Proceedings of the Public Workshop

"Beach protection: risk and management"

Yeppoon, 7 February 2002

Organised by:

CRC for Coastal Zone, Estuary and Water Management
and
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INTRODUCTION

In Queensland over 85% of the population lives near the coast. Yeppoon area is third fastest growing coastal area in Queensland. Number of population growth from 5600 in 1976 to 12,000 in year 2001 and generally the coastal population growth to 17,000 at present. The management of coastal resources is integrally related to country's economy. In developed countries, such as Australia in addition to economic consideration there is also an interest in quality of life. A large influxes of new settles in coastal areas is because people find the lifestyle associated with the coast to be important. One constraint on the coast is that it is essentially linear; it is a narrow strip of land along the coast. As new areas become popular and open up for development, the additional coastal zone is measured in kilometres. The coastal zone is essentially a scarce commodity. The coastal zone is fragile and there is worldwide tendency for coast to erode. This put high priority on protecting and maintaining what little is there, particularly because real estate values along the coast are so high.

Beach profiles respond to storm – calm cycles by shifting sand in the cross-shore direction. But any beach profile will need additional material during times of high stress, such as during infrequent combinations of high wave action and storm surge resulting from low atmospheric pressures, cyclones, etc. Nature has provided for such emergencies by stockpiling large quantities of sand in dunes. Thus the dunes are a long-term protection against coastal erosion, because they provide adequate elevation of the land contours to prevent flooding and form emergency reservoir of sand. Ideally, a dune-beach system can thus take a care of emergency situations for millennia to come. In modern coastal engineering design and coastal management the fundamental principles are:

- Not disturb existing dune-beach systems,
- Encourage growth of dune-beach systems, and
- Emulate dune beach systems wherever possible

It is in agreement with the general trend in implementation of so-called "soft" shore protection. Greed and ignorance have disturbed many dune-beach systems with the serious and costly consequences.

Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management (Coastal CRC) together with Central Queensland University organised this public workshop to keep open discussion about the matters of beach protection from the researchers and local community points of view. One of the goals of CRC is to recognise coastal ecosystem for its intrinsic value through community participation in integrated approaches to restoration development and management.

During the workshop the speakers covered a wide range of topics:

- Prof Rodger Tomlinson, Director of the Griffith Centre for Coastal Management, Griffith University, topic of presentation is risk of beaches damaging connected with possible storms or cyclones. After so many years of reasonably calm weather along the Capricorn Coast many of us forget what type of damage might be caused by a cyclone. Do we expect some climate changes and more severe weather conditions in the nearest future? Prof Tomlinson is trying to answer this question.
- Jeff Callaghan, the Head of the Bureau's Severe Weather Unit in Queensland, is presenting history of tropical cyclones along the Capricorn Coast. From November to April, 1858 to 2000 there were about 200 tropical cyclone impacts along the Australian east coast. How many of them struck our Capricorn Coast? What is probability to expect in our lifetime a sever cyclone again? What type of damage could be expected? What should we know about cyclones? There are some questions discussed in Callaghan's paper.

- David Robinson, A/Manager of Coastal Services, Environmental Protection Agency, Brisbane presents State Coastal Management Plan recently developed by EPA for Queensland coastal zone. This State Coastal Management Plan delivers a vision and direction for coastal management in Queensland. Presented paper discusses this matter in relation to the Capricorn Coast area.

- Dr Steve Mullins, School of Humanities, Faculty of Arts, Health and Science, CQU, is involved in collection of the historical material about development of Yeppoon region. His presentation remains us about changes which happened to the Capricorn Coast during the last 80 years.

- A/Prof Jurek Piorewicz, the Faculty of Engineering and Physical Systems, CQU, presents a general review of traditional "hard" engineering method of beach protection versus " soft" solution and their potential application to the Capricorn Coast beaches.

The workshop was well attended with representatives of the Livingstone Shire Council, local organisations and private public, total 62 persons. It ended with open discussion to allow expressing public opinions, problems or concerns connected with the management of our Capricorn Coast. The discussion went from a general view to particular problems along the Capricorn Coast beaches. During discussion time Chair of the Livingstone Shire Council, Mr Bill Ludwig, and speakers answered several questions related to the history of the coastal development, current management problems and planning for the future beach protection in the Capricorn Coast area.

Editor
J. Piorewicz

PROGRAMM OF THE WORKSHOP

9:30am	Opening by B. Ludwig, Chairman, Livingstone Shire Council
9:45am – 10:30am	Lecture: " Beaches our asset. Planning and management for natural variability on open coastlines" Prof Rodger Tomlinson, Theme Leader, CRC Brisbane
10:30 am – 11:15am	"History of cyclones on the Capricorn Coast" Jeff Callaghan, Bureau of Meteorology, Brisbane.
11:15am – 11:45am	Coffee time
11:45am – 12:30pm	State coastal management plan – Queensland's coastal policy" David Robinson, Acting Manager Coastal Services, Environmental Protection Agency, Brisbane.
12:30pm – 1:15pm	"History of Capricorn Coast development and coastal protection" Dr Steve Mullins, CQU.
1:15pm– 2:00 pm	Lunch
2:00pm - 2:45pm	Hard/soft methods of beach protection. The Capricorn Coast case study". A/Prof Jurek Piorewicz, CQU
2:45pm – 4:00pm	Open forum for participants. Panel discussion
4:00pm – 4:30pm	Coffee time
4:30pm – 5:00pm	Summary of workshop

Beaches – Our Asset
Planning and Management for Natural Variability on Open Coastlines

Professor Rodger Tomlinson PhD FIEAust
Director, Griffith Centre for Coastal Management
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[Note: This lecture was originally presented in June 2001 as an Inaugural Professorial Lecture titled: Vanishing Beaches – Perception or reality?]

ABSTRACT

The beach is vital to Australia's economy and cultural life. As a natural system, the beach can vary in width due to a range of natural and man-made influences. An understanding of the causes of beach erosion is essential. In particular, an assessment of the likely future in terms of coastline stability will require an understanding of what constitutes a major storm or a healthy beach, and what level of variability can we expect in coastal processes. Without this understanding it is difficult to put the postulated long-term changes due to climate change and sea level into perspective.

On the world scene beach erosion has become a major issue for community debate and concern. However, many in the community have a perception that the beach should or does remain constant. Others, are aware of variability, but have not been exposed to the extremes of variability. The management of our beaches is clearly an issue in which the community at large has a vested interest. The perception of what beach erosion is within the community is an important factor in the development of effective management strategies.

This lecture deals with the current state of the beach worldwide, with particular reference to historical and current beach erosion problems in the South East Queensland – Northern New South Wales region. The various causes of natural variability and man-made influences on beaches are discussed using case studies as examples of how the cause of an erosion problem can be clarified by placing the current condition into a spatial and temporal context over short and medium terms.

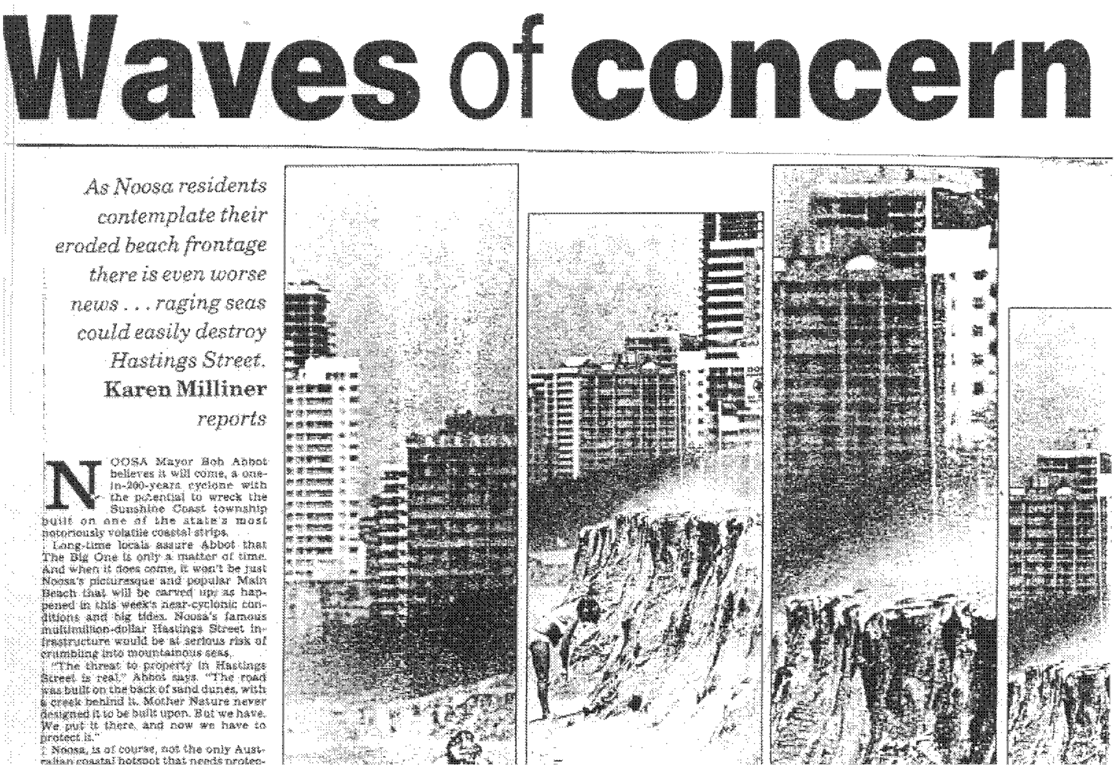
The causes of erosion have been well documented and can be classified as follows:
- Short term natural variability – beach fluctuations, storms
- Medium term natural variability – periodic changes in coastal climate and beach conditions
- Medium term erosion – disruption to local sediment budget due to man's activities
- Long term natural variability – sea level rise, geological realignment, reduction in sediment supply

The latest research into the climatic factors influencing the short, medium and long term prediction of beach erosion will be presented and discussed in terms of local evidence. In the short to medium term, natural and man-made influences can be accommodated with effective management for sustainable development on the beach front. In the long-term, our coastal communities may have to rethink their location and may be forced to consider a retreat from the beach.

INTRODUCTION

Australians love the beach. We expect to be able to use the beach at the times most convenient to us. When a beach is responding unfavourably to a natural or man-made influence, our coastal managers are often left with no choice but to act to restore the beach to the condition we want to see. Depending on the circumstances, the community will wait for natural recovery, but if an election or a peak tourist period is looming, action may be required out of phase with the natural processes. We expect such action because we generally have an idea of what our "natural" beach should look like.

Invariably, there will be a response to a beach fluctuation that implies that the beach is vanishing. When this happens the media will report the disaster in the most dramatic way (Figure 1). Of course, the reporting often can be distorted, as is the case in this article where the images are of the Gold Coast and yet the story is about Noosa.



Waves of concern

As Noosa residents contemplate their eroded beach frontage there is even worse news . . . raging seas could easily destroy Hastings Street. **Karen Milliner** *reports*

NOOSA Mayor Bob Abbot believes it will come, a one-in-200-years cyclone with the potential to wreck the Sunshine Coast township built on one of the state's most notoriously volatile coastal strips.

Long-time locals assure Abbot that The Big One is only a matter of time. And when it does come, it won't be just Noosa's picturesque and popular Main Beach that will be carved up; as happened in this week's near-cyclonic conditions and big tides. Noosa's famous multimillion-dollar Hastings Street infrastructure would be at serious risk of crumbling into mountainous seas.

"The threat to property in Hastings Street is real," Abbot says. "The road was built on the back of sand dunes, with a creek behind it. Mother Nature never designed it to be built upon. But we have. We put it there, and now we have to protect it."

Noosa, is of course, not the only Australian coastal hotspot that needs protec-

Figure 1 Recent Newspaper Report on Noosa Beach

However, the reporting can also be a real story about a very real event such as the erosion on the Gold Coast in 1967 (Figure 2). Major fluctuations such as caused by cyclones can cause disastrous outcomes for beachfront properties and local and regional economies.

Following this event, Gold Coast City Council's Coastal Engineer, Sam Smith, documented a range of perceptions of Gold Coast residents with regard to their experiences including those during the 1967 storm events (Smith 1994). These are presented below and highlight a number of the issues to be discussed in later sections.

- When interviewed during a period of calm weather over 90% of beach front residents believed that they wouldn't be affected by erosion
- The public think that a typical significant storm (*which in reality may have a 1 in 6 or so year return period*) is a very rare event and is soon forgotten

- There is a turnover of 70% of the beachfront population every decade
- The visible beach represents the whole beach
- A variation in width of the visible beach to 10 m per day is acceptable, but more is an erosion event (*This level of variation is just noise on the overall profile changes*)
- Only 5 % accept that the active beach goes out to a water depth of 15m

- The public at large do not accept the reality that 30-40m recession can occur
- There was a general belief that the dune will prevent erosion (*The dune may be only 5% of the total volume of sand that can be activated in a storm*)
- The wave breaking closest to residential property is the one doing the damage therefore the storm waves breaking offshore are not moving sand (*The waves are only breaking out to sea because sand has been moved offshore*)
- Seawalls will protect (*They do, but they also require maintenance*)
- Property owners believe that a hard surface or structure is the best protection
- There will never be an event bigger than the last one
- The amount of erosion didn't depend on the state of the beach before-hand
- A 1 in 100 year event will not occur for 100 years


The Sydney Morning Herald

Five houses collapse into pounding sea

DOZENS MORE IN DANGER – STORM HAVOC

Figure 2 - 1967 Report on Gold Coast storm erosion

Other observations made by Sam Smith were:

- Visible erosion is not necessarily a function of the biggest waves
- The media will sensationalise
- Locals are likely to understand what is happening and act – tourist will pack up and leave
- The perception of erosion hazard of new residents on the coast is similar to that of the tourist

More recently Godber (2000) undertook a property owner survey and showed that the closer you live to the coast the more you understand the potential impacts of beach erosion, and similarly the longer you have lived there the more you understand.

The management of our beaches is clearly an issue in which the community at large has a vested interest. The perception of what beach erosion is within the community is an important factor in the development of effective management strategies. It would seem that today in many respects there has been little change in the perception of beach erosion from those expressed in the findings of Sam Smith. Of greater concern is that the level of coastal development has greatly expanded, and that since the mid 1970s the eastern sub-tropical coast of Australia has not experienced an "erosion" event of the magnitude of that shown above for 1967.

Many in the community have a perception that the beach should or does remain constant. Others, are aware of variability, but have not been exposed to the extremes of variability. At Palm Beach for example, "erosion" events are often reported by the media, but studies show that at least for the last 40 years or so the shoreline as defined by the waterline (MSL) has not changed measurably. The key issue here is that property alignments have been placed within the natural active dunal system and normal erosion cycles bring waves up to and beyond the property boundaries.

To assess our likely future in terms of coastline stability, we need to understand what constitutes a major storm; what defines a healthy beach, and what level of variability can we expect in coastal processes. Without this understanding it is difficult to put the postulated long-term changes due to climate change and sea level into perspective.

A major part of the problem of perception lies in the use of the term erosion. Usually what is being referred to is the natural submersion of sand offshore forming a storm bar that is nature's way of protecting the beach. The term has such negative connotations that it should only be applied to events or actions which modify the overall sand "budget", such as the impacts of the extension of the Tweed training walls in the 1960s.

It should be objective of any coastal management plan for an area such as the Gold Coast to proactively mitigate against "erosion" caused by the likes of groynes and training walls. It should also be an objective to enhance the capability of the natural system to respond to natural forcing. Encouraging dune rehabilitation is one effective way. It is important that the community contribute to the debate on the resourcing of coastal management strategies, but in order to do that effectively the issues of perception versus reality need to be clarified.

BEACH EROSION – a worldwide perspective

Worldwide, there is a widespread concern about beach erosion. It is estimated that beach erosion has occurred on 70% of the world's beaches over the last century (Bird 1985). Mean annual recession of beaches worldwide is 1 metre per year but with specific regions experiencing up to 40 metre per year recession. The majority of these extreme occurrences of recession are caused not by natural processes such as sea level rise but by interference with the supply of sand to beaches by the trapping of sand by construction on the coastal dunes, and poor tidal inlet management practices.

The literature is full of reports on coastal erosion from every country imaginable, and in general the belief is that it is persistent and that policy is required to address the long-term ramifications. The economic impact of erosion events is enormous. Scientific studies in Malaysia, Sri Lanka, Great Britain, Denmark, The West Indies and Japan – to name a few - can be cited which show considerable lengths of coastline where beach erosion creates a major social, environmental and economic impact. For example, in Malaysia 226 kilometres of beaches are suffering critical erosion. In Hawaii it is estimated that 25% of Oahu's beaches have been lost or severely narrowed over the last century.

Bosch et al (2000) highlight the rapid increase in population in coastal areas of the United States, for example, where 53% of the population live on the coast. In 1960 there was a population density of 72 people per km^2 on the coast. By 2015 the prediction is a density of 126 per km^2.

Equally, States with the highest overall population growth include all of the beach states such as Florida, South Carolina and Georgia. Bosch et al have estimated that the coast is worth over $58 billion in tax revenue alone. However, disaster costs are estimated at $50 billion annually mainly from storms and surges. The economic cost of recent hurricanes - Hugo, Andrew and George - was $9, $27 and $5.9 billion respectively. Berz (1992) likened natural disasters to growth industries, with insured losses quintupling since the 1960s (Figure 3). Indeed Sallinger (20000) states that of the most severe catastrophes in US history, hurricanes account for two-thirds of the insured property losses.

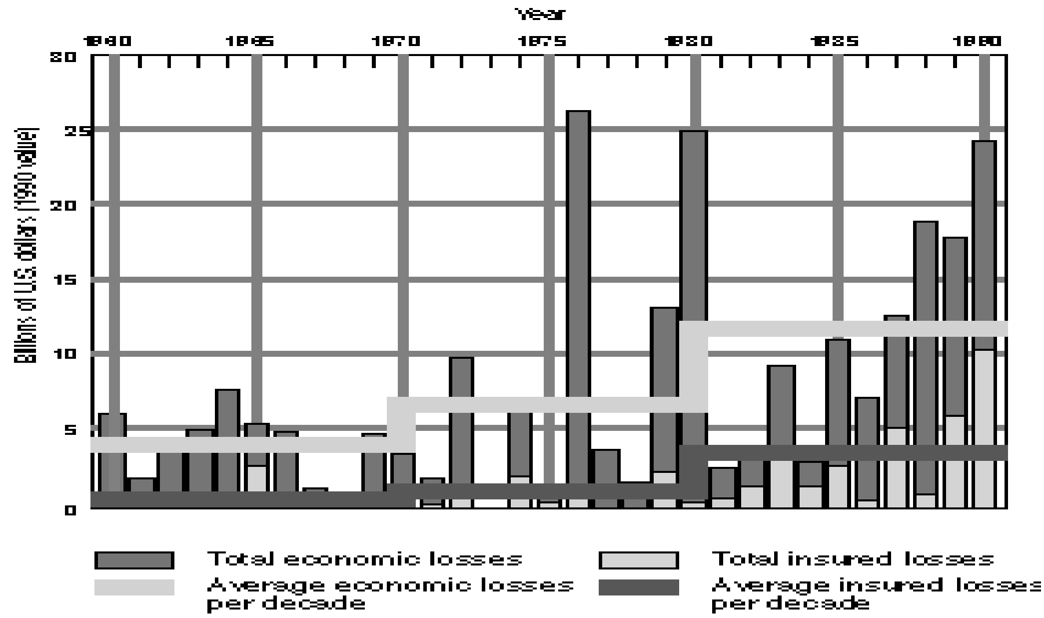


Figure 3 Natural disasters are a growth industry (Berz,1992)

In Louisiana alone, the barrier island shoreline is eroding at some locations at a rate of 20 metres per year as a result of hurricanes and other natural processes. The land is subsiding because of compaction of Mississippi delta sediments. The net effect is that sea level is rising at 1 centimetre per year. As the barriers protect wetlands these are disappearing at a rate of 40 square kilometres per year (Sallinger, 2000).

Komar (2000) reports on a range of coastal problem areas in the United States where the beaches appear to be vanishing. Komar presents a view of acceptance of the inevitability of beach erosion in the US. He states that people are a cause of coastal erosion, not just its victims.

The impact of an eroding shoreline was dramatically highlighted in 1999 when after much debate the historic Cape Hatteras lighthouse in North Carolina was dragged a third of a mile back from the shore, where it was in danger of being engulfed by the Atlantic (Figure 4). When the lighthouse was built in 1870, it was about 1,500 feet away from the beach, but the intervening years had eaten the land away. This erosion is in reality a consequence of longshore processes redistributing sand from the exposed flank of Cape Hatteras to the lee of the Cape.

The most significant cause of beach erosion on the US East Coast is the hurricane, which can result in a storm surge that can increase water levels by between 3 and 5 metres. Hence the waves break that much higher and there is considerable overwash of the barrier islands. On the US West Coast, particularly in recent years, major storms have taken a different form: El Nino. The nasty weather associated with the El Nino patterns begins when the temperature of surface water in the tropical Pacific becomes unusually warm. The heated water expands, temporarily raising tidal levels along the coast. The high tides then combine with storm waves to erode the beach. On both US coastlines the development of harbours, and the dredging associated with it, is the main cause of localised erosion. The mechanisms causing this type of erosion have been well demonstrated at the Tweed River Entrance and will be discussed in a later section.

It is interesting to note that some of the most well known beaches - those in southern California popularised by Hollywood and the “Beach Boys” – are not natural, but are the product of engineering projects undertaken before and during the Second World War. Komar (2000) reports that most of the harbors in southern California were created in that period - some carved out of the land, others dredged from natural bays. The easiest way to dispose of the dredged sediment was to dump it on the beach. Although the work was not intended to nourish the beaches, its effect was just that. Historical records have shown that the volume of sand dumped on southern California beaches at that time was immense - many hundreds of thousands of cubic metres a year. But since the early 1960s there has been little expansion of the harbors, and that source of sand has effectively dried up. Another interesting example of massive erosion is the recession of the Nile Delta shoreline, which is retreating as fast as 200 metres a year. It is generally believed that this has been caused by the construction of the Aswan High Dam on the Nile River, which was completed in 1970. Whilst it is true that the Dam did cut off the movement of sediment down the Nile, trapping it in Lake Nasser, the erosion problems had begun in the early 1900s. Further investigation revealed the real culprit: early in the century the volume of water flowing from the Nile each year into the Mediterranean decreased abruptly. In that same period, the climate changed throughout northern and central Africa, and bodies of water such as Lake Chad began to dry up. The implication was that a sharp decline in rainfall around the turn of the century had reduced the amount of silt the Nile carried to the shore, and thus increased the speed of erosion. The construction of the dam had merely aggravated a problem that began with a regional climatic shift.

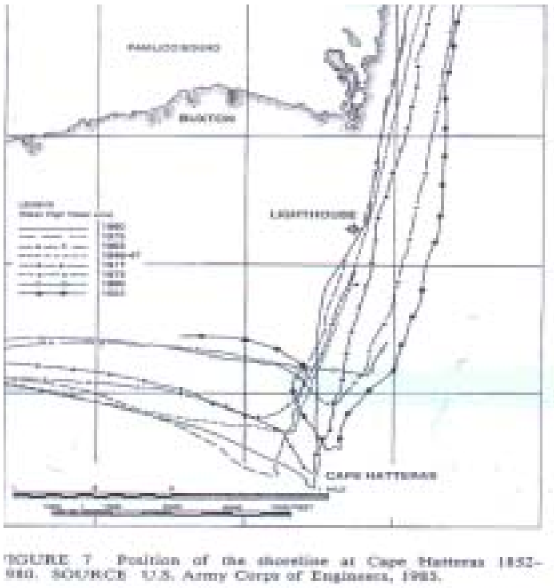


Figure 4 – Cape Hatteras Lighthouse in North Carolina

Coastal Erosion – an Australian perspective

The beach is a very valuable commodity to most of Australia's coastal communities because it attracts economic activity. The economic activity is in the form of tourism and supporting industries, and from local recreational, social and cultural activity. Coastal communities represent almost 80% of Australia’s population. Therefore, any adverse or beneficial effects on the beach and dune systems of Australia's coastline will be felt by all Australians whether directly or indirectly. Blackwell (1997) states that given Australia has 16,000km (8% of the world) of sandy coastlines – “loss of a beach can result in substantial local and non-local systemic economic effects, through lost recreational, industrial and environmental values. Proactive planning is the key to the future…”

Beach erosion issues are being managed along all of Australia’s developed coastlines, but we have yet to see the widespread public debate shown in the United States and other countries. Generally, most attention is given to the major events such as the storms of the late 1960s and early 1970s on the Queensland and New South Wales coastlines. Smith (1994) reported on the impacts of the 1967 storms when 5 cyclones hit the Gold Coast in one year after 2 decades of wide sandy beaches. Some 70 metres of sand “vanished” from the visible beach: then the last cyclone in the sequence took the lot. The impact was dramatised in the press as shown above and exaggerated on television. The media message was that the Gold Coast was ruined. As a result tourists stayed away and it took 3 years to get out of the economic depression. Natural recovery from that event took until 1971. The economic impact was assessed by Maitra and Walker (1972) and if translated into today’s economy a 1 in 25 year event such as 1967 would cost the Gold Coast 13% of tourism dollars or $305 million. A minor event of say 1 in 5 years would cost $47million. The value Australians place on living on the beach front is shown clearly in Figure 5 below.

THE BEACH – Naturally Variable or Progressively Vanishing

What is a beach? To most, the beach is a strip of sand between the water and the first onset of vegetation on the landward side. To a coastal geomorphologist or a coastal engineer the beach extends from the back of the dune system; through the section of the visible beach under water and out to a depth generally considered to be about 15 metres below Mean Sea Level (MSL). At this depth it is very difficult to detect with any ease any regular movement of sediment on the bottom.

A natural beach may move landward or seaward under the influence of wave action and ocean currents. This movement is the result of sand being transported from the beach to offshore areas during periods of heavy wave action and subsequently being returned in calm periods. A good cover of vegetation on the frontal dune landward of a sandy beach traps the sand blown from the beach by the wind and causes the dune to grow and advance towards the sea. This process, when accompanied by progressive growth of dune vegetation, can result in large volumes of sand being stored in the frontal dune. During periods of heavy wave action sand is moved from the beach to offshore areas, the beach moves progressively landward. Eventually this landward movement reaches the frontal dune. Sand is then supplied to the beach by progressive slumping of the frontal dune, slowing down the rate at which the beach moves landward. The larger the frontal dune the greater its ability to continue to supply replacement sand to the beach during periods of heavy wave attack.

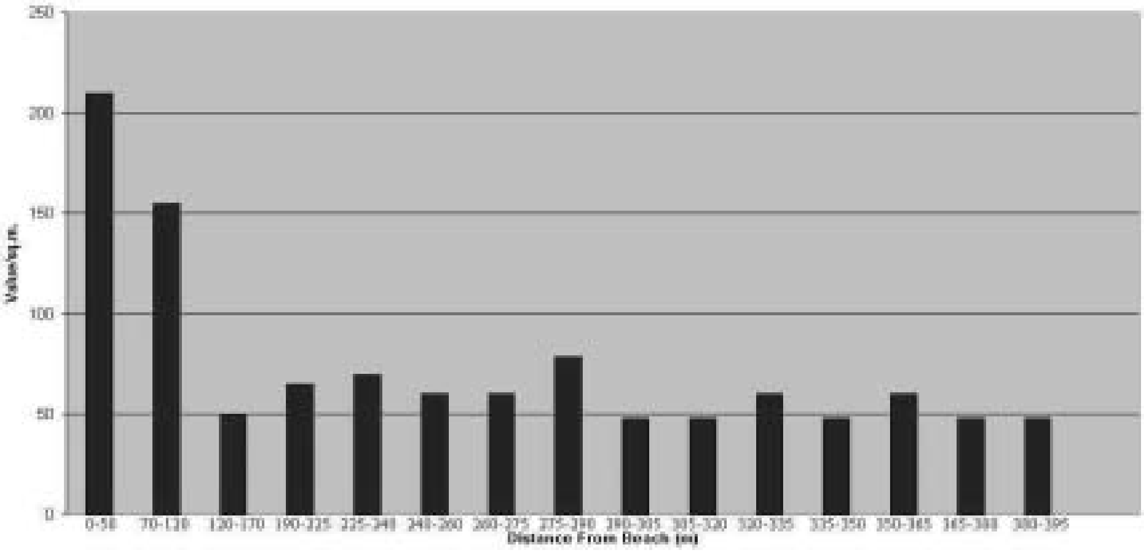


Figure 5 Property values – Main Beach

Most people expect the landscape around them to remain fixed. Our society requires that all property be clearly defined by lines on a map; our political systems are similarly defined. In nature, systems are not fixed: our weather varies constantly, ecosystems develop and decline, mountains erode and lakes silt up. On the coast, constantly varying waves and currents act to modify the shore "line”. On a developed coastline there is usually a fixed property line, and one could say that if the shore ”line” is moving closer to our fixed property lines then the beach is eroding.

Types of Beach Erosion

On the Gold Coast and other parts of the eastern seaboard of Australia, beach erosion is a fact of life, but to what extent do we understand the causes of erosion and the long-term implications? Is the erosion “real”, in the sense that the beach will vanish if nothing is done to manage the problem, or is it “perception”, in that the beach is a dynamic system and we may be witnessing it’s natural variability.

The causes of erosion have been well documented and can be classified as follows:
- Short term natural variability – beach fluctuations, storms
- Medium term natural variability – periodic changes in coastal climate
- Medium term erosion – disruption to local sediment budget due to man’s activities
- Long term natural variability – sea level rise, geological realignment, reduction in sediment supply

SHORT TERM NATURAL VARIABILITY – Submersion or "Claytons Erosion"

A daily visit to the beach will demonstrate that the beach width varies constantly due to the change in tide and wave conditions. This is what might be termed "noise" in the system and it can be clearly seen on the coastal web-cams that have been established recently. As discussed earlier, this is not erosion in the negative sense of the term, rather it could be termed "submersion" because nature takes sand from the visible beach and submerges it offshore as part of a self-protecting system. This kind of erosion could also be called "Claytons erosion" – the erosion you are having when you are not having erosion.

Data collected by coastal researchers such as Sam Smith over many years have been analysed to show that the annual variability under average conditions is considerable. It is clear from these data that reports of erosion for a particular beach which are based on a limited number of "snapshots" in time of beach profile or aerial views, cannot be relied on to give a representative value of the beach fluctuations. Beach behaviour must be considered statistically if the only data is from random aerial photographs or surveys. This highlights the problem of coastal management studies being carried out over a few years of specific conditions and long term planning being based on this.

Shoreline Changes At Palm Beach

Recent studies of Palm Beach have provided a clear indication that despite the perception that the visible beach defines the overall stability of the beach, there is no correlation between the visible beach and the amount of sand in the whole beach profile. From a management point of view this is critical, as it is the health of the whole beach that is important. As shown in Figure 6 the average range of shoreline variations for Palm Beach is approximately 30 metres (+ or - 15 metres) during the last 14 years, with a maximum 40 metres on the beach survey line ETA 32 which is between 7th Avenue and 9th Avenue. In 1974 and July 80, after the cyclone events, the shoreline position was 100 metres landward of the actual position. There are no abnormal variations of Palm Beach compared to the behaviour of a normal beach. The narrowness of the buffer make the variations, which are relatively natural, threatening for property development, located just 5 metres behind the boulder wall.

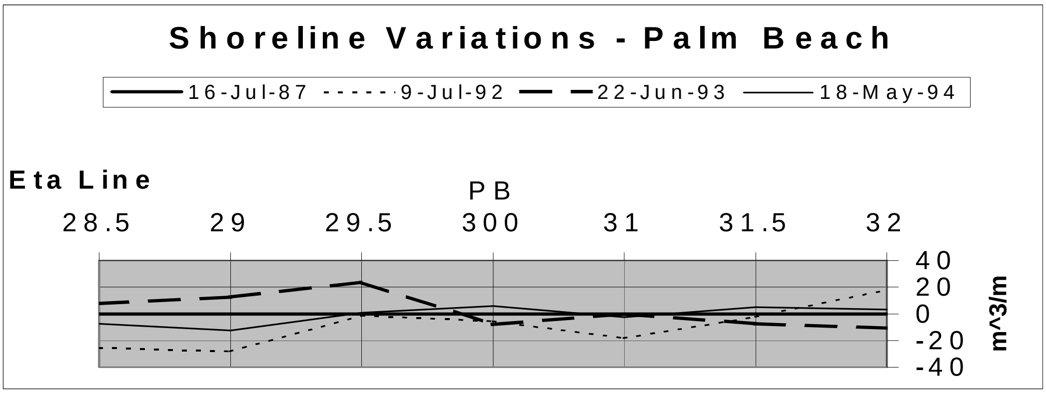


Figure 6 - Shoreline Position along palm Beach 1987 - 1994

Although we could expect variations of the shoreline to be related to the variations of sand volume in the total offshore beach profile, there is no evidence that the rate of erosion/accretion of the visible beach is proportional to the sediment input in the beach compartment. This is shown by comparing the sand volume data (Figure 7) with that of the shoreline position (Figure 8). For instance, on Currumbin beaches, a loss of only 127 m^3/m from the beach profile have induced shoreline erosion of more than 64m between November 95 and June 96. At the same location and for a different period, a loss of 117 m^3/m from the beach profile has only induced 0.64 metres shoreline erosion during a 3 month period.

The visible beach is a minor part of sand redistribution along the beach profile that goes offshore underwater. The seabed is a "sand eater", because it temporarily stores the supply of sand in building the storm bar that will protect the visible beach or berm. Even if there is an additional volume of sand in the active prism, the berm will only reach its natural position after the accretion and stability of the seabed and the storm bar when the wave climate requires its build-up. Without the condition of stability, the recovery of the berm is slower, even under large amounts of accretion in the prism (the volume of sand which is available for movement on the beach profile).

The accretion of the berm is faster when the seabed is stable and is not required to build up a storm bar. The most part of the temporary erosion of Palm Beach is due to the onshore-offshore sand redistribution. The active prism plays a role in the wave energy absorption and the visible beach is just a minor compartment of the total profile. However, natural exchange with the dune and the underwater profile represents a non-negligible amount of sand:

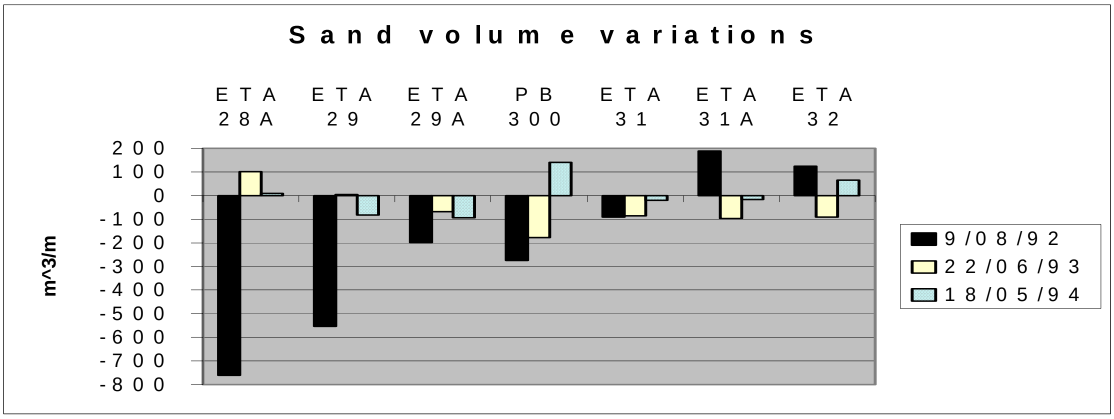


Figure 7 - Sand Volume along Palm Beach

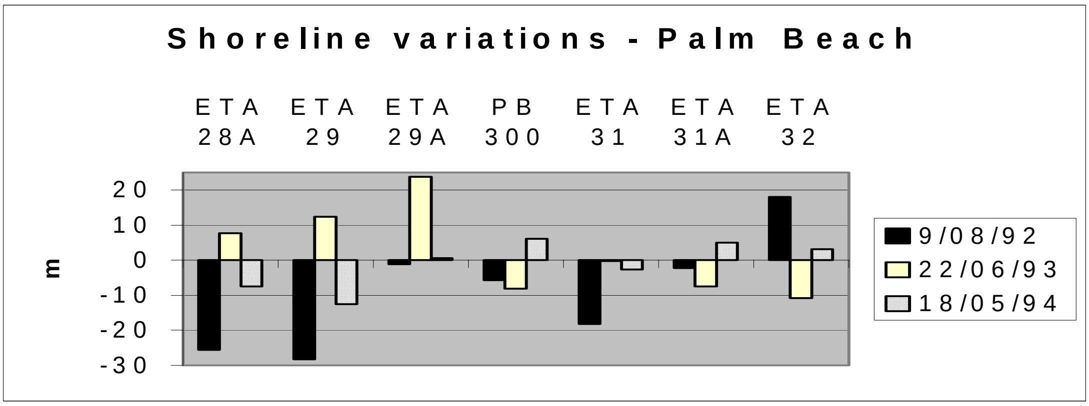


Figure 8 – Beach Width along Palm Beach

- the storm bar extends some 100-200m seaward from the MSL water level
- the storm bar moves back onshore after storm cut
- the seabed out to 400m can move by over 3m vertically to build up the storm bar

From the surveyed profiles of the beach we can recreate the wave climate history and understand that even under a lack of supply, the beach has been able to keep the shoreline around its equilibrium position. During high-energy storms, huge sand movement extends sometimes between –10 m to –20 m, without any apparent erosion or accretion of the shoreline.

Short Term Natural Variability - Extreme Events

At the extreme end of the scale of natural variability is the impact of a cyclone or major storm. The majority of our cyclones impact on the coastline in north Queensland. But occasionally they track down the coast bringing with them very high waves and wind conditions. The occurrence of these events on the Gold Coast is shown in Figure 9.

Equally, large low-pressure systems in the Tasman Sea can generate very large south easterley storms which can cause significant damage to our coastline Cyclones can generate waves up to a recorded height of 13 m off the Gold Coast beaches. As waves travel into shallow water they are transformed through shoaling and refraction processes and possibly end up with wave heights of about half of that by the time waves break at the shore. This energy is dissipated effectively through transfer of the kinetic energy of the wave to mechanical energy of moving sediment around on the seabed. Nature becomes self-regulating and the sand is generally moved offshore and deposited in a bar from where even more energy is dissipated helping to protect the beach. The consequences of these large events can be that up to 100 metres of beach appears to vanish. The social and economic impacts of this have been discussed above. All things being equal the majority of the sand submerged offshore during the event will, however, return to the beach over subsequent calm periods.

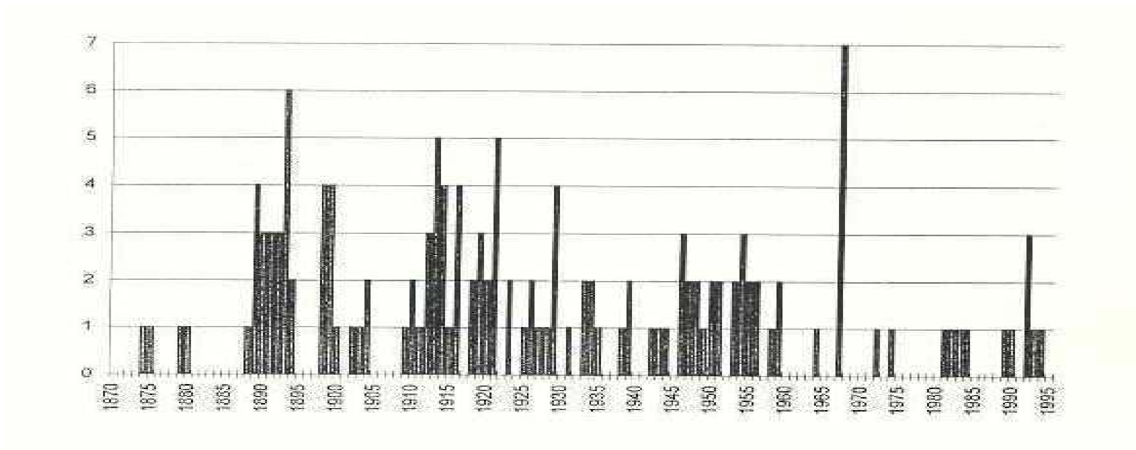


Figure 9 – Cyclone Occurrence – Gold Coast

To put these events into perspective you would need to experience one. Part of the difficulty in preparing management strategies for such events is that the majority of the population are new residents or holidaymakers. The number of people who experienced the Gold Coast storms of 1996, 1988, 1974, 1972, 1967 1954, 1936, 1921 and 1896 would certainly diminish exponentially going back in time and yet there is evidence that the magnitude of these storms increases on average in the order shown.

Figure 10 shows a photograph taken in 1936 after the storms of that year exposed an old seawall believed to be constructed in the 1920s to protect Narrowneck. This wall was replaced in 1936 and was exposed again in recent years. This is a good example of the cut and recover cycle we see when major storms hit.

Figure 10 – Beach Protection at Narrowneck 1936

MEDIUM TERM NATURAL VARIABILITY – "The right place at the wrong time"

What about the medium-term – a period of time of say 10 to 70 years. This is a lifetime for many of us and is a time frame that engineers and coastal managers can relate to, because it usually encompasses the design life of many management decisions. A brief examination of the history of development of places such as Byron Bay, Tweed Heads and Noosa for example indicates a key parameter in the issue of this medium term variability and the need for beach erosion protection. These and many of our coastal communities were first developed at times when there was relative calm weather and wide beaches. They may also have been located for purposes that are no longer relevant. This is particularly the case for Byron Bay with the original need being for sheltered mooring for sailing ships. Being in the lee of a major headland may be ideal for this purpose, but because these locations demonstrate high levels of natural variability in beach width they are not ideal for subdivision. Invariably, many of our coastal communities have been located in the right place in a broad sense, but at the wrong time in terms of accommodating the natural variability of the coast.

Our coastal residents don't always live in the one spot for any length of time with the majority of people who live on the Coast arguably have only moved there since the 1970s and in a sense have not experienced major events.

People who live at Byron Bay similarly have on average only moved there recently The "known" characteristics of the beaches at Byron Bay which is seen to be normal are only so within the context of a relatively cyclone free period for the last thirty years. Noosa is in the same situation with very few who claim a knowledge of the system having lived there for more than a few years.

There are significant changes to beaches at longer-time styles and there are a number of causes including El Niño. However at an even longer time scale we are seeing evidence of far more significant variation that appear to cause erosion cycles on the beaches over periods of 20 to 30 years. These variations can be quite significant. A report undertaken for example in 1978 for the region of coastline from Cape Byron up to the Tweed Coast demonstrated that in the preceding 20 years or so the coastline there had been receding at a very significant rate. Major pieces of infrastructure such as the Kingscliff bowling club were under significant threat from erosion and great concerns were held as to whether this would be a continuing trend which would see the shoreline recede right back into beach front developments. These predicted outcomes have not eventuated however, and yet at other locations such as Noosa there has been significant erosion over the same period.

The development of our beach front has really only occurred since the 1940s and has intensified significantly since the mid-1970s. In many cases the original land development in our coastal communities occurred during periods of relatively calm weather and wide beaches. This was the case at Currumbin where an early subdivision at the turn of last century was gazetted to the seaward of the current Marine Parade, only to disappear in storms a few years later. This can be seen in the history of Noosa for example. In the 1920s there was very little real development on the coastline. Kiosks were known to be built on sleds so they could be pulled landward in the event of the major storm. In the 1940s major structural damage to public infrastructure was evident, but still no one was concerned as the beach always returned.

As development pressures intensify in the Sixties and Seventies the need to protect property becomes the dominant factor in coastal development (and as such, when major storms occur in the late 1960s, the immediate responses is to construct rock protection for the properties). In the case of Noosa, development intensified within the estuary and the need to protect those developments from a scouring river channel resulted in major structural changes to the coastal region with the relocation of the river entrance. The system then develops a new equilibrium and the local authority is faced with ongoing beach management in order to maintain appropriate beach width and to maintain the economic driver that their communities have come to depend on.

The same situation exists at Palm Beach where property development has occurred right up to the high water mark on many sections of the beach. Following the 1967 damage the rock wall was put in place to protect those properties, but still development continues. Under these circumstances the natural scheme of things has been replaced with an artificial set of parameters. Prior to this sort of development the beach was a dynamic system of variable width, of variable form but always returning to an average condition. Once properties are developed near the shoreline we have an artificial boundary condition imposed on the beach system, which still wishes to move in response to those natural conditions but is restricted by the imposition of a hard boundary.

A dilemma for beach front residents is that these boundary conditions have been imposed on our natural systems, but are our communities willing to except the price of the imposition.

Whilst news reports will indicate gloom and doom about the state of our beaches, a comparison of recent events with the 1967 cyclone, shows they have relatively minor impacts on our beach systems, and in a sense our communities have moved into a period of complacency because of this lack of major natural occurrence.

The lack of major storm events along our sub-tropical coastline in the last 20 or 30 years may be the result of what is termed the Pacific Decadal Oscillation (PDO). This oceanic circulation can result in very significant changes in the overall water mass energy over periods of 20 to 30 years.

Figure 11 shows an index for the PDO which characterises activity in the western Pacific corresponding to the periods of our most severe storms in southeast Queensland. Most evident are the very intense storm activities that occurred from 1967 through to 1974. But it can also be noted that since that time there has been very little in terms of major impact except for the possibility of a minor storm cyclonic event in the early 1990s. What does all this mean in terms of our beach systems as a resource?

sand around major headlands such as Noosa and Cape Byron. As a result sand builds up on the beaches to the south of these headlands and is stored away in the coastal dunes. Consequently, the reduction in the average sand transport past the headland results in persistent erosion on the beaches to the north. This has occurred at both Noosa and Byron Bay. It is an irony that major storms are perceived to be the main cause of short term erosion, but they may also be the necessary mechanism for medium term stability of the beaches over a wider region.

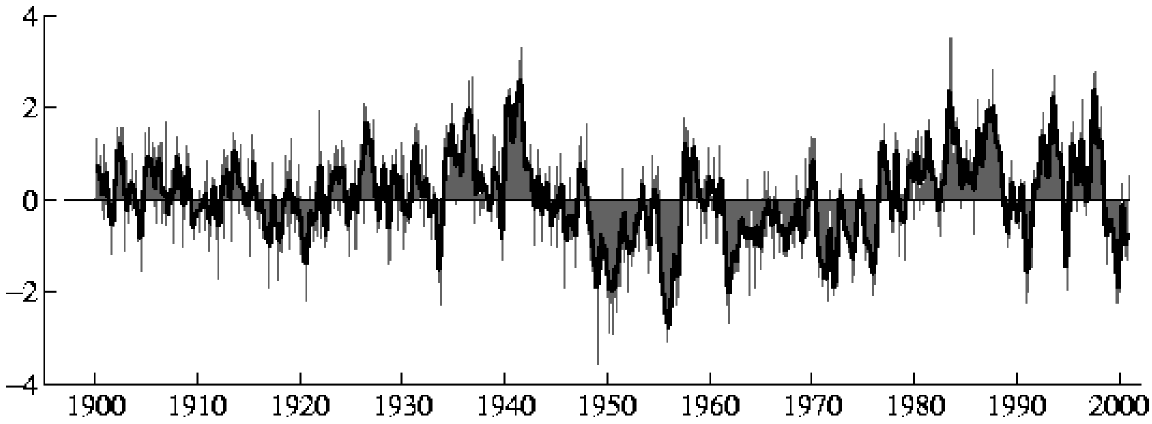


Figure 11 – Index of Pacific Decadal Oscillation

This oceanic feature may hold the explanation for the progressive erosion that has occurred at some locations since the late 1970s. During periods of reduced storm activity there is less energy to mobilise

MEDIUM TERM EROSION – "The beach versus development"

It is generally acknowledged that much of the erosion evident along the coast of the US in particular, but in many other countries as well including Australia, is directly related to man's activities. Bird (1985) puts the blame on five major activities – these being:

- the stabilisation of river and tidal inlets;
- dredging activities (stemming from the above)
- the construction of buildings and facilities on sand dune systems;
- sand mining; and
- any forms of human recreational activity which directly result in beach and dune degradation and or erosion.

As noted earlier, Komar (2000) has identified harbour dredging as the major influence on the Californian Coastline. On the eastern coast of the US, tidal inlets have been trained and dredged for navigation purposes for well over a century. Sand dredged from inlets has until relatively recently been dumped offshore and lost to the active beach system. This has resulted in severe erosion downdrift of inlets. Once depleted of sand supply the beach is particularly vulnerable to storm attack..

Along our coastline, the Tweed River entrance is a classic example of the impact of entrance training works on the longshore movement of sand. Following the extension of the training walls in 1962-1964 a large volume of sand began to be trapped on the updrift beach of Letitia Spit. This combined with other modifications to the movement of sand past the entrance, namely the infilling of the entrance in response to dredging and the growth of a new ebb tidal delta, resulted in a depletion in supply of sand to the Gold Coast beaches of up to 10 million cubic metres. The resulting erosion of beaches at Rainbow Bay, Coolangatta, Kirra and Bilinga over the subsequent thirty or so years has had a major impact on the recreational amenity and economic activity of that part of the coast. Major engineering works have been carried out to overcome these impacts culminating in the artificial bypassing system currently in operation.

Now that a permanent solution – The Tweed Bypassing System – is in place it has highlighted the role of perception within the community and the engineering profession in the management of an artificial beach system. There is an expectation by some that the beaches at Rainbow Bay and Coolangatta should be kept quasi-constant and have certain features. The evidence of how that system worked prior to the 1960s would suggest that it was highly variable in terms of the width of the visible beach and other characteristics. The community's expectation also varies at each beach location. Duranbah Beach for example, has become one of the most popular surfing spots on the coast because there usually is a wave breaking on the Tweed ebb tidal delta – one of the outcomes of the bypassing system will be to reduce the size of the delta. At Rainbow Bay the "traditional " shallow lagoon separated from the surfing breaks off Snapper Rocks is seen as a desirable feature to be maintained – however there has been substantial volumes of sand off Rainbow and Coolangatta as part of the natural system as is clearly shown in the photo of Coolangatta in Figure 12. The community's perception of what is natural or desirable often is contrary to the reality of the system.

Other less severe erosion takes place when smaller structures such as groynes are constructed. This usually managed by nourishing the beach to compensate until the structure is fully bypassing the natural flow of sand. Coastal development is targeted as the other major cause of erosion. This is because if the development has occurred on the active part of the beach dune system then the need to protect the structure from undercutting during storms results in the locking up of sand which would normally feed the natural system of storm bar building.

Figure 12 – Greenmount Beach

Isolated development will have a minimal effect in this regard, but where there is ribbon development there is a gradual denuding of the dunal sand supplies. The issue of “property versus the beach” is commanding much research, public debate, and governmental deliberation in the US. It is a fundamental question of whether to retreat in the face of a receding shoreline or to protect property at all costs. Despite the extensive development along the Gold Coast there is generally a sufficient sand buffer available to accommodate natural variability due to storms. In some cases, such as Palm Beach, that buffer is very minimal and at Noosa Main Beach it is non-existent under the current wave climate regime. At Byron Bay and Narrabeen in Sydney the question of property protection is becoming a major community issue. Warringah Shire Council adopted a buyout policy as part of its approach to the ongoing erosion at Narrabeen beach.

Attitudes to beach protection seem to vary considerably around the world. Publications such as Searle et al (1985) are typical of those that attempt to increase the understanding of the need for coastal protection and the consequences of not doing so. There are many more publications that identify the role of protection structures in overall beach erosion and present the view that there should be no further hardening of the shoreline. In particular, there are many perceptions about the role of seawalls, the benefits of nourishment and the need for long term strategies. Seawalls are often singled out for mention, and it is well known that the seawall will lock up sand normally used by nature to accommodate the storm erosion. What seems to be lost on many commentators is that the seawall has been placed there <u>after</u> properties have been threatened by erosion not before, and as is the case on the Gold Coast, the seawall is a last line of defence. Similar confusion exists about beach nourishment. The classic comments from eminent environmental commentators on TV programs include criticism of beach nourishment because a storm came and removed it – what is not discussed is what would have happened had there been no nourishment. Nourishment can be resoundingly successful as demonstrated by the work done at Surfers Paradise in 1974 where the nourishment was required to circumvent the natural recovery processes following an extended period of storm events. It is frustrating to read many reports on beach erosion where the commentators presumably prefer the easy way out by washing their hands of the complex legal, social, economic and political issue of prior beachfront land ownership which will control one of the most likely alternatives to beach protection – that of retreat from the shoreline.

NOOSA – A Case Study

The following section outlines the findings of a recent study of Noosa Beach (Jackson et al 1999) which highlight a range of the issues discussed in previous sections. It is presented as an example of how the cause of an erosion problem can be clarified by placing the current condition into a spatial and temporal context over short and medium terms. Noosa is a good example of the complexity of many beach erosion problems that are partly due to natural variability and partly due to interaction with human activity.

The contemporary recorded history of Main Beach at Noosa is one of constant concern over the width of the beach and the consequent loss of amenity and threat to property. The impression is given throughout the documentation (and by local residents) that the beach is highly vulnerable to even relatively minor storm attack. A real concern is that another cyclone of the magnitude of those experienced in years gone by will devastate the beach.

For at least 100 years prior to the late 1960s, the Noosa Beach estuary system was in dynamic equilibrium. The earliest surveys of the area were hydrographic charts dated 1870 and 1876. These were carried out to support navigation into the Noosa River for the purposes of transport of primary goods out of the region and transport of prospectors heading for the Gympie gold fields. Major events such as cyclones and floods disrupted this system for short periods of time, but the system seemed to recover without any major concern.

Property development in the first half of the 20th Century was of a temporary nature and coastal construction acknowledged the variability in beach widths. Cyclones reported in 1893, 1910, 1928, 1931, 1936, 1947, 1954 all created considerable erosion of the beach front, with the loss of dunal casuarinas on many occasions. The cyclone seasons of 1947/48 and 1954/55 were particularly severe when 3 cyclones struck in succession each time. In both the 1928 and 1947 cyclones, property was either damaged or, in the case of the 1928 event, relocated away from the erosion scarp. Photographic evidence shows that these storms cut back to within the property boundaries along Hastings Street (Figure 14).

Apart from temporary retreats from the storms there were only a few documented attempts at coastal management. These included the construction in the late 1930s of a paperbark-stake fence that acted to retard the backwash during run-up of large waves.

Figure 13 Noosa River entrance from the late 1960s

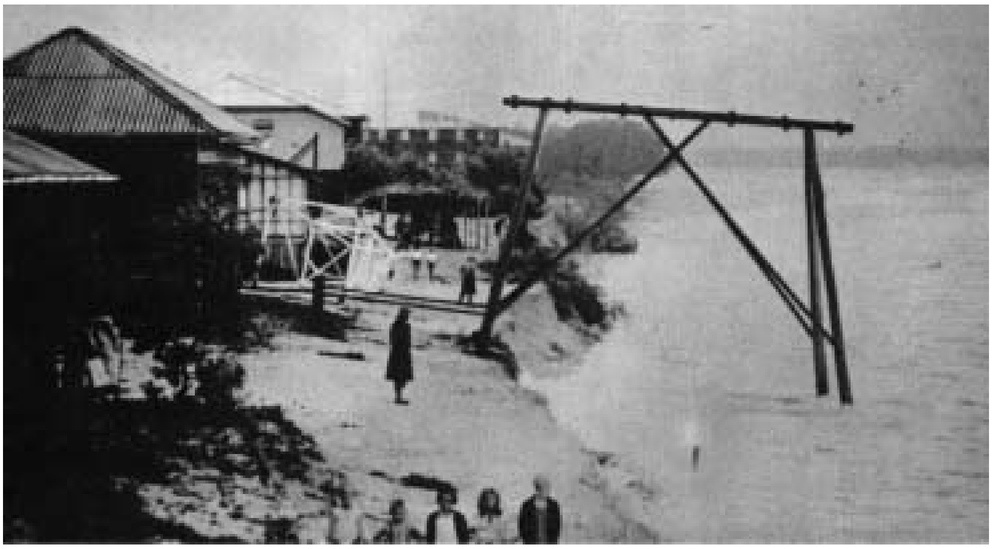


Figure 14 Property damage during 1947 storm

The key features in the period up to the mid 1960s are as follows:

- For most of the 100 year period for which data are available, the beach alignment was fairly consistent along the eastern end of Main beach and the present alignment, although partially modified by the seawall, is along this alignment (Figure 15).
- The beach was uncharacteristically wide in 1940 following a rapid accretion from the 1926 alignment – as with other coastal resort areas in Queensland and New South Wales, this period also corresponded to the first significant increase in the level of property development.
- The beach was again significantly wider in 1967, with the cutback due to the 1967/68 cyclones clearly shown by the 1969 alignment.
- The entrance location varied longshore by a few hundred metres over the 100-year period.
- Using entrance migration as an indicator of the magnitude of longshore sediment transport, it would appear that, prior to 1926, 1940 and 1967, sand was in good supply, with the 1940 and 1967 conditions being notable.

In general, it can be inferred that prior to about 1967, Noosa spit was relatively stable with the natural dune system accommodating storm cutback. It would appear that the regular impact of cyclones (on average one large event every 10 years) did not have any long-term recession effects. Recent investigations have led to the conclusion that cyclones not only cause immediate storm cut-back, but also provide the driving mechanism to release large quantities of sand from the south around Noosa Heads and into the Laguna Bay system, thereby providing a long-term supply of sand to rebuild the beach. This process is evident in the beach behaviour described above in that the beach is not only at its widest in between cyclone events, but also is transporting the largest amount of sand longshore causing entrance migration.

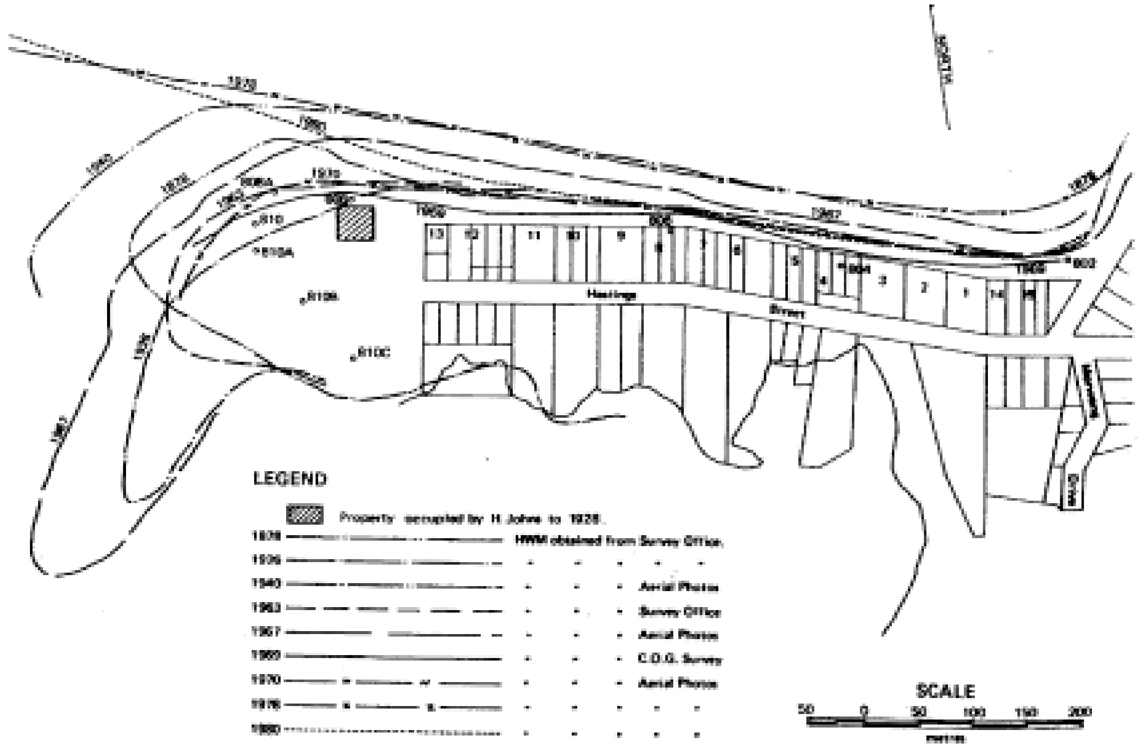


Figure 15 High Water Marks along Main Beach

By the mid-1960's, substantial property development was commencing at Noosa, with plans to carry out major reclamation within the estuary for residential development. The major storm events in 1967 – 1968 caused significant damage that prompted property owners to dump rocks for protection along Noosa Main Beach (Figure 16). It should be noted that this and previous severe erosion occurred before the training wall, groyne and seawall construction, and was the catalyst for the boulder wall construction.

This was consolidated into a rockwall running the full length of Main Beach, which is shown fully exposed in Figure 17. Following the construction of the wall, the recovery of the beach was slow initially, and had not fully recovered by the time of the storms of 1972-74. In this period, there was no useable beach at high tide for much of this time. These storms caused significant erosion of the spit at Noosa Woods with major damage being caused there during the floods of January 1976.

Beach nourishment was planned after the 1972-74 events, but a relatively small amount was pumped onto the beach as the council was unable to afford a complete nourishment exercise. The source of the sand was the flood-tidal delta within the estuary. Following the cyclones and flooding of the mid-1970s, 1977 was a very dry year. Large amounts of sand returned to the beach during 1977-78 but did not cover the seawall. With the reduction in flooding came a return to normal regime conditions in the estuary, and signs by 1977 of a re-establishment of the northern channel as the main flow path.

In order to manage the movement of the tidal entrance channels within the estuary, the entrance was relocated in 1978. The effect of the entrance training on the beach has been to translate the ebb-tidal delta to the west, away from Noosa Woods and Noosa Main Beach. This has eliminated the protective offshore delta of sand. However, this shift of the entrance is not solely responsible for the erosion of the Noosa Beach foreshore, as historical photographs show that coastal erosion was occurring along Noosa Beach when the entrance was adjacent to Noosa Woods (Figure 17).

Figure 16 Individual Rock walls dumped by property owners in 1967 (Ref. Cato, 1979)

Figure 17 Rock wall along the foreshore in 1972-73 when the Noosa River estuary entrance was adjacent to Noosa Woods.

With the re-training of the entrance, a new vegetated and relatively stable beach has formed between Noosa Woods and the entrance groyne (Figures 18 and 19). It would seem that during this period the combination of the seawall and associated enhanced sediment movement, and the natural rapid infilling of the estuary (ala Tweed R entrance after dredging of the estuary) prevented the ebb-tidal delta from growing.

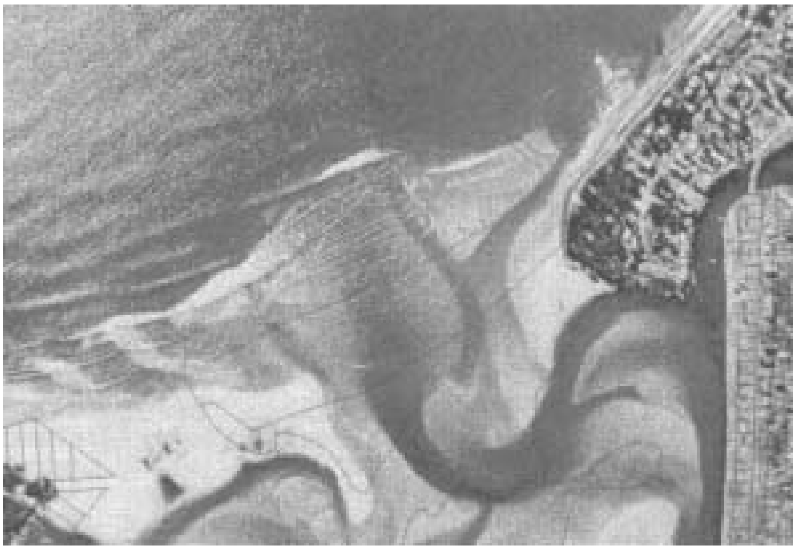


Figure 18 Entrance prior to relocation of river mouth - May 1978

Figure 19 Entrance after relocation - October 1978

The re-location of the entrance was followed by 200,000 m^3 of nourishment. This, however, had eroded back to the seawall by the end of 1980. In response to this a rock groyne was built at Noosa Woods with the intention to re-align the beach and create a useable beach to the east. Following the construction of the groyne, 220,000 m^3 was dredged from the estuary shoals for nourishment. Surveys showed erosion both east and west of the groyne from July 1983 to July 1987. The erosion was blamed on insufficient supply around Noosa Headland. A further 140,000m^3 was pumped onto the beach in December 1988, with recommendations that regular nourishment was needed if a usable beach was required.

In the period of time since this initial response to the training of the entrance and groyne construction in 1982-83, the system (Figure 20) has been slowly establishing a new entrance/beach equilibrium which has the following main features:

- The entrance is in filling in response to the dredging undertaken at various times for beach nourishment, as well as the re-alignment of channels to achieve a new regime.
- The ebb-tidal delta is continuing to grow slowly in sequence with the in filling. However, it no longer acts as a buffer for the recovery of Main Beach, nor as the "control point" for the beach alignment along Main Beach.
- The absence of major cyclone events has limited the supply of sand around Noosa Headland.
- A new "control point" for beach processes and alignment has been established with the combination of the new entrance location and the less extensive shoaling associated with the new ebb delta.
- The beach has realigned in response to this lower supply rate and the new "control point".
- In the period from 1983 (post Noosa Woods groyne) to the present, the new alignment has been "dynamically stable", albeit in a configuration which results in cutback to the seawall for much of its length and for the majority of the time.
- The estuary and beach systems are still strongly linked.

Figure 20 Aerial photograph of recent day conditions - February 1998

Summary

The current concerns at Noosa have there origins in a combination of medium term natural variability in sand supply to the beach and the nature of the management responses to the short term events in the 1970s. Solutions being considered for Noosa have been developed within the framework of a range of viewpoints on what are the key features that need to be enhanced or preserved, but there is general accord that a usable beach width needs to be maintained.

LONG TERM NATURAL VARIABILITY

Geological evidence shows that our coastline has experienced major fluctuations over many thousands of years in response to sea level rise and fall during the interglacial/glacial cycles. The levels have been in the range of 120 metres lower to 7 metres higher than the current levels. On average global sea-levels have been gradually rising since the conclusion of the last ice age approximately 15,00 years ago, with the level being relatively stable for the last 6000 years. In our region the shoreline would have been up to 10 km offshore during the last Ice –Age (Figure 21).

Over the last 100 years sea level is believed to have risen by 1 to 2 mm per year. These rates have varied significantly from one location to another because of factors such as land subsidence in places like the Mississippi Delta. Linked to this and other factors is beach erosion, which has occurred on 70% of world's beaches over last century. The mean annual recession is 1 metre per year but can vary up to 40 metres per year where there are a number of natural processes acting as well as erosion due to human activity.

In the case of the coastline in northern NSW and southern Queensland the shoreline is still realigning at a geological time scale to be in balance with the predominant wave climate – being from the southeast.

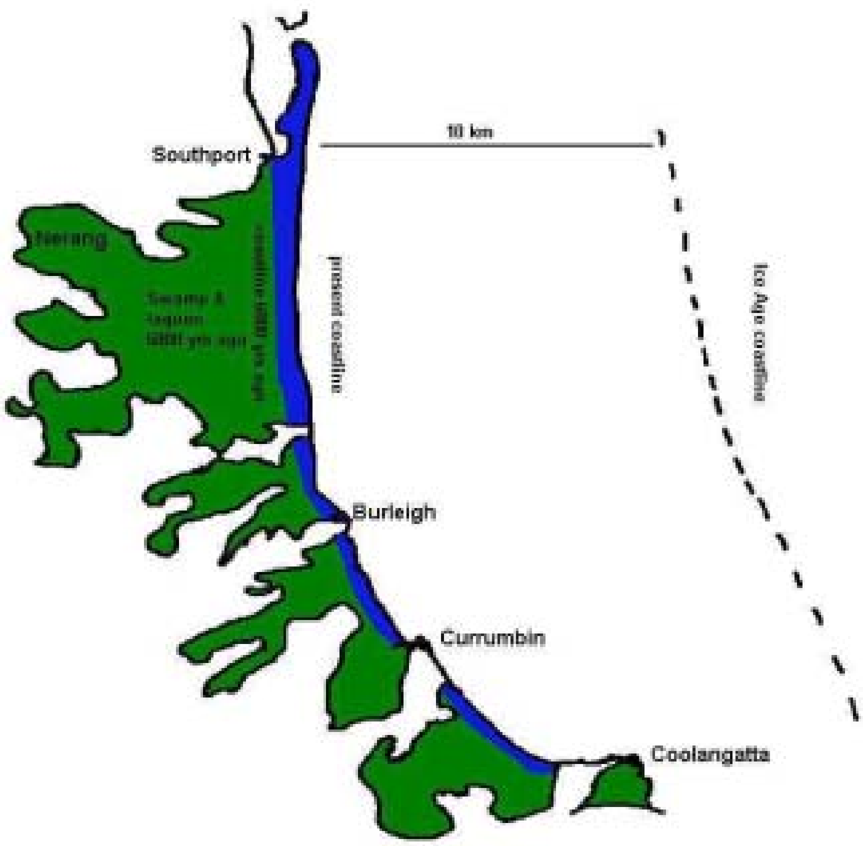


Figure 21 Ancient shoreline

The net result of this reshaping is that our coastlines are taking on the form of what are termed zeta curves or log spiral embayments. These shapes describe all the major embayments from the Clarence through to Fraser Island. The difficulty with this in a geological timeframe is that the supply of sediment into the system has diminished. The wave forces still haven't generated a full Zeta alignment in all these embayments and sediment is still moving alongshore. The only source of sediment would now appear to be from the beach itself and hence the southern end of embayments are continuing to erode as the beaches try to realign. Stephens et al (1981) have estimated that over the last 300 to 400 years the coastline has been receding at a rate of 0.2 to 0.35 metres per year at various places in our region. This process may take hundreds or thousands of years to reach an equilibrium and provided there is enough sand in the system, beaches to the North will be affected little by this process.

A recent study by Moratti and Lord (2000) of a site north of the Clarence River shows high levels of recession over a number of decades. They predict that this is likely to accelerate with sea level rise given that there are no more beach dunes left to provide the sand. This is the start of the regional littoral drift compartment which ends at Fraser Island and may be the first documented evidence that a period of regional long term recession may be commencing. The recession rates reported in this study were 0.9 to 3 m per year.

Byron Bay – A Case Study

In the case of Byron Bay, all of the available evidence suggests that the embayment has been experiencing long-term persistent recession, due primarily to the deficit in supply of sand around Cape Byron (and offshore losses due to the East Australia Current) – see Figure 22. Superimposed on this long-term recessional trend is considerable variation in location and in time and in particular there is strong evidence of the decadal scale trapping of sand to the south of Cape Byron as discussed earlier. As the shoreline adjusts to the prevailing wave climate (over hundreds of years) the brunt of the recession is focussed on the section of beach in the hook of the embayment where the wave shadow effect of the headland begins to diminish (and consequently the longshore transport rates begin to increase back to the regional open coast values). In Byron, this occurs around the Belongil area. Under long-term average conditions the beaches nearer the headland can appear to be experiencing less recession because of the large reserves of sand in the offshore profile providing a buffer. In recent times the groyne effect of the Memorial Pool revetment has also added to this perception of stability at least to beaches to the east. Given that this overall long-term recession is believed to be due to the deficit in supply at Cape Byron, it is reasonable to envisage a management strategy which could return sand to the system from the offshore lobes of sand to the south of Cape Byron.

Superimposed on the long-term trend are variations at a range of time scales from decades down to hours. Indeed it is still not clear that given our relatively short historical record whether what appears to be a long term recession can still not be explained in terms of decadal scale variability. The key to understanding the variability of the shoreline at locations such as Byron is in the nature of sand movement past major headlands such as Cape Byron. It would appear that here and at places such as Noosa there is a wave energy threshold needed to transport significant quantities of sand around the headland. During periods of calm average conditions sand will build up south of the headland with only nominal bypassing occurring. During such times sand supply to the downdrift beaches will depend considerably on the state of the offshore shoals that develop in the lee of the headland. Major storms provide sufficient energy to force higher rates of bypassing at the headland, with sand being transported across the embayment. This acts to isolate the beaches near the headland, but also replenishes the offshore shoals. During periods of regular major storms (at decadal frequency) – such as that occurring for the majority of this century, this cycle of headland bypassing would result in the beaches in the Belongil area being eroded during the storm, but recovering (albeit with a phase lag) as sand is returned to the beach from the offshore reserves. During the intervening calm periods an ever-decreasing supply from these reserves will maintain the beach.

However, as in the case of the period since the 1970s, the lack of major storms needed to activate the headland bypassing will result in depletion of the offshore shoals and consequently in recession rates increasing throughout the hook of the embayment. This increase would be particularly evident in the area where the offshore sand transport pathways intersects the shoreline – i.e. the Belongil area. As demonstrated by the response of the beach in this area following the 1999 storms (the beach has recently been in accretionary phase), this increase in recession rates is only temporary until sand supply is restored past Cape Byron. A return to more regular major storm events would thus see the recession rates reduce in the Belongil area.

Under the current scenario, a major storm occurring in the near future would now cause significant shoreline damage, but is needed to return the system to a more favourable condition – albeit one which has a long-term recessional trend.

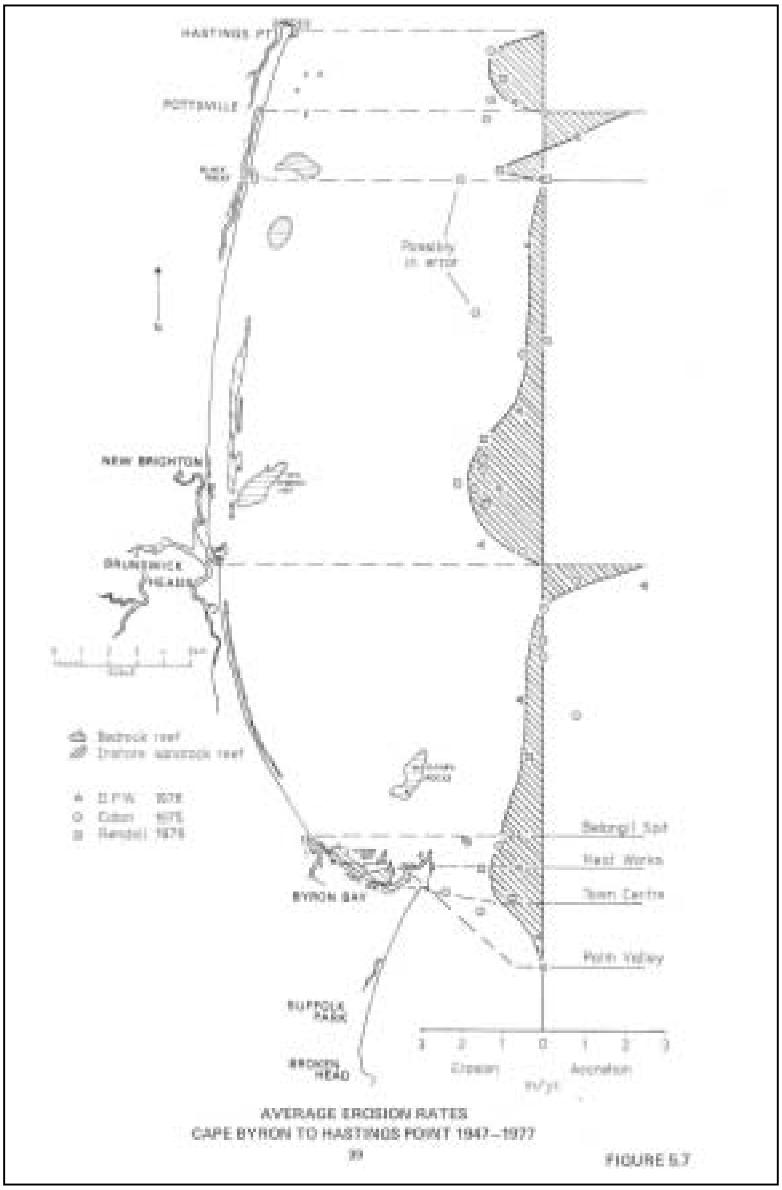


Figure 22 Bryon Bay Shoreline recession (Gordon et al 1978)

THE FUTURE – Vanishing beaches?

There is a worldwide trend of persistent beach recession of varying magnitude at various locations. In the previous section a range of causes are discussed in terms of an understanding of historical trends. Can the future for our beaches be predicted?

The issue receiving the most attention is sea level rise. The US National Oceans and Atmospheres Administration (Bosch et al 2000) position on climate change takes the view that sea level rise will not only inundate more land but changes in wave propagation and hence sediment movement will see land being lost from most US regions. Using a worst case scenario of 1 metre sea level rise by 2010 results in an estimated cost to coastal structures of $36 billion. The range of predictions for sea level rise is quite large. The Intergovernmental Panel on Climate Change (IPCC, 1996) predicts that a more realistic estimate is 37mm by 2010.

The CSIRO in Australia has predicted that sea level will rise by 0.8 to 8.0cm per decade due to global warming (McInnes, 2000 and Abbs et al 2000). The observed rise over the 20th Century has been 1 to 2 cm per decade.

Of equal concern for the long term is the likelihood of changes to the frequency and intensity of storms due to climate change. A key indicator of this are changes in the heat content of the world's oceans which have been measured and has been found to be increasing (Levitus et al 2000). As represented by Figure 23 the ocean's heat content has been increasing by 0.31^{0}c from 1948 to 1998. Strong et al (2000) use data from 1984 to show that warming in the tropics and mid latitude northern hemisphere is occurring which are balanced by downward trends in major regions in southern hemisphere, suggesting a period of stability.

Bosch et al (2000) have not identified any long term trend in over 80 years of storm frequency or severity data, but predict future trends to include gradual movement of tropical western pacific water to the east resulting in higher frequency of cyclones for islands in the central and east-central pacific. Of particular interest for our region is the likelihood of entering a new phase of the PDO in the near future, or an intensification of El Nino /la Nina events. Palumbo (2000) has developed a predictive model for extreme El Nino events and has confidently predicted the next to occur in 2014.

In Australia the predictions are less precise, but the CSIRO state that climate models do not give a consistent indication of future changes. However it is likely that global warming will enhance the drying associated with El Nino events. CSIRO also support the lack of trend evident in historical records of cyclone frequency. Their present indications are that:

- Regions of origin are likely to remain unchanged
- Maximum wind speeds will increase
- Preferred paths and poleward extent will alter
- Future changes in frequency will be modulated by El Nino Southern Oscillation (CSIRO, 2001)

Studies by NASA JPL (2000) show 15 to 20 year cycle in the temperature signals that define the Pacific Decadal Oscillation. There has also been a 70-year cycle over many centuries evident in tree rings to support the phenomenon. The PDO is manifested in a symmetrical pattern around the equator that in its cool phase is a horseshoe arc of warmer water from Japan to Australia surrounding a cooler equatorial mass. This pattern has been observed around 1976, 1957, 1941 and 1924. As discussed earlier these periods correspond to our severe weather periods in this region. The PDO data has shown that a warm positive phase has lasted from 1977 to 1999 and that we are now entering a cool phase. If it is ocean heat that drives our wave climate and hence our erosion cycles, and if the PDO is a measure of this feature, and if predictions are correct, then we are now entering a new cool phase and hence more energy off the eastern coast of Australia. The result will be a return to a period of more frequent cyclones and major storms and hence erosion events.

Of course as noted earlier, a return to more stormy conditions will not only bring exacerbated erosion. The more energetic event will also mobilise sand currently in reserves up drift of headlands for example, and the supply of this sand to embayments such Noosa and Byron Bay may bring a return to a less variable beach condition.

Where to from here?

If all of the predictions of coastal realignment, sea level rise, climate changes, PDO cycles and frequency and intensity of storms are correct then coastal economies may be faced with more erratic and severe business cycles and economic growth, especially those dependent on quality beaches to sustain their economies. It is an inexorable fact that the level of economic activity in coastal areas can be linked to the existence and perceptions of existence (through the media) of 'a wide sandy beach', The kind of damage caused by major storms can be economically disastrous both in terms of the cost of rehabilitation, but also the downturn in tourist visitation. A key concern is that this kind of impact is highly unpredictable. It is important that preventative measures be developed to mitigate against these impacts. While they may be costly, they may not be as expensive as the long-term costs of reactive, response or recovery measures alone. Severe erosion from destructive cyclonic and storm events not only destroys property and infrastructure along the coast, but more importantly, through the loss of the 'beach' destroys the foundation of coastal economies. The last severe cyclone that destroyed the Gold Coast economy was in 1967. Another similar event is long overdue and preventative beach and dune redevelopment measures are required to prepare for such a disaster.

The kind of beach management strategies being implemented on the Gold Coast are very effective at dealing with the short and medium term variability. In the longer term policies will need to be developed to deal with the potential loss of beaches and the lack of sand to replenish them. In the US the problems faced by the East Coast barrier islands highlight the issues being faced by coastal communities.

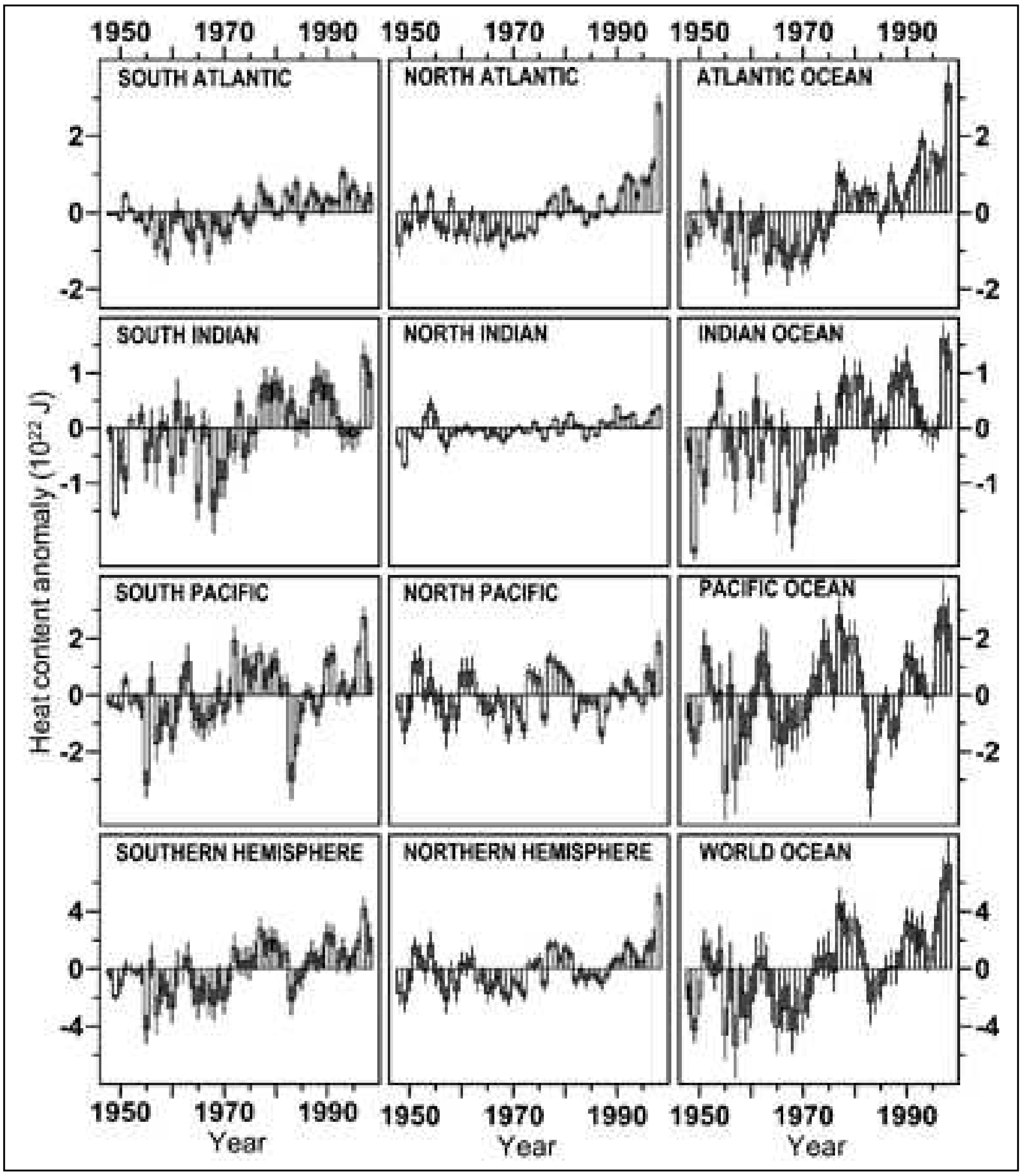


Figure 23 World Ocean's Heat Content (Levitus et al 2000)

Titus (2000) presents a range of engineering options being presented to the community for debate (Figure 24). At a policy level a number of US States have legislated against the use of hard structures, opting instead for policies such as the rollover easement. Under these circumstances properties under threat cannot be protected but can be moved landward to the extent of the property.

CONCLUSIONS

Are our beaches vanishing? The community often believes they are and gets very concerned. In the absence of disruptions to sand supply, short term fluctuations will occur – however the beach often can't cope with these because of the artificial boundary conditions of coastal development applied to them. In the medium term, natural and man-made influences require effective management for sustainable development on the beach front. In the long-term, like many sites in the US, our coastal communities may have to rethink their location and may be forced to consider a retreat from the beachfront.

As these issues are debated it will be more important to consider that each area of concern will have its own causes of erosion. In our local region we see Maroochydore coping with medium term natural fluctuations in coastal processes; at Palm Beach the shoreline is stable but the beach front developments are on the part of the active system; at Coolangatta - Kirra large scale beach management is required to deal with a major man-made disruption to the supply of sand and at Noosa there is a combination of issues.

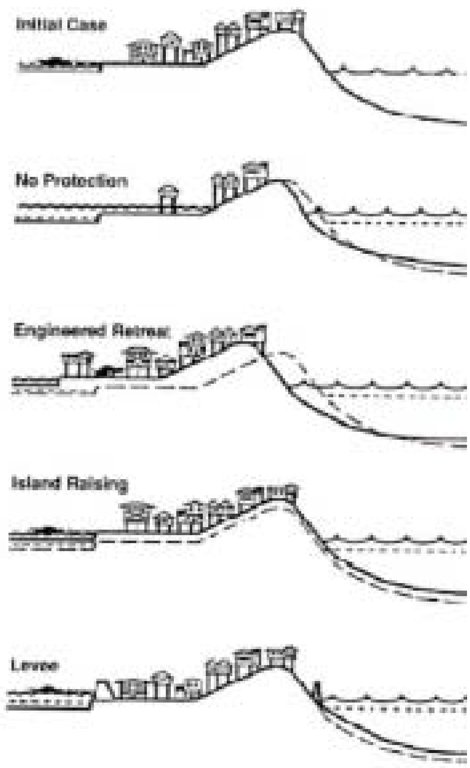


Figure 24 – Engineering Options for Long Term Management

Overall it would seem that there is a need to:
- Extend the time frames of decision making with respect to beach protection and management.
-Develop better communication and education for the community on beach processes to clarify the reality of the coastal environment.

Ultimately, with effective management and long term planning it is hoped that our beaches can be maintained in a condition similar to that at Kirra in 1936 – a abundance of sand and happy holiday makers.

ACKNOWLEDGEMENTS

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HISTORY OF CYCLONES ON THE CAPRICORN COAST

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ABSTRACT

Tropical cyclones form on the monsoon trough, which in summer usually lies over the North Queensland Coast. Consequently the Capricorn Region is less affected by tropical cyclones than is North Queensland. Nevertheless tropical cyclones have in the past impacted on the Capricorn region and known details of these impacts are detailed in this study. Tropical cyclones threaten this area mostly in January, February and March, although some have occurred in April. There is a strong year-to-year variation in tropical cyclone numbers in the region, with nearly twice as many impacts occurring during La Niña conditions than during El Niño. Several case studies are presented of cyclone impacts with particular reference to coastal effects from waves and storm surge. In this regard the size as well as the intensity of different tropical cyclones are compared.

INTRODUCTION

Tropical cyclones

Tropical cyclones are severe atmospheric disturbances, which in the Southwest Pacific Ocean, mostly occur between the latitudes of ten degrees and thirty degrees (Neumann 1993). They can develop within two latitude degrees of the equator, although this is very rare. These systems have a circular structure of rain, cloud and very high winds surrounding a calm clear centre with very low atmospheric pressure. Due to the rotation of the earth the vortex circulation is clockwise in the Southern Hemisphere. Typically, the size of the clockwise swirling circulation is between 80 km and 800 km. Average wind speeds (over 10 minutes) in excess of 140 km/hr (75 knots) are relatively common in the circular heavy rain bands close to and encircling the calm centre (eye).

The World Meteorological Organization definition of a tropical cyclone is: *A non-frontal cyclone of synoptic scale developing over tropical waters and having a definite organised wind circulation with average wind of gale force* (*34 knots* or *63 km/h) or more surrounding the centre.*

Most tropical cyclones develop along the Inter-Tropical Convergence Zone (ITCZ) where the trade winds of both hemispheres meet. The ITCZ changes position with the seasons penetrating to about latitude 15 degrees North between July and October and to latitudes 10-15 degrees South between January and April. Over the Australian summer the trade winds from the Northern Hemisphere cross the equator and are deflected eastwards by the rotation of the earth forming the northwest monsoon. The convergence zone where this monsoon flow meets the southeasterly trades is referred to in Australia as the monsoon trough.

Tropical cyclones are accompanied by destructive winds and, very heavy rain which often produces disastrous flooding overland after landfall. Over the ocean the intense wind fields generate very large waves and strong ocean currents, which can result in coastal inundation at landfall. Very low atmospheric pressure near the centre of the cyclone also raises the level of the ocean although this effect is secondary when compared with the effect of the wind (Anthes 1982). The coastal inundation is known as storm surge and globally is the major cause of loss of life from tropical cyclones. The destructive force of tropical cyclones is usually expressed in terms of the strongest wind gusts, which can be expected. The maximum wind gust is related to the central pressure of the cyclone. The Bureau of Meteorology uses the five category system shown in Table 1 for classifying tropical cyclone intensity in Australia. Severe tropical cyclones are those of Category 3 and above.

Category	Maximum wind Gust Km/hr (knots)	Potential damage
1	<125 (68)	Minor
2	125(68) to 170(91)	Moderate
3	170(91) to 225(133)	Major
4	225(133) to 280(166)	Devastating
5	>280(166)	Extreme

Table 1…Australia tropical cyclone category scale.

TROPICAL CYCLONE CLIMATOLOGY- ROCKHAMPTON REGION

The Tropical Cyclone Coastal Impacts Program (TCCIP) was launched in 1994 to help focus research attention and resources on the problem of increased hazard levels and vulnerability of our coastal communities from tropical cyclone impacts. Seed funding for specific research projects, was provided by the National Greenhouse Advisory Committee. This has since been augmented by funding from Queensland Emergency Services, The Australian International Decade for Natural Disaster Reduction Committee, Australian Research Council, US Office of Naval Research, the Insurance Industry as well as substantial commitments by Macquarie University, Bureau of Meteorology, James Cook University and Australian National University.

As part of the TCCIP, the Severe Weather Section of the Bureau of Meteorology in Brisbane has reviewed the record of tropical cyclones in eastern Australia. Part of this work included cataloguing tropical cyclone impacts over eastern Australia. Earlier work on tropical cyclone impacts was carried out by Holthouse (1971) who spent several months searching through the archives of the Bureau of Meteorology in Brisbane. This was a very useful work, however he concentrated on only twenty of the more notable events. Other lists of tropical cyclone activity over eastern Australia, such as Lourensz (1981) and an archived list of Australian tropical cyclones available on the web, consists of track data and estimated central pressure data only.

Details of tropical cyclone impacts in this study are taken from the work carried out by the Severe Weather Section, which were compiled from the following sources: -

(I) Published and unpublished Bureau of Meteorology tropical cyclone seasonal summaries;
(ii) Results of Rainfall Observations in Queensland, H.A. Hunt, Commonwealth Meteorologist (1914);
(iii) Results of Rainfall Observations in Queensland, W.S.Watt, Commonwealth Meteorologist (1940);
(iv) Australian Hurricanes and Related Storms (1925), S.S.Visher and D. Hodge, Bulletin No 16, Bureau of Meteorology;
(v) Archived newspaper clippings held by the Bureau of Meteorology;
(vi) Archives of the Brisbane Courier Mail held at the Queensland State Library;
(vii) Archives of the Rockhampton Morning Bulletin at the Rockhampton Library;
(viii) Archives of the Maryborough Chronicle.

Rockhampton is located near the Tropic of Capricorn and well south of the average position of the monsoon trough and therefore has less direct exposure to tropical cyclones then centres such as Townsville. However the Rockhampton region has been exposed to destructive winds, flooding, storm surge and phenomenal seas from tropical cyclones in the past.

Tropical cyclone season

Overall 37 tropical cyclones are known to have caused an impact in the Rockhampton area between St. Lawrence and Gladstone (see details of all these impacts listed in the appendix). The monthly distribution of these 37 events were as follows:

January	February	March	April	Total
9	14	12	2	37

This list helps define the tropical cyclone season in Rockhampton, which is most active over January, February and March.

INTER-ANNUAL VARIATION OF TROPICAL CYCLONE IMPACTS

Australia's rainfall is associated with year-to-year variations in sea surface temperatures in the tropical Pacific Ocean. Variations in ocean temperatures in the tropical Pacific are often associated with the El Niño/Southern Oscillation (ENSO), the most important coupled ocean-atmosphere phenomenon causing global climate variability on inter-annual time scales. A useful measure of ENSO activity is the Southern Oscillation Index (SOI), which is defined here as ten times the normalized difference in monthly pressure anomaly between Tahiti and Darwin. El Niño is usually associated with a large negative SOI, where tropical waters around Australia often have relatively cool temperatures and waters over the equatorial Eastern Pacific are anomalously warm. El Niño is often associated with drought in Australia (e.g. Nicholls 1992a, Allan 1991). La Niña is usually associated with a large positive SOI, where tropical waters around Australia have relatively warm temperatures while waters over the equatorial Eastern Pacific are anomalously cool. La Niña is associated with increased rainfall in Australia.

The relationship between the number of tropical cyclones in the Australian region and the SOI) is well-known (e.g., Nicholls, 1984, 1985, 1992; Solow and Nicholls, 1990; Basher and Zheng, 1995). This relationship can be used to predict cyclone activity. Low values of the SOI, typically associated with an El Niño, during the Southern Hemisphere spring usually indicate that the ensuing cyclone season will have fewer than normal cyclones. During such years cyclone activity usually increases in the central South Pacific (Basher and Zheng, 1995).

SOI data are available for thirty-two of the thirty-seven tropical cyclones which impacted on Rockhampton and below we have examined these data to see if there is any relationship between the SOI and tropical cyclone impacts in the Rockhampton region. The SOI values are the three-monthly averages centred on the month of occurrence.

Range of SOI	Number of impacts
< - 10.0	3
-10.0 to – 5.0	5
- 4.9 to – 1.1	3
- 1.0 to + 1.0	2
+ 1.1 to + 4.9	4
+ 5.0 to +10.0	6
> +10.0	9

Table 2. Tropical cyclone impacts for different ranges of SOI.

From Table 2 these data show that almost twice as many impacts (15 against 8) occurred with La Niña type conditions (SOI ∃+5) when compared with El Niño type conditions (SOI #-5). There was a tendency for an impact to be associated with a positive SOI. Two events occurred when the SOI was near zero and 19 events when the SOI was clearly positive and 11 events when the SOI was negative.

TROPICAL CYCLONE CHARACTERISTICS

Severe tropical cyclones

Tropical cyclones are classified as severe if they reach at least the category 3 level of intensity. From Table 1 severe tropical cyclones are capable of inflicting major (category 3), devastating (category 4) or extreme (category 5) damage. A severe tropical cyclone, which probably fluctuated between category 4 and category 3 intensities, caused widespread damage over the region during March 1949. The track of the cyclone through the region has been constructed in Figure 1.

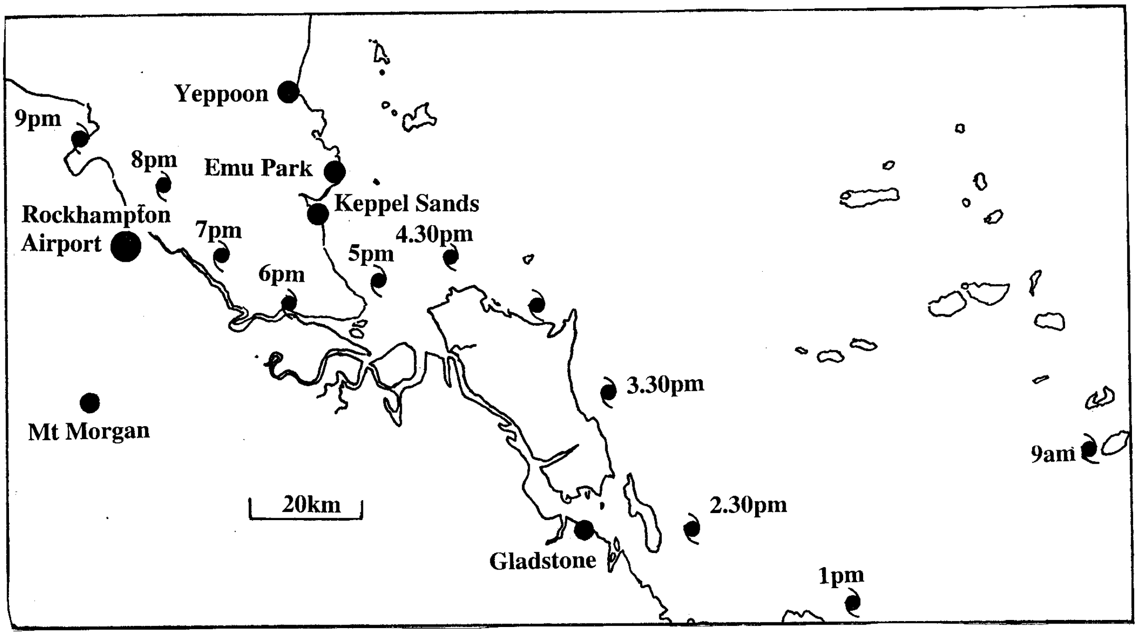

Figure 1. Track of the 1949 severe tropical cyclone From 9am 2 March 1949 to 9pm 2 March 1949.

The lowest barometer reading at Gladstone was 975.3hPa at 2.30pm 2 March 1949 when the wind there was changing from southwesterly to southerly and increasing to 65 knots (120 km/h). This indicated that the centre of the cyclone was passing to the east of Gladstone at this time.

The eye of the cyclone passed over Cape Capricorn (northeast point on Curtis Island) between 2pm and 4.25 pm 2 March 1949. The wind there was calm at 4.25pm and then rapidly increased to 65 knots (120 km/h) at 4.30pm. The worst of the wind damage occurred at Emu Park around 4pm when the wind was from the northwest. This indicated that the cyclone passed to the south of Emu Park.

At 7pm 2 March 1949 the wind at Rockhampton was southwesterly at 50knots (93km/h) and the bar was 968.1hPa. This data implied that the cyclone then was near to and slightly south of east of Rockhampton. The lowest bar at Rockhampton was 965.1 hPa at 8pm when the wind was form the south-southeast at 52 knots (96km/h). Thirty minutes earlier the maximum wind gust of 87 knots was recorded at Rockhampton. We have calculated that the cyclone passed just to the north of Rockhampton shortly after 8pm 2 March 1949. The cyclone traveled more than 40km overland before passing to the north of Rockhampton when its central pressure was near 960hPa. Tropical cyclones rapidly weaken soon after landfall so that the central pressure of this cyclone as it approached Yeppoon was likely 950 hPa or less.

The mean sea level charts (Figure 2) show that the cyclone lay out to sea east of Yeppoon on 1 March 1949 when it would have been directing large waves towards the Capricorn Coast. The isobaric pattern indicated a cyclone of medium size. Seas badly damaged the beaches along the Capricorn Coast.

Variation in size

The height of wind waves increases with increasing wind speed and the duration of this wind together with the fetch of the wind. The fetch is the distance over which the wind blows along a great circle path. The limited fetches associated with circular wind fields can at times limit the growth of waves generated by a tropical cyclone. Tropical cyclones, which are large in size are not restricted by small fetches and thus can generate very large waves.

Tropical cyclone size, as distinct from intensity, is therefore a very important property of a tropical cyclone. For example tropical cyclone *David* in 1976 was a cyclone with a large circulation and had a major impact in the Yeppoon region even though it made landfall just to the north of St Lawrence.

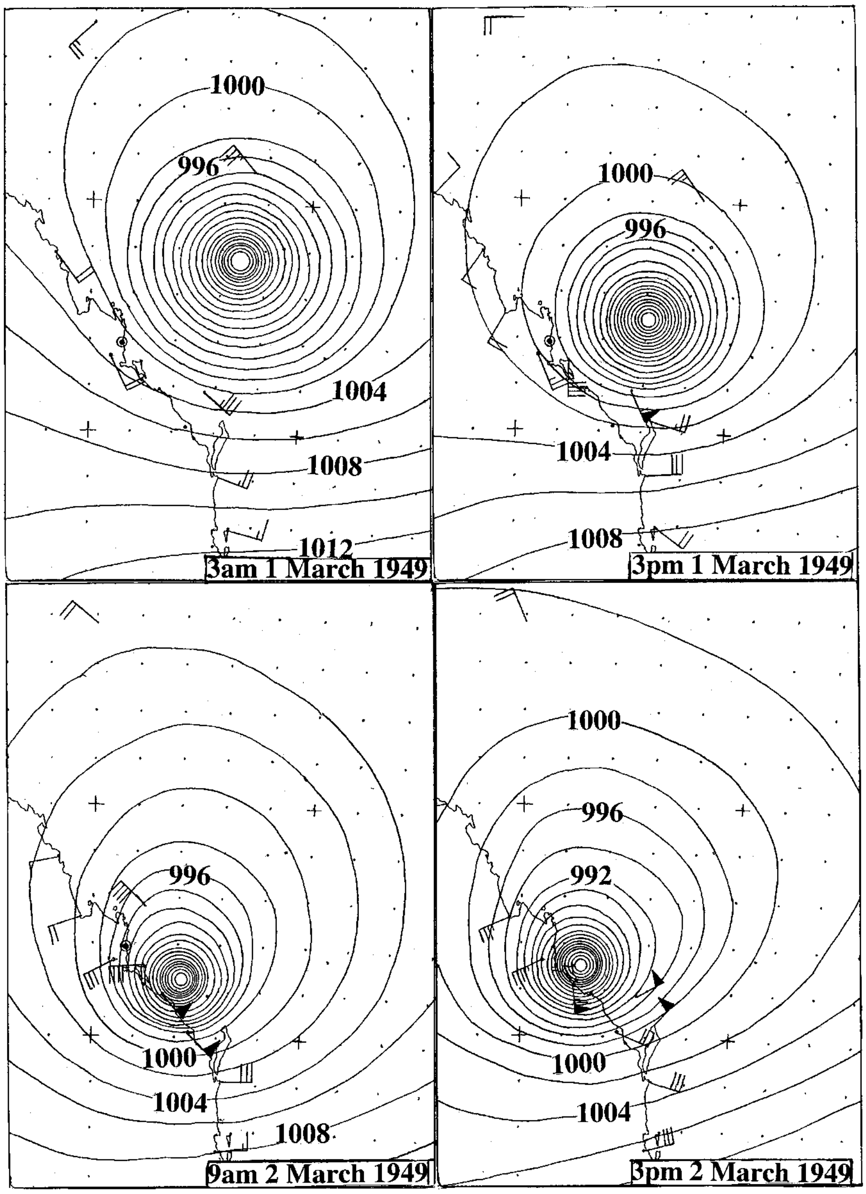

Figure 2…Mean Sea Level Pressure distribution (hPa) together with selected wind observations. Flag represents 50 knots (25 m/s) full barb represents 10 knots (5m/s) and half barb represents 5 knots (2.5m/s).

As *David* approached the coast (see track in Figure 3) it caused damage on Heron Island.
On 17 and 18 January 1976 the Island was buffeted by southeast swells with some inundation. On 19 January 1976 large northeast swells brought sea levels approximately one metre above normal with 2 metre waves breaking on the beach (inside the fringing coral reef). One wall of the TV room was pushed in by waves - water from waves entered the lounge bar, Manager's residence, office, cinema, Boatman's residence and games room.

Figure 4 shows the mean sea level weather chart for 9 am Monday 19 January 1976. The wind plots in Figure 4 indicate that there was a huge area of gales associated with *David* extending from Papua New Guinea waters down to areas off the northern NSW coast.

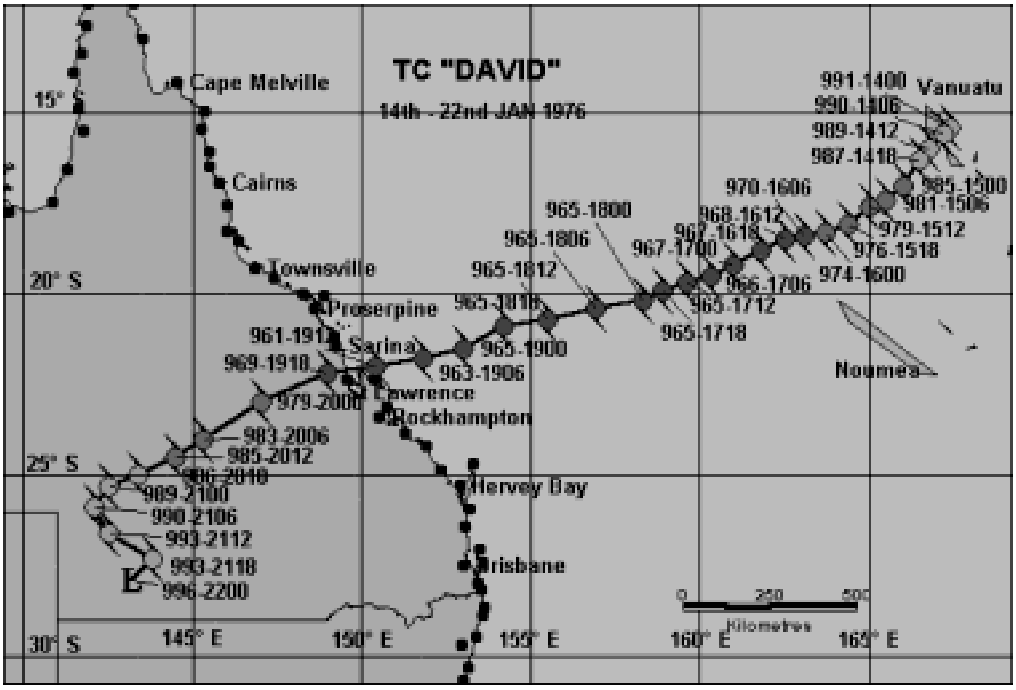

Figure 3. Track of tropical cyclone *David.* Numerical group ppp-ddhh with each cyclone position where ppp denotes the central pressure (hPa) and dd is the date (UTC) and hh is the hour (UTC). UTC is Australian EST – 10 hours.

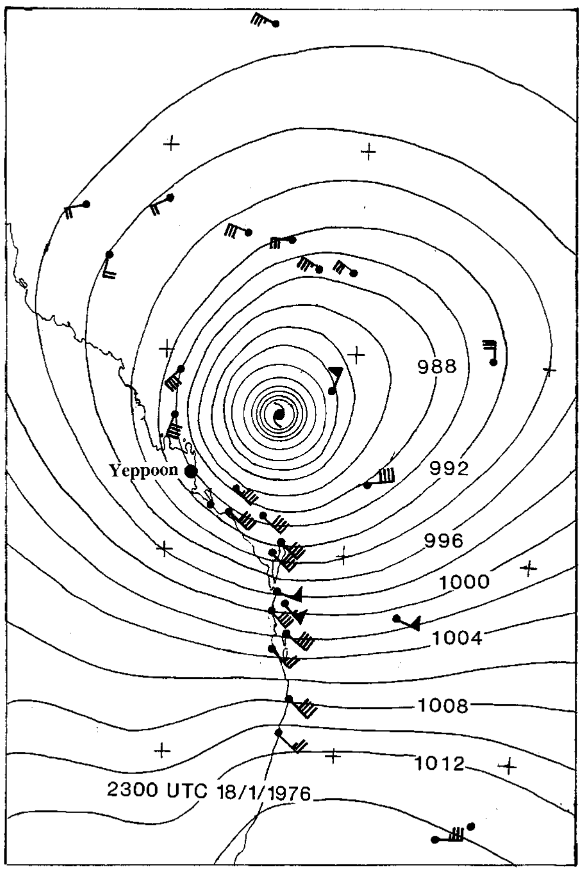

Figure 4. Tropical cyclone *David* at 9am 19 January 1976.
Mean Sea Level Pressure distribution (hPa) together with selected wind observations. Flag represents 50 knots (25 m/s) full barb represents 10 knots (5m/s) and half barb represents 5 knots (2.5m/s).

David crossed the coast in a sparsely populated area to the north of St Lawrence however winds unroofed 30 buildings in Yeppoon and several in Mt Morgan. Wind gusts reached 95knots (176km/h) at Pine Islet and 84knots(156 km/h) at the Gladstone Meteorological Office. Large seas combined with high tides caused considerable damage to breakwaters, retaining walls and other structures especially at Rosslyn Bay Harbour (Yeppoon) where the Breakwater was destroyed along with yachts and trawlers. At the Yeppoon wave recording stations the significant wave and peak height reached 3.8 m and 8.7 m. The 3.8m significant wave height at Yeppoon were recorded from 1700 UTC 18/1/1976 to 1700 UTC 19/1/1976 (readings every 12 hours) while the peak reading of 8.7m was recorded at 0500 UTC 19/1/1976. Storm surges (tide level minus predicted level) were measure about the coast and these were 1.2m at Port Alma, 1.45m at Port Alma and 1.25m at Gladstone.

Other large cyclones, which are known to have caused extensive sea damage near Yeppoon, were the 1893 cyclone, the Mackay 1918 cyclone and the 1936 cyclone. Details of the impact of these storms can be found in the appendix.

Small tropical cyclones

In contrast tropical cyclone *Simon*, was a very intense small cyclone. The track is shown in Figure 5 and notice that *Simon* made landfall in the remote and sparsely populated area north of Yeppoon. Its small size can be seen in Figure 6. Though the peak winds near the centre would have been much stronger than *David*, the effect on Yeppoon was minimal with only tree damage even though it was much closer to Yeppoon than *David* was.

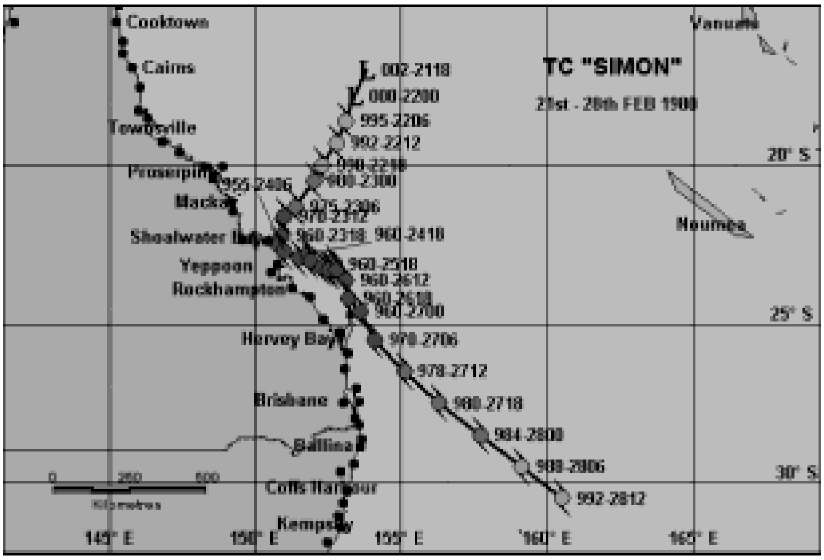

Figure 5. Track of tropical cyclone *Simon.*

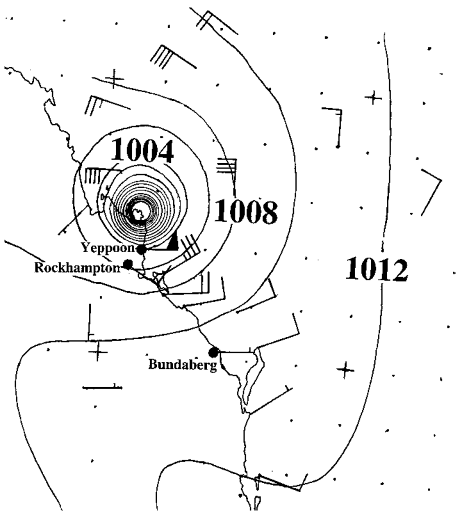

Figure 6. As in Figure 2 except for Tropical cyclone *Simon* at 9am 24 February 1980.

Simon was rapidly intensifying and moving towards the coast when it recurved seawards over Port Clinton. The Glen at Shoalwater Bay reported trees of all sizes blown down while at Stockyard Point 40 % of all trees were blown down. It passed slowly to the north of Heron Is, which experienced wind gusts to 93knots (172km/h) and a great deal of damage. Neap tides saved the Island from swell damage. There was severe beach erosion on Great Keppel Island.

SUMMARY

Since 1863, 37 tropical cyclones have came close enough to the Capricorn Region to cause an impact. That is on average an impact from a tropical cyclone occurs about once in every four years in this region. Large cyclones can cause considerable damage to coastal areas even though the centres of these cyclones are well removed from the region.

Severe tropical cyclones have struck the area in the past and even Rockhampton, which is inland from the coast, suffered widespread destruction in 1949. The Capricorn region has undergone rapid development since then with a greatly increased population. Undoubtedly in the future the region will be hit another severe tropical cyclone similar to the 1949 event and this will present disaster managers with a serious challenge to limit the loss of life.

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APPENDIX

TROPICAL CYCLONE IMPACTS IN THE ROCKHAMPTON AREA

On the following pages are summarised all cyclones since 1863 affected the region of the Capricorn Coast.

The date of the cyclone refers to the day of landfall or the day of the major impact if it is not a cyclone making landfall from the Coral Sea.

The first number after the date is the SOI for that month followed by the three month running mean of the SOI centred on that month. This data is only available since 1876.

This is followed by information on the equatorial eastern Pacific sea surface temperatures where: -
W means a warm episode i.e. SST were above normal;
C means a cool episode and
Av means average SST

Cyclone	Impact
Middle to late Feb 1863	A tropical cyclone (TC) brought damaging winds and seas to region between Rockhampton and Hervey Bay. Houses unroofed in several centres with many trees blown down. Ketch driven onto rocks near Rockhampton. Severe erosion along shores of Hervey Bay with 10 metres lost to sea along a 32 km stretch of the coast. Twenty acres of forest were also lost to the sea.
17-19 Mar 1864	Gales with wind damage and flooding affected southeast Qld. Gales reached the Capricorn region with **trees down at Gladstone**. The barque *Panama,* 414 tons, was wrecked on the 18th on Breaksea Spit near Sandy Cape with 10 people on board. At 4 am on 19th wind shifted from ESE to NW with increased violence. The ship was then driven onto the beach and broke in two. One of the crew drowned and ten were lost and never seen again.
22 Jan 1874	A furious gale along the northern coast destroyed much property. At St Lawrence **a new wharf disappeared, the Post Office and miles of telegraph lines were blown down and several stores were wholly or partially destroyed**. Trees for miles around were uprooted. The schooner *Countess of Belmore* was badly damaged. **At Keppel Bay some of the houses were partially unroofed and the jetty was washed away. Although it was neap tides the sea rose 3 feet higher than ever before**. The ketch *Hibernia* was driven ashore on Northwest Island (all safe). The *James Patterson* grounded on Masthead Island (all rescued). The S.S. *Lord Ashley* was caught in it and was almost wrecked.
25 Feb 1874	The ship *Southern Belle* encountered a furious gale off Frazer=s Bay and narrowly escaped shipwreck. She was eventually towed into Keppel Bay on 5 March. The schooner *Chance* returned to Maryborough on 26th Feb disabled. It was 200 nm on its way to Noumea when it encountered a gale, which lasted for 2 weeks. The schooner *Io* struck SE gales on the 21st at Refuge Bay and NE gales off Gladstone on the 24th/ 25th.
24 Feb 1875	Steamer *Gothenberg* wrecked off Cape Upstart (near Ayr) in TC 102 lives lost. **On the 23rd NE gales struck Rockhampton with 8 inches (203mm) of rain registered**. Gales and flood rains also affected southeast Queensland.
17 Feb 1888 -2.2(-5.6) C	TC recurved just east of Mackay. *Geelong* ran aground and 2 were drowned. *Youyang* was dismasted. Several Mackay houses were completely demolished**. Wharves were awash at Rockhampton on the 20th**. Flooding occurred at Pialba with water three feet over the road at Stockyard Creek and rising and trees blown down in all directions. Enormous Breakers were raging outside of Fraser Island
24 Mar 1890 14.3(10.4) C	TC crossed the coast near Cardwell 24th and recurved over Fraser Island 28th bringing disastrous floods over much of Queensland and northern NSW. Widespread damage with 11 deaths at South Barnard Island, Cardwell**,** Dungeness, Halifax, Ingham, Townsville, around the Burdekin, Ayr and Mackay. **Emu Park: Wednesday 26th 15 inches (381mm) of rain fell in 12 hours and man was killed by lightning at 6.30 am Wed. The Schooner *Matha Reid* was dismasted and the captain knocked senseless and thought to have died.** Darling Downs: 2 policemen missing in floods near Dalby and at Roma 100 people were evacuated from floods. Beaudesert: man drowned in creek 28th. Stanthorpe: Numerous buildings washed away, man drowned and a large number of stock lost.
1 Feb 1893 7.7(5.9) C	TC crossed the coast near Yeppoon. At Yeppoon some iron was lifted off roofs, trees were uprooted and outhouses were overturned. Similar damage occurred at Rockhampton and Emu Park where one house was unroofed. The worst wind damage was observed along the railway to the north where numerous large trees were uprooted. Yeppoon recorded 509mm of rain in 24 hours and 586mm (gauge overflowed) at Woodlands in 24 hours. Large seas scoured large holes in the beach at Yeppoon rendering the access to the beach un-trafficable. The ladies bathing shed was washed away.

	The Bar dropped to **969 hPa** when the TC passed over the *Buninyong* near the Northumberland Group. Large seas wrecked 225-ton steamer *Dickey* on Dickey Beach Caloundra. Crohamhurst (on Stanley R) recorded 907 mm of rain in 24 hrs to 9am 3 Feb. Following this rain; the worst known floods affected the southeast Queensland with more than 25 deaths.
28 Jan 1910 5.6(8.5) C	TC crossed the coast to the north of Cairns on the 27th, then recurved west of Cairns before passing back out to sea on the 30th. Wind and sea damage at Cairns and Cooktown with the *Bombala* run aground. At 9am on the 30th the bar at Mackay was 990.9 hPa with strong SW winds. At 9pm a whole gale from ESE was blowing at Sandy Cape. **There were washouts and railway line flooding in the Rockhampton area.**
21 Jan 1918 14.6(17.9) C	A TC crossed the coast just north of Mackay with a disastrous storm surge, flooding and widespread wind damage. The lowest pressure of **932.6 hPa** was recorded near Mackay at 7.30 am 21$^{st.}$ In Mackay the death tally was 20 on the 31st January 1918 and it is now though that a total loss of thirty people lost their lives in the cyclone and the subsequent floods in Central Queensland**.** **The cyclone was very large in size and destructive winds extended down to Rockhampton with the worst damage occurring after the winds shifted from SE to NE. Several houses were unroofed in North Rockhampton and along Lakes Creek Road. Trees were uprooted including large jacaranda trees. Many houses had verandas blown off and lost portion of their roofs. Two men were drowned at Rockhampton. At Yeppoon, a man drowned, trees were uprooted, three buildings were badly damaged or unroofed and several houses were lifted off their blocks. At Emu Park many houses were badly damaged and the fishing fleet suffered severely. At Mt Morgan roofing iron was lifted off buildings** and at Clermont thousands of trees were uprooted along all the surrounding roads and buildings lost roofing iron. Widespread flooding occurred in Central Queensland **including a record flood at Rockhampton with widespread property damage.**
5 April 1921 -7.1(1.3) C	This tropical cyclone passed close to the vessel *Camira*, which was hove to near North Reef **(120km east of Yeppoon). The vessel was in cyclonic conditions for 16 hours and 500 rams were swept overboard. Large seas would have affected Yeppoon but we have no record of the impact.** The cyclone then passed east of Bustard Heads where a bar reading of 979 hPa was obtained. It went on to cause a great deal of damage in Bundaberg and is one of the worst cyclones to strike that centre. It then passed between Maryborough and Hervey Bay. Bathing houses were washed away at Pialba and 2 men were badly injured by a storm surge.
21 Apr 1928 11.9(7.7) C	TC recurved near Mackay and over Broadsound. Floods with extensive damage affected the Callide, Dawson and Dee Valleys. Houses washed away and 9 people drowned. Extensive flooding south to border with extensive crop losses and thousands of cattle lost. Low parts of Brisbane were flooded with one drowning.
22-23 Feb 1929 18.0(13.0) C	TC moved towards the coast and recurved away east of Bowen. **31.33 inches (795mm) of rain fell in 65 hours at Rockhampton. Fitzroy River peaked at Rockhampton pm Sat 23rd (reached just over 25 feet (7.6m)) and two men drowned in the Rockhampton area. Bridges and crops were badly damaged around Rockhampton.**
28- 29 Feb 1929 18.0(13.0) C	Cyclone recurved towards southeast and redeveloped off the Central Coast. Bar down to 986.1hPa at Double Island Point 8pm 28th . Huge seas off the south coast. Heavy easterly swell was reported at Sandy Cape on 27th which would have affected the Capricorn Coast region as well. Widespread severe sea damage Gold Coast and northern NSW.
1-8 Feb 1931 -14.9(-0.8)W	TC entered Coral Sea near Cooktown and moved down to Hervey Bay. **Passed southwards over North Reef (120 km east of Yeppoon) with a central pressure of 982 hPa.**
22 Mar 1936 1.8(8.0) C	A tropical cyclone with a very large area of gales recurved seawards of Fraser Island. There was extensive sea and storm surge damage on the Gold Coast and in Moreton Bay. **At Yeppoon waves came over the sea wall and entered a beach Cafe.**

27-29 Jan 1939 17.0(12.8) C	Low moved offshore between Rockhampton and Mackay and became slow moving TC. Shipping delayed by gales and high seas. Flooding with stock losses and towns isolated in Dawson Valley.
8 Feb 1942 -3.6(-7.5) End W	**TC crossed the coast north of Rockhampton. Trees uprooted, fences blown down and iron ripped off roofs. Main grandstand at the Show-grounds was unroofed. The city was blacked out from downed power lines.**
16 18 Feb 1942 -3.6(-7.5) End W	TC crossed coast near Cardwell and moved back out to sea north of Mackay on the 18th. Extensive damage and loss of life occurred from flooding in the Burnett River and Dawson and Callide Valleys. In the Dawson Valley and Callide head waters the towns of Rannes and Wowan were evacuated with much loss. The death toll was 6 (maybe7) - 2(maybe 3) in Bundaberg, 1 Monto, 1 Mundubbera and, **1 Boyne Island** and 1 in Chinchilla.
31 Jan 1943 9.4(11.2) C	**TC crossed coast near Rockhampton. Flooding along the coast between Mackay and Maryborough.**
10 Feb 1947 - 4.1(0.9) C	TC crossed the coast at Broadsound. Floods in most east coast rivers. Some loss of life occurred as well as much damage to infrastructure.
2/3 Mar 1949 5.6(2.9) C	TC came close to Gladstone at 2pm on the 2nd and then crossed the coast south of Emu Park and passed close and to the north of Rockhampton. There was w**idespread damage in 15 towns. Two men died, one in Rockhampton and the other in Gladstone as they were blown from the roofs of their homes while making repairs. Another man was killed in Rockhampton after being struck by a falling branch. A child was killed in Bundaberg by a falling gum tree. A dairy farmer was drowned in the Biloela district and another man was drowned near Thangool.** The lowest barometer reading in Rockhampton (not in the eye) was **965.1 hPa** and the maximum wind gust on the airport anemometer was **87 knots just after 7pm on the 2nd.** A survey by the Mayor in Rockhampton showed that over 1000 **houses were damaged, 500 severely.** Most of the 1500 homes in Gladstone were damaged and many buildings were extensively damaged. At Yeppoon northwesterly winds were estimated at 87 knots and 100 buildings were noticeably damaged, 30 to 40 were badly damaged and 4 were demolished. In Yeppoon 25 inches (635mm) of rain was recorded in 24h, which flooded business premises. In Emu Park the damage was worse than Yeppoon where whole buildings collapsed and almost all houses lost all or parts of their roofs. Several houses were moved off their blocks. One house lost its roof with half the roofing iron blown 450 metres away and the rest blown into the sea. The worst wind was around the period between 3 and 40pm. The Yeppoon to Emu Park scenic road was devastated with trees littering the whole highway. The beaches were badly eroded with Kemp Beach suffering badly where most of the trees were damaged. 47 cattle carcasses were washed up onto the beaches. Heavy seas closed the ports of Rockhampton, Gladstone, Bundaberg and Maryborough while a lightship was grounded on Breaksea Spit. There were severe floods in Central Qld and **3 drovers were drowned.**
11 Mar 1950 17.6(17.3) C	TC crossed the coast at Carmilla (S of Mackay) with severe structural damage. At Carmilla one girl was killed and 4 others injured. Trees a metre in diameter were uprooted. 400 people live in the area and only 8 buildings left standing. The Hall and 3 houses were completely wrecked. 15 business houses and the school residence were uninhabitable. Every other house in town was unroofed. 20 farmhouses within 16 km of Carmilla were battered with windmills destroyed. Rail and farm buildings damaged between Kalarka and West Hill. **Easterly Gales were reported at Rockhampton on 11 March 1950 and 60-knot southerlies at Cape Capricorn (Curtis Island) on 10 March 1950.**
7 Mar 1955 2.9(5.1) C	TC crossed coast just south of Mackay with eye passing over Sarina and bar down to 963 hPa. Lugger *Barrier Princess* lost with 8 hands. Widespread structural damage and heavy flood rains. Bar down to 957 hPa on vessel Cape Hawke just off Mackay at 2pm 7th with SW wind Force 12 and over. **50 to 80 knot winds affected the coast between Cape Capricorn and Mackay and several buildings were unroofed at Yeppoon. Major floods Flinders Burdekin and Fitzroy Rivers.**
Connie 16 Feb 1959	TC crossed the coast at Guthalungra where pressure in the eye was recorded at 948 hPa. Severe wind damage occurred at Ayr Home Hill and Bowen. A man was killed at Ayr when a shop fell on him. The anemometer at Bowen recorded wind gusts up to 100 knots over a

-14.0(-4.8) W	2-hour period with forty homes totally destroyed, 190 badly damaged and 300 partly wrecked. Wind also caused considerable damage at Proserpine with 50 houses and the Hospital badly damaged. **There was even damage at Rockhampton as the cyclone moved** south. Floods extended down to NE NSW. On the 18th Brisbane had wind gusts to 48 knots with minor damage and power lines down. Fallen power lines in NSW killed a man.
Dinah 28/30 Jan 1967 14.6(7.8) Start C	*Dinah* caused **severe damage at Heron Island initially from inundation from large NE swells and a day later from winds.** It recurved and passed over Sandy Cape, which recorded a central pressure of 944.8 hPa and high water 10 metres above normal. Although well off the coast **many trees were blown down from Rockhampton** to Grafton. Houses were unroofed at Bundaberg Maryborough and along the Sunshine and Gold Coasts. Banana and cane crops were wiped out on the Tweed Coast and a severe wind gust overturned a car at Evans Head. **Huge seas and storm surge caused severe erosion at Emu Park, Yeppoon**, and in the Maryborough Bundaberg area. Storm surges affected the Sunshine Coast, Gold Coast and Moreton Bay. Storm surge also on the Tweed River isolating Fingal. A section of the esplanade collapsed at Surfers Paradise.
Fiona 20 22 Feb 1971 15.7(12.5) C	*Fiona* tracked from the Gulf and entered the Coral Sea near Rockhampton. Flooding in the Burdekin and Fitzroy Basins varied from minor to major with severe damage to infrastructure. Motorists were cut off for days. Paw Paw crops were lost near Gladstone by wind and rain effects. A 0.6 m to 0.9 m storm surge was observed at Gladstone and Bundaberg respectively.
Emily 2 Apr 1972 -5.5(-6.1) W	*Emily* crossed the coast just to the SE of Gladstone while rapidly weakening. Wind damage was confined to trees and sheds. The cyclone had been very severe and generated huge seas. **It claimed the lives of 8 seamen in three separate incidents** off the southern and central Queensland coasts. Flooding occurred with Kingaroy being isolated for a time and Breakfast Creek flooded some houses in Brisbane. **Trees were blown down at Yeppoon and large waves were lifted up on the seaward side of the breakwater on Rosslyn Bay Harbour.**
David 19 Jan 1976 11.8(14.7) C	*David* crossed to the north of St Lawrence. It passed over Gannet Cay AWS where a central pressure of 970 hPa was recorded. It was intensifying right up to the time of landfall. A feature was it huge size with gales extending from PNG waters down to Lord Howe Is. **It generated huge swells and these combined with large tides caused extensive damage to Heron Island as it passed to the north. It crossed the coast in a sparsely populated area however winds unroofed 30 buildings in Yeppoon and several in Mt Morgan. Wind gusts reached 95 knots at Pine Islet and 84 knots at the Gladstone Met Office. Large seas combined with high tides caused considerable damage to breakwaters, retaining walls and other structures especially at Rosslyn Bay Harbour (Yeppoon) where the Breakwater was destroyed along with yachts and trawlers.** Storm tides flooded houses and shops at Urangan, Noosa and Kirra. Storm surge at Beachmere on Moreton Bay cut all roads into the town. The Port of Brisbane was closed. At wave recording stations the significant wave (peak) height reached 5.8 m (8.9 m) at Double Island Pt and **3.8 m (8.7 m) at Yeppoon.** The 3.8m significant wave height at Yeppoon were recorded from 1700 UTC 18/1/1976 to 1700 UTC 19/1/1976 (readings every 12 hours) while the peak reading of 8.7m was recorded at 0500 UTC 19/1/1976. Storm surges (tide level minus predicted level) were measure about the coast and these were 1.2m at Port Alma, 1.45m at Port Alma and 1.25m at Gladstone.
Dawn 5/6 Mar 1976 13.2(9.3) End C	*Dawn* developed on the N Qld coast and moved down the coast crossing Fraser Island. Two homes were unroofed in N Mackay and trees were uprooted on Heron Is. Rainfalls up to 230 mm between Proserpine and Bundaberg caused flash flooding.
Simon 24 Feb 1980	*Simon* was rapidly intensifying and moving towards the coast when it recurved seawards over **Port Clinton with a radar eye diameter of 35 km. In this remote area it caused extensive damage to vegetation. It passed slowly to the north of Heron Is which**

1.1(-1.4) W	**experienced wind gusts to 93 knots and a great deal of damage. Neap tides saved the Island from swell damage.** Huge swells were observed but their energy was dissipated on the exposed fringing reef. There was severe beach erosion at Great Keppel Island. A yacht ran up onto Lady Elliot Island and a rescue helicopter turned over but there were no casualties. As the cyclone passed to the east of Fraser Island a ship near Indian Head reported wind gusts greater than 100 knots. Sandy Cape Lighthouse reported winds gusting to 92 knots. Houses lost roofing iron at Hervey Bay where there was flooding. The Burnett Heads wave recording station recorded significant (peak) wave heights of 4.5m (8.9m)
Elinor 3 4 Mar 1983 -28.0(-26.0) W	*Elinor* crossed the coast near Carmila. 2 yachts were wrecked near the coast. A one-metre storm surge was reported at Collins Is (Broadsound). Wind blew down 0.75 diameter trees, power lines and caused minor house damage along the Central Coast and Islands. **Heavy rain fell in the Yeppoon area.**
Ivor 19 Mar 1990 -8.5(-8.8) End W	*Ivor* crossed the coast near Princess Charlotte Bay as it was weakening. There was some structural damage to sheds and light damage to the main buildings in Coen. The cyclone retained its identity as a monsoonal low and moved through the eastern Gulf and back down the east coast with heavy rain south of its centre. **As it moved down the Central Coast unofficial 24 hr fall of 1000mm were reported near Yeppoon and this caused flash flooding and extensive damage in the Yeppoon area.**
Fran 16 Mar 1992 -24.2(-17.5) W	*Fran* crossed the coast neat the Town of 1770. The maximum anemometer wind gust recorded was **76 knots on Great Keppel Island (just off the coast from Yeppoon).** In Bundaberg 40 houses were unroofed, one was blown off its stumps and at Bargara the caravan Park was evacuated. Heavy damage to fruit and vegetable crops occurred in the Bundaberg district. At Burnett Heads the marina and 3 yachts were damaged and there was extensive damage to pontoons and yachts forced against a rock wall. Powerlines, trees, and roofs were damaged at Gympie. There was roof damage along the Sunshine Coast when *Fran* crossed Fraser Island on its way back out to sea. A storm surge inundated 20 business premises, 100 houses and 50 caravans at St Hervey Bay. **Heavy swells caused damage on Heron Island** and severe erosion on the Gold and Sunshine Coasts.
Rewa 20 Jan 1994 -1.6 (0.2) C	*Rewa* came within 100 km of the coast as it was recurving away from Australia. **Two men were rescued from a fishing trawler near Yeppoon by an army Blackhawk helicopter**.
Barry 9 Jan 1996 8.4(1.3) Weak C	*Barry* tracked from the Gulf through Central Qld. A surface trough extended from the centre to the east coast and was, associated with wind gusts to 70 knots as it moved down the coast from Sarina to Hervey Bay. This resulted in pockets of structural and tree damage along this part of the coast along with tides of up to a metre above normal.
Justin 1 9 Mar 1997 -8.5(-4.0) Start W	*Justin* lay well out to sea but was a very large cyclone and tides exceeded HAT at most centres between Bundaberg and Cooktown. The highest overall tide gauge recordings in relation to HAT were 0.4 m above HAT at Shute Harbour and 0.5 metres above HAT at Mackay. The Mackay wave station recorded significant (peak) heights to 4.8m (8.45m). Wind observations showed a large area of gales of relatively constant direction over open waters extending from around Hayman Island to the Capricorn Channel, a distance of some 500 km for more than 36 hours. The large waves and high tides resulted in severe beach erosion and inundation along coast and offshore Islands between Townsville and Bundaberg. **The Emu Park wave recording station registered a peak wave height of 6.76metres at 0000 UTC 10 March 1997 when the significant wave height was 2.89metres The peak significant wave height of 3.06 metres was recorded at 0930 UTC 9 March 1997. Port Alma tide gauge reported a peak storm surge of 0.68metres at 0210 UTC 9 March 1997.**

State Coastal Management Plan – Queensland's Coastal Policy

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1. Introduction

The State Government seeks to protect and manage Queensland's coastal resources, which encompass a range of ecological, economic and social values. The State Coastal Management Plan (State Coastal Plan) has been developed under the *Coastal Protection and Management Act 1995* (Coastal Act). It has the force of law as a statutory instrument and describes how the coastal zone and its resources are to be managed. The State Coastal Plan is presented in three chapters:

Chapter 1 Vision for Queensland's coast
Chapter 2 How Queensland's coastal zone is to be managed
Chapter 3 Role agencies and groups

It applies to the coastal zone, defined in section 11 of the Coastal act as "Coastal waters and all areas to the landward side of coastal waters in which there are physical features, ecological or natural processes of human activities that affect, or potentially affect, the coast or coastal resources". Schematically coastal zone is shown in Figure 1.

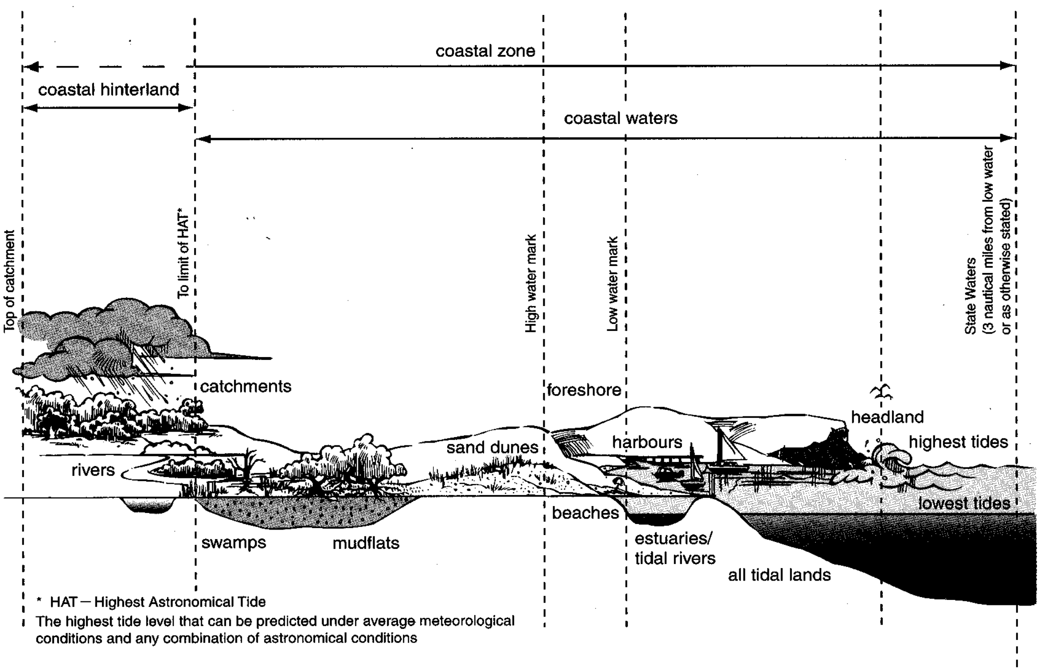

Figure 1. Coastal Zone

In the frame of this workshop, some fundamental information cited from the State Coastal Plan will be presented and discussed in relation to the local, Capricorn Coast interest.

2. Coastal management in the Queensland context

Based on statistical information it is known that Queensland has:
- coastline length of 9500 km – one fifth of Australia coast
- 1165 offshore islands and cays
- 70% coastline in public ownership
- 92 local councils – 41 have coastal boundaries, 51 are within coastal zone
- 85% of population living within coastal zone

Considering pressures on the coast, based on limited information it is known that:
- 25 of 57 river basins flowing to coast have regulated flows (e.g. dams)
- 25,000 of nitrogen and 700 kg of phosphorus from sewage treatment is discharged daily to the sea
- is high rate of invasion of exotic weed and marine species
- is “declining” population of barramundi, coral trout and mud crab
- sediments in river runoff threatens shallow water seagrass
- occurs higher incidence of cyclonic events, coastal damage from storm and other climatic changes

And finally based on limited information state of the coast is:
- Immense diversity of plants – 79 listed rare and threatened on continental islands
- Diversity of animal species – 550 crabs, 46 migratory waders, 6 of world’s 7 turtles, 10 dolphins, 18 whales, 1 dugong
- Loggerhead turtles declined by 50 – 80% since 1970s; humpback whales increased from 100 in 1962 to 2500 in 1996
- Coastal catchments – only 2.5%pristine; razing on 85%, urban are less than 2% and growing
- Declining water quality indicated by algal blooms
- Only freshwater wetlands in remote areas not modified
- Acid sulphate soils cover an estimated 2.3 million ha on coast

The coastal zone contains a number of different, but related, resources with distinct values. State Coastal Plan recognise 15 different coastal resources such as: coastal use and development, physical coastal processes, public access to the coast, water quality, Indigenous Traditional Owner cultural resources, cultural heritage, coastal landscape, conserving nature, coordinated management, and research and information.

With significant growth projected for the majority of coastal zone, urban development in the coastal zone ia a major challenge. From 1995 to 2000, the second fastest population growth in Australia occurred in Queensland, which increased by 9.2%. The most significant proportion of this growth was experienced in coastal centres including Brisbane, the Sunshine Coast and Gold Coast. Strong population growth was also recorded elsewhere in Queensland’s coastal zone. Many local governments along the coast face the challenge of accommodating rapid urbanisation and balancing demands associated with economic development, social wellbeing of the community and maintenance of health and sustainable environment. Increased development and population growth on the coast and adjacent areas also place human life and property at risk from the effects of coastal hazards, including storm tides.

The predicted global climate changes due to enhanced greenhouse effects will impact upon the coastal environment. Queensland may be vulnerable to the predicted changes in climate and its associated impacts, including sea level rise. Research into change, assessments of impacts and vulnerability, and planning to adopt will be an important long term management strategy. Some aspects of research connected with beach protection and its management, and cyclonic activities were presented in other papers during this seminar.

The main goal of the State Coastal Plan is finally to establish a coordinated and integrated framework and build on existing strengths a set polices where gaps currently existing. Finally the State Coastal Plan provides a common basis for decisions and actions and will, in the short to medium term, be reflected in other plans and management activities.

3. Coastal management issues

The State Coastal Plan identified ten topic areas that requires more detailed implementation of the principles. These topic are coastal use and development, physical coastal processes, public access to the coast, water quality, Indigenous Traditional Owner cultural resources, cultural heritage, coastal landscapes, conserving nature, coordinated management, and research and information.

3.1 Physical coastal processes

Because the main topic of this workshop is connected with beach protection and restoration, lets look with some details into the topic: physical coastal processes. The main outcome of this topic is that the coast is managed to allow for natural fluctuations to occur, including any that occur as a result of climate change and sea level rise, and provide protection for life and property. The following policies are issued:

- Adaptation to climate change, as it has significant impacts on the coastal zone and human settlement
- Erosion prone areas defined as areas that are vulnerable to erosion or encroachment from tidal waters within a 50 years planning cycle
- Shoreline erosion management
- Coastal hazards that include events such as storm tides, cyclone effects and related inundation
- Beach protection structures including seawalls, groynes and artificial reefs with their significant impact on coastal processes.

Adopted policy stated that construction of structures for the propose of beach protection (including artificial reefs, banks, wrecks, breakwaters and groynes) will only be approved where:

(a) there is demonstrated need in the public interest, and
(b) comprehensive investigation has been carried out and it can be demonstrated that:
    (i) there would be any significant adverse impacts on the longshore transport of sediment, and
    (ii) there would be no increase in coastal hazards for the neighbouring foreshore

4. Role of some agencies and group

The leading agency in coastal management is the Environmental Protection Agency (EPA) which coordinates the preparation of the coastal plans, administers the licensing and enforcement of coastal permits, and provides advice to local government and other agencies and persons regarding management best practice.

Local government is responsible for preparing planning schemes taking into account matters of state and regional interest. Thus the local government undertake the following:

- Funding, construction and management of coastal management infrastructure
- The acquisition and management of coastal lands to protect coastal resources
- The management of waterways in the coastal zone
- The funding, construction and management of water quality management infrastructure
- Cleaning of foreshore and waterways
- Managing public access to the coast

Community groups and individuals commit time and effort to developing strategies such as integrated catchment management plans, natural resource management strategies and to on-the-ground works and activities such as rehabilitation projects that contribute to managing coastal areas. In some cases, the State and Commonwealth governments support these efforts through funding programs such as Coastcare and Coast and Clean Seas.

5. Regional overviews

The Queensland coast has been subdivided into eleven coastal regions for the purpose of preparing regional coastal plans. The regions' boundaries are based on coastal local government boundaries. The eleven coastal regions are illustrated in Figure 2. The Capricorn Coast region extends from the northern boundary of Broadsound Shire to the southern boundary of Fitzroy Shire. The coastline includes a diverse range of landforms ranging from relatively high-energy sandy coasts in the southern Shoalwater peninsula and Keppel Islands, to extensive sheltered embayment and estuarine areas. The more sheltered areas contain extensive mangrove stands, mudflats and seagrass beds. Scenic rocky headlands are well represented by sites such as Double Head, Cape Townsend, Cape Manifold and many islands of the Keppel Group.

The largely undeveloped nature of much of the region's coastline provides an important contrast to most of the more developed southern coastal regions of Queensland.

The local governments in the region are Fitzroy, Livingstone, Rockhampton and Broadsound Shire Councils. They have existing planning schemes and are required to prepare new planning schemes under the *Integrated Planning Act 1997* by 30 March 2003.

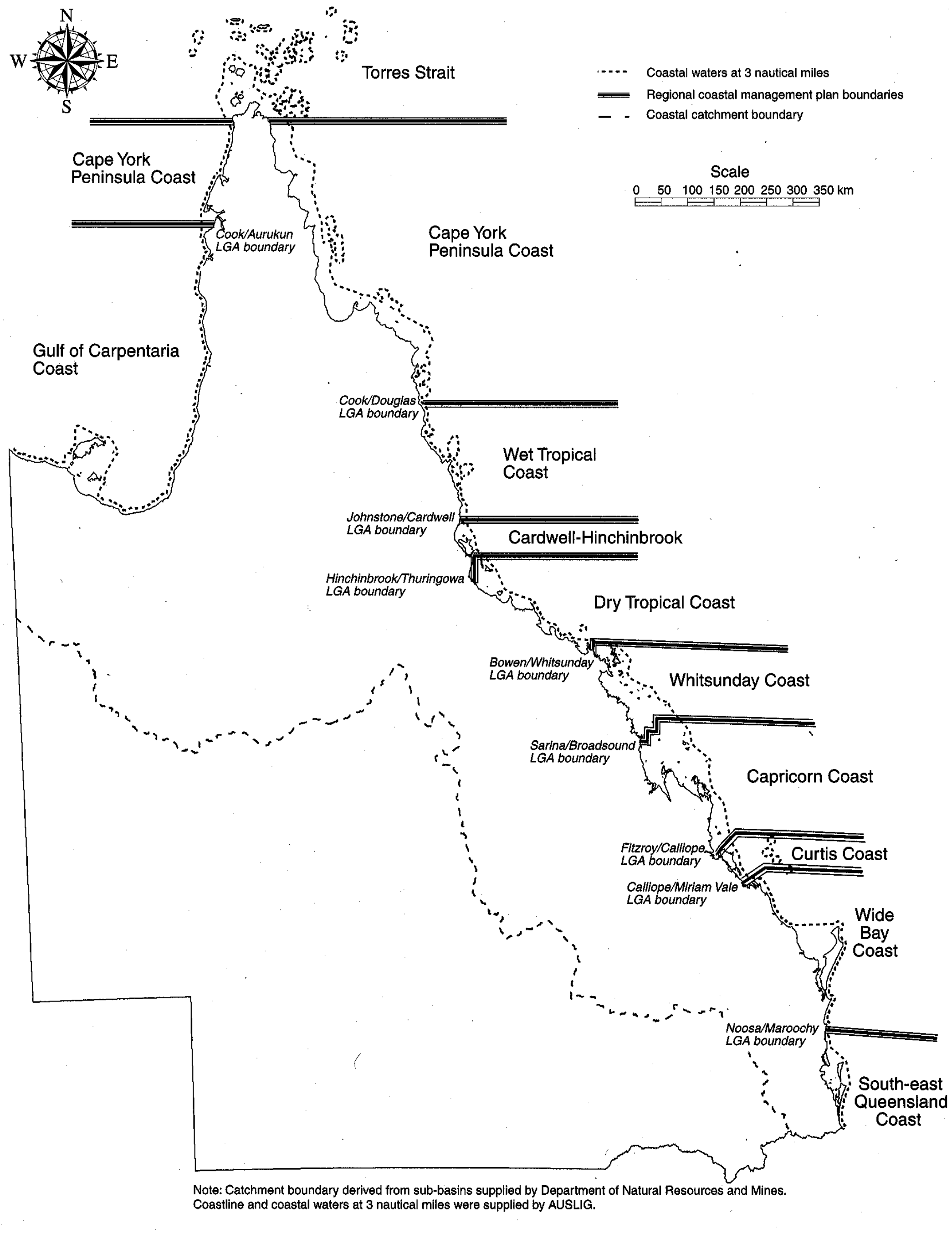

Figure 2. Queensland: coverage of regional coastal management plans

5.1 Coastal resources of Capricorn Coast

The Shoalwater Peninsula has received national recognition for both its natural and cultural heritage values, being the focus of a major Commonwealth Commission of Inquiry in 1993-94, which found that Shoalwater Bay should remain a military training area, with certain access rights provided to Indigenous groups and the conservation of natural and cultural values assured. The region includes significant freshwater wetlands, seagrass beds, tidal mudflats and mangrove habitats supporting substantial population of dugongs, marine turtles, shorebirds and commercially important marine and estuarine species. Shoalwater and Corio Bays are listed under Ramsar Convention and comprise the southernmost wilderness area on he east coast.

The Fitzroy River, which enters the coast at the southern extent of the region contributes extensive riverine floodplains and tidal wetlands to the landscape. The Fitzroy River plays a major role in he features of the coast, especially during flood events. On these occasions large volumes of sediment can be deposited up to 30 km north and east of the estuary, having a dramatic impact on the coastline, fringing reefs and islands.

The Bayfield area, to the south of the Shoalwater training area, has an extensive parabolic dune system. This landform offers diverse vegetation, including heathland and stringybark woodlands and significant freshwater wetland habitat is situated behind the dunes draining to Corio Bay.

Indigenous Traditional Owner and South Sea Islander cultural resources are common throughout the region and many are under threat due to the pace of development. Important cultural heritage values and resources are also associated with historical processes such as coastal exploration, coastal navigation, pastoralism, mining, the sugar industry, tourism and holiday resorts.

Use of the coast varies greatly within the region. In areas such as Yeppoon and Emu Park there is a high level of development, with residential and commercial facilities fronting the beaches and foreshores in some areas. A major nature-based tourism exists in the region, with specific emphasis on the area just north of Yeppoon and the Keppel Islands. Experiences offered include recreational fishing, scuba diving and camping. A local resort includes built wetlands that provide a supratidal waterbird habitat.

There is also considerable recreational use of waterways, bays and open waters. In the less developed areas, the prominent landforms and waters along the coast are often associated with recreational or conservation values that are highly regarded by the community.

Beef cattle grazing is the dominant rural land use, with some horticulture (e.g. pineapples, tropical fruits) occurring near Yeppoon. Commercial fishing targeting crabs, prawns, scallops, and barramundi is a significant industry. Port Alma has facilities for the export of local beef and salt from nearby salt-production facilities and import of materials for explosive manufacture.

5.2 Key coastal management issues of Capricorn Coast

The State Coastal Plan presents 23 important coastal management issues. Some of them are:

- Threats to water quality from agricultural and urban sources
- Expansion of residential development along the coastline, with associated adverse impacts on coastal resources
- Sustainable extraction of water from coastal streams and underground aquifers
- Impacts of acid sulphate soils
- Cyclone impacts and storm tide inundation
- Preservation of Indigenous Traditional Owner cultural resources from inappropriate access or use, including appropriate management of Indigenous Traditional Owners knowledge and information
- Identification and maintenance of cultural heritage resources (values, places and items)

6. Conclusions

Presented citations from the State Coastal Plan shows that the Queensland Government addressed the major challenges associated with protecting our coast for future generation. This Plan combines in one Coastal Act a vision of coastal management in several topics with their principles and policies. The continuity of this process

will be implementation of the State Coastal Plan through the actions so the decision makers will be required to take into account the aspects of this Plan relevant to the particular situation.
Finally during our workshop time only some elements of the Plan were discussed. The coastal management outcomes, principles or policies cannot be read in isolation but as an integrated package in the context of the Coastal Act.

7. References

Queensland Government, Environmental Protection Agency. State Coastal Management Plan – Queensland's Coastal Policy. Document prepared by Coastal Planning, EPA, August 2001 p 101.

REVIEW OF HARD/SOFT METHODS OF BEACH PROTECTION THE CAPRICORN COAST CASE STUDY.

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ABSTRACT

The shore zone, which is the area most directly influenced by marine processes, interact and continuously shapes and modifies the physical features of the shore, including beaches and sand dunes. Coastal engineering, as a part of the civil engineering, concerns all engineering problems in coastal areas. Beach protection is one of the coastal engineering problems of wide concern to the community.
This paper presents principles and modern trends in shoreline protection. Generally, long-term erosion problems occur due to littoral drift gradients. Based on the sediment transport capacity, the designer can attempt to design the proper defence system. There is now a tendency to avoid the construction of groynes, sea walls, etc. as long as possible. Most types of erosion problems can be solved by the proper "soft" solution. Based on this information, and in the light of the recent demands for proper coastal management the present situation, with respect to beach protection along the Capricorn Coast, is discussed briefly.

1. INTRODUCTION

The problem of coastal management appears with the increasing of the density of population when a man has settled and exploited the coastal zone - when a techniques progressed from the land towards the coastal waters and next farther offshore. Actually, for example, it is 5 cm of the coastline per person in Holland, about 70 cm in USA and 200 cm in Australia.

Including its external territories, Australia has one of the largest marine zones in the world (8.9 million km^2) and one of the longest coastlines (approx. 70,000 km). The coastline of mainland Australia itself, including Tasmania, is approximately 36,700 km, Queensland approximately 9,500 and the Capricorn Coast, the region of our interest about 75 km. Australia has also wide range of tides from over 12 m in the north of Western Australia down to 0.5m near Perth. Figure 1 shows schematically the range of tides around Australia.

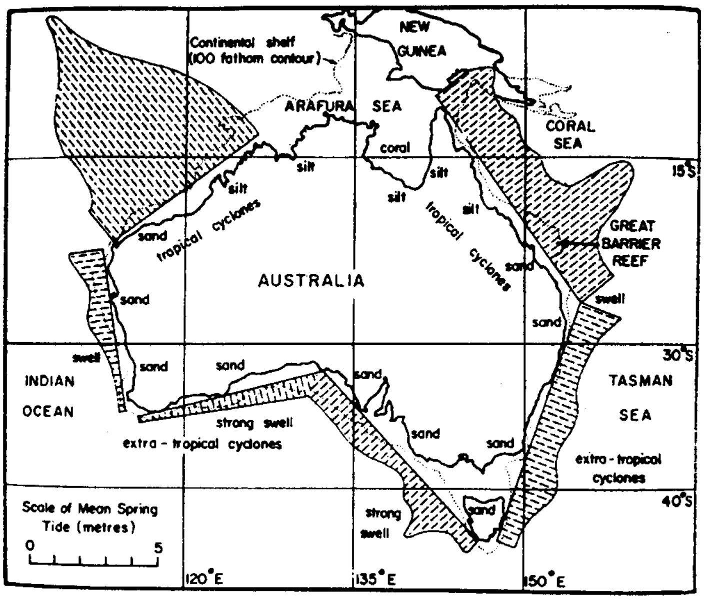

Figure 1. Tides around Australia (Silvester, Hsu 1997)

Coastal zone also contains the largest areas of coral reefs of any nation and the third-largest area of mangroves, and it has globally significant populations of a number of endangered species.

Based on the local government definition, Australia's coastal zone supports about 85 % of total population. The coastal zone is especially significant because it contains a high proportion of the resources used to produce goods and services. In particular, it is where most of the fishing industry, tourism and other service industries, and significant parts of the agriculture, forestry, mining (including petroleum) and manufacturing industries are concentrated.

Thus the coastal zone plays important role in our life. Development, and whole range of other human activities, can be successfully accommodated within the coastal zone, but proper coastal zone management should be well planned for the benefits of the present and future generations. The environment of the coastal zone is subject to continuing change brought about by natural processes. This is particularly the case in the shore zone, which is that area most directly influenced by marine processes such as the actions of waves, currents, tides and storm surges. these processes interact and continuously shape and modify the physical features of the shore zone, including beaches, spits, sand dunes and offshore sandbars. These physical features are part of a naturally dynamic system, their form and location change in response to changes in marine processes are studied by oceanographers and coastal engineers. In general "coastal engineering" is one of several specialised engineering disciplines that fall under the umbrella of civil engineering. Harbour works, navigation channel improvements, shore protection, flood damage reduction, and environmental preservation and restoration are the primary areas of endeavour.

Because coastal engineering is so extensive, a subdivision is made into three areas according to the type of problems experienced. These three main categories are Harbours, Morphology and Offshore.

"Coastal morphology" means the physical shape and structure of the coast. In other words: coastal morphology is the study of the interaction between waves and currents, and the coast, which results in sediment movement and eventually in coastal changes.

Coastal changes occur mostly as a result of changes in sediment transport along the coast. Sediment transport only occurs provided there is sediment to be transported. For example, erosion that occurs along some parts of the Adelaide beaches is largely a result of a natural lack of sand. On the other hand the Fitzroy catchment contributes significantly. Recent study of sediment transport in lower Fitzroy River found that average sediment transport towards the estuary is of the order of 5 million with the maximum up to 20 million cubic metres per year, including wash load (Franz, Piorewicz, 2001).

2. EROSION PROBLEMS

A natural beach profile changes almost continuously in shape due to varying boundary conditions. The cross-shore transports involved, cause the reshaping of the beach profile. Looking at the position of the dune foot as a function of time for an in principle stable cost, the histogram as in Figure 2 could be obtained. Over a number of years the coast is stable. At certain instances, however, the dune foot retreats over a much greater distance that the "normal" fluctuations (points A and B in Figure 2). The occurrence of a severe storm is the reason of that temporary retreat. To judge the safety of a row of dunes as an adequate sea defence, one has to be aware of the possible extreme positions of the points A and B.
In Figure 2 an essentially stable section of the coast was considered. In a steadily eroding section of the coast the cross-shore mode of sediment transport is not the only cause of the erosion problem. Continued erosion of coast occurs mostly due to gradients in the longshore sediment transport process. In Figure 3 a sketch has been given of a steadily eroding coast. It is assumed that the picture holds for a certain stretch of coast. For that specific part of the coast obviously the "outgoing" sediment transport is greater than the "incoming" transport. Generally the longshore transport can be estimated from some of several proposed formulae in the literature.

Figure 4 shows schematically what happens during a severe storm surge. Due to water level that is higher than normal and the rather high waves, sand is eroded from the unprotected dunes. This sand is transported in the offshore direction where it resettles. Prototype measurements and model test results have shown that the settlement of the eroded material occurs close to the original shoreline and there is no evidence that huge quantities of material are transported far into the sea. Dune erosion is relatively short process and erosion takes place within a few hours.

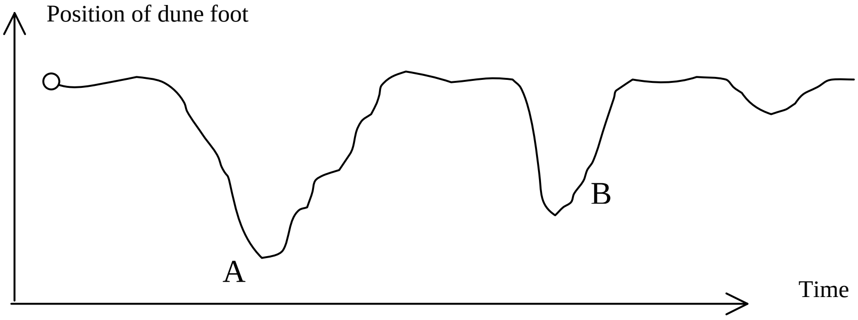

Figure 2. Position of the dune foot as a function of time

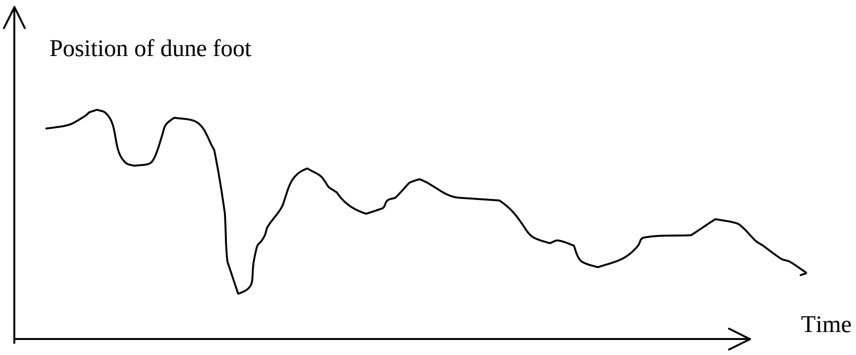

Figure 3. Steadily eroding coast

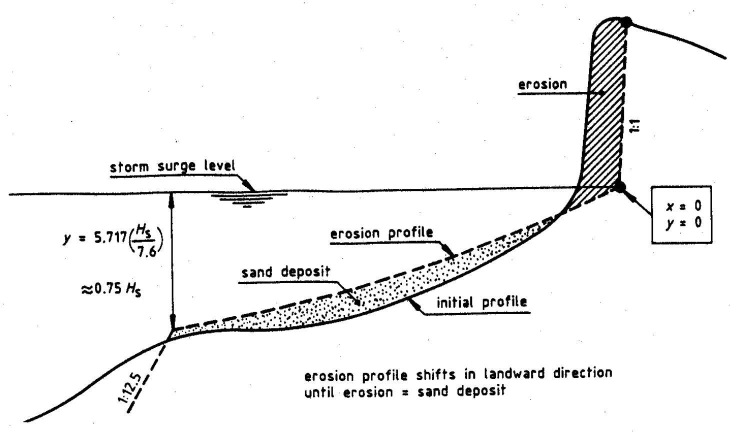

Figure 4 Post storm beach profile (Vellinga,

Inconvenient cross-shore transport is only assumed to occur during a storm surge. The problem is to decrease the expected erosion or to reinforce a dune that is obviously too weak. The response to beach/dune erosion has traditionally been the construction of artificial structures. However, these techniques have proved to be ineffective in many cases. For few decades, new "soft" methods have been considered and successfully tested. In the next section a short review of the traditional and modern techniques will be presented.

3. SHORE PROTECTION STRUCTURES

The different coastal structures have different influence on reshaping of the coastline. Figure 5 presents schematically different types of the structures and their location on the coast.

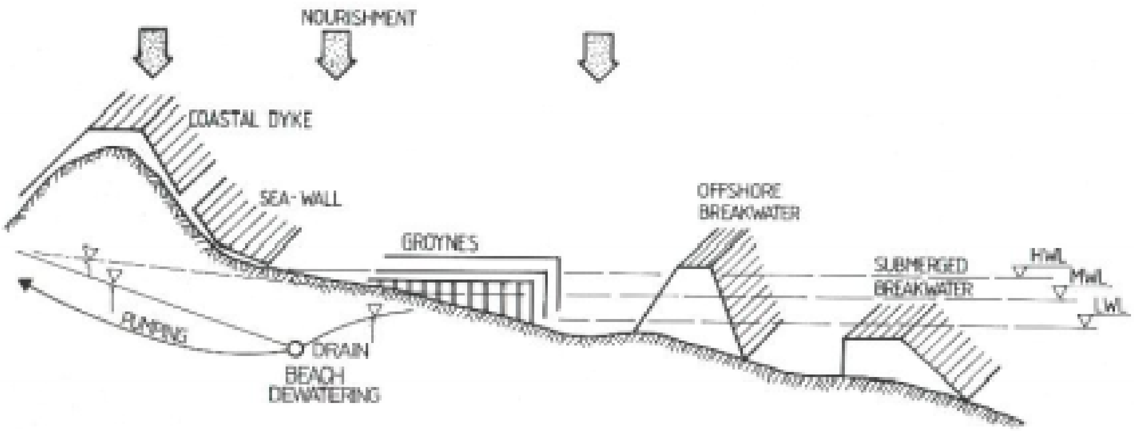

Figure 5. Different types of shore protection structures

3.1 Hard types of shore protection

Coastal dykes and rock-walls are generally defined as ***revetments.*** A revetments has been described as a cladding of stone, concrete or other material used to protect the sloping surface of an embankment, natural coast or shoreline against erosion.
Coastal dykes separate low level lands from the sea and protect them against storm actions. Dune system is a natural type of the coastal dykes. Reinforcement of the dune formation is one of the favourite solutions. Knowing the wanted safety, the actual necessary dune width and/or height can be computed. From the point of view of minimal sand supply, the widening of the dunes seems most appropriate.

Sea-walls and/or bulkhead are the massive structures built parallel to the coastline to prevent the cross-shore transport of material from the coast towards deeper water (Figure 6). They can be an appropriate counter-measure to prevent unwanted erosion due to a single occurrence of a storm surge; however, they do not diminish at all the retreat of the dunes above the highest level of the defence.

A sea-wall can make some local erosion more severe (Figure 7) by:

- erosion at the ends of the sea-wall due to superposition of the coming waves with waves reflected from the sea-wall,
- -erosion behind the sea-wall due to overtopping waves, and
- -erosion in front of the sea-wall due to strong wave currents caused by wave reflection.

Figure 6. Bulkhead on Yeppoon Main Beach at High Water

While many sea-walls have been built in all parts of the world, they cannot be recommended generally as beach protection. These structures increase the current flow by becoming hardened parallel shoreline. Gone is the absorption effect of a gradually rising beach, which drains energy from the waves by percolation and friction.

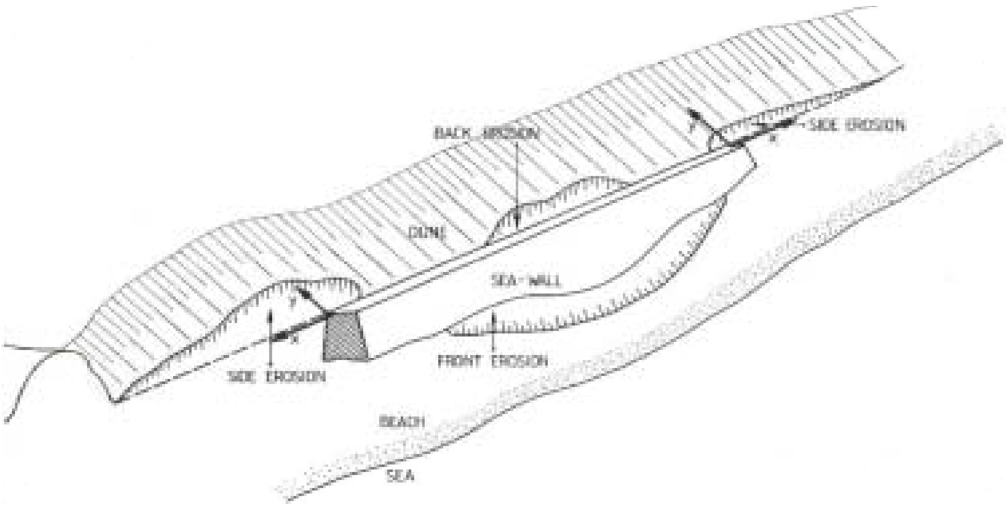

Figure 7. Possible local erosion around seawall

Sea-walls do not stabilize the shoreline in any long-term sense. These structures are more related to storm protection than stabilizing the shoreline over the daily processes which are so important in shaping the beach.

Groynes have been installed across the path of littoral drift in order to retain beaches where they have been needed. The groynes must extent through the breaker zone and have crests above the still water level to be completely effective (Figure 8). The area protected by the groins will not erode but will interrupt the longshore drift. Therefore severe erosion will result down drift of the last groin (Figure 9). The groynes simply displace the erosion problem. Still the groynes functional behaviour is the least understood.

Figure 8. Example of groynes application in Holland

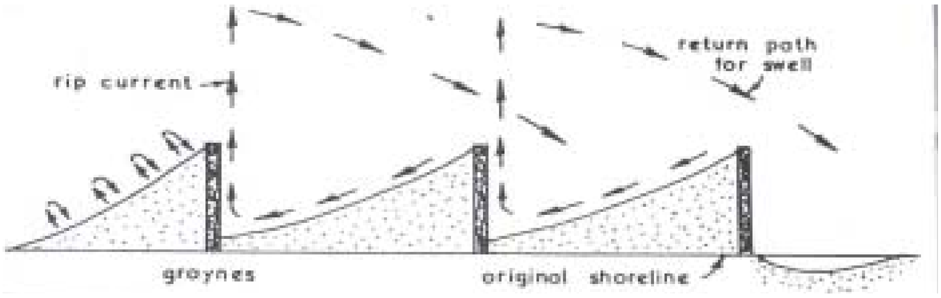

Figure 9. Shore-normal groynes

Offshore or detached breakwaters are built offshore parallel to the coast (Figure 10). These structures are constructed offshore in 3 to 5 m depth parallel to the coast, with spacings varying from ½ to 5 times their individual lengths. A group of breakwaters modify the wave pattern between them and the coast. Since wave heights are reduced behind the breakwater segments by diffraction and later also by refraction, the sand transport capacity behind the breakwater is reduced leading to the deposition of material supplied from “updrift” in the lee of the breakwater. Under certain conditions (wave climate, segment length, gap width, distance from the original coastline) sand will accrete behind a breakwater segment until it reaches the breakwater itself and forms a tombolo.

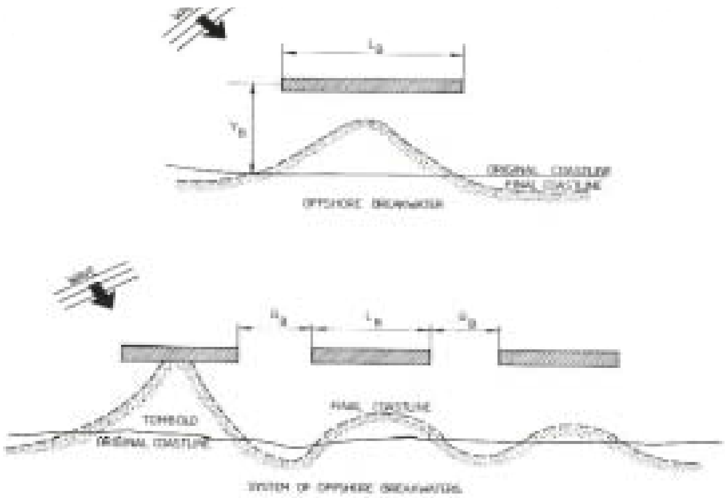

Figure 10. Principles of detached breakwaters

Submerged breakwaters are built parallel to the coast on a such depth that breaking wave will happen above the crest. The aim of the submerged breakwater is a gradual absorption of wave energy and accumulation of sediment transported towards the sea (Figure 11). It can influence the water quality by induced the water stagnation in the lee side of the structure during calm conditions.

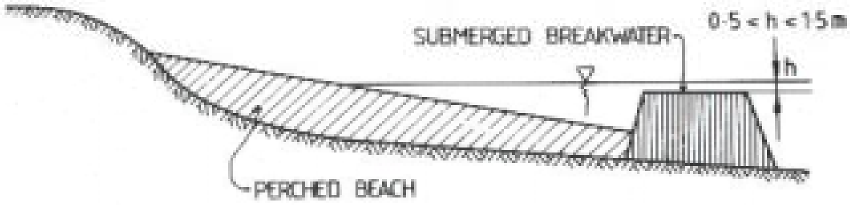

Figure 11. Submerged breakwater

Since the only way to retain sand where it is wanted is to reorient the beach normal to the incoming waves, a new concept has been developed by implementation so called headlands. That concept can be classified as “soft” solution.

3.2. Environment-friendly soft techniques for shore protection

“Hard” shore protection methods, such as seawalls, groins and detached breakwaters, no matter how well designed and implemented they may be, can hardly avoid fortification of the concomitant erosive, often devastating, effect on the down-drift shores, and anyway do not constitute an environmentally and financially attractive solution to be applied to long stretches of eroding shoreline. Engineers and scientists practising design and implementation of shore defending schemes are, for a few years now, aware of the public and private demand for improved shore protection technologies and encourage efforts that promise enrichment of the log of environmentally sound and financially attractive methods that can be safely applied.

Adverse environmental impacts and high cost of “hard” protection schemes have created interest to examine in detail the potential and range of applicability of the immerging and promising category of “soft” shore protection methods against such erosion. “Soft” methods, e.g. beach nourishment, headlands, artificial reefs, gravity drain systems, floating breakwaters, plantations of hydrophyle shrubs etc, applied mostly during the past 20 years, are recognised to possess technically, environmentally and financially advantageous properties deserving more attention and further developmental experimentation than has been given hitherto. A short review of this method is discussed below.

Beach nourishment is probably the simplest and most dependable means of maintaining an eroding beach by supplying sand from other sources. In order to carry out artificial nourishment, several questions must be answered: what kind of nourishment should be used, what size of material should be used, what amount of sediment should be suppled, where should the sediment be obtained. Methods of beach nourishment are shown schematically in Figure 12.

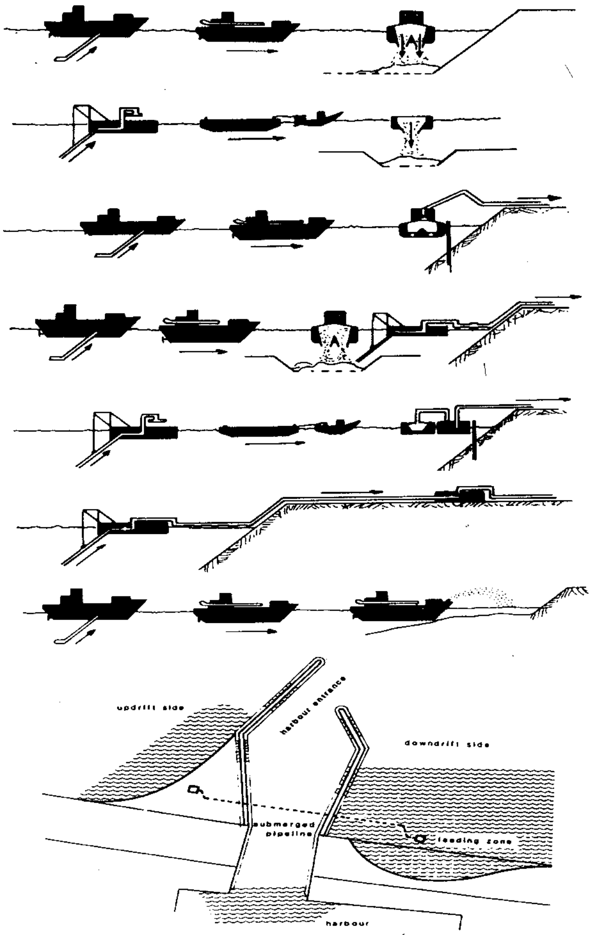

Figure 12. Different methods of beach nourishment (CUR Report 130)

Increasingly, sand supplies do become an adequate solution for (gradual) erosion problems. Contractors are able nowadays to supply large amounts of sand at still (relatively) decreasing costs. The seaside maintenance, its natural looks and one avoids the construction of "strange elements" in the coastal system which can hamper a next generation of probable higher-skilled coastal engineers. It should , however, be remembered that the same wave climate exists as before, which is oblique persistent waves in an erosive situation. Thus the never-ending repetition of supplying sand will occur. It may happens that up to 50% of any initial renourishment is lost in the natural process of a beach reshaping and repetition could be at as short as 2 years intervals. However, in USA, as it is shown in the last edition of the Coastal Engineering Manual (2001) up to 80% of coastal protection works has been done with the beach nourishment (Figure 13).

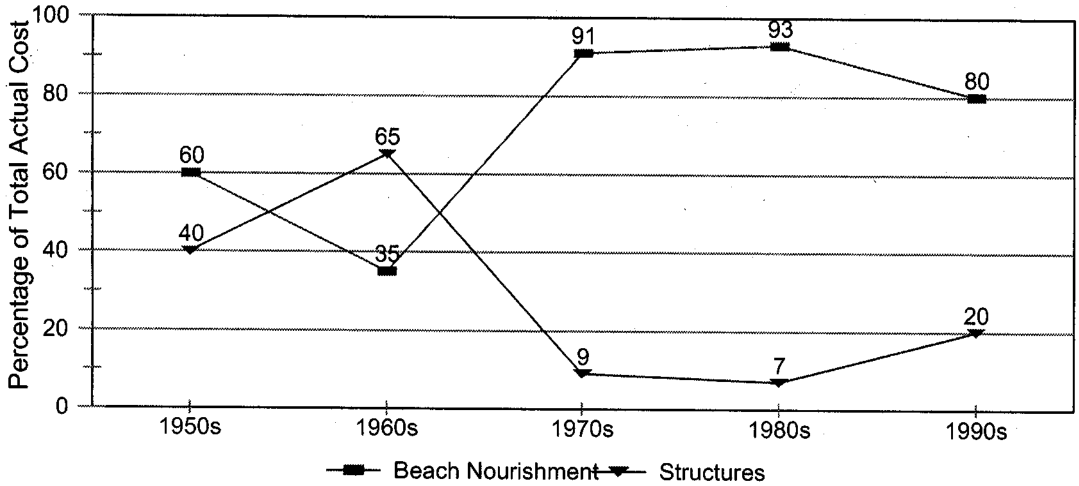

Figure 13. Implementation of beach nourishment in USA (CEM, 2001)

Headland Control. The observations of coastline behaviour of the seas or oceans, or analysis of aerial photographs indicate the existence of bays which are in stable conditions over geological time (Figure 14).

Figure 14. The Capricorn Coast, example of natural beach shaping in the form of bays.

Silvester (1972) first proved the principles of equilibrium shaped bay between headlands in the presence of persistent oblique swell and defined them as "crenulate shaped bays" (Figure 15). The term "headland control" is used when crenulate shaped bays are artificially created between man-made headlands. The aim is to give the beach a natural stable shape over the long term, possibly without need of any renourishment. Efforts have been made since early 1970s to understand the effects of headlands and to model stable bay characteristics. Guidelines in the design of the headland are given in Silvester and Hsu (1993).

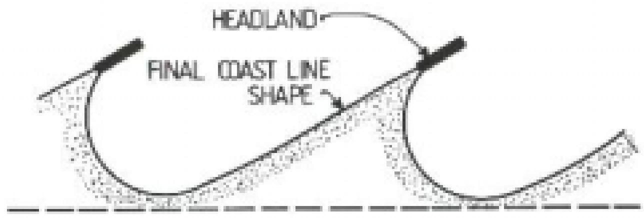

Figure 15. Headland control on straight beach

Beach Dewatering. The effects of water-table position on accretion and erosion of the beach face has been well documented in the literature (Weisman et al. 1995). One mechanism suggested is that with a low water table under the beach face, a relatively large fraction of the water volume in the uprush can infiltrate through the beach face, diminishing the volume and erosive effect of the backwash (Figure 16).

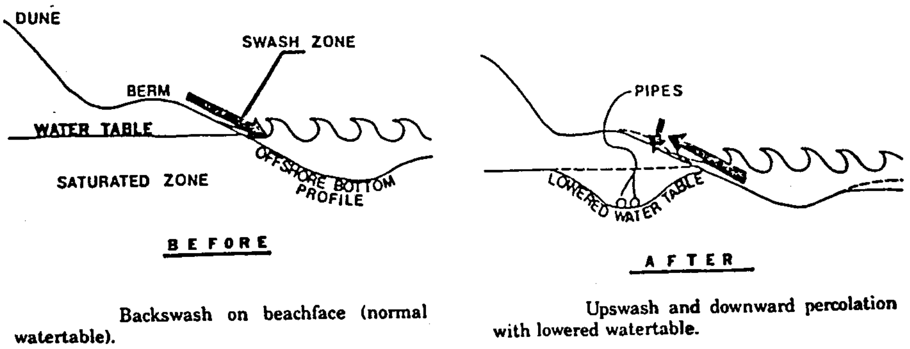

Figure 16. Principles of beach dewatering

The sediment deposition during uprush combined with a reduced backwash yields an accretion of the beach face. Basically, creating an unsaturated zone under the beach can be done by using low energy pump to draw water from buried horizontal perforated pipes. There have been several field tests of this technique in Denmark, USA, England, Italy, Japan, and Australia. The techniques experimented in New South Wales achieves lowering of the watertable without pumps (Davis and Hanslow, 1991). Drains were in this case normal to the shore and transfer water from the upper beachfront to the surf. Similar test was conducted on Yeppoon Main Beach as a final year engineering student project (Steedman, 1996). Unfortunately, the project was not continued on the following years.

The advantage of this method is that all the hardware is buried therefore invisible and no hazardous. This method helps the eroded beaches to recover faster than in natural conditions. The major questions for engineers concern the design and operation of a drain system. There are still many unsolved questions like location of the drain, specifically the depth and the distance behind the still water level, or drain system's effectiveness against tidal range.

There are a few patents connected with this type of beach protection:

- Pressure Equalisation Modules patented by S/C Skagen Innovation Centre, Denmark. They advertise effectives of their method almost in every condition. An example is shown in Figure 17 and 18 taken from their web site (www.skagen-innovation.dk)
  The later aerial photo (Figure 18) from 1999 illustrates very clearly that pressure equalisation modules are far more effective than the conventional groynes from 1950. As can be seen from the photo, these groynes are now completely covered by sand on the new and sustainable beach.

Figure 17. Aerial photo of the groynes at Gl. Skagen, before the implementation of pressure equalisation modules. (www.skagen-innovation.dk)

Figure 18. Aerial photo of the same location in 1999, 15 months after the implementation of pressure equalisation modules. (www.skagen-innovation.dk)

- Undercurrent stabilizers patented by Holmberg Technologies, USA. They are low profile geotextile tubes that run at right angles from dune or toe of the bluff, across the beach face to an appropriate distance offshore. As patented, no more general information is available.Some example of the effectiveness of their method is shown in Figure 19 (www.erosion.com/shore.html).

Figure 19. Example of undercurrent stabilizers application. (www.erosion.com/shore.html).

3.3 General comments

Coastal engineering and management in the past consisted of providing protection against erosion and flooding. Life in coastal areas was a continuous battle of man against the sea and all possible methods were mustered to take part in this battle. However, in modern approach we understood that beach profile respond to storm-calm cycles by shifting sand in the cross-shore direction, forming a dynamic equilibrium. But any beach profile will need additional material during sever cyclones causing combination of high wave action and storm surge. Nature has provided for such emergency by stockpiling large quantities of sand in dunes. The dunes are a long-term protection against coastal erosion, because they provide adequate elevation of the land contours to prevent flooding and form emergency reservoirs of sand. Therefore the modern coastal engineering design and coastal management consider:

- Not disturb existing dune-beach systems
- Encourage growth of dune-beach systems, and
- Emulate dune-beach systems wherever possible

Critics of shore protection will say that all shore protection is temporary – so why build it in interfere with nature, which eventually will have its own way? On a geological scale, protection is not even temporary, but neither is the coastal system we are trying to protect. On engineering time scale protection is indeed temporary. Even the very large protection systems require constant watchfulness, repair and change in management techniques. But temporary with respect to shore protection is long enough to be of benefit for most applications. In any case, economic considerations decide if a coast should be protected.

Given the necessity of shore protection, we should do it right. Unfortunately, there are few guidelines on how to build shore protection and any existing guidelines suffer from either too much simplification or too much generalization. As a result, much shore protection is build without adequate knowledge or appropriate design. Thus for the design of coastal protection the following questions need to be asked:

- Do we want (or need) shore protection?
- What are the available alternatives?
- How can we implement protection and leave the coast as natural and attractive as possible?

It is a wisdom in the phrase: “Man masters nature not by force but by **understanding**” (Jacob Bronowski, 1908 – 1974)

How do these questions apply to our Capricorn Coast? Let’s discuss it in the next chapter.

4. CAPRICORN COAST CASE STUDY

The Capricorn Coast is the name of the Central Queensland coastline from Cattle Point on the northern side of the Fitzroy River mouth northward to Stockyard Point, a distance of about 75 km (Figure 20). Yeppoon is the major town on the coast where the offices of the Livingstone Shire Council are located. The other is Emu Park located about 18 km south of Yeppoon. The favourable climate and recreational opportunities have encouraged extensive residential and commercial development. At present (year 2001) Yeppoon is the third fastest developing coastal township in Queensland. Its population is 12,000 people and up to 17,000 people has been living along the whole Capricorn Coast.

Figure 20. The Capricorn Coast - Locality plan

This region become also popular as a tourist destination for national and international tourists. This year the Capricorn International Resort celebrated its 16 anniversary. Rosslyn Bay has been for many years mainly a fishing port. After construction of a new breakwater and inside development it was official opening of the Keppel Bay Marina having 180 berths on 27 April 1996. It is the only safe, all weather harbour for 500 kilometres between Gladstone and Mackay.
It is evident that the attractiveness of the Capricorn Coast is growing. In such situation the problem of the beach conditions, its stability and vulnerability to erosion is very real. Any erosion caused by storms cause public demand for implementation of more and more effective measures to protect coast and public assets against possible erosion.

Beach Protection Authority, Queensland (BPA, 1979) carried out extensive field measurements and analyses of the Capricorn Beaches and estimated the likely dune erosion for this area, based on 50 years of the assessment of buffer zone. The BPA has adopted a planning period of 50 years based on the practical life of beachside structures, the maximum reasonable forward projection of estimated present beach erosion trends, and changing attitudes to beach management. Taking the 100 year return period, for wave condition of 6 hours persistence, there is an overall probability of 10% that this wave conditions will coincide with the higher of the two high tides on any day in the 50 years planning period. For such conditions the nearshore wave heights, run-up levels and likely dune erosion has been calculated. The results are summarised in Table 1. Definition of erosion distance is shown schematically in Figure 21.

Table 1 Events with 10% probability of occurrence in 50 years (BPA. 1979)

LOCATION	NEARSHORE WAVE HEIGHT [m]	RUN-UP [m AHD]	EROSION QUANTITY [m^3/m]	EROSION DISTANCE [m]
Farnborough (up to Sandy Pt)	5.3	4.3	175	35
Bangalee	3.0	4.4	75	25
Yeppoon	3.5	4.4	80	40
Lammermore	3.5	4.5	130	50
Kemp Beach	3.5	4.6	50	35
Mulambin	3.8	4.7	115	50
Kinka Beach	3.9	4.8	65	50
Emu Park	4.5	5.0	80	50
Keppel Sands	2.7	4.4	60	20

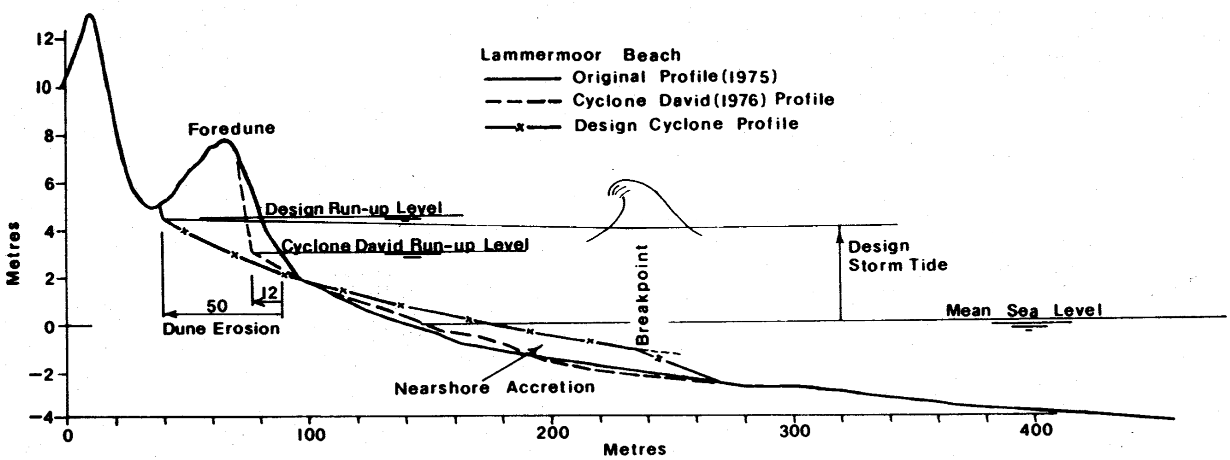

Figure 21. Cyclone dune erosion for Lammermore beach (BPA, 1979)

The results of the analysis presented in the Table 1 show serious erosion problem along all beaches of the Capricorn Coast. Therefore proper management is essential when development is considered. Discussion of the particular locations and some actions undertaken are shortly described in the next section.

5. MAINTENANCE OF THE LOCAL BEACHES

Farnborough

The Farnborough Beach, about 15 km long, exhibits extensive dune blowouts formations which have apparently been a more or less permanent features historically, allowing considerable vertical growth of dune heights. It represents a well established natural system of the dunes exposed to periodical erosion/sedimentation processes. In the region of the Capricorn International Resort erosion process in the years 1988-90 caused erosion up to 20 m. Since 1993, foredune redevelopment is clear and up to 30 m of foredune has been naturally rebuild. (Figures 22 and 23).

Figure 22. Farnborough beach near the Capricorn International Resort, situation in April 1989

Figure 23. Farnborough beach near the Capricorn International Resort, situation in January 2002

Bangalee

Bangalee area and further south towards Barwell Creek a new foredune ridge has been accreted in recent years, however, development adjacent to Barwell Creek is vulnerable to cyclonic erosion. In view of the general trend of accretion in the area no action had been considered so far. In the recent years the output from the Creek moved significantly southward, since 1989 for a distance of about 1000 m causing serious problem to the stability of the existing dunes (Figure 24). In the view of the progressing erosion in the last years some action connected with Barwell Creek stabilisation is required.

Figure 24. Farnborough beach near Barwell Creek, situation in January 2002.

Yeppoon

A seawall was constructed along most of Yeppoon Main Beach in the early 1930's and after being partly damaged by cyclonic wave attack in 1976, it was reconstructed and extended in the form of rubble mound rockwall (see Figure 6). In the light of BPA analysis, shown in Table 1, this reconstructed wall is inadequate to withstand severe cyclonic conditions. In early 1990's it was visible severe erosion of the beach causing some threatening to the stability of the existing seawall (Figure 25).

Figure 25. Erosion of the Yeppoon Main Beach, situation in early 1990's.

In 2001 additional reconstruction of seawall was conducted following BPA recommendation to strength the existing rockwall (Figure 26) before any works would be undertaken with the esplanade next to the beach for so called beautification of the Yeppoon recreation area.

Figure 26. Reconstructed rockwall on Yeppoon Main Beach, situation in January 2002

Generally, at present, the beach has been almost no useable on most high tides, and at low tides the sand remains saturated with ground water and is practically useful only for walking and fishing activities. Considerable benefit would be provided by the restoration of Yeppoon Main Beach. The recreational use of the beach would be substantially improved and a replenished beach would itself provide protection to the esplanade development behind it.

BPA in its report (BPA, 1979) concluded that the beach protection works for this beach are necessary and they recommended some form of beach nourishment. The Central Qld University has been undertaken a pilot study to investigate other “soft” option of the beach restoration by considering possibility to implemented headlands in right places (Figure 27).

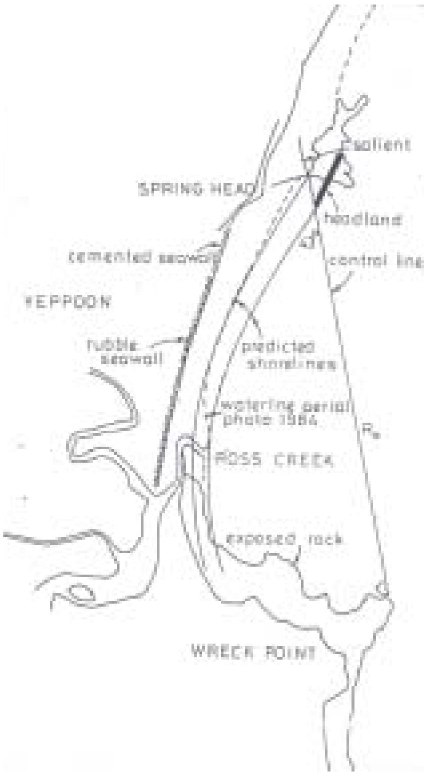

Figure 27. Considered headland to restore Yeppoon Main Beach

Lammermore
Along this beach, foredunes area is reaching up to 7 m above mean sea level in the northern part and reduced in heights towards southern end near Statue Bay (Figure28). Erosion presented in Table 1 indicates that the road along Lammermore Beach lies within the vulnerable buffer zone and could be threatened with erosion in the future. The similar situation is at the northern end where some residential development has taken place. As no immediate protection work is required or undertaken, the important would be proper dune management procedure to protect the natural vegetation and ensure that no wind erosion problems arise in the future.

Figure 28. Lammermore beach, situation in September 1989 (left) and January 2002 (right)

Kemp Beach

No serious erosion problems are evident at Kemp Beach and only a dune management program should be carried out to stabilise and protect foredune vegetation. (Figure 29).

Figure 29. Kemp Beach, situation in January 2002

Mulambin

Because of the high level of stability provided to Mulambin beach by the adjacent headlands and the relatively strong onshore transport of sand from offshore, Mulambin Beach has not experienced any measurable erosion in the last 50 years (Figure 30).

Figure 30. Mulambin Beach, situation in January 2002

Kinka Beach

Significant changes have taken place along the Kinka beach, particularly in its north and central parts since a causeway was constructed across the Mulambin Creek estuary, adjacent to Pinnacle Point, in 1939 (Figure 31). Extensive erosion in the central beach area reduced the dune width from about 90 m to almost none in the period 1960 - 1985 in spite of rockwall construction. Such situation threatens local residents about possible erosion of the Yeppoon - Emu Park road, and their properties (Figures 32,33).

Figure 31. Causeway just after construction in September 1939

Figure 32 Aerial Photo August 1961

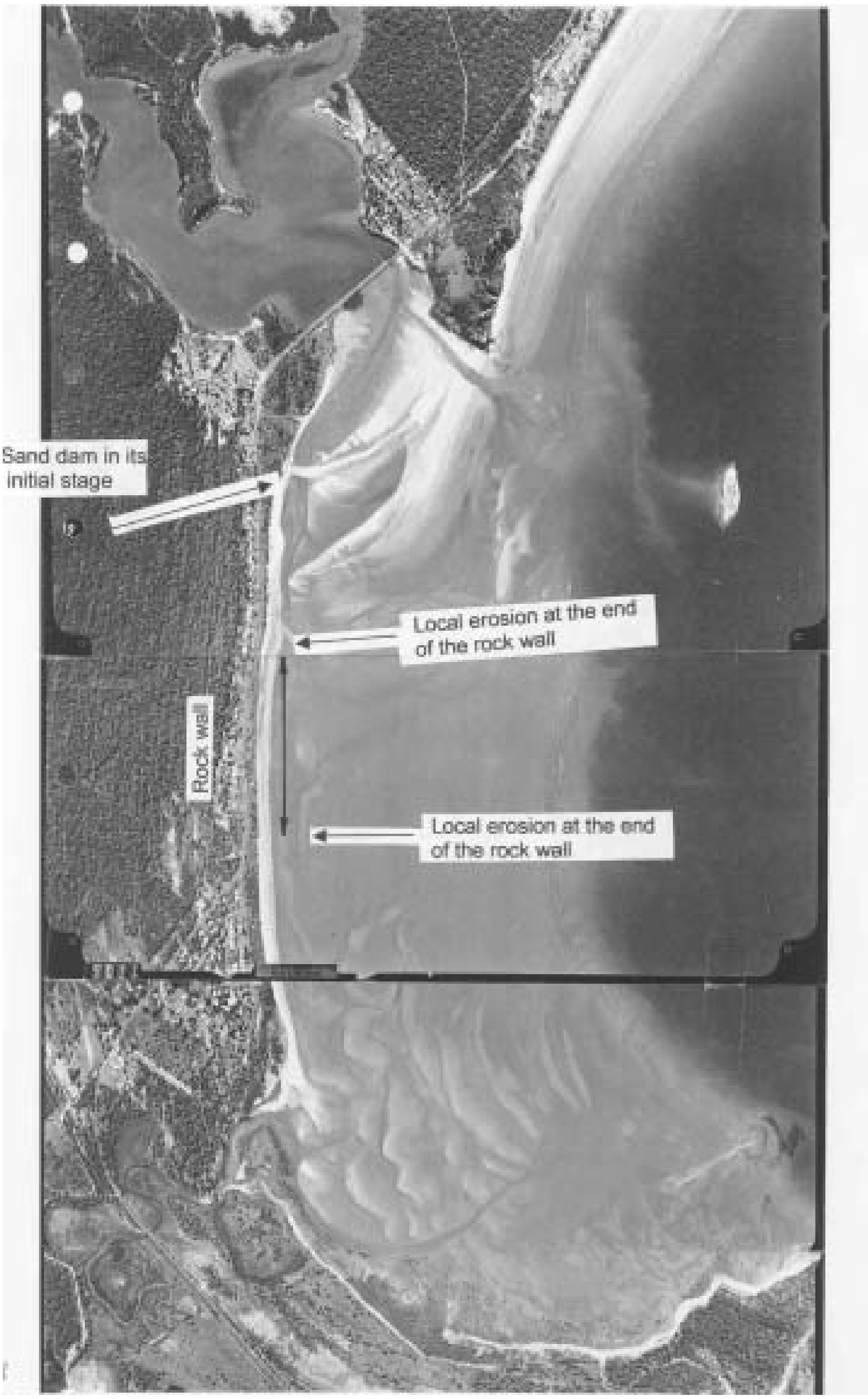

Figure 33. Aerial Photo May 1988

The Central Queensland University, CQU (previously Capricornia Institute) undertook investigations in 1987/88 to remove the risk of further erosion in the area (Piorewicz, 1999). A "soft" solution, which is compatible with environmental conditions, was recommended. This "soft" solution involved a new dredged channel and tidal lagoon as shown in Figure 34.

Before sand dam construction, the only used method of beach protection in this region was rock dumped directly on the dunes. This type of protection did not stop process of erosion, but only shifted it southward. The slow process of beach rebuilt started since the sand dam was constructed in 1988 with the visible and effective dune system improvement since 1993. Between 1993 and 1997, 80 percent of the rock wall was completely buried under the naturally accumulated sand and dunes get their natural shape and become covered with grass and shrubs. It is visible increase in dunes and dry beach (above MHWS mark) width (Figures 35, 36).

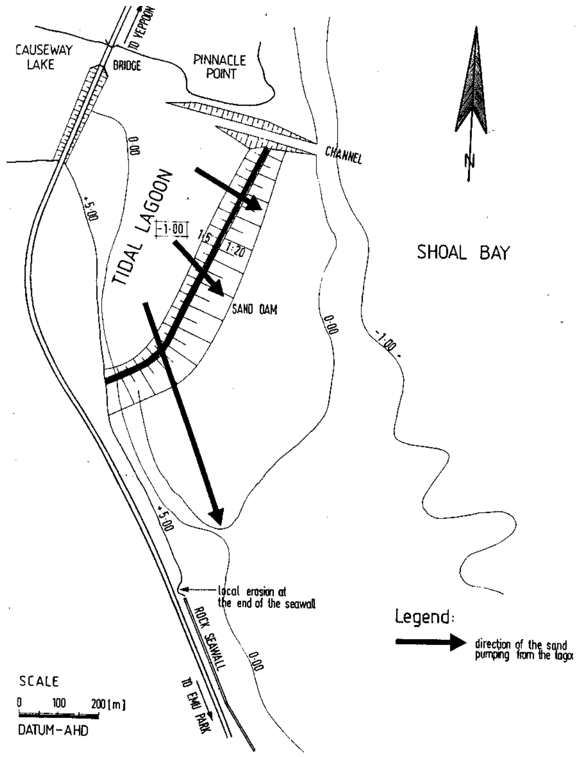

Figure 34. Implemented solution to restore north part of Kinka Beach

Figure 35. Improvement of Kinka Beach dune conditions for the period 1989 - 1998 - 2002

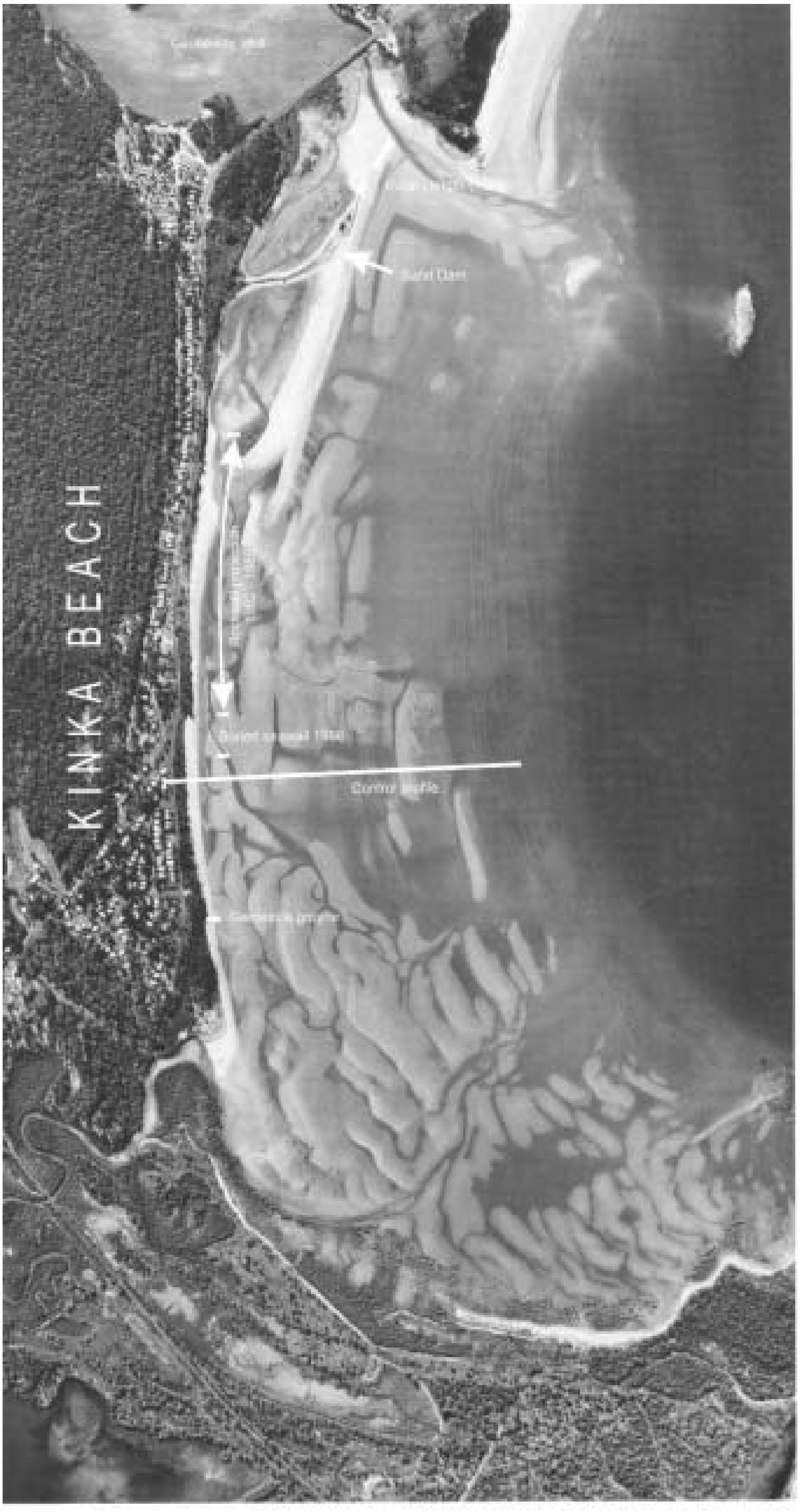

Figure 36. Aerial Photo 1996

The recent surveying shows significant accumulation of sand along the distance of about 700 m southward from the implemented sand dam. The source of this sand is likely to be the persistent swell actions from E to SE reshaping the beach agree with the Silvester's theory about crenulate shaped bay (Silvester, Hsu, 1993). Numerical modelling is planned to evaluate this expectation and compare actual situation of the beach with expected initially 10 years ago.

Figure 35 shows how the beach with initially strong erosion slowly return to its natural shape with dunes covered by greens. The process is still in progress. But it could be stopped if process of washing away the sand dam is not stopped. With not spending money for maintenance of the sand dam for the last 12 years it is now time to do it if one does not want that erosion problems on north Kinka Beach will come back.

The southern part of Kinka Beach was not considered at this stage of study. However, it was found in continues erosion process. Particularly at the south end of the temporary rockwall local erosion become very critical in 1996 (Figure 37). Buried seawall, length of 280 m, as well as groyne made of geo-textile bags were implemented at the beginning 1998, as recommended by BPA. Buried seawall was constructed as a southward extension of the existing temporary rockwall in the area shown in Figure 37. Cross-section of buried sea-wall is shown in Figure 38. View of buried seawall just after construction and at present, in January 2002, is shown in Figure 39. Geo-textile groyne marked on Figure 36 is shown in Figure 40. The effect of implemented solution has been currently monitoring by CQU (Piorewicz, 2001).

Figure 37. Erosion on south end of Kinka beach, March 1996

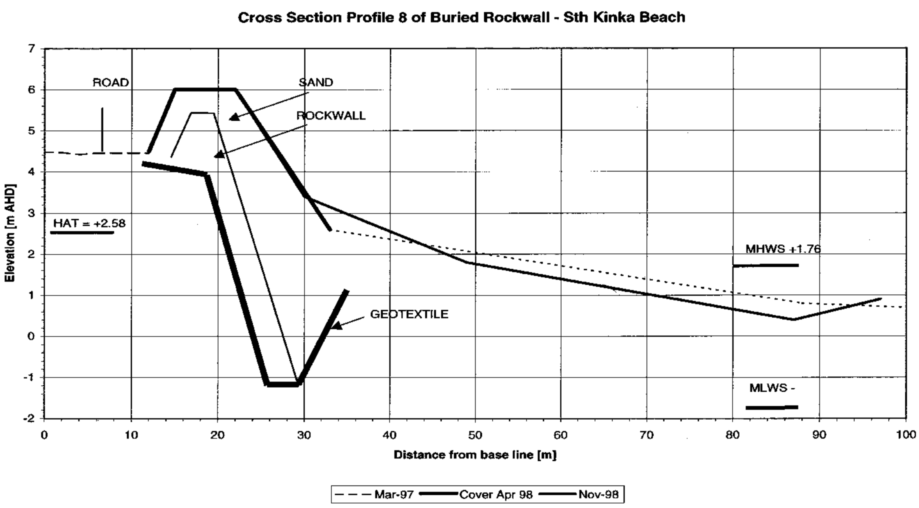

Figure 38. Buried seawall cross-section

Figure 39. Buried seawall April 1998 and January 2002

Figure 40. Geo-textile groyne on South Kinka, January 2002

Last year, LSC did beach renourishment in central part of Kinka Beach. It helps to accelerate natural buried process of existing temporary rockwall at its southern part. In the nearest future it is also recommended restoration of sand dam as well.

In the existing situation the weakest point of Kinka beach is its south part which can be flooded during a sever cyclone.

Emu Park

Erosion is not a problem along this section of the coast. At Emu Park the dune area is some 80 to 100 m wide and remains undeveloped and available for accommodate potential future erosion (Figure 41).

Figure 41. Emu Park beaches, January 2002

Keppel Sands

Keppel Sands beach is vulnerable to erosion and temporary protection with rubble and sleeper rockwall has been inadequate to protect the dune if "design" storm happens. Very flat and wide (up to 1 km) intertidal zone, shown in Figure 42, causes that any option for beach protection is very expensive. Some study has been carried out by BPA and CQU to find economically and environmentally accepted solution to improve natural sedimentation in this area. The optimal solution suggested by CQU, in its recent study, was extension of the existing groyne for another 100 m, creating this way headland which should help to restore the beach (Figure 43). View of extended groyne is shown in Figure 44. Monitoring has been carried at present and some conclusion about this approach to the beach restoration should be expected at the end of this year. Particularly the conclusions about south site of the beach where rockwall is exposed to the wave action (Figure 45).

Figure 42. Aerial photo of Keppel Sands

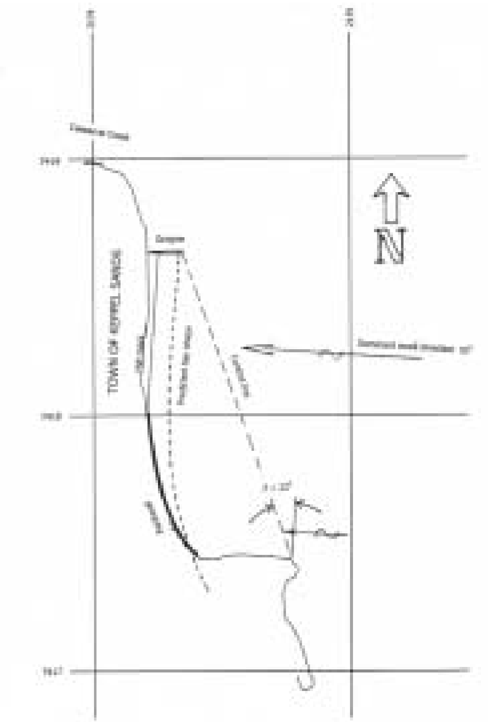

Figure 43. Expected shoreline changes as a results of groyne extension (Crenulate shaped bay approach)

Figure 44. Extended groyne on Keppel Sands Beach, January 2002

Figure 45. Keppel Sands, southern site of the beach. December 2001

6. CONCLUSIONS

Coastal zone management becomes recently the main national problem, as more and more people understand the value of the coastal zone as a national asset. Coastal engineering is a part of coastal management. One of the coastal engineering problems is beach protection. With the still increasing knowledge about coastal processes it is well accepted that no ideal solution exists for erosion control. The wave climate, tidal range, longshore transport, is among the many variables that must be considered at each individual site. Traditional engineering approaches to stabilisation of beaches near river mouths or estuaries were to use jetties or groynes, seawalls and nourishment. Nourishment, now widely used, has the advantage of leaving the beach uncluttered with structures and of not risking damage to adjacent shores. Its main disadvantage is the need to replace the losses seaward and/or alongshore periodically.

Engineering structures are generally more related to storm protection than stabilisation of the shoreline on the basis of the daily processes that are so important in shaping the beach. The concept of the existence of stable crenulate-shaped bay or beach dewatering could be promising means of stabilising a shoreline.

The Capricorn Coast is an area of extensive residential, tourism and commercial development. Short review of the beaches of the Capricorn Coast indicates its serious vulnerability to the design storms; however, costly solutions are not yet economically justified. Therefore implementations of simple solutions where natural processes are involved are very encouraged.

It is well known in coastal engineering that projects connected with the beach stability are usually realised without the satisfaction of knowing a prior what the success will be. Monitoring of those solution and structures, which are in place, therefore, is very important in order to learn more from nature. That information together with a continuous development in theoretical studies will allow for more rational criteria for design and construction of features to stabilise coastlines.

Remember: “MAN MASTERS NATURE NOT BY FORCE BUT BY **UNDERSTANDING**”

7. REFERENCES

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Issues From Discussion

The following issues were discussed during open discussion and some respond presented by by particular speakers and by the chair of LSC, Mr Bill Ludwig who summarised whole discussion underlining the actual involvement of LSC in preparation of storm surge risk map, in process of Yeppoon Main Beach beautification and restoration and in process of preparation of the coastal zone management plan following Governmental plan which was presented in the D. Robinson's lecture. He also underlined importance of keeping beaches in good conditions for public safety, and local business and tourist prosperity of our region.

- Concern about problems to beach erosion caused by public use i.e.: cars on beach, driving along beach, and uncontrolled walking on dunes?
- A storm surge over shallow lake like Causeway Lake may create flooding problems in the neighbour areas and a problems with an evacuation warnings system updateing.
- Business enterprises in the coastline buffer zone.
- Effectives of nourishment in front of rockwall
- Benefit in researching the effect of World War II and the large numbers of troops both at Yeppoon and Emu Park on the Coastal Highway and social impacts.
- Method of historical data collection should be more efficient and widely publicised.
- Acceleration of the rise of sea level in relation to local problems.
- Numerical model showing beach processes and potential changes to the shoreline of the Capricorn Coast.
- The priority of the community in relation to the coastal zone management.
- Dune vegetation as an effective method of dune stabilization.
- Approach to dune maintenance.
- Community education about significance of beach protection.
- The role of Local Council in making local coastal management program.
- The LSC responsibility to local erosion problems like for example severe dune erosion caused by uncontrolled southward progressing of Barlows Creek mouth.
- Cyclones risk and its knowledge within the local community.
- Programs of LSC, CQU, and CRC in relation to monitoring, planning beach restorations and/or protections on Capricorn Coast.
- Significance of a coastal ecosystem at the beach zone.

Attendance List

Beach Protection & Risk & Management Workshop
Bayview Towers, Yeppoon
Thursday 7th February, 2002

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11	Frank Evans	49225591	Community	Via paper
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26	Vicki Walford			
27	Bob Leicht		Save Bell Park Group	) TBA
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30	Claire Rodgers		Fitzroy Basin Association	
31	Mal Vanderheiden		Fishing Industry	
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34	Jim Fee	4933 6526		
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38	Michael Shera	4933 6119	Local Resident	
39	Fay Simons	4939 1187		

40	Horst Simons	4939 1187		
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42	Lou Liptak	49392365		
43	Daryl Williams	4939 2617	Wildlife Protection Society	
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49	Marlene Knox	4939 7727		
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58	E Schulz	4939 1046	Fishing Industry	
59	Jason Williamson	4936 1064	CQU	
60	Valda Reynolds	4939 7853	Bangalee	
61	Barry Reynolds	4939 7853	Bangalee	
62	Kirsten Muir	4935 1678	Stockyard Point Resident	
63	John Widdowson	4935 1678	Stockyard Point Resident	
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66	Dee Reeve	4930 9802	CQU	d.reeve@cqu.edu.au
67	Allan Briggs	4920 2625	CQIT Rockhampton	
68	Gail Hirning	4933 6157	Emmaus College	
69	Gayne Kidd	4934 4778	Keppel Sands Beach Recovery Committee	
70	Jenny Craigen	4939 5328	Lower Fitzroy Catchment Project	
71	Barry Whelan	4939 2617	Wildlife Preservation Society Qld	
72	Marlene Lennox	4939 7727	Woodbury resident	
		Speakers		
73	David Robinson	Email	EPA	Speaker
74	Jeff Calaghan	Email	BOM	Speaker
75	Ian McCarthy	Email	BOM	Speaker
76	Roger Tomlinson	Email	CRC CZ	Speaker
77	Jurek Piorewicz	Email	CRC CZ/CQU	Speaker
		Apologies		
	Greg Ralph	Requested notes, unable to attend	Baffle Creek Action Group	realf@discoverycoast.net
	Kirsten Livermore	Requested notes, unable to attend, in Canberra	Federal Member for Capricornia	