure		???	Moderate to High
	Central Coast Highway		Major to catastrophic	Extreme
2100 Coastal Risk Area, **Shelly Beach**	Dune vegetation	Likely to occur by 2100	Moderate	High
	Beach access ways		Minor	Moderate
	Picnic facilities		Moderate	High
	Surf club buildings Beach safety (life saver station)		Major Moderate	High Moderate
	Car parking		Moderate	Moderate
	Road access and sewer and water infrastructure		Major	High
2100 Coastal Risk Area, **Soldiers Beach**	Dune vegetation and landform	Likely to occur by 2100	Moderate	High
	Beach access ways		Minor	Moderate
	Surf club buildings		Major (site completely eroded by 2050)	High
	Car park		Moderate	High
	Soldiers Point Drive Water and sewer infrastructure		Moderate Minor to Moderate	High High

18.3.1 Coastal Hazard Assessment for Surf Clubs

Table 18.8 summarises the findings of the coastal hazard assessment for six surf club buildings along the Wyong coastline. The assessment uses the OEH 40/90 centimetre sea level rise benchmarks.

It is apparent that all of the surf clubs built on sand are on the boundary or partly within the immediate coastal risk area, as defined by the landward boundary of the zone of reduced foundation capacity. At 2050, all existing surf clubs on sand are partly or fully seaward of the zone of reduced foundation capacity and other than Shelly Beach, are inside the zone of wave impact and slope adjustment where severe erosion impacts can be anticipated. All surf clubs on sand are within the 2100 coastal risk area. North Entrance Surf Club is the most severely affected, but by 2100, surf clubs, car parks and access roads are affected at all sand based sites.

Table 18.8 - Coastal hazards at surf clubs

	Lakes Beach	**North Entrance**	**Shelly Beach**	**Soldiers Beach**	**South Entrance boatshed**	**South Entrance surf club**
Within zone of immediate wave impact or slope adjustment	Not affected	Not affected	Not affected	Passes across the seaward face of the surf club	On rock	On rock
Within immediate zone of reduced foundation capacity	Passes through the surf club	Crosses the front of the existing building	Passes across the seaward face of the surf club	Between surf club and car park	On rock	On rock
Within 2050 zone of wave impact and slope adjustment	Landward of the surf club, affects seaward part of car park	Landward of surf club	Just seaward of the surf club	Between surf club and car park	On rock	On rock
Within 2050 zone of reduced foundation capacity	Landward of the surf club, affects seaward part of car park	Landward of the surf club, at base of dune	Passes through surf club and Shelly Beach Drive	Landward of surf club, passes through car park	On rock	On rock
Within 2100 zone of wave impact or slope adjustment	Landward of the surf club and almost entire car park also affected, plus part of Central Coast Highway	Landward of surf club and of houses in Hutton Road	Passes through surf club and Shelly Beach Drive	Landward of surf club, passes through car park	On rock	On rock

	Lakes Beach	North Entrance	Shelly Beach	Soldiers Beach	South Entrance boatshed	South Entrance surf club
Within 2100 zone of reduced foundation capacity	Landward of the surf club and almost entire car park also affected, plus part of Central Coast Highway	Landward of surf club, along alignment of Hutton Road	Landward of Surf Club and lower section of Shelly Beach Drive	Landward of car park and access road	On rock	On rock
Within area of wave runup (using current sea level)	Seaward of surf club	Seaward of surf club	Seaward of surf club	Seaward of surf club	Landward of boat shed	Passes across seaward face of surf club

18.4 Other risks to coastline values

18.4.1 Inadequate or poorly maintained or managed recreational access

Poorly designed or maintained recreational access ways to beaches and along the coast could drive a number of potential consequences, including:

- Safety risks (injuries) to people visiting the coast (path ways, steps, ramps and viewing platforms, open stormwater drains). See also **Section 16.8** regarding geotechnical hazards at some viewing platforms.
- Reduced attraction for tourists – lack of features for marketing the coastline to visitors
- Reduced beach amenity – inappropriate or inadequate facilities at surf clubs or in foreshore reserves; insufficient parking at beaches.
- Reduced public access to beaches (see also **Section 9.0** and **Section 16.6**, public access may be compromised by coastal recession associated with sea level rise).
- Recreational access at popular locations reduces the resilience of coastal dune vegetation communities and habitat for threatened or protected species.
- Recreational access and usage affects the resilience of rock platform ecological communities, such as shellfish habitat and habitat used by shore birds (in addition to the impacts of sea level rise on these communities – see **Section 17.1**).

All of these risks, as stand-alone issues, are currently considered to be moderate. The threat/hazard of poorly located, designed or maintained beach access ways is considered to be possible. The likelihood of poor design or maintenance occurring is largely dependent on Council's available budget and competing priorities, but other social drivers such as vandalism and physical process drivers such as a higher storm frequency or intensity will also affect Council's capacity to provide sound design, location and maintenance. The consequences noted above vary in their importance, as summarised in **Table 18.9**.

Table 18.9 - Summary of risks associated with high community recreational pressure on coastal landscapes.

Hazard	Likelihood	Consequence	Assessed Risk
Poorly designed or maintained recreational access ways	Possible for all timeframes	Generally minor, but could (rarely) impact on human life. Affects the safety of beach users (trips, falls etc)	Generally **low**. High risks are possible where recreational users could be affected (injured) by collapse of structures, even though the probability of this occurring is lower than other scenarios.
Poorly managed beach access infrastructure	Possible for all timeframes	Reduces beach amenity and tourism attraction and economic viability. Generally minor.	**Moderate** Does not consider variance associated with existing conditions
High recreational usage	Possible for all time frames	Impacts on the stability of dune vegetation communities. Generally minor (dune communities are not EECs or threatened vegetation communities	**Moderate**
High recreational usage	Possible for all timeframes	Impacts on the ecological viability of rock platform habitats. Minor	**Moderate**

18.5 Which risks require urgent attention?

The risk assessment highlights that not all assets and values within the coastal risk area are equally vulnerable to the effects of sea level rise and climate change, or to other stresses.

Based on the risk assessment, the following risks are in the 'extreme' class or 'high' class, requiring urgent risk reduction measures. Diverse options which could be used to reduce high and extreme risks are evaluated in **PART D** and effective options are set out in **PART B**. Some of these options should be implemented now to reduce immediate high risks and to provide a risk aware framework for future development. Other measures can be delayed until the 2050 or 2010 planning periods, to provide the most cost effective risk reduction strategy.

Table 18.10 - Risks assessed as high or extreme, by timeframe and locality

Immediate planning period		**Can this risk be reduced?**
High risks	In the immediate period, coastal erosion risks at North Entrance Beach (particularly at Hutton Road and Curtis Parade) and at Hargraves Beach, can be considered to be considered as High. These locations are affected by coastal erosion recognised by OEH to make them 'Authorised Locations' for emergency coastal protection works. Geotechnical hazards at Cabbage Tree Harbour also affect private property and public access at a level that makes them High risks.	Risk reduction measures for existing development at these locations are discussed in **Sections 8.0**, **9.0 10.0** and **11.0** of **PART B**. These sections also present planning controls to reduce risks associated with potential new development
Moderate risks	Storm wave erosion of beach access infrastructure at all beaches Reduced foundation capacity of North Entrance Surf Club, Lakes Beach Surf Club and Soldiers Beach Surf Club	See **Section 9.0** in **PART B** for a range of potential risk reduction actions, including planning controls, design of access infrastructure and public assets such as surf clubs, structural protection and vegetation management
2050 planning period		
High risks	Loss (erosion) of existing surf club infrastructure at North Entrance, Lakes Beach, and Soldiers Beach Ongoing erosion and loss of structural beach access ways across dunes Erosion and inundation (not from wave runup) impacts on Central Coast Highway Major impacts on residential development at North Entrance, Hargraves Beach, Blue Bay and Toowoon Bay due to coastal recession. Impacts on private property at Cabbage Tree Harbour and Noraville from landslip.	See **Section 9.0** in **PART B** for a range of risk reduction options, including retreat and redevelopment of surf club infrastructure, asset registers and maintenance of access ways. **Section 9.0** of **PART B** also deals with planning controls for new development in coastal risk areas. **Section 11.0** in **PART B** addresses geotechnical hazard control measures.
Moderate risks	Erosion of car parking areas at North Entrance, Lakes Beach, Soldiers Beach Erosion of existing foreshore reserve facilities at Shelly Beach Impacts on sewerage infrastructure at all beaches (some only re connections to surf clubs) Erosion of caravan park sites such as Shelly Beach Loss of beach access and amenity at all beaches, with likely removal of pocket beaches and reduction of beach volume and width at other beaches.	See **Section 9.0** in **PART B** for a range of potential risk reduction measures such as planning controls for new development and modifications to existing development, retreat of mobile structures during storm events, planned relocation of major infrastructure, coastal protection works, community education about emergency procedures. **Sections 9.0** and **10.0** also address potential beach and dune nourishment options

2100 planning period		
Extreme risks	Loss of dune landforms and coastal vegetation, particularly where this exposes hind dune areas such as the lake system, major infrastructure or important ecological communities to significant impacts and changes. Changes to morphology and processes at the entrance to Tuggerah Lakes; potential breakthrough at Budgewoi, across Central Coast highway. Loss of public land along coastline, with roll back of shoreline into private property Erosion of houses and other private property structures at North Entrance, Hargraves Beach, Blue Bay and Toowoon Bay	Planning controls are a key tool for the longer term risks. See **Section 9.0** of **PART B**. Also **Sections 10.0** and **12.0**. Geotechnical hazard management measures are in **Section 11.0** of **PART B**.
High risks	Loss of existing surf club buildings and car parks, plus access roads at all beaches Erosion of sewer infrastructure at all beaches Geotechnical hazards at Cabbage Tree Harbour and Noraville Ongoing issues about safe beach access on public land	Erosion hazard lines are landward of all surf clubs and foreshore reserve areas by 2100. **See Sections 9.0**, **11.0** and **12.0** for a range of options to reduce risk