School of Civil and Environmental Engineering

Water Research Laboratory

Coastal Engineering advice for Ballina Ocean Pool

WRL TR 2018/23 | December 2018

By J T Carley, I R Coghlan, B M Miller, C D Drummond and A J Harrison

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Project details

Report title	Coastal Engineering Advice for Ballina Ocean Pool
Authors(s)	J T Carley, I R Coghlan, B M Miller, C D Drummond and A J Harrison
Report no.	2018/23
Report status	Final
Date of issue	December 2018
WRL project no.	2017078
Project manager	James Carley
Client	Ballina Ocean Pool Committee
Client address	Ballina Shire Council, PO Box 450, BALLINA, NSW 2478
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Client reference	

Document status

Version	Reviewed by	Approved by	Date issued
Draft	I R Coghlan	G P Smith	14/08/2018
Final	I R Coghlan	G P Smith	20/11/2018

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Executive summary

The Water Research Laboratory of UNSW Sydney undertook a coastal engineering study to assist with the design of a proposed ocean pool at Ballina NSW. The study comprised both fundamental coastal engineering work and interviews with people well acquainted with existing ocean pools. Ocean pools are widespread in NSW and South Africa, with limited numbers in other states and nations.

The main tasks undertaken were:

- Literature review on ocean pools;
- Detailed investigations of existing ocean pools;
- Ballina coastal processes and hazards;
- Design considerations for ocean pools;
- Wave overtopping calculations;
- Options (alongshore and cross shore) for pool location; and
- Wall shape and wave forces.

The following design dimensions are recommended by WRL for the Ballina ocean pool:

- Main pool: 50 m long x 20 m wide (could be narrowed to 15 m if required);
- Main pool 1.2 to 1.35 m deep in shallow end; 1.6 m in deep end;
- Children's/wading pool: 250 to 450 m^2;
- Children's/wading pool: ranging from zero to 0.7 m deep; and
- Constructed public space: 250 to 450 m^2.

Based on initial advice and local factors, the Ballina Ocean Pool Committee elected to locate the pool alongshore at approximately the location in Figure 9.1. Further refinement of the cross shore position is subject to detailed design. The Ballina Ocean Pool Committee also requested that the ocean pool have some wave flushing, a sand covered floor and minimal excavation. A seaward wall elevation of about 1.5 m AHD will be needed to allow frequent wave flushing.

Measures to manage uncertainty and risk are presented within the report. Architectural designs are being undertaken in parallel with this WRL report. Additional data collection and/or studies are recommended to further refine the concept design prior to detailed design. The results of these studies may result in minor shifts in the adopted plan location and wall elevation.

Contents

List of tables

List of figures

1 Introduction

1.1 Preamble

The Water Research Laboratory (WRL) of the School of Civil and Environmental Engineering at UNSW Sydney was engaged by the Ballina Ocean Pool Committee to undertake a coastal engineering assessment of a proposed ocean pool at Ballina NSW.

Depending on definitions, there are approximately 70 ocean pools in NSW, with most located between Newcastle and Wollongong. Fifteen ocean pools are located on Sydney's northern beaches. Most NSW ocean pools were built from the late 1800s to early 1930s. The last new construction was at Cronulla in the 1960s, however, most ocean pools in urban areas are renovated at intervals of 10 to 20 years.

The term "ocean pool" has been used in this report, however, they are also referred to as sea pool(s), rock pool(s), ocean baths, sea baths, and (in the UK) lido.

The original pools had little formal engineering design, but often involved local residents and/or life savers excavating favourable portions of rock shelves, and later enhancing these with concrete walls. These pools evolved through numerous construction iterations. They are a highly valued community asset and are now generally managed by the relevant local council.

Ocean pools are ubiquitous within NSW and some provinces in South Africa, while there is one each in Queensland (Caloundra) and South Australia (Edithburgh), and several in the UK (e.g. Bude), USA (Victoria Beach, Laguna Bay), Mediterranean and New Zealand (Dunedin). There are also numerous "ghost" ocean pools on many coasts, including NSW. These pools were either damaged by ocean forces, were excessively dangerous, filled with sand, or simply ceased to be repaired or maintained.

Ocean pools are highly popular with communities and complement traditional beach use. They offer the following advantages over swimming in the ocean:

- A barrier from sharks;
- No rips;
- Partial protection from large waves;
- Low dependence on the tide;
- Partial reduction in stinging jellyfish;
- A well-defined space for training and practising;
- Potentially better water quality than the ocean at certain times; and
- The potential for night swimming.

Ocean pools also offer the following advantages over conventional swimming pools:

- Ocean salt water is perceived as more natural and is more buoyant;
- Minimal chemicals are used for cleaning;
- Lower pumping and/or filtration costs;
- Potentially reduced costs for staffing, cleaning and maintenance; and
- They allow a close psychological connection with the ocean ("The Wild Edge" – Section 2.2).

1.2 Scope of work

The following tasks were undertaken for this project:

- Site survey and data collection;
- Coastal processes assessment;
- Consider potential locations;
- Investigate height of wall;
- Consider maintenance options;
- Investigate wall configurations and construction methodologies;
- Scoping for geotechnical investigations;
- Assess wave forces;
- Assess wave overtopping;
- Wall shape design; and
- Provide a viable marine environment.

2 Literature

2.1 Engineering literature

There is limited engineering literature on the coastal engineering design of ocean pools. This is because:

- Most ocean pools were constructed without formal design; and
- Few ocean pools have been constructed in the last 50 years.

The following works have been sighted by WRL.

2.1.1 WRL Reports

WRL Ocean pool studies

Munro C H and D N Foster (1964), "Investigation of Southern Swimming Pool Cronulla Beach", Technical Report 1964/04.

Foster, D N and R C Nelson (1967), "Investigation of Proposed Baths at South Cronulla Surfing Beach", Technical Report 1967/02.

Haradasa, D K C and J E Hills (1985), "Model Tests of Proposed Swimming Pool at South Cronulla", Technical Report 1985/02.

Carley, J T, C D Drummond and G P Smith (2016), "Options for Managing Large Rocks in North Curl Curl Ocean Pool", Letter Report WRL2016073 L20160922.

AWACS Reports (A joint venture between WRL and Manly Hydraulics Laboratory; MHL)

Haradasa, D, R Jacobs and A Gordon (1990), "Model Investigation and Hydraulic Design of Southern Swimming Pool Cronulla Beach", AWACS Report 90/14.

Rock shelf processes

Shand, T D, W L Peirson, M Banner and R J Cox (2009), "Predicting Hazardous Conditions for Rock Fishing - A Physical Model Study", Research Report 234.

2.1.2 Manly Hydraulics Laboratory (MHL) Reports

MHL (1996), "A Preliminary Study on the Upgrade Options for North Curl Curl Rock Pool", Report MHL727.

2.1.3 Other engineering literature

Jayewardene et al. (2011)

Jayewardene, I F W, R Jacobs, D W Cameron and L Skountzos (2011), "Case Studies in Improving Design Criteria for Ocean Swimming Pools Utilising Physical Modelling and Other Investigative Techniques", Australasian Coasts and Ports Conference, Institution of Engineers Australia.

This paper examined issues regarding eight ocean pools in NSW, including water quality and sand ingress.

Bosman and Scholtz (1982)

Bosman, D E and D.J.P. Scholtz (1982), "A Survey of Man-Made Tidal Swimming Pools along the South African Coast", Proceedings of the International Conference on Coastal Engineering, American Society of Civil Engineers.

Bosman and Scholtz (1982) documented the coastal engineering of 80 ocean pools on the coast of South Africa, predominantly in KwaZulu-Natal and Cape Province, many of which were constructed in the 1950s following a relatively large number of shark attacks. It is the most comprehensive published work on the engineering design of ocean pools, so has been summarised here in more detail than other works. They noted that there was a need/demand for more ocean pools and that no design criteria could be found.

The stated tidal range is about 1.5 m, which is comparable to NSW. Corbella and Stretch (2012) noted that littoral drift at Durban is approximately 650,000 m^3/year to the north-east, versus approximately 200,000 m^3/year at Ballina (Section 4.3.3).

They estimated that the 80 ocean pools for which they collected data accounted for about 90% of existing pools along 3,000 km of coast, that is, they estimated that there were a total of approximately 90 ocean pools in South Africa.

Noting that the paper is about 36 years old, the ocean pools at the time were filled by waves and tides, with no mention of pumps. They classified ocean pools into four types, namely (Figure 2.1):

- Pools partly enclosed by walls – usually on beaches with flatter slopes (Type a).
- Pools partly enclosed by walls, with high walls to exclude beach sand (Type d), with ramps and tapered channels to allow wave flushing.
- Pools fully enclosed by walls – usually on beaches with steeper slopes (Type b, Type c),
- Semi-detached pools (Type c) [referred to as island configurations by WRL].

They observed that pools with higher walls (Types b, c, d) located in the vicinity of sandy beaches modified the beach shape (Figure 2.1), and in particular, the sand build up surrounding Type (c) pools can eventually enter the pool.

Approximate wall crest levels relative to mean sea level (converted to MSL by WRL) are shown in Table 2.1. In Australia, Australian Height Datum (AHD) is approximately MSL (Section 4).

Wall level (m MSL)	KwaZulu-Natal (Number)	Cape Province
2.25	0	0
2.00	5	1
1.75	6	2
1.50	7	5
1.25	2	6
1.00	7	14
0.75	0	9
0.50	2	7
0.25	1	0
0.00	0	2
-0.25	0	0

Table 2.1 Crest levels of South African ocean pools

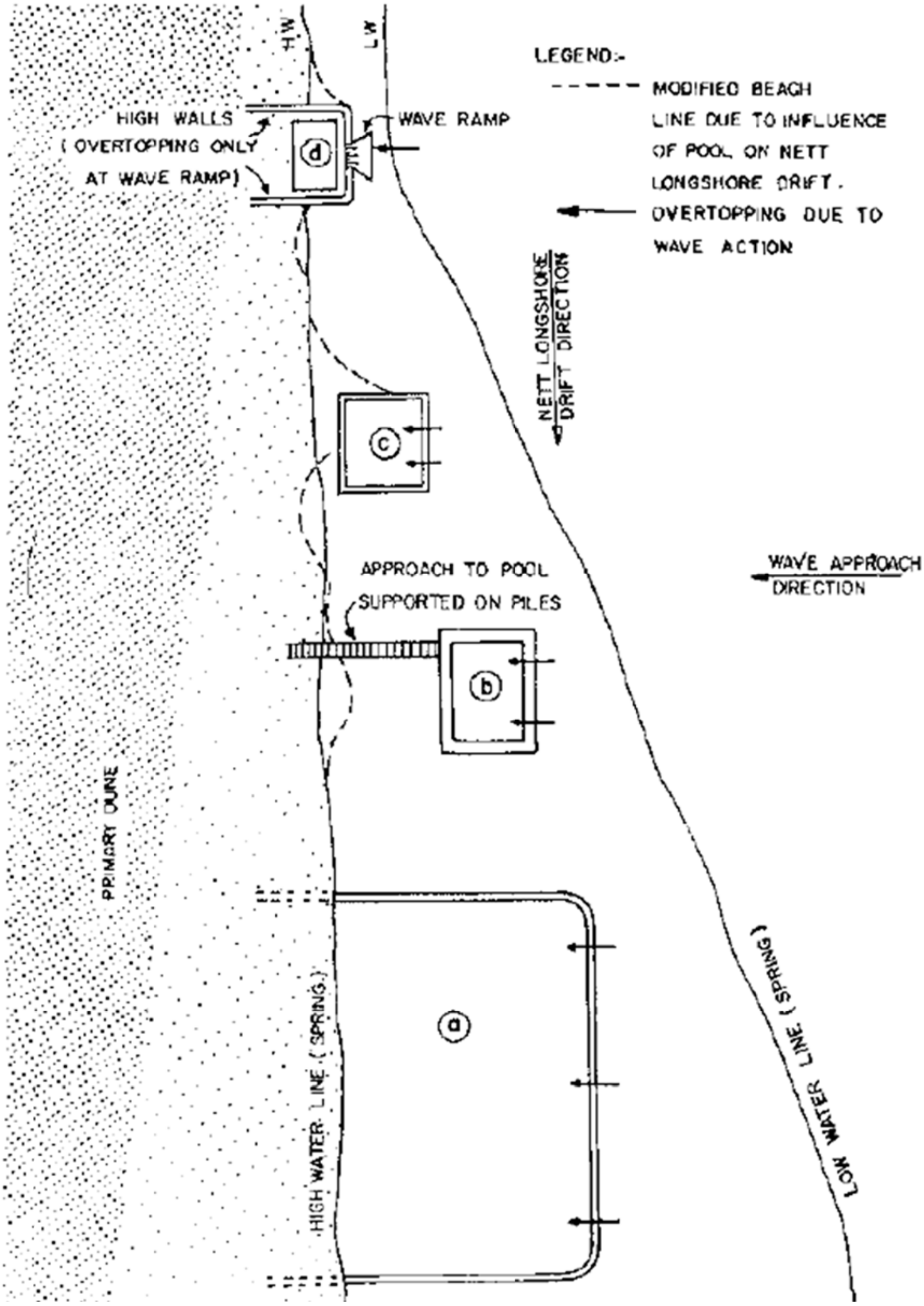


Figure 2.1 Schematisation of pools (Figure 3 of Bosman and Scholtz, 1982)

They also noted that:

> "Most pools were constructed of mass concrete founded on rock, with one pool constructed on steel sheet piles. The wall crest levels of most of the pools are above the mean high water spring tidal level with the predominance of crest levels about 0.1 m to 0.5 m above mean high water spring level.
>
> The majority of the pool walls facing the approaching waves have seaward slopes between 2:1 horizontal and vertical and crest widths between 0.4 m and 1.0 m.
>
> Pool floors consist usually of either sand or rock or combination of the two. Some pools have concrete floors.
>
> All pools are provided with drain pipes at the lowest position in the pool to allow drainage during low water spring tides."

Wave overtopping inflow rates for 13 pools were measured during high water spring tides and found to range from 20 to 650 m^3 per metre length of wall - no duration for this was given, nor the wave conditions which prevailed. On the assumption by WRL of 6 hour duration (above mean sea level), this translates to average rates of 0.9 L/s/m to 30 L/s/m.

They noted that:

> "A large number of pools are drained fortnightly to clean the pools, remove accumulated sand and to enable the rock and concrete surfaces to be washed with lime to control the growth of slippery algae. Other chemicals used to control algal growth are carbide and copper sulphate. …"
>
> "A few pools are frequently sanded up due mainly to incorrect siting. Two of these are sanded up to such an extent that they are out of use.
>
> Water replenishment at about eight of the pools is considered to be insufficient. This leads to stagnant water conditions and excessive algal growth.
>
> Some of the pools are dangerous since bathers can be washed from side or back walls out to sea.
>
> Parts of walls of three of the pools have been destroyed by waves."

Bosman and Scholtz (1982) recommended that the following design factors be considered:

> "(b) The siting of the pool: The pool should preferably be situated so that the walls can be founded on rock where possible. Where no rock foundation is present sheet piling could be considered as a foundation for the walls. Seasonal variation of the beach profile as well as longshore sediment transport in the beach zone should be considered in the siting to prevent the pool from being sanded up. Sufficient consideration should also be given to the aesthetic and ecological considerations to minimize the impact of the structure on the environment.
>
> (c) Water replenishment by wave action: Sufficient quantities of fresh sea water should enter the pool frequently enough and overflows should be situated so that adequate renewal of water throughout the pool is ensured. A general criterion for inflow would be to stipulate that inflow should occur at least during high water neap tides with dominant wave conditions. The walls should be built rather too low than too high since it will be easier to raise the walls if this is afterwards found to be necessary. The seaward slope of the wave-facing wall should be about 2 horizontally on 1 vertically or flatter since flatter slopes increase overtopping and stability.
>
> (d) Safety: The pool floor should be even and if the pool is not of uniform depth the slopes should be gentle. Situations where overwash from walls to sea can occur which could be a danger to bathers should be prevented. Intakes of drain pipes should be covered with grids. Notice boards indicating water depths should be provided.
>
> (e) Maintenance: The floor level of the pool should be above low water springs to allow drainage. It appears to be good practice to whitewash the walls with lime when the pool is cleaned as this apparently retards the growth of algae and shells and also gives the pool an attractive and tidy appearance."

2.2 Landscape design literature

The project: "The Wild Edge – A survey of coastal pools in NSW" by Nicole Larkin has collected data for 56 ocean pools in NSW by photographing and mapping their form/shape/topography with a drone (https://www.nicolelarkin.com/the-wild-edge/). The drone photography had been completed at the time of writing, with further analysis to be undertaken and extended to complete the documentation.

2.3 Sociological literature

Because of the popularity of ocean pools within the community and their integral place in society, especially before the proliferation of indoor/inland Olympic pools, there is a body of literature regarding social, cultural and heritage aspects of ocean pools. This literature is valuable in identifying the locations of ocean pools and documenting some of their characteristics.

2.3.1 McDermott (2005, 2011, 2012)

Marie-Louise McDermott (2005, 2011, 2012) wrote extensively on the origins, history, presence and culture of ocean pools in NSW and South Africa, including a 2012 PhD thesis. The PhD thesis documented 93 ocean pools in NSW, but noted that some of these were of marginal construction and/or were no longer maintained. It also documented 50 ocean pools in South Africa.

2.3.2 National Trust (2005)

The National Trust of Australia (NSW) published “Survey of Harbourside Ocean Pools of the Sydney Metropolitan Region (2005). The version viewed by WRL is dated “reprinted 2005”, however, the project brief is dated 1992-1993 and the document sheets are dated 1994. It documented 29 ocean pools and 45 “tidal (harbourside)” pools in the Sydney region, and included a description, history and status of each pool, together with sketches and photos. It contains minor descriptions of some engineering features such as balustrades and the presence of a pump enclosure, but doesn’t provide dimensions, levels, performance or engineering details.

2.3.3 O’Connell (2015)

Mary O’Connell (2015) compiled a series of ocean pool calendars featuring photos and information on ocean pools from Sydney, including for 2016. In a summary page, she noted:

> “There were two distinct periods of construction or expansion of Sydney’s ocean rock pools. The later nineteenth century saw early forms of public private alliances as local authorities built pools and leased them to private entrepreneurs or swimming clubs. Both Bronte and Bondi ocean pools were designed by a public works civil engineer, working for the NSW Water Board. These were opened to the public in the early 1890s while Randwick Council had excavated their Coogee pools as early as 1874.

The second period of creation, particularly on the Northern Beaches, was in the 1930s - the Depression era – when councils built pools with unemployed labour gangs. Les Murray's poem, The Ocean Baths, honours them …"

2.3.4 Web sites

There are numerous web sites devoted to ocean pools. Examples include:

- Ocean pools NSW: https://oceanpoolsnsw.net.au/; and
- All into ocean pools: https://allintooceanpoolsinc.org/.

2.4 Changes since original ocean pool construction

The following factors (both engineering and societal) have changed in Australia since the original construction of ocean pools from the 1890s to 1930s:

- Active shark management strategies in NSW and Queensland;
- Longer life expectancy and longer retirement;
- Improvements in access for people with a disability;
- Higher standards of surf life saving and professional lifeguards;
- The growth of recreational surfing;
- Increased awareness of sun safety;
- Higher safety standards and duty of care for public assets;
- The proliferation of (inland) fresh water Olympic pools using filtered, treated water;
- Generally improved swimming ability in people raised in Australia;
- Advances in coastal engineering and understanding of coastal processes;
- Improvements in pump technology; and
- Wider availability of less corroding or non-corroding reinforcement for concrete (e.g. galvanised steel, stainless steel, glass fibre, basalt fibre).

3 Detailed investigations of other ocean pools

3.1 Scope

WRL's scope involved investigating four ocean pools in detail, namely:

- Dee Why;
- North Curl Curl;
- South Curl Curl; and
- Freshwater.

The main criteria for selecting these pools were:

- They are well known to WRL engineers, who have long term knowledge of these pools as residents, surf life savers and swimmers;
- They cover a range of aspects, attachment to land, wave exposure, wave overtopping and safety; and
- They have different cleaning regimes and apparent water quality.

WRL engineers Ian Coghlan, Chris Drummond and James Carley undertook drone and RTK GPS surveys (Figure 3.1) of these pools and their surrounding rock platforms. These were combined with existing published seabed surveys and seabed composition maps (Gordon and Hoffman, 1989) to develop an approach path for ocean waves into the pools.

In addition to observations and measurements by WRL engineers, interviews were undertaken with present and retired Northern Beaches Council staff involved with the management and renovation of these pools, together with regular users.

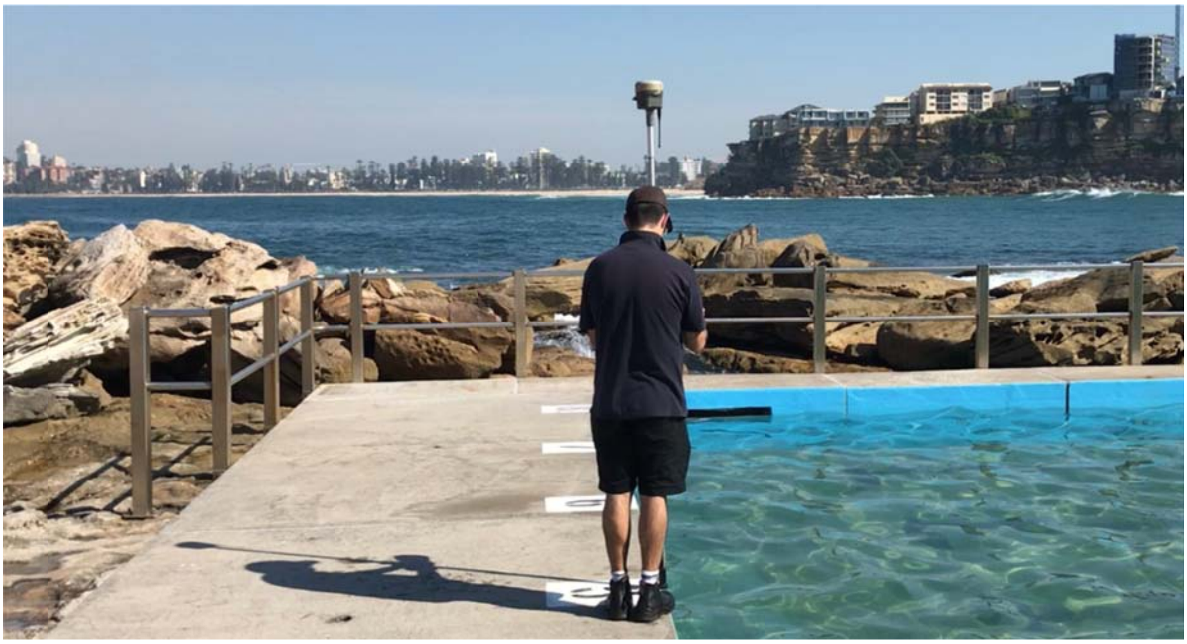


Figure 3.1 GPS surveys of Dee Why (top) and Freshwater (bottom)

3.2 Dee Why ocean pool

Dee Why ocean pool is shown in Figure 3.2. It comprises a main pool (50 m x 19 m), a children's/wading pool (21 m x 11 m) and steps/bleachers for public space (~400 m^2). The seaward wall crest is 1.8 m AHD. The main pool depth varies from 1.7 m to 0.7 m, while the wading pool varies from zero to 0.7 m. The dimensions, including depths are summarised in Section 3.6. Land based surveys undertaken by WRL were combined with the most recent seabed maps for Sydney to create transects offshore from the pool as shown in Figure 3.3, Figure 3.4 and Figure 3.5.

Figure 3.2 Dee Why ocean pool (Source: NearMap)

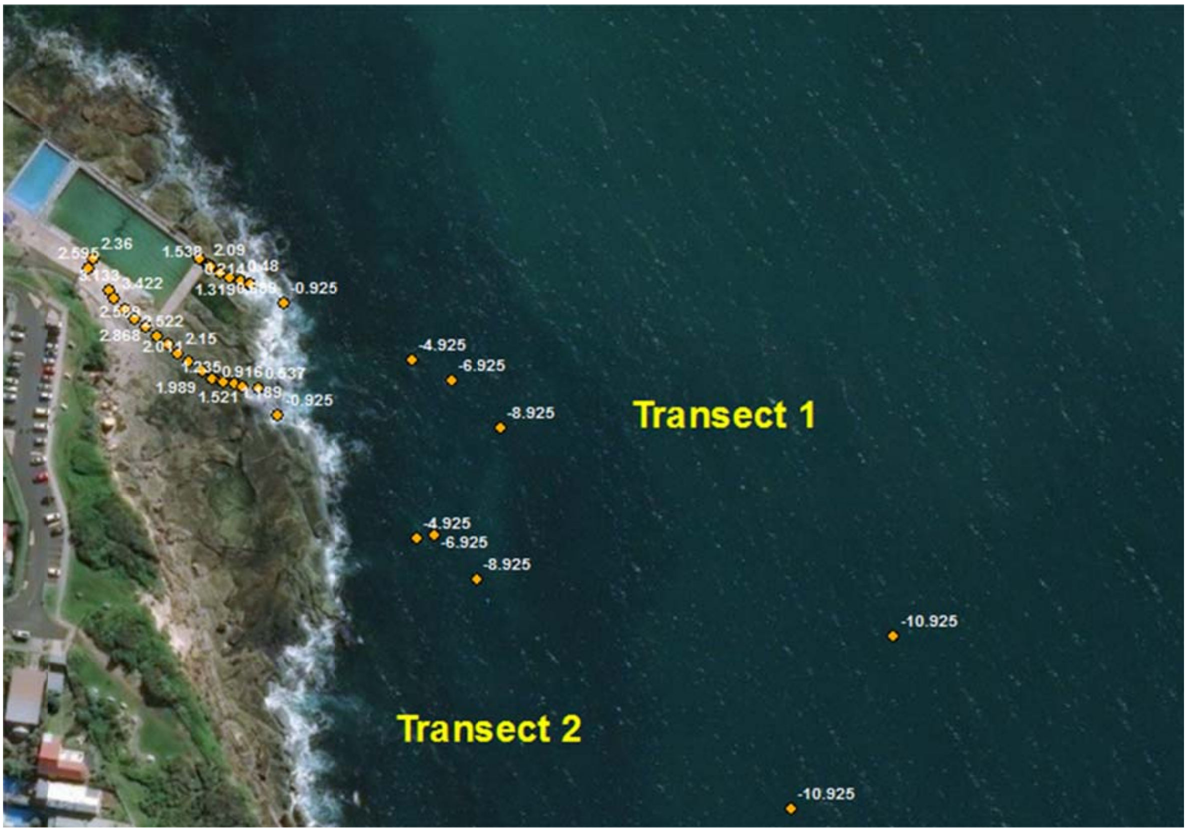


Figure 3.3 Dee Why transect locations

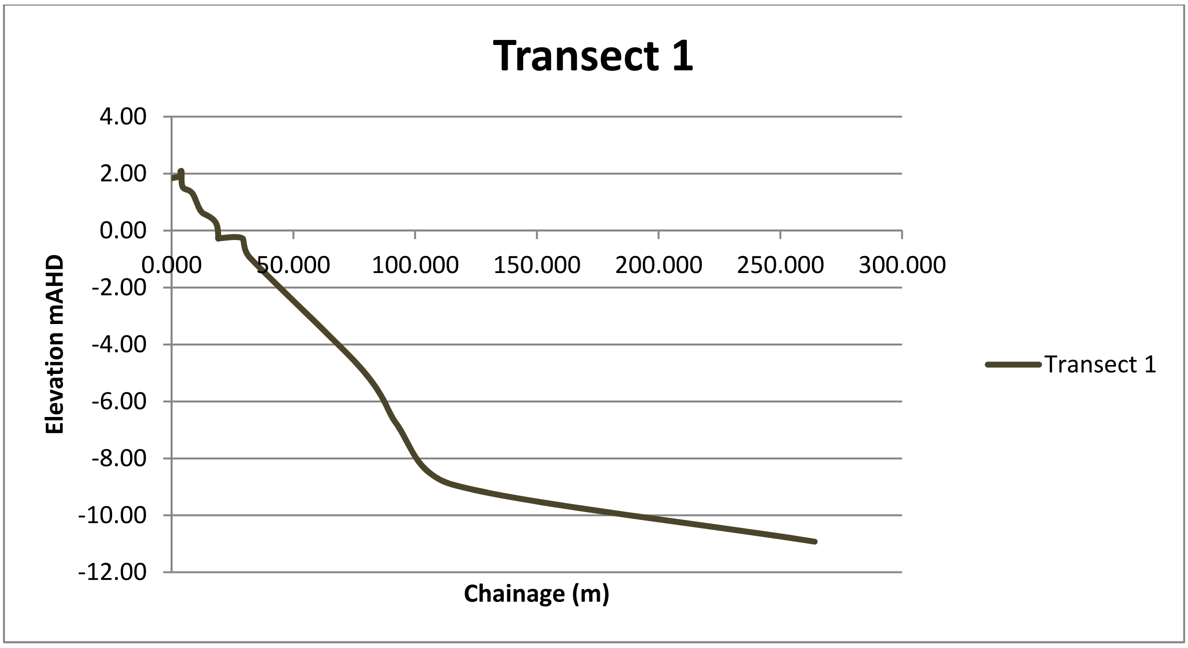


Figure 3.4 Dee Why transect 1

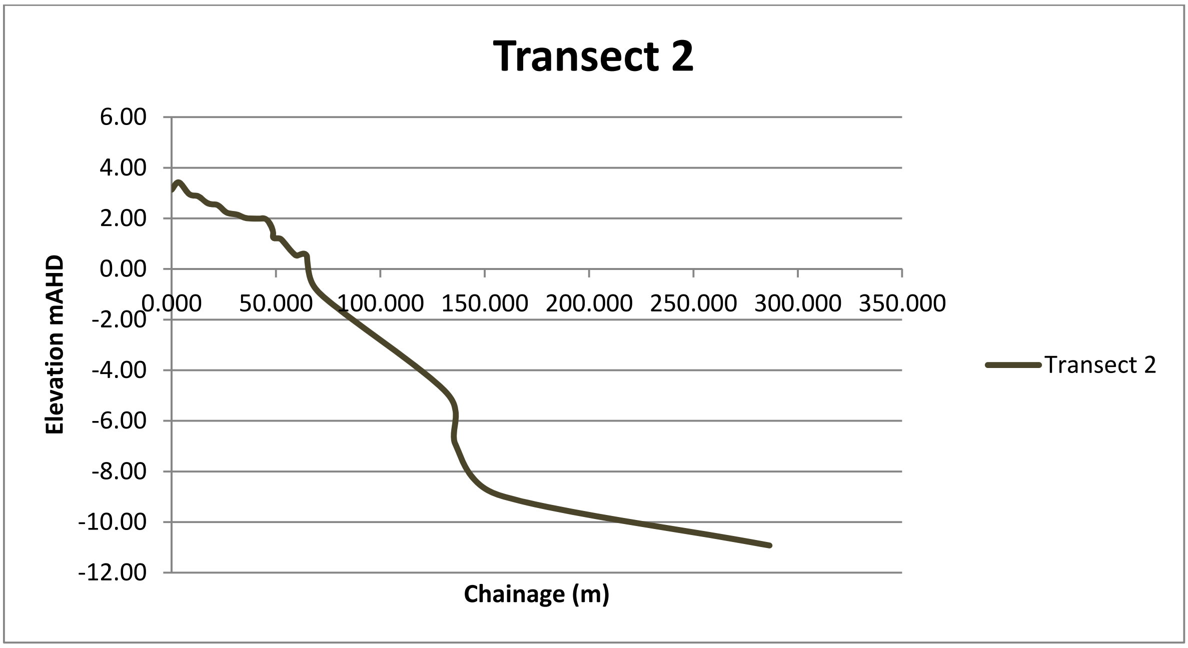


Figure 3.5 Dee Why transect 2

The walls and floor are concrete. The children's/wading pool is painted with blue chlorinated rubber paint, with a non-slip aggregate incorporated into the paint on the floor.

Under ambient conditions it receives very little wave flushing, consequently it utilises two Tsurumi pumps with the following characteristics: Model 80SFQ27.5, 80 mm bore, 3-phase, 2,000 L/minute (33 L/s), 123 kg.

Dee Why pool takes about 1 hour to drain and about 8 hours to fill.

Dee Why pool is cleaned fully once per week for most of the year and partly drained and refilled overnight in the middle of the weekly cleaning cycle. It still suffers from poor water quality during the peak of summer.

Sand ingress into the pool is minor and is able to be washed out as part of normal pool cleaning.

Boulders are transported into the pool during major storms about every 5 to 10 years.

The pool is dangerous about 1 to 6 times per year (Figure 3.6 and Figure 3.7), but the attachment to the land and stepped nature of the pool surrounds (Figure 3.6) allows for safe refuge.

The northerly aspect and cliff/bleachers on its southern side make this pool pleasant in winter.

Figure 3.6 Dee Why wave overtopping (1)

A bike rider gets 'salted' at Dee Why. Picture: Jenny Peachey

Figure 3.7 Dee Why wave overtopping (2)

3.3 North Curl Curl ocean pool

North Curl Curl ocean pool is shown in Figure 3.7. It comprises a main pool (33 m x 12 m) and a natural children's/wading pool (33 m x 11 m). There is minimal constructed public space, but substantial natural rock shelves. The seaward wall crest is 1.6 m AHD. The main pool depth is about 1.2 m, while the wading pool varies from zero to 1.2 m. The dimensions, including depths are summarised in Section 3.6. Land based surveys undertaken by WRL were combined with the most recent seabed maps for Sydney to create transects offshore from the pool as shown in Figure 3.10 and Figure 3.11

Figure 3.8 North Curl Curl ocean pool location (Source: NearMap)

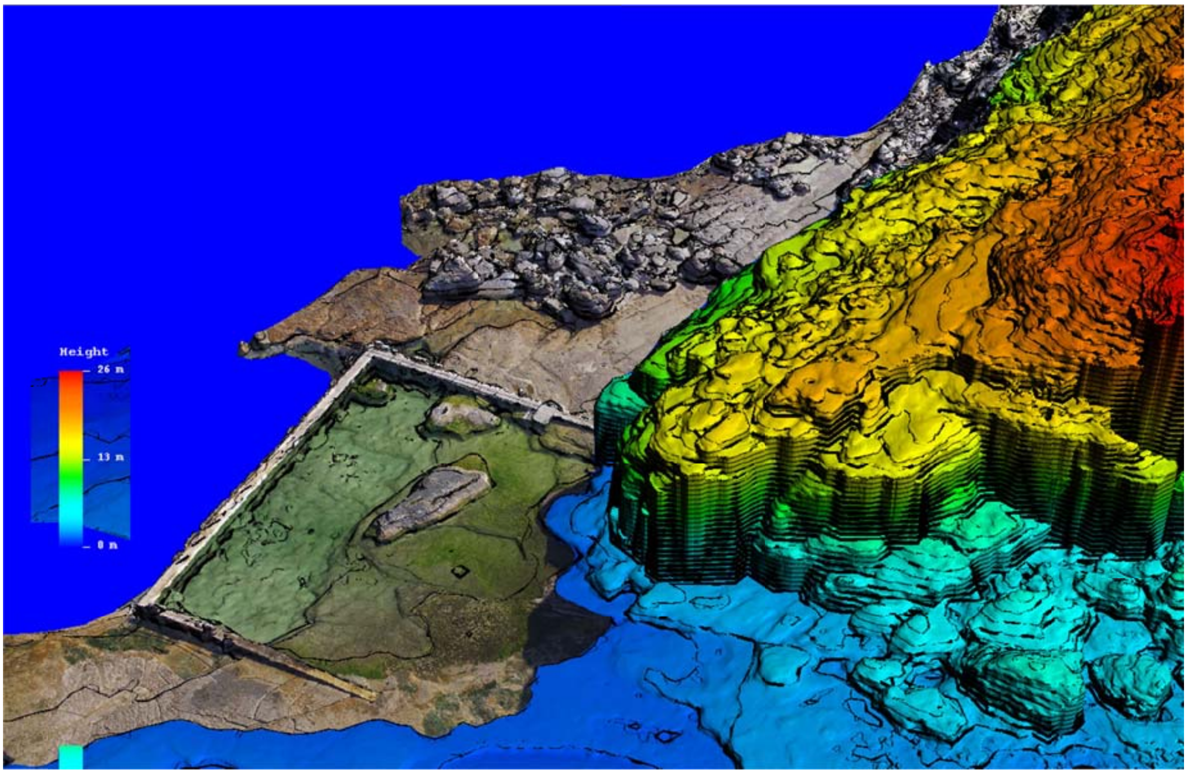


Figure 3.9 North Curl Curl ocean pool terrain

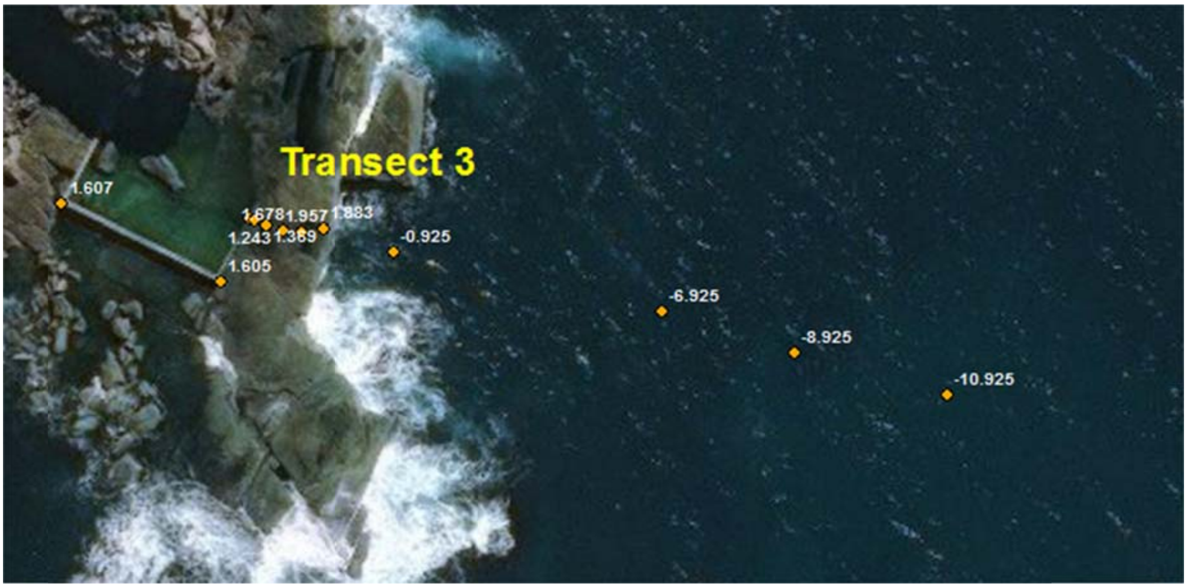


Figure 3.10 North Curl Curl transect locations

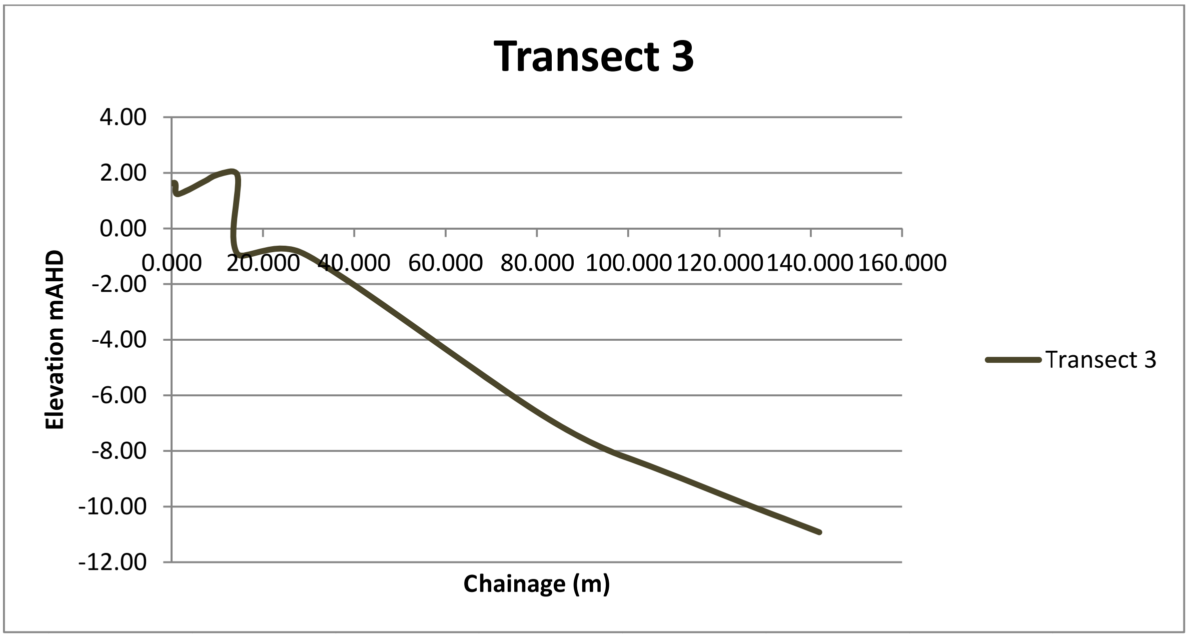


Figure 3.11 North Curl Curl ocean pool transect 3

This pool is quite remote by Sydney standards. Access can be gained around the foreshore during very low tides, or via a remote bush path and very steep steps.

The walls are concrete while the floor is a mix of rock and sand.

There is no pump.

North Curl Curl pool is cleaned about twice per year, to remove algae/slipperiness from the steps by water blasting and/or algaecide. The pool is half drained to do this.

Because of the low intervention, the pool supports its own ecosystem, however, this includes numerous sea urchins. The walls are covered in a variety of organisms, some of which are soft, but some of which are hard and sharp, which can result in cuts to the feet of swimmers if they push off the walls hard.

Due to its wave exposed location, the water quality is generally good. However, as there is no pump, during hot weather with small waves and low tides, the pool can harbour “pelican itch” – a parasite/lice carried by birds which buries into human skin and dies, causing significant itching.

Sand ingress into the pool is minor due to its remoteness from the sandy beach and seabed.

Boulders are transported into the pool during major storms about every 5 to 10 years, and sometimes damage the pool balustrade (Figure 5.3).

The pool can be dangerous even in ambient conditions during high tides - about once per week to once per fortnight (Figure 3.12 to Figure 3.14). Numerous injuries due to wave overtopping have occurred at this pool. Christopher Drake died at this pool and his death was the subject of a coronial inquest in 2014 (MacMahon, 2014). The pool is close to an island type in form, with only a minor connection to the land. This accentuates its danger, as swimmers can be washed out of the leeward side of the pool into the surf and rips.

The known danger of this pool means that it is actively managed during patrol season (Figure 3.15).

Figure 3.12 North Curl Curl ocean pool overtopping (1)

Source: Pamela Pauline, australianphotography.com

Figure 3.13 North Curl Curl ocean pool overtopping (2)

Source: amandabauer.blogspot.com

Figure 3.14 North Curl Curl ocean pool overtopping (3)

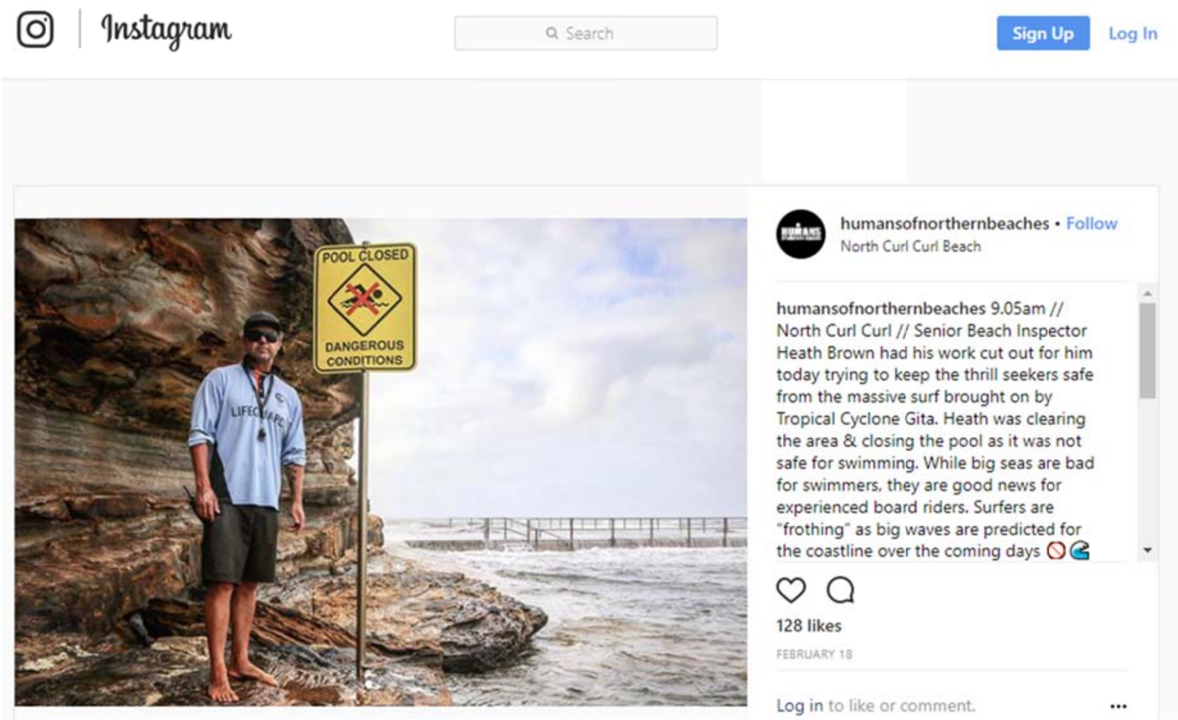


Figure 3.15 North Curl Curl ocean pool closure

3.4 South Curl Curl ocean pool

South Curl Curl ocean pool is shown in Figure 3.16. It comprises a main pool (50 m x 13 m), a children's/wading pool (30 m x 15 m) and a promenade/public space (~240 m^2). The seaward wall crest is 1.5 m AHD. The main pool depth varies from 1.6 m to 1.2 m, while the wading pool varies from zero to 0.7 m after they have been emptied of sand. The dimensions, including depths are summarised in Section 3.6.

Land based surveys undertaken by WRL were combined with the most recent seabed maps for Sydney to create transects offshore from the pool as shown in Figure 3.17 and Figure 3.18.

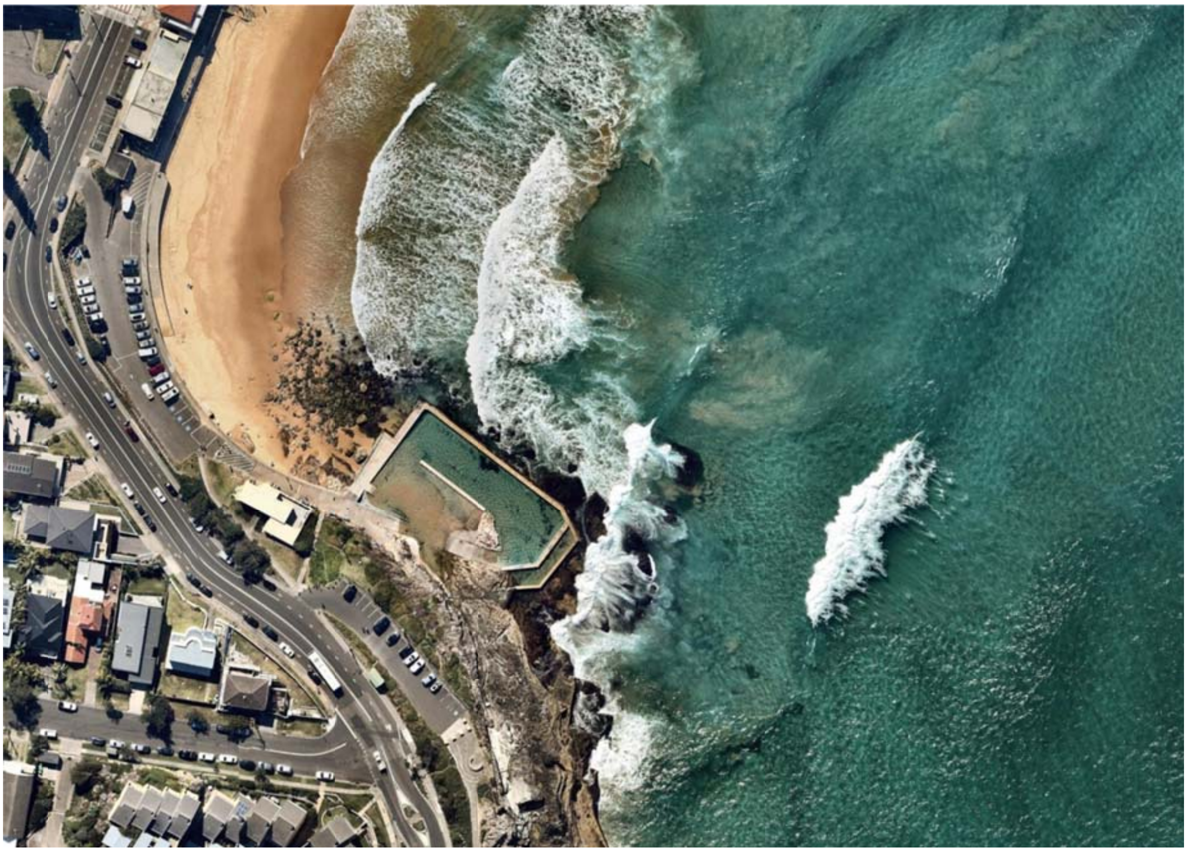


Figure 3.16 South Curl Curl ocean pool location (Source: NearMap)

Figure 3.17 South Curl Curl transect locations

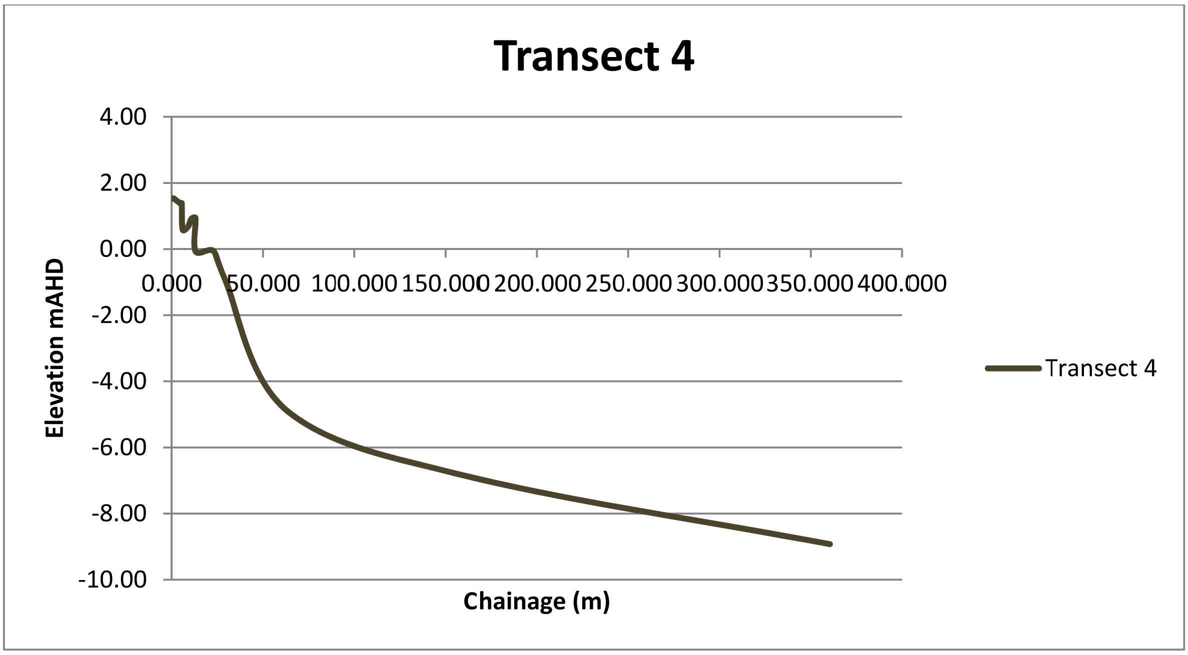


Figure 3.18 South Curl Curl ocean pool transect 4

The walls are concrete and painted with blue chlorinated rubber paint. The floor is a combination of concrete, excavated rock and sand. There is level access from an adjacent car park and a ramp into the wading pool.

Under ambient wave conditions at high tide, it receives substantial wave flushing. It is equipped with a Tsurumi pump with the following characteristics: Model 80SFQ27.5, 80 mm bore, 3-phase, 2,000 L/minute (33 L/s), 123 kg. However, due to wave flushing, the pump is only required when waves are very small.

South Curl Curl pool takes about 1 hour to drain and about 8 hours to fill.

South Curl Curl pool is cleaned once per week for most of the year. It rarely suffers from poor water quality, except during the peak of summer at the end of the weekly cleaning cycle.

Sand ingress into the pool is substantial when wave heights are moderate to large (significant wave height; Hs, above about 2 m). It is estimated that there are about five sand removal campaigns with a bobcat per year and about four with a loader excavator, that is, nine on average (Figure 3.20). This amounts to about $13,000 per year in sand removal expenses by a contractor.

The pool regularly accumulates small quantities of seaweed, and occasionally fills with more substantial quantities of it. Occasionally seaweed mixes with sand on the bed and eutrophies, forming a malodorous sludge, which needs to be removed by machine.

Boulders are transported into the pool during major storms about every 5 to 10 years.

The pool is dangerous about 6 to 12 times per year (Figure 3.19), but its attachment to the elevated surrounding land allows for safe refuge, and serious incidents are rare.

The northerly aspect and cliff/promenade on its southern side make this pool pleasant in winter.

Figure 3.19 South Curl Curl ocean pool overtopping

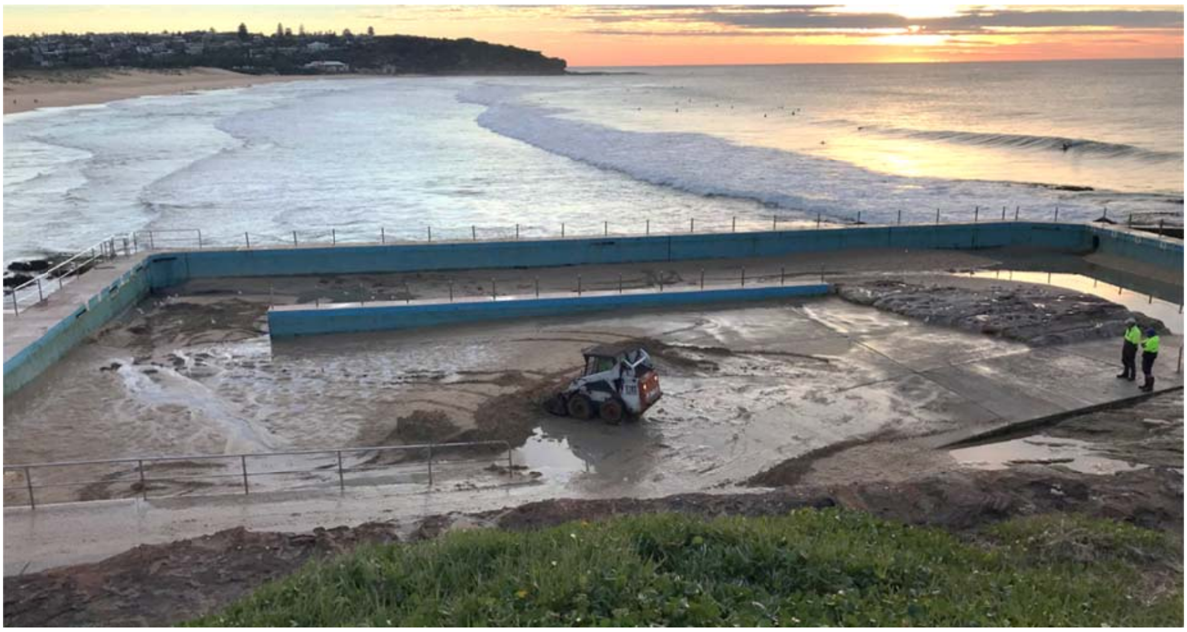


Figure 3.20 South Curl Curl ocean pool sand removal

3.5 Freshwater ocean pool

Freshwater ocean pool is shown in Figure 3.21. It comprises a main pool (50 m x 18 m) and a promenade/public space (~420 m^2). There is no children's/wading pool, which results in occasional collisions/conflicts between users, noting that there are nearby small natural rock pools. The seaward wall crest is 1.5 m AHD. The main pool depth varies from 1.7 m to 1.2 m. The dimensions, including depths are summarised in Section 3.6. Land based surveys undertaken by WRL were combined with the most recent seabed maps for Sydney to create transects offshore from the pool, as shown in Figure 3.23 to Figure 3.25.

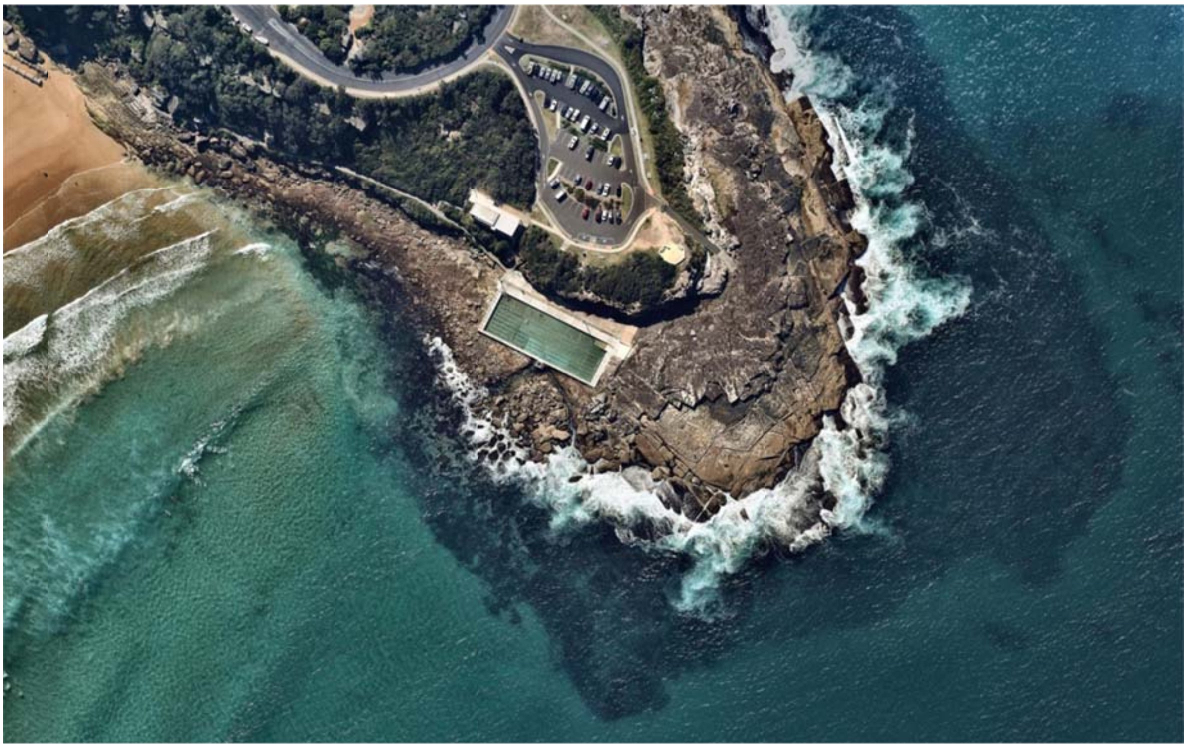


Figure 3.21 Freshwater ocean pool location (Source: NearMap)

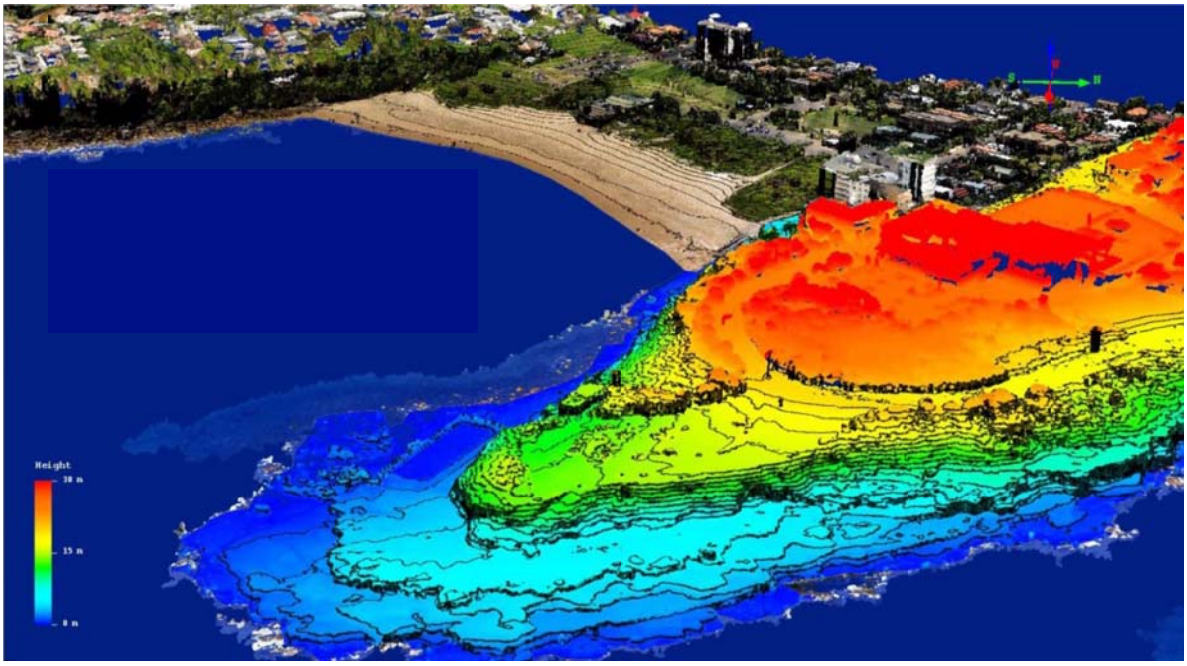


Figure 3.22 Freshwater ocean pool terrain

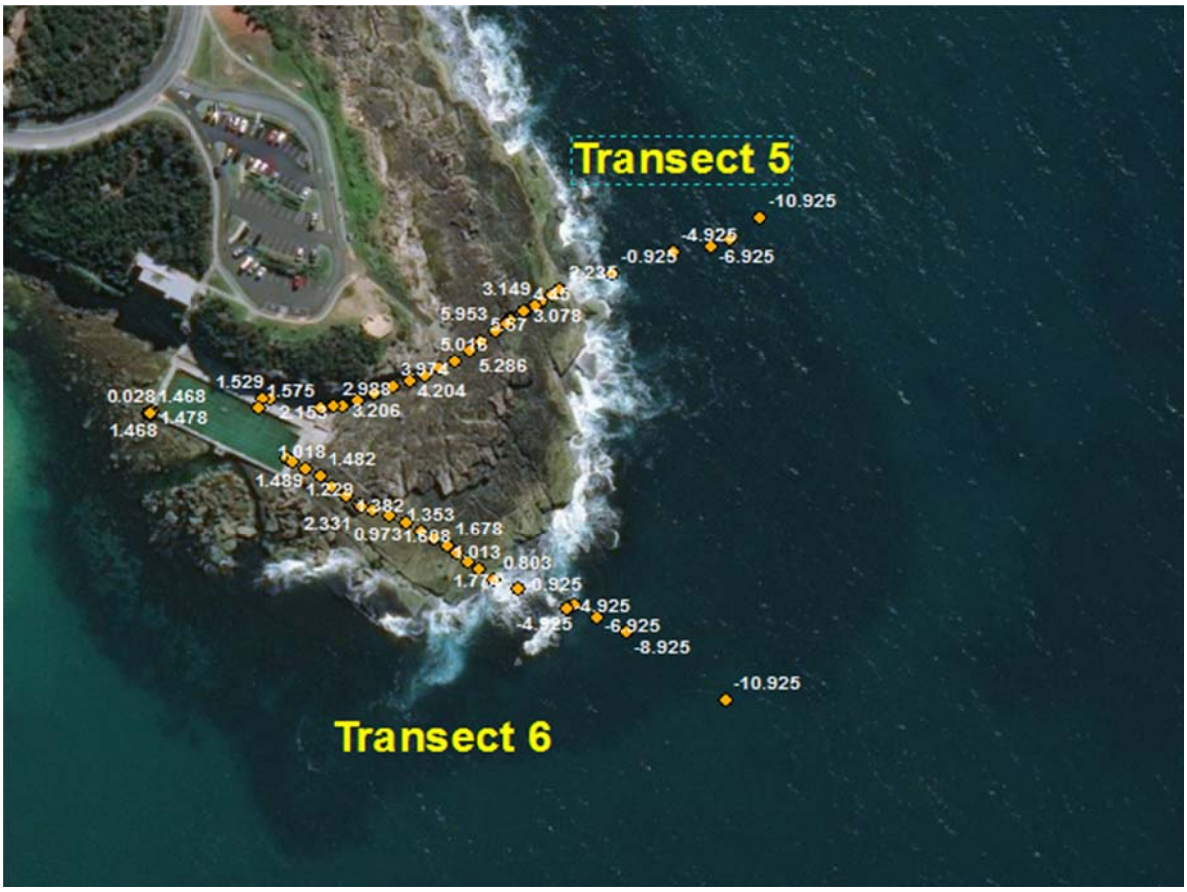


Figure 3.23 Freshwater transect locations

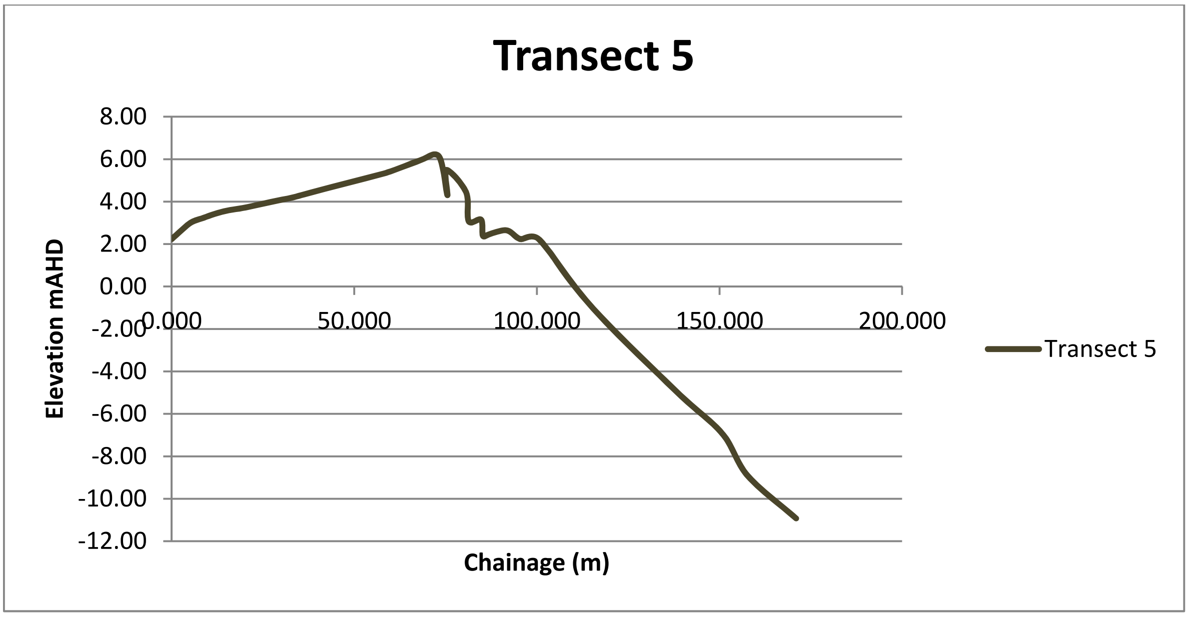


Figure 3.24 Freshwater transect 5

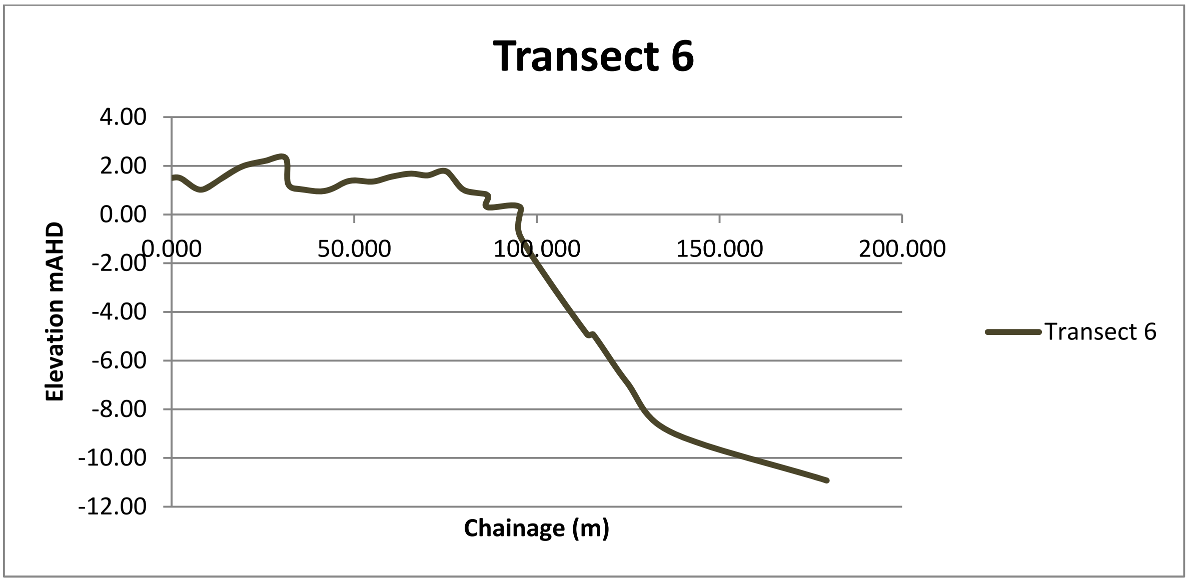


Figure 3.25 Freshwater transect 6

The walls are concrete and painted with blue chlorinated rubber paint. The floor is concrete with black painted lane lines. There is stair access from an adjacent car park, plus a pathway from the nearby beach and steep/rough ramp access for service vehicles and machines. There is a ramp with a gradient of about 1V:4H into the pool which is wide enough for service vehicles.

Except during very high tides and/or large waves, it receives minimal wave flushing. It is equipped with a Tsurumi pump with the following characteristics: Model 80SFQ27.5, 80 mm bore, 3-phase, 2,000 L/minute (33 L/s), 123 kg. This pump is run a large proportion of the time to maintain water quality.

Freshwater pool takes about 1 hour to drain and about 8 hours to fill.

Freshwater pool is cleaned fully once per week for most of the year and partly drained and refilled overnight in the middle of the weekly cleaning cycle during peak months. It still suffers from poor water quality during the peak of summer.

Sand ingress into the pool is minor and is able to be washed out as part of normal pool cleaning.

Boulders are transported into the pool during major storms about every 10 years.

The pool is dangerous about 1 time per year, but the attachment to the land and stepped nature of the pool surrounds allows for safe refuge except during extreme storms, when overtopping water approaches via Transect 5 in Figure 3.24

The pool sometimes accumulates small quantities of seaweed which is removed as part of normal cleaning.

Its location on the southern side of a cliff means that it is colder than other locations in winter, but is well protected from summer north-east winds. Therefore, it is only lightly used in winter, but is heavily used in summer.

3.6 Summary of pool dimensions

A summary of pool dimensions for the four ocean pools studied in detail is shown in Table 3.1. As noted in the table, (most of) these pools contain the following elements:

- A main swimming (lap) pool;
- A smaller children's/wading pool; and
- Constructed public space.

In addition, WRL has acquired the seaward wall levels from numerous other ocean pools from a range of sources, including direct surveys by WRL associated with other projects. While these levels are useful, the propagation of waves into a pool is also dependent on the pool's location, coastal exposure and geometry of the surrounding rock shelf and seabed, rather than just the level itself. These levels are shown in Table 3.1.

Pool	Wall level (m AHD)	Length (m)	Width (m)	Deep depth (m)	Shallow depth (m)	Area (m^2)	Volume (m^3)
Main pool							
Dee Why	1.8	50	19	1.7	0.7	950	1,140
North Curl Curl	1.6	33	12	1.2	1.2	396	475
South Curl Curl	1.5	50	13	1.6	1.2	650	910
Freshwater	1.5	50	18	1.65	1.2	900	1,283
Children's/wading pool							
Dee Why		21	11	0.7	0	231	81
North Curl Curl		33	11	1.2	0	363	218
South Curl Curl		30	15	0.7	0	450	158
Freshwater		n/a	n/a	n/a	n/a	n/a	n/a
Constructed public space							
Dee Why		50	8			400	
North Curl Curl		0	0			0	
South Curl Curl		40	6			240	
Freshwater		60	7			420	

Table 3.1 Dimensions of four Sydney ocean pools

Pool	Source	Accuracy	Location	Outer wall level (m AHD)
Sawtell	UNSW Aviation LiDAR	±20 cm	south	1.8
Black Head	UNSW Aviation LiDAR	±20 cm		2.0
Forster Pool	UNSW Aviation LiDAR	±20 cm	north and west	1.6
The Entrance Baths	WRL RTK-GPS	±4 cm		2.0
Pearl Beach	WRL RTK-GPS	±4 cm		0.94
Bilgola Pool	UNSW Aviation LiDAR	±20 cm		1.9
Mona Vale Pool	UNSW Aviation LiDAR	±20 cm		1.5
North Narrabeen Pool	WRL RTK-GPS	±4 cm		1.4
Queenscliff Pool	WRL CDD Drone	±10 cm		1.6
Bondi North outer	UNSW Aviation LiDAR	±20 cm	west	0.5
Bondi North inner	UNSW Aviation LiDAR	±20 cm	west	1.0
Bondi Icebergs	UNSW Aviation LiDAR	±20 cm		2.4
Ross Jones Coogee	UNSW Aviation LiDAR	±20 cm	inner pool west	1.0
Wylie's Baths Coogee	UNSW Aviation LiDAR	±20 cm	east	1.0

Table 3.2 Crest levels of other ocean pool walls (not exhaustive)

3.7 Ecological habitat

Many ocean pools provide some form of internal ecological habitat, while almost all provide ecological habitat on their outside walls.

In a somewhat circular argument of cause and effect (or chicken and egg), pools with high human use are generally kept free of internal ecological organisms. This is because organisms such as oysters, barnacles and urchins will cause injuries to pool users. The frequent reporting of injuries in an attractive pool may result in more aggressive management practices to keep injury-causing organisms out of the pool (Figure 3.26).

Conversely, more remote pools with lower human use, such as North Curl Curl and Sawtell have thriving internal ecosystems. This requires knowledge on the part of pool users to modify their behaviour, such as avoiding pushing or touching walls with feet and hands, and avoiding walking in certain areas. In pools with abundant internal ecosystems, there is a reluctance by pool managers to drain or aggressively clean the pool, so as not to damage the ecosystems. Preservation of good water quality in such pools requires frequent wave flushing of the pool.

A potential compromise exists at North Narrabeen (Figure 3.27), whereby an internal lap pool with clean surfaces is contained within a larger pool in which some areas are left more natural, but this pool is heavily used and therefore fully drained for cleaning and sand removal (Figure 3.28).

Figure 3.26 Removal of sea urchins – Wylie's Baths, Coogee

21/12/2014, Note inner lap pool within larger pool

Figure 3.27 North Narrabeen ocean pool (1) (Source: NearMap)

23/7/2018, Note machines removing sand from pool

Figure 3.28 North Narrabeen ocean pool (2) (Source: NearMap)

4 Ballina coastal processes

4.1 Tides and water levels

Water levels are composed of the following components:

- Astronomical tides which are forced by the sun and moon;
- Tidal anomalies or residuals which may be forced by wind (wind setup), barometric pressure and trapped waves;
- Wave setup inside the surf zone; and
- Wave runup on beaches, cliffs and structures.

These components are shown in Figure 4.1 and described below.

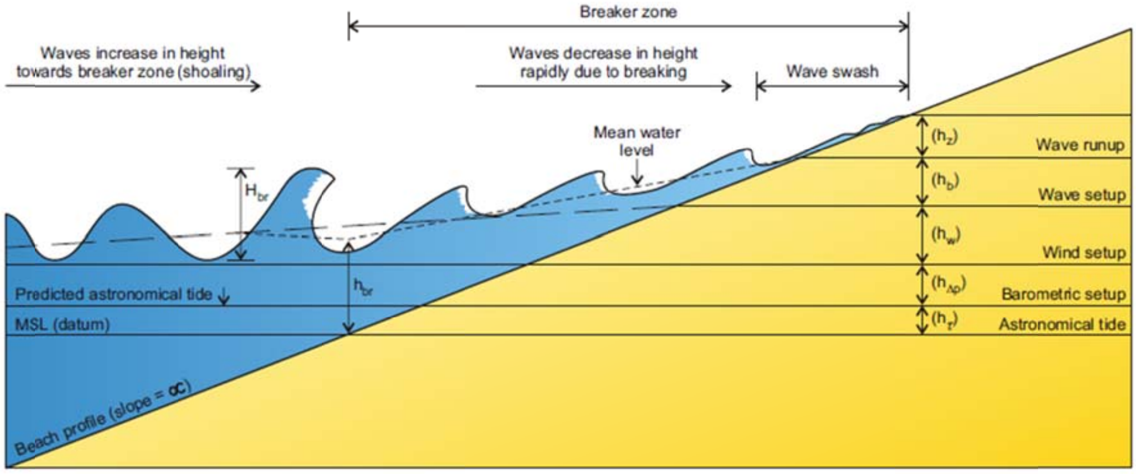


Figure 4.1 Components of elevated water levels (Adapted from NSW DECCW, 2010)

4.1.1 Tides

There is only a minor variation in tides along the NSW coast. While there are in excess of 100 tide gauges in NSW, the main data relevant for Ballina is:

- Fort Denison (Sydney) from 1914 to present; and
- Ballina, located 900 m upstream from the entrance on the southern breakwater from April 1986 to present, noting that this is sometimes affected by river flows and wave setup in the river mouth.

Published water levels are shown in Table 4.1 relative to tide datum (lowest astronomical tide, LAT) and Australian Height Datum (AHD), which is approximately mean sea level. The following adjustments have been made between LAT and AHD (MHL, 2010):

- Fort Denison (Sydney): AHD = LAT + 0.925
- Ballina: AHD = LAT + 0.860

Tidal plane	Sydney (m LAT)*	Sydney (m LAT)**	Sydney (m AHD)	Ballina (m LAT)*	Ballina (m AHD)
Highest astronomical tide	2.1		1.18	1.9	1.04
Mean high water springs	1.6	1.57	0.65	1.4	0.54
Mean high water neaps	1.3	1.33	0.41	1.1	0.24
Mean sea level		0.95	0.02		0
Mean low water neaps	0.6	0.56	-0.37	0.5	-0.36
Mean low water springs	0.3	0.32	-0.61	0.2	-0.66
Lowest astronomical tide	0.0	0.00	-0.93	0.0	-0.86

* From Australian National Tide Tables (2010)

** From MHL (2017)

Table 4.1 Tidal planes for Sydney and Ballina

Tides on the NSW coast are semi-diurnal, that is, there are two high tides and two low tides per day It is also of note that the NSW coast experiences a diurnal inequality at times of spring tides, and this manifests as a large high tide in the morning during summer (Christmas “king tides”) and at night during winter (Figure 4.2).

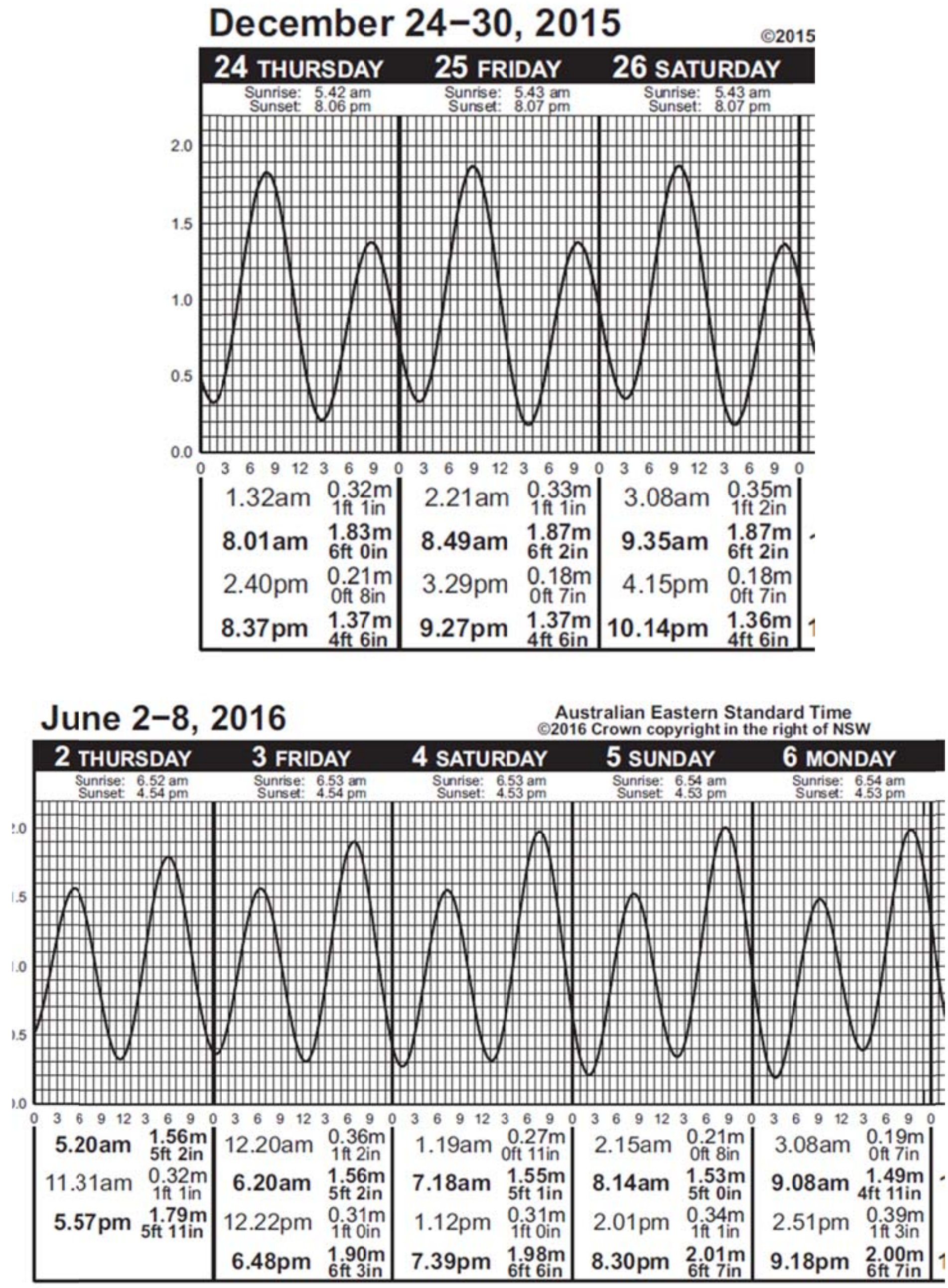


Figure 4.2 Diurnal inequality of tides in NSW (MHL, 2015)

4.1.2 Other sea level anomalies

Other sea level anomalies (often referred to as tidal anomalies) can result in differences between the actual water level and the predicted tidal water level(s). Anomalies can include a combination of short-term factors, such as variations in seasonal temperature, air pressure, wind stress, and coastal-trapped waves and longer term effects caused by variations in global atmospheric and oceanic patterns. A comprehensive summary of sea level anomalies along the NSW coastline is discussed in MHL (2010).

In addition to conventional "storm surge", anomalies over time scales of days to months to years can be caused by:

- Ocean Density Changes;
- Coastal Trapped Waves;
- El Niño - Southern Oscillation; and
- Inter-decadal Pacific Oscillation (IPO).

4.1.3 Extreme water levels

Extreme water levels (excluding wave setup and runup) for Sydney and Ballina are shown in Table 4.2, based on MHL (2010) and NSW DECCW (2010), with sea level rise discussed in Section 4.1.4. While the Ballina numbers are geographically more relevant, they are based on limited data (about 30 years) and may include a component of river flow, whereas the Sydney data is based on about 100 years of measurement and is not subject to river/rainfall effects. Within the required tolerance of a functioning ocean pool, the tides and extreme water level values for Sydney and Ballina are sufficiently similar. Typical values of components which result in sea level exceeding normal tides are shown in Table 4.2.

Average recurrence interval (ARI)	Sydney (m AHD) 2018	Ballina (m AHD) 2018	Ballina (m AHD) 2060 0.2 m SLR	Ballina (m AHD) 2060 0.4 m SLR
1 year	1.24	1.41	1.61	1.81
10 year	1.35	1.54	1.74	1.94
100 year	1.44	1.58	1.78	1.98
200 year	1.46			
500 year		1.59	1.79	1.99

Source: MHL (2010) and NSW DECCW (2010)

Table 4.2 Extreme water levels for Sydney and Ballina (excluding wave setup and runup)

Component	Typical Range (m)	Additional Comments
Barometric set-up	0.1 – 0.4	Barometric set-up can cause a 0.1 m increase in water level for every 10 hPa drop below 1013 hPa (i.e. average atmospheric pressure).
Wind set-up	0.1 - 0.2	Storm surge (the combination of barometric and wind set-up) can raise coastal water levels in NSW by up to 0.5 m (Couriel et al., 2014).
Wave set-up	0.7 - 1.5	Measurements taken on open coast beaches in NSW suggest that a wave set-up of up to 1.5 m can be expected at the shoreline during severe storm events (Nielsen, 2010).
Wave run-up	3.0 - 6.0	Design levels for wave run-up on open coast beaches in NSW exposed to waves may be up to 10 m AHD (Coghlan et al., 2016).

(after NSW Government, 1990 with updates)

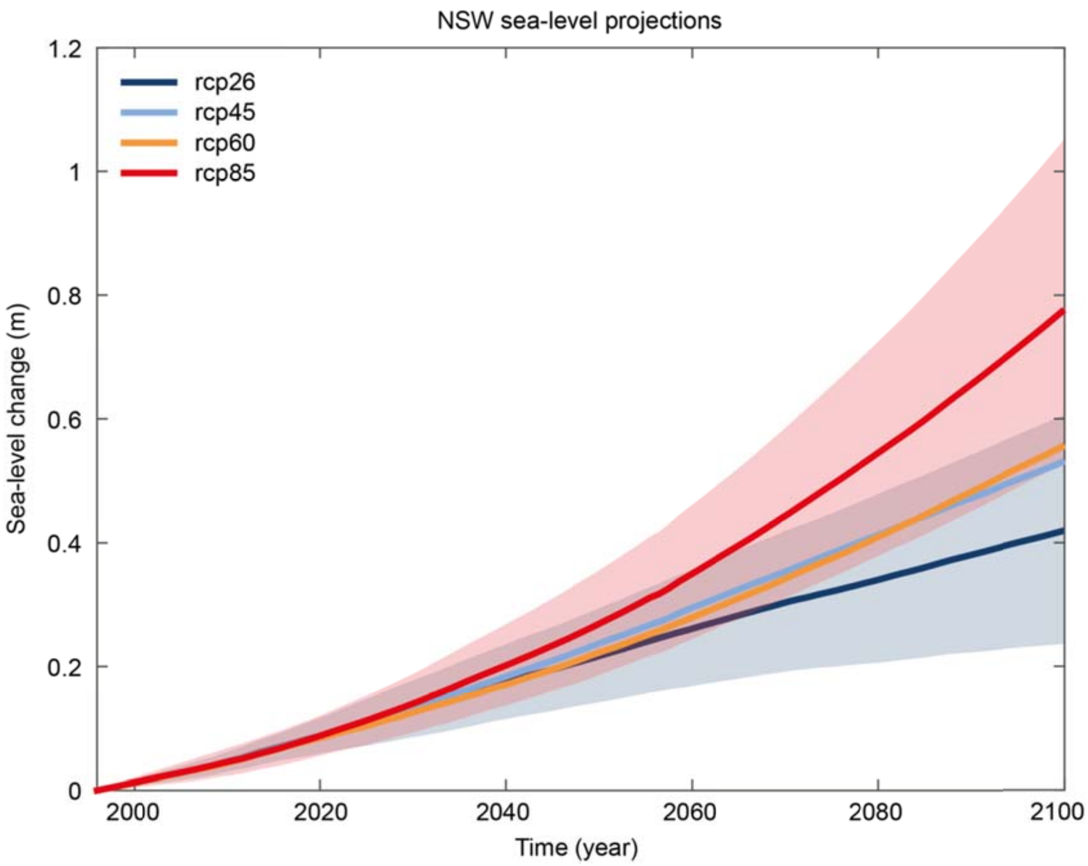
Table 4.3 Elevated water level components due to storm events

4.1.4 Sea level rise

The two longest tide gauge records (Fremantle and Sydney) reveal rising sea levels prior to 1960, relatively stable sea level rise rates between 1960 and 1990, followed by an increased rate of rise from the early 1990s (White *et al.*, 2014). White *et al*. (2014) reported that for the period between 1966 to 2009, (when there are observations of most sections of the Australian coastline), the average rate of relative sea level rise around Australia was 1.4 ± 0.2 mm per year, which is slightly less than the global averaged rise for the same period (CSIRO & BOM, 2015).

Sea level rise projections averaged along the NSW coastline, provided for each IPCC representative concentration pathway (RCP) scenario, are shown in Figure 4.3 (following McInnes *et al.*, 2015). This illustrates that sea levels are projected to increase under all scenarios.

For an ocean pool asset life of 50 years, sea level rise scenarios of 0.2 m and 0.4 m has been considered in this report.



Note: The central values are given for each scenario and the *likely* range (66% confidence limits) given for the unmitigated greenhouse gas emission scenario (RCP8.5) and the strong mitigation scenario (RCP2.6). For the two intermediate scenarios (RCP4.5 and RCP6.0) only the central values are shown (for clarity). Following McInnes et al. (2015).

Figure 4.3 Sea level rise projections relative to the land for NSW

4.2 Waves

The NSW coast is subject to a generally moderate wave climate predominantly from the south to south-east. Previous studies have found an average offshore significant wave height of between 1.5 to 1.6 m and average peak period of 9.4 to 9.7 s (Lord and Kulmar, 2000). This generally moderate wave climate is periodically affected by large wave events originating from coastal storm systems.

A network of wave buoys is in place from Byron Bay to Eden in NSW, with the Queensland buoy off North Stradbroke Island also relevant to northern NSW (Figure 4.5). A recent rigorous study of NSW wave statistics was undertaken by Shand et al. (2010). The key wave buoy relevant to Ballina is the Byron Bay wave buoy. All wave buoys have downtime due to instrument loss and malfunction. Nevertheless, analysis undertaken in Shand et al. (2010) of other nearby buoys in NSW and Queensland indicated that the Byron bay wave buoy provided a suitable and representative record, except that it may slightly underestimate 10 year and 100 year ARI wave heights due to being out of operation during several major storms. Consequently, Coffs Harbour values are also presented below.

The Byron Bay wave buoy measures waves in about 60 to 80 m of water (Figure 4.6). These waves were transformed to the -10 m AHD isobath using the NSW Government's nearshore wave transformation toolbox (Figure 4.4, Baird, 2017).

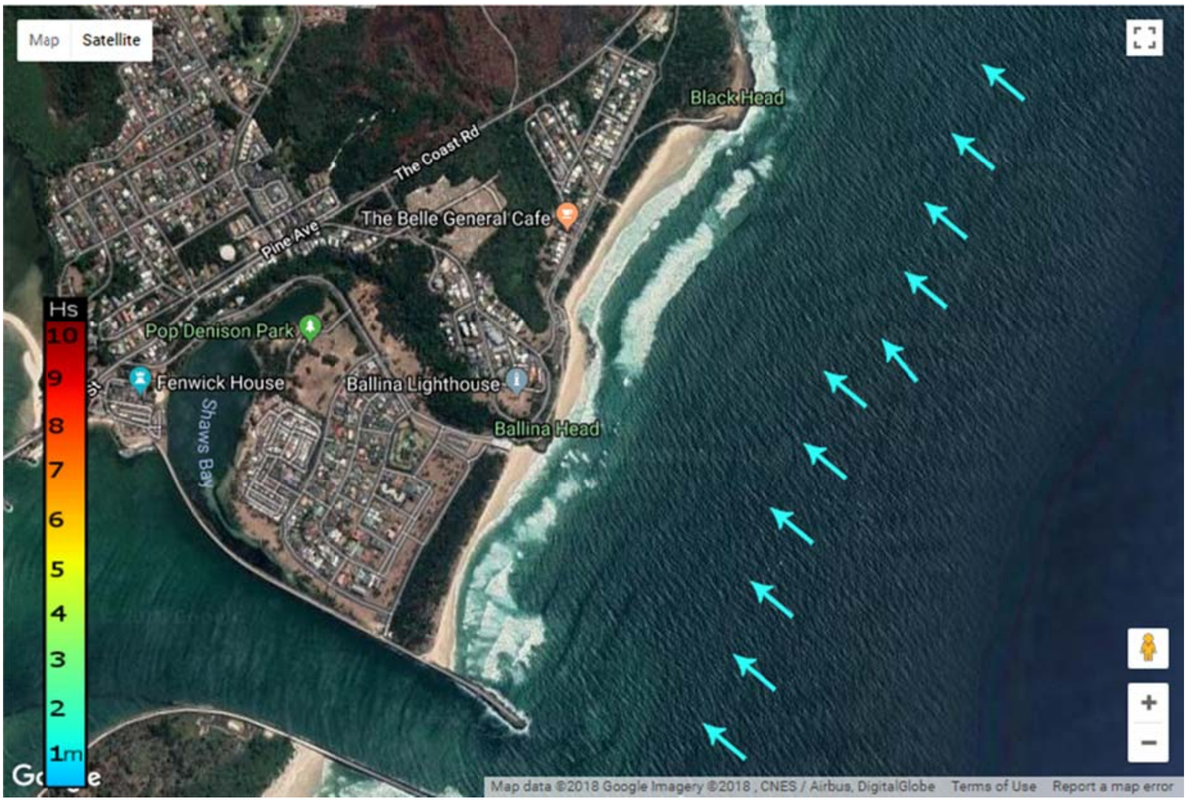


Figure 4.4 Wave transformation to 10 m contour with NSW coastal model

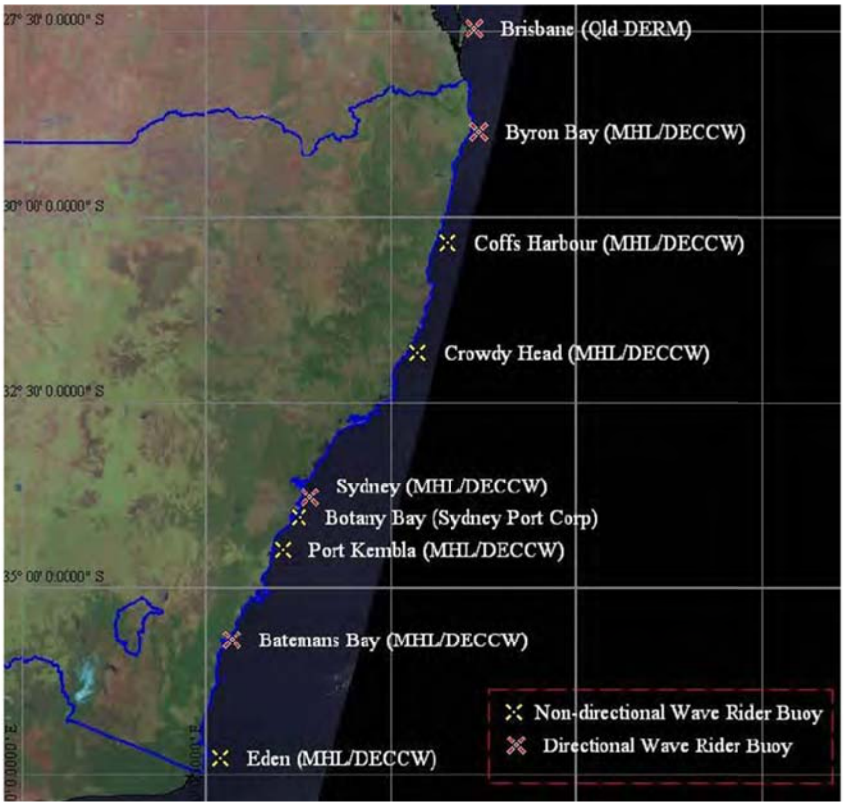
(Source: http://www.forecast.waves.nsw.gov.au/)

Key offshore wave statistics for the Byron Bay and Coffs Harbour wave buoys are shown in Table 4.4, with H_s being the significant wave height and T_p being spectral peak wave period. Note that the higher wave periods generally do not occur during storm conditions, so also shown in Table 4.4 is the associated typical wave period that would occur during the defined storm event. Other statistics and directional analysis are shown in Figure 4.7, Figure 4.8 and Figure 4.9.

Parameter	Byron Bay value	Coffs Harbour value
Analysis period	1976-2009	1976-2009
Effective record length	24.3 years	28.5 years
Mean H_S	1.66 m	1.58 m
Median H_S (exceeded 50%)	1.50 m	1.43 m
H_S exceeded 10%	2.59 m	2.44 m
H_S exceeded 1%	3.93 m	3.85 m
1 year ARI Hs	5.2 m	5.2 m
1 year ARI H_S associated T_P	11.4 s	11.4 s
10 year ARI H_S	6.4 m	6.7 m
10 year ARI H_S associated T_P	12.3 s	12.3 s
100 year ARI H_S	7.6 m	8.1 m
100 year ARI H_S associated T_P	13.1 s	13.1 s
Mean T_P	9.59 s	9.58 s
Median T_P (exceeded 50%)	9.50 s	9.50 s
T_P exceeded 10%	12.20 s	12.20 s

Source: Shand et al. (2010)

Table 4.4 Wave climate parameters for Byron Bay wave buoy



Source: Figure 3.1 of Shand et al. (2010)

Figure 4.5 Wave buoy locations

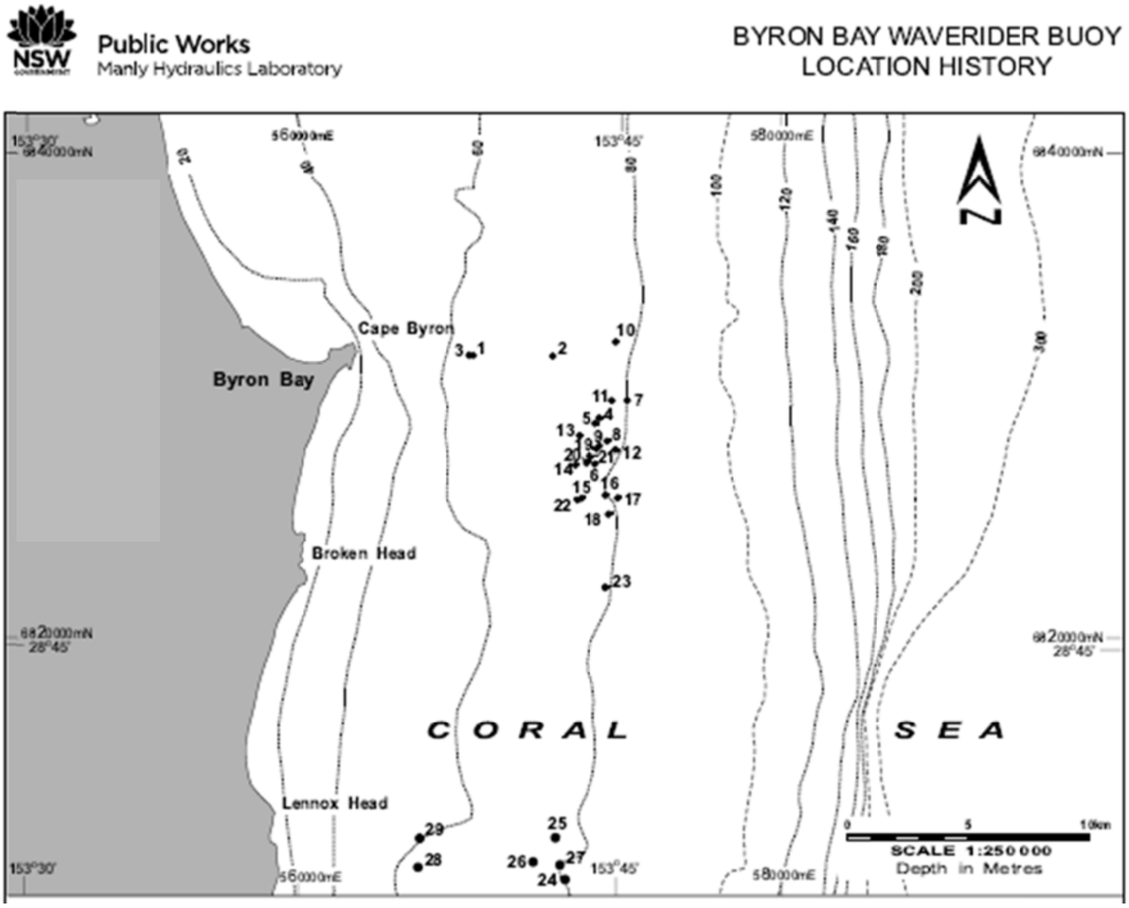
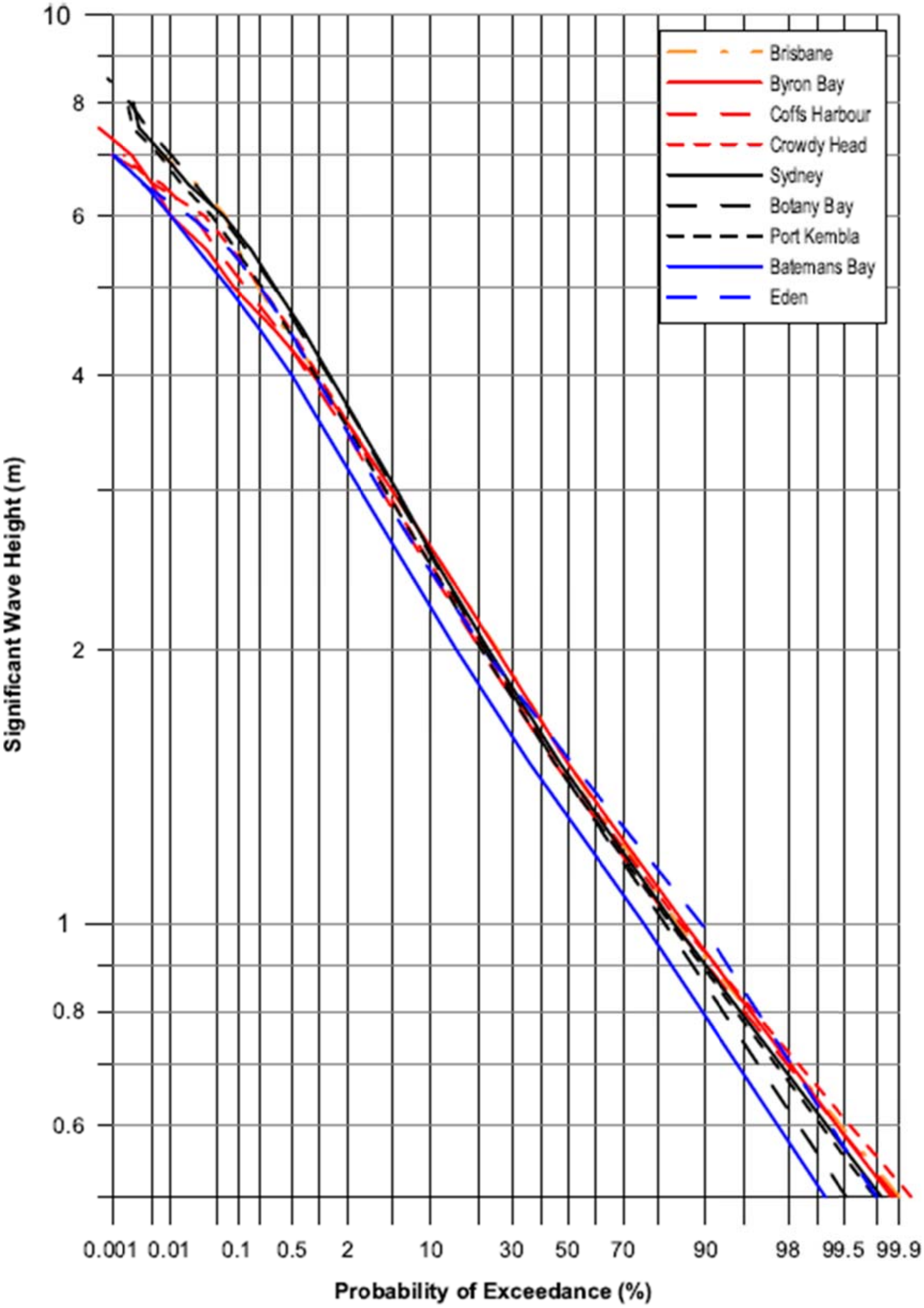
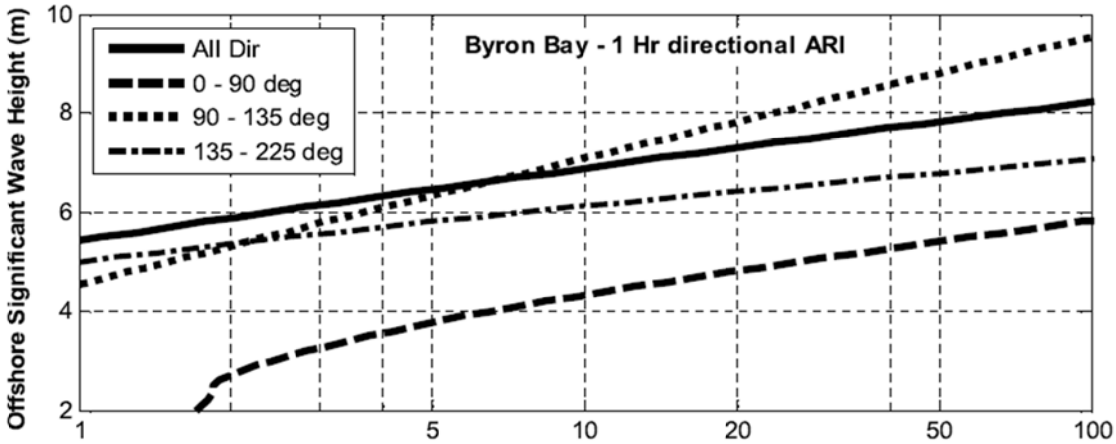


Figure 4.6 Byron Bay wave buoy locations (MHL)



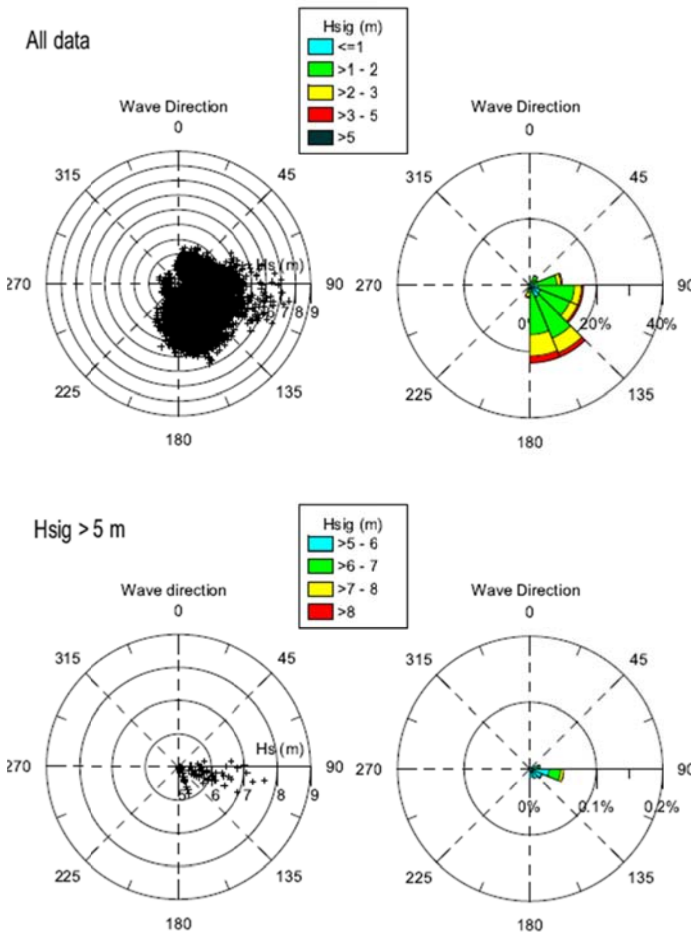
Source: Figure 4.1 of Shand et al. (2010)

Figure 4.7 NSW wave climate exceedance



Source: Figure 4.14 of Shand et al. (2010)

Figure 4.8 Byron Bay wave buoy directional extremes



Source: Figure C.2 of Shand et al. (2010)

Figure 4.9 Byron Bay wave buoy directional wave climate

4.2.1 Wave setup

Wave setup is a quasi-steady increase in the water level inside the surf zone due to the momentum of breaking waves. Wave setup at the back of a beach can be approximated as 15% of the significant wave height (H_s). The still water level including wave setup is shown in Table 4.5.

Average recurrence interval (ARI) or condition	Ballina (m AHD) 2018	Wave setup (m)	Wave setup level (m AHD)		
			Present	2060 0.2 m SLR	2060 0.4 m SLR
50% (median)		0.23			
10% exceeded		0.39			
1% exceeded		0.59			
1 year with MHWS	0.54	0.78	1.32	1.52	1.72
1 year	1.41	0.78	2.19	2.39	2.59
10 year	1.54	0.96	2.50	2.70	2.90
100 year	1.58	1.14	2.72	2.92	3.12

Source: MHL (2010) for still water level, WRL calculations for other variables

Table 4.5 Wave setup levels for Ballina

4.3 Other coastal processes and hazards

4.3.1 Richmond River training walls

The coastal processes and landscape are heavily influenced by the Richmond River training walls (breakwaters). With regard to the designers of many of the training walls (breakwaters) on the NSW coast including Ballina, Gourlay (2000) had the following commentary:

> "These British engineers were for the most part competent, well experienced with tides and their influence and conscious of the destructive force of waves but were not always appreciative of the significance of wave-induced sediment transport."

The following is an extract from Coltheart and James (1987), who reported the history of the Richmond River training walls.

> **1889-1911**: "Breakwater construction commenced in 1889. Improvements to the entrance were undertaken from 1878; from that date to 1892, £46,467 had been spent on this work. In the late 1890s work on the southern breakwater was carried out day and night.

The 1892 works were based on the design by Sir John Coode [Chief Engineer of the British Admiralty]. Work on the northern breakwater was suspended in October 1904, 534 feet short of Coode's design. Construction of the southern breakwater continued until 4 February, 1911. The southern breakwater was then 61 feet short of the length recommended by Coode."

1911-1962: Various repairs undertaken.

1964-1968: "… a 600 foot extension of the northern breakwater commenced in August 1964. In 1966-1967 an increase of only 114 feet was achieved due to extremely rough weather conditions. Cyclone 'Dinah" reduced the length of the wall by 61 feet. … Twenty concrete blocks, each 30 tons, were placed to armour the end of the northern breakwater on completion."

During times of river floods and normal outgoing tides, the Richmond River also has the potential to impact water quality in the proposed pool (Figure 4.10).

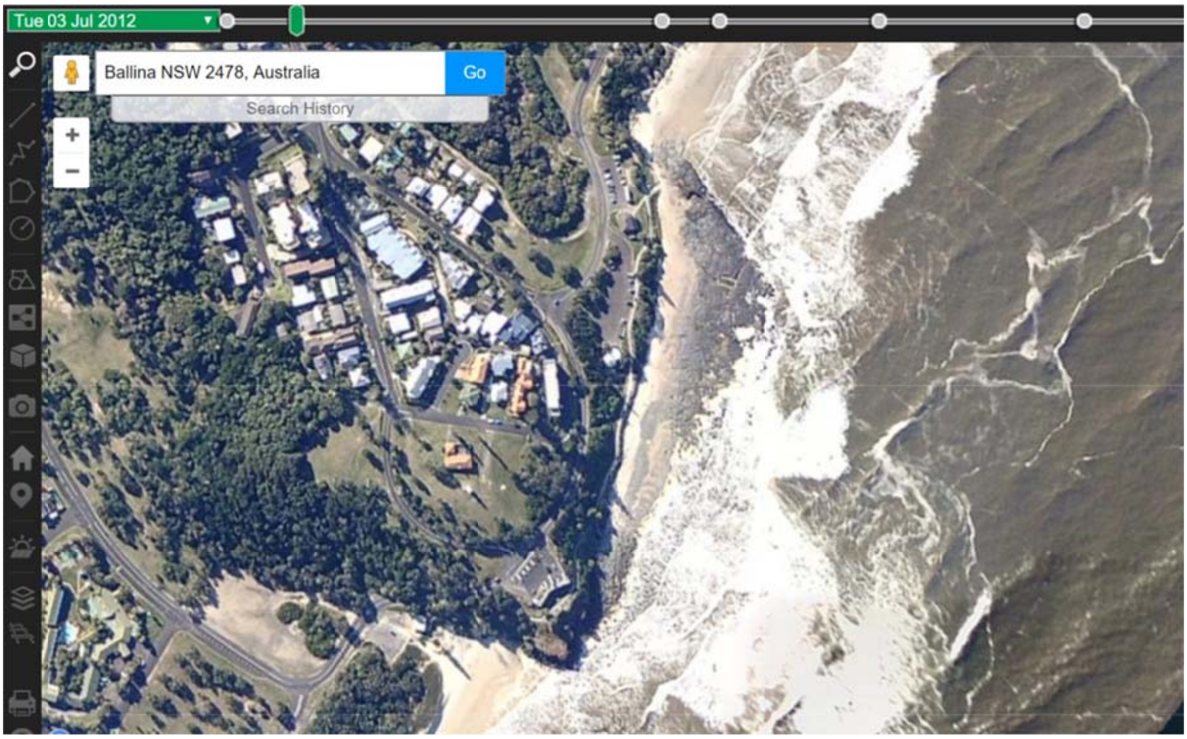


Figure 4.10 Flood water from Richmond River (3 July 2012, Source: NearMap)

4.3.2 Stormwater outfall

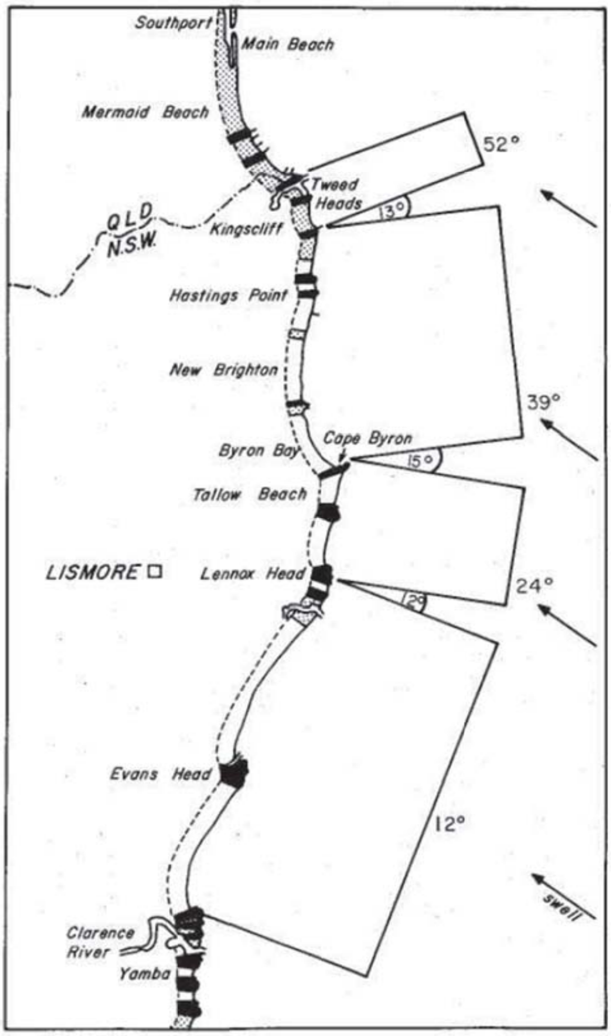
A stormwater pipe is located at the southern end of Shelly Beach and discharges onto the rock shelf (Figure 4.11). This is normally predominantly buried in sand and appears to be founded on the rock shelf. During times of sand accretion, it is predominantly buried, but associated flows discharge from further up the pipe, possibly due to sand blockage (Figure 4.12). This outfall should be considered in the pool design.

Figure 4.11 Stormwater outfall with eroded beach (Source: NearMap)

Figure 4.12 Stormwater outfall with accreted beach (Source: NearMap)

4.3.3 Littoral drift

In NSW, net northward littoral drift generally prevails north of about Newcastle (Chapman et al, 1982; Gordon, 1987; Cowell et al, 2001), which will generally transport sand northward over the longer term (Figure 4.13). South of about Newcastle, most coastal embayments are reasonably closed littoral compartments between headlands.



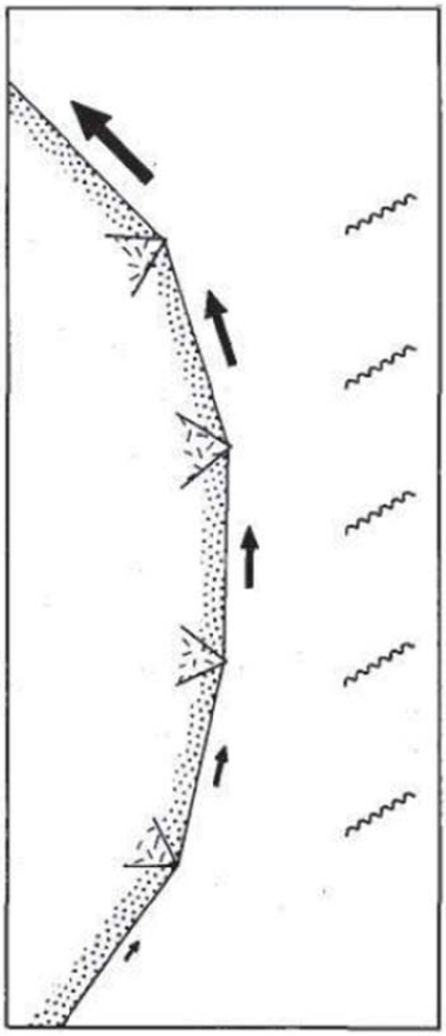


Figure 4.13 Littoral drift in northern NSW (Stephens et al, 1981)

There have been few detailed assessments of coastal processes for the Ballina region. Modelling presented in Patterson (2007) estimates that net littoral drift (longshore transport) of sand at Ballina is 248,000 m^3/year northward.

Numerous studies have estimated that net littoral drift at the Tweed River is of the order of 500,000 m^3/year northward, composed of approximately 600,000 m^3/year northward and 100,000 m^3/year southward. While no studies have been undertaken for Ballina, the cross shore distribution for the Gold Coast (Figure 4.14) shows that most of this littoral drift occurs landward of the -4 to -5 m AHD depth contour.

The differential between Yamba and the Gold Coast is illustrated in concept in Figure 4.15, and is the reason why recession is experienced on many beaches of the northern NSW coast, notwithstanding that Lighthouse and Shelly beaches are considered to be stable pocket beaches.

This high littoral drift also means that the potential for changes to beach planform associated with structures and sand ingress into an ocean pool is much larger than in the Sydney region where net littoral drift is small and often nil, especially when compared with Sydney pools where there is reef rather than sand offshore.

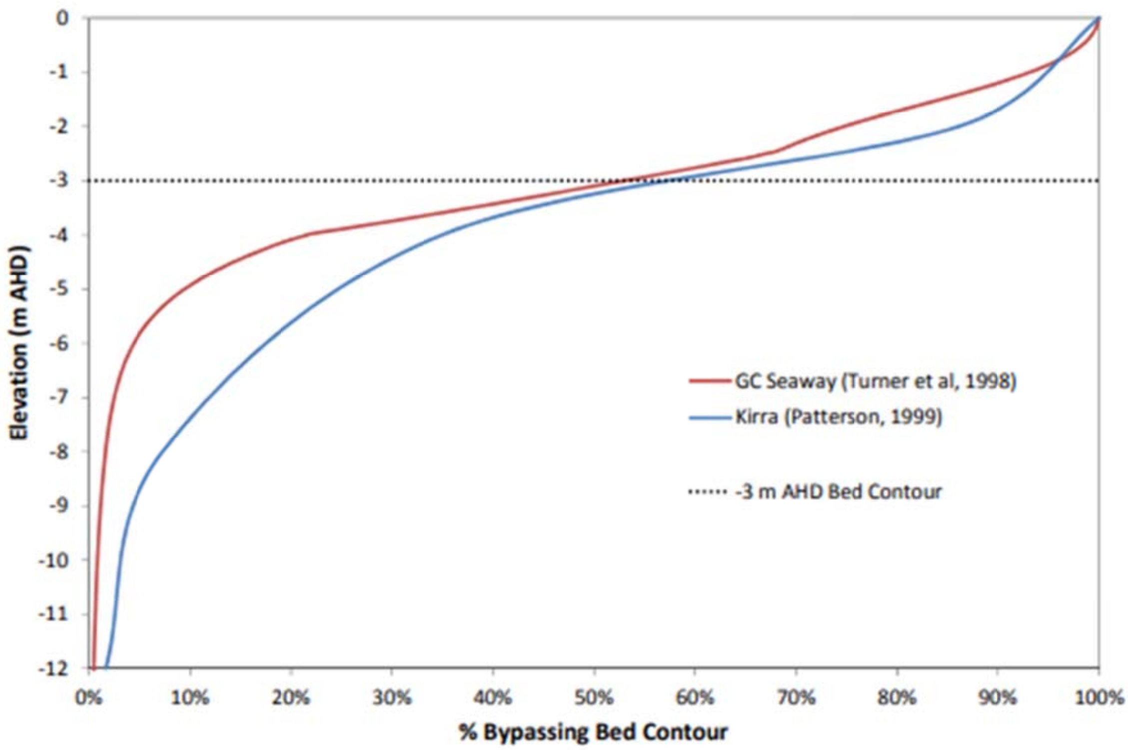
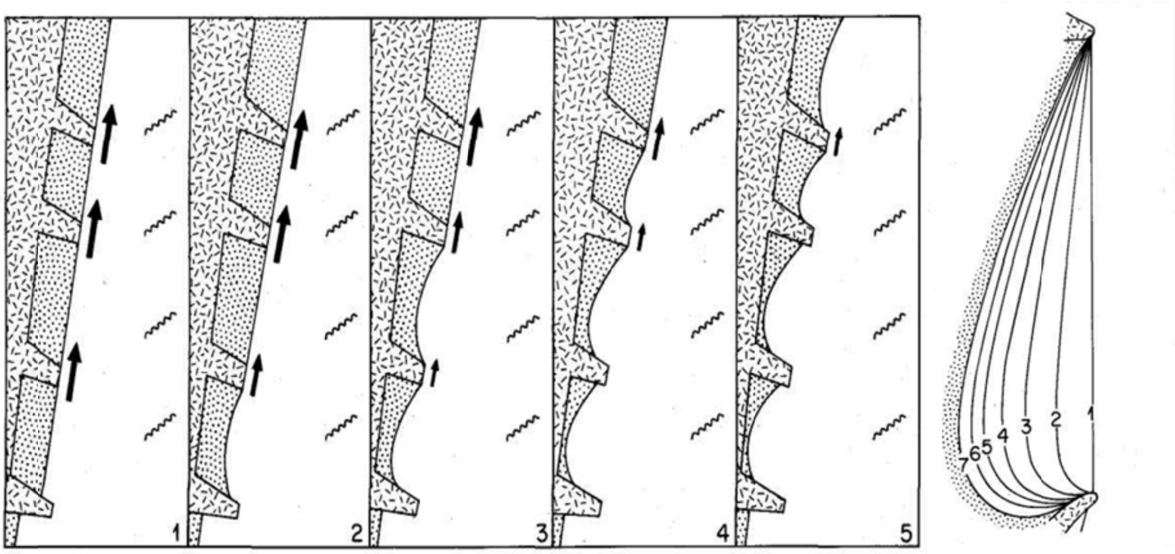


Figure 4.14 Comparison of cross-shore distribution of littoral drift

(Source: Coghlan et al., 2013)



Source: Stephens et al., (1981)

Figure 4.15 Coastal evolution and headland bypassing on a littoral drift coast

4.3.4 Storm erosion and vertical sand movement

An illustration of vertical change in a regularly surveyed beach (ETA63 profile at Surfers Paradise on the Gold Coast) is shown in Figure 4.16. Profile change measured by photogrammetry at profiles 1 and 2 (Figure 4.17) at Shelly Beach since 1945 is shown in Figure 4.18 and Figure 4.19. This shows that, based on limited data points, the sand seaward of about 2.5 m AHD has moved vertically within a 2 m range at Shelly Beach and within about a 0.8 m range over the rock shelf. Indicative vertical change in sand levels from a range of sources is shown in Table 4.6, noting that the presence of the rock shelf at the southern end of Shelly Beach will limit erosion there. The vertical change in Table 4.6 exceeds that measured in photogrammetry because the photogrammetry is based on limited data points which may not coincide with extreme events. Allowance for storm erosion and other coastal hazard components are covered in the next section.

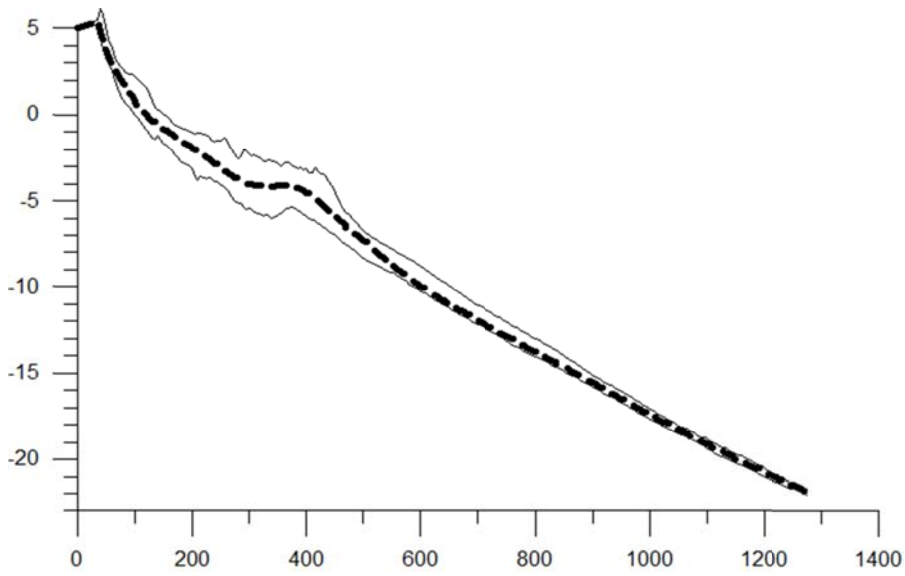


Figure 4.16 Envelope of ETA63 profile at Surfers Paradise

(1976 to 1997, Gold Coast Council data)

Figure 4.17 Photogrammetry transects (P1 at south of Shelly Beach, P4 at north)

(Source: http://www.nswbpd.wrl.unsw.edu.au/photogrammetry/nsw/)

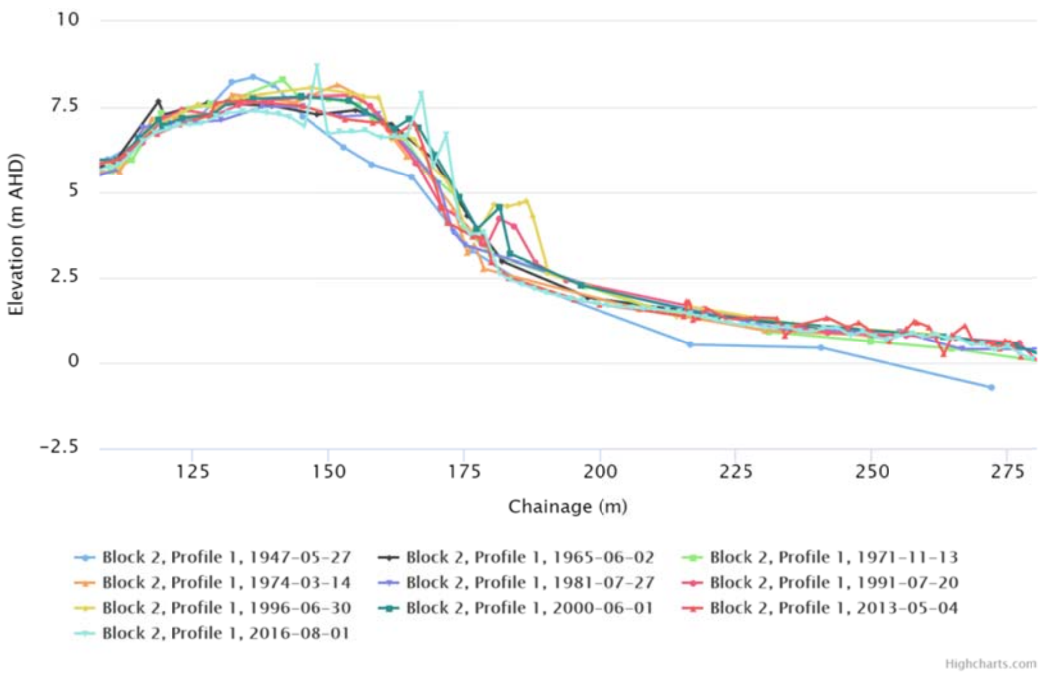


Figure 4.18 Photogrammetry profiles Block 2, Profile 1

(Source: http://www.nswbpd.wrl.unsw.edu.au/photogrammetry/nsw/)

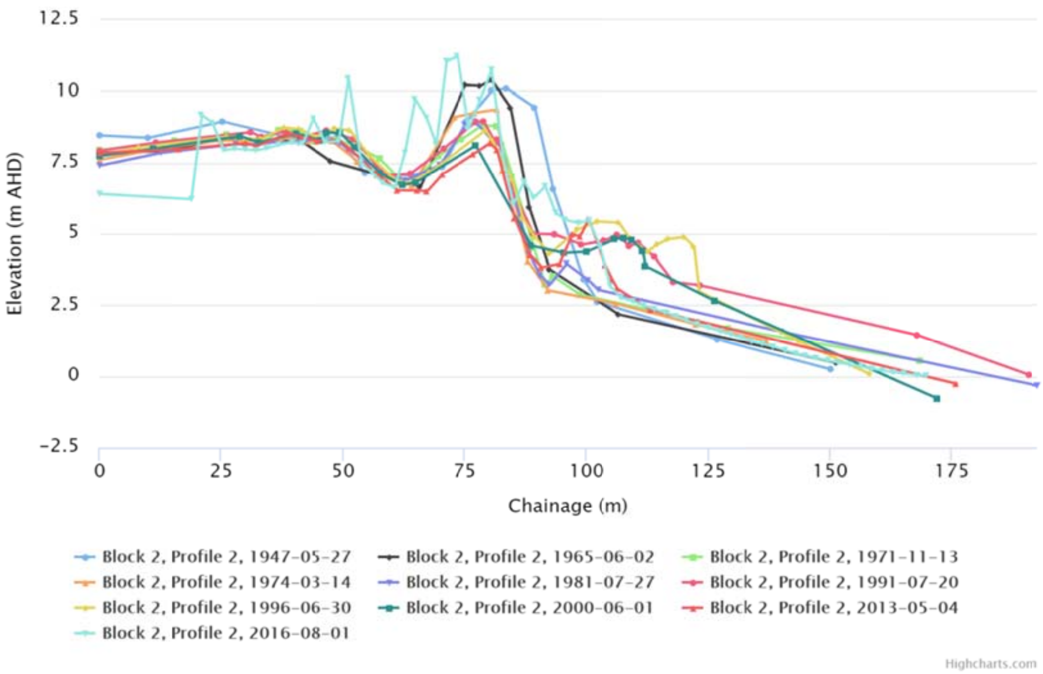


Figure 4.19 Photogrammetry profiles Block 2, Profile 2

(Source: http://www.nswbpd.wrl.unsw.edu.au/photogrammetry/nsw/)

Average sand level (m AHD)	Gordon (1987) high demand	Gordon (1987) low demand	Chapman and Smith (1983)

+4	±2.75	±2.0	±2.25
+2	±2.50	±1.9	±2.75
0	±2.25	±1.8	±2.75

Table 4.6 Published vertical profile change from other studies

4.3.5 Coastal hazard components

The most recent coastal hazard definition study was undertaken by WBM (2003) under the principles of the NSW Coastal Protection Act (1979). The 1979 Act has been superseded by the NSW Coastal Management Act (2016).

The Coastal Protection Act (1979) defined "coastal hazard" to mean the following:

(a) beach erosion;
(b) shoreline recession;
(c) coastal lake or watercourse entrance instability;
(d) coastal inundation;
(e) coastal cliff or slope instability;
(f) tidal inundation; and
(g) erosion caused by tidal waters, including the interaction of those waters with catchment floodwaters.

Values from WBM (2003) for these hazards (either directly published by WBM or calculated by WRL from WBM numbers) relevant to Shelly Beach are shown in Table 4.7.

Hazard	Criteria	Value
Beach erosion*	"Design" or 100 year ARI Distance equivalent for 6 m AHD dune	200 m^3/m 33 m
Underlying recession	From photogrammetry since 1945	NIL
Allowance for beach rotation	From photogrammetry since 1945	10 m
Recession due to future sea level rise**	0.2 m sea level rise 0.4 m sea level rise	10 m 20 m
Wave runup	"Design" or 100 year ARI	>5 m AHD

* This value is for sandy parts of Shelly Beach, noting that there is only a thin veneer of sand over bedrock at pool site

** Based on Bruun factor of 50

Table 4.7 Coastal hazard allowances

As noted in Table 4.7, the presence of the Richmond River training walls and headlands has stabilised Lighthouse and Shelly Beaches, so that they have experienced no long term recession since 1945.

4.3.6 Sand characteristics

The results of sand sampling undertaken by Professor Andy Short for the Australian Beach Safety database (ABSAMP, 2009) are shown in Table 4.8. These indicate a median grain size D_{50} of 0.21 to 0.26 mm and low shell content for Lighthouse and Shelly beaches (despite its name). While additional sampling would likely result in some scatter of the results, the results are reasonably consistent and broadly within WRL's expectations for D_{50} of 0.2 to 0.3 mm in northern NSW. Furthermore, the differences in measured values may be scatter rather than intrinsic differences between beaches.

Location		Median grain size D_{50} (mm)	Shell content (%)
Sharps	swash	0.20	0.5
Angels North	swash	0.29	5.2
Angels South	swash	0.20	0.5
Shelly	swash	0.26	2.1
Lighthouse	swash	0.21	0.4
Patches	swash	0.21	0.7

Table 4.8 Sand characteristics (Source: ABSAMP, 2009)

4.3.7 Wind-blown sand

Annual wind roses for Ballina Airport and Cape Byron from the Bureau of Meteorology are shown in Appendix B. A more rigorous analysis could correct these values for elevation and other variables such as season and other times of the day.

For a median sand grain size of 0.21 mm, USACE (2006) gives the following thresholds of motion for wind-blown sand:

- Dry sand: 6.8 m/s (13 knots, 25 km/hour); and
- Wet sand: 11.9 m/s (23 knots, 43 km/hour).

Given that the wind speed is sufficient to move dry sand on a frequent basis, subject to the final pool design, consideration should be made to wetting areas of sand which may be mobilised by wind into the pool. This could be achieved through the routing of water drained from the pool.

4.4 Seabed composition

Detailed seabed composition maps are available for the Sydney coast, but are not presently available for Ballina. Nearmap aerial photos for the subject area were examined. The photo with the clearest depiction of the offshore area was taken on 29 July 2014 (Figure 4.20). This shows some areas of offshore reef, but a predominantly sandy seabed. Consequently, most breaking/broken waves are likely to contain suspended sand.

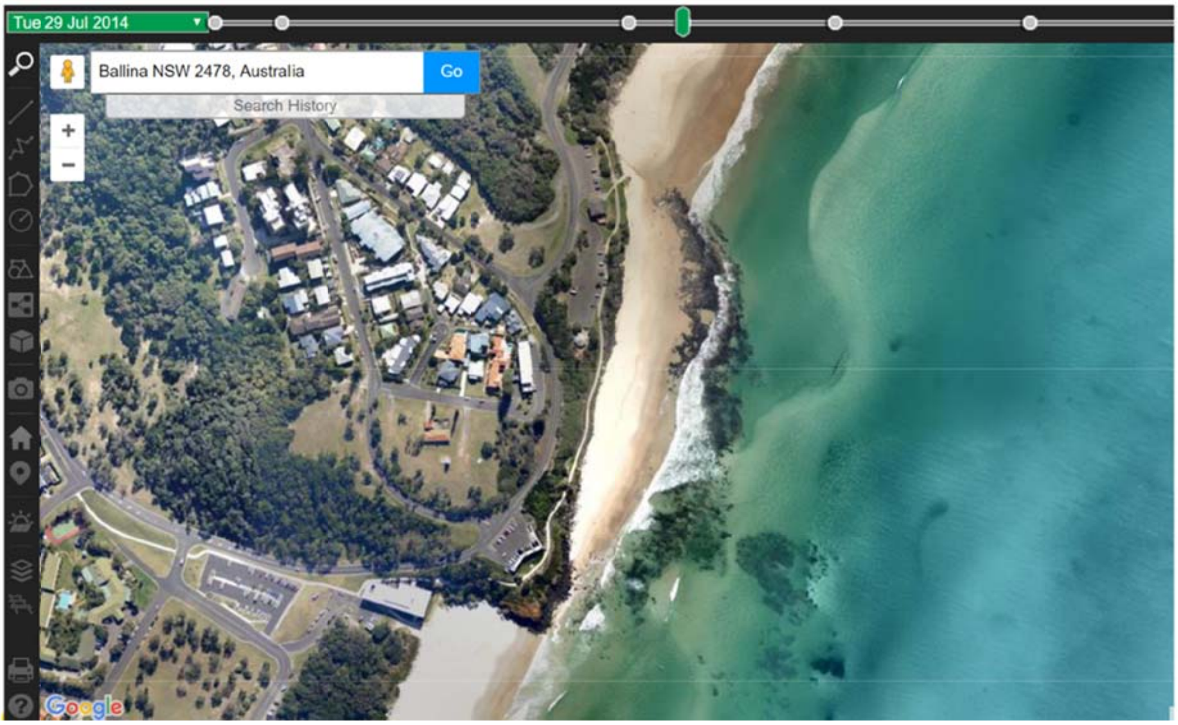


Figure 4.20 Seabed composition (29 July 2014, Source: NearMap)

5 Design considerations

5.1 Engineering design of structure

Establishing the design working life of a maritime structure is critical for determination of subsequent design parameters. WRL has adopted a nominal design life of 50 years for the ocean pool. This is a typical design life for a normal maritime structure (AS 4997, 2005). As discussed elsewhere, most heavily-used ocean pools in NSW are renovated at intervals of 10 to 20 years, with minor maintenance at more frequent intervals.

Having established the design life, an appropriate level of design risk needs to be adopted, to develop design waves and water levels. An annual probability of exceedance for significant wave height and still water level forms the design "event" or design conditions.

Australian Standard (AS) 4997 recommends design significant wave heights based on the function and design life of the structure as reproduced in Table 5.1. AS 4997 recommends that the design water levels accompanying these waves should not be below Mean High Water Springs (MHWS).

Function Category	Structure Description	Encounter Probability (a, b)	Design Working Life (Years)			
			5 or less (temporary works)	**25** (small craft facilities)	**50** (normal maritime structures)	**100 or more** (special structures/ residential developments)
1	Structures presenting a low degree of hazard to life or property	~20%(c)	1/20	1/50	1/200	1/500
2	Normal structures	10%	1/50	1/200	1/500	1/1000
3	High property value or high risk to people	5%	1/100	1/500	1/1000	1/2000

(a) Apart from the column "Encounter Probability (calculated by WRL), the table is a direct quote from AS 4997-2005.

(b) Inferred by WRL.

(c) The encounter probability for temporary works, normal maritime structures and special structures in Function Category 1 is ~20%. However, the encounter probability for small craft facilities in Function Category 1 is 39%.

Table 5.1 Design life and design event (source AS 4997-2005)

Based on this guideline, selection of the 200 to 500 year ARI event may be suitable for the proposed "normal" maritime structure. However, coastal hazard assessments for local government areas typically consider the 100 year ARI as the design criteria for deriving coastal setbacks and inundation areas. As such, there is a reasonable basis for accepting some reduction in the design conditions. The guideline gives no further direction on the recommended design water level. Use of this conservative design water level indicates that selection of the reduced design significant wave height is robust for preliminary design. This could be revisited at detailed design stage.

5.2 Design elements

This report is primarily focussed on coastal engineering issues, so is not an exhaustive review of applicable legislation and standards pertaining to swimming pools. Additional studies into this may need to be made.

The following design elements need to be considered for an ocean pool:

- Pool location:
  - Access;
  - Proximity to rivers, drains, groundwater and stormwater;
- Pool design:
  - Dimensions;
  - Disabled access;
  - Maintenance access;
  - Lane lines;
  - Lane rope attachments;
  - Scuppers;
  - Concrete mix;
  - Handrails, balustrades, chains;
  - Children's/wading pool;
- Pump(s):
  - Primary insitu pump(s);
  - Portable pump;
  - Pump location and type;
- Pool floor:
  - Concrete, sand or rock;
  - Slope to drain;

- Drain valve:
  - Size;
  - Location;
  - Slope and fall to drain valve;
  - Valve type;
- Lighting:
  - Night swimming;
  - Cleaning;
- Maintenance provisions:
  - Vehicle access;
  - Painting and surface finishes;
  - Cleaning protocols and triggers;
  - Storage of cleaning equipment;
  - Chemical use;
- Amenities and services:
  - Change rooms, toilets and showers;
  - Electricity;
  - Parking for cars and bicycles; and
  - Signage.

5.3 Pool location

Due to its complexity and importance to the overall project, pool location is discussed separately in Section 7.

5.4 Pool dimensions

5.4.1 FINA dimensions

While the proposed pool will not be suitable for official accredited swimming competitions due to its salt water, official FINA (Fédération internationale de natation; English: International Swimming Federation) dimensions are presented in Table 5.2 for reference. Additional criteria (such as greater depth) apply for pools intended for Olympic Games and world championships, which are not realistic for Ballina.

Pool type	Length(m)	Width (m)	Lane width (m)	Depth with starting blocks (m)*	Depth without starting blocks (m)
50 m pool	50.000	25	2.5	1.35	1.0
25 m pool	25.000	25	2.5	1.35	1.0
Water polo (men)	30	25	n/a	1.8 to 2.0	1.8 to 2.0

* "Depth - A minimum depth of 1.35 metres, extending from 1.0 metre to at least 6.0 metres from the end wall is required for pools with starting blocks."

Table 5.2 FINA pool dimensions

5.4.2 Swimming Australia depth guidelines

Swimming Australia Limited (2015) considered Standards Australia Limited Pool Depth Guidelines (2006) and the Royal Life Saving Society (SU 1.22) "Safe Water Entry For Competitions" and concluded:

> "Where the recommended pool depth sought is in relation to entry into water for competition or training with novice swimmers then there should be no concourse diving into water with a depth less than 1.35 and no platform dives into water with a depth of less than 1.8 metres. Where the recommended pool depth sought is in relation to recreational users then there should be no platform or concourse dives into water with a depth of less than 2.0 metres."

5.4.3 Children's/wading pool

Many successful ocean pools incorporate a swimming (lap) pool and a separate children's/wading pool. The wading pool allows children and non-swimmers to be separated from lap swimmers, and offers shallower wading depths for children and non-swimmers. As discussed above, successful children's/wading pools typically have an area of 230 to 450 m^2 and maximum depths of 0.7 m with a ramped floor.

5.4.4 Width of pool walls

Access for maintenance and repairs may be required on all pool walls. Wider walls make this easier and safer for workers. As a minimum, walls should be wide enough to wheel a trolley carrying heavy equipment, say 600 mm to 1 m. Vehicle or machine access (> 2.4 m wide) on some walls is advantageous.

5.4.5 Suggested pool dimensions

Based on the above and measurements of existing ocean pools, the following pool dimensions are suggested:

- Main pool: 50 m x 20 m (8 lanes). 1.2 m to 1.35 m deep in shallow end and 1.6 m in deepest part, with “No diving” signs;
- Children’s/wading pool of 250 to 400 m^2, grading from zero depth to 0.7 m maximum depth; and
- Constructed public space of 300 to 400 m^2 would also enhance community use of the pool.

5.5 Other design elements

5.5.1 Design for access and mobility

Design for access and mobility is covered in AS 1428.1-2009 and the National Construction Code (NCC, 2019). Conventional requirements for ramps are a minimum width of 1 m, maximum gradient of 1V:14H and maximum distance of 9 m between landings (for 1V:14H gradient). This would mean a maximum vertical distance 0.64 m between landings.

The National Construction Code (NCC, 2019) is focussed on performance based design. It also presents studies regarding wheelchair stability on slopes in air. Subject to a holistic analysis of the project, NCC (2019) permits a ramp to be not steeper than 1V:6H over a sloping ramp length of 6 m. In reality, much of a ramp approach into a pool will be under water, where different physical forces and stability prevail.

If a wading pool is designed for 20 m width and 0.7 m maximum depth, complying ramp access could be part of the pool’s floor.

If an island pool location is adopted, disabled access would be more complex. This could take the form of an elevated bridge or some form of matting on the sand. The matting may be buried in sand at times and may be damaged by waves at other times.

5.5.2 Lane lines, lane ropes and attachments

Many pools with a concrete floor have lane lines painted on the bottom (Figure 5.1). These allow swimmers using the middle lanes to keep in their lane and reduce collisions with other swimmers.

Lane ropes are used in many ocean pools during times of high pool use and/or while running carnivals/races. Flush mounted stainless steel attachments (Figure 5.1) are preferred.

Figure 5.1 Stainless steel lane rope attachment and scupper

5.5.3 Scuppers

Scuppers serve the following functions:

- Allow a pool to keep a near constant water level;
- Prevent excessive loss of water from inside the pool through splashing and waves made by swimmers; and
- Allow floating debris and surface scum to discharge from the pool.

Typical design of scuppers (Figure 5.1) is a rectangle of about 1 m long by 100 mm high. Most Northern Beaches pools have a concrete slab of about 150 mm thickness above the scupper. This allows sufficient concrete cover to the reinforcement. It means that the pool surrounds are about 250 mm above the water level of the pool.

Detailed design of a pool can consider the following with respect to scuppers:

- Locating the scuppers to assist with intended pool circulation patterns;
- Designing scuppers with different invert levels to assist with intended pool circulation patterns; and
- Locating the scuppers with reference to prevailing winds, to assist with removal of floating debris.

5.5.4 Concrete mix and reinforcement

Some areas of some pools on Sydney's northern beaches have been constructed/repaired using rounded river pebble aggregate in the concrete mix, rather than conventional angular basalt aggregate. This is to reduce the hazard of sharp aggregate injuring or being uncomfortable for wet/bare feet. This is probably most relevant on the pool surrounds and the pool floor at depths where wading can be undertaken.

Corrosion of reinforcement steel has been a major problem with concrete structures in the marine environment. Many ocean pools were constructed with mass concrete without reinforcement. Partial excavation meant that the walls did not have to be very high, and therefore had lower wave forces acting on them. Recent advances in technology and availability mean that reinforcement of stainless steel, glass fibre or basalt fibre could be used, subject to detailed design.

Some insitu concrete work will be inevitable, however, many upgrade projects have involved some use of precast concrete. For formed concrete, the recommendation has been to form and pour on the same day where possible, which precludes complex reinforcement systems being tied in place.

5.5.5 Handrails, balustrades, chains and fencing

Most ocean pools have some form of perimeter balustrade where an external fall hazard is present (generally interpreted as more than 1 m). There are two main types used:

- Two rail balustrades (Figure 5.2 and Figure 5.3) which comply with AS 1657-2018; and
- Post and single chain balustrades (Figure 5.4).

Photo: James Carley WRL UNSW

Figure 5.2 Two rail ocean pool balustrade (Freshwater)

Photo: Andy Prentice

Figure 5.3 Two rail ocean pool balustrade and debris damage (North Curl Curl)

Photo: James Carley WRL UNSW

Figure 5.4 Post and single chain pool balustrade

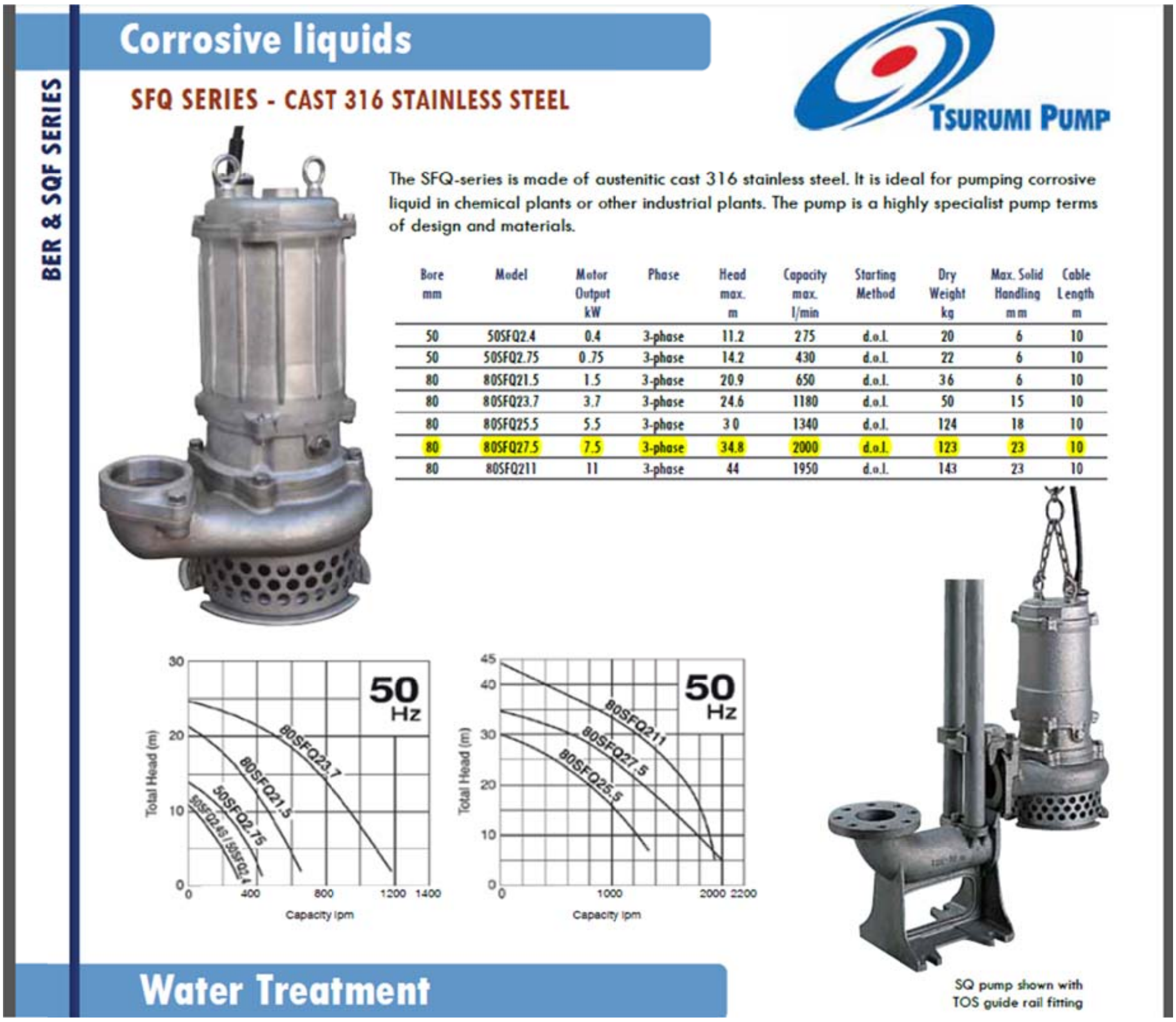
These are occasionally damaged (probably) by boulder impacts during storm events. The designs shown incorporate modular elements, so can be more easily repaired in the event of damage.

To WRL's knowledge, there are a small number of ocean pools in NSW with fencing (Bondi Icebergs, McIver's Baths, Wylie's Baths, Thirroul, Shellharbour and Ulladulla Ocean Pool), however, this is sometimes to control access for pools with paid entry for the Sydney pools. All other ocean pools in NSW are unfenced, probably on the premise that they present a hazard less than the surrounding ocean.

5.6 Pumps

All people with expertise in ocean pools recommended that one or more pumps should be the primary method for filling and maintaining water quality in an ocean pool. This has evolved since the early ocean pools were exclusively wave filled. The use of a pump rather than wave filling allows for reduced ingress of sand in areas such as Ballina where there is substantial sand offshore.

Five ocean pools in the former Warringah Council area use a cast 316 stainless steel submersible Tsurumi pump with the following characteristics: Model 80SFQ27.5, 80 mm bore, 3-phase, 2,000 L/minute (33 L/s), 123 kg (Figure 5.5).



Bore mm	Model	Motor Output kW	Phase	Head max. m	Capacity max. l/min	Starting Method	Dry Weight kg	Max. Solid Handling mm	Cable Length m
50	50SFQ2.4	0.4	3-phase	11.2	275	d.o.l.	20	6	10
50	50SFQ2.75	0.75	3-phase	14.2	430	d.o.l.	22	6	10
80	80SFQ21.5	1.5	3-phase	20.9	650	d.o.l.	36	6	10
80	80SFQ23.7	3.7	3-phase	24.6	1180	d.o.l.	50	15	10
80	80SFQ25.5	5.5	3-phase	30	1340	d.o.l.	124	18	10
80	80SFQ27.5	7.5	3-phase	34.8	2000	d.o.l.	123	23	10
80	80SFQ211	11	3-phase	44	1950	d.o.l.	143	23	10

Figure 5.5 Tsurumi pump details

Five ocean pools in the former Pittwater Council area use an equivalent submersible Grundfos pump.

Three ocean pools in the Northern Beaches Council area rely on wave filling only (Newport, Mona Vale and North Curl Curl), with the first two often filling with sand and seaweed.

Northern Beaches Council also keeps a Sykes transportable pump for assistance, cleaning and as backup.

Northern Beaches Council staff report that the pools with a pump typically take 8 to 12 hours to fill. There are problems at some pools with pumps clogging with seaweed or sand. Pumps are serviced/overhauled about twice per year and last about 10 years in total.

Submersible pumps and their housing need to be below the lowest operating water level. This means they (or their housing) are exposed to wave impacts and construction and servicing is difficult.

While Northern Beaches Council pools have adopted submersible pumps, there are advantages and disadvantages with the use of NPSH (net positive suction head) pumps. NPSH pumps would require a foot valve and backup priming mechanism, but allow the pump infrastructure to be out of the wave impact zone, with only the much simpler and smaller scale inlet within the wave impact zone.

5.7 Pool floor

Most ocean pools have a concrete floor which slopes towards a drain valve. Some have floors comprising sand and/or natural rock, with the rock smoothed and levelled in places.

Most people with experience in ocean pools recommended a concrete floor. In common with many design elements of ocean pools which have evolved, most heavily-used ocean pools in urban areas have a concrete floor, while more remote pools with less use sometimes have a more natural floor.

A concrete floor has the following characteristics:

- Advantages:
  - Easier to clean and remove excess sand;
  - Seaweed and other contaminants may mix with sand floors, creating odour and sludge;
  - Reduced leakage from pool;
  - Smoother underfoot for pool users;
  - Ability to paint lane lines on the bottom; and
  - Easier access for service vehicles and machines.

- Disadvantages:
  - More expensive; and
  - Less natural surface.

Sand and/or natural rock floors have the following characteristics:

- Advantages:
    - Potentially reduced cost; and
    - More natural habitat.

- Disadvantages:
    - More difficult to clean;
    - Potential for the pool to leak;
    - Potential for sludge to form in sand;
    - Lane lines cannot be marked on bottom; and
    - Potential hazard if crevices are present.

5.8 Drain valve

All pools known to WRL have a drain valve. On Sydney's northern beaches, these are typically 600 mm diameter, cast iron gate valves (Figure 5.6). Most Sydney pools can be drained in about 1 hour. The invert of these valves should be located no lower than the mean low water neap level, with some consideration for future sea level rise. Cast iron/stainless steel has been the preferred material due to its strength and resistance to impacts.

Reasonably safe low tide access to the drain valve is needed for workers.

Figure 5.6 Gate valve for draining pool

5.9 Maintenance

5.9.1 Frequency

Most Northern Beaches Council ocean pools are cleaned once per week at low tide most of the year by a work crew of three. This involves draining the pool and cleaning as described below. The frequency is relaxed to once per fortnight during winter. Two of the most heavily used pools (Dee Why and Freshwater) do not experience substantial wave flushing, so are partly cleaned a second time most weeks during summer. This partial cleaning involves half draining and refilling without other active cleaning.

Cleaning is much easier when a vehicle carrying the cleaning equipment can be driven into the empty pool, obviating the need to unload, cart and reload. Such vehicle access can also serve as disabled access.

More natural pools, such as North Curl Curl are partly drained about twice per year and the steps blasted/scrubbed to remove algae. Due to the habitat in this pool, there is a reluctance to fully drain it for an extended length of time.

5.9.2 Surface finishes and cleaning of surfaces

Most Northern Beaches pools use a blue coloured chlorinated rubber paint coloured on their walls, while the floors are generally unpainted concrete. The smooth paint surface is used as it reduces the propensity for organisms to attach to walls and reduced weathering of concrete through cement erosion. Pools with a concrete floor generally have black lane lines painted on the floor. Walls are typically painted once per year, while lane lines are typically painted twice per year. Non-slip epoxy coatings have been trialled on precast pool surrounds at South Curl Curl, but they have not fully bonded to the concrete.

While more aggressive chemical cleaners have been used in the past, cleaning of surfaces for Northern Beaches Council pools is now undertaken with a high pressure water blaster. Painted horizontal surfaces and/or surfaces requiring additional treatment are cleaned with "Cyndan Algae Died B". Cyndan (cyndan.com.au) describes this as: "a non-chlorine liquid treatment formulated to control and remove algae, mildew and bacteria. Algaecide for killing algae in pools, ponds, air conditioning cooling towers, fountains, etc."

5.9.3 Sand removal

Water velocities required to move sand are shown in Figure 5.7 (Hjulstrom, 1935). As described in Section 4.3.6, indicative sand size for Ballina is 0.2 to 0.3 mm. It should be noted though, that (based on observations from WRL engineers) due to winnowing and sorting, the sand which gets transported into ocean pools is usually finer than the surrounding beach, however, no details for this are available.

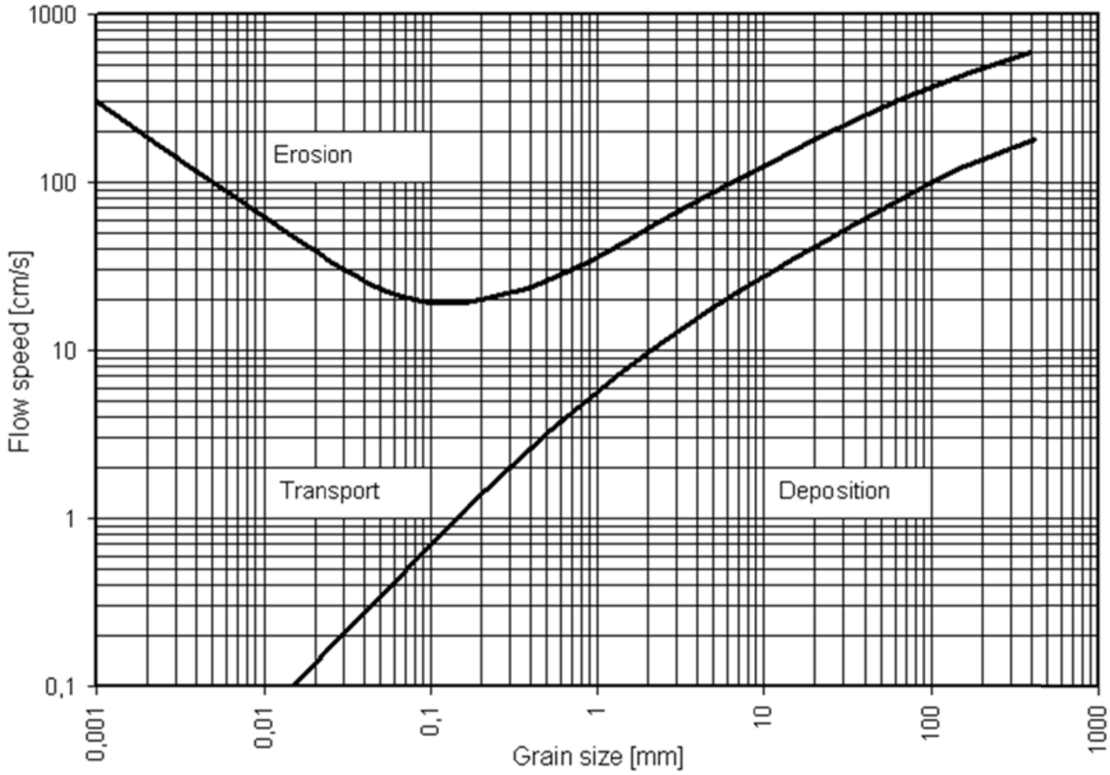


Figure 5.7 Hjulstrom diagram for sand erosion

From Figure 5.7, sand of 0.2 to 0.3 mm will mobilise under the following water velocities:

- Initial transport (bed load/ripples): 0.015 to 0.02 m/s; and
- Erosion/scour: 0.2 m/s.

Indicative swimming speeds are as follows:

- Victorian Police swimming test:
  - 100 m in 4 minutes = 0.42 m/s.
- Surf Life Saving Australia Surf Rescue Certificate (≥ 13 years' old):
  - 200 m in 5 minutes = 0.67 m/s.
- Surf Life Saving Australia Bronze Medallion (≥ 15 years' old):
  - 400 m in 9 minutes = 0.74 m/s.
- Surf Life Saving Australia Gold Medallion and professional lifeguard:
  - 800 m in 14 minutes = 0.95 m/s.
- World record:
  - 50 m in 20.91 s = 2.39 m/s.

Reconciling the above, humans can swim faster than the velocities required to erode sand, but apart from elite swimmers, not much faster, and therefore any active sand removal through velocity scour is probably not viable while swimmers are using the pool.

Thin veneers of sand are usually removed by hosing with pumped water (Figure 5.8) as part of normal pool cleaning operations. Thicker sand deposits require removal with earthmoving plant (Figure 5.9). Pool design and operation also needs to plan for the scenario of earthmoving plant or vehicles breaking down inside the pool, since a rising tide could result in environmental contamination.

Figure 5.8 Sand removal Bondi Icebergs (Source: Aquabumps)

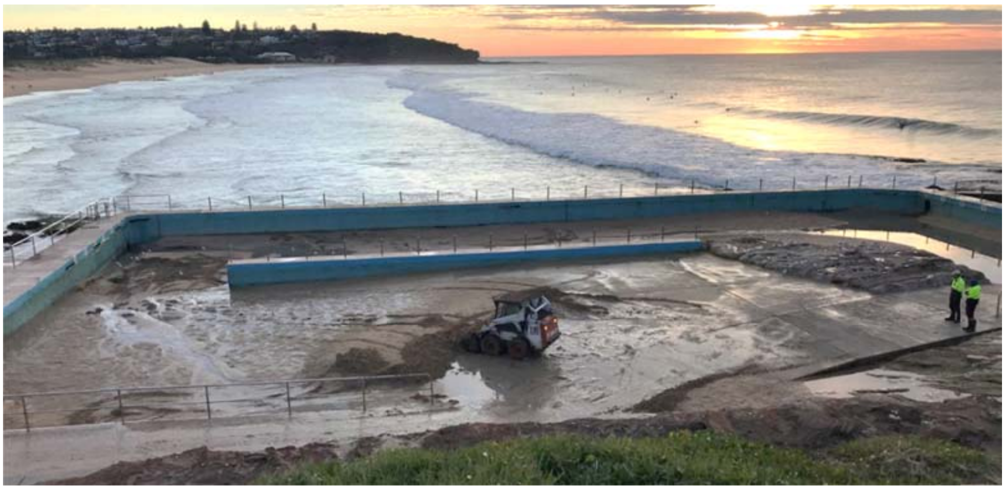


Photo: James Carley WRL UNSW

Figure 5.9 Sand removal South Curl Curl

5.9.4 Indicative maintenance costs

Indicative annual maintenance costs for Sydney ocean pools are as follows, where FTE is full time equivalent:

- Works gang for cleaning (team of three, with 3 x 0.2 FTE per pool): $40,000 per annum;
- Supervisor (0.2 FTE): $20,000 per annum; and
- Pump overhauls: $5,000 per annum.

For most pools, minor sand removal is part of routine cleaning, but for pools with higher sand ingress:

- Sand removal by machine for pools such as South Curl Curl: $13,000 per annum.

As discussed in the report, most ocean pools require upgrading at intervals of about 10 to 20 years. Funds for this are usually obtained through additional grants. Management of ocean pools is also undertaken within a local Council's normal asset portfolio management system.

6 Wave overtopping calculations

6.1 Background

A basic model was set up using the EurOtop (2016) document to compare wave overtopping between existing ocean pools and Ballina. The schematic cross section for this is shown in Figure 6.1.

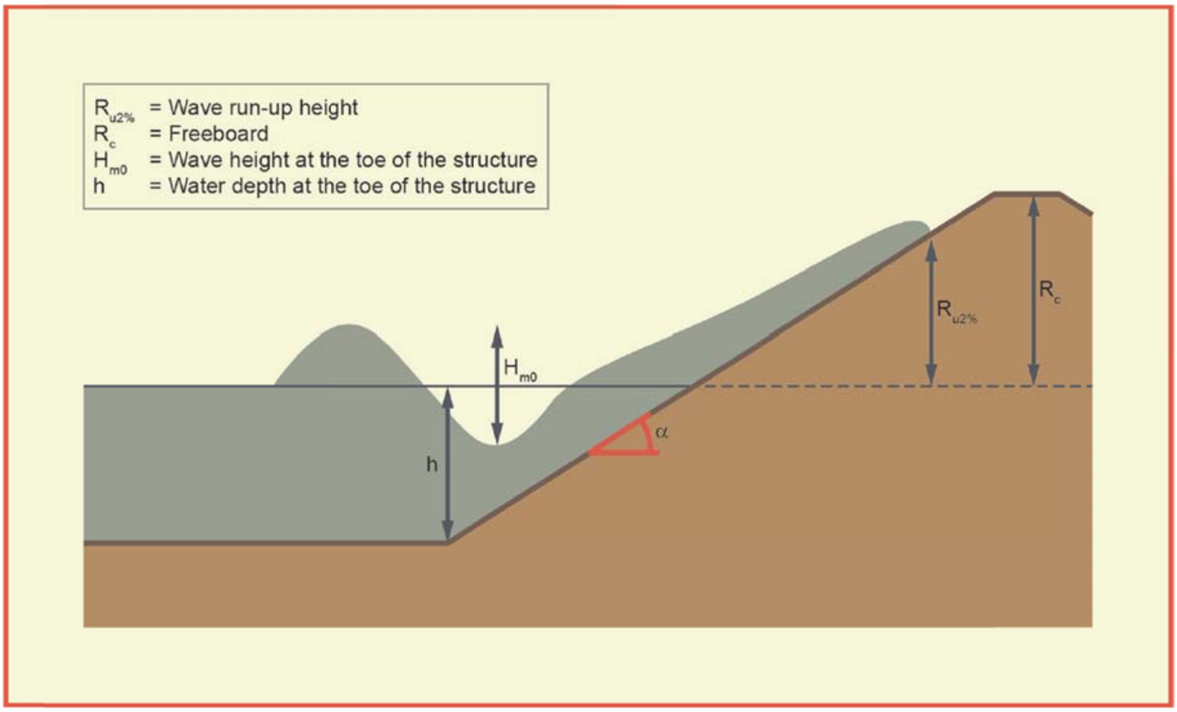


Figure 6.1 EurOtop cross section for overtopping

An example of the wave overtopping process from a WRL physical model is shown in Figure 6.2. A range of wall geometries can be adopted to reduce wave overtopping (Figure 6.3 to Figure 6.5), noting that wave overtopping has both positive and negative impacts on an ocean pool.

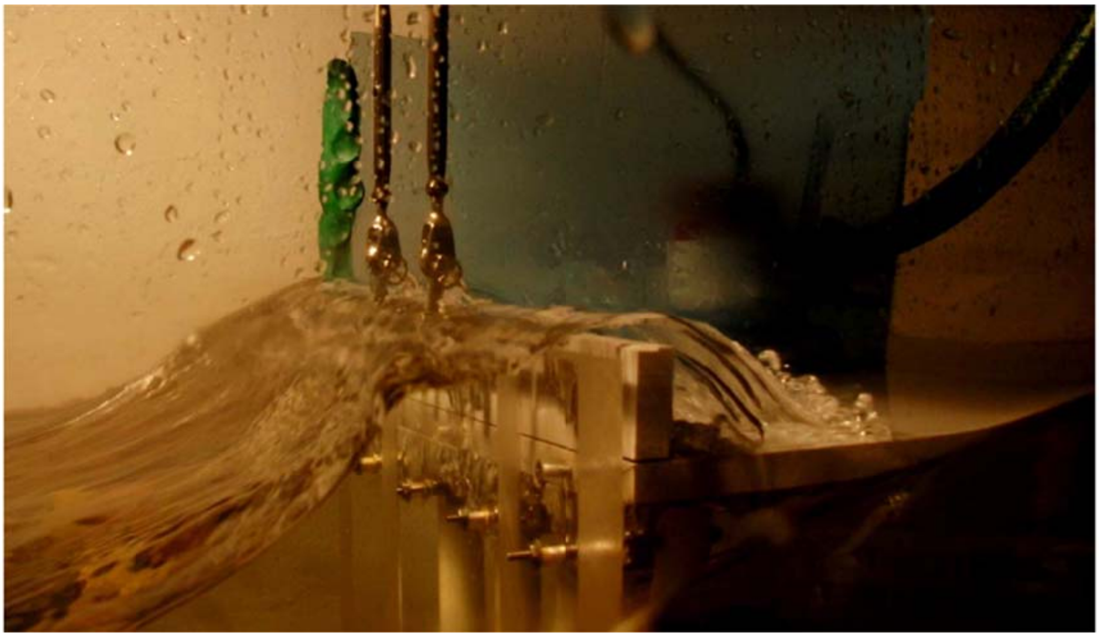


Figure 6.2 Wave overtopping physical model

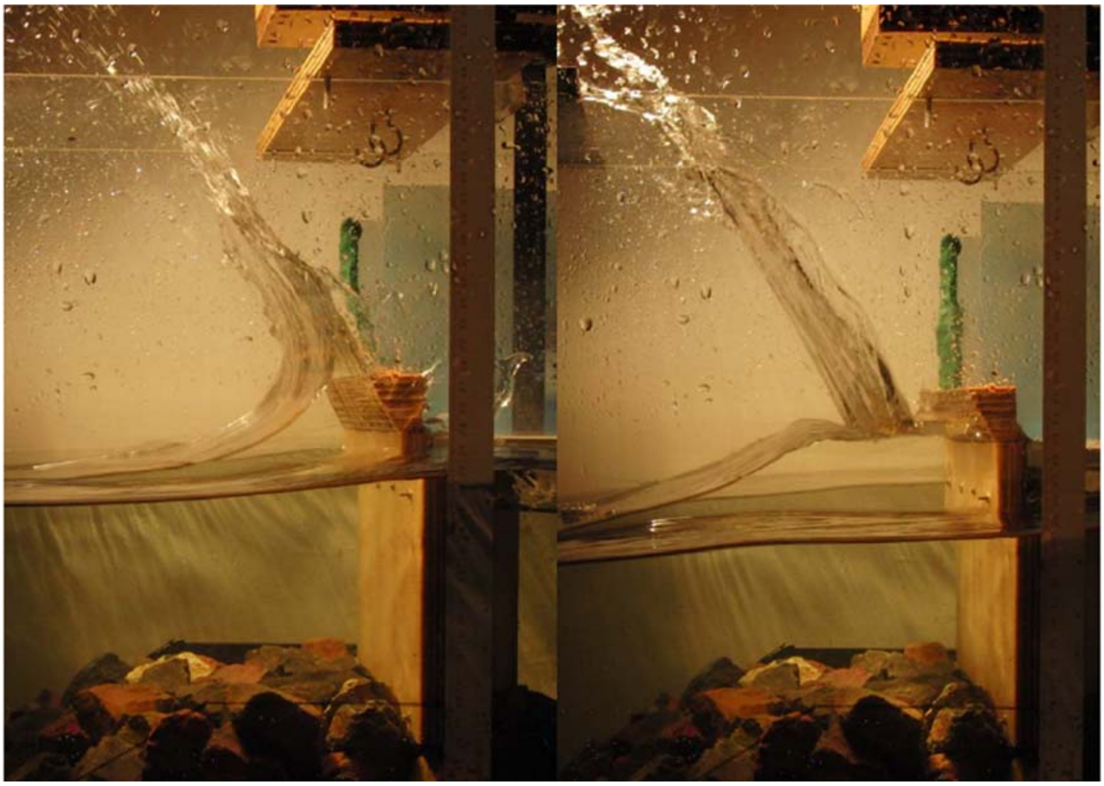


Figure 6.3 Angled wave deflector wall physical model

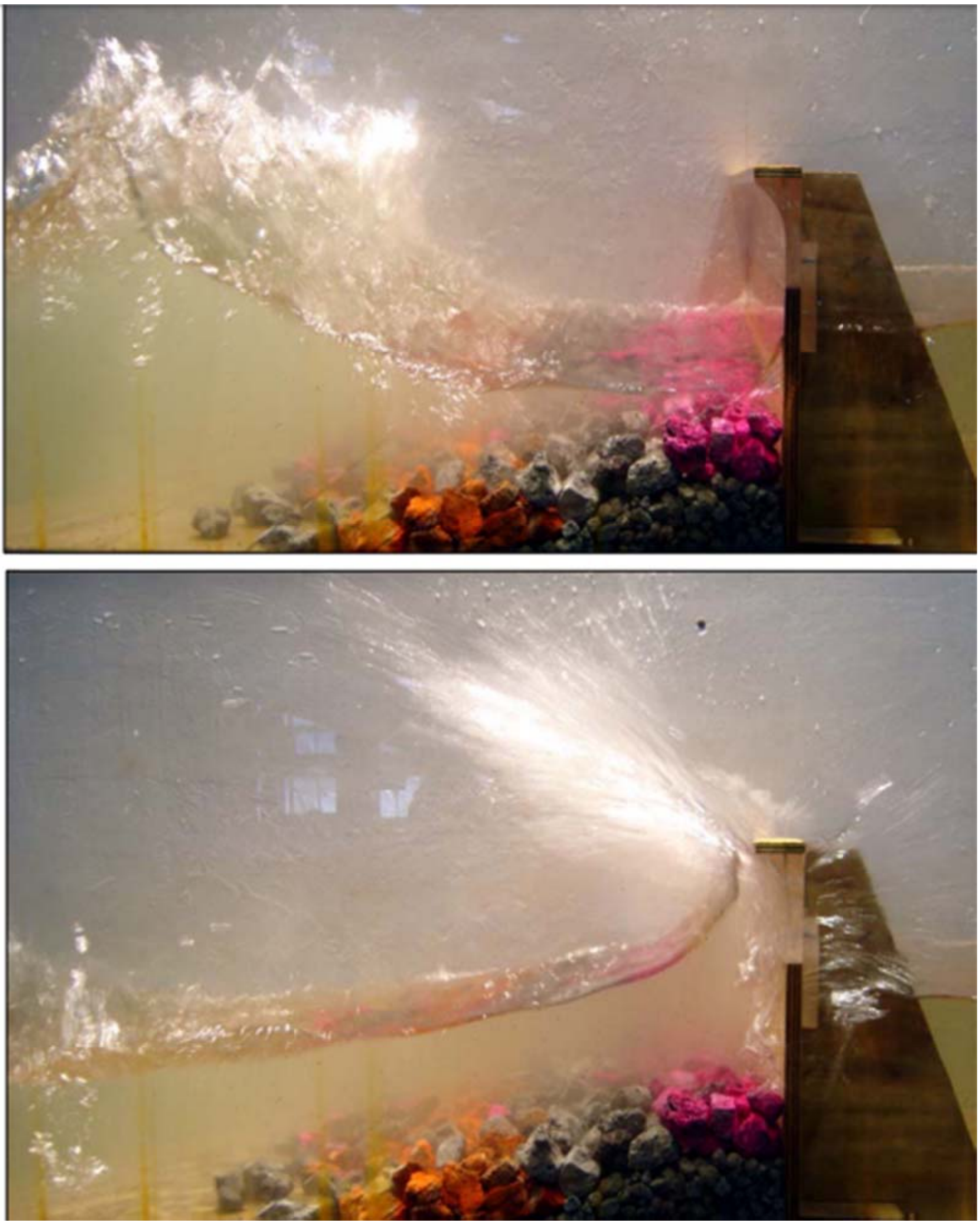
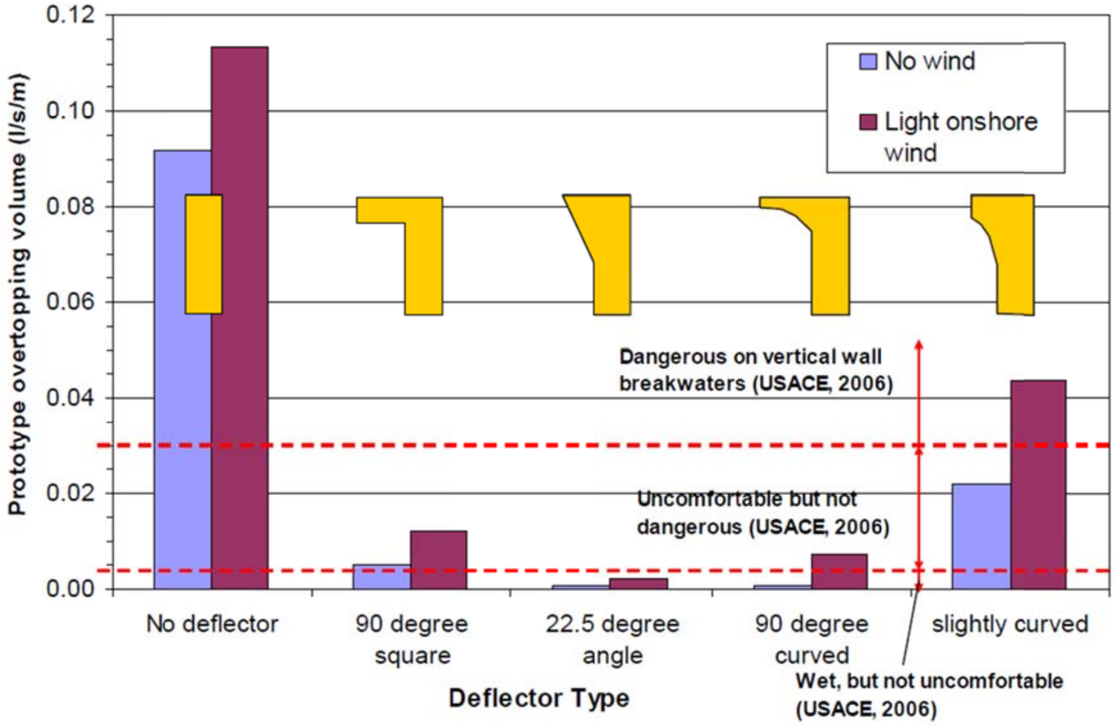


Figure 6.4 Curved wave deflector wall physical model



Note: From model tests for separate WRL project

Figure 6.5 Various wave deflector wall shapes

6.2 Overtopping calculation models

WRL set up a numerical model (Dally et al, 1985; SBEACH) for each shore normal transect to the -11 m AHD contour for each pool location (Figure 6.6). Details of the model are given in Larson and Kraus (1989) and Larson et al. (1990). The transects were derived by joining WRL's land/drone survey to the hydrographic charts (Section 7).

This was interfaced with EurOtop (2016) equations 5.12 and 5.13 [design and assessment approach] to define the overtopping at the seaward edge of the pool using depth limited Hs from SBEACH. WRL's procedure was compared to overtopping measurements and geometry for Cronulla determined in a physical model (Haradasa et al, 1990) and good agreement was found.

The overtopping model was applied with a spring tide for the following conditions:

- Ambient/median wave conditions;
- 10% exceedance wave conditions; and
- 1 year ARI wave conditions.

Note that almost all ocean pools are dangerous in conditions exceeding 1 year ARI, so wave overtopping for larger events was not modelled. Events larger than 1 year ARI will need to be considered for structural design of the pool.

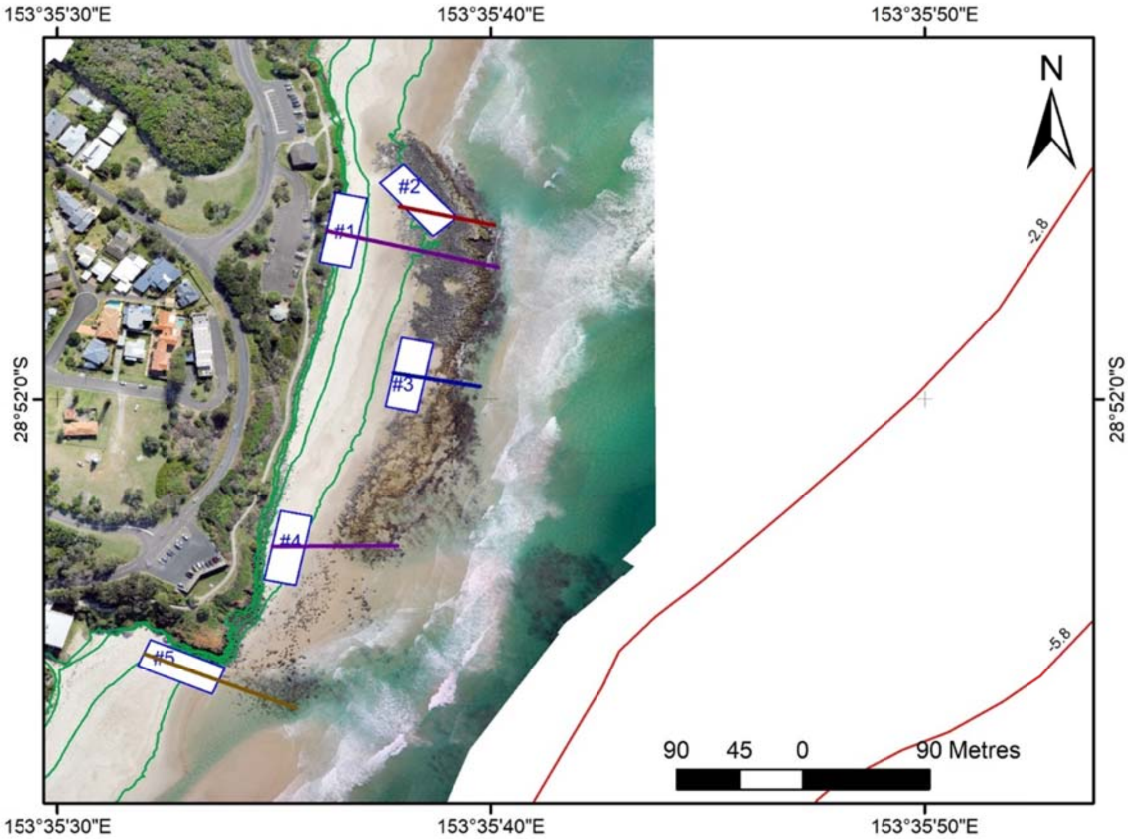


Figure 6.6 Ballina transects locations

6.2.1 Overtopping estimates for four Sydney pools

Overtopping estimates for four Sydney ocean pools are shown in Figure 6.7 to Figure 6.9. EurOtop (2016) recommends that its techniques be used as order of magnitude estimates only. The values found concur with the qualitative observations of WRL's engineers.

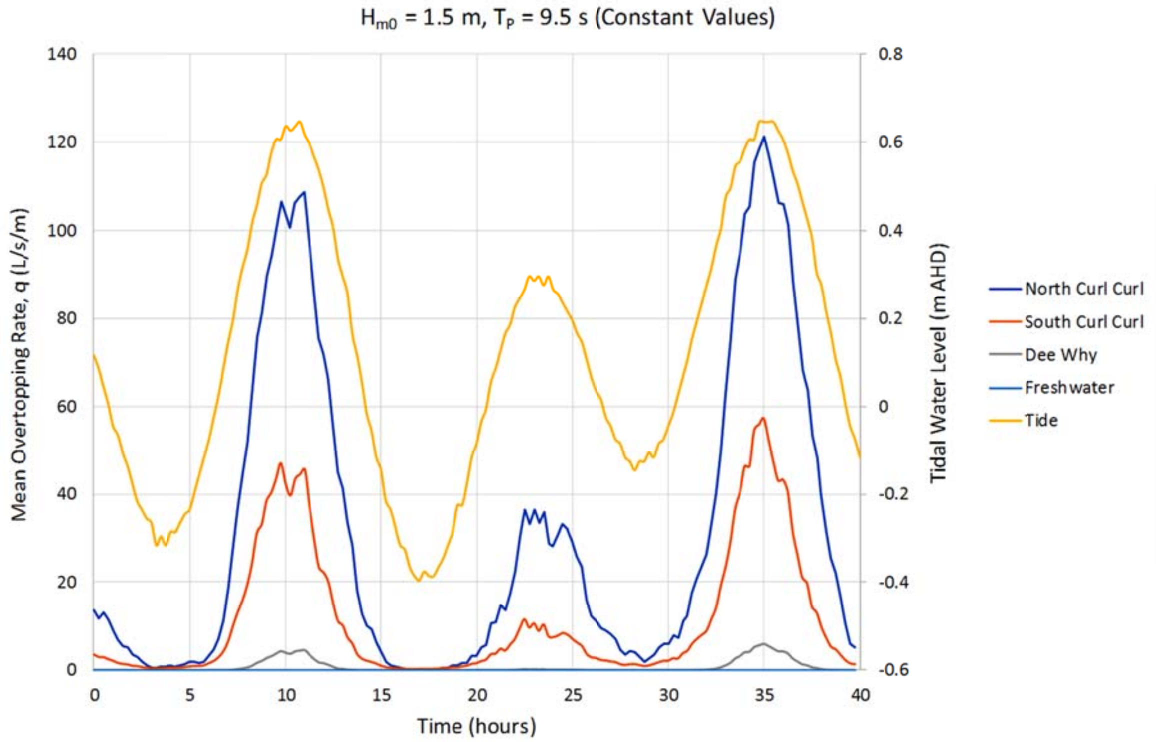


Figure 6.7 Overtopping Sydney pools ambient waves

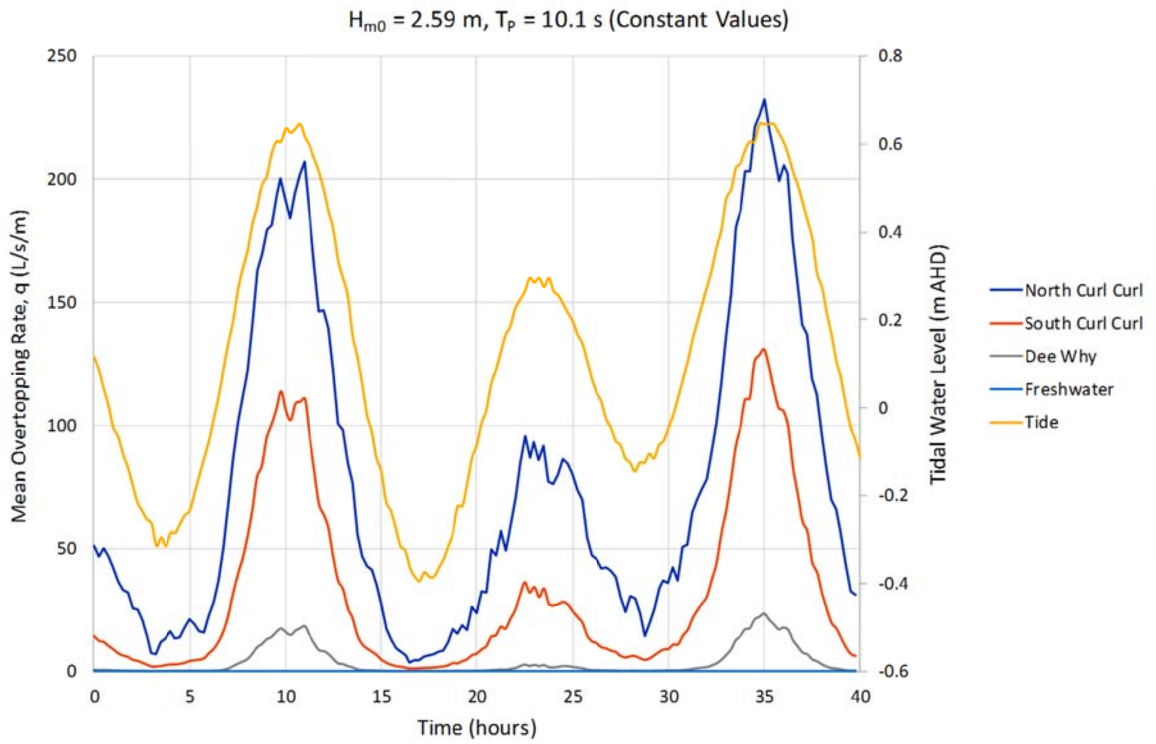


Figure 6.8 Overtopping Sydney pools 10% exceedance

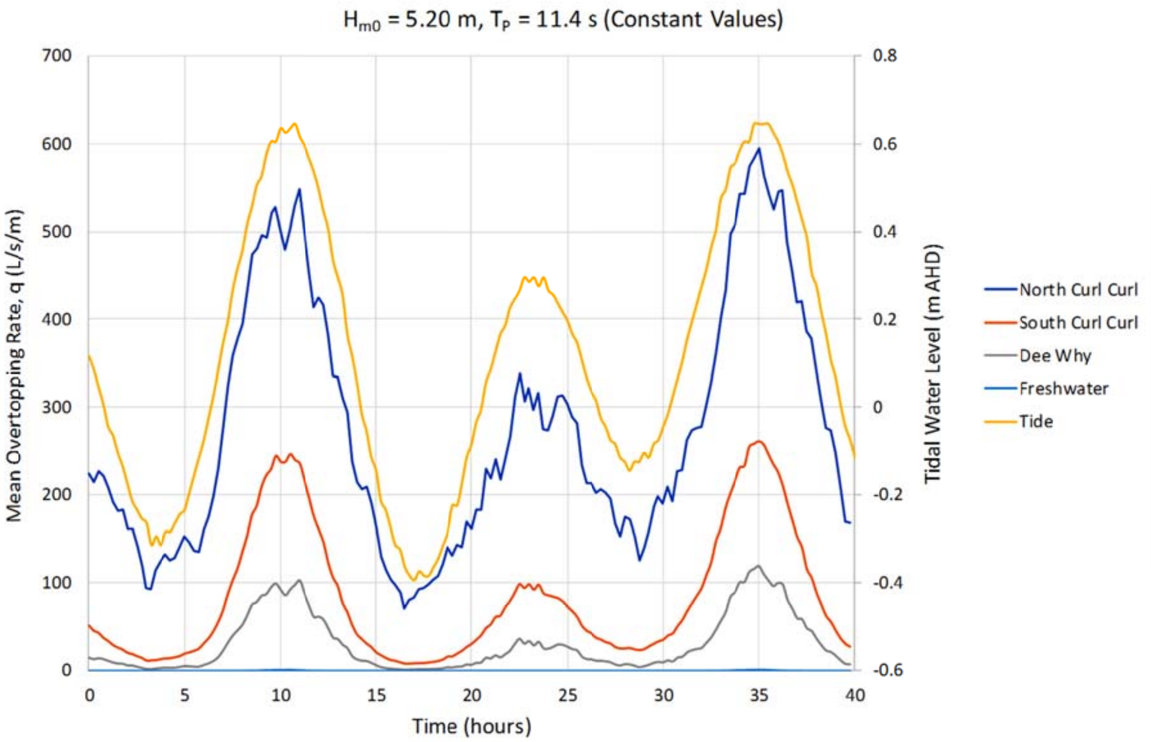


Figure 6.9 Overtopping Sydney pools 1 year ARI

7 Potential Ballina ocean pool alongshore locations

7.1 Land levels

The following information was used to ascertain land levels:

- A land survey by registered surveyor Michael Hajjar Surveying (2017) of selected areas dated 20/7/2016 and 29/8/2017 (Figure 7.1);
- UNSW Aviation LIDAR survey undertaken on 25/5/2017 (Figure 7.2); and
- This was supplemented by an optical drone survey by WRL on 8/8/2018 (Figure 7.3).

A three-dimensional image of the terrain created by WRL is available at https://skfb.ly/6AKMU

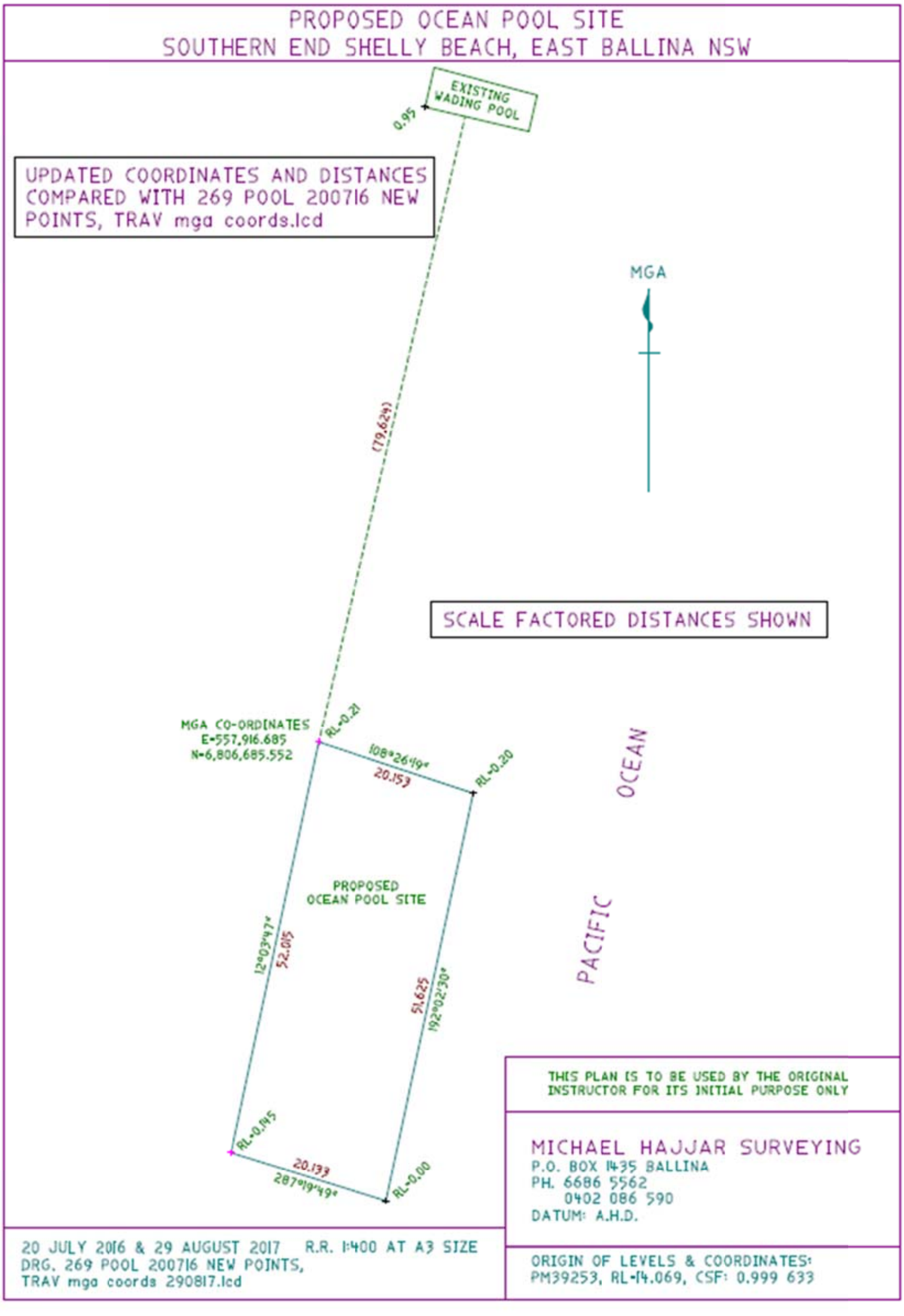


Figure 7.1 Land survey by Michael Hajjar Surveying (2017)

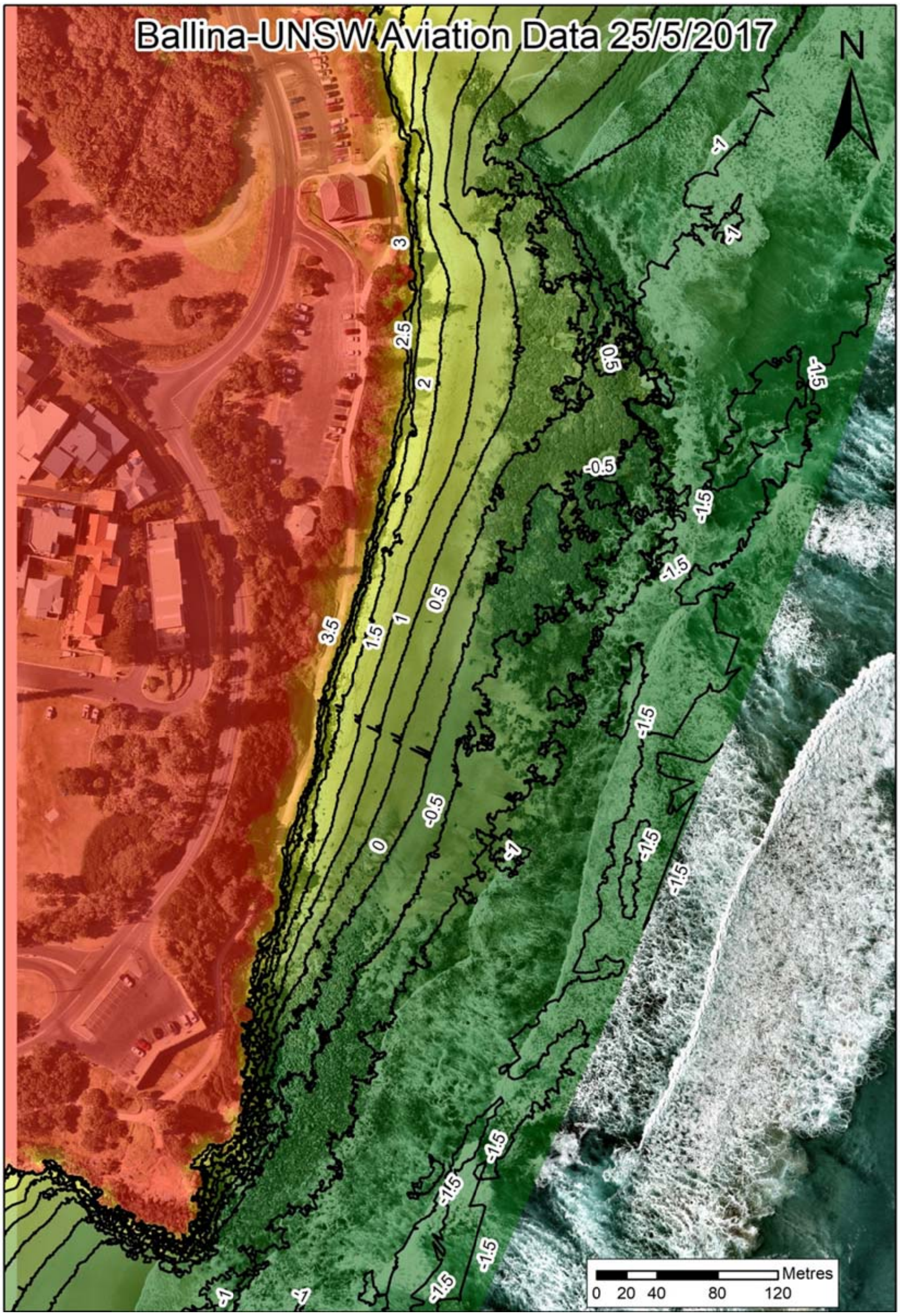


Figure 7.2 UNSW LIDAR survey data transformed into contours

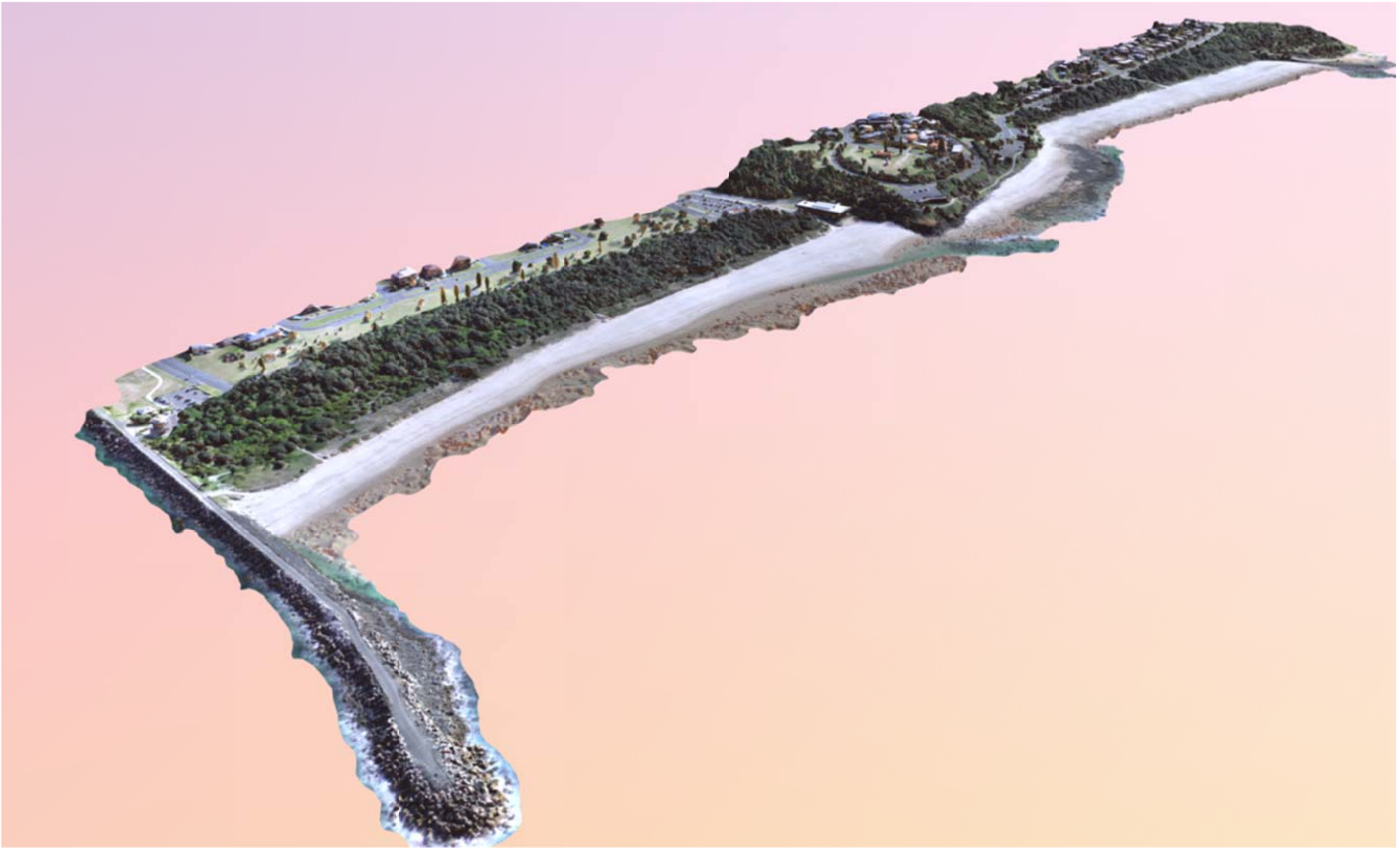


Figure 7.3 WRL optical drone survey

7.2 Seabed levels

In searches by WRL, regular surveys for the NSW Government associated with the Richmond River entrance do not extend as far north as the study area. WRL's drone data is only valid above the waterline at the time of the survey.

Seabed levels were obtained from the Australian Hydrographic Service [AHS] 2018, Australian Electronic Navigation Charts (ENCs) AU5220P2 "Ballina (Richmond River)" and AU429153 "Wooli Wooli River to Evans Head" in unencrypted S.57 format. WRL has a licence to use this data from the Australian Hydrographic Service.

The provision of this data carries the following condition:

> "Certain material in this product is reproduced under licence by permission of the Australian Hydrographic Service. ©Commonwealth of Australia 2018. All rights reserved. This information may not be copied, reproduced, translated, or reduced to any electronic medium or machine readable form, in whole or part, without the prior written consent of the Australian Hydrographic Service."

Members of the Committee pointed out that there is frequently a trough just seaward of the rock shelf associated with the interaction between the surf zone and the edge of the rock shelf. This trough is evident to WRL but has not been picked up in the hydrographic surveys due to its hazardous location in shallow water directly fronting the rock shelf. It would be possible to survey this area in more detail through alternative techniques such as wading/swimming and jet ski, which may be undertaken at the detailed design stage of the project.

7.3 Potential pool locations

A range of potential pool locations in the vicinity of Shelly Beach have been developed in consultation with the Committee, other experts and WRL engineers. These locations are shown for a 50 x 20 m pool in Figure 7.4 and do not include a wading pool. These locations may be varied by up to 20 m without significantly altering the assessment described below.

Note that this shows a 50 m x 20 m footprint only for preliminary analysis. A wading pool is also likely.

Figure 7.4 Potential pool locations

A multi-criteria assessment of these locations is shown in Table 7.1, While proximity to existing facilities (toilets, showers, change rooms) is desirable, the cost of facilities is relatively low compared with the cost of a new ocean pool.

In addition to the dependence on location, many criteria can be altered/managed through the elevation of the pool walls, external wall shape (Section 6), and/or the extent of excavation versus wall height.

The marine ecology report by Southern Cross University (Benkendorff et al, 2018) did not note major problems with any of the potential locations.

7.3.1 Overtopping estimates for Ballina alongshore ocean pool locations

The same procedure described in Section 6.2 was applied to obtain overtopping estimates for five potential ocean pool locations in Ballina and are shown in Figure 7.5 to 7.13. These include wall crest levels of 1.5, 2.0 and 2.5 m AHD. EurOtop (2016) recommends that its techniques be used as order of magnitude estimates only. The values found concur with the qualitative judgement of WRL's engineers.

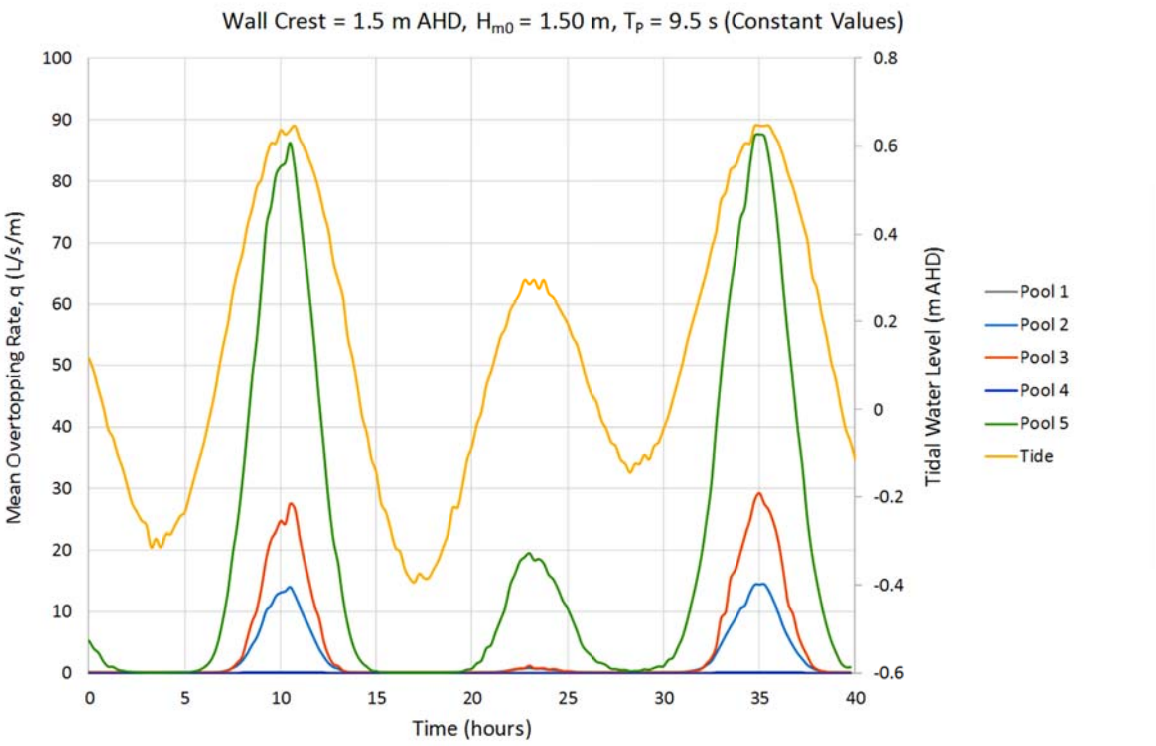


Figure 7.5 Overtopping Ballina pool positions ambient waves, wall at 1.5 m AHD

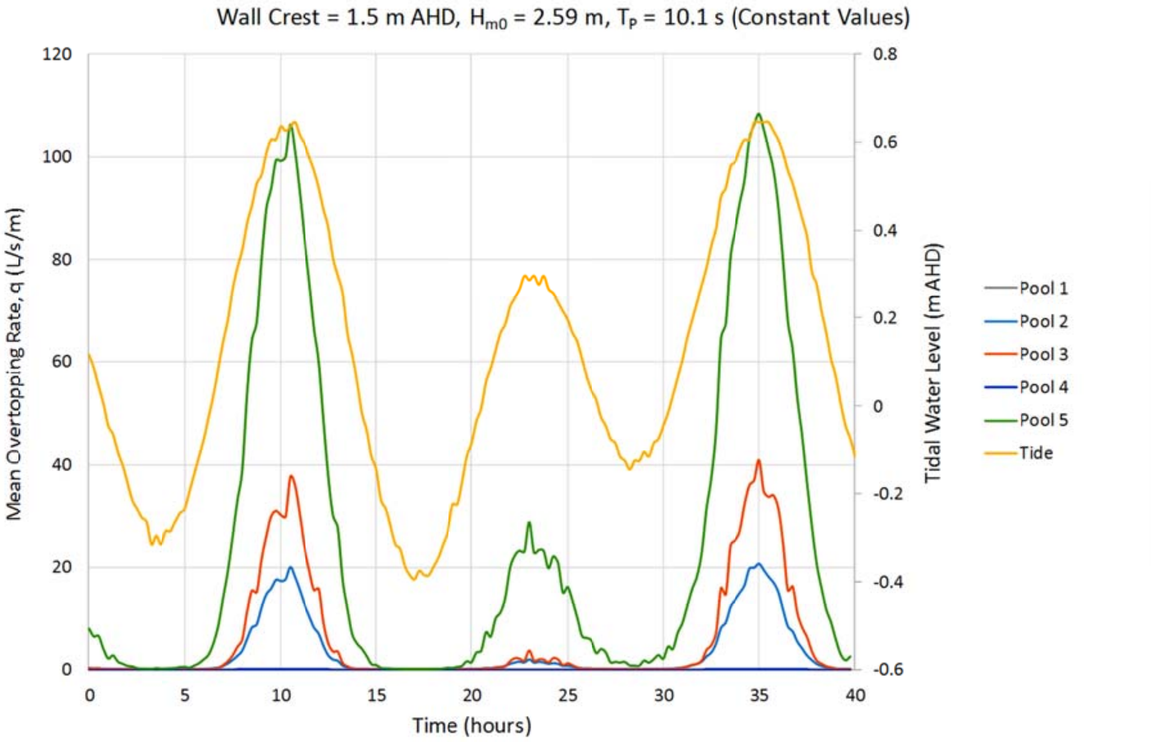


Figure 7.6 Overtopping Ballina pool positions 10% exceedance waves, wall at 1.5 m AHD

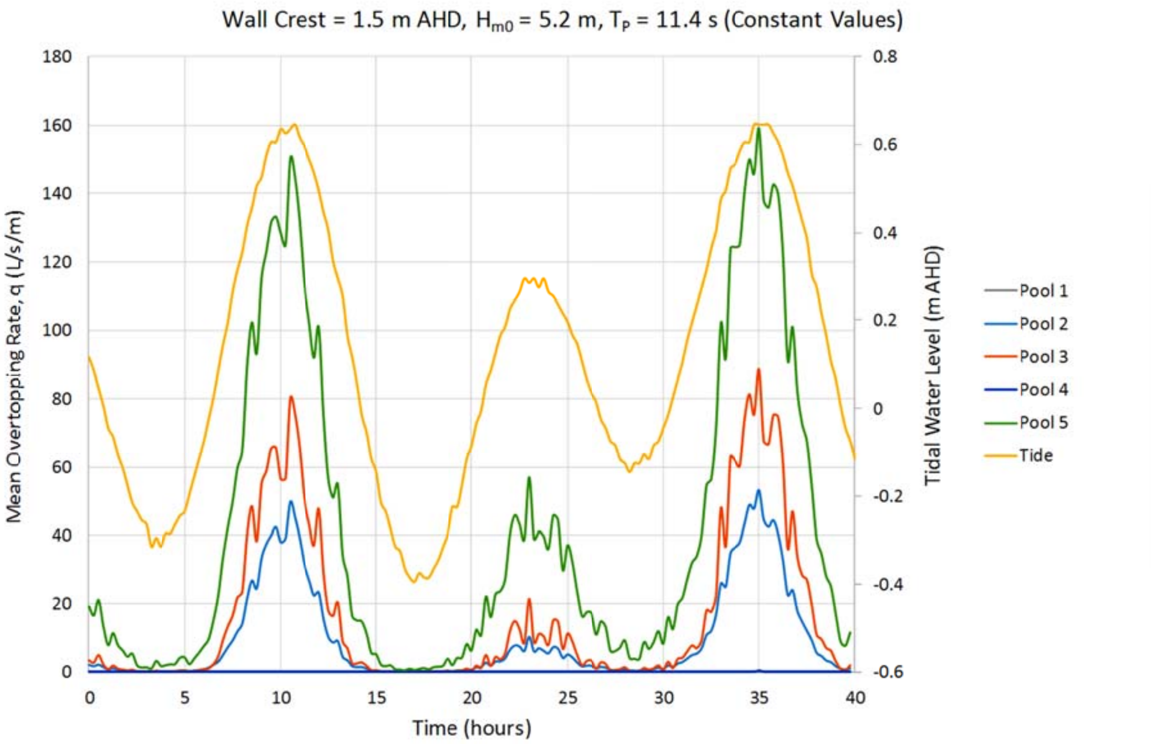


Figure 7.7 Overtopping Ballina pool positions 1 year ARI waves, wall at 1.5 m AHD

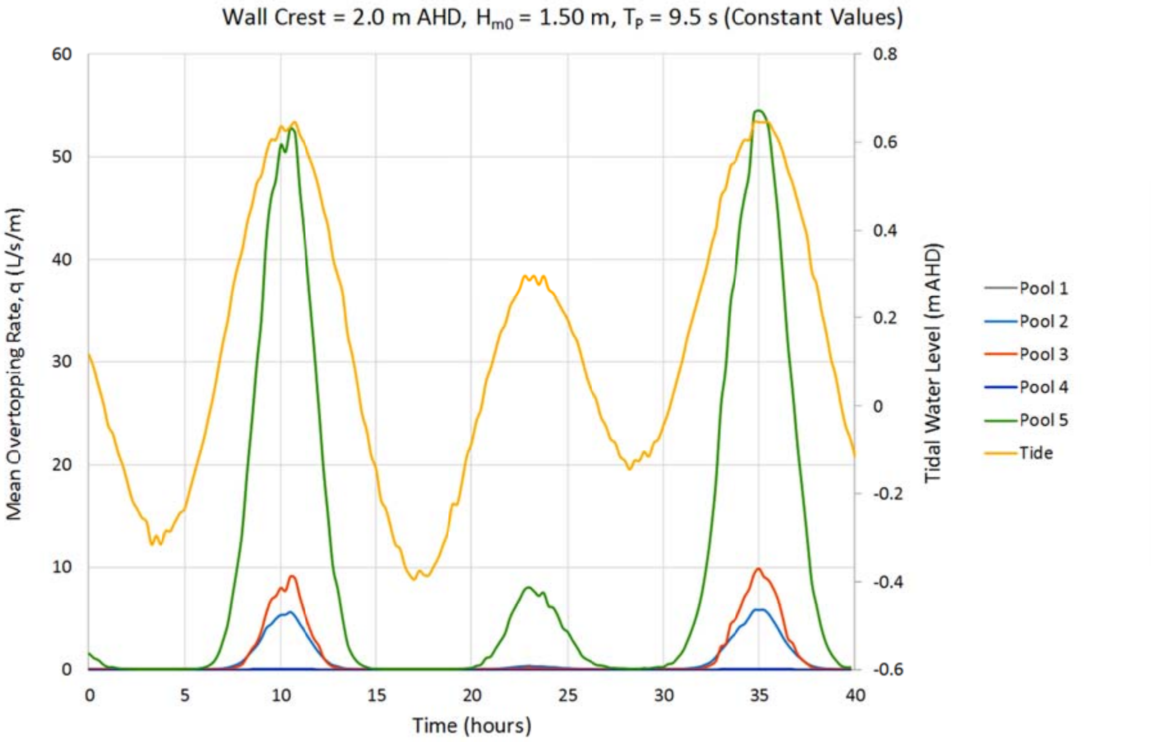


Figure 7.8 Overtopping Ballina pool positions ambient waves, wall at 2.0 m AHD

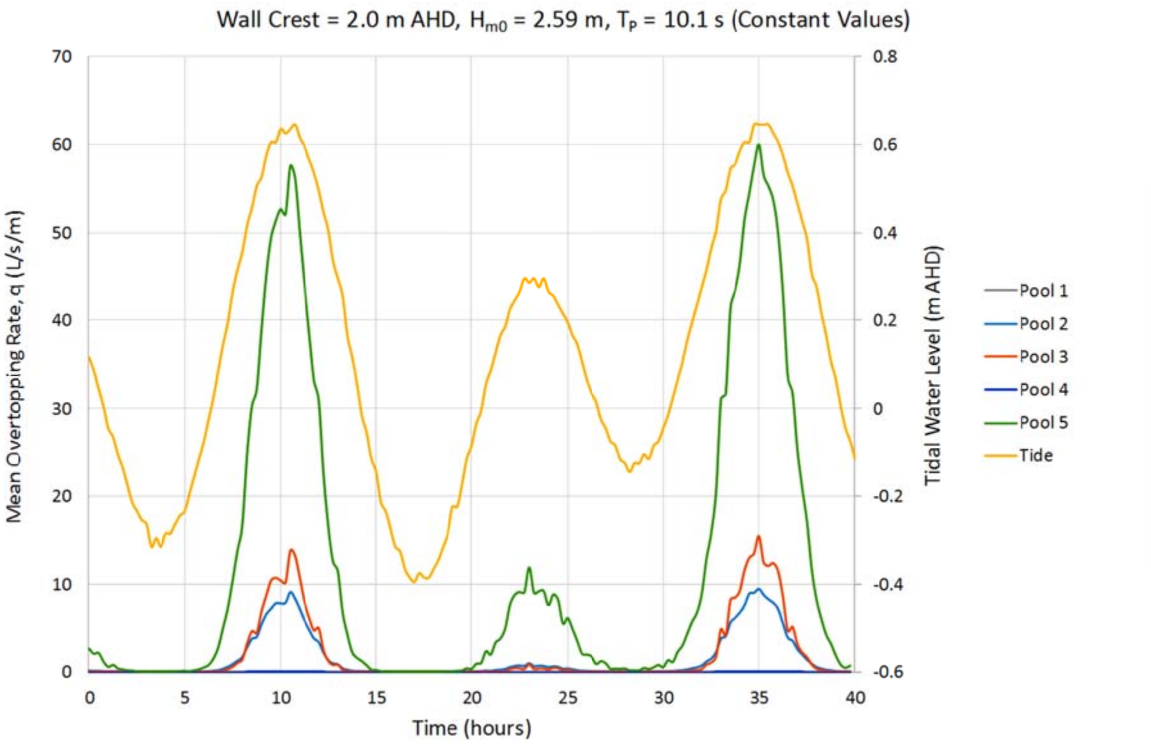


Figure 7.9 Overtopping Ballina pool positions 10% exceedance waves, wall at 2.0 m AHD

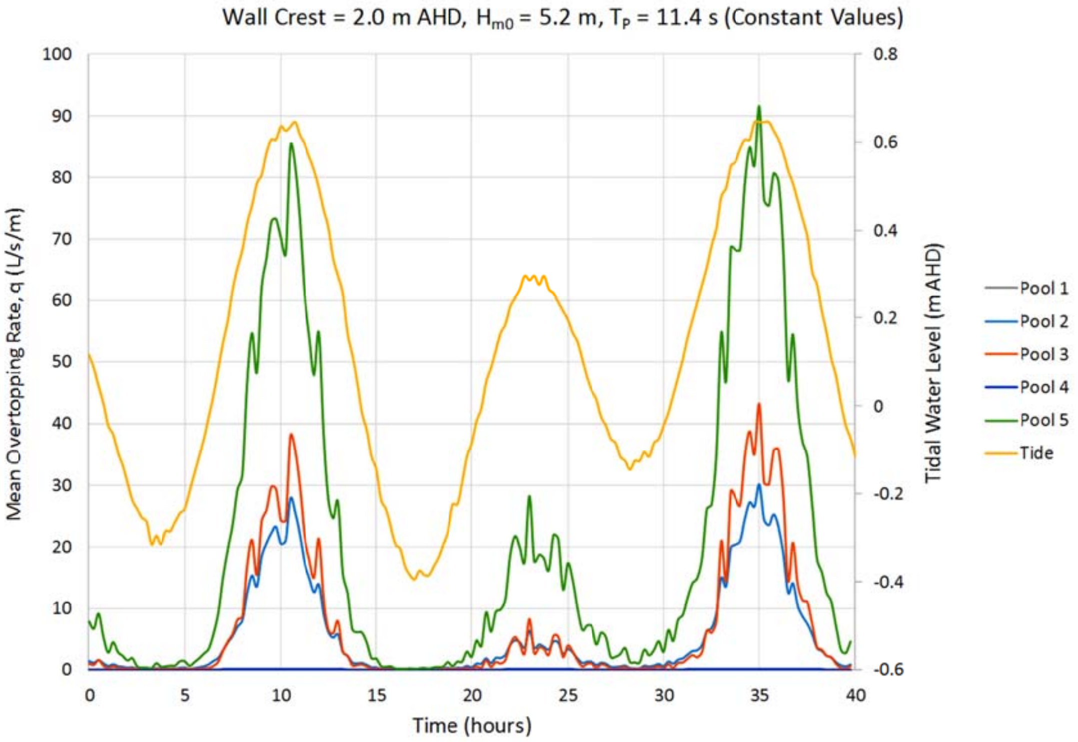


Figure 7.10 Overtopping Ballina pool positions 1 year ARI waves, wall at 2.0 m AHD

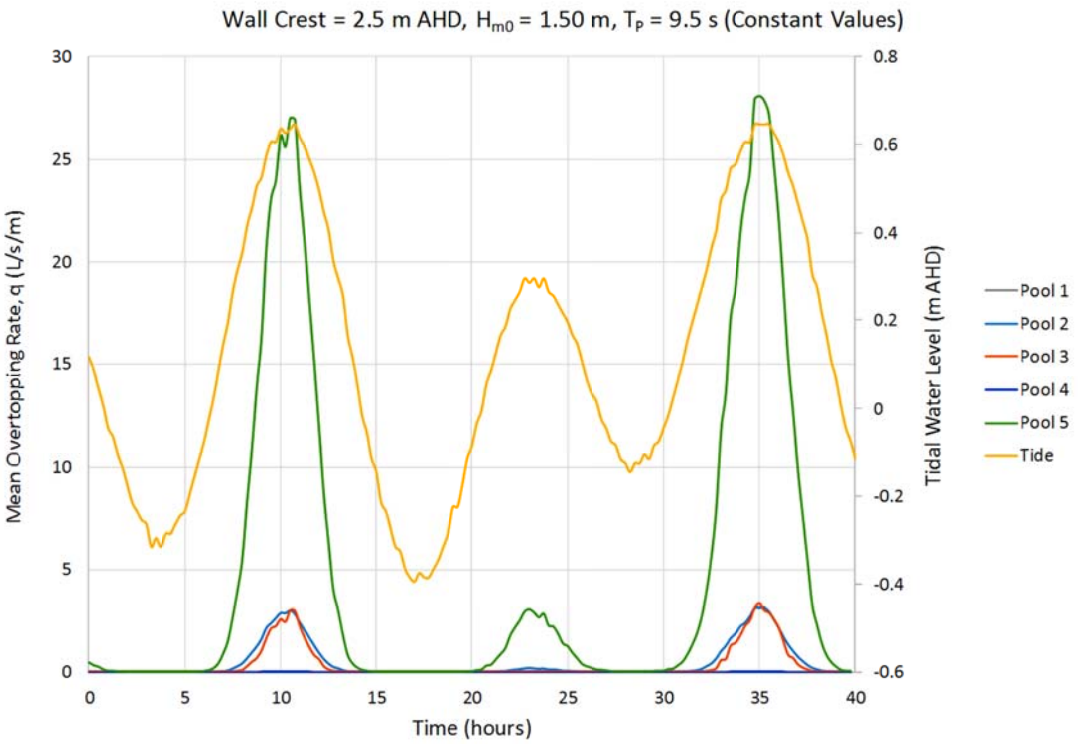


Figure 7.11 Overtopping Ballina pool positions ambient waves, wall at 2.5 m AHD

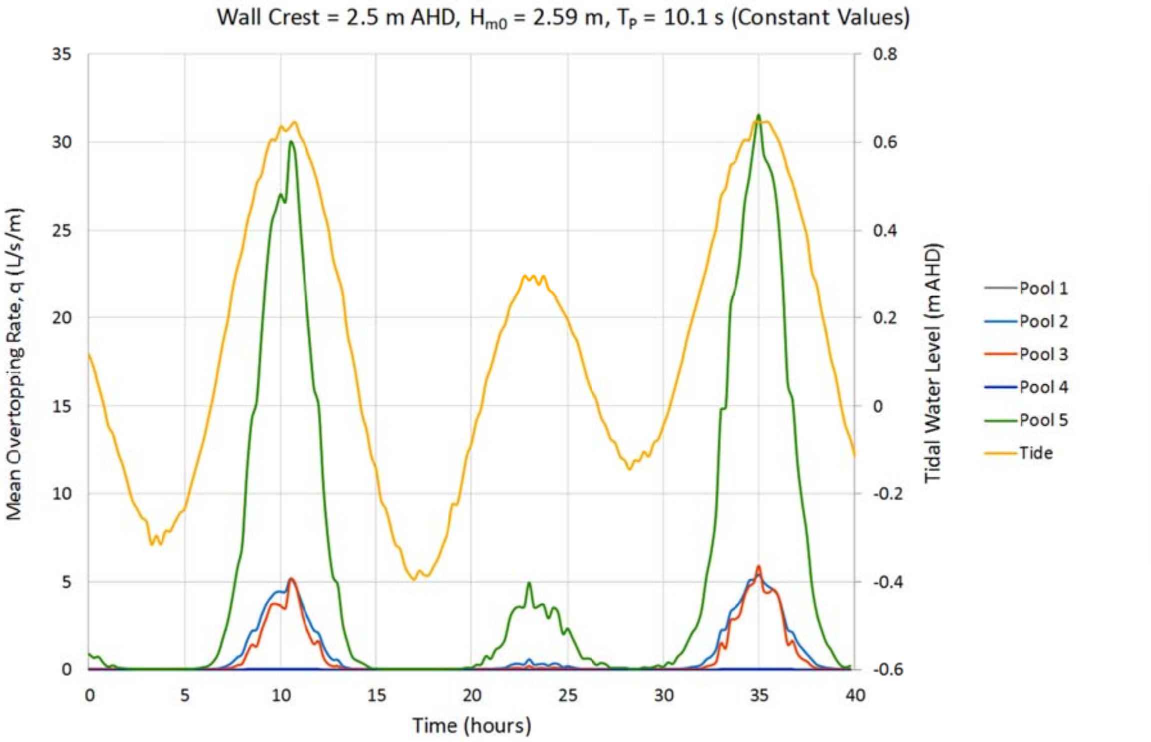


Figure 7.12 Overtopping Ballina pool positions 10% exceedance waves, wall at 2.5 m AHD

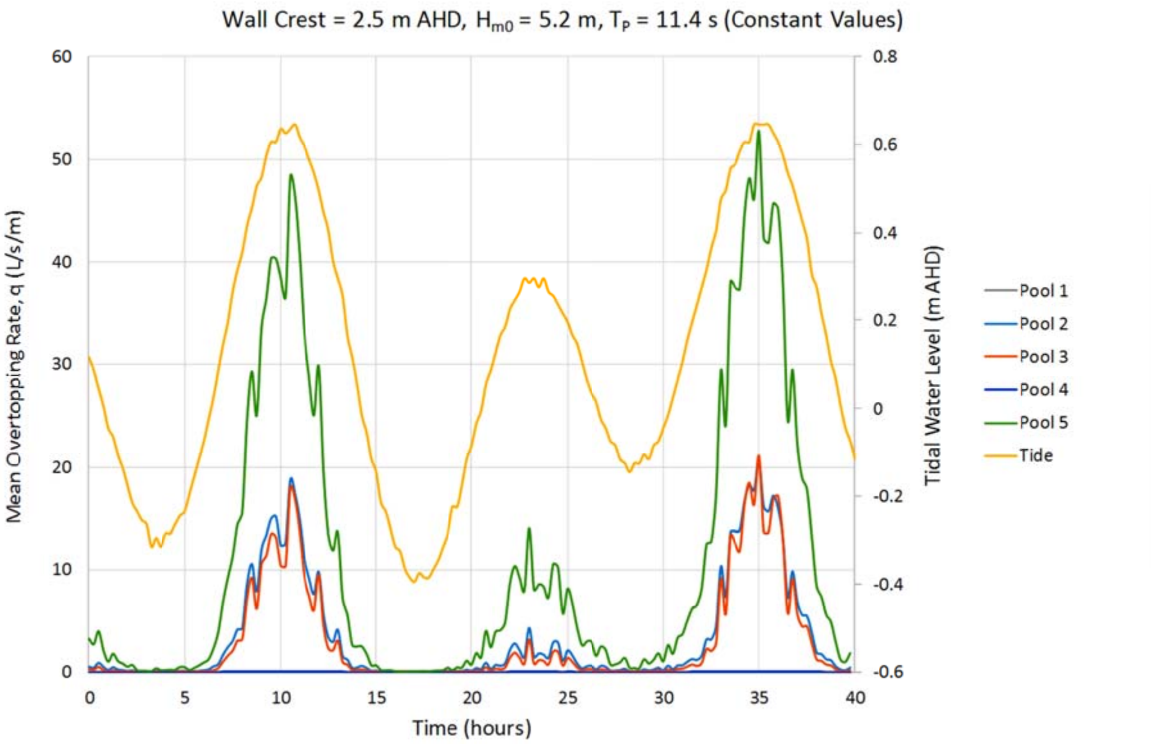


Figure 7.13 Overtopping Ballina pool positions 1 year ARI waves, wall at 2.5 m AHD

7.4 Impacts of location on shoreline

Much of the foreshore around Ballina Head has some form of rock boulder armouring at the back of the beach. These rock boulders and the underlying rock shelf limit erosion at the back of the beach. Nevertheless, as discussed in Section 4.3, and as documented in the frequent photos taken by Mr John Wise, the veneer of sand over the rock shelf is variable and mobile.

The possible impacts of ocean pool construction on the high tide dry beach line (approximately +2 m AHD) is shown in Figure 7.14 to Figure 7.18. The impact is shown for existing, ambient and post-storm conditions. This is based on professional coastal engineering judgement and experience only. The impacts would also be dependent on the elevation of the pool walls – a higher pool will have greater impacts, whereas a pool substantially excavated into the rock shelf will have minor impacts (but may be more prone to filling with sand and wave overtopping).

Notes: Black dashed line is present 2 m AHD contour based on optical drone survey by WRL on 8/8/2018;
Yellow dashed is with pool under ambient conditions; Red is post-storm. Existing and future armouring may modify these.

Figure 7.14 Potential pool shoreline impacts – position 1

Notes: Black dashed line is present 2 m AHD contour based on optical drone survey by WRL on 8/8/2018;
Yellow dashed is with pool under ambient conditions; Red is post-storm. Existing and future armouring may modify these.

Figure 7.15 Potential pool shoreline impacts – position 2

Notes: Black dashed line is present 2 m AHD contour based on optical drone survey by WRL on 8/8/2018;
Yellow dashed is with pool under ambient conditions; Red is post-storm. Existing and future armouring may modify these.

Figure 7.16 Potential pool shoreline impacts – position 3

Notes: Black dashed line is present 2 m AHD contour based on optical drone survey by WRL on 8/8/2018;
Yellow dashed is with pool under ambient conditions; Red is post-storm. Existing and future armouring may modify these.

Figure 7.17 Potential pool shoreline impacts – position 4

Notes: Black dashed line is present 2 m AHD contour based on optical drone survey by WRL on 8/8/2018;
Yellow dashed is with pool under ambient conditions; Red is post-storm. Existing and future armouring may modify these.

Figure 7.18 Potential pool shoreline impacts – position 5

Location/Criteria	1	2	3	4	5
Description	Northern end landward	Northern end seaward	Central seaward	Southern end landward	Northern Lighthouse
Attachment/island	Attached	Island	Island	Attached	Attached
Safety from waves	High	Moderate	Low	Moderate	Moderate
Wave flushing	Low	Moderate	High	High	High
Absence of sand infill	High	Moderate	Low	Moderate	Low
Impact on beach processes	Low	Moderate	Moderate	Low	Low
Engineering certainty	High	Moderate	Low	Moderate	Moderate
Ease of construction	Moderate	Moderate	Low	Moderate	Moderate
Distance to facilities	Low	Moderate	Moderate	High	Low
Difficulty of disabled access	Low	Moderate	High	Moderate	Low
Potential boulder impacts	Low	Moderate	Moderate	High	Moderate
Separation from floodwater	High	Moderate	Low	Moderate	Low

Note: Criteria worded so that low is generally a negative attribute and high is generally a positive attribute

Table 7.1 Multi criteria analysis of potential pool locations

8 Concept design

8.1 Design parameters

The following design parameters are recommended for the Ballina ocean pool.

- Pool dimensions:
  - Main pool: 50 m long x 20 m wide (could be narrowed to 15 m if required);
  - Main pool 1.2 to 1.35 m deep in shallow end; 1.6 m in deep end;
  - Children's/wading pool: 250 to 450 m^2;
  - Children's/wading pool: ranging from zero to 0.7 m deep;
  - Constructed public space: 250 to 450 m^2;
- Pool wall minimum elevation 1.5 m AHD, and preferably higher;
- Minimum elevation of lowest point in pool floor: -0.2 m AHD (higher is preferable);
- Scuppers 100 mm high, with a further 100 mm of concrete over them, that is, the pool deck is 0.2 m above the normal pool water level;
- A predominant reliance on pumping to fill and replenish the pool's water; and
- Allowance for machine and vehicle access.

It is strongly recommended that the design incorporates input from a landscape architect or architect.

8.2 Pool location and features

Following consideration of WRL's initial studies and multiple local (non-engineering) criteria, the Ballina Ocean Pool Committee elected to pursue a design at Location 3 (Figure 7.16), with additional sensitivity to be the cross shore position at this location (Section 9).

The Ballina Ocean Pool Committee also requested that the ocean pool have some wave flushing, a sand covered floor and minimal excavation.

Architectural designs are being undertaken in parallel with this WRL report.

8.3 Additional studies

The following additional data collection and/or studies are recommended to further refine the concept design prior to detailed design:

- A detailed bathymetric survey from the edge of the rock shelf; and
- A (segment of) trial wall should be constructed in its proposed position and be monitored with an imaging system (e.g. http://ci.wrl.unsw.edu.au/).

The results of these studies may result in minor shifts in the adopted plan location and wall elevation.

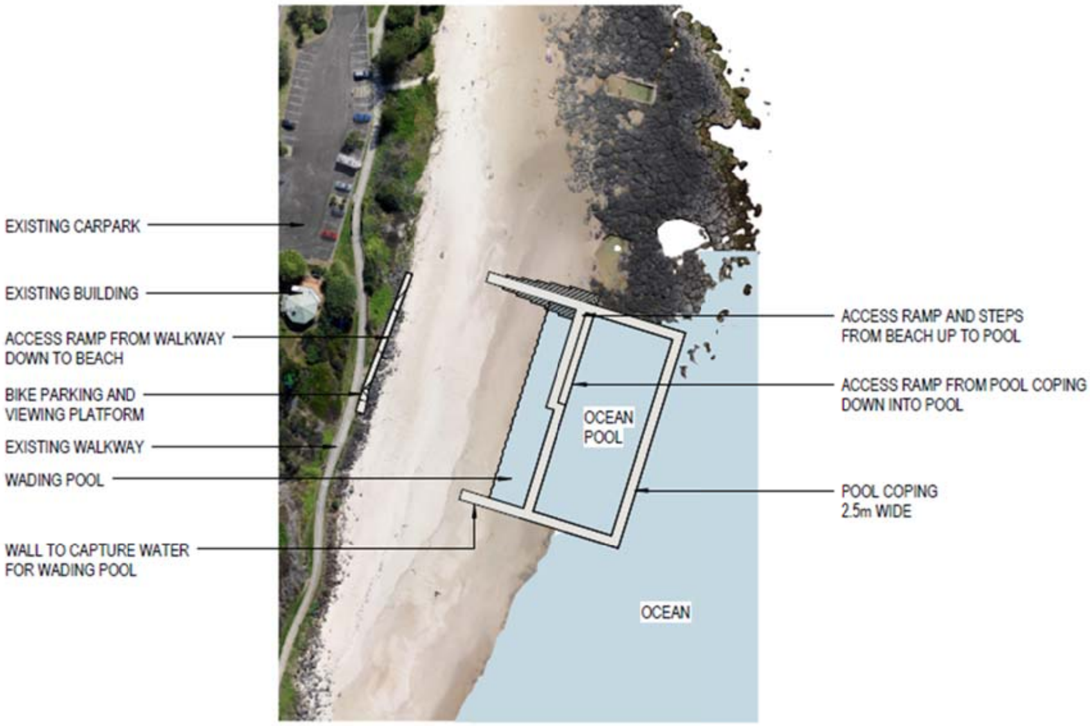
9 Wave overtopping sensitivity for preferred location

As previously discussed, the following criteria will determine the preferred ocean pool location:

- The Ballina Ocean Pool Committee has requested that a design in the vicinity of Location 3 (Figure 7.4, Figure 7.16) be pursued (Figure 9.1);
- The Ballina Ocean Pool Committee has requested that the pool is flushed by waves and not separated from the ocean, however, it may still be pump assisted;
- Of the four existing ocean pools studied in detail, the experience of WRL engineers (and others who assisted with this study) is that:
    - South Curl Curl ocean pool is generally acceptably safe to the community and receives sufficient ocean flushing so as to rarely rely on its pump to maintain good water quality;
    - North Curl Curl ocean pool is excessively dangerous at times;
    - Dee Why and Freshwater ocean pools are generally acceptably safe to the community, but during the peak summer months, are often not sufficiently flushed to maintain acceptable water quality (noting that this is partially a function of user numbers).
- Allowing for 100 mm high scuppers and 100 mm of concrete above the scuppers, the normal operating water level of a pool will be 0.2 m below the wall height;
- It is easier to raise a pool than lower it in the future; and
- Additional design studies will be undertaken prior to detailed design which may further refine the pool position and elevation.

Therefore, WRL has undertaken additional wave overtopping calculations for a range of cross shore positions (the nominal position as shown in Figure 9.1 and further setbacks of 5, 10, 15 and 20 m) and wall elevations (1.5, 2.0 and 2.5 m AHD) for the preferred pool alongshore location compared to South Curl Curl ocean pool (1.5 m AHD wall level). These are set out in Figure 9.2 to 9.10.

This indicates that a seaward wall level of about 1.5 m AHD on a reasonably seaward alignment will be required at Ballina to have comparable (but slightly less) wave overtopping and flushing to South Curl Curl.



Source: caw building design October 2018

Figure 9.1 Pool position 3 (cross shore position may vary)

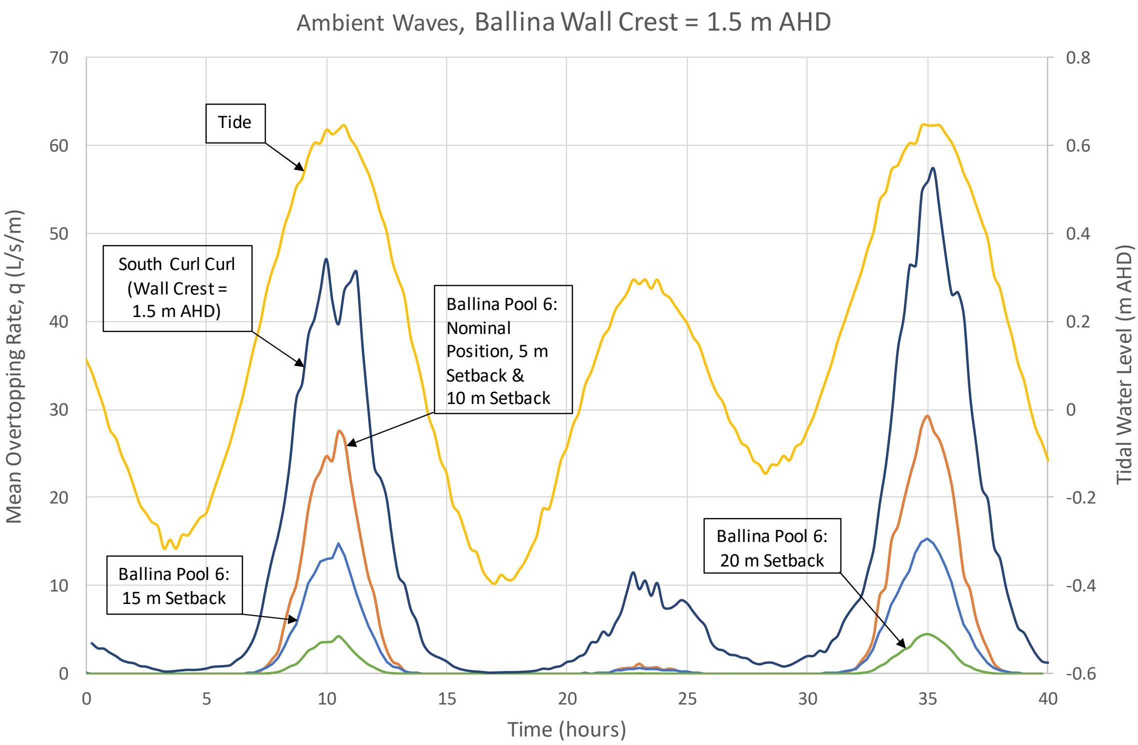


Figure 9.2 Overtopping for Pool position 3 (wall at 1.5 m AHD), ambient waves

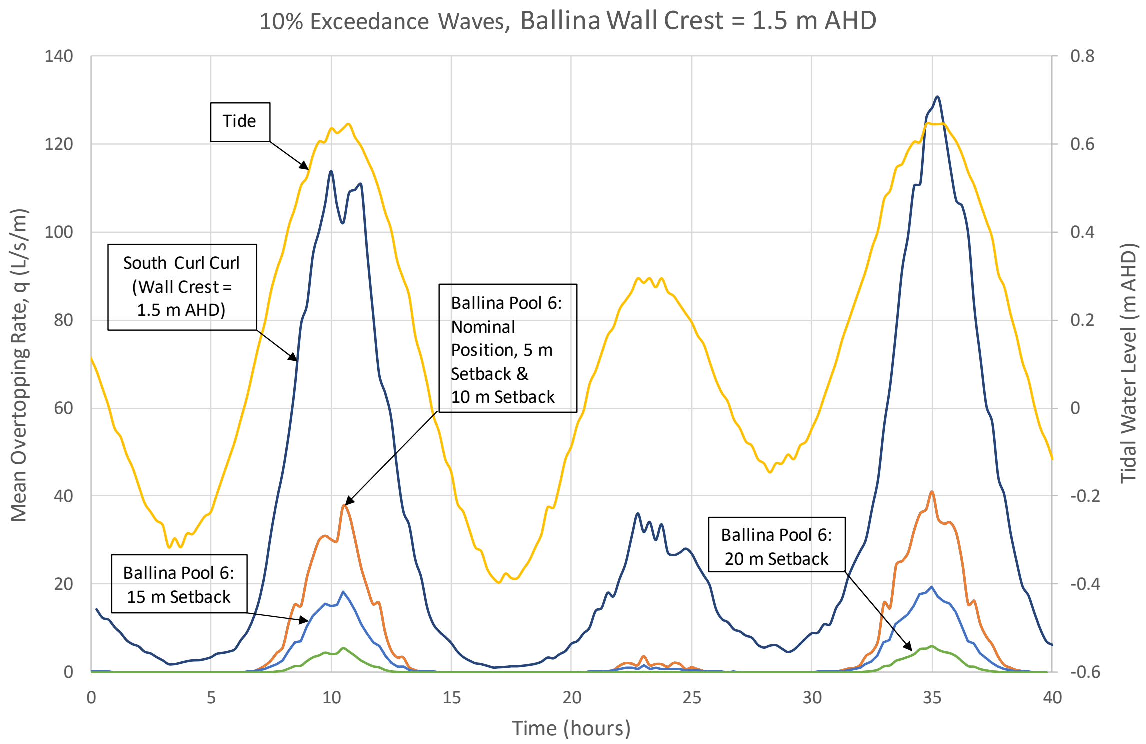


Figure 9.3 Overtopping for Pool position 3 (wall at 1.5 m AHD), 10% exceedance waves

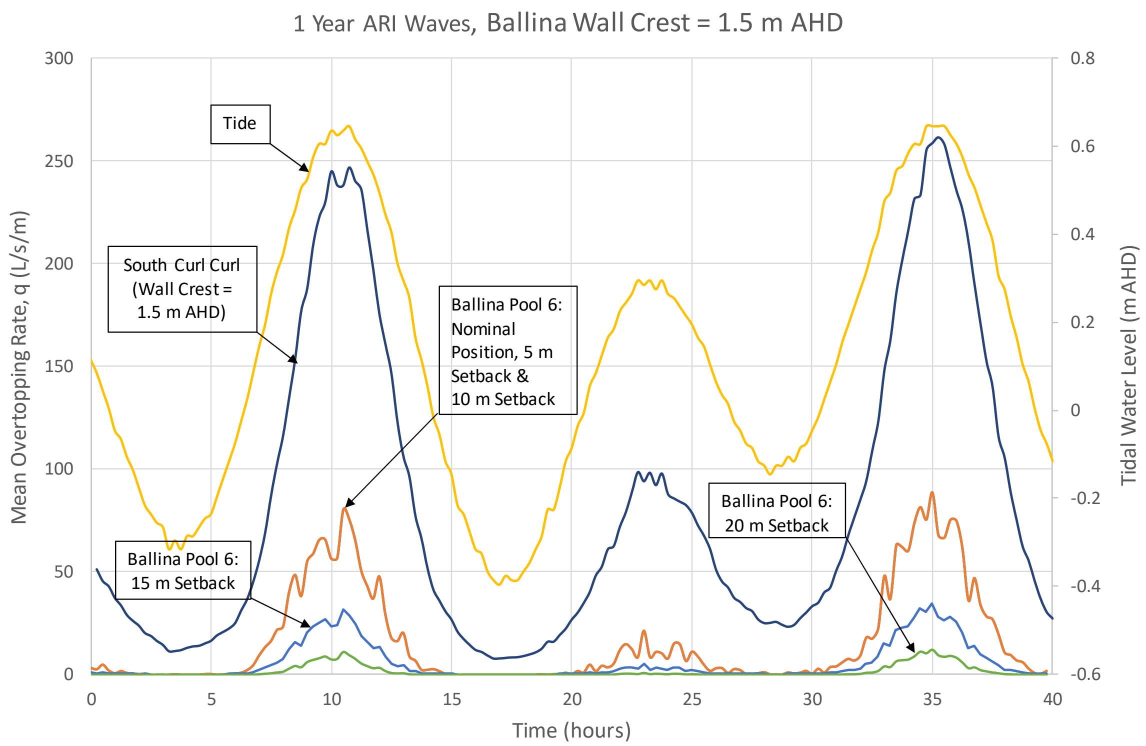


Figure 9.4 Overtopping for Pool position 3 (wall at 1.5 m AHD), 1 year ARI waves

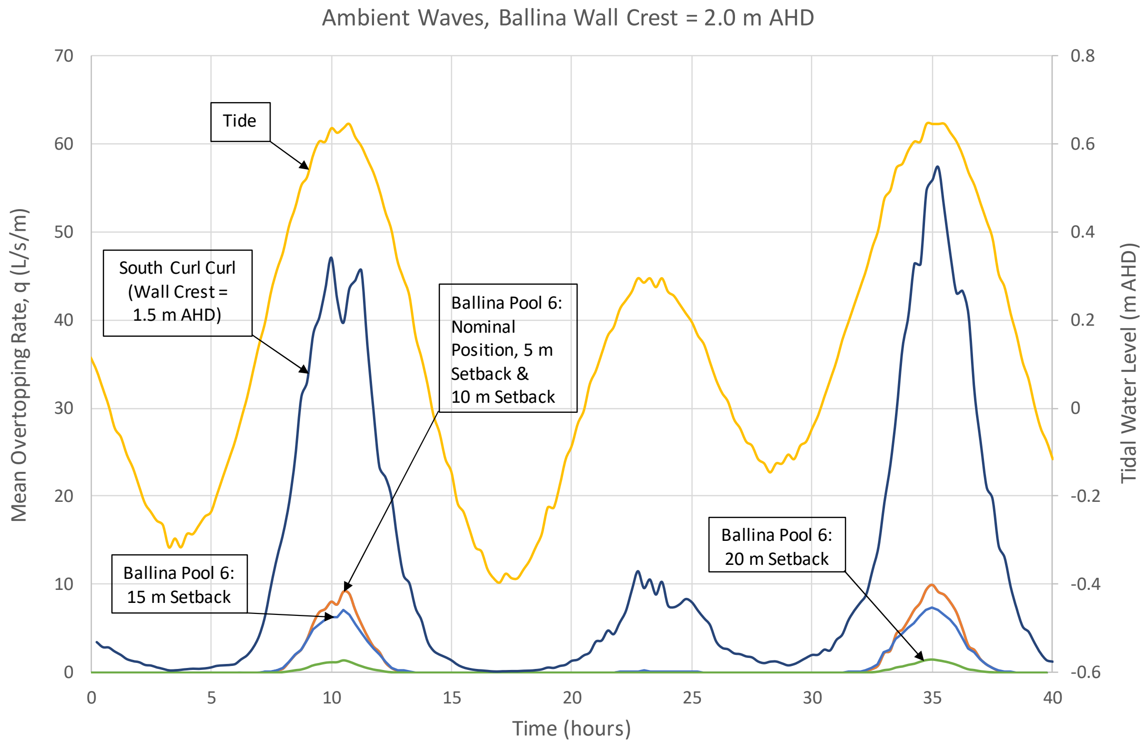


Figure 9.5 Overtopping for Pool position 3 (wall at 2.0 m AHD), ambient waves

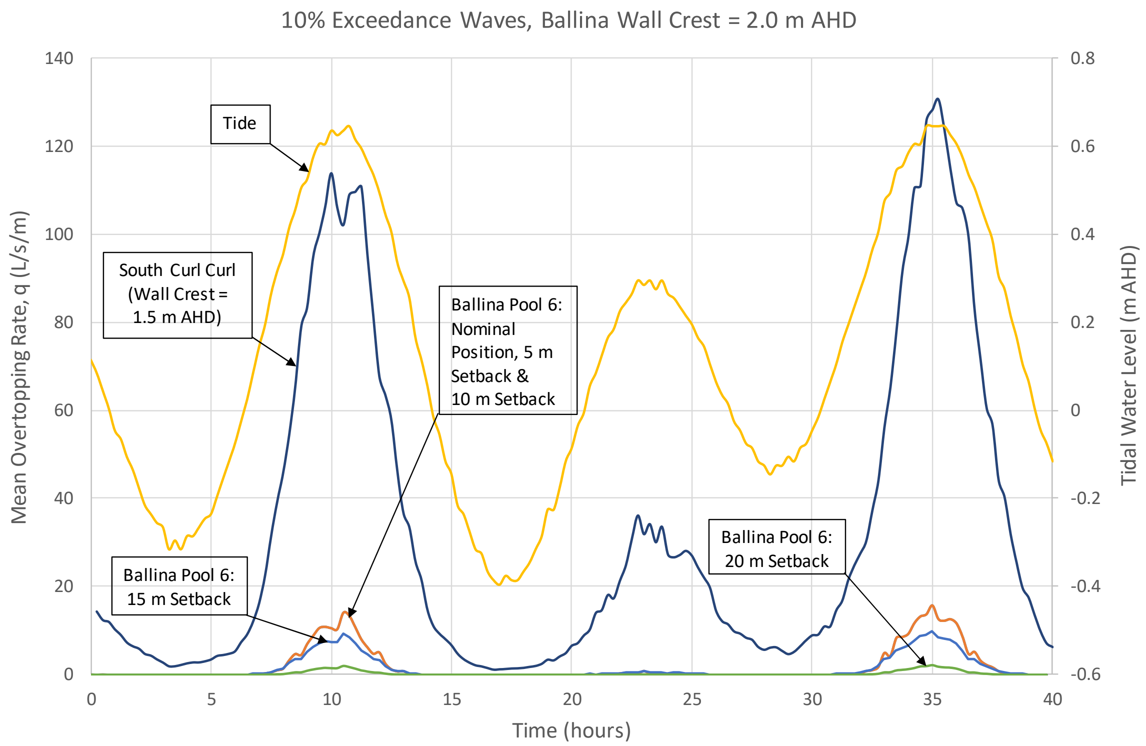


Figure 9.6 Overtopping for Pool position 3 (wall at 2.0 m AHD), 10% exceedance waves

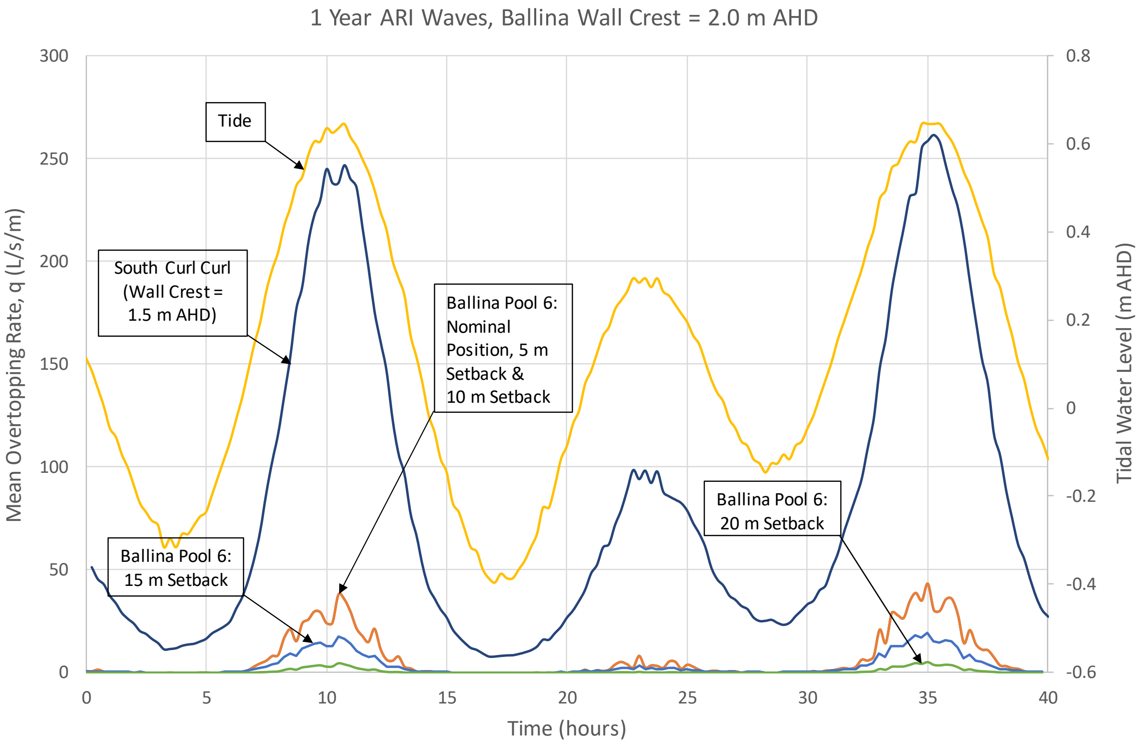


Figure 9.7 Overtopping for Pool position 3 (wall at 2.0 m AHD), 1 year ARI waves

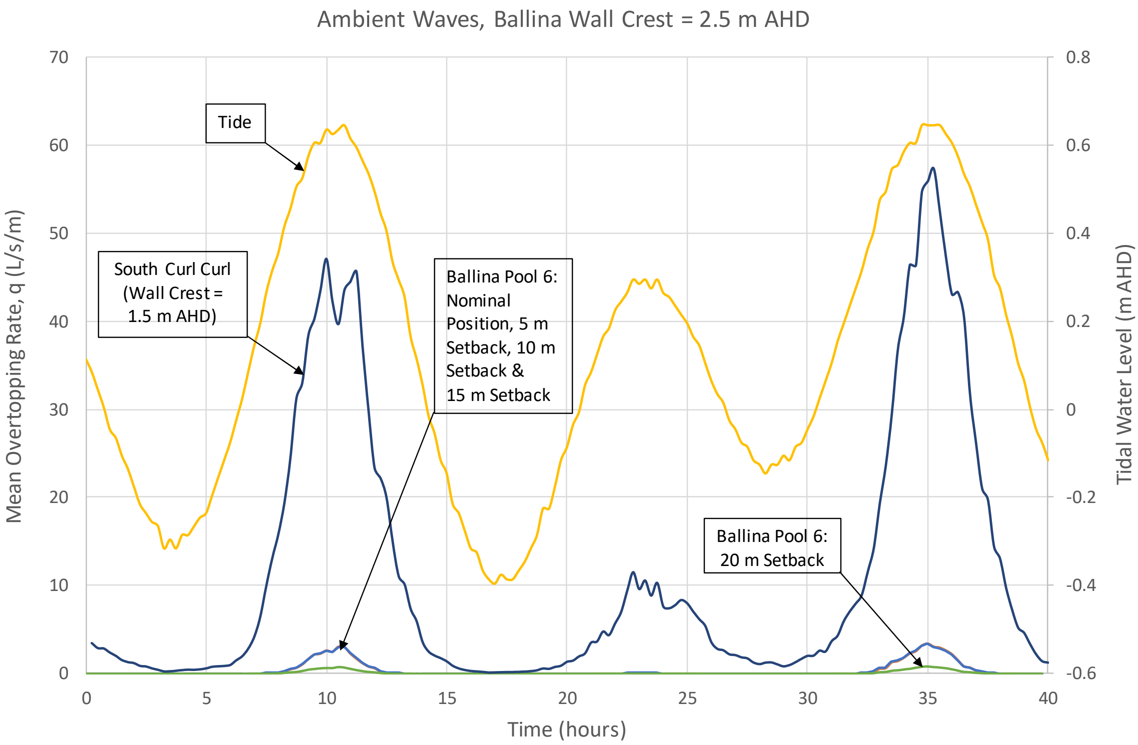


Figure 9.8 Overtopping for Pool position 3 (wall at 2.5 m AHD), ambient waves

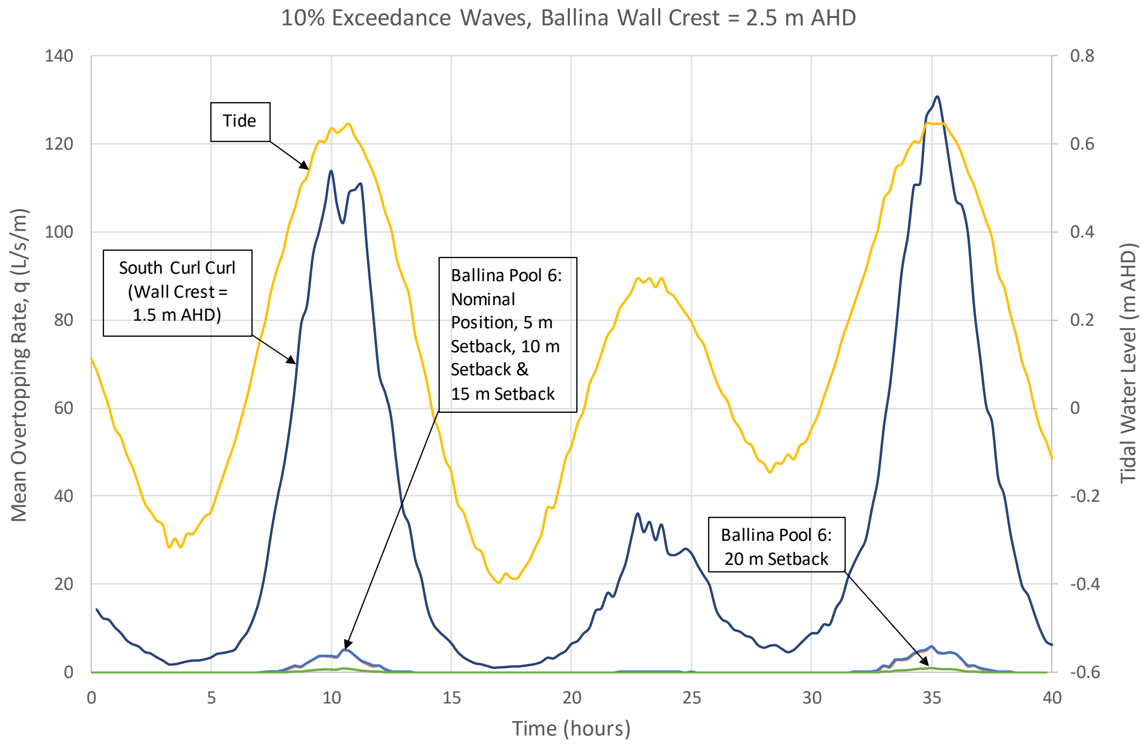


Figure 9.9 Overtopping for Pool position 3 (wall at 2.5 m AHD), 10% exceedance waves

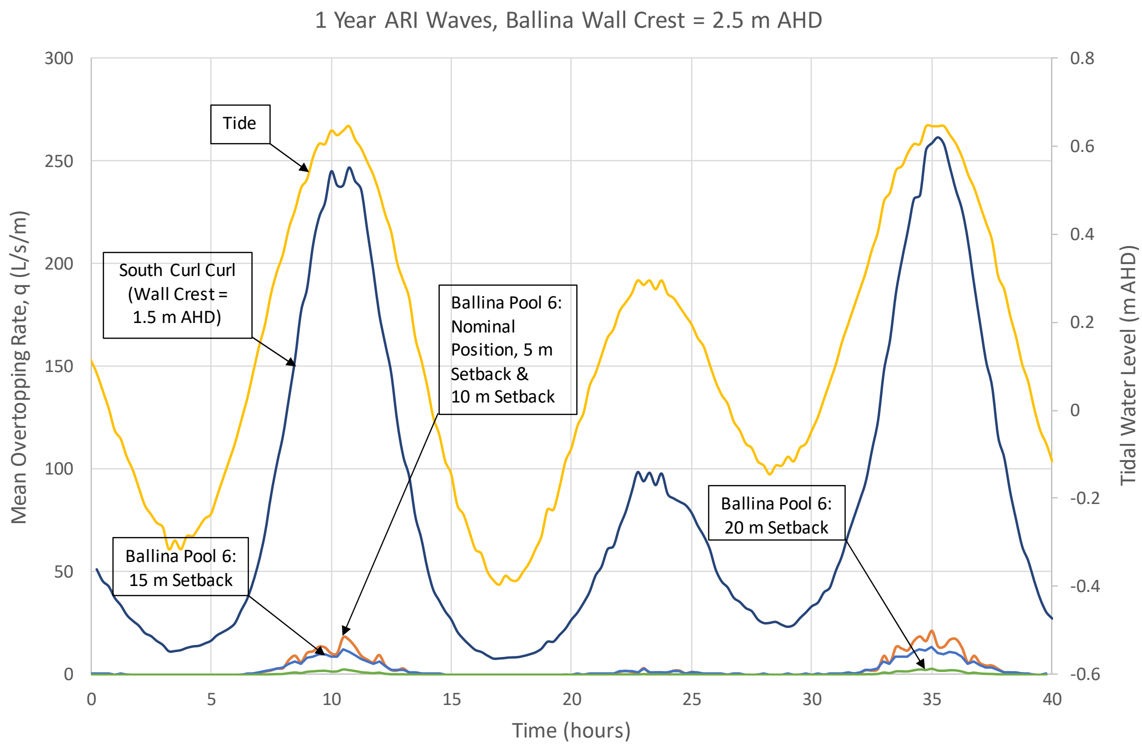


Figure 9.10 Overtopping for Pool position 3 (wall at 2.5 m AHD), 1 year ARI waves

10 Wall shape and wave forces

10.1 Wall shape

The final shape of the walls can be determined during detailed structural design. Gently sloping walls will convey more water and sand into the pool, so basic vertical or steeply sloping walls (1H:0.25V on seaward face) are recommended for the initial design. More complex wave overtopping shapes (Section 6) could be considered with future sea level rise, or future upgrades where reduced overtopping is desired.

10.2 Wave forces

For vertical walls, wave forces on the seaward face are shown in Table 10.1 for a range of possible configurations. These were calculated according to Kortenhaus (2001, 2003) and are suitable for preliminary design. Due to the size of the project, a physical model is recommended for detailed design.

Bed Level (m AHD)	SWL (including wave setup)	Forces (kN/m) Pool Crest (m AHD)				
		1	1.5	2.0	2.5	3.0
-1	0	71	71	71	71	71
	0.5	134	154	159	159	159
	1.0	170	224	258	280	283
	1.5	*	265	335	385	418
	2.0	*	*	382	466	535
	2.5	*	*	*	520	614
	3.0	*	*	*	*	680
0	0.5	18	18	18	18	18
	1.0	42	64	71	71	71
	1.5	*	96	134	154	159
	2.0	*	*	170	224	258
	2.5	*	*	*	265	335
	3.0	*	*	*	*	382
1	1.5	*	11	18	18	18
	2.0	*	*	42	64	71
	2.5	*	*	*	96	134
	3.0	*	*	*	*	170
2	2.5	*	*	*	11	18
	3.0	*	*	*	*	42

Table 10.1 Wave forces on seaward pool wall

11 Management of uncertainty and risk

Potential means for management of uncertainty and risk are listed in Table 11.1.

Uncertainty or risk	Control measure	Comment
Uncertainty in coastal engineering data and calculations	Undertake additional bathymetric data collection prior to detailed design Undertake instrumented field trial prior to detailed design Undertake physical model of pool prior to detailed design	
Excessive sand ingress into pool	Monitor and remove as part of maintenance Increase wall height Alter shape of seaward wall Increase reliance on pump	
Excessive sand accumulation outside pool	Monitoring Routine bypassing with machinery Re-route water flows to optimise erosion and accretion Raise walls in locations	Most sand movement will be seaward of pool Existing rock shelf limits sand scour and availability
Sea level rise and climate change	Raise walls as part of upgrades Modify seaward wall shape	Upgrades are typically undertaken at 10 to 20 year intervals It is easier to raise a pool than lower it
Large waves in pool	Warning signs Forecasting system Closure by lifeguards/life savers	
Poor water quality	Monitoring Pool closure at times Altered cleaning regime	
Excessive wave reflections from pool	Alter seaward wall shape Introduce dissipative rock armour on seaward face	
Access ramp/track gets buried in sand or damaged	Monitor and mechanically move sand Construct higher level elevated track or bridge	

Table 11.1 Management of uncertainty and risk

12 Summary and conclusions

The Water Research Laboratory of UNSW Sydney undertook a coastal engineering study to assist with the design of a proposed ocean pool at Ballina NSW. The study comprised both fundamental coastal engineering work and interviews with people well acquainted with existing ocean pools. Ocean pools are widespread in NSW and South Africa, with limited numbers in other states and nations.

The main tasks undertaken were:

- Literature review on ocean pools;
- Detailed investigations of existing ocean pools;
- Ballina coastal processes and hazards;
- Design considerations for ocean pools;
- Wave overtopping calculations;
- Options (alongshore and cross shore) for pool location; and
- Wall shape and wave forces.

The following design dimensions are recommended by WRL for the Ballina ocean pool:

- Main pool: 50 m long x 20 m wide (could be narrowed to 15 m if required);
- Main pool 1.2 to 1.35 m deep in shallow end; 1.6 m in deep end;
- Children's/wading pool: 250 to 450 m^2;
- Children's/wading pool: ranging from zero to 0.7 m deep; and
- Constructed public space: 250 to 450 m^2.

Based on initial advice and local factors, the Ballina Ocean Pool Committee elected to locate the pool alongshore at approximately the location in Figure 9.1. Further refinement of the cross shore position is subject to detailed design. The Ballina Ocean Pool Committee also requested that the ocean pool have some wave flushing, a sand covered floor and minimal excavation. A seaward wall elevation of about 1.5 m AHD will be needed to allow frequent wave flushing.

Measures to manage uncertainty and risk are presented within the report. Architectural designs are being undertaken in parallel with this WRL report. Additional data collection and/or studies are recommended to further refine the concept design prior to detailed design. The results of these studies may result in minor shifts in the adopted plan location and wall elevation.

13 References and bibliography

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- All into ocean pools: https://allintooceanpoolsinc.org/
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- The Wild Edge (Larkin, 2018), https://www.nicolelarkin.com/the-wild-edge/
- WRL Coastal Imaging: http://ci.wrl.unsw.edu.au/

Appendix A People who assisted with this study

WRL acknowledges the contributions of the following people who assisted with this study.

A 1 Ballina Ocean Pool Committee

The vision and volition of the members of the Ballina Ocean Pool committee members is acknowledged:

- Ms Michelle Bourke;
- Mr Jeff Johnson;
- Mr Peter Lucena;
- Mr Bill McInerney;
- Mr Craig Nowlan; and
- Mr John Wise.

A 2 Expert opinions

The following individuals were interviewed in this study and provided knowledge, experience, expertise, information and opinions regarding ocean pools. However, the opinions in this report are those of WRL and may not represent the position of the individuals below:

- Mr Bill Andronicus;
- Associate Professor Kirsten Benkendorff;
- Associate Professor Rob Brander;
- Associate Professor Ron Cox;
- Mr Angus Gordon;
- Mr Nick Hoskin;
- Mr Russell Jenkins;
- Ms Nicole Larkin;
- Mr Levi Littlejohn;
- Mr Doug Lord;
- Mr Andy Prentice;
- Northern Beaches Council pool maintenance staff;

- Mr Rick Pybus;
- Ms Courtney Tallon; and
- Professor Bruce Thom.

Appendix B BOM wind rose plots

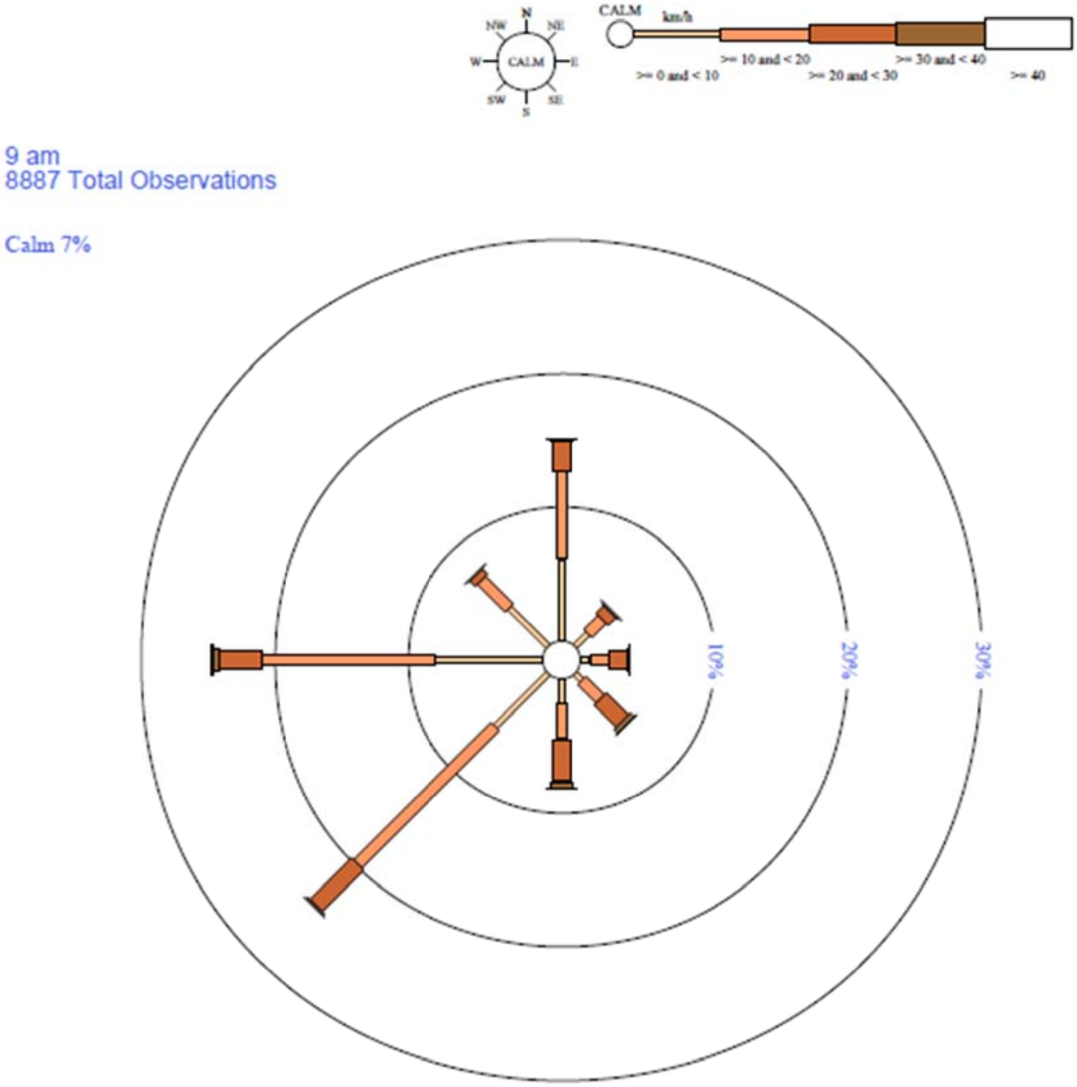
For a median sand grain size of 0.21 mm, USACE (2006) gives the following thresholds of motion for wind-blown sand:

- Dry sand: 6.8 m/s (13 knots, 25 km/hour); and
- Wet sand: 11.9 m/s (23 knots, 43 km/hour).

Rose of Wind direction versus Wind speed in km/h (19 Nov 1992 to 10 Aug 2017)
Custom times selected, refer to attached note for details

BALLINA AIRPORT AWS
Site No: 058198 • Opened Nov 1992 • Still Open • Latitude: -28.8353° • Longitude: 153.5585° • Elevation 1.m

An asterisk (*) indicates that calm is less than 0.5%.
Other important info about this analysis is available in the accompanying notes.



Rose of Wind direction versus Wind speed in km/h (19 Nov 1992 to 10 Aug 2017)

Custom times selected, refer to attached note for details

BALLINA AIRPORT AWS

Site No: 058198 • Opened Nov 1992 • Still Open • Latitude: -28.8353° • Longitude: 153.5585° • Elevation 1.m

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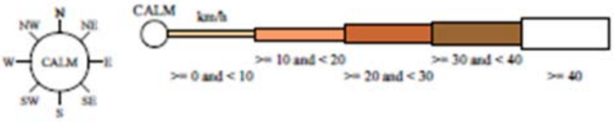
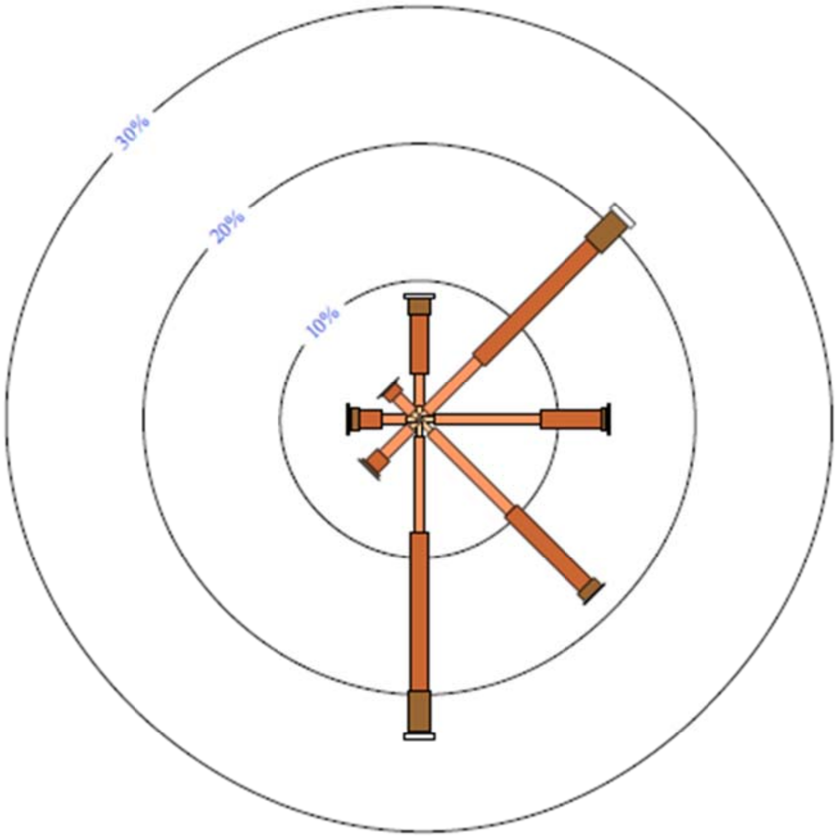


3 pm
8857 Total Observations

Calm 1%



TCZANNUAL Page 1

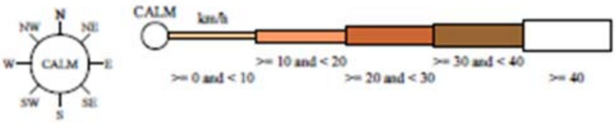
Rose of Wind direction versus Wind speed in km/h (01 Jan 1957 to 15 Aug 2007)

Custom times selected, refer to attached note for details

BYRON BAY (CAPE BYRON LIGHTHOUSE)

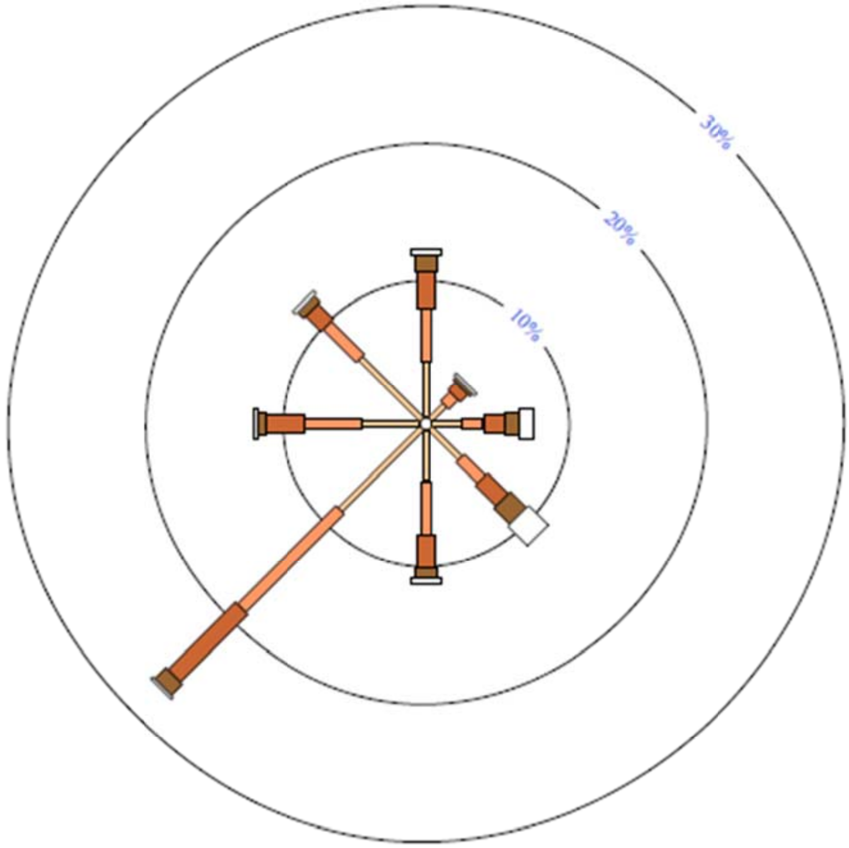
Site No: 058009 • Opened Jan 1948 • Closed Sep 2012 • Latitude: -28.6388° • Longitude: 153.6361° • Elevation 95m

An asterisk (*) indicates that calm is less than 0.5%.
Other important info about this analysis is available in the accompanying notes.



9 am
17754 Total Observations

Calm 2%



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Rose of Wind direction versus Wind speed in km/h (01 Jan 1957 to 15 Aug 2007)

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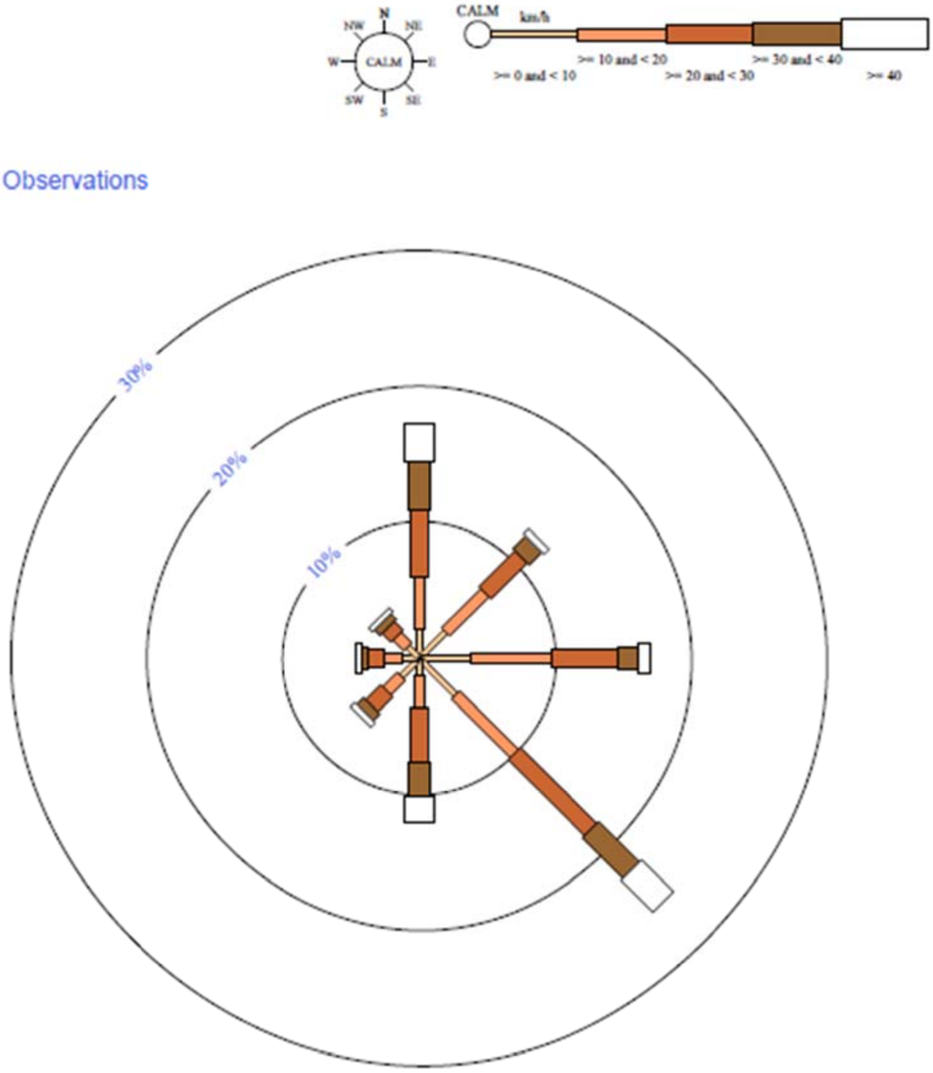

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