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REPORT

Whartons Creek

Entrance Management Study and Plan

Client: Wollongong City Council

Reference: M&W8A0530R001D03

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Executive Summary

Whartons Creek is located at the northern end of Bulli Beach. The entrance is trained by gabion walls on both sides and is intermittently closed and open to the ocean. Migration of the entrance breakout channel to the north towards Bulli Surf Life Saving Club (SLSC) can result in the development of a steep erosion scarp and back beach scour over a lateral distance of up to 150 m. This results in beach safety and amenity issues and impacts on beach accessways and dune vegetation.

This study sought to develop an affordable, low-key management strategy to prevent or reduce the likelihood of creek entrance migration to the north through: analysing available data to identify factors influencing entrance breakout and orientation; assessing past entrance management practices; and consulting with stakeholders with local knowledge of Bulli Beach and the behaviour of the Whartons Creek entrance.

Based on an assessment of likely costs, effectiveness, advantages and disadvantages (including potential environmental impacts), six feasible options were identified comprising sand relocation/ beach reshaping, mechanical breakout of the entrance and two options for extension of the existing northern training wall. Following consultation with Bulli SLSC, the Wollongong Estuary and Coastal Zone Management Committee and Council staff, a combination of options was selected for entrance management.

This report incorporates the subsequent Entrance Management Plan for Whartons Creek based on the preferred management strategy:

- of periodical relocation of sand from the south side to the north side of the entrance in conjunction with cleaning/ regular removal of sand from the Bulli ocean pools, once certain triggers are met; and
- very infrequent event-based relocation of sand or mechanical entrance breakout prior to/ at the commencement of an intense rainfall event.

This management strategy would be evaluated after three years, based on a comprehensive monitoring program. Should this strategy be considered unsuccessful in terms of effectiveness in preventing periodical issues associated with beach safety, amenity and access or with regard to benefit-cost, an alternative management strategy would be implemented comprising a geotextile sand-filled bag extension of the northern gabion entrance training wall.

1 Introduction

1.1 Background

Whartons Creek is located within the Wollongong Local Government Area (LGA) and flows from its headwaters in the Illawarra Escarpment through Bulli to the northern end of Bulli Beach, see **Figure 1**. The creek entrance is trained by gabion walls on both sides and is intermittently closed and open to the ocean. Migration of the entrance breakout channel to the north towards Bulli Surf Life Saving Club (SLSC) can result in the development of a steep erosion scarp and back beach scour over a lateral distance of up to 150 m. This results in beach safety and amenity issues and impacts on beach accessways and dune vegetation. This project, to reduce impacts from creek breakouts to the north, was identified in the *Dune Management Strategy Implementation Plan*, endorsed by Wollongong City Council (WCC) in August 2013.

Figure 1 Whartons Creek Locality

Plates 1 to **2** illustrate the severity of erosion due to breakout channel scour. **Plate 3** shows closed beach accessways and warning signage installed by Wollongong City Council (WCC) when there is a risk to public safety and **Plate 4** shows damage to a board and chain beach access one month after a breakout.

Plate 1 Breakout channel scour (WCC 28/6/2014)

Plate 2 Steep scarp near SLSC (WCC 19/11/2013)

Plate 3 Closed beach accessway (WCC 19/11/2013)

Plate 4 Damaged beach access (WCC 27/12/2013)

1.2 Study Objectives

To address the impacts of breakout channel scour to the north, WCC commissioned this study with the objectives being to:

- Provide Council with an affordable and more effective solution for management of entrance breakouts than current beach management practices.
- Develop a formal Entrance Management Plan so Council can obtain one approval/ licence covering ongoing entrance management.
- Prepare a Review of Environmental Factors (REF) for entrance management which can be periodically updated as required.

1.3 Scope of Work

The scope of work for this study comprised:

- Review of relevant reports including coastal and estuary processes studies, and plans and strategies including entrance plans/ policies for other Wollongong LGA intermittently closed and open lakes or lagoons (ICOLLs) for the purpose of informing this study.
- Site inspection and discussions with WCC, Office of Environment and Heritage (OEH) staff and Bulli SLSC members on current/ past entrance/ beach management practices.
- Data review and analysis including records from an OEH automatic recorder in Whartons Creek (water level and salinity), rainfall (Bureau of Meteorology (BoM) Bellambi Station), offshore wave data (Port Kembla directional waverider buoy), topographical surveys and photomonitoring.
- Options Identification, taking into account WCC's objectives for the study.
- Options Assessment with regard to likely effectiveness in managing creek breakout channel direction, estimated costs and potential impacts e.g. on beach amenity and creek ecology.

1.4 Acknowledgements

The Entrance Management Plan was developed with input from Council staff including the Project Manager and works and beach services staff; Bulli SLSC, OEH and Wollongong's Estuary and Coastal Zone Management Committee (ECZMC). The study was prepared with funding assistance from OEH's Coastal Management Program.

1.5 Consultation

Issues associated with northern entrance channel migration, identified in correspondence to WCC and as illustrated in **Plates 1** to **4** are:

- impact on beach use and access to and from the beach
- temporary closure and damage to beach accessways
- stagnant water from Whartons Creek ponding on the beach.

The Bulli SLSC in a letter to WCC in support of the grant application for this study, provided the following information on the impacts of creek scour to the north and associated restricted beach access.

- Patrol equipment (flags, rescue boards etc) needs to be carried around past Bulli Rock Pool over the exposed rock platform
- Club's All Terrain Vehicle (ATV) has had to tow the trailer with Inflatable Rubber Boat (IRB) to Woonona Beach (south of Bulli Beach) to launch the IRB for patrols.
- Patrol members need to monitor the dune in case of scarp collapse, as well as monitoring the rock pool and surf.
- Lack of beach access impacts on training and surf skis have to be carried over the rock platform to launch at Bulli Beach.
- Nipper activities have to be relocated to a wider section of the beach several hundred metres to the south.
- The steep scarp is a hazard to SLSC junior members as well as the general public.

The SLSC President also advised that:

- The creek entrance channel seems to deviate north nearly every summer (there are no specific records of this apart from photos provided for the study) and that it has a long history of going north.

The study findings and potential management options were presented to representatives of Bulli SLSC, WCC works and beach services staff, and the ECZMC on 14 July 2015. A working draft of this document was then circulated to these stakeholders with an invitation to comment on the study and management options. Questions raised following the presentation are addressed in this report and feedback on the preferred options was used to develop the Entrance Management Plan.

1.6 Relationship to Council's Strategic Planning

This document has been prepared as a deliverable of the WCC Annual Plans 2014-15 and 2015-16. The specific action to develop this plan fits within the Integrated Planning and Reporting (IPR) Framework:

Wollongong 2022 Community Strategy Plan Community Goal: *1 We value and protect the environment.*

→ Wollongong 2022 Community Strategy Plan Objective: *1.1 The natural environment is protected and enhanced.*

→ Wollongong 2022 Community Strategy Plan Strategies:
1.1.3 The potential impacts of natural disasters, such as those related to bushfire, flood and landslips are managed and risks are reduced to protect life, property and the environment.
1.2.1 A suite of actions to manage and protect against the future risk of sea level rise is enacted.

→ Delivery Program 2012-2017 5 Year Actions:
1.1.3.2 Implement a coordinated approach to floodplain and stormwater management
1.2.1.1 Finalise and Implement the Coastal Zone Management Plan

→ Annual Plan 2014-15 and 2015-16 Annual Deliverables:
Commence the Whartons Creek Entrance Management Plan
Continue implementation of priority actions from the Dune Management Strategy.

Within WCCõs IPR, this document can be described as a Supporting Document ï Implementation Plan Proposal. Supporting Documents include long, medium and/ or short term outcomes which support the development of IPR legislated documents, such as the Community Strategic Plan, Delivery Program and Annual Plan.

1.7 Other Relevant Plans and Strategies

A brief summary of relevant coastal, estuary and dune management plans follows. Further information on coastal hazards, catchment flooding and entrance management studies can be found in **Appendix A**.

1.7.1 Coastal Zone Management Plan

The *Wollongong Coastal Zone Management* (BMT WBM Draft 2012) identified a number of public assets at risk from coastal hazards at Bulli Beach, including the SLSC and pedestrian/ cycle path. It was recommended that, prior to any future asset upgrades/ redevelopment, assessments be made to determine whether the asset should be relocated, or redesigned to withstand impacts from coastal hazards.

1.7.2 Estuary Management Plan

Management Actions identified for Whartons Creek in the *Estuary Management Plan for Several Wollongong Creeks and Lagoons* (GHD 2007a) included to:

- establish and maintain a well vegetated riparian zone using locally indigenous plant species
- investigate re-grading of the creek banks to provide a less steep and wider riparian corridor
- stabilise the dune at the entrance and revegetate behind the gabions which form the entrance training walls.

1.7.3 Floodplain Risk Management Plan

The *Combined Catchments of Whartons, Collins and Farrahars Creeks, Bellambi Gully and Bellambi Lake Floodplain Risk Management Study and Plan* (Lyall & Associates 2014) made the following recommendations for the Whartons Creek catchment:

- construction of a flood deflection levee on the western (upstream) side of Franklin Avenue near the railway corridor (see **Figure 1**)
- replacing the existing Franklin Avenue culverts with a bridge
- upgrading the retarding basin near Gordon Hutton Park (west of the railway corridor).

These recommendations were to address overland flooding to the northeast. Overbank flooding from Whartons Creek downstream of Franklin Avenue was not identified as an issue.

1.7.4 Dune Management Strategy for the Patrolled Swimming Areas

The *Wollongong Dune Management Strategy for the Patrolled Swimming Areas of 17 Beaches* (GHD 2014) considered actions to improve sight lines for surf lifesaving patrols while also maintaining recreational amenity and beach access. Options identified were to build an observation tower, build a tower and remove vegetation from the frontal zone, or raise the level of the observation area at the Bulli SLSC. It was noted that removal of stabilising dune vegetation increases the risk of impacts from coastal hazards.

The *Dune Management Strategy Implementation Plan* (2013) included the following options in relation to Bulli Beach: assess status of seawall for protection against coastal hazards; build a tower; removal of vegetation from the frontal zone and reshaping; and the preparation of an entrance management policy for Whartons Creek (this project).

1.7.5 Waniora Point Restoration Plan

The *Coastal Processes and Restoration Plan for Waniora Point, Bulli* (WorleyParsons 2008) concluded that erosion of the Waniora Point Headland is predominantly a surficial process and that the rock pools (childrenö pool and main pool) at Waniora Point are unlikely to be causing significant effects on sediment transport processes. Development of a landscape master plan was recommended incorporating fencing and vegetation to control access at the headland. To reduce the frequency of works to remove sand from the childrenö pool a number of pool modifications were provided for consideration, along with other suggestions such as relocation and/ or demolition of the existing childrenö pool.

2 Description of Site

2.1 Historical Changes

The following information is summarised from WorleyParsons (2008), with additional information provided from WCC and with reference to available historical aerial photographs.

- The first rock pool, constructed in 1903, was located to the south of the current pool which was built in 1935.
- Heavy mineral mining for titanium was undertaken at Bulli Beach from 1953.
- A retaining wall/ seawall (now buried in the vegetated dune) is located in front of the SLSC and extends south for about 70 m. An early 1950s photo (**Plate 5**) provided by Bulli SLSC shows the sandstone wall in the background, and a 1958 photo shows the wall and steps in front of the SLSC (**Plate 6**). WCC excavated two test pits in front of the SLSC in 2014 that revealed the wall was constructed of hand-packed sandstone with rendered face. It was founded on beach rounds/ armour layer without a lower footing bed or piling evident. WCCȏs geotechnical engineer concluded that the wall appears too low and is of a construction that falls well short of current engineering standards for seawalls.
- Excavation through the dunes and Waniora Headland for the sewer main occurred in the 1970s.
- The 1948 aerial photo (**Plate 7**) shows the Whartons Creek entrance in its current position with limited riparian vegetation and minimal dune vegetation. The 1986 aerial photo (**Plate 8**) shows the alignment of the 1950s wall with Norfolk Island Pines directly behind this. The 1986 photo (**Plate 9**) shows recent dune planting. The 1993 aerial photo (**Plate 10**) clearly shows the gabions on the northern side of the creek entrance and establishment of dune vegetation and beach accessways seaward of the now buried sandstone wall.
- From a review of historical aerial photographs between 1948 and 2006, when Whartons Creek was open it generally meandered to the north or directly southeast on Bulli Beach, although the entrance was usually closed.
- As shown in the aerial photographs, the sand/ vegetation interface at the northern end of Bulli Beach is more seaward than in 1948, with dune rehabilitation works in the mid-1980s leading to substantial seaward migration.

Plate 5 Sandstone wall early 1950s (Bulli SLSC)

Plate 6 Sandstone wall and steps 1958 (Bulli SLSC)

Plate 7 1948 Aerial photograph showing area largely devoid of vegetation and original rock pool (WCC)

Plate 8 1986 Aerial photograph showing back beach devoid of dune vegetation (WCC)

Plate 9 1986 Photograph showing recent dune planting and breakout to north (OEH 1986)

Plate 10 1993 Aerial Photograph showing established dune vegetation (WCC)

From Bulli Beach photogrammetry (1961 to 2005) and a 2013 onground survey, GHD (2014) calculated that at the northern end of the beach the:

- beach width ranged from 15 to 50 m prior to the dune rehabilitation works, and from 30 to 40 m in the period after these works
- beach volume ranged from 70 to 180 m^3/m before the works, and from 160 to 190 m^3/m after the works
- dune volumes ranged from 60 to 90 m^3/m in the pre dune works period, and from 120 to 130 m^3/m in the post works period
- dune height ranged from 2 to 3 m AHD before the works, and from 4 to 5 m AHD after the works.

A plot of the 2 m contour from available photogrammetry between 1961 and 2005 by CLT (2010) shows the seaward migration of the shoreline between these dates and the impact of beach erosion as a result of the 1974 storms (see **Appendix A**). The most seaward position of the 2 m contour (1972, 1993 and 2005), i.e. when the beach was in an accreted state, is approximately 40 m out from the end of the northern gabion wall. Sections produced from WCC surveys in 2014/2015 indicated the position of the 2 m contour was between about 30 to 40 m out from the end of the northern gabion wall, hence the beach is currently in a similarly accreted state.

2.2 Foreshore Use

The Bulli SLSC and Bulli Beach Café are located at Waniora Point as well as the childrenÕs and main rock pools, see **Figure 2**. The northern end of Bulli Beach is a popular patrolled area for locals and tourists, with the Bulli Tourist Park and RubyÕs Kiosk located on the southern side of Whartons Creek. The flagged swimming area can be anywhere between the SLSC and up to 100 m south of Whartons Creek, depending on conditions. **Plate 11** shows the flagged area near the SLSC in January 2015, with the creek channel meandering to the northeast.

The beach has a gentle grade to the vegetated dunes at the rear. There are two formal beach accessways through the dune between the creek entrance and SLSC, plus a sand access ramp for the SLSCÕs ATV. Grassed open space with a playground is located behind the dunes. A shared pedestrian/ cycle path provides access along the beach through the grassed open space. Carparks are located on the northern side of Waniora Point and the northern side of Whartons Creek.

2.3 Zoning and Tenure

Under the *Wollongong Local Environmental Plan 2009*, downstream of the railway corridor, the creek is zoned IN2 General Industrial where it crosses Franklin Avenue, E2 Environmental Conservation, RE1 Public Recreation either side of Artis Street, then R2 Low Density Residential through the Waniora Public School and Bulli High School grounds to Farrell Road. East of Farrell Road, the creek and entrance area are zoned RE1 Public Recreation. The RE1 zone along the foreshore extends about 75 m seaward of the shared pedestrian/ cycle path creek crossing (footbridge) and cuts through the vegetated dune system. The creek entrance and beach/ dune seaward of this are unzoned.

The foreshore RE1 zoned land is Community Land and the unzoned foreshore land is Crown land. The Whartons Creek entrance channel and beach are within Crown land reserved for recreation (Reserve 81722), land reserved for future public requirements (R1011268), and land below Mean High Water Mark reserved from sale or lease generally (R56146) (NSW Trade & Investment 2015).

Plate 11 Flagged swimming area north of creek (WCC 23/1/2015)

2.4 Topography and Geology

East of the railway corridor, the Wollongong Geological Sheet (Bowman 1974) shows alluvium, gravel, beach and dune sand to the north of Whartons Creek, with levels rising up to 15 m AHD. Australian Height Datum (AHD) is approximately equal to Mean Sea Level (MSL). South of the creek and west of the Bulli Tourist Park is fine to medium grained, bioturbated andesitic sandstone with interbedded quartz-lithic sandstone grey mudrock, carbonaceous mudrock coal and laminates. Ground levels rise more steeply on the southern side of the creek, up to a high point of 27 m AHD near the railway corridor. Dune crests are about 4 m AHD to the north of the creek entrance and up to 6 m AHD to the south.

2.5 Water Quality

WCC monitored water quality at 36 sites in 23 creeks and lagoons on approximately a monthly basis between August 2002 and March 2006. One site was located within the freshwater reach of Whartons Creek. Monitoring results were compared to ANZECC (2000) guidelines for fresh and marine waters, using the trigger values for the protection of aquatic ecosystems in slightly to moderately disturbed systems. Faecal coliform results were assessed against trigger values for recreational activities. Results were presented in five categories, e.g. meeting guideline criteria for less than 10% of the time over the monitoring period, ranging to at least 75% of the time.

Results for Whartons Creek indicated dissolved oxygen saturation values were low (met the guidelines only 10 to 25% of the time), nutrient concentrations were elevated (nitrate concentrations met the guidelines only 10 to 25% of the time) as were copper and zinc (copper only met the guidelines 10 to 25% of the time). Faecal coliform counts met the guideline criteria for primary contact recreation 25 to 50% of the time.

A water quality snapshot at four sites undertaken by GHD (2007b) during ecological surveys in March 2007 also found low dissolved oxygen concentrations (4.2 to 5 mg/l), turbidity ranging from 11 to 17 NTU, pH of 7.6 to 7.9 and electrical conductivity of 706 to 795 µS/cm indicating freshwater conditions. It was noted that water quality sampling took place during a period of wet weather when the entrance was open which would have resulted in higher turbidity levels due to catchment runoff.

2.6 Ecology

Estuarine vegetation along Whartons Creek is confined to an area approximately 200 m long and 10 m wide, largely surrounded by mown Kikuyu Grass. Dense Common Reed and Sea Rush (approximately 2 to 5 m wide) line both sides of the creek and grade into terrestrial vegetation west of the Bulli Tourist Park bridge. Swamp Oak and the introduced Lantana are also scattered along the creekline. Beach grasses including Hairy Spinifex, Sea Rocket, Beach Daisy and Beach Pennywort fringe the entrance bar. Beach grasses grade into coastal dune vegetation which includes Coastal Tea Tree, Coastal Wattle, Coastal Rosemary and the introduced Lantana and *Senna pendula* (GHD 2007b).

The estuarine reaches of Whartons Creek provide limited habitat for fauna but do provide potential foraging opportunities for species such as common microchiropteran bats, insectivorous birds and reptiles. The entrance bar and shallow areas of the creek provide potential foraging habitat for a range of common coastal species. A number of common bird species were recorded within the estuarine reaches including the Welcome Swallow, Australian Raven and Silver Gull. Although the threatened Sooty Oystercatcher was recorded near the entrance berm, there is limited foraging habitat available for this species within the creek itself (GHD 2007b).

A fish survey for Whartons Creek in March 2007 returned 263 individuals comprising six species. Whartons Creek was the least diverse of the four Wollongong LGA creeks/ lagoons sampled, with 85% of the fish being Flathead Gudgeon and 10% Sand Mullet. The remaining 5% comprised Sea Mullet, Longfinned Eel, Smallmouth Hardyhead and the introduced Mosquito Fish. A macroinvertebrate survey indicated generally lower overall diversity compared to other creeks (GHD 2007b).

GHD (2007b) attributed the low diversity and abundance of aquatic fauna to:

- limited tidal flushing
- lack of suitable nursery habitat (mangroves, seagrasses, saltmarsh) and tidally inundated mud flats
- poor water quality and riparian habitat condition.

2.7 Infrastructure

East of the railway corridor, Whartons Creek flows via culverts under the Franklin Avenue bridge crossing at Artis Street, culverts under Farrell Road and bridge crossings at the Bulli Tourist Park and creek entrance. Stormwater system information provided by WCC indicates approximately 13 pipelines discharge to Whartons Creek in this reach.

Just to the west of the tourist park bridge, a 370 mm diameter pipe discharges to the creek, between the footbridge and the tourist park bridge a 600 mm diameter pipe discharges to the creek and further east a 750 mm diameter pipe discharges into the northern side of the entrance, downstream of the footbridge, see **Figure 2**. WCC records indicate that the vertical distance to the invert of this pipe is 1.09 m. The creek bank height (top of gabion baskets) in this location is 2.86 m AHD, therefore the invert level of the outlet is approximately 1.77 m AHD. The level of the concrete plinth under the pipe is 1.43 m AHD.

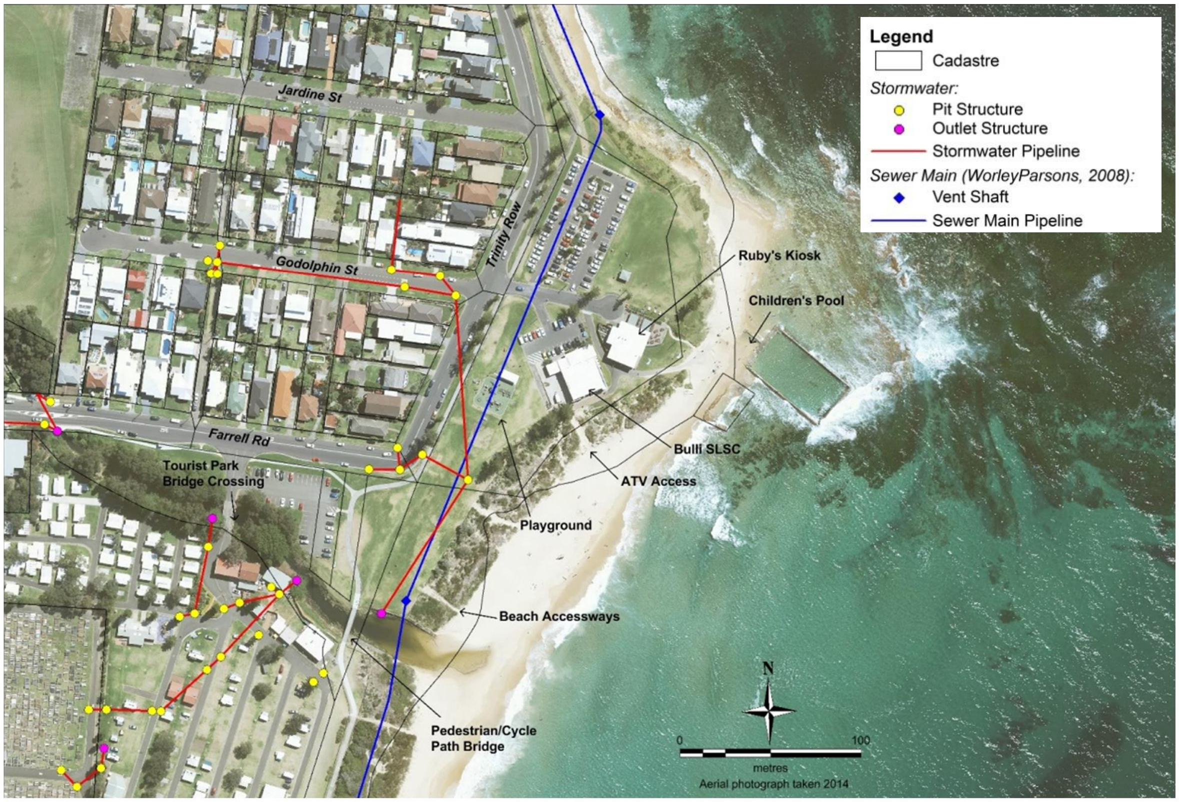


Figure 2 Whartons Creek Features and Infrastructure

As shown in **Figure 2** a 1200 mm diameter sewer main traverses Bulli Beach east of the shared pedestrian/ cycle path and the tourist park. A pit and vent is located immediately to the north of where the main crosses Whartons Creek. The level of the sewer main is estimated to be at around MSL or 0 m AHD (WorleyParsons 2008).

The pedestrian/ cycle path links to the beach accessways either side of the creek. The footbridge deck level is 4.0 m AHD on the northern side and 4.5 m AHD on the southern side (bridge slab is 0.66 m thick). The width of the creek channel (waterline width) under the bridge at 11.15 am on 13 March 2015 was 10.4 m and the distance from the underside of the mid-point of bridge to the waterline was 1.82 m. The entrance was closed. The gauge immediately upstream of the bridge recorded a water level of 1.69 m AHD at this time.

The bridge to the tourist park is about 90 m to the west of the footbridge and is about 10 m wide. The channel width under the bridge around 11.15 am on 13 March 2015 was 7 m. The distance from the underside of the bridge to the waterline was 1.85 m (bridge slab depth 0.35 m, so bridge deck level about 3.9 m AHD). Inquiries with the Tourist Park manager indicated the creek water level was about 0.9 m under the bridge during the last major flood (31 January 2008), a level of about 2.65 m AHD. Modelling by Lyall & Assoc. (2011) indicated a creek water level of 3 m AHD on the upstream side of the tourist park bridge for a 100 year Annual Average Recurrence Interval (ARI) flood event.

2.8 Entrance Condition and Training Works

As noted in **Section 1.1**, rock filled gabions line the creek on each side of the entrance below the footbridge, see **Plates 12** and **13**. The gabions appear to have slumped slightly on the northern side of the creek, leaving a gap between the stormwater headwall and creek bank (see **Plate 14**). At the beach end the gabions have collapsed, rocks have been removed, and at times broken wires protrude through the sand (see **Plate 15**).

GHD (2007b) noted that the estuarine section of Whartons Creek is relatively stable with only the left (north) bank between the footbridge and tourist park exhibiting moderately active erosion.

Plate 12 Northern side of Whartons Creek entrance

Plate 13 Southern side of Whartons Creek entrance

Plate 14 Stormwater pipe headwall

Plate 15 Gabion wires on beach (WCC 20/02/2015

2.9 Entrance/ Beach Management

Based on discussions with WCC staff and review of recent monitoring data, **Table 1** provides a summary of past entrance management activities and artificial breakouts. Beach raking is also carried out at the northern end of Bulli Beach in summer.

Table 1 Summary of Beach/ Entrance Management Practices at Whartons Creek

Entrance Management Activity	Description and Date*	Estimated Frequency
Berm height management	Prior to 2009, WCC kept the berm low at the entrance in conjunction with pool maintenance activities. This management technique ceased following a review of work procedures.	Every 1-2 months
Entrance channel realignment and beach restoration	Following two breakouts to the north, one in 2009 and in late 2013, the beach did not re-establish naturally and major reshaping work was undertaken in October 2009 and on 7 February 2014 involving excavation of a channel straight out from the creek and moving excavated sand to the north to fill in the remnant creek scour channel at the toe of the dunes.	Every 2-5 years
Mechanical breakout (dry notch)	WWC has excavated a dry notch a couple of times in recent years to direct the pending natural creek breakout straight out to the ocean. Mechanical breakouts are not required for flood mitigation purposes, see **Appendix A** for more information.	Once per year
Unauthorised channel excavation	Members of the public have also been observed digging a channel across the beach berm to let creek waters flow straight out to the ocean when the channel has turned to the north. Correspondence to Council notes one such occurrence on 1 June 2014 and another attempt was evident in photos taken on 25 July 2014.	Up to 2 times per year
Build-up sand on north side of entrance channel	WCC builds up sand on the northern side of the creek entrance to block potential northern migration of the breakout channel. This work was undertaken just prior to 16 May 2014 and on 18 March 2015.	About 4 times a year

** Based on photomonitoring 21/2/2015-11/6/2015, other photographic records and discussions with WWC*

As WCC has no adopted plan for management of Wharton Creek entrance, each time it is necessary to undertake major work, an environmental impact assessment and application has to be prepared to obtain a licence from the land owner (Crown Lands). The current licence, issued on 13 July 2014, is valid for two years. Previous licences were issued for shorter periods (January to June 2014) and for October 2009.

Building up sand on the northern side of the creek entrance to block potential northern migration of the breakout channel is undertaken in conjunction with removal of sand from the rock pools at the northern end of the beach, as well as the previous berm height management. Sand is removed from the children's section of the pool about every 4 weeks in summer and 6 weeks in winter when the pool is cleaned, with sand removed from the main pool about three to four times per year (WorleyParsons 2008). Sand removed from the pools is not used to build-up the northern side of the entrance but placed to the north at the base of Waniora Headland. This is considered an appropriate practice to maintain a sand buffer around Waniora Headland. Choosing to relocate sand southwards from the pools to the entrance would also increase the need for sand removal from the pools which is not desirable. Sand used to build-up the northern side of Whartons Creek is taken from the beach berm to the south.

3 Coastal and Estuarine Processes

3.1 Coastal Evolution and Morphology

The Illawarra escarpment produces steep stream profiles with a rapid gradient transition to the coastal plain. This results in decreased downstream channel capacity and large floodplains to accommodate floodwaters. This is reflected in the geomorphological characteristics of the Illawarra streams, which display compound channel morphologies as a result of the common recurrence of high magnitude flood events. Compound channel streams typically have an inner óactive channelôformed and maintained by frequent small flows and a larger ómacro channelôrelated to the higher and more infrequent flood volumes. Whartons Creek rises in the Illawarra escarpment and then flows in a channelised form through the coastal plain to the ocean. The creek is 3.4 km long and has a catchment area of 210.8 ha (GHD 2007b).

The Wollongong coastline illustrates the influence of the Illawarra escarpment with a higher occurrence of rocky headlands and protected short beaches compared to the longer beach and sand dune systems to the south (GHD 2007b).

Bulli Beach is a relatively straight 950 m long, south-southeast facing beach that extends south from Waniora Headland to the lower Flat Rock. The entire beach is exposed to nearshore waves averaging 1.5 m, which usually maintain 4-6 rips, including permanent rips against the rocks at either end, and 2-4 shifting beach rips. The intervening bars are usually attached to the beach, but are separated by a trough during and following periods of high waves - conditions that can also generate a second outer bar running the length of the beach (Surf Life Saving Australia 2015).

The dominant process influencing the morphology of the NSW coast is the action of waves, particularly during storm events. Tidal influence is minimal as the coast is characterised as a micro-tidal zone. As a result, the majority of estuaries along the NSW South Coast are wave-dominated in their form, with fluvial input being the variable factor in determining their final morphology and functioning.

ICOLLs (intermittently closed and open coastal lakes and lagoons) fall under the wave-dominated barrier estuary classification. ICOLLs periodically open to the ocean during rainfall events and subsequently close through the action of tides and waves moving sand onto, and building the beach berm. ICOLLs and coastal creeks are generally narrow, shallow water bodies that develop on prograding coastal sequences formed from beach ridges, dunes and barriers (GHD 2007b).

Whartons Creek is a very small ICOLL, with an estimated volume of 1880 m^3, based on an adopted water depth of 0.8 m and estuary area of 2350 m^2. Tidal processes would very rarely penetrate any distance upstream of the entrance, except during king tides and large ocean storm events. Wave action may bring sand into the creek during storm events. Fluvial processes are small in the estuary due to the limited catchment area, with no fluvial delta present (GHD 2007b).

3.2 Wave Climate

The dominant offshore wave direction along the Wollongong coast is from the SSE. The average annual wave climate from the Port Kembla waverider buoy is shown in **Figure 3**.

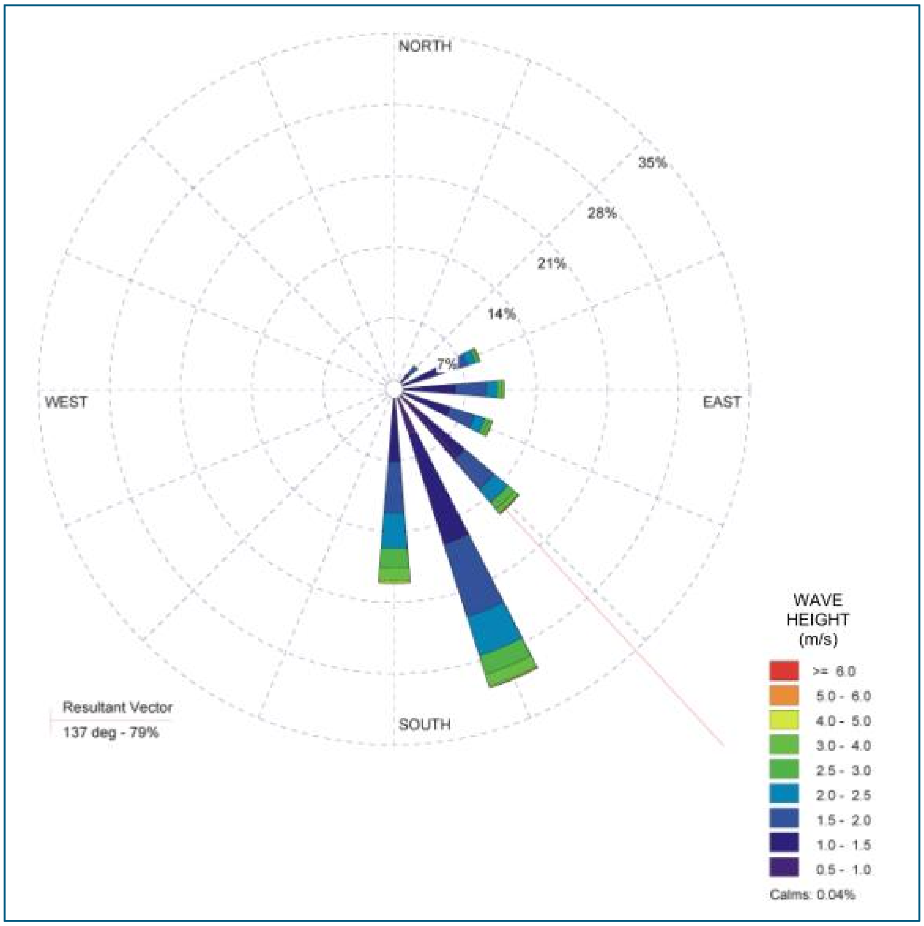


Figure 3 Annual Average Wave Climate Port Kembla (1992-2005) (CLT 2010)

CLT (2010) modelled nearshore wave heights in 6 m depths for a range of ARI storm events at two locations along Bulli Beach, immediately south of Whartons Creek entrance and at the southern end of the beach. Significant wave heights (Hs) near the entrance ranged from 4.03 m for a 5 year ARI event to 4.33 m for a 100 year ARI event, and at the southern end of the beach from 4.51 m for a 5 year ARI event to 4.89 m for a 100 year ARI event. Back-beach breaking wave heights for severe storms along the NSW open coast would typically vary between 2 and 3 m.

3.3 Water Levels

Water levels along the Wollongong LGA coastline vary mainly in response to tides. Other processes that can affect coastal water levels include storm surge, wave setup and sea level rise due to climate change. Water levels inside the entrance of Whartons Creek respond to freshwater flows within the catchment.

Predicted tides for the Wollongong area note respective mean spring and neap tide ranges of 0.7 and 1.2 m. Highest Astronomical Tide (HAT), the highest tide due to the gravitational effect of the moon, sun and planets, is 1.13 m AHD, or 0.5 m above Mean High Water Springs (MHWS). HAT is predicted to occur approximately once every 19 years on average.

Storm surge is due to the combined effect of inverse barometric setup and setup due to the wind shear pushing up water levels along the shoreline. Storm surge in severe events can reach 0.5 m, as it did in the Sydney region in the May-June storms of 1974.

Extreme elevated water levels predicted for Fort Denison in Sydney Harbour are representative of extreme still water levels for the Wollongong area and are summarised in **Table 2**.

Table 2 Extreme Elevated Water Levels at Fort Denison, Sydney Harbour (CLT 2010)

Average Recurrence Interval ARI (years)	Level (m AHD)
10	1.35
20	1.38
50	1.41
100	1.44

Sea level rise is predicted to occur as a consequence of climate change due to the thermal expansion of the oceans and melting of the polar and glacial ice sheets. Sea level in the Sydney region has risen by approximately 0.15 m over the past century. Over the last 20 years or so, sea level has been rising at 3 mm/year (CLT 2010). The former NSW Government sea level rise benchmarks of 0.4 m and 0.9 m above 1990 MSL, by 2050 and 2100 respectively, were adopted in previous WCC coastal zone and flood risk management studies. WCC is yet to adopt a formal sea level rise policy.

Whartons Creek water levels are measured at an OEH gauge operated by Manly Hydraulics Laboratory (MHL) just upstream of the footbridge, or approximately 130 m from the Mean Tide Line. Over the 16 month period from December 2013 to April 2015, measured water levels fluctuated between 0.7 m AHD and 2.5 m AHD. The mean water level over this period was 1.35 m AHD. A plot of the measured water levels is presented in **Figure 4**. Salinity levels are shown in **Figure 5.**

The water level response in the entrance is indicative of whether the entrance is open or closed to the ocean. The creek was closed for at least 2 months before February 2014, after which it broke out and remained open for about 1.5 months. The water level gauge was damaged in mid-March 2014 and not reinstated until the beginning of May 2014 during which a severe rainfall event of 115 mm in 24 hours occurred (such an event is predicted to occur up to once a year on average). The gauge was re-established at the beginning of May 2014 and remained operational though to the end of the analysed record in late April 2015. Other observations from the water level record are:

- At breakout the creek water level immediately drops to around 1 m AHD.
- The largest water level fluctuation associated with a breakout occurred in mid to late August 2014 when the mean water level in the creek fell over 1 m (water level prior to breakout was about 2.3 m AHD).
- The entrance remained essentially open and tidally ventilated from August 2014 to about the end of April 2015, a period of 8 months except for a brief period in early January 2015.
- During periods when the entrance was closed the sustained water level in the entrance did not drop below 1.5 m AHD, and on occasions was as high at 2.0 m AHD or even slightly higher.

3.4 Nearshore Coastal Processes and Sediment Transport

The interaction of tidal excursion, breaking waves on the beach, shoreline composition and morphology drive nearshore coastal processes.

The swash face slope at the creek entrance is typically 1V in 15H as indicated by surveys completed by WCC between July 2014 and April 2015, see **Appendix B**. The mean tidal excursion at the water line is therefore about 8 m. Typical offshore wave heights of 1.5 m with mean wave period of 6 s (CLT 2007) will shoal, break and runup the beach face for a distance of approximately 20 m. From time to time, the wave runup level will exceed the beach berm level which is typically around 2 m AHD, and overtop into the creek entrance. Furrows may form across the berm from the swash action and if the water level is sufficiently charged in the creek entrance, this process of water delivery into the creek and localised lowering of the berm could precipitate a minor breakout.

The water line position opposite the entrance is essentially a response to waves, currents and water levels, and supply of sand. During storms, waves will erode sand off the beach face leading to a landward translation in the water line. This action is reversed in subsequent fairweather periods when low height swell acts to rebuild the beach. Wave runup increases during storms, and the opportunity for overflow into the creek entrance also increases.

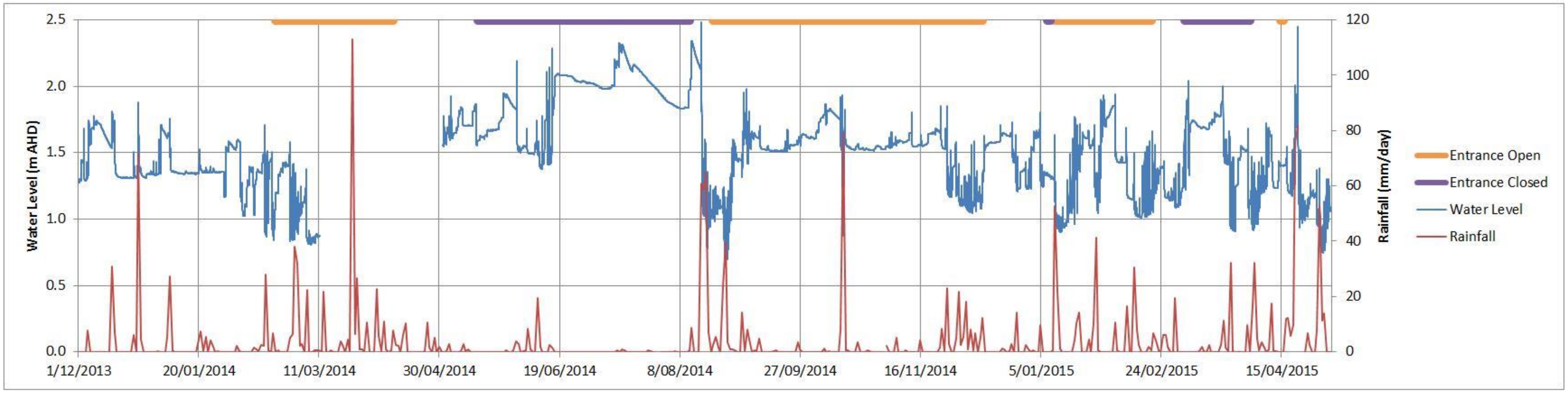
Net northerly longshore sand transport is expected at Bulli Beach due to the dominant SSE wave direction. However, there is no evidence of extensive net longshore transport as the beach is essentially compartmentalised between rocky reefs. As noted in WorleyParsons (2008), there may be some transport of sand from Woonona Beach around Flat Rock into the compartment.

In the case of cross-shore sand transport, an analysis of photogrammetric data between 1961 and 2005 found that Bulli Beach became flatter near MSL in 1974, presumably as a result of the major ocean storms, and it took until 1993 for the former beach slope to ŏrecoverô(WorleyParsons 2008). CLT (2010) noted that the southern end of Bulli Beach experienced heavy erosion as a result of the 1974 storms, losing over 200 m^3/m of sand in some areas. At the northern end of the beach some erosion was also experienced, but the extent of this was significantly less due to the wave protection offered by rocky outcrops that surround the headlands. Between 1974 and 1993, there was considerable accumulation of sand above the mean water level.

3.5 Salinity Regime

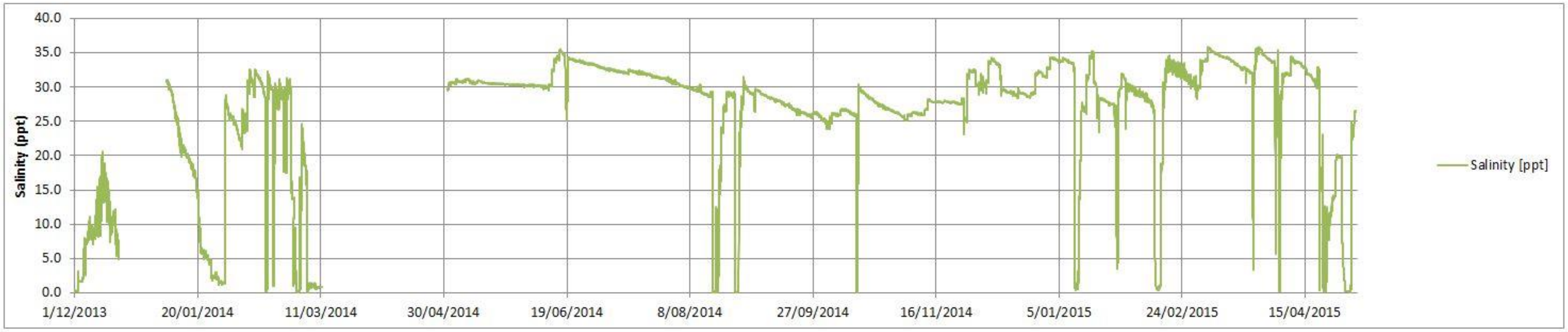
Salinity is also measured at the Whartons Creek entrance gauge. A plot of salinity concentration from December 2013 through to April 2015 is presented in **Figure 5**.

Salinity in the creek appears to approximate ocean salinity (> 25 ppt), except at particular times when the concentration drops significantly to almost zero. It is interesting that the periods of low salinity were very short lived, with ocean salinity levels rapidly re-established. It is noted that the entrance was open for long periods during the period of record. About 15 occasions can be counted over the 16 month period when salinity dropped in excess of 20 to 25 ppt. These marked salinity changes are due to freshwater inputs associated with relatively high rainfall events or wet periods of sustained lower rainfall as indicated by the rainfall records shown in **Figure 4**, associated with a breakout during which saltwater is purged from the entrance and lower creek. A sustained entrance opening would clearly lead to rapid re-establishment of oceanic salinity levels inside the entrance.



Notes: gaps in water level data due to gauge damage, where creek is not shown open or closed relates to times when the entrance was shoaled or just closing or gaps in photomonitoring.

Figure 4 Whartons Creek Water Levels and BoM Bellambi Station Rainfall Records December 2013-April 2015



Note: gaps in salinity data due to gauge damage.

Figure 5 Whartons Creek Salinity Levels December 2013-April 2015

3.6 Entrance Behaviour

3.6.1 Fluctuations in Beach Berm Levels

Surveys of the entrance area and adjacent beach were carried out by WCC monthly between July 2014 and April 2015. Survey plans are included in **Appendix B**. Shore-normal cross sections were extracted through the entrance throat, and 30 m north and south along the beach as shown in **Figure 6**.

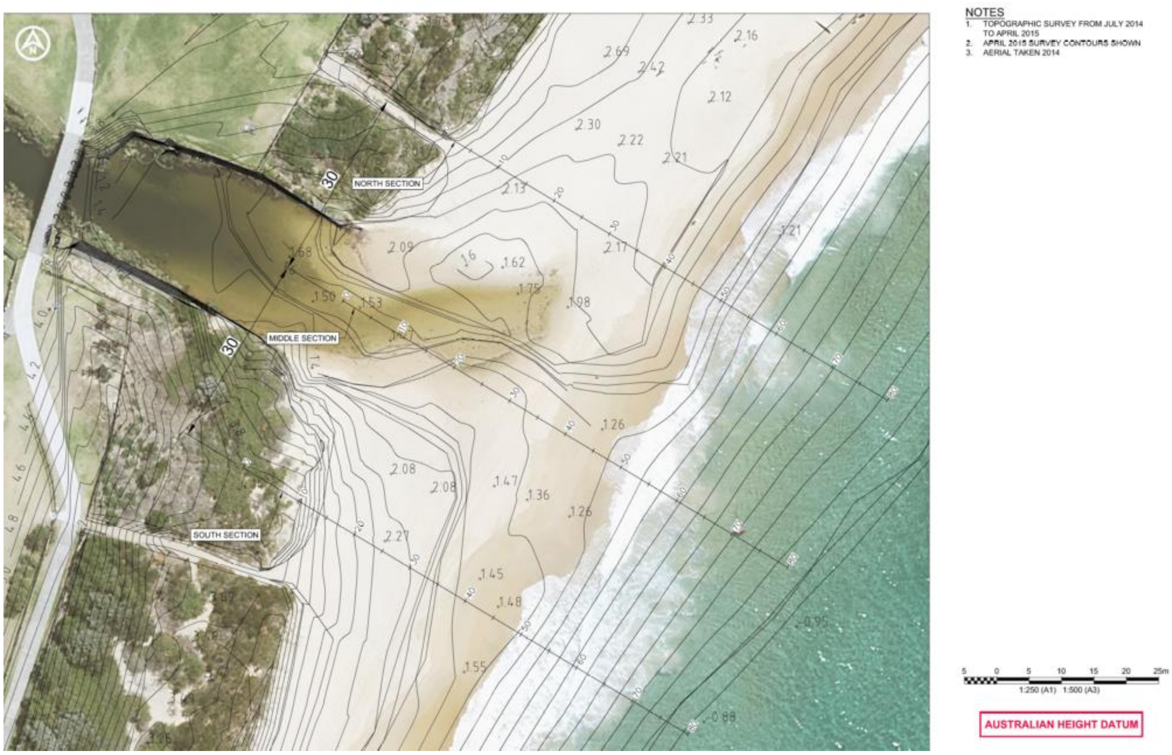
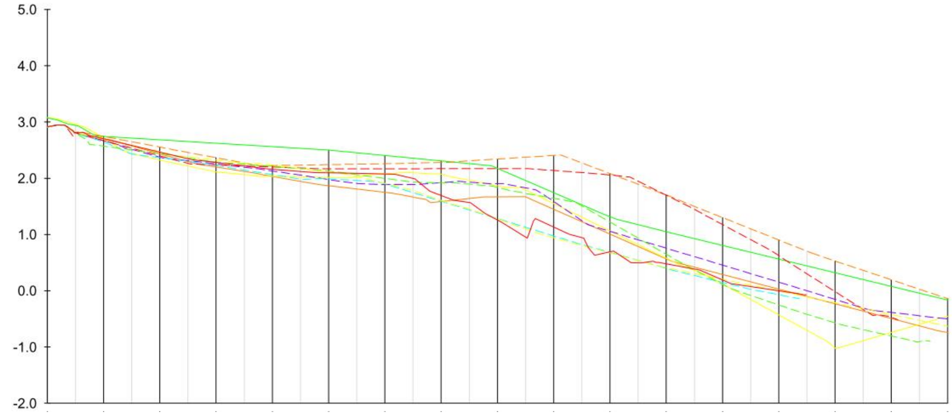


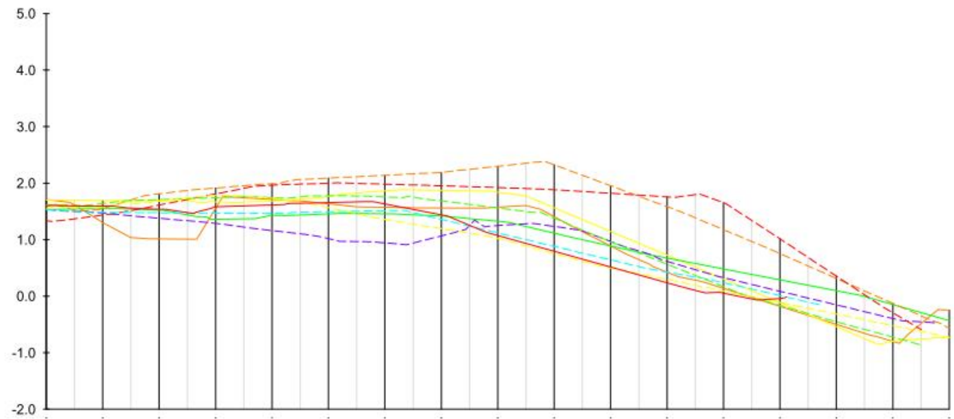
Figure 6 Location of Shore-Normal Cross Sections

The surveys show an accreted beach berm crest between 2.3 and 2.4 m AHD located about 30 m from the mean water line. The fluctuation in beach level at this crest point ranges up to 1.5 m (minimum depleted berm level approximately 0.9 m AHD), with the major breakout clearly shown between August and September 2014, and a lesser breakout shown between March and April 2015.

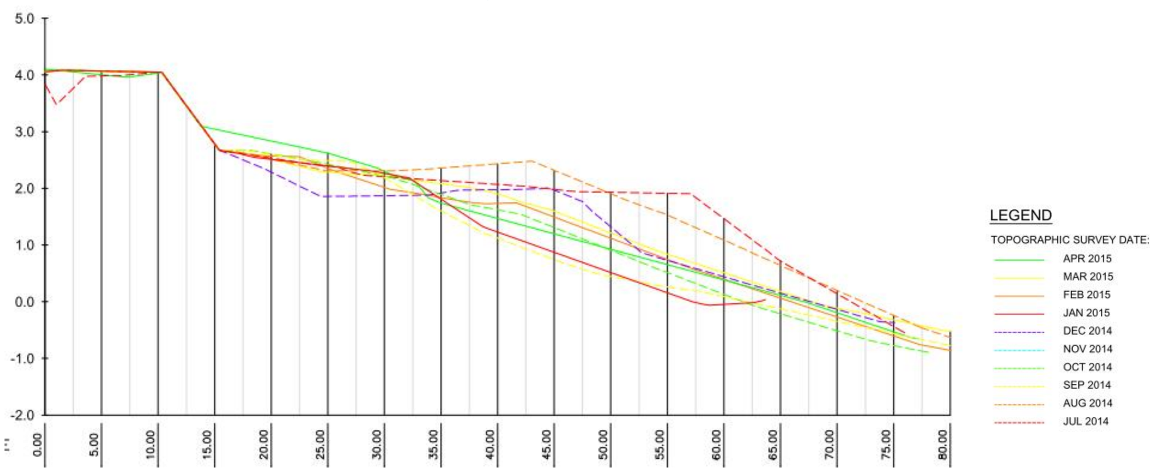
As expected, the recovery of the berm was delayed over the period the creek was open (August 2014 to February 2015). The cross sections show little bias in beach width or berm height variation overall between the sections north and south of the entrance throat.



Section North of Entrance



Section through Entrance



Section South of Entrance

Figure 7 Cross Sections July 2014 to April 2015

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3.6.2 Entrance Orientation

A close inspection was made of the monitoring photos taken by WCC to characterise the condition of the entrance as being open or closed, and to gauge what general orientation the entrance throat held in those conditions. Reference was also made to WCC's monthly surveys. A summary of the monitoring and rainfall data is provided below. **Plate 16** shows the entrance on 19 November 2013.

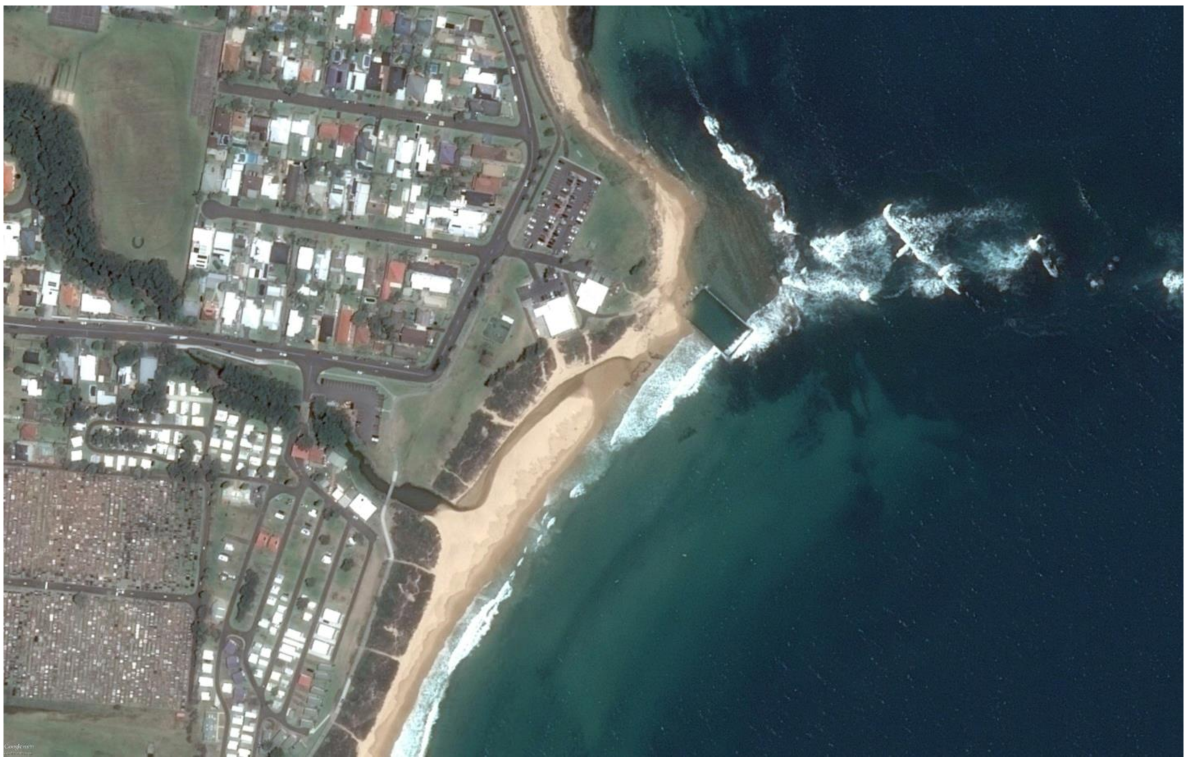

Plate 16 2013 major breakout to the northeast (Google Earth Pro V 7.1.4.1529. (19/11/2013). CNES / Astrium 2015)

- Following excavation of the creek channel directly out from the entrance on 7 February 2014 and using the sand excavated from this to fill the northern scour channel, the entrance channel remained open to at least mid-April with the orientation varying from south to southeast, see **Plate 17**. The data suggests the directional basis was more easterly through this two month period to early May 2014. Rainfall was relatively high during this period, up to a daily average of 22 mm between 21 and 28 March.
- From early May 2014 it appears the entrance started tracking northeast and action was taken by WCC on 16 May to prevent this by mounding sand on the northern side of the entrance, after which the entrance remained closed during a period when there was no rainfall.
- The entrance started flowing northeast again and on the 1 June 2014, two children dug a channel through the beach berm directly out from the creek allowing pooled water to flow directly to the ocean. This easterly opening was short lived and the entrance channel re-established to the north within a few days. By 13 June 2014, the entrance had closed and remained so for about 2 months when very little rain fell.

- The entrance was open again by 22 August 2014 after an average daily rainfall of 19 mm from 12 August 2014 and essentially remained so for 6 months. The entrance orientation first tracked east, then northeast. Overwash into the entrance during high seas was observed at the end of September, see **Plate 18**. Entrance shoaling was noted in late October 2014.

Plate 17 Entrance flowing southeast (WCC 3/4/2014)

Plate 18 Seas washing over berm into creek (WCC 4/9/2014)

- From early November the entrance tracked east, then northeast. Entrance shoaling was noted in early January 2015.
- After average daily rainfall of 27 mm between January 9 and 11, the entrance opened and tracked east, northeast and then north, see **Plates 19** and **20**. Entrance shoaling was noted in early March 2015.
- On 18 March 2015, WCC mounded sand across the channel north of the entrance to direct flow to the east, after which entrance shoaling was noted.
- Following an average daily rainfall of 28 mm between 16 and 23 April 2015, the entrance was flowing to the northeast before shoaling around mid-May 2015.
- The entrance was open again by 28 May and flowing to the northeast before shoaling by 11 June 2015.

Plate 19 Open entrance after heavy rain (WCC 11/1/2015)

Plate 20 Entrance open and flowing north (WCC 6/2/2015)

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3.6.3 Factors Influencing Creek Openings and Orientation

Factors influencing creek breakouts, time over which the entrance remains open and entrance channel orientation include:

- **Rainfall intensity and duration**: Whartons Creek has a relatively small catchment and water volume, hence water levels within the creek respond relatively rapidly to rainfall events.
- **Exposure to swell waves**: the proximity of creek entrances to headlands and reefs affects their exposure to waves. Whartons Creek is located at the northern end of Bulli Beach which faces southeast and hence the entrance is directly exposed to waves from this direction. Waniora Headland and associated reefs provide some protection from swell waves from the northeast.
- **Wave climate**: as noted in **Section 3.4** the dominant offshore wave direction is from the SSE. However, swell waves reaching the shoreline are modified by refraction due to nearshore bathymetry and nearshore wave-induced currents (e.g. rips and longshore currents). Typically, nearshore wave action (onshore currents) and tidal currents act to rebuild the entrance berm after breakout (NSW Government 1990). However, extreme waves would erode the beach berm and major ocean storms are typically accompanied by high rainfall leading to entrance breakout.
- **Longshore currents**: these currents drive sediment transport along the beach and hence are responsible for differentials in beach berm height. Longshore currents are generated by waves breaking at an angle to the beach, by feeder currents to rip cells, and from longshore variations in water level resulting from nearshore wave conditions and wind stress. Discharges from small coastal creeks often flow alongshore within a nearshore channel before crossing the offshore bar at a rip location (NSW Government 1990).
- **Water level differential**: spring low tides can increase the intensity of an entrance opening (greater velocities and scour) due to the relatively large difference in water levels between the ocean and creek.

Analysis of Available Data from December 2013 to April 2015

The monitoring tasks undertaken by WCC have permitted an improved understanding of the morphological behaviour of the entrance. As discussed below, rainfall largely dictates the occurrence of entrance openings. Typical minor to moderate waves are of little consequence, and there was no evidence from analysis of data between December 2013 and April 2014 that the wave direction plays a part in entrance channel orientation. In addition, management interventions by WCC and others over this time did not result in a sustained redirection of the creek entrance channel once it had tracked to the north.

A sustained opened condition it would seem requires a sustained period of wet weather which is attributed to the relatively small catchment and waterway volume. If the entrance is closed during a period of low rainfall, it is unlikely to reopen and there is no suggestion from the data that a sustained opening can be triggered solely by a coastal (wave) storm event.

The average rainfall encountered over the August 2014 to April 2015 opening period (8 months) was slightly lower than during the February to April 2014 opening period (2.5 months), although there were short high rainfall intensity periods, specifically between the 9 and 11 January 2015, and between the 16 and 23 April 2015. The major creek opening event that occurred around the 23 April 2015 due to the East Coast Low only lasted about one week before the beach berm was re-established. Monthly rainfall totals for March 2014 (290.4 mm), August 2014, January 2015 and April 2015 were well in excess of long term (1997-2015) averages as shown in **Table 3**.

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Table 3 Mean Monthly Long Term (1997-2015) and June 2014-May 2015 Rainfall Totals

Mean Rainfall	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May
2014/ 2015	42.0	2.6	279.8	37.4	93.8	47.4	110.4	170.8	96.2	71.8	301.8	113.2
1997 - 2015	112.7	80.4	88.3	57.9	78.2	97.5	74.4	78.4	142.4	104.6	105.1	88.2

Using a water balance model and rainfall records (University of Wollongong station) from May 2006 to the end of April 2007, GHD (2007b) estimated the frequency of Wollongong coastal creek and lagoon openings. For this 12 month period there were seven rainfall events with a high probability of causing major estuary breakouts (24 hour rainfall exceeding 30 mm and/ or several smaller consecutive events), and a further nine events with the potential to generate minor breakouts (Ó25 mm total rainfall in a three day period).

No correlation was evident from the available data between offshore wave direction and entrance channel breakout bias. An inspection was made of the wave climate during the monitoring period, with specific reference to average wave directions. Directional deepwater waverider buoy data for Port Kembla was available up to the end of 2014 and for Sydney to the end of April 2015. The Port Kembla data is representative of conditions at Bulli Beach. An attempt was made to correlate the offshore wave direction records between Sydney and Port Kembla in order to extend the wave information to cover the 2015 monitoring window, however a low correlation was observed and this was omitted. Accordingly, this limited the wave direction-entrance behaviour correlation assessment to a 10 month period ending December 2014, as shown in **Table 4**.

Mounding sand on the northern side of the entrance and artificial breakouts appear to do relatively little to prolong an easterly to southerly bias. Within a fortnight of mounding sand on the northern side of the entrance on 16 March 2014, the channel had largely re-established to the northeast. This was also essentially the case for similar work in March 2015.

The action of two children on 1 June 2014 may well have drained the pond which had formed at the entrance behind the berm, but did nothing to encourage or prolong an easterly bias in the entrance channel across the beach as noted in **Table 4**. The water level as recorded inside the entrance on 1 June 2014 was 2.19 m AHD at 10.00 am, dropping 0.5 m in about an hour and by up to 0.7 m by 5.00 pm.

Although relatively short lived, the most significant entrance modification affecting directional bias of the entrance was the beach reshaping work carried out by WCC on the 7 February 2014. Over the February through to April 2014 period the channel alignment was south to southeast, quite different from that observed over between August 2014 and April 2015 when the entrance retained an easterly to north easterly bias.

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Table 4 Summary of Entrance Monitoring and Wave and Rainfall Data

WCC monitoring event	Photo monitoring/ survey dates	Available wave data between monitoring dates (Port Kembla buoy) Average Hso (m)	Average Tp (s)	Average wave direction (deg TN)	Max Hso (m)	Average daily rainfall between photo dates (mm)	Entrance Condition Open S	Open SE	Open E	Open NE	Open N	Shoaled/ Closing/ Just closed	Closed	**Comments:** green shading indicates management intervention by WCC or others
1 photo	21-Feb-14						X	X						Reshaped beach to N on 7 Feb to make safe after severe northerly excursion of entrance
2 photo	28-Feb-14					2	X	X						
3 photo	7-Mar-14	0.9	10.7	139	2.0	14	X							
4 photo	21-Mar-14	1.0	9.9	107	2.1	2	X	X						
5 photo	28-Mar-14	1.4	10.2	125	2.4	22	X							
6 photo	3-Apr-14	1.1	8.4	133	1.9	4		X	X					
8 photo	11-Apr-14					6	X	X						
9 photo	16-May-14					0			X			X	X	Mounded sand on N side
10 photo	30-May-14					0							X	
	1-Jun-14									X			X	Northerly pond on beach breached by kids
	3-Jun-14								X					Pond emptied and entrance reestablished to north in few days
survey	8,9,10,14-Jul												X	
11 photo	13-Jun-14	1.6	9.0	148	3.0	3							X	
12 photo+surv	27-Jun-14	1.4	10.5	165	4.1	0							X	
13	11-Jul-14	1.3	10.4	149	2.5	0							X	
14	25-Jul-14	1.2	9.8	134	3.4	0							X	Unauthorised attempt to breakout entrance
15	12-Aug-14	1.2	11.9	153	3.1	0							X	
16	22-Aug-14	1.8	12.4	157	2.5	19			X					Wave data missing 16-23 Aug
17	4-Sep-14	1.6	10.2	112	2.1	8			X	X				Wave data missing 3-4 Aug
survey	9-Sep-14									X				
18	19-Sep-14	1.3	9.4	141	2.7	1			X	X				Wave data missing 4-7 Aug
19	2-Oct-14	1.4	9.0	121	2.9	0				X	X			
survey	2,7-Oct-14									X				
20	16-Oct-14	1.4	8.6	93	2.2	6			X					Wave data missing 14-16 Oct
21	31-Oct-14					0			X			X		Large wave data gaps
survey	5,6-Nov-14								X					
22	13-Nov-14	1.5	8.9	145	2.9	0			X					
23	28-Nov-14	1.5	9.6	135	2.4	3			X					Wide opening - 23mm on 27 Nov
survey	3-Dec-14								X					
24	12-Dec-14	1.8	9.2	104	4.3	6			X	X		X		
25	9-Jan-15					2				X		X		
26	11-Jan-15					27			X	X				Recent opening, deep channel through berm, 53mm on 11 Jan
survey	19-Jan-15								X					
27	23-Jan-15					4			X	X		X		
28	6-Feb-15					5			X	X		X		
survey	18-Feb-15									X				
29	20-Feb-15					4				X				Recent opening
30	6-Mar-15					3				X	X	X		
survey	17-Mar-15										X		X	
31	19-Mar-15					0			X				X	Pool head facing E, sand mounded on N side on 18 March
32 photo+surv	16-Apr-15					5			X			X		
33	23-Apr-15					28				X				Major opening, dune erosion due to East Coast Low
34	30-Apr-15					2				X		X		
35	18-May-15								X			X		
36	28-May-15									X		X		Minor opening
survey	3-Jun-15									X		X		
37	11-Jun-15									X		X		Significant opening before current closing indicated by wide and low berm

Notes: where unshaded cross notes channel direction, entrance was only open on high tide or prior to mounding sand on north side or no observations were available.

3.6.4 Potential Impacts of Climate Change on Entrance Behaviour

The potential impact of climate change on rainfall patterns in temperate regions is predicted to be an increase in the frequency and intensity of storm events which could lead to an increase in estuary breakouts. This may be offset to some degree by rising sea levels causing transgressive migration of barrier systems and an increase in berm height, leading to higher ICOLL water levels being required for estuary breakouts (GHD 2007b).

4 Entrance Management Options

4.1 Do Nothing/ Reshape Beach after Breakout

The do nothing option would mean no management intervention to direct creek breakouts and keeping the current configuration of the trained entrance and gabion baskets. This does not mean that creek breakouts would follow a natural cycle as the impact of the trained entrance is likely to have increased the frequency of natural breakouts. Based on a comparison of water level data (1992-2003), CLT (2007) found that the average annual number of breakouts for Towradgi Lagoon (which is also trained by gabion baskets) was almost twice that of the untrained Fairy Lagoon. However, it was noted that water level data prior to installation of the gabions was not available to confirm the impact of the training works.

As noted in **Table 1** major erosion occurred at the northern end of Bulli Beach in 2009 and 2013 which resulted in major impacts on beach amenity and access as described in **Section 1.5**. Less significant events would also impact on beach amenity and access, requiring beach maintenance. Based on this, it has been assumed that significant impacts due to northward migration of the entrance channel could occur every 2-5 years. Costs would still be incurred for the ódo nothingô option as board and chain beach accessways would need to be repaired/ raised as sand levels built up. There would also be costs associated with maintaining/ replacing the gabion baskets. As shown in **Plate 15**, some of the gabion baskets are damaged, with broken wires posing a potential safety issue.

Other ócostsô associated with the ódo nothingô option include additional time to set up for beach patrols and increased emergency response times when normal pedestrian and vehicular access from Bulli SLSC is not possible to due to the steep scarp. As noted in **Section 1.5**, SLSC patrol members also need to monitor beach goers (especially children) to ensure they are not at risk from collapse of the steep scarp, as well as monitoring those in the rock pools and surf.

If no entrance management activities were undertaken there would continue to be periodical damage to the vegetated dune north of the creek, together with damage to beach and access for WCC Lifeguards and Surf Life Savers. Recovery of the beach following scour from the entrance channel is likely to be slow (months) and, in the past, impacts have been considered unacceptable necessitating creek realignment and beach restoration as described below.

The last creek diversion works undertaken by WCC in February 2014 involved excavation of an area approximately 3 m wide by 10 m in length to a depth of 1 m (30 m^3 of sand). This sand was placed on the northern side of the excavated channel and then moved by a dozer and spread over the back of the beach to fill the creek scour channel as shown in **Plate 21** (WCC 2013). The cost associated with creek realignment and reshaping the beach was approximately $20,000. Based on monitoring data, the impact of these works resulted in a south to southeast entrance channel orientation for only about two months before reshaping of the beach berm under natural processes resulted in the entrance channel reverting to the east/ northeast.

Plate 21 Reshaping of beach/ dune following entrance scour (WCC Feb 2014)

4.2 Manage Berm Height/ Dry Notch

4.2.1 Build-up Northern Side of Entrance

This is the current WCC approach and is undertaken periodically in conjunction with ocean pool cleaning, while the machinery is already on the beach. It involves moving sand from the beach berm to the south of the entrance and mounding this up on the northern entrance bank as shown in **Plates 22** and **23**. At the time of the 2014 photo (**Plate 22**) monitoring notes indicated that the creek was only just closed (tidally). In 2015 (**Plate 23**), it was noted that sand had been placed the previous day as the entrance had started deviating to the north. The entrance was not opened in the process.

Based on monitoring information, it is estimated that this work would be undertaken about 3-4 times per year. Although it can be cost-effectively undertaken as part of normal pool maintenance works (cost approximately $2,500), timing may not coincide with an imminent breakout to the north. In addition, it appears that the effect of these works in encouraging an east/ southeast channel orientation is short lived due to fairly rapid beach berm reshaping under natural processes.

Plate 22 Entrance following 2014 works (WCC 16/5/2014)

Plate 23 Entrance following 2015 works (WCC 19/3/2015)

4.2.2 Regular Berm Shaping

This option was the management option employed by WCC prior to 2009, where the beach berm at the entrance was shaped to maintain a lower ónotchô in an attempt to ófixô the location of creek breakouts, with sand removed from the berm placed to the north of the creek. The dry notch would be at least the width of the entrance (about 20 m between the gabions).

In an assessment of options for Towradgi Lagoon, CLT (2007) estimated that works to maintain the berm at a lower height would be required monthly or bi-monthly. As was the case previously, this work could be undertaken cost-effectively in conjunction with pool maintenance at a cost of about $2,500. As noted in **Section 2.9** pool cleaning is undertaken monthly in summer and about 6 weekly in winter.

This option is likely to lead to more frequent entrance breakouts as the entrance would be artificially maintained at a lower level and may reduce the period of time the entrance is open (depending on wave conditions) due to reduced hydraulic head to drive entrance scour. More frequent breakouts would impact creek ecology and may also impact on beach amenity. As for the option above, the beach berm would be reshaped relatively quickly by natural processes in between works.

4.2.3 Event-Based Dry Notch Excavation

As noted in **Table 1**, breakout of Whartons Creek is not required for flood mitigation purposes. However, on occasions WCC has excavated a dry notch to direct the creek breakout channel to the east/ southeast when breakout is imminent.

Based on the review of data from December 2013 to April 2015, breakouts could occur around 3-4 times per year. Note that this is dependent on rainfall patterns. WCC indicated that the cost to excavate a dry notch is about $5,000.

Timing of this work, such that a breakout coincides with the turning of the high tide could promote a deeper scour channel and longer period over which the channel maintains the alignment. However, this may be short-lived depending on nearshore wave direction. This option requires monitoring of rainfall, water level and tide data and is dependent on plant being available at the optimum time for breakout. It would be expected that this option would result in fewer breakouts than regular berm maintenance as it does not interfere with the natural process of berm building.

4.3 Northern Creek Training Wall Extension

To control creek breakouts to the north using this option alone, it would be expected that the training wall would need to extend to at least the crest of the beach berm. As shown in **Figure 6**, the general alignment of the toe of the frontal dune is approximately 10 to 15 m out from the end of the gabion walls with the berm crest further seaward. The structures would normally be buried under the beach and only exposed when beach levels were low following storm events. The low profile of the training wall would have little impact on sediment transport. Hence sand would not be expected to build-up to any significant extent on the southern side of the wall and erode on the northern side of the wall when sediment transport was to the north.

A number of construction types could be used to extend the northern training as described below, including geotextile bags. Using geotextile bags would provide the flexibility to sequentially trial various training wall extensions to establish an optimum length and configuration. This óoptimumô design would involve a compromise between creek entrance training, beach amenity, access requirements for maintenance vehicles along the beach, risk of damage and cost.

Note that the structures described below (and shown in **Figures 8** and **9**) are at a conceptual level. The concept design focusses on taking into account the impacts of extreme rainfall events, but also has regard to damage during extreme wave events. In an extreme ocean storm, the vegetated frontal dune would be substantially eroded, see location of current 100 year Hazard Line on **Figure 8** (**Appendix A** provides more information and predicted future hazard lines). It is clear from this that there would be little point in designing a creek training wall to withstand an extreme ocean storm event, as the dunes it would be designed to protect from creek scour would be eroded by storm waves. Hence maintenance/ restoration of the structure, along with the dune would be required after major storm events.

A longer northern training wall would stabilise the entrance more to the east/ southeast, but northward migration of the breakout channel could still occur around the end of the structure due to the dominant direction of sediment transport to the north. However, the resulting scour channel (which would extend further seaward and typically through the crest of the beach berm) would be shorter before reaching the waterline. Although the location of the berm crest is variable, the creek would typically discharge seaward of this (highest point on the beach), hence instances of the channel bending around the end of the structure and causing erosion as far back as the toe of the vegetated dune would not be expected.

4.3.1 Geotextile Bag Trial Extension

This would likely involve an extension to the northern gabion wall using 2.5 m^3 sand filled geotextile bags, configured with either two bags at the bottom and one on top (three bag configuration), or a larger three bottom, two middle and one top bag (six bag configuration). A three bag, 10 m extension could initially be trialled to assess its effectiveness. The bags would be filled with sand from the area south of the entrance and moved into position with an excavator. Additional bags could be filled and buried in the beach south of the entrance and added to the original structure as required, or could be used as replacement bags if they were needed at short notice due to damage from storms or vandalism. This option would involve continuation of WCCös current photomonitoring and beach surveys. The length of the trial would depend on weather conditions (i.e. frequency of breakouts) but would be expected to be at least 12 months and up to three years. Once an optimum length and configuration was identified, the structure could be maintained as is. A conceptual cross section showing the geotextile bag extension is shown in **Figure 9**.

For the purpose of option comparison, the estimated cost for a 10 m long, three bag training wall with vandal deterrent covering each side would be approximately $50,000 and a six bag configuration approximately $60,000. Note that site preparation is a large component of these costs, compared to materials. The design life of these structures would be around 15 years largely governed by vandal damage, general durability of exposed geotextile materials and severity of actual ocean storm events. The predicted location of the slumped back beach erosion scarp (hazard line) for a severe storm event occurring today is approximately 5 m landward of the seaward end of the existing northern gabion wall.

More efficient entrance training may result in an increase in the frequency of entrance breakouts. Being a ésoftô engineering option means the geotextile entrance training wall could be readily adapted to changing conditions, such as any change in shoreline position due to sea level rise and the position of the toe of the vegetated dune should further shoreline accretion (perhaps unexpectedly) occur.

Figure 8 Training Wall Extension Concept Plan [100 year ARI immediate Zone of Slope Adjustment line shown CLT (2010)]

4.3.2 Rock Training Wall

As an alternative to a geotextile bag wall and if a longer life extended entrance training option was required, a rock rip-rap training wall extension could be considered once the optimum length of the wall was determined through the trial described above. For the purposes of options comparison a training wall 10 m long and 1.5 m high, constructed with igneous rip-rap with a D50 of 0.4 m has been costed. This option would involve removing the gabions at the eastern end of the existing training wall to achieve the design height. A conceptual cross section showing the rock training wall extension is shown in **Figure 9**.

Based on the indicative concept described above the cost of a rock rip-rap training wall extension is estimated at $90,000. The estimated design life of the structure would be 40 years. However, as the structure could sustain damage during an extreme ocean storm event, larger rock (1-1.5 m nominal diameter) may be required at the seaward end, increasing costs.

In addition to an extension, consideration could be given to building a rock rip-rap training wall to the bridge to achieve a slight narrowing/ deflection of the existing northern wall alignment to further assist in directing flows to the south. Costs and the potential for excessive beach scour due higher flow velocities through a narrower channel would need to be considered at the detailed design stage, along with redesign of the stormwater outlet at the entrance.

Although achieving the same benefits as a geotextile bag structure and being less likely to suffer damage, a rock rip-rap extension would have more impact on beach amenity when exposed.

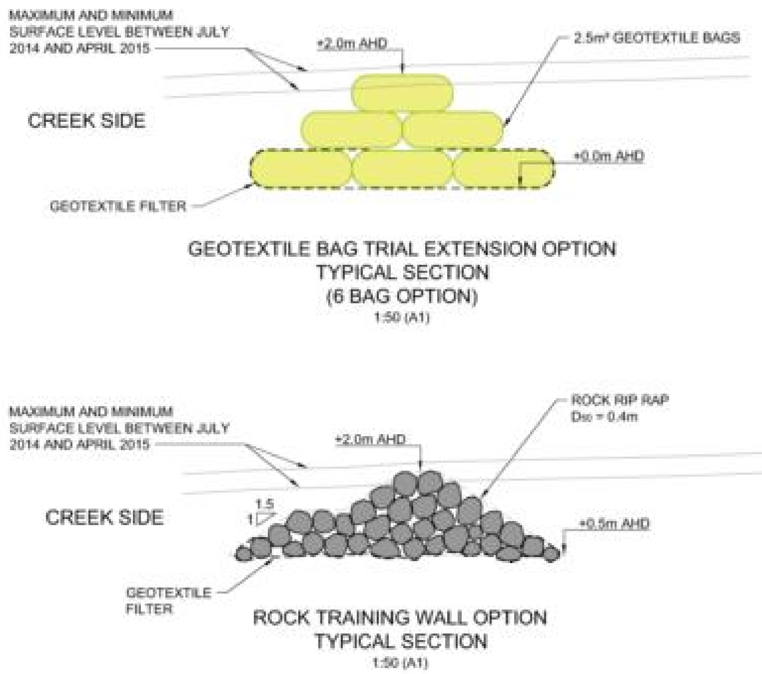

Figure 9 Conceptual Training Wall Cross Section

4.3.3 Gabions

As noted in **Section 2.8** and illustrated in **Plates 14** and **15**, the existing gabion wall on the northern side of the entrance has been subject to deformation and basket wires have broken at the eastern end of the wall. Gabions are not suitable structures along the open coast as they are subject to wave damage, vandalism and pose public safety issues when broken wires are exposed on the beach. In addition, once the gabion basket is damaged, rocks from within the basket would be shifted onto the beach under wave action and could pose a hazard to beach users. As shown in **Figure 8**, the entire creek entrance is currently at risk from erosion during a 100 year ARI ocean storm event with high future maintenance implications for this option. In view of this, an extension of the training wall using gabions has not been considered further.

4.4 Pipe/ Culvert Outfall

Piping the creek has not been considered in any detail as channelising even a modified natural system, such as Whartons Creek, would be inconsistent with environmental policy such as the *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI 2013) and would have a major impact on creek ecology. To avoid being blocked with sand, the outlet would need to extend several tens of metres from the shoreline into the surf zone and be a fully engineered coastal structure.

This would be a high cost option inconsistent with WCCôs objectives for an óaffordableô solution. In addition, installation of a pipe/ culvert at the entrance would require modification of the stormwater system (as shown in **Plate 12** a stormwater pipe discharges into the entrance area) and may impact on local stormwater flooding. As shown in **Figure 2**, the sewer main crosses the creek entrance at approximately 0 m AHD and excavation to ensure the pipe/ culvert would normally be buried under the berm could impact on this pipeline.

A pipe/ culvert outfall would impact on beach amenity, and extending into the patrolled swimming area would pose a hazard to swimmers and surfers. As such this option was not considered further.

5 Options Assessment

5.1 Summary of Options, Costs and Potential Impacts

To provide an indication of maintenance requirements for built options, **Table 5** shows the probability of various storm events affecting Bulli Beach over 15 years (the design life of geotextile bags) and the associated approximate distance of eroded beach in relation to the estimated current seaward end of the northern gabion wall. **Table 6** provides a summary of the options described in **Section 4**, apart from the options not considered practical on environmental and public safety grounds, i.e. gabion extension and piping the entrance. The assessment is presented in terms of:

- Likely costs (indicative only, not including costs associated with detailed design, impact assessment or approvals). As the design life of geotextile bags is 15 years, estimated costs over 15 years for each option has been provided for comparison.
- Likely effectiveness in achieving and maintaining a breakout straight across the beach and/ or mitigating the impacts of entrance scour on the dunes to the north.
- Other advantages such as timing in conjunction with other beach maintenance activities.
- Disadvantages including potential adverse impacts on beach access, visual amenity, recreational use and ecology.

Table 5 Probability of Various ARI Storm Events Occurring Over 15 Years

ARI Storm Event	Estimated Volume Eroded (m^3/m)	*Approximate Distance Eroded from Current Buried Seaward End of Northern Gabion Wall (m)	Probability over 15 Years (%)
100 year	250	-10	14
50 year	220	-5	26
20 year	180	0	54
5 year	120	5	96
2 year	80	10	100

**Estimated horizontal distance to Zone of Slope Adjustment (+ve measured seaward). Based on CLT (2010) and storm erosion trends for NSW open coast after Gordon (1987)*

As described in **Section 2**, it is noted that Whartons Creek is a modified system as a result of:

- riparian corridor clearing
- catchment development and discharge of urban stormwater to the creek
- bridge constrictions
- entrance training works.

As noted in **Section 2.6**, GHD (2007b) identified water quality issues and low species diversity within the creek system. In view of this, none of the options identified below is likely to have a significant impact on creek ecology. Generally, these works would be permissible without consent under *State Environmental Planning Policy (SEPP) Infrastructure*. As noted in **Section 2.9**, a licence under the *Crown Lands Act 1989* is required for major beach reshaping and would also be required over the area occupied by a training wall extension. A training wall extension may also require approval from the Coastal Panel under the *Coastal Protection (CP) Act 1979*, unless it is included in a Coastal Zone Management Plan. Adoption by WCC and certification of the Wollongong Coastal Zone Management Plan (CZMP) under the *CP Act* is pending release of the Stage 2 Coastal Reforms. The current draft CZMP does not include an action to implement an entrance management plan for Whartons Creek. Further information on approvals, environmental impacts and mitigation measures will be provided in a Review of Environmental Factors (REF) for the preferred management option.

None of the options described in **Table 6** are inconsistent with the recommendations of relevant reports listed in **Section 1.7**, nor would they significantly impact on the implementation of management actions under these plans and strategies.

Table 6 Summary of Options Assessment

Option	Indicative Cost	Likely Effectiveness*	Advantages	Disadvantages
Do Nothing	$2000 (reinstate accessways as beach recovers) $10,000 over 15 years	N/A	- does not interfere with natural coastal processes, however, creek entrance is already modified	- periodical impacts on beach access, amenity and safety - damage to vegetated dune and accessways - relies on natural processes to re-establish beach and dune which could take an extended period of time
Excavate Channel and Reshape Beach	$20,000 $86,000 over 15 years	Medium term	- restores beach amenity - assists in directing creek breakouts to the south/ southeast - no structures required	- likely to be required every 2 to 5 years - damage to vegetated dune and accessways - temporary impacts on beach access, amenity and safety - new licence likely to be required each time works are needed
Build-up Nth Side of Entrance	$2,500 $113,000 over 15 years	Short term	- can be incorporated in regular pool maintenance	- likely to be required 3-4 times per year - entrance may breakout to north between scheduled maintenance activities
Maintain Low Berm	$2,500 $225,000 over 15 years	Short term	- can be incorporated in regular pool maintenance	- work undertaken every 1-2 months - entrance berm building between scheduled maintenance may result in breakout to north
Dry Notch Excavation (Event-Based)	$5,000 $226,000 over 15 years	Short term	- opportunity to maximise channel scour to southeast	- likely to be required 3-4 times per year - requires rainfall/ water level /tide monitoring - needs to be undertaken at short notice and possibly out of hours

Option	Indicative Cost	Likely Effectiveness*	Advantages	Disadvantages
Geotech Bag Training Wall extension (Nth Side)	$50,000 to $60,000 Maintenance $35,000 over 15 years	Long term	- easily removed/ modified to determine optimum configuration - trains entrance to southeast - utilises sand from beach system, no environmental issues if bags break - can be modified to adapt to changing conditions	- trial requires ongoing monitoring - subject to damage from ocean storms and vandalism - may affect vehicle access for maintenance activities on high tides - likely to require partial rebuilding within 15 years - relatively short design life - breakouts to north at end of structure still possible - more complex approvals process
Rock Training Wall extension (Nth Side)	$90,000 Maintenance $20,000 over 15 years	Long term	- trains entrance to southeast - potentially long design life - can be raised/ lengthened to adapt to changing conditions	- visual impact - impact on beach amenity - subject to damage in severe ocean storms - may affect vehicle access for maintenance activities on high tides - will possibly require maintenance due to storm damage within 15 years (depending on design criteria) - breakouts to north at end of structure still possible - more complex approvals process

** short term (a matter of days or weeks), medium term (a number of years), long term (provided structure maintained)*

5.2 Preferred Approach for Entrance Management

Based on stakeholder feedback (refer to **Appendix C** for more detail), the preferred management options included the geotextile bag training wall extension or an ongoing program of event-based dry notch excavation and/ or build-up of the north side of the entrance. The geotextile bag training wall option was preferred by the Bulli SLSC for beach amenity reasons and it was also one of the preferred options of OEH representatives and a representative of the Department of Primary Industries (DPI) on the ECZMC.

Council staff indicated that they would prefer not to install a wall extension on the beach, due to the impact of such a structure on beach management operations, and the perceived high maintenance costs due to potential storm damage. A dune reshaping project is being considered for Bulli Beach in 2016-17 as part of the Dune Management Strategy Implementation Plan, which would potentially impact on a new structure. Due to these concerns, an ongoing program of managing the sand height north of the entrance or an event based dry notch excavation was preferred, at least in the short term. These options were also supported by OEH and DPI (as an alternative to the geotextile bag training wall extension).

Other options that were preferred by members of the ECZMC included excavation of a channel and reshaping the beach or maintenance of a low berm and building up the south side of the entrance.

Based on the feedback received, the preferred entrance management strategy is:

- A three year plan for a program of sand relocation to build up the north side of the creek, based on specific operational triggers, with a simple procedure able to be implemented by City Works staff when cleaning out the Bulli pools.
- A review of this program to be undertaken in three years, including actual costs and impacts, based on monitoring and reporting as outlined in **Section 6**, Entrance Management Plan.
- This review to inform the long term management approach to follow, i.e. continuation of this program or reconsider proceeding to a detailed design for geotextile bag training wall extension.

6 Entrance Management Plan

The three year program for entrance management would comprise:

- monitoring
- relocation of sand in conjunction with regular Bulli Beach pool cleaning once triggers were reached
- event based sand relocation or dry notch excavation (mechanical breakout)
- reporting and review of Entrance Management Plan.

6.1 Monitoring

In addition to the monitoring and reporting program below, it is recommended that:

- A survey staff is installed to AHD in the vicinity of the pedestrian bridge in a location where there is always standing water (the existing pole for the water level recorder may be suitable, rather than installing an additional pole to mount the staff). The location needs to consider potential damage during flood flows and visibility, so that the water level can be easily read during site inspections.
- An additional photomonitoring point on the southern bank of the entrance is established to provide a view looking north of the creek entrance. Entrance monitoring photo points 1 and 2 near the childrenφs pool and café can be discontinued and monitoring frequency to be reduced, see below.
- A survey cross section through the creek entrance (central profile in **Figure 6**) is included in WCCφs regular Bulli Beach profile survey (currently carried out monthly).

Daily Monitoring

- Bulli seven day forecast (BoM website)

Regular Photomonitoring

Photomonitoring is to be undertaken prior to pool cleaning to determine if intervention is necessary, daily after intervention for about 1 week to determine the success of intervention, and following major rainfall and ocean storm events. Routine monitoring should occur on average about fortnightly however, if conditions are unchanged from the previous site visit this can simply be noted in the spreadsheet without taking new photographs.

Field Observations to be recorded in spreadsheet:

- photo date and time
- water level (read from survey staff)
- entrance condition (open, closing, closed)
- entrance orientation (S, SE, E, N, NE)
- berm height or height either side of channel (estimated from highest level of sand above creek water level)
- nearshore wave direction (estimated from observation, i.e. from south, onshore, from north)
- comments, e.g. unauthorised attempt to breakout entrance, major scour channel, minor scour channel

Additional Data (to be added to field observation spreadsheet)

- total average daily rainfall between monitoring dates (Bellambi BoM Station)
- average offshore wave height and direction (Port Kembla waverider buoy) (when available - to compare with estimated nearshore wave direction on day of photo)

6.2 Triggers

The following triggers for action are based on the findings of the Entrance Management Study and should be reviewed and refined annually, based on the results of ongoing monitoring.

- Case 1: Periodical Intervention (potential for entrance to meander north) - entrance closed and:
  - back beach area on north side of creek lower than berm crest, and/or
  - water level 2.0 m AHD or higher, and/ or
  - ponded water in entrance extends almost to seaward end of northern gabion wall (i.e. water/ berm interface is close to 18 m seaward of dune fence) and estimated difference between water level and berm height is less than 300 mm.
- Case 2: Event-based Intervention (potential for breakout) - entrance closed and predicted rainfall of around 20 mm/ day over three days, or higher rainfall over shorter period.

Despite this intervention, if the entrance meanders and breaks out to the north without resulting in a major impact on the beach, no action is proposed while it is open. Following closure, any remaining remnant northern channel should be filled to encourage subsequent breakouts to the east or south. In the event that an entrance breakout to the north results in major damage to the dune toe and beach accessways, this intervention program can be viewed as unsuccessful and should be reviewed.

6.3 Procedure

6.3.1 Works

In Case 1, sand relocation to be undertaken in conjunction with next scheduled maintenance of the childrenôs pool (undertaken at around 4 week intervals in summer and 6 week intervals in winter).

In Case 2, during swimming season, sand to be relocated or dry notch excavated for artificial breakout. Outside the swimming season, event-based entrance management would be a lower priority.

Sand relocation for Case 1 or Case 2 (see **Figure 10**):

- Sand to be excavated from between the south gabion training wall and first beach accessway to the south, from a few metres out from the toe of the vegetated dune out to the swash zone, an area of about 900 m^2 excavated to a depth of around 300 mm (up to approximately 270 m^3 of sand).
- Sand to be placed between the northern side of north gabion training wall and first beach accessway which is approximately 20 m to the north, extending from the toe of the vegetated dune to the highest point on the beach berm (variable but typically about 30 m seaward of the end of the northern gabion wall). The relocated sand should be on average at least 400 mm deep but at the lowest point in the beach profile would need to be at least 600 mm deep. Depending on the level of the back beach it may also be necessary to place sand over the vegetated toe of the dune so the beach profile slopes to the ocean. In the event that nearshore waves are from the northeast and hence sand movement is to the south, it may be necessary to place sand further north beyond the access track to maintain this

sand volume north of the entrance for a longer period of time than would otherwise result under these conditions.

- Additional sand to be placed immediately adjacent to the southern side of the end of the north gabion training wall for a distance landward of 10 m or more, if possible (depending on available plant) to reduce the entrance bed depth adjacent to the wall with the aim of pushing a subsequent scour channel to the south.

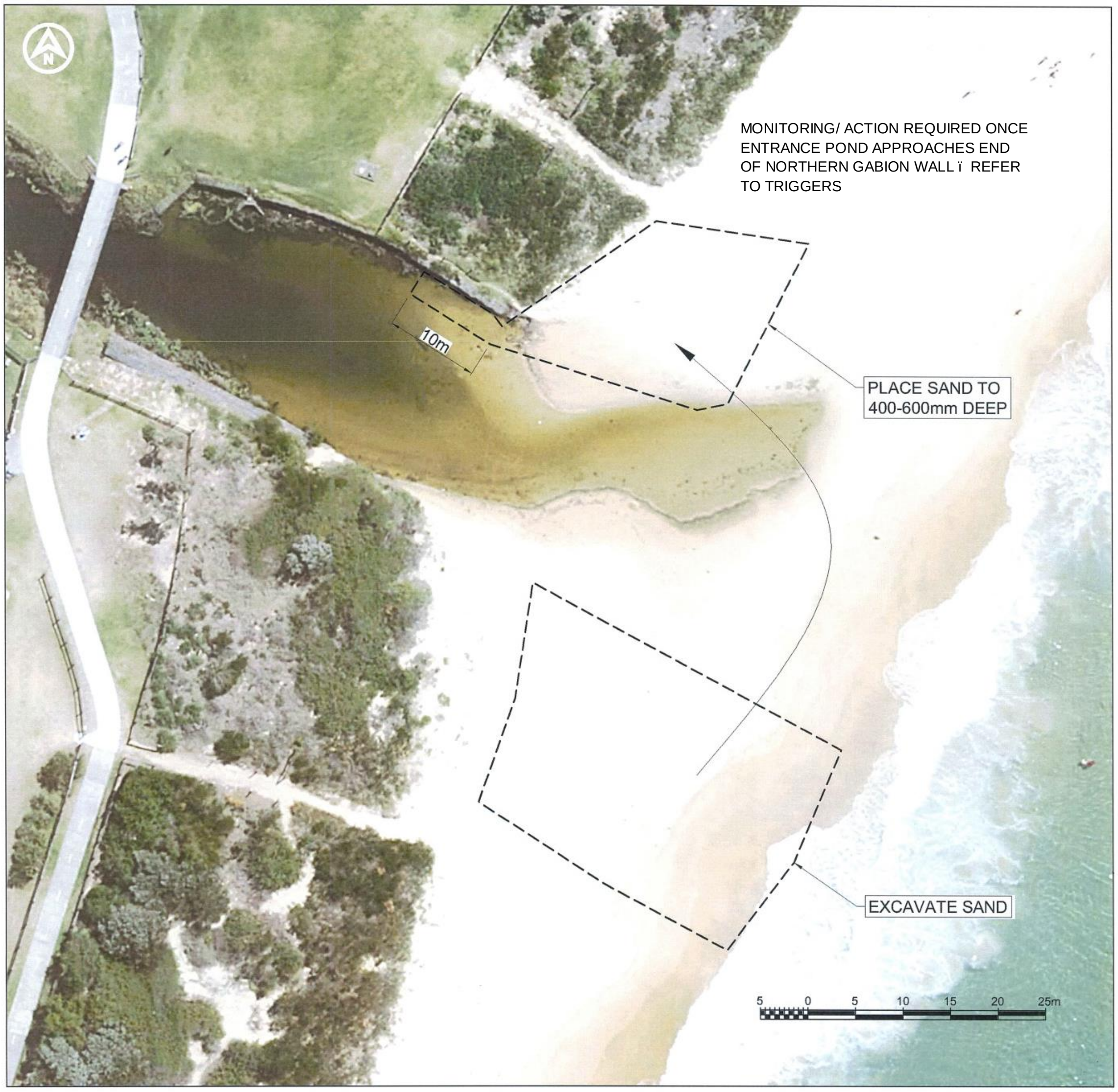

Figure 10 Typical Sand Relocation for Case 1 or Case 2

Mechanical breakout for Case 2 only (see **Figure 11**):

- Immediately prior to predicted rainfall or on commencement of rainfall event, pilot channel to be excavated perpendicular to the shoreline and a few metres out from the seaward end of the entrance water/ berm interface on the southern side of the entrance. Channel to be around 600 mm wide or wider (depending on excavator bucket), about as deep as the water depth in the entrance and extending out to swash zone.
- Last few metres of channel to be excavated through to water in entrance to induce breakout as close as possible to highest tide of the day, so that the maximum entrance scour is achieved with the falling tide.

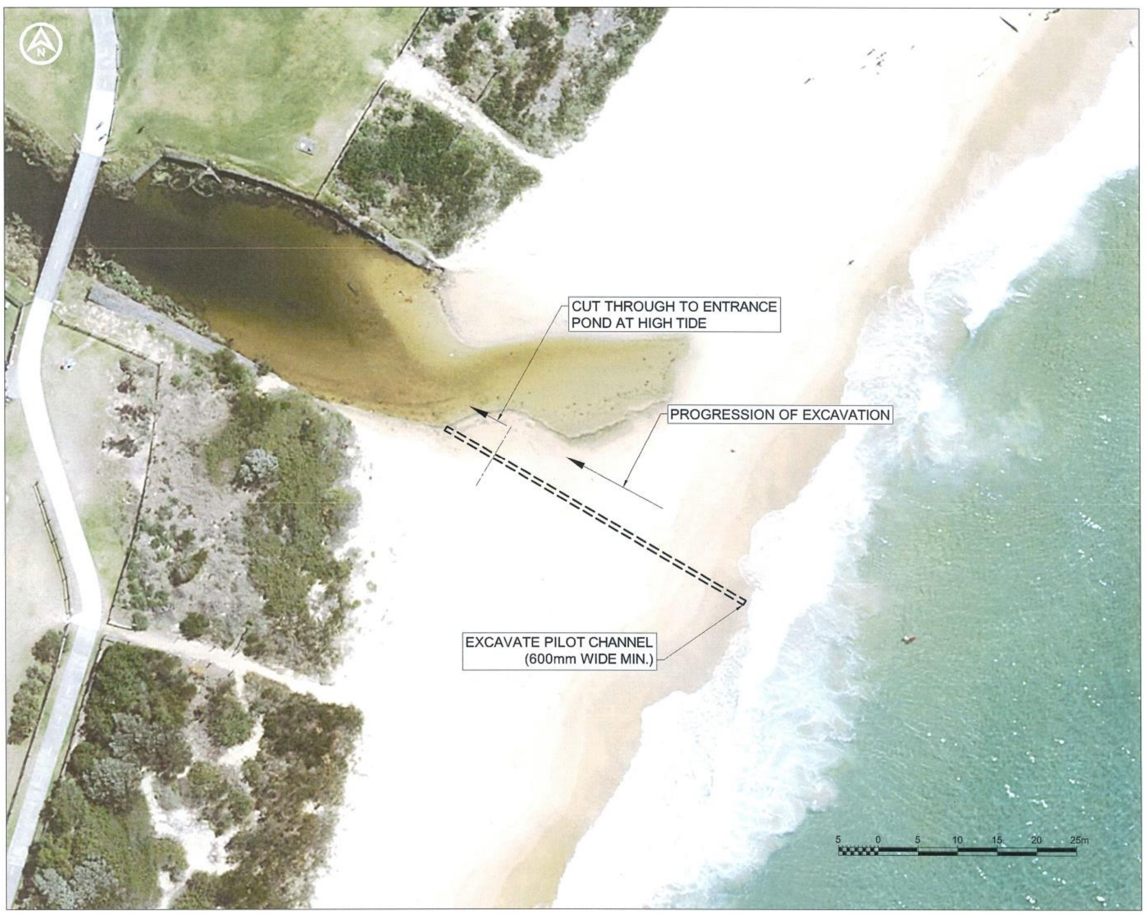

Figure 11 Typical Mechanical Breakout for Case 2

Based on available monitoring information for the period July 2014 to April 2015, up to three Case 1 and one Case 2 interventions may be required per annum.

6.3.2 Notification

- Council lifeguards and Bulli SLSC to be advised of timing of works during swimming season.
- In addition, for mechanical breakout, temporary signage to be installed to warn of high velocities during breakout and potential localised water pollution from creek discharge.

6.4 Reporting

6.4.1 Works

During/ following sand relocation and mechanical breakout photographs should be taken and the following details recorded:

- date of works
- plant involved and start and stop time (to estimate costs)
- approximate volume of sand moved
- for mechanical breakouts:
  - time of breakout and time of highest tide
  - water level in creek at breakout
  - estimated nearshore wave direction.

6.4.2 Annual Reporting

Annual reporting and assessment of the preferred entrance management strategy should include the following.

- Plot of rainfall (Bellambi BoM Station) and water level from automatic recorder in creek and inclusion of entrance condition (open/ closed) to extend the data record in the Entrance Management Study.
- Average berm height, average rainfall total immediately prior to entrance breakout, average water level at breakout, number of breakouts, typical longevity of breakouts (distinguish between natural and mechanical breakouts).
- Weather patterns influencing breakouts/ beach condition, e.g. higher or lower than average monthly rainfall, atypical seasonal offshore wave climate, severe weather (e.g. occurrence of BoM warnings for hazardous surf and damaging waves).
- Assessment of the likely impact of sand relocation works and mechanical breakouts on entrance orientation and maintenance of desired orientation to E, SE or S (e.g. desired entrance orientation achieved at breakout, channel orientation maintained until subsequent closure or for an extended period of time, little or no impact of creek breakouts on beach access, amenity or recreational use).

6.5 Action Plan

Table 7 indicates actions required to implement the Sand Relocation and Mechanical Breakout Strategy and, in the event that this is considered unsuccessful after the trial period, the Geotextile Bag Extension to the northern gabion training wall.

Table 7 Entrance Management Strategy Implementation Plan

Entrance Management Strategy	Action	Responsibility	Timeframe/ Frequency
Sand Relocation and Mechanical Breakout	Prepare environmental impact assessment	Draft REF prepared as part of this study	2016
	Obtain long term (at least 3 years) regulatory approvals	Environment Strategy & Planning Division	2016
Sand Relocation and Mechanical Breakout	Photomonitoring	Environment Strategy & Planning Division	2016-2019 (fortnightly)
	Survey (entrance cross section)	Environment Strategy & Planning Division and Project Delivery Division	2016-2019 (monthly)
	Periodical sand relocation (Case 1 trigger)	City Works & Services Division	2016-2019 (in conjunction with pool cleaning as triggers are met)
	Event-based sand relocation or mechanical breakout (Case 2 trigger)	City Works & Services Division	2016-2019 (depending on weather conditions)
	Reporting and annual review of triggers, work procedures, evaluation of outcomes, costs	Environment Strategy & Planning Division	2016-2019 (annually)
	Review of Entrance Management Plan	Environment Strategy & Planning Division	2019
	Adopt revised/ updated triggers and work procedures for ongoing entrance management	Environment Strategy & Planning Division	2020 (if 2016-2019 program considered successful)
	Revise original environmental impact assessment	Environment Strategy & Planning Division	2020 (if 2016-2019 program considered successful)
	Obtain ongoing approval for Entrance Management Plan	Environment Strategy & Planning Division	2020 (if 2016-2019 program considered successful)
Geotextile Bag Extension (only if above strategy is not considered successful)*	Prepare concept design and detailed design for geotextile bag northern training wall extension	Project Delivery Division	2020
	Prepare environmental impact assessment	Project Delivery Division	2020
	Obtain planning and regulatory approvals	Project Delivery Division	2020 (provided no significant adverse impacts identified)
	Construct training wall extension	Project Delivery Division and City Works & Services Division/ contractor	2020
	Monitor and review and extend if necessary	Environment Strategy & Planning Division	2020-2023

** To proceed, this project would have to be nominated and included in WCC's four year Capital Works Program.*

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Internet References
www.beachsafe.org.au/beach/nsw366

Appendices

A1.1 Coastal Erosion

Cardno Lawson Treloar (CLT 2010) produced hazard lines for the immediate, 2050 and 2100 planning periods as shown in **Figure 1**. The hazard lines were based on adoption of:

- 100 year ARI event storm demand of 250 m^3/m
- 0.4 and 0.9 m sea level rises above 1990 MSL by 2050 and 2100 respectively.

No long term recession due to sediment loss was identified from the photogrammetry, hence **Figure 1** represents shoreline recession due to sea level rise for the 2050 and 2100 planning periods. **Figure 2** shows plots of the position of the 2 m AHD contour for different photogrammetry dates. The impact of severe storm erosion is apparent in 1974, along with a more seaward shoreline position since1961.

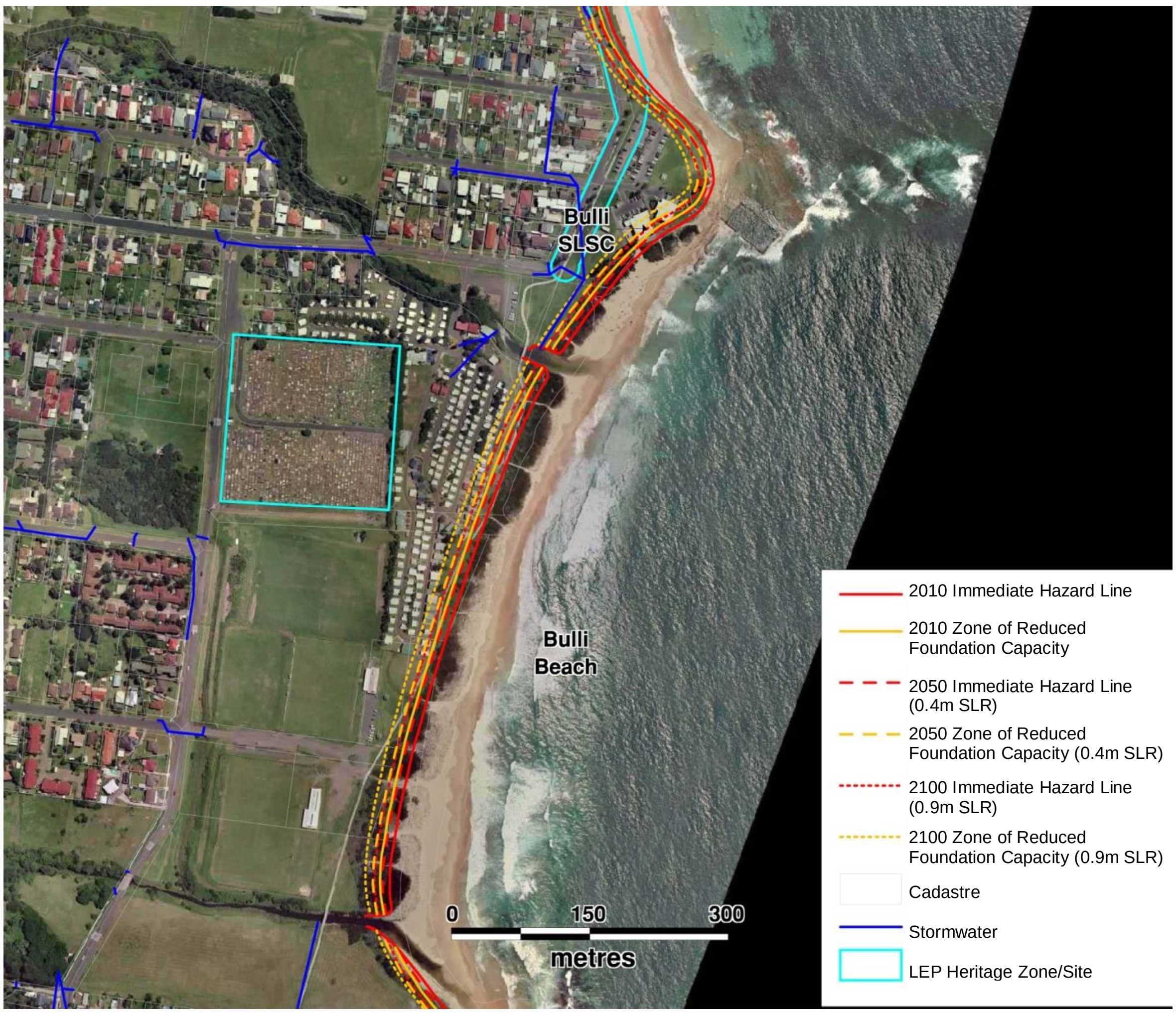


Figure 1 Immediate, 2050 and 2100 Coastal Hazard Lines (CLT 2010)

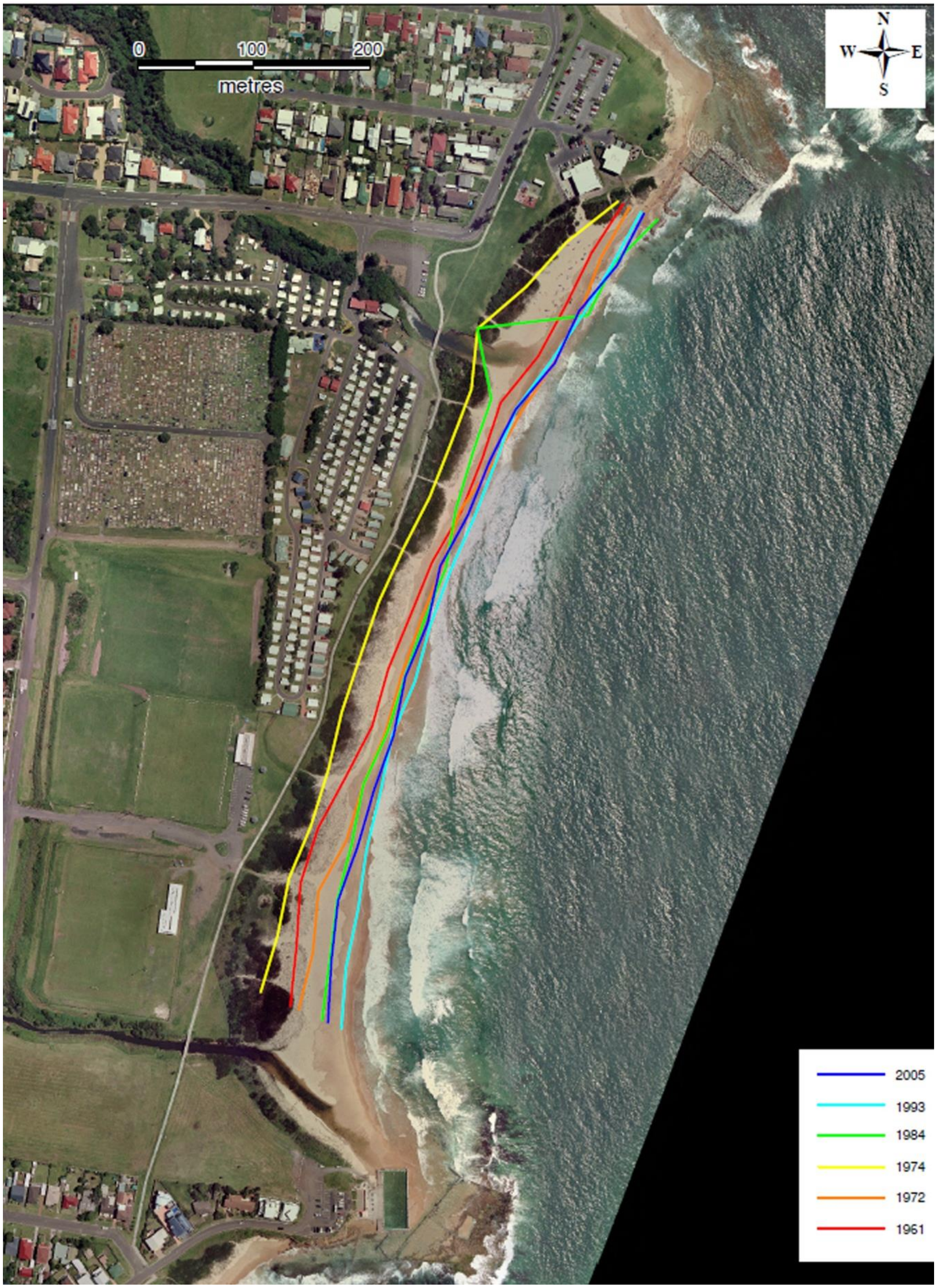


Figure 2 Historical 2 m AHD Shoreline Change (CLT 2010)

A1.2 Coastal Inundation

The extent of coastal inundation due to 100 year ARI ocean storm event is shown in **Figure 3**.

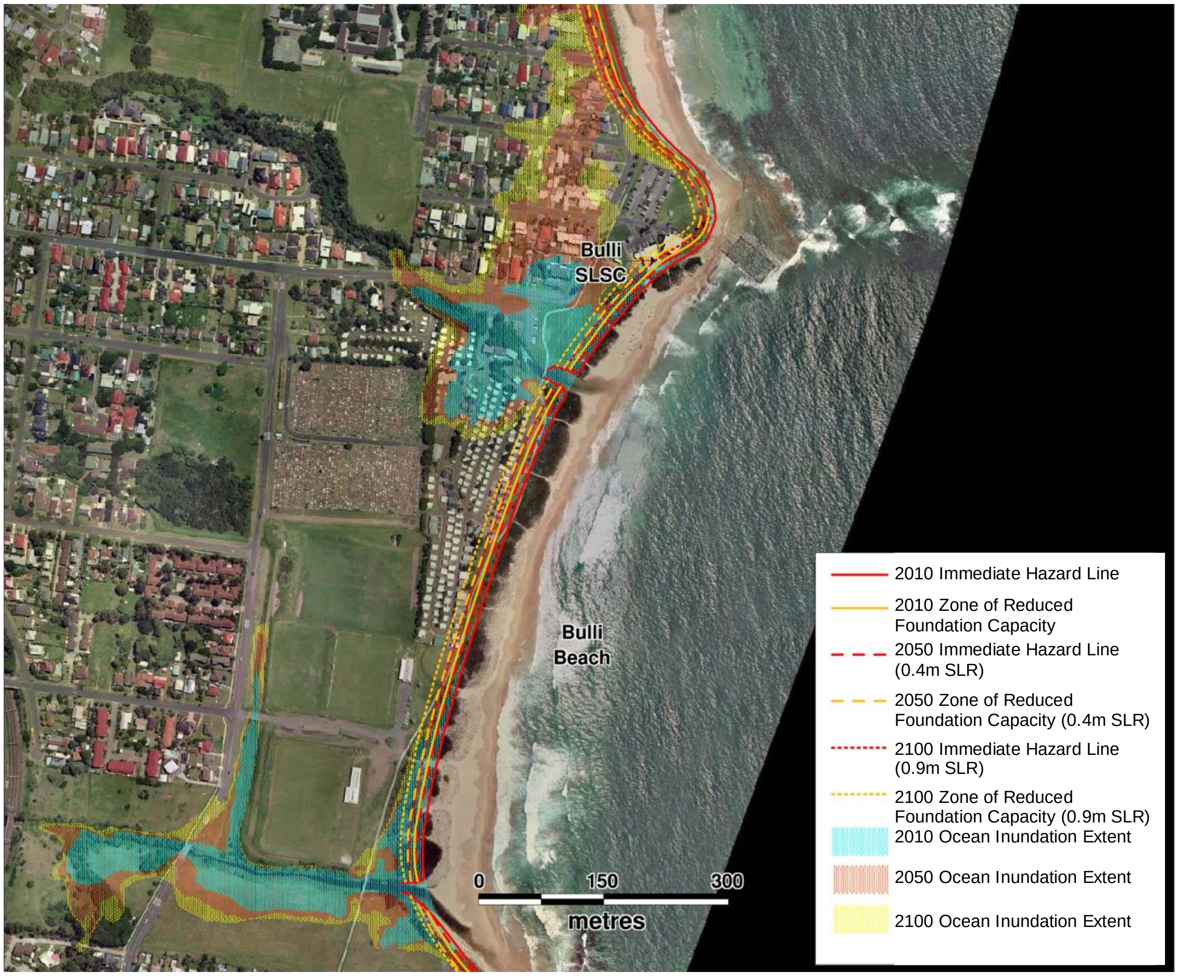


Figure 3 Immediate, 2050 and 2100 Coastal Inundation Extents (CLT 2010)

A1.3 Catchment Flooding

Lyall & Associates (2011) determined that when the capacity of the culverts under Franklin Street (immediately east of the railway corridor) is exceeded floodwaters are diverted from the Whartons Creek channel and flow east through several residential properties and the grounds of Waniora Primary School and Bulli High School before discharging north of Waniora Point to Sandon Point Beach. This is illustrated in **Figure 4** from the Flood Study which shows flows during a 100 year ARI event are essentially contained within the creek banks in the downstream reach, with flood flows in the creek at a level of about 3 m AHD in the vicinity of the Bulli Beach Tourist Park.

The yellow line in **Figure 4** indicates the catchment boundary, the red dotted line the extent of flood prone land and the numbers refer to the water surface levels in m AHD. The black dotted line represents the numerical model boundaries.

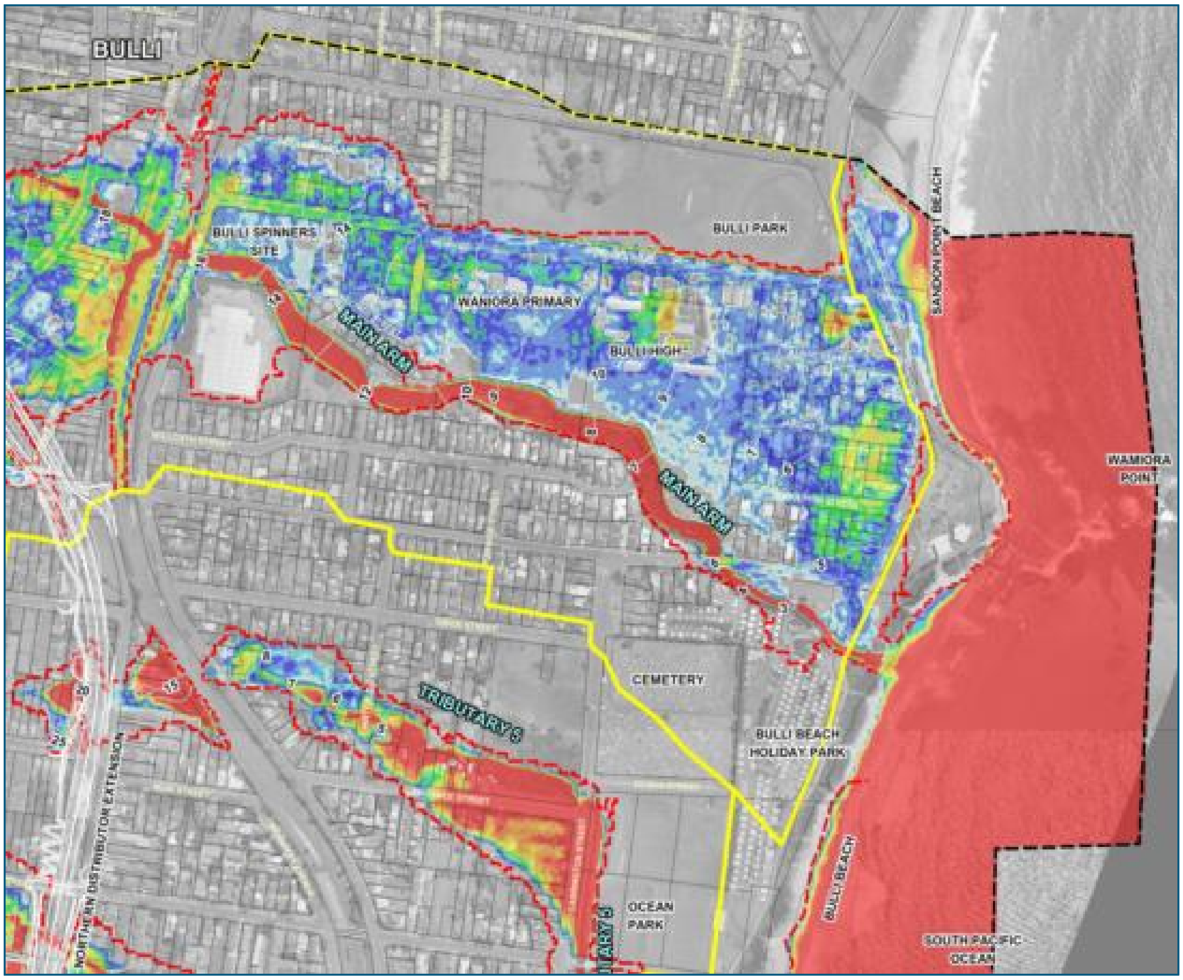


Figure 4 Modelled 100 Year ARI Flood Heights (Lyall & Assoc. 2011)

The Floodplain Management Study (Lyall & Assoc. 2014) recommended construction of a flood deflection levee on the western (upstream) side of Franklin Avenue and replacing the existing Franklin Avenue culverts with a bridge, as well as upgrading the upstream retarding basin. As shown in **Figure 5** from the Floodplain Management Study and Plan, the impact of these works would not substantially affect downstream creek behaviour (i.e. flood flows would still be contained within the creek banks).

Lyall & Associates (2014) also modelled the impact of varying berm heights at the creek entrance and found this had little impact on flood extents. For the maximum berm height modelled (3 m AHD), there was a small encroachment of flood waters into the Bulli Beach Tourist Park, compared to the flood extent of lowest berm height modelled (1.5 m AHD). The impact on flooding from the intermediary berm heights of 2 m and 2.5 m AHD was essentially the same as the 1.5 m AHD berm height.

As the main issue for the lower part of the Whartons Creek catchment is inundation of the essentially flat floodplain to the north of the creek, there were no recommendations in relation to berm height management for flood mitigation purposes.

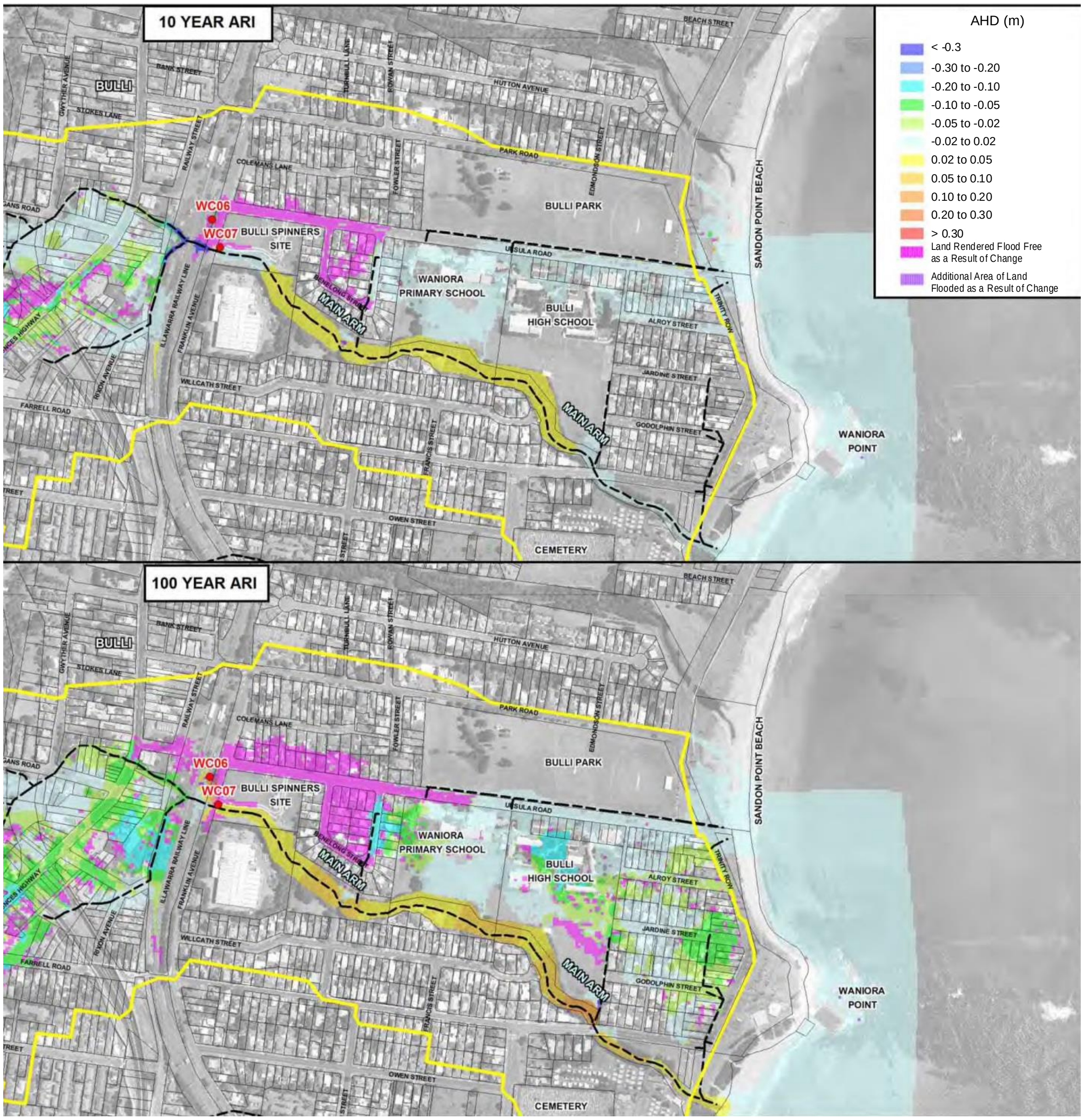


Figure 5 Modelled Impact of Recommended Flood Mitigation Works (Lyall & Assoc. 2014)

In relation to projected 0.4 m and 0.9 m level rise impacts (by 2050 and 2100 respectively above 1990 MSL), Lyall & Associates (2014) indicated the following.

- The area of land within the Bulli Beach Holiday Park currently classified as a low flood risk would change to medium flood risk.
- The extent of land at medium flood risk would be greater than that currently at low flood risk.
- The extent of land at high flood risk would not change.

A1.4 Catchment Runoff Assessment

GHD (2007) undertook a catchment runoff assessment for a number of Wollongong coastal creeks and lagoons, including Whartons Creek. This involved calculating the critical (peak) runoff volume generated by a 1 year Average Recurrence Interval (ARI) storm (found to be the 18 hour duration design event) using a simple water balance model to incorporate evaporation losses and infiltration. The coastal plain through which Whartons Creek flows is characterised by soil landscapes that are prone to flooding from permanently high water tables and have soils of high permeability. For the Whartons Creek catchment the peak runoff volume was calculated to be 81,000 m^3.

The rainfall excess (amount of rainfall that turns to runoff following saturation of the catchment) required to produce runoff equal to or greater than the creek volume was also calculated. The estimated volume of Whartons Creek was 1880 m^3, based on an adopted water depth of 0.8 m and estuary area of 2350 m^2. The rainfall excess to flush Whartons Creek was estimated to be 0.9 mm which corresponds to a 1 year ARI design storm of between one and two hours duration (equivalent to approximately 30-45 mm rainfall).

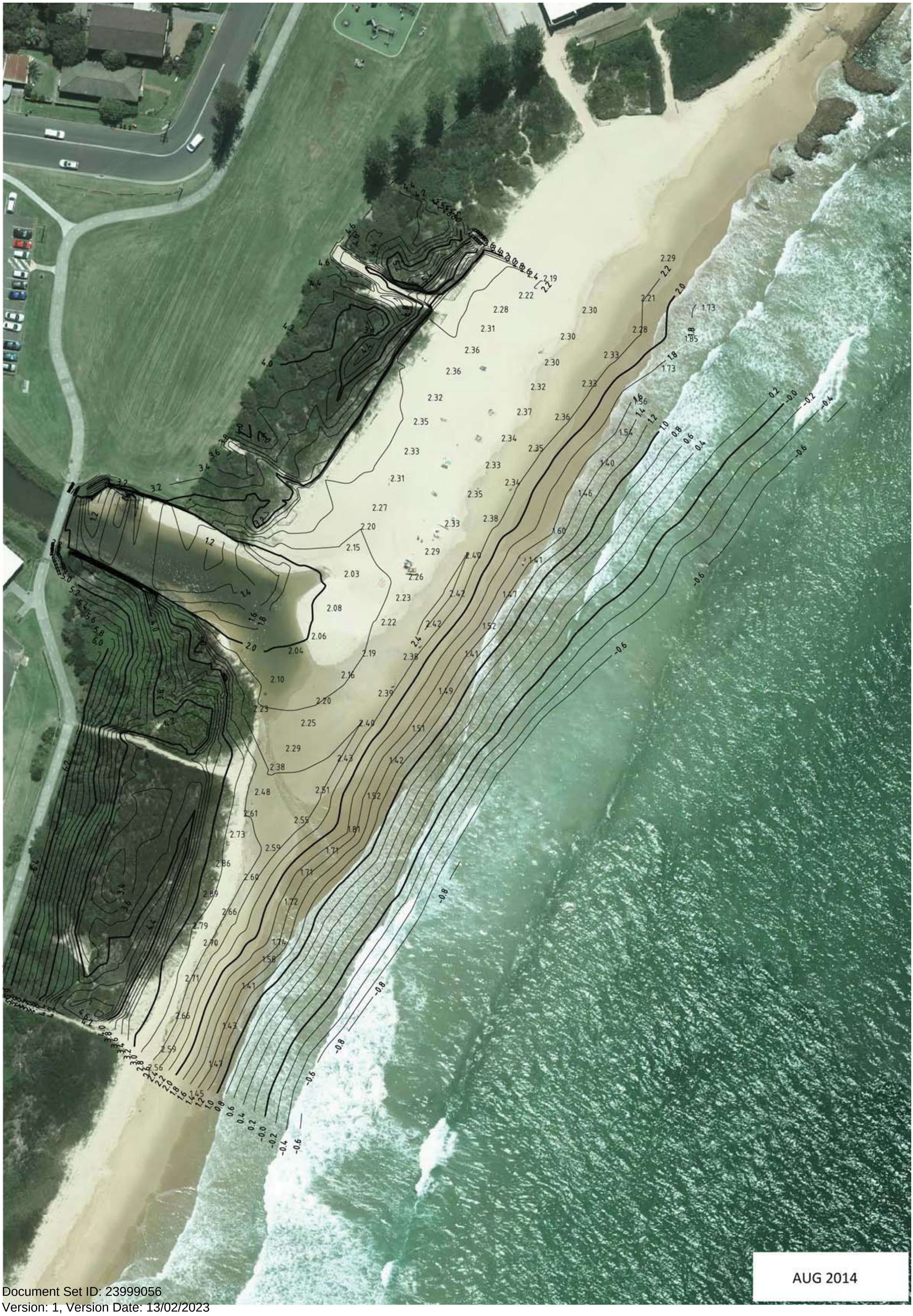
GHD (2007) then analysed rainfall events (University of Wollongong station) from May 2006 to the end of April 2007 to estimate the frequency of coastal creek and lagoon opening and flushing. For this 12 month period there were seven rainfall events with a high probability of causing estuary flushing (24 hour rainfall exceeding 30 mm and/ or several smaller consecutive events), and a further nine events with the potential to generate conditions to at least open the creeks and lagoons to the ocean resulting in partial flushing (Ó25 mm total rainfall in three day period).

Royal HaskoningDHV

Appendix B Entrance Surveys

WCC carried out topographic surveys at approximately one month intervals at the entrance to Whartons Creek between July 2014 and June 2015. A copy of these surveys follows.


JUL 2014



AUG 2014


SEPT 2014


OCT 2014

2.4
2.35
2.27
2.27
1.88
2.30
2.39
2.34
1.85
2.35
2.38
2.41
2.44
2.45
2.45
2.46
1.97
2.53
2.41
2.47
2.48
2.42
2.35
2.42
2.35
2.29
2.01
1.53
1.58
1.8
1.57
1.62
1.68
1.58
1.70
1.74
1.70
1.64
1.56
1.36
1.45
1.54
1.55
1.48
1.63
0.21
-0.6
-0.8
NOV 2014


DEC 2014


JAN 2015


FEB 2015


MAR 2015

APR 2015


JUN 2015

Appendix C Stakeholder Feedback on Options

WCC Feedback on the Options for the Management of the Entrance of Whartons Creek, Bulli

This document compiles the feedback received from key stakeholders based on:

- Presentations by consultants Haskoning Australia at a Stakeholder Meeting and the Estuary and Coastal Zone Management Committee (ECZMC) Meeting on 14th July 2015; and
- Responses received following review of the draft *Entrance Management Study and Plan for Whartons Creek* dated 24 July 2015.

Comments/Discussions	Response/Action	Preferred Option
Bulli Surf Life Saving Club – Stakeholder Meeting 14 July 2015 and subsequent correspondence		
Issues include public safety with regards to sand dunes (particularly children playing in them) and creek leaving stagnant water in front of surf club is a health hazard. For beach amenity reasons, they would prefer the sand filled bag option – but would need to confirm this position with the rest of the Club before commenting further. As the beach is exposed to southerly swell and can't change natural processes recognise that the training wall extension would aim to reduce frequency/ severity of northward migration but not be a 'total' solution. President requested copy of presentation for AGM with background information on the study and timeframes for exhibition etc. After viewing the presentation by the consultants and listening to comments by stakeholders on the day, Geo-textile Training Wall is preferred.	Amended presentation sent to Keith Caldwell	Geotech Bag Training Wall Extension
Council Staff - Stakeholder Meeting 14 July 2015 and subsequent correspondence		
Council has worked with sand bags previously, with sand bags being filled by Council workers – they have worked recently. Suggested proactive option of monitoring the water level. Need access along beach following erosion events due to storms – training wall extension may form barrier for bulldozer/ machinery may hit bags/ rocks. Beach raking work may also be impacted by the training wall. Ensure consultation with Dune Crew during any design for structural options.	Structural options would impact on these current work practices and this will be considered. Appropriate markers would have to be considered in detailed design. Consultation will occur.	No specific option preferred at the meeting – see subsequent feedback.
Structural options seem an expensive trial, considering there was no guarantee that this is a viable solution. Suggests that more rocks or sandbags would be required due to storm and weather patterns (increased cost). Suggests that a similar process to the Towradgi and Fairy Meadow management plan with triggers for action - maintain or open as required either when the pool is being cleaned or arrange for plant and labour to attend as needed. Suggests a geotech report needed to determine suitability of area for such structures.	Bag number would be assessed during detailed design. Cost for both three bag and six bag configuration included in draft Study. Goetech report would be included in detailed design if structural option is preferred.	Event based and/or build up north side of entrance

Comments/Discussions	Response/Action	Preferred Option
Prefers a similar approach to Fairy and Towradgi creek entrances. Utilisation of existing maintenance plan for Bulli rock pool that has machinery utilised at the site every 4 - 6 weeks. Concerns about the associated cost of the bag retaining wall, and their longevity within a beach environment subjected to annual storm swell conditions from various directions.		Event based and/or build up north side of entrance
Prefer to avoid structures on the beach. An ongoing formal program of sand relocation based on triggers would be suitable for Works crews.		Event based and/or build up north side of entrance
Prefer to avoid structures on the beach. Prioritising of other infrastructure projects may delay implementation of such an infrastructure project.		Event based and/or build up north side of entrance
Prefer not to put structures on beaches, as they could alter local coastal processes, and detract from the naturalness of the area. Also considers the geotextile bag option is not a foolproof solution. Preference is to open the entrance and open it straight out, when it is about to open. The challenge with this option would be in being able to predict when the creek is about to open. This will require the consultants to analyse the water level records, and the catchment hydrology, to come up with trigger points - similar to what was done for Fairy and Towradgi Creeks. Managing the berm height to certain pre-determined criteria will be a never-ending job, given the dynamic nature of this part of the beach.	Management plan to include triggers and process to guide the works if preferred option.	Dry Notch Excavation (Event Based) with trigger points
Office of Environmental Heritage - Stakeholder Meeting 14 July 2015, ECZMC Meeting 14 July 2015 and subsequent correspondence		
If revetments are used, the limitations of the design and this being a "trial" should be clear, so as not to create unrealistic community expectations. Beach/ dune to north of training wall extension would need maintenance following ocean storm erosion events. Commented that velocities at entrance were quite high and concepts as shown could suffer scour and undermining during breakouts.	Haskoning to investigate flow velocities. This was followed up and flow velocities would be considered in any detailed design.	No specific option preferred at the meeting – see subsequent feedback.
Rock sizing for rock revetment (is 0.4m sizing too small?) for coastal & riverine processes. Consideration of larger coastal events on structure integrity (and associated maintenance). Possible improvements to durability of revetment (temporary geotech) using vegetation in northern interface with vegetated dune (with suitable species such as *Lomandra*). This could reduce erosion associated with catchment flows overtopping structure and improve longevity of the option should the temporary geotextile prove effective. It could also work to reduce post event maintenance. There is limited information in the report by which to readily identify a preferred option. The environmental assessment and approval process issues (including Coastal Protection Act requirements) are also yet to be considered. It would be useful for some discussion of this in the report. Further work could also be done on the economics around the various options (as raised in the Committee). Managing the berm height may prove to have limitations as would the maintenance of a dry notch, however these could also be better costed in the study so as to assist in decision making. The costings and economic evaluation could also better clarify initial costs as well as anticipated costs over a longer period (say 5,10 & 20 years).	Proposed maintenance costs to be reviewed in draft Study (this was included in subsequent draft dated 24 July 2015). Consideration of vegetation during detailed design if this options is preferred. Additional approval requirements to be included in draft Study (discussion on approvals was included in section 5.1 of subsequent draft dated 24 July 2015). Additional long term costings to be included in draft Study (this was included in subsequent draft dated 24 July 2015).	No specific option preferred at the meeting – see subsequent feedback.

Comments/Discussions	Response/Action	Preferred Option
The three options mentioned under item 4.5 in the report are expected to work, provided the structures are properly designed. The word 'trial' has been used for a geotextile bag structure in order to decide the minimum effective length of the structure with a view to save cost. That is a reasonable approach. Council's present arrangement of ongoing maintenance of the erosion at the north of the entrance, as and when necessary, can also be considered as an alternative option. However, it is a nuisance that the beach, dune and even dune plantation at the subject area can disappear without any notice. As expected structural options will be comparatively expensive. These options may also need minor maintenance cost (i.e. topping up of geotextile and rock structures). The proposed shot term option of controlling the breakouts by maintaining berm height will not be effective and sustainable.	Maintenance cost to be included in the draft Study (this was included in section 5.1 and Table 6 in subsequent draft dated 24 July 2015).	Structural option or build up north side of entrance
Estuary and Coastal Zone Management Committee Members - ECZMC Meeting 14 July 2015		
Cost of structural options vs reshaping option is a concern and suggested that option 1 is actually more cost effective. Clarification was provided that while reshaping may only be required 3-4 years, other works on the entrance are required in between.	Further detail on long term costs needed in draft Study (this was included in subsequent draft dated 24 July 2015).	Excavate Channel and Reshape Beach
The monitoring time is not very long (since 2013). What is the impact of storm cut on the processes? Has there been any storm cut modelling done? Where is beach at the moment in terms of beach state? What is the mobility of the beach and how would it affect wall placement?	Haskoning Australia to look at Coastal Zone Study and incorporate further detail in draft Study (some additional information about accreted state included in section 2.1 of subsequent draft dated 24 July 2015).	None given
Suggestion to position the training wall to first accessway north, so that sand will build up against it to take the pressure off the bags. Remove gabion baskets from the entrance. Do not replace with any control devices. Respond to breakouts to the north by skimming the berm (berm management as per prior to 2009), except the sand be replaced to the south of the entrance. Sand from the pool to be placed near the northern end of the beach, possibly south of the access to the beach by the surf club, adjacent to the dune to allow for wind transport along the beach with a view to build up the berm north of the entrance during summer period.	Haskoning Australia advised that this would not be desirable as it would allow the creek to meander to the north and the objective is to prevent this. Detailed design would address potential scour along geotextile bag wall.	Maintain low berm and build up south side of entrance
Department of Primary Industries – ECZMC member, feedback received subsequent to 14 July 2015 meeting		
Provided link to guidelines for ICOLL openings in section 6.4 of the policy and guidelines for fish habitat conservation and management: http://www.dpi.nsw.gov.au/fisheries/habitat/publications/policies,-guidelines-and-manuals/fish-habitat-conservation Should WCC wish to develop an event based entrance management, DPI - Fisheries is happy to work with Crown Lands to generate a permit covering an extended period of time, say 5 years, to save the need to repeatedly apply for relevant permits/licences. Considers a 10m geotextile training wall on the northern side of the entrance seems a reasonable alternative given the small nature and highly modified nature of Whartons Creek - it allows the flexibility for removal if necessary and is not an excessive length. REF should examine the anticipated increase in opening events and the subsequent impacts to aquatic ecosystems within Whartons Creek.	REF will include assessment of impacts of aquatic ecosystems in Whartons Creek.	Event based management or geotextile training wall