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Coastline Processes
and Manly’s Seawalls

Practical Problem

TeXed and written by Mario Oertel
Silent fluid
Whipped by wind
Gathers strength in tumbling dance
Rolling thunder in the kelp-shred foam.

Blue force
A crystal power
Foaming head and smoking tail
Sending kamikaze hand of liquid loam.

Dolphin rider
Churning tumbler
Meet your goal of rock and sand
Sighing crash at your journey's close.

"The Twelve Apostles Gallery - Victoria"
Contents

Acknowledgements v

Introduction vii

I Coastline Processes 1

1 The Beach System 3
   1.1 General ......................................................... 3
   1.2 Wind .......................................................... 4
   1.3 Waves .......................................................... 4
   1.4 Waterborne Sediment Transport .............................. 5
      1.4.1 General ..................................................... 5
      1.4.2 Longshore Transport ..................................... 6
      1.4.3 Onshore/Offshore Transport .............................. 6

2 Coastal Protection 9

3 Summary 11

II Manly’s Seawalls and their History 13

4 General 15

5 Seawalls 19
   5.1 Description ...................................................... 19
   5.2 Classification of Seawalls .................................... 19
6 The History of Manly’s Seawalls 21
   6.1 General .................................................. 21
   6.2 The Marine Parade Seawall ............................... 21
   6.3 Manly Ocean Beach Seawall ............................... 22
   6.4 Construction and Damage ................................. 22

7 Present Seawalls at Manly’s Beaches 25
   7.1 General .................................................. 25
   7.2 Manly’s Seawall Types ................................. 25
      7.2.1 Rigid Reinforced Earth Seawall .................. 27
      7.2.2 Rigid Vertical Blockwork Seawall ................ 27
      7.2.3 Rigid Subvertical Blockwork Seawall .......... 27
      7.2.4 Rigid (semi-rigid) Sloped Seawall .............. 28
      7.2.5 Rigid Sloped Stepped-Face Seawall ............ 28
   7.3 Manly’s Seawall Area I ......................... 28
   7.4 Manly’s Seawall Area II ............................ 28
   7.5 Manly’s Seawall Area III ........................... 31
   7.6 Manly’s Seawall Area IV ............................ 31
   7.7 Manly’s Seawall Area V ............................. 31
   7.8 Manly’s Seawall Area VI ............................ 33
   7.9 Manly’s Seawall Area VII ........................... 33
   7.10 Manly’s Seawall Area VIII ........................ 36

8 Summary ................................................... 39

9 Final Statement ........................................... 41

III Appendix ................................................ 45

Appendix - Glossary of Coastal Terminology 47
List of Figures

1.1 Coastal Zone Terminology [2] ......................................... 5
1.2 Sediment Budget [2] .................................................. 5
1.3 Beach Profiles: Accreted and Storm Conditions [2] ............... 7

4.1 Australia - Sydney - Manly ........................................ 16
4.2 Manly’s Seawall Areas ............................................. 17

7.1 Manly’s Seawall Types ............................................. 26
7.2 Manly’s Sloped Stepped-Faced Seawall ............................ 27
7.3 Manly’s Seawall Area I ............................................. 29
7.4 Manly’s Seawall Area II ............................................ 29
7.5 Manly’s Seawall Area II ............................................ 30
7.6 Manly’s Seawall Area II ............................................ 30
7.7 Manly’s Seawall Area III .......................................... 31
7.8 Manly’s Seawall Area IV .......................................... 32
7.9 Manly’s Seawall Area V .......................................... 32
7.10 Manly’s Seawall Area V .......................................... 33
7.11 Manly’s Seawall Area VI .......................................... 34
7.12 Manly’s Seawall Area VI .......................................... 34
7.13 Manly’s Seawall Area VI .......................................... 35
7.14 Manly’s Seawall Area VII ......................................... 35
7.15 Manly’s Seawall Area VII ......................................... 36
7.16 Manly’s Seawall Area VIII ....................................... 37
7.17 Manly’s Seawall Area VIII ....................................... 37
7.18 Manly’s Seawall Area VIII ....................................... 38
Introduction

This report was written as a part of an internship at the Water Research Laboratory (WRL) of the University of New South Wales (UNSW) in Australia.

The State New South Wales (NSW), the most populous state of Australia, is located in the southeast of the country. Nearly 6,500,000 people live in an area of 801,600 square km. These are approximately 30% of the Australian inhabitants.

The coastline of NSW is characterised by small pocket beaches bounded by rocky headlands in the south, and longer sweeping beaches of golden sand in the north. Coastal areas are major destinations for local, national and international tourists. More than 80% of the State’s population lives and works along the eastern seaboard. The coastline is under regular attack from the natural forces of wind and waves. In response to these processes, the coastline is ever changing. Beaches and sand dunes erode and are rebuilt in response to wave action; sand dunes can migrate inland in response to wind attack. Man’s activities in the coastal zone can exacerbate these processes.

Coastline hazards are not a minor problem. Beach erosion accompanying storms of the early 1970’s caused the loss of 20 houses and other assets valued at many millions of dollars along the central and north coasts. Coastal erosion became a problem for homes, commercial buildings, streets etc. that were built up all along the coastlines. So, in 1975, the NSW State Government established the Beach Improvement Program to protect heavily used beaches. In the following years up to today, lots of other initiatives relevant to coastal management were enacted. [2]

This report is split into two main parts. The first part is about coastline processes, especially about coastal erosion and protection at sandy beaches. This part should create a foundation of knowledge for the need of seawalls, to assist in understanding the following chapters. The second part handles with Manly’s seawalls and their history, including a chapter about seawalls in general.

A glossary of coastal terminology for assisting readers in understanding technical terms is given in the Appendix.
Part I

Coastline Processes
Chapter 1

The Beach System

1.1 General

Beaches and coastal lands are exposed to never ending attack by the sea and the atmosphere. Waves, winds (storms) and increased water levels reshape the beaches and move sediments onshore, offshore and alongshore. This can damage or destroy coastal developments and reduce beach amenity. [2]

To manage all these coastline hazards, it is necessary to understand the various processes that cause them.

There are many different influences that may change, destroy or damage the beaches and the coastal structures:

- wind,
- (storm) waves,
- waterborne sediment transport,
- elevated water levels,
- currents,
- dune vegetation,
- rainfall and runoff,
- coastal entrances,
- climate change, and
- human activities.
In the following only the first three listed possibilities are described.

1.2 Wind

Strong winds (intense storms) close to the coast are able to erode the shoreline and to damage coastal developments, e.g. unroofing buildings, uprooting trees and even causing the collapse of buildings. Sediment transport associated with strong winds accelerates the migration of sand dunes and the smothering of coastal developments. Also storms may increase the water levels which damage the beaches and coastal structures, too.

The coastline of NSW is frequently attacked by severe storms originating over the Tasman Sea. These storms are capable of causing rapid erosion along the southeastern coastline. The low pressure systems from the Tasman sometimes generate secondary lows, which intensify the storm systems. Under these conditions gale force winds, with a wind speed of above 50 km/hour, are generated. In May 1974, for example, a secondary low developed off the NSW coast, creating wind speeds of over 140 km/hour between Northern Sydney and Newcastle. This storm caused severe erosion of beaches and destroyed many built assets.

1.3 Waves

Waves (generated by wind blowing) are a very dominant phenomena that shapes the coastline. They are one of the reasons for erosion, longshore drift and elevated water levels - because of their capacity to transport sediment. This energy is mostly dissipated in the short distance between wave breaking and the wave runup limit.

Within the surfzone, waves are the major mechanism of waterborne sediment transport.

A coastal structure must withstand the influence of waves and their maximum forces.

Important characteristics of waves are:

- wave height,
- wavelength,
- wave period,
- wave speed, and
1.4 Waterborne Sediment Transport

1.4.1 General

The waterborne sediment transport is a natural process. Sediment is transported onshore, offshore and alongshore by the action of waves and currents (see figure 1.2). An understanding of waterborne sediment transport is essential to the better
management of coastal areas.

For this, four different zones can be distinguished (see figure 1.1):

1. **Deep Water Zone**: Here, the water depth is large, the wave crests are straight and its velocity and direction relative to the shore are constant.

2. **Refraction Zone** (Breaker Zone): The waves "feel" the bottom, their wave length and velocity along the crest vary as they propagate towards the shore from the deep ocean. Each wave crest progressively bends and attempts to align itself parallel to the shoreline. The waves steepen and eventually break.

3. **Surf Zone**: The zone between the breaker zone and the shore. The breaker line is not fixed, since, the breaking varies with the wave height. In this zone the longshore sediment transport is significant and responsible for the shoreline changes, especially due coastal structures.

4. **Swash Zone**: This is limited by the highest point on the beach that the breaking waves running up to, and the lowest point to which the water recedes between waves. [6]

### 1.4.2 Longshore Transport

The longshore transport refers to the movement of waterborne sediments along the coast. This occurs predominately in the surf zone. Depending upon wave and current situations, longshore drift will trend towards one end of the beach or the other. On some beaches, sediment transport in both directions is balanced, resulting zero net drift. On other beaches, there is commonly a potential for net drift because of dominant wave climates. [2]

### 1.4.3 Onshore/Offshore Transport

During storms, the steep waves erode sand from the beach berm and dune areas and transport it offshore to build a "storm bar". A pronounced "dune scarp" in the foredune area commonly marks the landward extent of storm erosion. The resulting beach profile is termed the "Storm Profile" (see figure 1.3). The effect of a storm bar is to widen the surf zone and flatten the slope of the surf and swash zones. This causes waves to break further offshore, which imposes a self regulating limit on beach erosion.

At other times, ocean swell of longer period and lower height tends to rebuild the beach with sand from the offshore bar (see figure 1.3). This rebuilding process commences immediately after a storm.
Figure 1.3: Beach Profiles: Accreted and Storm Conditions [2]
A major storm event can move some of the sand offshore beyond a depth from which it can not return to the beach system. When this occurs there can be a net permanent loss of sand from the beach’s sediment system, or it takes several years to take most of the sand back to the beach. [2] [6] [3]
Chapter 2

Coastal Protection

A populated coastline requires some degree of protection against destructive events which may threaten infrastructure sited close to the active zone. There is a need for measures which protect humans and their properties against these natural effects.

A variety of coastal protection measures can be used to enhance or preserve beach amenity and to protect coastal developments at risk of erosion or recession. These include

- seawalls,
- groynes,
- offshore breakwaters,
- bulkheads,
- revetments,
- jetties,
- artificial headlands,
- beach nourishment, and
- dune rehabilitation and management.

The requirements of a beach erosion control and protection measure follows from the past and the technical progress up to date. To be effective, the type of protection must be compatible with coastal processes at the site. Information about the longshore sediment transport, together with likely long term shoreline changes from erosion, accretion or recession is required. A detailed understanding of coastal processes and hazards is essential to the successful design, construction and operation of coastal protection works. [2]
In the following of this report only the protection measure "Seawall" will be described detailed (see Part II on page 15 ff).
Chapter 3

Summary

Sandy beach coastlines are ever changing areas under continuous change by natural forces. Where public and private infrastructure (and its occupants) has been constructed within this naturally active zone, structural protection may be needed.
Part II

Manly’s Seawalls and their History
Chapter 4

General

Manly, a suburb in the North of Sydney (see figure 4.1), has over 1.5 km of long sandy beaches. Most of the shore faces east to east-north-east to the Pacific Ocean/-Tasman Sea. Nearly the whole beach is exposed to waves and storms, though the south end in particular has some protection from waves from the south to south-east. The effects of ocean storms on the built environment has been mitigated by the construction of seawalls.

On Manly’s beaches the most prominent shore protection measures are the seawalls. From Queenscliff Beach in the north down to Shelly Beach in the south (approx 2.5 km) there is a connected structure, consisting of different types of seawalls. For the following, the area of Manly’s beaches - including Queenscliff Beach, North Steyne Beach, Manly Beach, Fairy Bower Beach and Shelly Beach - will be classified into different sections (Manly’s Seawall Areas I-VIII, as shown in figure 4.2), in which exist the varying types of seawalls.
Figure 4.1: Australia - Sydney - Manly
Figure 4.2: Manly’s Seawall Areas
Chapter 5

Seawalls

5.1 Description

A Seawall is a structure to separate the land area from the water area. It is built along the shoreline parallel to the beach. The primary purpose of a seawall is the protection of areas in the rear of the beach against attack of waves and storms and to impose a landward limit to coastal erosion. Seawalls are necessarily massive and expensive and should be constructed only where the adjoining shore is highly developed and storm attack is severe. They can be built of many materials including steel, concrete, rock, plastics, bitumen, ceramics etc. The face of a seawall may be vertical, subvertical, curved, stepped or sloping.

Seawalls can be constructed anywhere up the beach profile, but they are best located in the higher regions of the beach where only waves from extreme storm events can reach them. If constructed too far seaward on a sandy beach, they destroy beach amenity. [2][6]

5.2 Classification of Seawalls

Seawalls can be classified as:

- rigid,
- flexible, or
- semi-flexible. [2]

A rigid seawall could be a gravity wall, sheet piling, a caisson or a concrete revetment. They have a compact nature with a minimum plan area with the tendency not to harbour rubbish. However, they can fail by a single large wave, toe erosion
(undermining) or geotechnical instability (overturning) - catastrophically. Mostly rigid seawalls tend to be highly reflective to incoming waves which can result in accelerated sand loss in front of the wall during a storm, and delay beach rebuilding following a storm. To protect the foundations of a rigid seawall from undermining, rock scour blankets, gabions, etc. can be used. It is also possible to found the structures at depth on non-erodible materials. However, there’s a general tendency away from rigid structures due to their cost and risk of catastrophic failure.

Flexible seawalls are constructed from quarry rock, shingle and specially manufactured concrete units. They are not as compact as rigid seawalls but they can withstand striking deformation without total failure occurring. The failure is progressive rather than catastrophic. Flexible seawalls are also less reflective than rigid structures. A disadvantage is the tendency to harbour rubbish because of the broken nature of their surface.

A combination of the characteristics of rigid seawalls and flexible seawalls are the semi-flexible seawalls. They are compact but may not fail as easy as rigid seawalls.
Chapter 6

The History of Manly’s Seawalls

6.1 General

Manly’s 2.5 km long seawall has been constructed in stages between 1887 to 1999 to a number of different designs. From time to time, the wall has suffered damage during storms. Consequently, over the years, about 20% of the original seawall at Manly has been rebuilt or substantially repaired.

In the past, Manly’s seawall was split into two main sections; the Marine Parade Seawall built in the late 1890’s occupying the southern 800 metres or so of the embayment shoreline, and the Manly Ocean Beach Seawall which was commenced at The Corso some ten years prior to the Marine Parade seawall but only finally completed at Queenscliff in the late 1930’s.

Over the more than 110 year history of the walls, there have been nine instances of recorded damage. This is an important finding that shows that, over the full life of the structure, the wall has been damaged, on average, once every 12 years. [4]

Initially, this more than 100 years old seawall was built as a vertical and subvertical rigid blockwork seawall (see subsections 7.2.2 and 7.2.3).

6.2 The Marine Parade Seawall

The Marine Parade Seawall (Area VIII, Section 1) was built in 1897/98 when the sewer was provided. It was clearly founded on bedrock in most areas and was fronted by exposed reef except at Fairy Bower Beach.

Today, the Marine Parade Seawall remains largely as originally constructed except for concrete toe reinforcement on Fairy Bower Beach. The only notable instance of storm damage that has been recorded for this seawall was in May/June 1974.
6.3 Manly Ocean Beach Seawall

Construction of the Manly ocean beach seawall (Areas I to VII, Section 2) commenced at The Corso in 1887 and was only finally completed some 70 years later at the northern end of the embayment. Today, the once connected monotype structure is split into many areas due to seawall damage and failures in past storm events.

6.4 Construction and Damage

In the following table the construction and damage dates are listed. The second column gives the information about the area (see Manly’s Seawall Areas in figure 4.2).
<table>
<thead>
<tr>
<th>Date</th>
<th>Area</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1887</td>
<td>VIII</td>
<td>first seawall constructed (360m) [Manly Ocean Beach Seawall]</td>
</tr>
<tr>
<td>29.5.1889</td>
<td>IV to VIII</td>
<td>trees uprooted, fences damaged and part of Manly Corso submerged</td>
</tr>
<tr>
<td>1897/98</td>
<td>V to VII</td>
<td>seawall extended (219m) [Marine Parade Seawall]</td>
</tr>
<tr>
<td>7.-10.5.1898</td>
<td>IV + V</td>
<td>two large trees uprooted and part of seawall collapsed</td>
</tr>
<tr>
<td>1900</td>
<td>V</td>
<td>wall extended (approx 100m)</td>
</tr>
<tr>
<td>1902</td>
<td>V</td>
<td>wall extended (10m)</td>
</tr>
<tr>
<td>14.5.1913</td>
<td>VII</td>
<td>dressing sheds and walls washed away</td>
</tr>
<tr>
<td>14.-16.5.1913</td>
<td>VII</td>
<td>dressing sheets demolished</td>
</tr>
<tr>
<td>May 1913</td>
<td>VI + VII</td>
<td>storm washed away large sections of promenade and seawall; beachfront facilities destroyed</td>
</tr>
<tr>
<td>1932</td>
<td>IV + V</td>
<td>seawall first constructed</td>
</tr>
<tr>
<td>1937/38</td>
<td>III</td>
<td>seawall extended</td>
</tr>
<tr>
<td>1938</td>
<td>I + II</td>
<td>seawall first constructed</td>
</tr>
<tr>
<td>1939</td>
<td>III to V</td>
<td>heavy seas cause damage at Manly</td>
</tr>
<tr>
<td>1942</td>
<td>VII</td>
<td>seawall faced with concrete</td>
</tr>
<tr>
<td>1943</td>
<td>II</td>
<td>seawall destroyed, not replaced after storm</td>
</tr>
<tr>
<td>26.6.1950</td>
<td>III + IV</td>
<td>huge seas smashed 100-150 yards of seawall; council engineers estimated 20,000 AU$ damage</td>
</tr>
<tr>
<td>1950</td>
<td>II + III</td>
<td>wall collapsed</td>
</tr>
<tr>
<td>1955/56</td>
<td>IV</td>
<td>seawall reconstructed, seawall replaced with concrete faced revetted embankment and coping at promenade level</td>
</tr>
<tr>
<td>1962</td>
<td>II</td>
<td>reconstructed seawall, comprising precast concrete blocks</td>
</tr>
<tr>
<td>5.9.1967</td>
<td>VII</td>
<td>waves wash away 20m of seawall</td>
</tr>
<tr>
<td>May 1968</td>
<td>I + II</td>
<td>storm waves dislodge coping stones</td>
</tr>
<tr>
<td>Date</td>
<td>Area</td>
<td>...continuation</td>
</tr>
<tr>
<td>----------------</td>
<td>------</td>
<td>----------------------------------------------------------</td>
</tr>
<tr>
<td>May 1974</td>
<td>I to III</td>
<td>coping stones dislodged from crest of wall due to wave action; seawall scour apron undermined causing subsidence of pattern placed blockwork wall</td>
</tr>
<tr>
<td>May/June 1974</td>
<td>VIII</td>
<td>part of seawall damaged</td>
</tr>
<tr>
<td>1975</td>
<td>VII</td>
<td>&quot;Reinforced Earth&quot; seawall constructed</td>
</tr>
<tr>
<td>1998/99</td>
<td>VI</td>
<td>stepped-face seawall constructed</td>
</tr>
</tbody>
</table>
Chapter 7

Present Seawalls at Manly’s Beaches

7.1 General

As described in Chapter 4, Manly’s connected seawall can be classified into different areas. In the following each of these areas will be photographed and described. These areas will be described from north (Queenscliff) to south (Shelley Beach).

7.2 Manly’s Seawall Types

The different cross section types of Manly’s seawalls may be grouped into six principal rigid seawall categories:

- vertical "Reinforced Earth" seawall (see figure 7.1a),
- vertical blockwork seawall (see figure 7.1b),
- subvertical blockwork seawall (see figure 7.1c),
- vertical concrete faced blockwork seawall (see figure 7.1d)
- sloped interlocking concrete block seawall (see figure 7.1e), and
- sloped stepped-face seawall (see figure 7.2).

On the top of every type of Manly’s seawalls, there is a continuous concrete slab or clay paver footpath following the seawall alignment.
Figure 7.1: Manly’s Seawall Types
7.2 MANLY’S SEAWALL TYPES

7.2.1 Rigid Reinforced Earth Seawall

The Reinforced Earth seawall in Manly is about 20 years old, and has suffered no damage. It was built with many prefabricated concrete panels which are anchored in the backward ground. The result is a typical vertical ”Reinforced Earth” surface as shown in figures 7.1a.

7.2.2 Rigid Vertical Blockwork Seawall

The vertical blockwork walls are the oldest at Manly (more than 100 years old), and they have withstood the test of time surprisingly well. Over 50% of the overall embayment seawall is vertical blockwork. Notable instances of storm damage have occurred at Fairy Bower in 1974. In total, it is estimated that some 5 or 10% of the original vertical blockwork walls have been damaged or destroyed since construction.

As shown in figure 7.1b the vertical blockwork walls are gravity walls, which were made out of big stones - grounded on bedrock or on small foundations. In some areas, the walls are protected against undermining/scour of their footing by a rock apron/toe protection rocks on their seaward side. This rock protection is generally buried beneath the sand, but becomes exposed after large storm events.

In 1942 the vertical blockwork walls north of the Manly Surf Club up to the Corso were faced with concrete (see figure 7.1d).

7.2.3 Rigid Subvertical Blockwork Seawall

Subvertical blockwork seawalls are of similar appearance to vertical blockwork walls - with the difference of a sloped surface under the sand level (see figure 7.1c).
The majority of damage to the Manly embayment seawall has occurred to these subvertical blockwork structures. About 40% of the original length of these walls failed during storms in 1943 and 1950.

### 7.2.4 Rigid (semi-rigid) Sloped Seawall

Sloped walls cannot be classified into a special seawall group. Some say they are rigid, others say they are semi-rigid or semi-flexible. But the sloped seawalls largely conform to present day design practice. Nevertheless, the structure in Manly at Upper Steyne was severely damaged in the June 1974 storms.

Manly’s sloped seawalls are *sloped interlocking concrete block seawalls*. Their typical design is shown in figure 7.1e.

### 7.2.5 Rigid Sloped Stepped-Face Seawall

In 1998/99 the newest seawall in Manly was built - the sloped stepped-face seawall. This wall combines the present day seawall design with useful properties. It was built on top of the old wall which acts as the landward footing. At the wall bottom concrete bored piers form the seaward footing (see figure 7.2). Up to date this wall had not the chance to demonstrate its stability.

### 7.3 Manly’s Seawall Area I

Manly’s Seawall Area I (see figure 4.2 on page 17) starts in the north of Manly at Queenscliff Beach at the south-western entry to the Lagoon. On a length of approximately 200 metres southward there is a *rigid subvertical blockwork seawall* (see figure 7.3). Its height over present sand level is about 1.0 to 2.5 metres.

### 7.4 Manly’s Seawall Area II

From the southern end of Area I down to the intercept point of the beach with the extension of Pacific Street, Seawall Area II is located. In this area the height of the *rigid* (to semi-rigid) *sloped seawall* varied between 0.5 metres (see figure 7.4) and 2.5 metres. Every 50 to 70 metres stairs are arranged (see figures 7.5 and 7.6).
Figure 7.3: Manly’s Seawall Area I

Figure 7.4: Manly’s Seawall Area II
Figure 7.5: Manly’s Seawall Area II

Figure 7.6: Manly’s Seawall Area II
7.5 Manly’s Seawall Area III

On the next following 200 metres to North Steyne Surf Club there’s once again a rigid subvertical blockwork seawall of 2 metres height (see figure 7.7). The surf club building represents the frontier between Manly’s Seawall Areas III and IV.

7.6 Manly’s Seawall Area IV

A rigid (to semi-rigid) sloped seawall was built south of the Surf Club building (see figure 7.8). This seawall also has a height of approximately 2 metres over present sand level. The Seawall Area IV ends some 10 metres north of Carlton Street.

7.7 Manly’s Seawall Area V

Manly’s Seawall Area V includes a long blockwork seawall. This wall is nearly 600 metres long and stretches in a big radius curve from the southern end of Area IV down to The Corso. In the northern part of this Area V the wall is a rigid subvertical blockwork seawall (see figure 7.9). In the southern part a rigid vertical blockwork seawall was built (see figure 7.10).
Figure 7.8: Manly’s Seawall Area IV

Figure 7.9: Manly’s Seawall Area V
7.8 Manly’s Seawall Area VI

The wall in this area is the most characteristic and important seawall in Manly. This is because of the location directly in front of the main pedestrian zone - The Corso. The wall represents the newest seawall in Manly and it was built up as stairs which are the main entrance for the beach visitors. Over a length of about 150 metres there are three different kinds of superstructures included:

1. small stairs for pedestrian access (see figure 7.11),
2. wide stairs to sit on (see figure 7.12),
3. shower area (see figure 7.13).

The height of this wall is on its total length approximately 2 metres. This rigid sloped stepped-face seawall is constructed of monolithic reinforced concrete rather than discrete masonry units.

7.9 Manly’s Seawall Area VII

Manly’s Seawall Area VII is split into two sections. In the first section, from Wentworth Street to the corner at Ashburner Street, there is a 150 metres long rigid vertical concrete faced blockwork seawall (see figure 7.14). Around the corner the second section begins. A rigid vertical ”Reinforced Earth” seawall is located in front of the Manly Surf Club (see the right side of figure 7.15).
Figure 7.11: Manly’s Seawall Area VI

Figure 7.12: Manly’s Seawall Area VI
Figure 7.13: Manly’s Seawall Area VI

Figure 7.14: Manly’s Seawall Area VII
7.10 Manly’s Seawall Area VIII

The most southward Seawall Area in Manly (No. VIII) is attached directly at the Reinforced Earth seawall (see figure 7.15). The seawall follows the complete footpath from Manly Surf Club to Shelly Beach (see figure 7.17). This rigid vertical blockwork seawall (see figure 7.16) has big stones lying in front of the wall (see figure 7.18) in most of its sections.

A substantial concrete footing has been added to the portion near Fairy Bower Beach (see figure 7.17).
Figure 7.16: Manly’s Seawall Area VIII

Figure 7.17: Manly’s Seawall Area VIII
Figure 7.18: Manly’s Seawall Area VIII
Chapter 8

Summary

Manly’s connected wall, consisting of different seawall types, was built between 1887 and 1999. The many different surfaces characterize the structure and its influence on the beach system.

Over the years, the once monotype structure has been modified to a multi-surface-seawall, due to partial failure and damage in past storm events and preventative upgrading of some sections. Some walls - especially the vertical blockwork seawalls - have withstood the test of time surprisingly well. Others failed on their first "test" in a storm event.

Up to date there are six different types of seawalls in the eight "Manly Seawall Areas" (I to VIII).

The seawalls are Manly’s most important shore protection measure and provide a unique physical environment where the ocean vista dominates the backshore area.
Chapter 9

Final Statement

In this report I have created a foundation of knowledge in relation to the principles of coastline processes. My aim is to assist readers in understanding technical terms about shore protection measures using Manly’s seawalls as my example.

To manage the existing coastline hazards (sea and atmosphere attacks) it is necessary to understand the various processes that cause them. Only with this knowledge it is possible to design up-to-date shore protection measures.

This report summarises the history of Manly’s seawalls since their construction in 1887 till present day which includes the failures and damage caused by past storm events and their reconstruction.
Bibliography


Part III

Appendix
Appendix - Glossary of Coastal Terminology [3]

**Accreted Profile** - The profile of a sandy beach that develops in the "calm" periods between major storm events. During such periods, swell waves move sediment from the offshore bar back onto the beach to rebuild the beach form.

**Accretion** - A build up of sand which may cause or be associated with a seaward movement of the beach profile.

**Aeolian Transport** - Transport (of sand) by wind.

**Bar** - On ocean beaches, a feature comprising a mound of sand located in the surf zone and which is normally parallel to the shore.

**Barrier** - A system of sediment deposits extending above sea level, separating the ocean from the hinterland, rivers, estuaries etc.

**Bathymetry** - Description of the shape of the ocean bed (underwater contours etc.). The measurement of depths of water.

**Beach Erosion** - The offshore movement of sand from the sub-aerial beach during storms.

**Beach Profile** - A cross-section of a beach, generally normal to the water line, showing the elevation of the surface relative to some datum. It may also extend some distance offshore.

**Berm** - The relatively flat section of the beach profile between the top of the swash zone and the toe of the erosion escarpment or frontal dune.

**Bluff** - Vertical or near vertical cliff face (relatively erosion resistant rock) or moderate to steep slope (less erosion resistant rock or soils perched on rock strata).

**Breaker Zone** - That area of coastal waters where shoaling effects cause swell
waves to break. This typically occurs in the shallower waters over an offshore bar.

**Breaking Waves** - As waves increase in height through the shoaling process, the crest of the wave tends to speed up relative to the rest of the wave. Waves break when the speed of the crest exceeds the speed of advance of wave as a whole. Waves can break in three modes: spilling, surging and plunging.

**Breakwater** - Structure protecting a shoreline, harbor, anchorage or basin from ocean waves.

**Buffer Zone** - An appropriately managed and unalienated zone of unconsolidated land between beach and development, within which coastline fluctuations and hazards can be accommodated in order to minimise damage to the development.

**Coastal Process** - The active forcing functions (waves, winds, currents etc.) and their interaction with and effects on the coastal environment (sediments, beach and cliff erosion etc.)

**Coastal Structures** - Those structures on the coastline designed to protect and rebuild the coastline and/or enhance coastal amenity and use.

**Coastal Zone** - The zone affected by coastal processes and its immediate hinterland.

**Diffraction** - The "spreading" of waves into the lee of obstacles such as breakwaters by the transfer of wave energy along wave crests. Diffracted waves are lower in height than the incident waves.

**Dune Field** - The system of incipient dunes, foredunes and hinddunes that is formed on sandy beaches to the rear of the beach berm.

**Erosion** - The depletion of the land mass by natural forces, such as the reduction of a beach by waves and/or wind. Commonly perceived as the landward movement of an erosion escarpment during storm events.

**Erosion Escarpment** - A near vertical step formed by wave erosion at the back of a beach. Usually indicates the landward extent of wave incursion during recent storm events.

**Foredune** - The most seaward dune in a dune system (with the exception of an INCIPIENT FOREDUNE, if this exists).

**Frictional Attenuation** - As applied to water waves, the reduction in wave
energy as a result of resistant to water particle movement at the sea bed (bottom friction).

**Groynes** - Low walls built perpendicular to a shoreline to trap longshore sediment. Typically, sediment buildup on the updrift side of a groyne is offset by erosion on the downdrift side.

**Groyne Field** - A system of regular spaced groynes along a section of shoreline.

**Hinddunes** - Sand dunes located to the rear of the foredune.

**Incipient Foredune** - Small dune at the base of the most seaward dune in a dune system.

**Littoral Drift** - The sedimentary material which is moved in the littoral zone by waves and currents.

**Littoral Transport** - The movement of littoral drift.

**Littoral Zone** - Extends from the onshore dune system to the seaward limit of the offshore zone and possibly beyond.

**Longshore Currents** - Currents flowing parallel to the shore within the inshore and nearshore zones. Longshore currents are typically caused by waves approaching the beach at an angle. The "feeder" currents to rip cells are another example of longshore currents.

**Longshore Transport** - Synonymous with LITTORAL TRANSPORT.

**Nearshore Zone** - Coastal waters between the offshore bar and the 60 m depth contour.

**Net** - With respect to sediment transport is the resultant difference of the volume of transport in all directions, i.e. the time averaged resultant effect.

**Nourishment** - The replenishment of a beach with sand. Commonly used to increase the beach width after erosion.

**Offshore Bar** - Submerged sandbar formed offshore by the process of beach erosion and accretion. Typically, swell waves break on the offshore bar. Also known as longshore bar.

**Offshore Zone** - Coastal waters to the seaward of the nearshore zone.
**Onshore/Offshore Transport** - The process whereby sediment is moved on-shore and offshore by wave, current and wind action.

**Plunging Waves** - The wave crest breaks suddenly and with tremendous force by curling over a near vertical wave face.

**Refraction** - The tendency of wave crests to become parallel to bottom contours as wave move into shallower waters. This effect is caused by the shoaling process which slows down waves in shallower waters.

**Rip Currents** - Concentrated currents flowing back to sea perpendicular to the shoreline. Rip currents are caused by wave action piling up water on the beach. Feeder currents running parallel to the shore (longshore currents) deliver water to the rip current.

**Sea** - Wind-generated waves which are still within the generating area. Seas usually exhibits irregular, short periods and more peaked crests than waves which have travelled outside the generating area (i.e. SWELL).

**Seawalls** - Walls built parallel to the shoreline to limit shoreline recession.

**Sediments** - Unconsolidated detrital material consisting of organic and/or inorganic fragments. The composition and textural characteristics (gravel, sand, mud) vary with sediment source (local, fluvial, marine) and the transporting medium.

**Shoaling** - The influence of the seabed on wave behaviour. Such effects only become significant in water depth of 60 m or less. Manifested as reduction in wave speed, a shortening in wave length and an increase in wave height.

**Shoreline Recession** - A net long term landward movement of the shoreline caused by a net loss in the sediment budget.

**Spilling Waves** - The wave crest breaks gradually as the wave travels to the shore. Characterised by the appearance of white water at the crest.

**Storm Profile** - The profile of a sandy beach that develops in response to storm wave attack. Considerable volumes of sediment form the beach berm, the incipient dune and the foredune can be eroded and deposited offshore. The landward limit of the storm profile is typically defined by a backbeach erosion escarpment.

**Storm Bar** - An offshore bar formed by sediments eroded from the beach during storm conditions.
**Subaerial** - That section of the beach which is above the waterline.

**Subaqueous** - The portion of the beach profile below the water surface.

**Surf Zone** - Coastal waters between the breaker zone and the swash zone characterised by broken swell waves moving shorewards in the form of bores.

**Surging Waves** - The wave does not "break" but maintains its basic shape as it moves towards the shore, where it surges up the beach. Very little white water is evident before surging waves reach the shore.

**Swash Zone** - That area of the shoreline characterised by wave uprush and retreat.

**Swell** - Wind-generated waves that have travelled out of their generating area. Swell characteristically exhibits a more regular shape and longer period than the sea (c.f. SEA).

**Wave Height** - The vertical distance between a wave trough and the following wave crest.

**Wavelength** - The distance between consecutive wave crests or wave troughs.

**Wave Period** - The time taken for consecutive wave crests or wave troughs to pass a fixed point.