Draft Narrabeen Lagoon Entrance Management Strategy

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Prepared for Northern Beaches Council

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Enhancing Society Together

REPORT

Narrabeen Lagoon Entrance Management Strategy

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Executive Summary

The Draft Narrabeen Lagoon Entrance Management Strategy considers how Northern Beaches Council currently manages the Narrabeen Lagoon entrance and whether improvements could be implemented. The draft Strategy reviewed the activities Council currently employs, namely mechanical openings and entrance clearance operations, and identified, analysed and evaluated possible alternative options. The Draft Strategy presents a prioritised set of recommendations for implementation that are expected to improve the management of the entrance both in terms of efficiency and outcomes.

The Draft Strategy:

- Reviews the current lagoon conditions, environment and other influencing factors.
- Reviews international best practice entrance management and more specifically Intermittently Closed and Open Lake or Lagoon (ICOLL) entrance openings and considers how the management of Narrabeen Lagoon aligns to other approaches employed in the industry.
- Identifies, analyses and evaluates alternate options compared to current management practices.
- Provides prioritised recommendations that are expected to improve the efficiency and or effectiveness of Council's management of Narrabeen Lagoon entrance.

Narrabeen Lagoon is one of approximately 70 ICOLL's in NSW whose entrance periodically fills in with sand, closing it to the ocean. Flooding occurs within the lagoon catchment after heavy rain or from the ocean during severe ocean storms. The height of the accumulated sand barrier between the lagoon waters and the ocean, called the beach berm, influences the height of inundation during flooding events. In the past, flooding of the Narrabeen Lagoon catchment has caused property damage, restricted property access and has been a general inconvenience to the community (Cardno, 2019).

Since 1975 Council has actively managed the entrance of Narrabeen Lagoon to reduce the flood risk to homes and businesses, with mechanical openings being a short term measure and entrance clearance a medium term measure:

Short Term Management – Mechanical Opening

The short term emergency measure is when the blocked entrance is mechanically broken out by excavators, subject to certain trigger conditions being satisfied, and is referred to as a 'mechanical opening'. Modelling undertaken as part of this project confirmed that mechanical opening is most successful at reducing water levels in the lagoon when the water level within the lagoon is higher than the ocean water level (lagoon water level at least at 1.0-1.3 m AHD). This provides the necessary force for effective scouring of sand to help the entrance remain open as long as possible.

Medium Term Management – Entrance Clearance Operation

The periodic medium term management measure is an entrance clearance operation, which involves the artificial removal of sand from the lagoon entrance on a much larger scale. This allows water to flow through the entrance more easily as it improves the hydraulic efficiency of the entrance by reducing the area of shallow water and therefore friction effects from the sand shoals. It also means that even when the entrance does eventually close again, mechanical openings for flood mitigation purposes are more likely to be successful. Excavators are used to remove sand from the entrance and stockpile it, and trucks then move the sand and deposit it on the southern Collaroy-Narrabeen beachfront. Entrance clearance operations have been carried out at relatively regular intervals (3-5 years) since 1975, typically removing between 30,000 m^3 to 50,000 m^3 of sand per operation.

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Long Term Alternatives

Potential alternate options to the current medium term management practices were identified through consultation with Council and industry experts with a thorough understanding of Narrabeen Lagoon. These included options with high upfront costs for permanent infrastructure, for implementation over the longer term. Options were included in an options paper and refined following community consultation, with the following options short listed for further detailed investigation:

- **Ebb Tide Channel** – enhancement of an ebb tide (outward flowing) dominant channel by installing submerged control structures or walls downstream of Ocean Street Bridge perpendicular to the left-hand bank (looking downstream). Modelling indicated that the walls would not be effective in generating the desired increase in ebb tide currents to maintain an ebb tide dominated entrance channel to keep the lagoon open.
- **Mobile Sand Pumping** – establishment of a semi-permanent, mobile sand pumping system. Such a system would facilitate pumping of excavated sand as a slurry within a pipeline along the beach to selected discharge points for subsequent redistribution and regrading (beach replenishment) by earthmoving equipment.
- **Low Flow Pipes** – installation of low flow pipes at the lagoon entrance to provide some release of rainfall runoff (mitigation of build-up in lagoon water level and thus benefit to lagoon flooding), and allow tidal exchange between the lagoon and the ocean, when the entrance is otherwise closed for prolonged periods. Modelling showed the low flow pipes would provide a reduction in properties experiencing flood events up to 20 year ARI however they would have no influence on lagoon entrance closure behaviour and periodic entrance clearance operations would still be required as part of this management option. The installation of low flow pipes would lead to prolonged lowering of the lagoon water level and is likely to have a significant impact on lagoon ecology and the overall recreational amenity of the lagoon.

Recommendations and Implementing the Strategy

Following review of current short and medium term practices and investigation of potential alternate options, a draft Strategy with a prioritised set of recommendations for implementation has been developed, as shown in **Table 1** below. This draft Strategy is expected to improve the management of the entrance both in terms of efficiency and outcomes. Options for the Short Term relate to mechanical opening of the lagoon for flood mitigation purposes and options for the Medium / Long Term relate to managing large volumes of sand in the longer term, with a view to maintaining an open entrance for as long as is practicably possible. These options are still in draft form, for consideration by the community during public exhibition.

Table 1: Draft Entrance Management Strategy prioritised recommendations

Management Option Type	Option Description	Recommendation	Priority
Short term	Maintain mechanical opening of the lagoon entrance for the primary purpose of flood mitigation	Develop a flexible set of trigger conditions to allow for openings to be undertaken in a wider range of conditions, including extenuating scenarios.	High

Management Option Type	Option Description	Recommendation	Priority
		Refine guidelines for where the pilot channel is to be excavated, locating it in a position that works more effectively with the natural configuration of the entrance. Review and update Council's OMS procedures and REF for lagoon openings.	High
		Enhance collection of data, including through the use of remote data sensing equipment, and use this data to refine flood forecasting, improve the location of the entrance channel etc. and evaluation of the success of entrance openings.	Medium
		Enhance publicly available information on Council's website and the MHL flood warning webpage to support understanding of how and why Council manages the Narrabeen Lagoon entrance. Information could include a decision matrix/tree, trigger levels for mechanical openings, and real-time updates on conditions.	Medium
Medium / Long Term	Continue periodic entrance clearance operations	Review design and frequency of entrance clearance operations on an ongoing basis, with consideration for factors including beach rotation and climate change. Investigate more frequent, smaller scale, strategic removal of sand from the flood tide shoals. Consider trialling a focus on the western shoal or a regime tidal channel.	High
	Mobile sand pumping option	Review mobile sand pumping if lower cost pricing is available from a contractor delivered scheme rather than Council purchasing pipes and pumps.	Low
	Review processes for entrance clearance	Review payment methods and procurement strategy for contractor; and Review tracking method for excavation depths and extent during works.	Medium
	Reshape, revegetate and maintain Birdwood Park dune	Reshape the dune, with relocation of sand away from western side and re-creation of the beach on the western side of the dune.	High
		Revegetate the denuded areas of the dune, to stabilise it and to limit wind-blown sand entering the lagoon. Extend the vegetation as far north as practicable, to reduce alongshore width of the lagoon entrance berm to reduce sand entering lagoon.	High
		Maintain the dune. Maintain the vegetation, monitor the profile of the dune and adjacent beaches and manage sand movement. Consider sand-catching fences.	Ongoing

1 Introduction

1.1 Background to the project

Located on Sydney's Northern Beaches, Narrabeen Lagoon is a popular location for local residents and tourists alike, due to its natural wildlife and environment, bushwalks, water sports and other recreational activities. The lagoon and its surrounding environment are also home to many important aquatic ecosystems. The area is highly urbanised with many residential properties surrounding the lagoon's foreshore.

Narrabeen Lagoon is one of NSW's approximately 70 Intermittently Closed and Open Lakes and Lagoons (ICOLLs), the largest of the four coastal lagoons within the Northern Beaches Local Government Area and it is also the largest in the Greater Sydney Metropolitan Area (SMEC 2011). Storms and ocean tides cause sand to infill the narrow channel entrance at North Narrabeen (refer **Figure 1-1**), which leads to intermittent closing of the lagoon to the ocean.

In the past, flooding of the Narrabeen Lagoon catchment has caused property damage, restricted property access or otherwise has been a general inconvenience to the community. Flooding occurs after heavy rain in the catchment, or from elevated ocean water levels (which can be due to storm surge and/or king tides), or a combination of both (Cardno, 2019). Ocean levels have on occasion been observed to be so high that some incoming waves have splashed over the Ocean Street Bridge, requiring closure of the road (e.g. on 5 June 2012). The photos below were taken with elevated ocean levels on 6 June 2012.

Figure 1-1: Elevated ocean levels on 6 June 2012

Over the last forty years Council has actively managed the entrance of Narrabeen Lagoon so that it is mostly open, reducing the flood risk of homes and businesses. During periods of entrance closure or constriction, Council will intervene and undertake a mechanical opening of the lagoon entrance once the lagoon level rises and pre-determined "trigger" conditions are met.

Every few years Council undertakes a larger scale removal of sand, known as an entrance clearance. This management practice involves the removal of between 30,000 and 50,000 cubic metres of sand from the greater entrance area (west and east of the Ocean Street Bridge) with heavy machinery, with the objective of keeping the entrance in open condition for a number of years (depending again on ocean and rainfall conditions). Each entrance clearance operation requires significant planning and funding and takes many months to complete.

The Narrabeen Lagoon Floodplain Risk Management Plan (Cardno, 2019) identified entrance clearance works as the highest ranked option for flood mitigation within the catchment. It also called for, as a matter of high priority, the preparation of an Entrance Management Strategy to undertake a technical investigation into whether (and if so, how) the current entrance management practices for Narrabeen Lagoon could be improved.

Council has prepared this draft Strategy to review the current practices and establish the most effective way to continue to manage the Narrabeen Lagoon entrance. This report reviews all aspects of entrance management, including short term emergency response arrangements, medium term clearance works and for the long term, investigates some alternative options to the current medium term practices.

1.2 Community engagement and key stakeholders

Community and key stakeholder engagement was undertaken in two stages during the development of this draft Strategy. Stage 1 sought feedback on the identified management options proposed to be investigated further. Stage 2 will seek feedback on the draft Narrabeen Lagoon Entrance Management Strategy, including the prioritised recommendations for implementation.

1.2.1 Stage 1

Stage 1 community and key stakeholder engagement for this draft Strategy was conducted over a six-week period, from 10 February 2021 to 28 March 2021, and consisted of a series of activities that provided opportunities and platforms for community and stakeholders to contribute. Consultation included the preparation of an interactive options report (RHDHV, 2021). The web-based report tool, or iReport, included an educational video on management of the Narrabeen Lagoon entrance. The community and stakeholder engagement report is provided in **Appendix F**, and summarised below.

This engagement sought community feedback on the way Council currently manage the entrance and the alternate and long term options being considered. A total of 96 submissions were received through the project page on Council's website. The consultation and responses highlighted the diversity of opinion in the local community about the key issues and management objectives for Narrabeen Lagoon. Community feedback also revealed a high level of local and historic knowledge and sense of public ownership of Narrabeen Lagoon.

A variety of themes were identified within the submissions. While no individual theme was represented in the majority of submissions, the two most common themes were:

- Support for further investigation and potential implementation of a sand pumping scheme; and,
- Options that maximise the duration of lagoon entrance open conditions should be prioritised.

1.2.2 Stage 2

Council will undertake a second stage of community and key stakeholder engagement to seek feedback on this draft Strategy. Engagement will include:

- Public exhibition of the draft Strategy document;
- Presentation/s of supporting information to assist the community understand the draft Strategy; and,
- Opportunities to hear directly from Council staff and technical consultants, which may include public presentations, one-on-one meetings, attending relevant committee meetings etc.

A summary of the outcomes of the engagement will be included in the final Strategy.

1.3 Managing a complex environment

Balancing the management of this popular recreation location, with the protection of important aquatic ecosystems, whilst mitigating flooding to reduce risks to the many residential properties and infrastructure assets surrounding the lagoon's foreshore is a complex task. It is important that the evaluation and analysis undertaken in this draft Strategy carefully considers the environmental, economic and social impacts, both positive and negative, for each option. Some key considerations include:

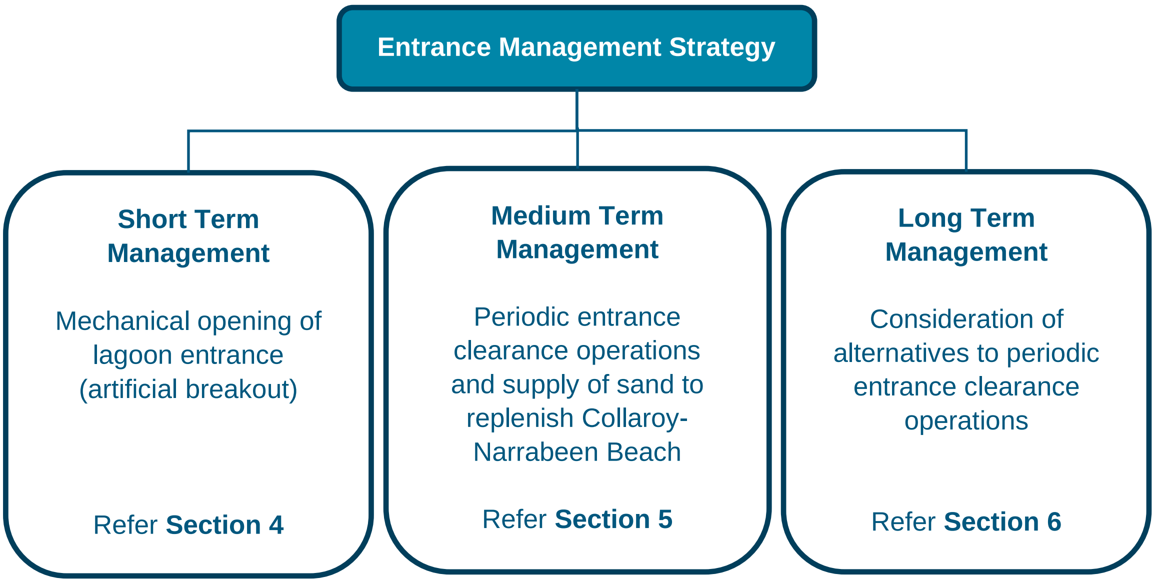
- The lagoon itself comprises a fragile and diverse aquatic and terrestrial ecosystem. The impacts of any proposed options on flora, fauna, ecological communities and other natural lagoon characteristics needs to be thoroughly considered.
- The lagoon is a highly valued recreational resource, with the entrance forming part of a national surfing reserve.
- Catchment conditions vary over time and can influence runoff, and therefore flooding.
- Effective emergency response is required to reduce the risk of flooding, especially of low-lying properties surrounding the lagoon.

It is important to note that from BMT WBM's (2013) flood study of Narrabeen Lagoon it was concluded that regardless of the implementation of Council's policy to mechanically open the entrance during flood events, significant flood inundation is expected during major catchment floods. Therefore, during large rainfall events, short-term strategies alone will not be able to completely mitigate flood inundation.

It should also be noted that when catchment flooding occurs in combination with elevated ocean levels or when elevated ocean levels alone present a flood risk (as is the case in the photos of Narrabeen Lagoon in **Figure 1-1** above), mechanical opening of the lagoon entrance would not reduce the severity of foreshore flooding. In fact, if during a flood event the ocean level is higher than the lagoon water level (which can occur due to the combination of astronomical tide, storm surge, and wave setup), then having the ICOLL entrance closed may in fact lessen the flood impact. A permanently open estuary would likely have greater flood impacts in the long term due to sea level rise as a result of climate change (Coffs Harbour City Council, 2018).

1.4 Overview of this report

The draft Entrance Management Strategy (EMS) for Narrabeen Lagoon is structured based on the three main elements as shown below. Short, medium and long term entrance management procedures are investigated in detail in **Sections 4, 5 and 6** respectively of this report:



This report considers the available data and literature to investigate the current short and medium term strategies in place for managing the Narrabeen Lagoon entrance, including the reasoning behind them. It also reviews best practice for ICOLL entrance management, to aid in the discussion of opportunities for improvements and innovation, weighing both the costs and benefits of environmental, social and economic factors before outlining recommendations for future management.

For long term entrance management, this report documents the development of concept proposals for each of the potential long term entrance management options under consideration and the assessment of the feasibility and economic, social and environmental impacts and risks of the options against the ‘base case’ or current entrance management practices undertaken by Council. This assessment is informed by review of existing literature, morphodynamic modelling of selected options and cost estimation by a quantity surveyor. The final section, **Section 7** presents prioritised recommendations for implementation.

Refer to the **Glossary** for the definition of technical terms used in this report.

2 Understanding Narrabeen Lagoon

2.1 Physical environment of the lagoon

2.1.1 Lagoon and catchment

The Narrabeen Lagoon catchment area covers some 55 km^2, which includes 2.2 km^2 of water surface area (SMEC, 2011). The catchment area and major creeks is shown in **Figure 2-1**.

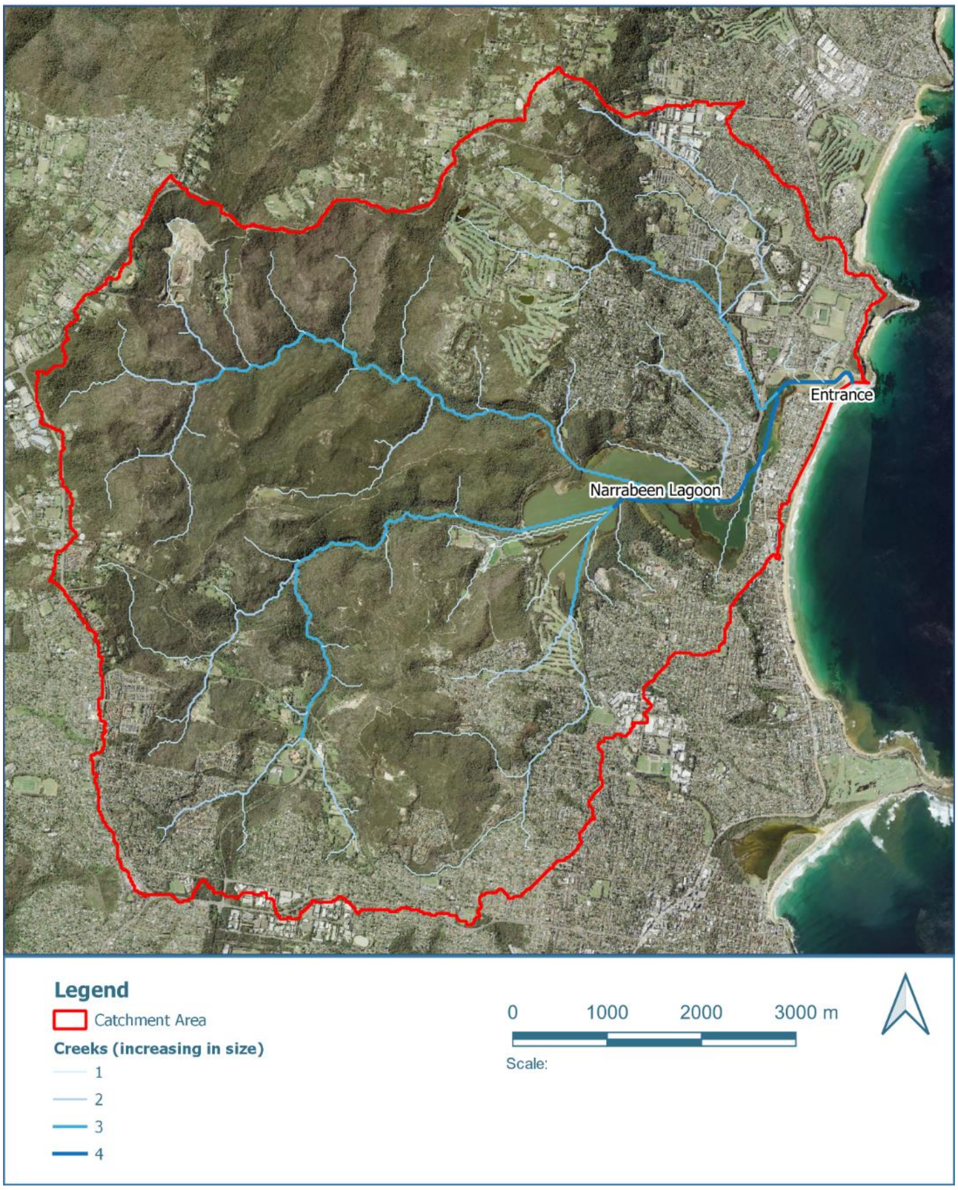


Figure 2-1: Catchment showing major creeks

The catchment can be separated into several major sub-catchments associated with five main creeks (Nareen, Mullet, Deep, Middle and South Creeks) that feed into the lagoon. From an elevation of around 200 m AHD in the north-west of the catchment around Terrey Hills and Ingleside, and 150 m AHD in the south and south-west of the catchment around Belrose and Frenchs Forest, the topography of the

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catchment is undulating and grades relatively steeply from the upper slopes to the floodplain areas around Narrabeen Lagoon and the Warriewood Valley. The areas of minor to moderate slopes are concentrated around the fringes of Narrabeen Lagoon, Warriewood Valley to the north and Oxford Falls in the central area of the catchment within the Middle Creek sub-catchment (Cardno, 2019).

Up to 49% of the catchment is natural bushland (Alluvium, 2021), that supports biodiverse habitats on the foreshores of the lagoon, along the creeks and the valleys beyond. Other land uses within the catchment include a mixture of urban development (residential, commercial and industrial), recreational areas such as golf courses and playing fields, and semi-rural zones. Land use and land-based activities directly contribute to issues of water quality and accelerated sedimentation in the lagoon (BMT WBM, 2013).

Narrabeen Lagoon itself can be geographically divided into three distinct areas: the western basin, the central basin, and the eastern channel. The western basin is large and shallow, with average depths of about 1 metre. It receives water primarily from Deep Creek, Middle Creek and South Creek, which combined drain approximately 70% of the total Narrabeen Lagoon catchment (BMT WBM, 2013).

The central basin of Narrabeen Lagoon was dredged extensively from the 1920s through to the 1980s. While some areas within the central basin have escaped the dredging, most of the area is now between 2 and 6 metres deeper than the original depths (WBM, 2001).

The eastern channel has also undergone extensive dredging since the 1920s, with typical depths now about 2 to 4 metres below mean water level. The ocean entrance to Narrabeen Lagoon is located at the northern end of Narrabeen Beach, between Narrabeen Head, and a sand dune known as Birdwood Park.

When the Narrabeen Lagoon entrance is open, it is subject to tidal influences. The ebb tide is the tidal phase during which the tidal current is flowing seaward out of the lagoon, and the flood tide is the tidal phase during which the tidal current is flowing inland into the lagoon. A large flood tide shoal at the entrance significantly restricts tidal penetration into the lagoon, while ocean conditions and sand deposition are responsible for entrance closure (BMT WBM, 2013).

The historical photos below in **Figure 2-2** show aerial photos of the entrance up until 1975, with many showing a large degree of infilling with sand.


1930 1941


1955 1962


1965 1970


1971 1975

Figure 2-2: Historical photographs of Narrabeen Lagoon 1930-1975

2.1.2 Water quality

Historical water quality data for Narrabeen Lagoon has ranged from good at the entrance, where there is effective tidal flushing when the entrance is open, to poor in the western basin, which typically showed elevated concentrations of nutrients and algae (SMEC, 2011).

More recently, Council has been running an ecological lagoon water quality monitoring program which looks at water clarity and algae (refer **Table 2-1**). The report card for this program shows that over the past 10 years overall water quality within Narrabeen Lagoon is of good quality (B Grade) (see https://files.northernbeaches.nsw.gov.au/sites/default/files/documents/general-information/lagoons/lagoonsummaryreport2011-2020.pdf). The ecological water quality monitoring identifies that the status of the entrance, be it open or closed, has no significant impact on the overall water quality of the lagoon. In 2015/16 for example the lagoon entrance was predominantly closed and the lagoon achieved a rating of 'good'.

The water quality within the lagoon for recreational purposes (i.e. swimming), as opposed to ecological health, is measured by the Beachwatch program implemented by the Department of Planning, Industry and Environment (DPIE). Note that this program only tests water samples for bacteria to show signs of faecal pollution which is a good indicator for whether or not a site is safe for human health, and more specifically swimming. The presence of bacteria alone is not necessarily a good indicator of poor ecological health.

There are two Beachwatch monitoring locations within Narrabeen Lagoon, one at Birdwood Park (on the entrance channel) and the other at Bilarong Reserve (in the lagoon's central basin). The annual results from State of the Beaches reports over the past 6 years are summarised in **Table 2-2**. These indicate that the recreational water quality at Birdwood Park is typically good but can be poor at times, and at Bilarong Reserve it is typically rated poor for swimming. This is consistent with the description of lagoon water quality within the Narrabeen Lagoon Estuary Processes Study (WBM, 2001) which notes that water quality in the central and western basins (which includes Bilarong Reserve) is dominated by the quality of catchment runoff as tidal flushing in these areas is poor.

Tidal flushing at the eastern channel (including Birdwood Park) improves water quality under normal conditions. However, during periods of high catchment runoff the outflowing ebb tide volumes would far exceed the inflowing flood tide volumes, resulting in little penetration of oceanic waters (if any) until quite some time after the high runoff event (WBM, 2001).

When the entrance is open it still takes typically more than 90 days for the water in the lagoon to flush, or exchange. Considering this flushing time, having the entrance open is not necessarily the main influencing factor for water quality throughout the lagoon. The water quality is impacted by a number of factors including catchment runoff events and the marine-dominated lower entrance channel area. Depending on the volume of catchment runoff, the entire western basin can become fresh and the central basin can also experience fresh to brackish conditions (SMEC, 2011).

During and immediately after catchment runoff events, the lagoon is dominated by freshwater. Salinity is low, pH is neutral and the water temperature is generally cooler. Runoff events also introduce poor water clarity, known as turbidity, due to the stirring of the bed sediments, as well as suspension of fine sediments that are washed off the catchment and into the lagoon (SMEC, 2011).

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Table 2-1: Ecological lagoon water quality monitoring program results

Sampling Period	Turbidity	Chlorophyll-a	Overall Water Quality
2011 - 2022	D	D	D
2012 - 2013	B	B	B
2013 - 2014	B	B	B
2014 - 2015	B	D	C
2015 - 2016	B	B	B
2016 - 2017	B	B	B
2017 - 2018	C	C	C
2018 – 2019	C	B	B
2019 - 2020	B	C	B

Table 2-2: Recreational water quality in Narrabeen Lagoon

Period	Bilarong Reserve	Birdwood Park
2014 - 2015	Poor	Good
2015 - 2016	Poor	Poor
2016 - 2017	Poor	Poor*
2017 - 2018	Good	Good
2018 - 2019	Poor	Good
2019 - 2020	Good	Good

* Provisional only as based on limited data

Water pollution primarily occurs from runoff in urbanised land use areas of the catchment. It is considered that this can be more efficiently managed through the control of inputs, rather than opening the estuary artificially (Stephens & Murtagh, 2011; Coffs Harbour City Council, 2018). Such strategies may include the use of stormwater management measures, such as pollutant traps (e.g. GPTs) and water harvesting, and the pursuit of opportunities for native revegetation to offset urbanised land use areas.

2.1.3 Ecology

The lagoon itself comprises a fragile and diverse aquatic and terrestrial ecosystem. It has been identified by the NSW Department of Primary Industries (DPI) as key fish habitat with significant seagrass meadows being a key contributor to the quality of this habitat. The seagrass meadows provide nursery habitat for economically important juvenile fish species (SMEC, 2011).

Two main species of seagrass exist within the lagoon, namely *Zostera capricorni* (commonly known as Eelgrass or ribbon weed) and *Halophila ovalis* (commonly known as Seawrack or paddle weed). *Z.capriconi* is the dominant species and occurred in beds from 0.05 – 0.8 m depth. *H.ovalis* occurred more commonly in the shallower areas, often as a band between the shore and the *Z.capriconi* beds (SMEC, 2011).

The foreshore vegetation of Narrabeen Lagoon consists of a mosaic of vegetation types subject to varying degrees of inundation, run-off, and sedimentation. A number of these ecological communities rely on periodic inundation due to higher water levels when the lagoon entrance is closed. In addition, there are considerable areas which have been modified by landscaping works. Several vegetation communities are listed as endangered ecological communities (EEC) under the NSW Biodiversity Conservation Act 2016 (BC Act). Vegetation types along the shore of Narrabeen Lagoon include:

- Estuarine Swamp Oak Forest
- Swamp Sclerophyll Forest on Coastal Floodplains
- Coastal Alluvial Bangalay Forest
- Coastal Saltmarsh
- Estuarine Reedland (*Phragmites australis*)
- Coastal Sand Tea-tree-Banksia Scrub
- Coastal Foredune Wattle Scrub
- Exotic Vegetation (Parks and Gardens/Weed Dominated)

The foreshore vegetation also has a number of ecological functions, including:

- Stabilisation of foreshore substrate
- Nutrient and pollutant retention from catchment runoff
- Provision of habitat for wildlife
- Provision of detrital material to the aquatic detritus food-chain

The lagoon provides a variety of habitats for bird life including mudflats, reedbeds and shrubland. The islands within the lagoon provide protection from land-based predators and contain the vegetation communities Swamp Oak Floodplain Forest and Coastal Saltmarsh, that are listed as endangered under the BC Act (Cardno, 2019).

Mangroves are also becoming more common in the lagoon. This is likely to be the result of the lagoon entrance being open more frequently and for longer periods resulting in a more marine environment. The expansion of mangroves in the lagoon may need to be assessed and managed accordingly in the future, especially if the lagoon is open to the ocean more frequently (SMEC, 2011).

The lagoon and surrounding area are an important stopover for migratory birds and are home to one third of the bird species that are represented in Sydney. Over 193 species have been recorded in the locality and 12 of these are listed under either the Environment Protection and Biodiversity Conservation Act, 2016 or BC Act as threatened. Many are waterbirds associated with coastal estuaries and wetlands or migratory species (SMEC, 2011).

A total of 272 fauna species have been recorded in the Narrabeen Lagoon catchment since 1990. The dominant terrestrial vegetation type, Swamp Oak Floodplain Forest, also provides potential foraging resources for many bird species especially the Glossy Black Cockatoo (*Calyptorhynchus lathami)* and Yellow-tailed Black Cockatoo (*Calyptorhynchus funereus*).

Several threatened fauna species have been identified within the catchment. These include the Powerful Owl (*Ninox strenua*), and Grey-Headed Flying Fox (*Pteropus poliocephalus*). Other threatened species that occur here including Glossy Black-Cockatoo, Black Bittern (*Ixobrychus flavicollis*), Osprey (*Pandion haliaetus*) and Rosenberg's Goanna (*Varanus rosenbergi*) (SMEC, 2011).

Several species of common frogs (e.g. *Litoria peronii*, *L. phyllochroa* and *Crinia signifera*) utilise the upstream freshwater areas associated with the lagoon. In addition, the surrounding terrestrial habitats provide an abundance of resources for many species of mammal including possums, swamp wallabies, water rats and bandicoots (SMEC, 2011).

2.1.4 Recreation

Narrabeen Lagoon and the surrounding catchment is valued for its visual amenity and its protected, relatively safe environment for water-based recreation and associated foreshore activities. It is an important recreational area for both the local community and tourists and is visited by over 1,000 people a day. A number of different recreation clubs have formed due to the lagoon and some of the more popular activities individuals undertake include fishing, bushwalking, swimming, canoe/kayaking, sailing, stand-up paddle boarding, boating, windsurfing, bird watching and picnicking (SMEC, 2011). The entrance of the lagoon forms part of a designated National Surfing Reserve.

Historically, a speed boat club used to operate out of Middle Creek, however there is now an 8 knot speed limit on the lagoon, reducing the use of powerboats and jet skis. This has enabled passive water-based recreational activities to be undertaken whilst having less of an impact on the environment and on other recreational users enjoying the amenity of the lagoon and its surrounds.

2.1.5 Historical catchment development

Since European settlement, the lagoon and its catchment have undergone many changes and modifications, which has affected its natural characteristics and how it functions as an Intermittently Closed and Open Lake or Lagoon (ICOLL) system.

In 1883, the Narrabeen Lake Bridge was constructed at Pittwater Road, and by the early 1900s residential development commenced within the catchment. The first Ocean Street Bridge was built in 1928. Over the past 100 years, the catchment has become increasingly urbanised, including extensive residential, farming and commercial development within its floodplain, along with the associated construction of roads and bridges along the foreshores, and the modification of creeks with infrastructure such as sewers, stormwater pipes and weirs.

Around the turn of the century, Narrabeen Lagoon was relatively shallow and mostly closed to the ocean. A bathymetric survey undertaken in 1911 indicated that the majority of the eastern channel had a depth of approximately 1.5 – 2.5 feet below High Water Ordinary Spring Tides (HWOST). This equates to a bed level of approximately 0.0 to +0.25 metres Australian Height Datum (AHD). This historical survey also indicated that the central basin area of Narrabeen Lagoon had a bed level that was in the range of 0.0 to -0.4 metres AHD, with depths generally increasing in a westerly direction. There was also a small deeper channel between Wimbledon Island and the mainland.

Widespread dredging of the Lagoon commenced in 1911 and continued until 1985. By this time the bed level of the whole eastern channel had been lowered by about 2 - 3 metres, while an area within a 200-metre radius of Wimbledon Island had been dredged to a depth of about 6 metres, leaving deep holes that typically exhibit poor water quality, with low dissolved oxygen levels and elevated nutrients. While dredging achieved deeper water depths in the lagoon, it did not affect flood behaviour. Dredging in the western and central basins did not improve flood conveyance.

With the lagoon mainly closed to the ocean, flooding has also been an issue for residents over the last century. As early as 1913, Council would manually open the lagoon entrance using a team of men with shovels when water levels got too high (refer **Figure 2-3** and **Figure 2-4**), to alleviate local flooding (Pittwater Online News, 2016).

Figure 2-3: Men digging flood mitigation channel, April 1927 (Source: State Library of NSW)

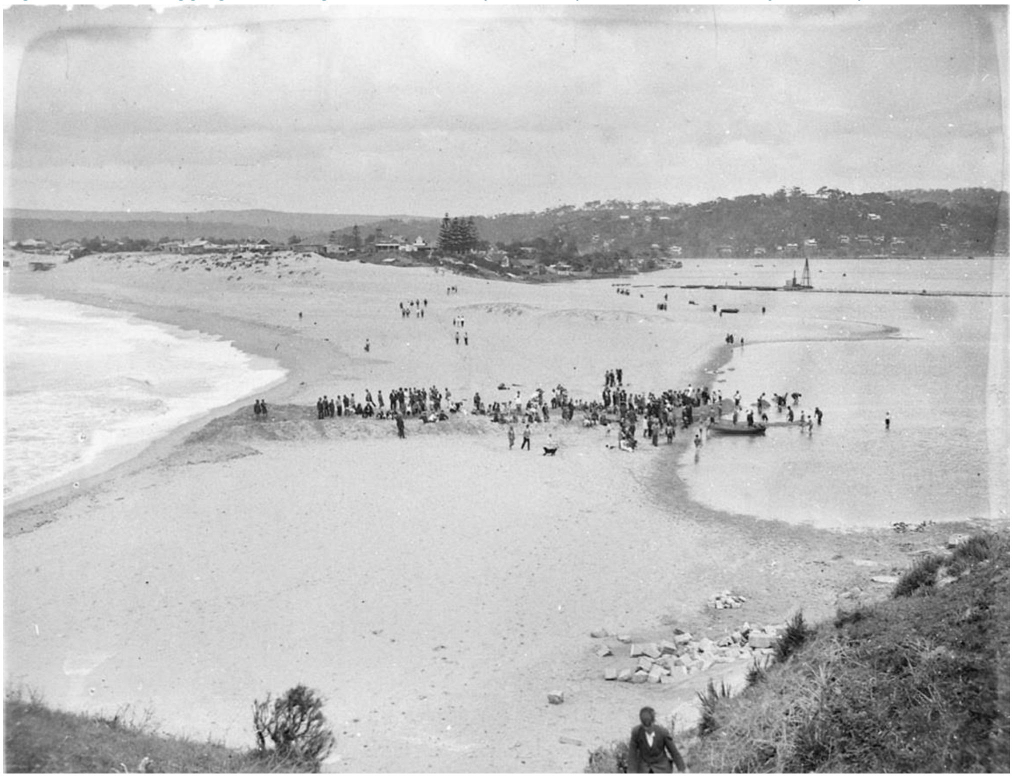

Figure 2-4: View of flood mitigation channel from Narrabeen Headland, April 1927 (Source: State Library of NSW)

The combined environmental impacts from urbanisation, dredging, and entrance management practices, led to an overall decline in lagoon water quality and ecosystem health. The total area of seagrass within the lagoon has declined since at least the 1960's, and until the 1970's, the lagoon received septic runoff from the surrounding development, resulting in extensive macroalgae blooms and odour problems.

Historically, both State Government and Council have attempted to mitigate the negative environmental issues resulting from urbanisation of the catchment through better environmental management, stricter development controls, and community education.

2.2 Coastal processes and entrance dynamics

2.2.1 Conceptual understanding of coastal processes

Narrabeen Lagoon drains intermittently to the Tasman Sea through a narrow channel at North Narrabeen Beach. The lagoon is considered an ICOLL, that alternates between being open or closed to the ocean due to natural forces that act to close the entrance (waves, incoming tides and wind) and those that act to maintain an open entrance (outgoing tides and catchment flood flows).

The lagoon entrance naturally closes due to the littoral movement of sand into the lagoon entrance as a result of wave, current and wind processes along Narrabeen Beach, with the volume of sand moved into the entrance exceeding the volume of sand removed from the entrance by the outgoing tide. Studies over the past 30 years have confirmed that ocean waves and currents, wind borne sand and ocean storms act to close the entrance, while flood events open it by washing away the sand mound barrier, known as a 'berm', at the entrance.

Historical records show that prior to 1970 the lagoon was predominantly closed. However, by the early 1970's the Council found that it was necessary to mechanically open the lagoon on a regular basis to allay growing community concerns regarding potential flooding within the catchment and water quality within the lagoon. The lagoon is now predominantly open due to large scale routine excavation of sand within the entrance channel, which has been occurring approximately every four years since 1975. When the lagoon is open to the ocean, the water levels are maintained at approximately 0.2-0.4m AHD due to the presence of a natural rock weir at the lagoon entrance, which limits the amount of water that can leave the lagoon, and due to so-called 'shallow water effects' and friction.

When the lagoon entrance is closed to the ocean, rain and floodwaters fill up the lagoon in a manner that is similar to adding water to a bathtub with the plug in. As such, significant flooding of low-lying areas can and does occur due to heavy rain. Flood levels can also depend on the height of the entrance berm and the ability of the flood waters to open a natural channel, like pulling the bathtub plug out.

Flooding within the lagoon can also occur when the lagoon entrance is open due to elevated ocean levels caused by severe storms. This occurs as a result of a combination of astronomical tide levels, storm surge, and wave setup, which can exacerbate rainfall-based flood events by preventing the outflow of flood waters. This flooding has the potential to cause major damage to properties surrounding the lagoon's foreshore. This flooding can also obstruct travel and potential evacuation through the local road network.

The flood risk to foreshore properties is currently managed by artificial intervention to remove sand build-up from the lagoon entrance, which allows the lagoon to drain to the ocean (the speed of which depends on oceanic conditions at the entrance), thereby reducing risk to properties from flooding due to rainfall. This is currently done in two ways; one is a short-term emergency measure to open a channel through the entrance berm (mechanical opening) and the other a medium term periodic operation to remove bulk sand from within the entrance area and berm (entrance clearance operation). Removal of the sand at the blocked entrance allows the lagoon to drain.

2.2.2 Coastal processes and entrance dynamics details

To assess entrance management strategies, it is important to understand the natural processes acting within the beach embayment and at the lagoon entrance and the impacts of artificial intervention on these natural systems.

Figure 2-5 depicts the main physical coastal processes (erosive and accretionary) relevant to Collaroy-Narrabeen Beach Embayment and the interaction of Narrabeen Lagoon Entrance within the wider context of the embayment.

The conceptual understanding of coastal processes at the entrance of the lagoon is shown schematically in **Figure 2-6** and described below.

Flooding of areas surrounding the lagoon can be exacerbated when there is an accumulation of sand at the entrance, which creates a constriction that reduces the hydraulic efficiency of the entrance for discharge of flood flows. In simple terms, sand builds up in the entrance area and reduces the amount of water that can flow out of the lagoon. Several tens of thousands of cubic metres of sand can be accommodated within the lagoon entrance across two flood tide shoals on the eastern (lower) and western (upper) side of Ocean Street Bridge.

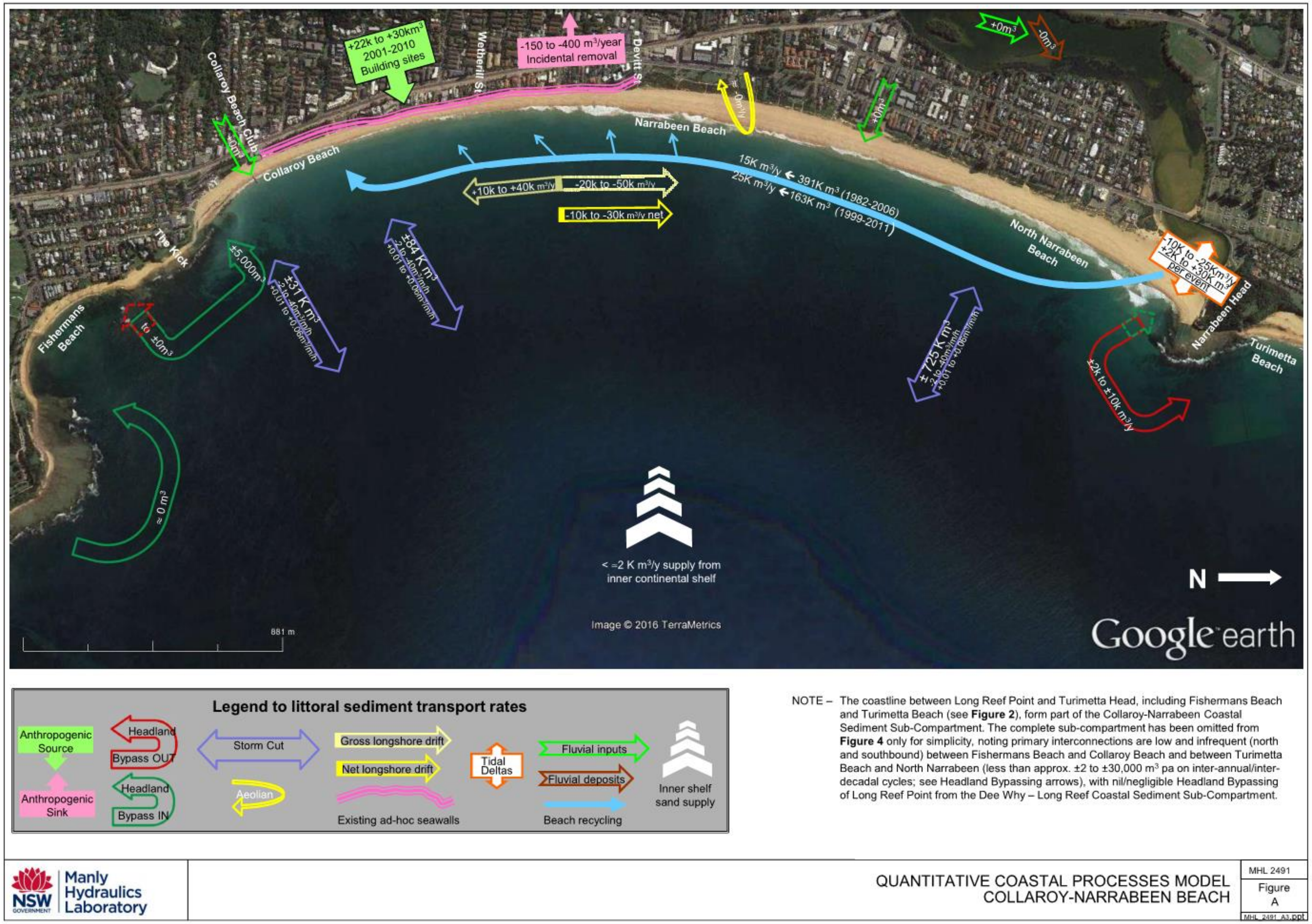

Figure 2-5: Coastal processes model for Collaroy-Narrabeen Beach embayment (Source: Manly Hydraulics Laboratory)

Figure 2-6: Conceptual understanding of coastal processes at Narrabeen Lagoon entrance

The lagoon has a flood dominated tidal current regime and the entrance is subject to progressive infilling as sand is transported into the entrance by wave action and flood tides and reworked further upstream to accumulate on the lower (downstream of Ocean Street Bridge) and upper (upstream of Ocean Street Bridge) flood tide shoals (refer **Figure 2-7**). Ingress of sand through the entrance is largely dependent on sand availability at the ocean entrance and available space within the lagoon entrance, that appears to have no direct connection to the long term sand transport rates; aside from during storm events (Morris, 2010). Following the 2006 entrance clearance operation, Morris (2010) observed a pattern of initial rapid infilling following entrance scour and then a slower rate of infilling as the system approached closure (Cardno, 2019).

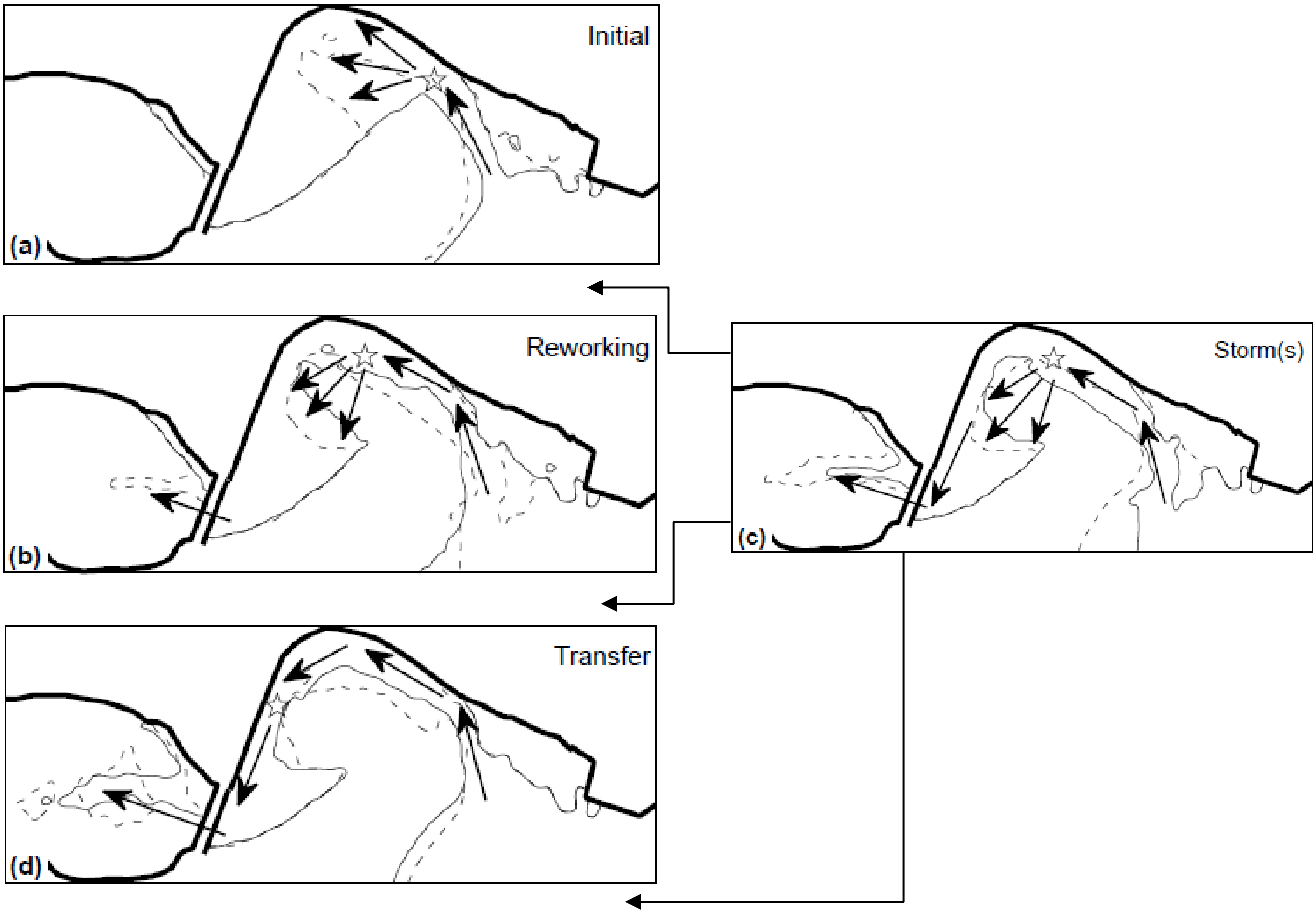

Figure 2-7: Lagoon entrance morphodynamics (Morris, 2010)

The shallowness of the lagoon entrance channel introduces so-called ‘shallow water effects’ for movement of tides within the lagoon. These effects result in an elevated average water level in the lagoon, a shorter duration flood tide (i.e. incoming tide) with higher peak flow rate, and a longer duration ebb tide (i.e. outgoing tide) with lower peak flow rate. The friction in the channel also has an effect in reducing tidal energy, although it does not greatly alter the hydraulics of the lagoon system. The inequality in flood and ebb tide flow rates caused by a shorter flood tide period with larger peak flow rate compared to a longer ebb tide period with lower peak flow rate , in combination with wave stirring at the lagoon entrance, has an important influence on the dominant sand transport direction in the entrance channel. The result is the net transport of sand by tides into the lagoon entrance (Cardno, 2019).

Sand enters the lagoon entrance area under the action of waves, which mobilise the sand within the surf zone and deliver it to the seaward end of the entrance channel. Sand is also transported towards the entrance alongshore within the swash zone by waves breaking and running up at an angle to the beach alignment. Other mechanisms for sand transport into the lagoon include wind-blown transport of beach sand over the dune and wave overtopping of the beach berm adjacent to the entrance channel, which can mobilise sand from the berm and deposit it into the entrance channel behind (so-called washover transport, refer **Figure 2-8**).

Figure 2-8: Overtopped beach berm following large swell (left), Sand washover into lagoon entrance (right) (May 2021)

It is well known that Collaroy-Narrabeen Beach experiences decadal cycles of beach rotation whereby there is either a net sand transport to the northern end or to the southern end of the beach resulting in varying beach widths at the ends depending on the stage of the cycle (refer **Figure 2-9**). This is caused by changes in predominant wave direction associated with the El Nino-Southern Oscillation (ENSO) climate cycle. This process affects sand availability at the entrance.

The clockwise beach rotation in recent times has increased beach berm sand volumes and width at North Narrabeen, resulting in an increased frequency of entrance clearance campaigns and an increased level of effort when undertaking mechanical opening of the entrance. As such, the future entrance management regime of entrance clearance campaigns will need to provide flexibility for more frequent entrance clearance campaigns to be completed during periods of clockwise beach rotation and less frequent campaigns to be completed during periods of anti-clockwise beach rotation.

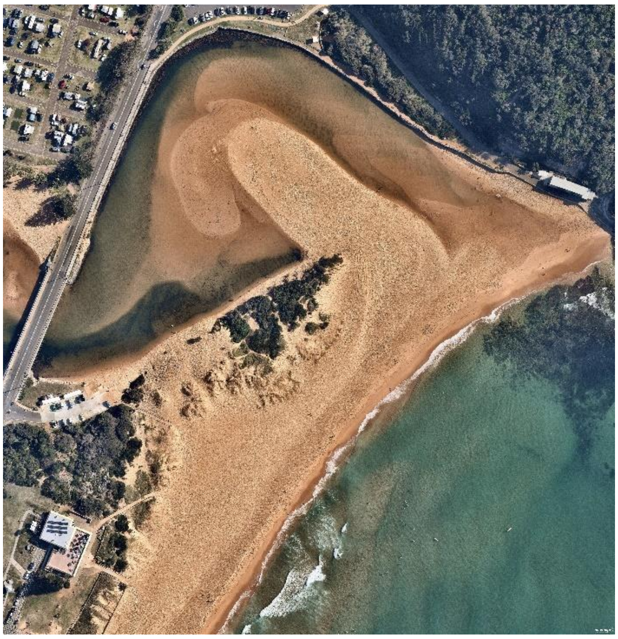

Figure 2-9: North Narrabeen beach states (Left: October 2020 – clockwise rotation; Right: June 2010 – anti-clockwise rotation)

Once sand is deposited within the entrance channel, its movement is dictated by the action of tidal currents and catchment flood events. As noted above, under the action of tidal currents the sand is transported further into the lagoon entrance and deposited as entrance shoals due to the dominance of the flood tide currents. Catchment floods act to scour the entrance and transport sand seaward. However, this entrance scour is an episodic process that does not happen anywhere near as frequently as tidal and wave action.

The severity of rainfall-based flood events at Narrabeen Lagoon is often directly impacted by whether the ICOLL is closed or open, and, when the entrance is open, the volume and configuration of sand that has accreted within the entrance shoals will also impact the conveyance of flood flows and resultant lagoon flood water levels. Based on data between 1984 and 2010, it was determined that Narrabeen Lagoon was open (either naturally or artificially) approximately 75% of the time (Morris, 2010).

Based on analysis of records provided by Council, the lagoon was open for approximately 76% of the time during the 2010 to 2020 period, including an extended period of open conditions between November 2011 and September 2015. Based on Council records, in the last 5 years between September 2015 and the end of 2020 the lagoon was open for approximately 60% of the time, indicating that periods of entrance closure have increased in recent times. Analysis of the water level record at the Ocean Street Bridge gauge over the 26-year period of available record (5 August 1994 to 21 October 2020) determined that the entrance was open for 73% of the time, which is similar to the result determined by Morris (2010) and likely to represent the long term percentage open statistic under current entrance management practices.

As noted above, beach rotation at Collaroy-Narrabeen Beach has a significant influence on the entrance condition, with periods of clockwise rotation in recent times resulting in a wider beach berm at North Narrabeen Beach, increased periods of entrance closure, and corresponding increased frequency of entrance clearance campaigns and level of effort when undertaking mechanical opening of the entrance.

The periodic excavation of the flood tide delta at the lagoon entrance (i.e. entrance clearance operations) results in a higher likelihood of the lagoon entrance becoming open and remaining open. Numerical modelling completed by Cardno (2019), concluded that the Council's medium term entrance management strategy is effective in its aim to reduce flood levels. In comparison to a closed and shoaled entrance condition, entrance clearance reduces peak flood levels throughout the lagoon by around 0.38-0.54m or more for the more frequent floods of 20% and 5% AEP[1]. The 1% AEP flood event had reductions of between 0.35 m and 0.46 m, while the 0.1% AEP flood event had reductions of 0.27-0.37 m.

However, the entrance clearance operation only provides a short to medium term improvement in the hydraulic efficiency of the entrance for flood mitigation whilst the underlying driving processes for entrance shoaling and closure remain unchanged. As such, the natural system acts to restore its equilibrium position after being disturbed by the entrance clearance and the flood level reduction benefit is reduced over time as the entrance becomes constricted with progressive shoaling.

2.2.2.1 Birdwood Park Dune

The Birdwood Park dune is part of the North Narrabeen beach dune system. Prior to 1974, it was a low dune spit at a height of approximately 3 - 4.5 metres above mean sea level, that would allow overtopping by large waves during severe storm events. Aerial photos of the entrance from 1930 to 1975 shown in **Section 2.1.1** of this report (refer **Figure 2-2**) show that it was quite common for the entrance area to be choked with a large volume of sand. Additional historical photos are provided in **Figure 2-10** and **Figure 2-11** below.

Figure 2-10: Narrabeen looking west – from Scenes of Narrabeen album, ca. 1900-1927 – Sydney & Ashfield, State Library

[1] *Annual Exceedance Probability, refer* ***Glossary***.

Figure 2-11: Narrabeen entrance – shortly after construction of the Ocean Street Bridge, ca. 1920s

During the May 1974 storm, elevated ocean water level conditions and wave action resulted in washover of the entire sand spit in the Birdwood Park area, with sand completely infilling the channel downstream of the Ocean Street Bridge and also being transported into the channel upstream of the bridge. The Ocean Street Bridge was seriously damaged, as shown in the photos below (refer **Figure 2-12**).

Figure 2-12: Damage to Ocean Street Bridge in 1974

After the 1974 storm, the dune was substantially raised by the then Public Works Department to prevent further wave overtopping, using sand excavated from the entrance area. Further sand replenishment work on the dune was undertaken in 1982, and the formation of a more substantial and stabilised dune occurred in 1984, by pushing sand landward from the beach berm. Over the past few decades, the dune has increased in height and width through the process of capturing sand that would have otherwise blown over the top of it and into Narrabeen Lagoon. Following establishment of Birdwood Park dune, it was observed that the frequency of entrance closure was reduced in comparison to when a low flat area of unvegetated sand existed previously.

The Birdwood Park dune has several important functions including stabilising the position of the lagoon entrance channel, providing protection from wave washover sand deposits into the lagoon, protecting the

Ocean Street Bridge and the adjacent foreshore, and limiting wind-blown sand transport into the lagoon. The dune system also acts to retain sand that may otherwise be available for transport into the lagoon entrance under the action of waves and tidal currents. **Figure 2-13** shows the functional model of dune vegetation from the Dune Management Manual (DLWC, 2001), which includes the trapping of sand on the incipient or frontal dune.

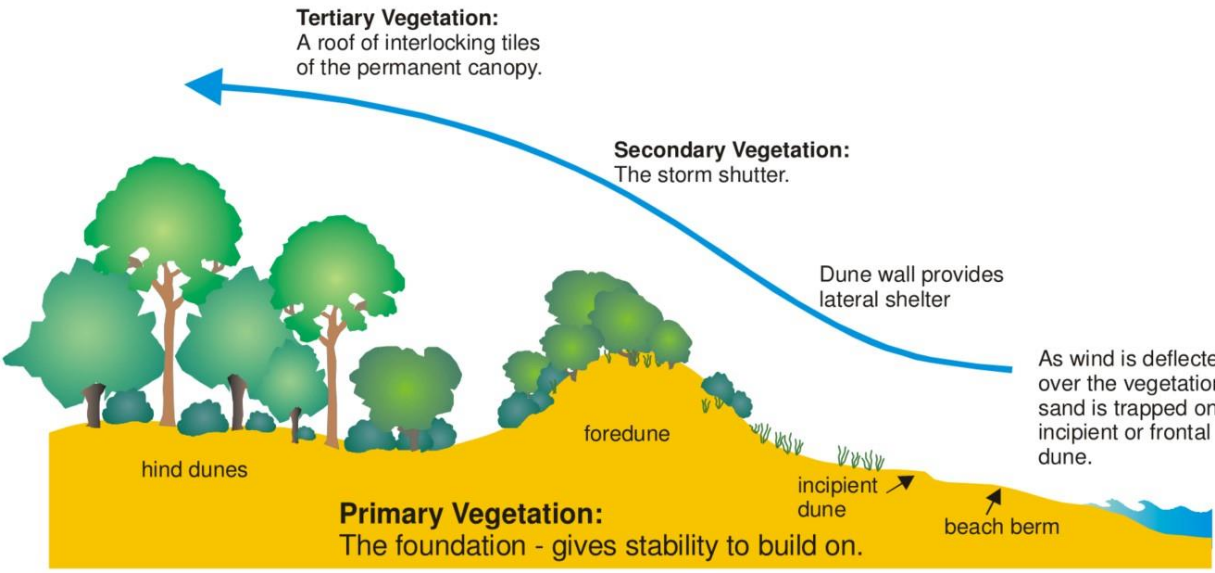

Figure 2-13: Functional model of dune vegetation (DLWC, 2001)

The growth of the dune has led to some community concerns about its size and the impact on sight lines for both Council and volunteer lifeguards when viewing swimmers and beach users from North Narrabeen Surf Club. Council carried out community consultation when developing the North Narrabeen Beach Reserve and Birdwood Park Masterplan in 2013.

Council continues to review management of the dune and opportunities to redistribute sand during planning for future Narrabeen Lagoon entrance clearance works while maintaining the dune height to mitigate the impacts of coastal hazards.

Water Research Laboratory (WRL, 2012) identified that the Birdwood Park dune could be lowered to 7 or 6 m AHD from a coastal erosion perspective. However, at a 6 m AHD elevation, wave runup and overtopping during a large storm event could compromise the stability of the remaining dune, increasing risk to public and private assets located to the west of Birdwood Park.

It has also been observed in recent times that significant vegetation has been lost from Birdwood Park dune, leaving large, denuded areas, as demonstrated by comparison of the aerial photos provided in **Figure 2-14**. This has led to weed invasion and areas of dune exposed with little or no vegetation. The dune has been subject to revegetation and bush regeneration since the re-profiling, however this has been largely unsuccessful.

Recent observations suggest the western side of the dune appears to be progressing west into the lagoon, probably due to wind and recreational activity pushing the sand into the lagoon.

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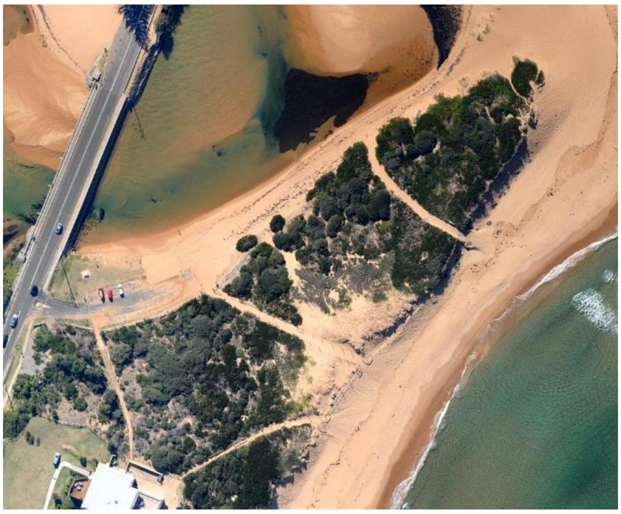

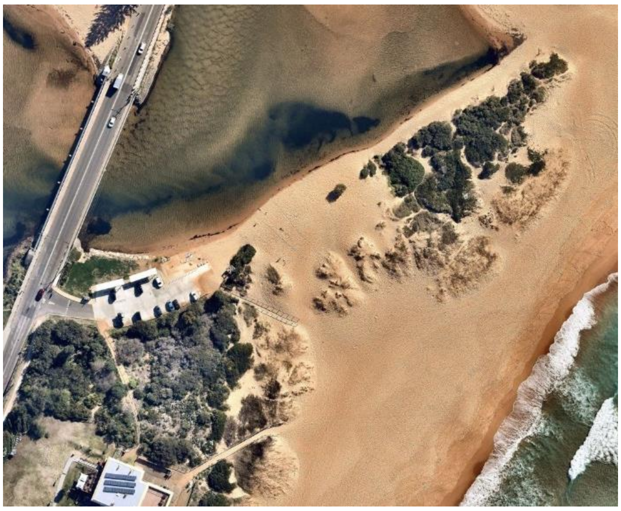

Figure 2-14: Birdwood Park dune aerial photograph comparison – June 2010 (left), August 2021 (right) (Source: Nearmap)

2.3 Lagoon entrance environment

2.3.1 Aquatic habitat

The intertidal and subtidal areas of the lagoon entrance area encompass approximately 900 m and 550 m of the northern and southern shorelines of Narrabeen Lagoon respectively. Numerous environmental studies have been undertaken in this area, both east and west of the Ocean Street Bridge, over the past decade to inform previous entrance clearance operations. The key findings of these studies are detailed below.

The northern shoreline of the lagoon abutting the east side of Ocean Street, the Narrabeen Head Lookout car park and walkway to the ocean pool is predominantly vertical sandstone seawall, while the northern shoreline between the west side of Ocean Street Bridge and the vertical sandstone fishing wharf is predominantly a sandy beach adjacent to the caravan park with some vegetated sections. East of Ocean Street Bridge, the southern shoreline is predominantly sandy beach linked to Birdwood Park Dune and to the west the shoreline includes a mixture of seawalls or unprotected foreshore at the edge of residents' landscaped gardens or parkland (Cardno, 2021).

The northern and southern abutments of Ocean Street Bridge are sloped revetments of riprap (rock material) and concrete. Several concrete piles under the bridge are installed directly into soft sediment habitat. Narrow, low relief subtidal rocky reefs occur in all areas abutting rocky seawalls and abutments. Intertidal rocky reef habitat occurs along the vertical sandstone wall and bridge abutments. The bridge piles in the channel also provide some limited intertidal rocky reef habitat. These areas are largely colonised by Sydney rock oysters (*Saccostrea glomerata*) along with other invertebrates commonly found on intertidal rocky reefs in the Sydney region (Cardno, 2021).

Fringing, subtidal, rocky reef areas occur adjacent to the vertical sandstone wall on the north-eastern shoreline, and under and to the west of the bridge on the southern shoreline. The subtidal rocky reef areas comprise loose sandstone/riprap dislodged from the seawall and abutments and some natural bedrock. A sparse cover of brown macroalgae, *Sargassum spp*. occurs in these areas.

Invertebrates in the subtidal rocky reef areas include the sessile cunjevoi (*Pyura stolonifera*) and a number of mobile invertebrates commonly found on subtidal rocky reefs in the Sydney region. Subtidal soft sediment habitat covers the remaining areas in the channel. A majority of infauna in soft sediment areas of

Narrabeen Lagoon comprise polychaetes (Class Polychaeta), bivalves (Class Bivalvia) and gastropods (Class Gastropoda). Other infauna, albeit in smaller numbers, include nemerteans (Phylum Nemertea), nematodes (Phylum Nematoda), crustaceans (Phylum Arthropoda) and echinoderms (Phylum Echinodermata). Infauna in the soft sediment of Narrabeen Lagoon are common to the estuaries of south-east Australia (Cardno, 2021).

Seagrasses to the east of Ocean Street Bridge are normally limited to a small, fragmented patch of high density *Zostera muelleri* subsp. *capricorni* (Zostera) which co-occurs with a larger bed of low relief rocky reef on each side of the southern end of the Ocean Street Bridge (near the abutment, Birdwood Car Park). One small, fragmented patch of high density Zostera has been recorded near the stormwater outlet opposite the Narrabeen Head Lookout car park, among rocky reef and *Sargassum* spp.

Seagrass are not normally observed directly below Ocean Street Bridge. West of the bridge, however, there are normally two large beds of high density Zostera: one extending in a south to south-westerly direction adjacent to the Lakeside Park shoreline; the other on the bank at the southern edge of the Study Area, extending south-west from Malcolm Street, Narrabeen. One fragmented bed of high density *Zostera* was recorded recently adjacent to the northern shoreline, and the fishing platform, among wrack, 80 m north-west of Ocean Street Bridge. Several fragmented beds fringing the shoreline were recorded on the southern bank towards the end of Malcom Street, Narrabeen. Fringing beds of various density Zostera were recorded adjacent to the western side of Ocean Street Bridge (Cardno, 2021).

Seagrass can be easily destroyed and if seagrass meadows are damaged, their recolonisation can be very slow. The leaves of the seagrass grow quickly but the rhizome (stem) grows relatively slowly. The ability of seagrass to recover after disturbance varies between seagrass species.

It must be noted that estuarine vegetation, including seagrass, are protected under the Fisheries Management Act 1994. Seagrass functions to slow down water currents and stabilise the seabed, and provides important habitat for aquatic fauna, particularly fish breeding grounds and nurseries for juvenile fish.

2.3.2 Terrestrial habitat

The riparian areas of the lagoon entrance area include publicly accessible sand dunes, native/remnant riparian corridors, planted/landscaped verges and gardens and handstands and man-made structures. The riparian vegetation surrounding the entrance area can be classified into six communities. Five of these communities can be categorised into native plant community types based on their floristics, landscape and the local geology. The remaining community is comprised of native/exotic verges/gardens.

The vegetation along the northern shoreline is mostly native/exotic verges and gardens along the sand dunes, roadside and car park, although some isolated Coastal Swamp Oak (*Casuarina glauca*) occur along the Pelican Path walkway. A small patch of Coastal Sand Tea-tree Banksia Scrub extends into the riparian area from the east. This path consists of a moderately dense canopy of coast tea-tree (*Leptospermum laevigatum*) over a native/exotic understorey (Cardno, 2021).

Three vegetation communities exist on the southern shoreline and foredune: Coastal Foredune Wattle Scrub, Spinifex grassland, and Estuarine Reedland. The latter of the three is also potentially associated with a Threatened Ecological Community (TEC) listed under the BC Act and EPBC Act.

The Coastal Foredune Wattle Scrub occurs on the sand dunes east of the Ocean Street Bridge and is characterised by a mixed overstorey of coast tea-tree and coastal wattle (*Acacia longifolia* subsp. *sophorae*) over a native/exotic understorey. This vegetation community extends south towards the North

Narrabeen SLSC. There are a number of blowout areas within this dune vegetation, largely on Birdwood Park Dune (the northern-most dune). Spinifex grasslands co-occurs with Coastal Foredune Wattle Scrub on the incipient zone at the Birdwood Park Dune.

Dense stands of common reed (*Phragmites australis*) are present on the western side of the Ocean Street Bridge, foreshore of the residential complex and the foreshore of Lake Park. There are no overstorey species in the Estuarine Reedland (Cardno, 2021).

2.3.3 Fauna species

The vegetation within the entrance area provides habitat for several native bird species, reptiles and fish. These areas are likely to experience substantial existing levels of disturbance from human traffic and pets, and are thus more suited for disturbance tolerant, urban species. The sandflats (open beach areas) provide potential foraging habitat for native shore/wading birds as the water level drops. Much like the vegetated areas, these open areas are also likely to experience substantial human and pet traffic, and are considered suboptimal for habitation. Fishing raptors such as Osprey are known to forage in the waters of Narrabeen Lagoon and fly over the entrance while foraging in nearby open water.

Seagrass meadows provide shelter and food for fish and are generally considered nurseries for many fish species. Studies have shown that across the lagoon, fish were most abundant in the central and western basins, and least abundant in the eastern channel and entrance area. However, the species diversity across the lagoon was fairly even (15 species in the eastern channel, 13 in the central basin and 12 species in the western basin).

In 2009, consultancy firm BMT WBM recorded the Hairy Pipefish (*Urocampus carinirostris*) in a fish survey of Narrabeen Lagoon. This species is listed as protected under the Fisheries Management Act 1994 and is also a listed marine species under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (BC Act). Any activities that may adversely affect the viability of this species in the lagoon need to be carefully managed. Key habitats for *U. carinirostris* are the lower reaches of rivers and estuaries or other protected inshore habitats where it was found in seagrass (Zostera) beds (Cardno, 2021).

Overall, 47 threatened fauna species listed under the BC Act have been recorded in the locality of Narrabeen Lagoon. Of these, a number of birds are considered to utilise the aquatic and estuarine environment of the lagoon. However, as previously discussed, they are more likely to inhabit areas when there is low human interaction.

Two threatened species that have been recorded in the general lagoon area include the Powerful Owl (Ninox strenua) and the Grey-Headed Flying Fox (Pteropus poliocephalus). Glossy Black Cockatoo and Grey Headed flying fox may also use the Swamp Oak Floodplain Forest on the islands upstream of the entrance area as foraging vegetation (SMEC, 2011).

A number of migratory species have also been recorded in and around Narrabeen Lagoon. These migratory species utilise coastal areas including coastal lagoons for foraging, breeding and nesting habitat. The lagoon provides suitable foraging habitat for species such as Osprey (P*andion haliaetus*); Great Egret (*Ardea alba*); White-bellied Sea-Eagle (*Haliaeetus leucogaster*); and Caspian Tern (*Sterna caspia*) as they feed on fish and some also feed on frogs and invertebrates in shallow water and foreshore vegetation. Only the Osprey is considered to have nesting habitat at Narrabeen Lagoon with a successful nest site being located between Middle Creek and Wakehurst Parkway (Cardno, 2021).

2.4 Flood behaviour

2.4.1 Flood Study and Floodplain Risk Management Plan

Council manages flood risk in accordance with the NSW Government's Floodplain Development Manual, producing the Narrabeen Lagoon Flood Study (BMT WBM, 2013) and the associated Floodplain Risk Management Study and Plan (Cardno, 2019).

2.4.2 Findings from the Narrabeen Lagoon Flood Study

In 2013, BMT WBM completed 'The Narrabeen Lagoon Flood Study', which discussed Narrabeen Lagoon's existing flood behaviour and established the basis for subsequent floodplain management activities. The report studied design flood conditions on the Narrabeen catchment for a range of events (0.1% to 50% AEP, including the probable maximum flood). This allowed for catchment and ocean derived flooding to be analysed for these conditions and conclusions drawn from the results.

Conclusions from the flood study are summarised below:

- It was found that the rise in flood water levels was relatively fast due to the catchment's rapid response to rainfall. Large magnitudes of water level increase can occur in only a few hours. This has implications for flood warning and emergency response.
- Regardless of the implementation of Council's policy to mechanically open the entrance during flood events, significant flood inundation is expected during major catchment floods.
- There are several low-lying areas within the catchment that are at the greatest risk during flood events.
- Potential sea level rise will result in worsening flood conditions due to higher ocean water levels, higher entrance sand berm levels and associated higher initial water levels in the lagoon.
- Due to the potential sea level rise, Council's trigger levels (currently 1.0-1.3 m AHD) for mechanical opening may need to be reconsidered in the longer term. Future trigger levels will likely need to be significantly higher to result in effective scouring of sand at the lagoon entrance.

2.4.3 Findings from the Floodplain Risk Management Study and Plan

The Narrabeen Lagoon Floodplain Risk Management Study and Plan (FRMSP) was developed based on the Narrabeen Lagoon Flood Study prepared by BMT WBM in 2013.

The Narrabeen Lagoon FRMSP purpose was to direct and co-ordinate the future management of flood prone land within the Narrabeen Lagoon catchment. It also aimed to educate the community about flood risks so that they can make more informed decisions regarding their individual exposure and responses. The FRMSP described existing flood behaviour and economic damages.

There is potential for substantial damages to occur in relation to relatively small flood events such as the 20% AEP (occurs every five years on average) flood event, due to inundation occurring above the floor level for 229 properties. In the rarer 1% AEP (occurs every 100 years on average) 659 properties are inundated above the floor level. The average annual damages for the Narrabeen Lagoon floodplain under existing conditions is around $11.5 million.

The assessment of management options in the Floodplain Risk Management Study identified the most beneficial options (in terms of hydraulics, economics, environmental and social issues). The Floodplain Risk Management Plan presented a priority list of actions that is a mix of structural and non-structural options to reduce the likelihood and / or consequence of flooding at various locations in the catchment. These options are being progressed separately to this draft Entrance Management Strategy, and include:

- Flood modification measures (e.g. levees, detention basins, channel works and upgrades);
- Property modification measures (e.g. house raising, voluntary purchase, land swap);
- Emergency management measures (e.g. flood warning systems, evacuation planning); and,
- Flood planning levels.

The Narrabeen Lagoon Floodplain Risk Management Study investigated the impact of entrance management options on flooding. It reviewed the trigger level at which mechanical opening occurs, and assessed the consequences of changing that trigger level. Morphological modelling was conducted for a range of different trigger level scenarios, which included lowering the trigger level (from 1.3 m AHD) to 1.1 m AHD, and raising it to 1.5 m AHD. The lower trigger levels were assessed in order to determine if earlier mechanical opening could significantly reduce the subsequent peak flood levels. The higher trigger level was assessed in order to determine if a management regime consisting of less frequent mechanical openings could be adopted without negatively affecting flood levels within the lagoon (refer **Table 2-3**).

- It was noted by Cardno (2019) that a lower trigger level of 0.8m AHD had also been assessed by Tulk & Beadle (2017). The results of this investigation showed that lowering the trigger level by 0.5 m to 0.8 m AHD reduced peak flood levels for a 1% AEP event by approximately 0.15 m (refer **Table 2-4**). Note that for a 1% AEP there is a 1% chance in any given year of the event occurring. This means that on average 1 event of this size will occur every 100 years. Reductions in flood level for a 20% AEP scenario, meaning there is a 20% chance in any given year the event will occur, were deemed likely to be even less effective.
- It was concluded that reducing the mechanical opening trigger level from 1.3 m AHD to 1.1 m AHD may be a viable alternative to the present practice, however reductions in the 20% AEP peak flood levels were relatively modest, at 7 cm and the efficiency and effectiveness of mechanical entrance opening would be reduced with lower levels. Conversely, it was concluded that while increasing the lagoon trigger level may result in less frequent mechanical openings and more confidence in achieving a fully scoured entrance opening, the increase in flood level for a relatively common 20% AEP event (around 12 cm) was likely to be unacceptable to both Council and the local community. Therefore, it was concluded that Council's current mechanical opening level of 1.3 m AHD was appropriate for present day mean sea level conditions.

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Table 2-3: Mechanical entrance opening – modelling Results for 20% AEP catchment event (Cardno, 2019)

Mean Sea Level Scenario	Trigger Level (m AHD)	U/S Ocean St Bridge		U/S Pittwater Rd Bridge		U/S Deep Creek Bridge	
		Flood Level (m AHD)	Δ to 1.3 (m)	Flood Level (m AHD)	Δ to 1.3 (m)	Flood Level (m AHD)	Δ to 1.3 (m)
Present Day	1.1	2.42	*-0.07*	2.48	*-0.07*	2.49	*-0.06*
	1.3	2.49	*0.00*	2.54	*0.00*	2.55	*0.00*
	1.5	2.61	*0.12*	2.66	*0.12*	2.67	*0.12*
2050 (+0.4 m)	1.5	2.69	*0.20*	2.73	*0.19*	2.74	*0.18*
	1.7	2.75	*0.26*	2.79	*0.25*	2.80	*0.25*
	1.9	2.91	*0.43*	2.95	*0.41*	2.96	*0.40*
2100 (+0.9 m)	2.0	3.06	*0.57*	3.08	*0.54*	3.09	*0.53*
	2.2	3.14	*0.65*	3.17	*0.63*	3.18	*0.62*
	2.4	3.29	*0.80*	3.32	*0.78*	3.32	*0.77*

Table 2-4: Impact of entrance management actions on lagoon 1% AEP flood Levels (Tulk & Beadle, 2017)

Flood AEP (%)	Location	Present Trigger Level (1.3m AHD)	Option Trigger Level (0.8m AHD)	Option Trigger Level (1.1m AHD)	Option Trigger Level (1.5m AHD)
1	Ocean St Bridge	2.94	*-0.14*	*-0.05*	*+0.09*
	Pittwater Rd Bridge	3.03	*-0.15*	*-0.06*	*+0.08*
	Deep Creek Bridge	3.04	*-0.15*	*-0.06*	*+0.08*

2.5 Recreation

Narrabeen Lagoon is one of the most popular public recreational locations on Sydney's Northern Beaches, being the only ICOLL in Sydney that allows primary contact recreational activities. Further, the recreational values of the lagoon are closely linked with environmental quality and significance of a place as well as the opportunities, activities and facilities available for public recreation and visitation.

Narrabeen Lagoon has been consistently used for public recreational purposes since the late 1800s. Recreational use of the lagoon has been documented through newspapers and photographs and through the establishment of clubs and organisations since the 1970s. One of the main impacts on recreation in a historical context has been the fluctuating water quality and depth of the lagoon throughout the last century (SMEC, 2011).

It is important to note that the main effect of the mechanical opening of the lagoon to protect low-lying properties from flooding, is the resultant lowering of the water level across the entire lagoon. This can impact many water-based activities such as sailing, boating, windsurfing, stand-up paddleboarding, and fishing due to the exposure of sandbars, shallower sandbanks and seagrass beds.

However, an open lagoon also normally leads to improved recreational water quality within the lagoon near the entrance. This leads to a greater uptake of swimming and other primary contact activities, especially near Birdwood Park where many families come down for picnics and to swim and splash with younger children in the relatively calm waters of the lagoon compared to the ocean beach.

The entrance area plays host to many water-based and terrestrial recreational activities including:

- Swimming, paddling and playing in the water;
- Surfing;
- Snorkelling;
- Stand-up paddleboarding and kayaking/canoeing;
- Fishing;
- Picnics and BBQs;
- Cycling;
- Walking/strolling/jogging; and,
- General passive recreation/relaxing/cafes etc.

Of major importance is the surf break at North Narrabeen Beach adjacent to the lagoon entrance. The world-famous surfing beach has played an important part in the history of surfing culture in Australia. The North Narrabeen break is internationally known to be one of the most consistent quality surf breaks on the east coast of Australia. The break has produced many surfing champions over multiple generations and has been home to top tier local, state, national and international surfing events for decades, most recently the World Surf League Championship Tour event, Narrabeen Classic in 2021. The social, recreational and economic benefits of the break to the local area is difficult to measure, but is highly significant and valuable. The swimming and bodysurfing conditions are also of high quality, and the beach is patrolled by surf lifesavers throughout much of the year. North Narrabeen became a National Surfing Reserve in 2009, which reflects its importance and recognises it as warranting protection for current and future generations of surfers and other beach-goers.

Sand banks, rips, rocky underwater reefs along with swell characteristics, play an important role in the creation of a good surf break. The quality of the North Narrabeen surf breaks is produced from a function of all these factors. The "Alley" surf break as it known is an A-frame shaped break caused by the rock platform under the break, which is covered by a thin layer of sand. The headland rip that travels from the beach alongside the headland rock pool creates the wave shape that forms the “Alley Rights” wave and also has an impact on “The Point” wave, situated off the rock pool. It is arguable as to whether the waves are improved when the lagoon entrance is open as the additional current that may be generated from the ebb tide discharging through the open lagoon entrance could make the rip current too deep under certain conditions, and in certain areas the bathymetry is already governed by the rock platform. It is difficult to determine the impact of an open lagoon on the “Alley lefts” break, which is the most famous and consistent of the North Narrabeen surf breaks. The quality of the breaks are determined by the swell size, direction, period and the wind and tide conditions. The quality of the Alley Left sand banks on any individual day is generally the result of recent large swells (or lack thereof), as well as the decadal rotation of the whole Collaroy-Narrabeen Beach (more or less sand volume at North Narrabeen compared to Collaroy Beach). This is expected to have an impact as more sand along the surf banks at North Narrabeen generally causes longer running quality waves. Overall, many local experts agree that whether the lagoon is open or not does not play a major role in the quality of the surf break compared to a vast array of other factors.

2.6 Heritage

2.6.1 Aboriginal heritage

The NSW Aboriginal Heritage Information Management System identifies two known Aboriginal sites are located within 500 m of the Narrabeen Lagoon entrance area.

A midden and open campsite are located on Narrabeen Headland north of the area, and a shelter with midden is located at Turimetta Head. No known Aboriginal sites are located within the entrance area itself that could be impacted by the future works. It is unlikely that unidentified Aboriginal sites or places would be uncovered in the future (Cardno, 2021), but if they are, they would need to be investigated further as part of the consent process.

2.6.2 Non-aboriginal heritage

A number of items exist in the entrance area that are considered to have minor heritage value including a Stone Wall located along Ocean Street immediately adjacent to Birdwood Park, a group of Washington Palms near Malcolm Street, and Narrabeen rockpool (Cardno, 2021).

North Narrabeen Beach is also of importance as it was awarded the status of a National Surfing Reserve in 2009 due to its rich surfing history and consistent high-quality waves.

2.7 Literature review

2.7.1 Council strategies and policies

As part of investigations into appropriate entrance management strategies a review of the current policies and strategies that inform the management of Narrabeen Lagoon Entrance and other available relevant literature has been undertaken. This literature review (presented in **Appendix A**) has contributed to development of the recommendations within this report. A summary of the information found from review of key literature is provided below.

2.7.1.1 Narrabeen Lagoon Entrance Study (Manly Hydraulics Laboratory, 1989)

In 1989, the Manly Hydraulics Laboratory completed the Narrabeen Lagoon Entrance Study, a detailed report for Warringah Shire Council to facilitate the development of an entrance management strategy for

Narrabeen Lagoon. This study provided a summary of historical lagoon entrance management, the environmental and social impacts of extended entrance closure on the lagoon, and a discussion and quantification of the sediment processes and water balance acting at the lagoon entrance.

It also provided a detailed assessment of four potential longer term management strategies, including formal operations procedures and costings, that were considered to provide solutions to the entrance management problems. These strategies included:

- mechanical breakout and entrance clearance operations
- ebb tide fluidisation of channel bed
- excavated entrance and low training wall(s)

The first option (which is currently employed) was identified as the most viable option for short and medium term entrance management.

2.7.1.2 Warringah Coastal Lagoons Entrance Management Review (BMT WBM 2009), and Warringah Lagoons Review of Environmental Factors and REF Supplementary Information (Warringah Council, 2011)

In 2009 and 2011, BMT WBM on behalf of Warringah Council prepared the 'Warringah Coastal Lagoons Entrance Management Review' and 'Warringah Lagoons Review of Environmental Factors', and 'Review of Environmental Factors – Supplementary Information' reports. The review considered the short-term mechanical opening of Narrabeen, Dee Why and Curl Curl Lagoons based on trigger levels and gave a detailed description of the proposed activities to be undertaken to enact the mechanical openings. The REF and Supplementary Information assessed the impacts of the construction and operation of the mechanical opening on a variety of factors including physical, chemical, biological, community, natural resources, Aboriginal heritage and other cultural heritage. The impacts were found to be either negligible or positive.

2.7.1.3 Infilling and sedimentation mechanisms at intermittently open-closed coastal lagoons (Morris, 2010)

Morris' (2010) University of New South Wales doctoral thesis investigated infilling mechanisms and sedimentation processes at ICOLL entrances in order to understand how the changing morphology of these systems affected the tendency for entrance closure. It also investigated the impacts of climate change on the future of these systems. Data was collected between 2006 and 2008 from the Narrabeen Lagoon entrance following the mechanical removal of the flood tide delta at the lagoon entrance in 2006 (for mitigation of flood risks).

Morris found that sedimentation occurred rapidly (at variable rates) at the lagoon entrance by forms of infilling rather than backfilling[2]. The lower flood tide shoal (downstream of Ocean Street Bridge) was observed to form and grow first followed by the upper flood tide shoal (upstream of Ocean Street Bridge).

Additionally, Morris' investigation into climate change suggested that the natural cycle at which the entrance opens, and closes would accelerate leading to decreased periods in which the entrance was open to the ocean. Morris' research also suggested that higher frequency, smaller-scale entrance clearances would be more efficient than the current large-scale removal of the entire flood tide delta (every 3-5 years). This was due to studies determining that rates of infilling were dependent on accommodation space (area within the system available for the deposition of sand being transported into

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[2] *Backfilling becomes an important process when rapid sedimentation occurs on the flood tide shoal, forming a barrier to the passage of sand deeper into the lagoon.*

the entrance) with little or no direct correlation with longshore sand transport delivery (except during storm events).

2.7.1.4 Lagoon Entrance Management OMS (Warringah Council, 2013)

In 2013, Warringah Council developed the Lagoon Entrance Management Operational Management Standard, OMS 455. The OMS provides guidelines, principles and procedures required to ensure safe and effective implementation of mechanical opening of the entrances at Dee Why, Curl Curl and Narrabeen Lagoons. Under this OMS, the trigger level for mechanical opening for Narrabeen Lagoon is between 1.0 m and 1.3 m AHD. The OMS is discussed further in **Section 4**.

2.7.1.5 Narrabeen Lagoon Flood Study (BMT WBM Pty Ltd, 2013) and Narrabeen Lagoon Floodplain Risk Management Study & Plan (Cardno, 2019)

The findings from these two documents are discussed in **Section 2.4.2** and **Section 2.4.3**.

2.7.2 Relevant State frameworks

Due to its influence on flooding behaviour ICOLL entrance management can be considered as part of a Coastal Management Program or Floodplain Management Program.

2.7.2.1 Coastal Management Program

Under the NSW Coastal Management Framework, a council identifies if it intends to artificially manage an ICOLL entrance. If the council decides to do this, their adopted policy/management framework may include triggers to consider impacts of the entrance opening based on:

- tidal inundation and flood levels;
- the health and water quality of the estuary and fringing wetlands; and,
- community use of the estuary.

Additionally, the framework should consider long term impacts on the environment as well as impacts from climate change. Occasionally, the management policy of the entrance will support lack of artificial intervention to allow a more natural regime to take place. This occurred in the entrance management plan of Swan Lake (Shoalhaven City Council, 2004; Stephens & Murtagh, 2011). In this case, a relatively high lagoon opening level of 2.5m AHD has been set and the inconvenience of minor inundation of foreshore areas is considered to be acceptable for a very short period of time (i.e. in an unexpected flood event). Based on experience at Swan Lake, at or prior to this level, the lake would be expected to open naturally and may require only occasional intervention by Council when the beach berm is unusually high.

2.7.2.2 Floodplain Management Program

Floodplain Risk Management Plans produced under the Floodplain Management Program assess the impact of all options to reduce flooding including artificial entrance management. They must adequately assess the benefits and risks of artificial intervention. Before an entrance management policy can be set to incorporate floodplain management, the environmental and social impacts must also be considered.

2.8 Council's current entrance management activities

The main goal of Council's current lagoon entrance mechanical openings and clearance is to minimise the potential impact and risk of flooding on public and private commercial, industrial and residential properties. The entrance clearance operations also aim to maintain or enhance water quality in the Lagoon and to conserve or enhance the biological diversity of the Lagoon system.

A summary of the current practices and further definition of EMS elements is provided below.

2.8.1 Short Term Management

The short term emergency management activity undertaken by Council when the lagoon entrance is closed and certain trigger conditions are satisfied, is to complete what is called a mechanical opening. A mechanical opening involves the use of excavators to dig a channel through the beach berm to connect the lagoon to the ocean, allowing water to flow out of the lagoon into the ocean and ultimately lowering the lagoon water levels (refer **Figure 2-15**). The main aim of this activity is to reduce or prevent the flooding of low-lying areas around the lagoon foreshore in the event that lagoon water levels are elevated and moderate to heavy rainfall is forecast.

As is explained in more detail in **Section 4**, mechanical openings are most successful at draining the lagoon when the water level within the lagoon is higher than the ocean water level (lagoon water level at least at 1.0-1.3 m AHD). This provides the necessary water level height difference between the lagoon and ocean, called the hydraulic head, required for effective scouring of sand in the channel to result in the entrance remaining open for as long as possible.

Figure 2-15: Mechanical opening of the lagoon entrance (4 June 2021)

2.8.2 Medium Term Management

As opposed to the small scale, short term mechanical openings Council also periodically undertakes a larger scale operation to remove a much greater volume of sand from the lagoon entrance area (refer **Figure 2-16**). This keeps the entrance open for typically a few years, but even when the entrance does eventually close again, it means that short term mechanical openings can work when required for flood mitigation purposes. Entrance clearance operations have been carried out at relatively regular intervals (3-5 years) since 1975, removing approximately 30,000-50,000 m^3 of sand per operation.

Medium term entrance management, including entrance clearance operations, is discussed further in **Section 5** of this report.

Figure 2-16: Excavators removing the entrance shoals (left), Unloading and regrading of sand for beach replenishment (right)

2.8.3 Environmental considerations for entrance management

When an ICOLL is open with an efficiently operating entrance, lagoon water levels are more responsive to the changes in the tide. The whole tidal cycle rises and falls over time. If lagoon water levels stay low for an extended period of time, during the lower tidal cycles there can be harm to the fringing ecosystems. Vegetation on the banks of the lagoon can dry out and die off, resulting in a loss of habitat as well as destabilisation of the banks themselves. Seagrasses exposed for too long can also die, impacting on the epifauna requiring them for survival.

The rock shelf on the northern side of the entrance area acts like a weir, helping to prevent the water level in the lagoon from getting too low on the outgoing ebb tide. This in turn protects the fringing ecosystems and beds of seagrasses, including all of the environmental benefits provided by them.

When ICOLLs are opened for increased periods of time, the characteristics of the waterbody become more aligned with marine conditions, known as marinisation, due to increased salinity. This also can fundamentally change the long term ecosystem, often resulting in an expansion of mangroves at the expense of more freshwater tolerant species, with associated impact on the fauna species sheltering within these locations.

It is not uncommon for the perception of community members to be that when an ICOLL is closed it is more polluted (due to visual water clarity, smell, etc.), impacting on their enjoyment of the estuary, and this often results in calls for the local Council to keep the ICOLL open permanently. As discussed in **Section 2.1.2**, water quality monitoring results show that Narrabeen Lagoon has achieved 'good' ecological water quality ratings even in years when the entrance has been predominantly closed. The Beachwatch monitoring, which is used an indicator for human health, indicated that recreational water quality at Birdwood Park, near the entrance, is typically good but can be poor at times, and therefore is likely to be influenced by the entrance being open as it receives good tidal flushing. At Bilarong Reserve, in the Central and Western Basin area, recreational water quality is typically poor. This is consistent with the description of lagoon water quality within the Narrabeen Lagoon Estuary Processes Study (WBM, 2001), which notes that water quality in the central and western basins is dominated by catchment runoff as tidal flushing in these areas is poor, therefore an open entrance will not necessarily improve recreational water quality here.

Even though tidal flushing at the eastern channel (including Birdwood Park) improves water quality under normal conditions, during periods of high catchment runoff the outflowing water volumes would far exceed the inflowing flood tide volumes, resulting in little penetration of oceanic waters (if any) until quite some time after the high runoff event (WBM, 2001). When the entrance closes, tidal flushing is prevented and the water quality in the lagoon would migrate slowly to the condition of the water flowing into it from the catchment. As such, the water quality with the lagoon can be dictated by catchment runoff whether the entrance is closed or open.

As previously mentioned, water pollution primarily occurs from runoff in urbanised land use areas of the catchment and this can be more efficiently managed through the control of inputs, rather than entrance openings (Stephens & Murtagh, 2011; Coffs Harbour City Council, 2018).

3 Review of State, National and International Entrance Management

3.1 Background to ICOLL entrance management

ICOLLs are naturally occurring, and self-regulating systems and it is generally considered preferable not to artificially change these systems due to the adverse impacts that can occur. The opening and closing process is natural, and the ecosystem including the aquatic, plant and animal communities have adapted to these changing environmental conditions resulting in healthy ICOLLs when left alone. When ICOLL entrances open naturally, the outflow scours the entrance resulting in wide entrances that stay open for long periods of time. If these entrances are artificially opened when the water level is low, then the outflow of water does not scour the entrance as effectively. This results in the entrance closing more quickly due to the deposition of sand from wave action.

Generally, artificial management of ICOLLs involves opening the entrance at a lower level than the natural breakout range or changing the height, location or configuration of the beach berm so that natural breakout range is lowered. Training walls or other permanent actions, while possible, are generally not used as they will permanently open the estuary. This can have significant environmental impacts and is discussed in more detail below (Stephens & Murtagh, 2011; Coffs Harbour City Council, 2018).

ICOLLs are considered as the most sensitive type of estuary to artificial change resulting from human intervention. This is due to their connection to the ocean meaning that their management is often considered one of the most difficult tasks facing coastal engineers today (Haines, 2008). Hence, it is important to consider each ICOLL individually, and plan their management effectively and consider all impacts of artificial change.

While there are many environmental impacts of artificially interfering in the management of ICOLLs, around half of the ICOLLs in NSW are in fact artificially managed due to mitigation of flood inundation for the urbanised catchment around their foreshores. The main reason for artificially opening an ICOLL is to mitigate potential damage to low-lying properties and other assets at risk due to rising water levels from flood events. This is often due to increased pressure from local communities for Council to protect their assets (Stephens & Murtagh, 2011). Another trigger for opening entrances is “alleviating actual or perceived water quality problems, through the introduction of tidal processes” (Haines, 2008).

A review of entrance management policies and procedures of ICOLLs across State, National and International levels has been undertaken and detailed discussion is available in **Appendix B**. A summary of key findings is presented below.

3.2 NSW ICOLL entrance management

3.2.1 Narrabeen Lagoon in NSW context

Narrabeen Lagoon is the largest ICOLL in the Sydney Metropolitan area and is a unique waterway with respect to its size and catchment urbanisation. Of the approximately 170 estuaries in NSW, Narrabeen Lagoon is in the top 25% for both estuary size and catchment size (refer **Figure 3-1**). In comparison, Dee Why Lagoon and Curl Curl Lagoon are both around the 50% mark, or median value for estuary size and in the bottom 25% for catchment size, and Manly Lagoon is around the 50% mark, or median value for both estuary size and catchment size.

In 2008 Haines considered a number of different features of the lagoon and determined that Narrabeen Lagoon represents a relatively unique instance of an ICOLL (refer **Figure 3-2**). Over the long term Narrabeen Lagoon:

- is mostly open;
- has potential for tidal water exchange under the right conditions, which sees the exchanging of ocean and lagoon waters (note this predominantly occurs in the entrance);
- can maintain water quality even with pollution entering from the catchment; and,
- usually maintains a similar water level.

In combination, these factors demonstrate that Narrabeen Lagoon has relatively stable and favourable conditions with respect to public amenity (i.e. visual and recreational).

In summary, in the context of NSW, Narrabeen Lagoon represents a large estuary (more specifically ICOLL), in terms of both estuary surface area and catchment area, that is on average over the long term open to the ocean. The Lagoon exhibits both stable water quality and quantity that provides favourable conditions for the community in both visual and recreation amenity.

The Lagoon is situated in a highly urbanised area, and as a result of the favourable stable conditions, the local community has become accustomed to certain level of 'service' provided by the Lagoon (e.g. acceptable water quality and water level). When this level of 'service' is no longer provided Council receives a significant amount of public feedback; distinguishing management of Narrabeen Lagoon as having a relatively high sensitivity to community awareness and feedback when compared to other ICOLLs on the NSW coastline.

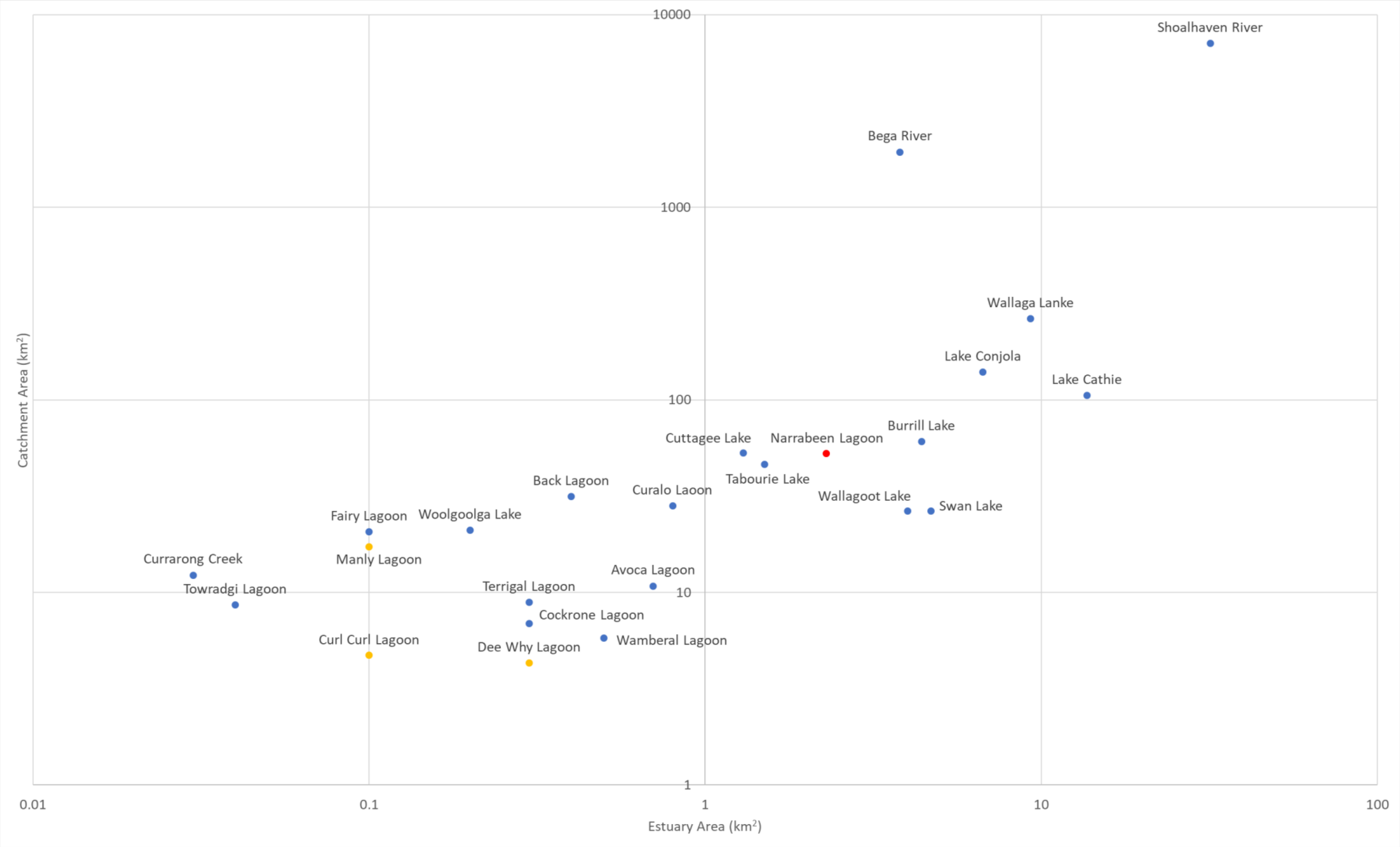

Figure 3-1: Narrabeen Lagoon in selected NSW context (estuary size vs. catchment size)

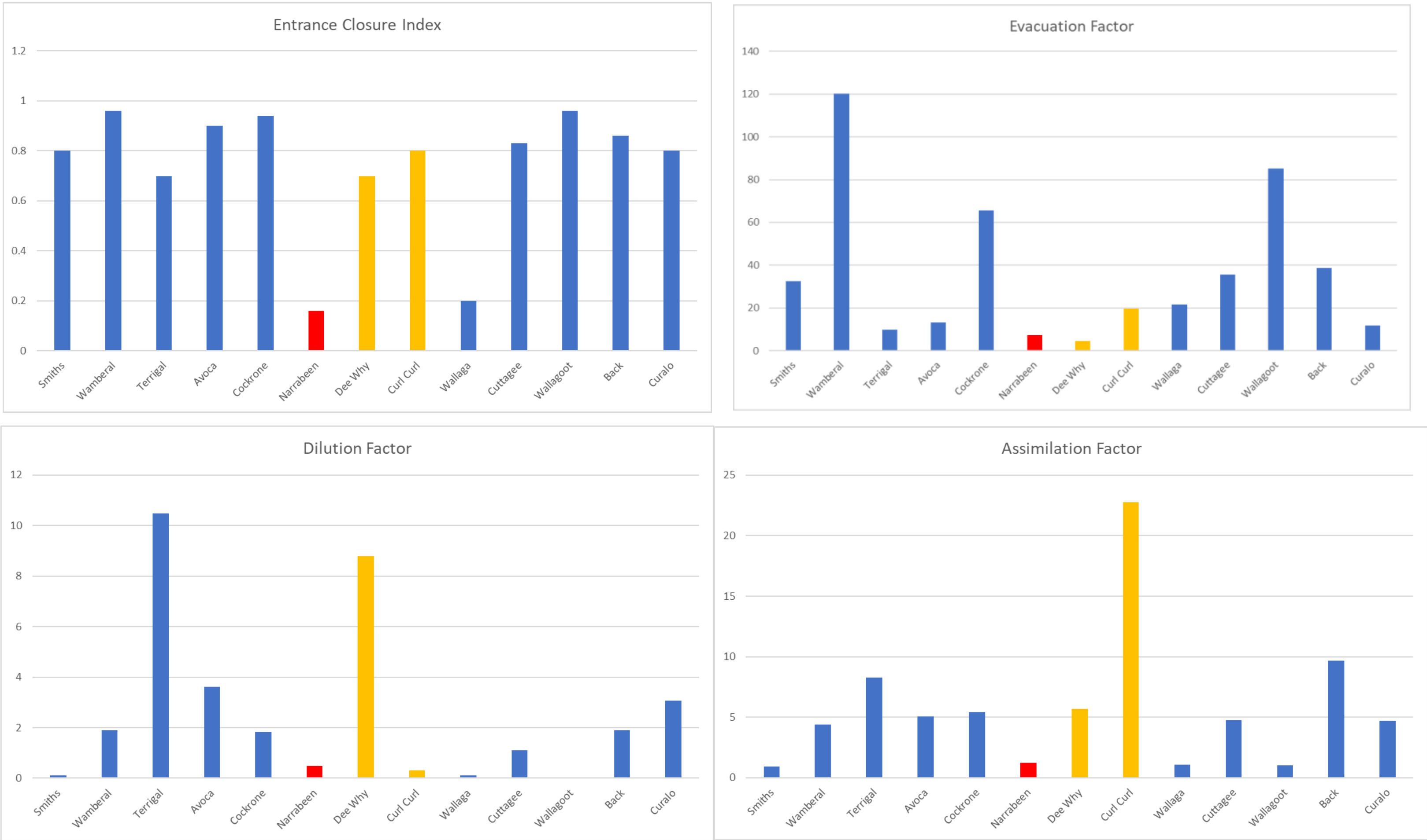

Figure 3-2: Morphometric factors of selected NSW lagoons (Haines, 2008)
Entrance Closure Index: indicates how often the entrance is closed over the long term. The lower the score the more often it is open.
Evacuation Factor: a low number here, which Narrabeen Lagoon has, indicates that there is potential for tidal water flushing.
Dilution Factor: mg/L; a low number here, like Narrabeen Lagoon, indicates that the lagoon has a higher potential to maintain its water quality even when pollution is entering from the catchment.
Assimilation Factor: a low number here indicates that Narrabeen Lagoon has a relatively stable water level.

3.2.2 ICOLL Entrance Management at other NSW Councils

The review of policies from other NSW Councils made it apparent that there are many similar lagoon entrance management philosophies up and down the NSW coast (refer **Table 3-1**). All councils had set appropriate trigger levels, based on a range of factors to ensure that floods were mitigated as efficiently as possible, as part of their estuary management plans. These councils all had detailed procedures for monitoring ICOLL entrances. All trigger levels were considered carefully for each ICOLL and set to ensure a reduction in flood risk while conserving the ecosystems within the lake based on current water depths and future rainfall. However, differences arose in respect to the factors that impacted either the trigger water level or when artificial intervention was allowed. Some of these differences are summarised below:

- Greater Taree Council had salinity and water quality indicators impacting the trigger levels due to the oyster and shellfish production requirements.
- Port Macquarie-Hastings Council had triggers impacted by salinity levels.
- In Bega Valley Council and Shoalhaven City Council, while there were still triggers to open entrances to avoid flooding, this was impacted by endangered shorebird nesting. The mechanical opening of the entrance could only be operated during months where shorebirds did not nest and after surveying that the mechanical openings would not impact their nesting. The Shoalhaven River had similar reasons for trigger levels being set as Narrabeen, as they were based on the water level in the river (head difference) to ensure scouring of the pilot channel.

Individual trigger levels were set for all ICOLLs (refer **Table 3-1**) and carefully considered based on a number environmental, social and economic factors. Example entrance management decision trees for Bega, Port Macquarie and Shoalhaven City Councils are provided in **Figure 3-3**.

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Table 3-1: Selected NSW entrances – short term response trigger levels and entrance management policies

<table>
<tr><th>Responsible</th><th>Entrance</th><th>Warning Trigger Level (m AHD)</th><th>Emergency Trigger Level (m AHD)</th><th>Entrance Management Policies</th></tr>
<tr><td rowspan="6">Bega Valley Shire Council</td><td>Back Lake</td><td>1.2</td><td>1.4</td><td rowspan="6">• Decision tree for management decision(s) (refer Figure 3-3)
• Minimal intervention in the long term; returning to a ‘natural as possible’ breakout regime.
• Progressive and opportunistic raising of assets to levels above 3m AHD.
• Progressive and opportunistic removal of assets that are currently affected by inundation close to or just above the trigger level.
• Maintaining a buffer of no new development within close proximity to and below an elevation of 3.0m AHD around water body.</td></tr>
<tr><td>Bega River</td><td>1.26</td><td>1.36</td></tr>
<tr><td>Curalo Lagoon</td><td>1.0</td><td>1.2</td></tr>
<tr><td>Cuttagee Lake</td><td colspan="2">1.8</td></tr>
<tr><td>Wallagoot Lake</td><td>1.2</td><td>1.4</td></tr>
<tr><td>Wallaga Lake</td><td>1.1</td><td>1.25</td></tr>
<tr><td>Mid Coast Council (Formerly Greater Taree City Council)</td><td>Farquhar Inlet</td><td colspan="2">2.0</td><td>• (TBC[3]) Triggers for entrance opening works (Excavation of Notch through Berm):
1. A flood level of 1.6m AHD is reached at the Farquhar Inlet gauge
2. Salinity levels at Farquhar Inlet fall to below 12 ppt
3. Closure of the Scotts Creek shellfish harvest area for more than 120 consecutive days, combined with a weekly rainfall reading at Taree Airport greater than 80mm
• (TBC) Dredging of temporary pilot channel to connect main river water body and entrance.
• (TBC) Dredging of permanent pilot channel, including Training wall, to connect main river water body and entrance.</td></tr>
<tr><td rowspan="5">Central Coast Council (Formerly Gosford City Council)</td><td>Wamberal Lagoon</td><td colspan="2">2.4</td><td rowspan="5">• Artificial opening of lagoon entrance at predefined trigger water levels to prevent flooding of surrounding properties.
• reduction in catchment pollution via stormwater runoff through implementation of vegetated buffer zones and WSUD features.</td></tr>
<tr><td>Terrigal Lagoon</td><td colspan="2">1.23</td></tr>
<tr><td>Avoca Lagoon</td><td colspan="2">2.09</td></tr>
<tr><td>Cockrone Lagoon</td><td colspan="2">2.53</td></tr>
<tr><td>Pearl Beach</td><td colspan="2">2.75</td></tr>
<tr><td rowspan="2">Wollongong City Council</td><td>Fairy Lagoon</td><td>1.3</td><td>1.6</td><td rowspan="2">• Artificial opening of lagoon entrance at predefined trigger water levels to prevent flooding of surrounding properties.
• (TBC) Maintaining a ‘dry notch’ (i.e. a low or ‘saddle’ point in the beach adjacent to the entrance which the Lagoon can preferentially flow across).</td></tr>
<tr><td>Towradgi Lagoon</td><td>1.4</td><td>1.6</td></tr>
<tr><td rowspan="6">Shoalhaven City Council</td><td>Burrill Lake</td><td>1.1</td><td>1.2</td><td rowspan="6">• Decision tree based on water level for management decision(s) (refer Figure 3-3)</td></tr>
<tr><td>Currarong Creek</td><td colspan="2">n.a.</td></tr>
<tr><td>Lake Conjola</td><td>1.0</td><td>1.2</td></tr>
<tr><td>Shoalhaven River</td><td>2.5</td><td>3.0</td></tr>
<tr><td>Swan Lake</td><td>2.2</td><td>2.5</td></tr>
<tr><td>Tabourie Lake</td><td colspan="2">1.17</td></tr>
<tr><td>Coffs Harbour City Council</td><td>Woolgoolga Lake</td><td colspan="2">1.6</td><td>• Scenario decision trees based on water level for management decision(s)</td></tr>
<tr><td>Port Macquarie-Hastings Council</td><td>Lake Cathie</td><td>1.2</td><td>1.6</td><td>• Decision tree based on water level for management decision(s) (refer Figure 3-3)</td></tr>
</table>

[3] *To Be Confirmed.*

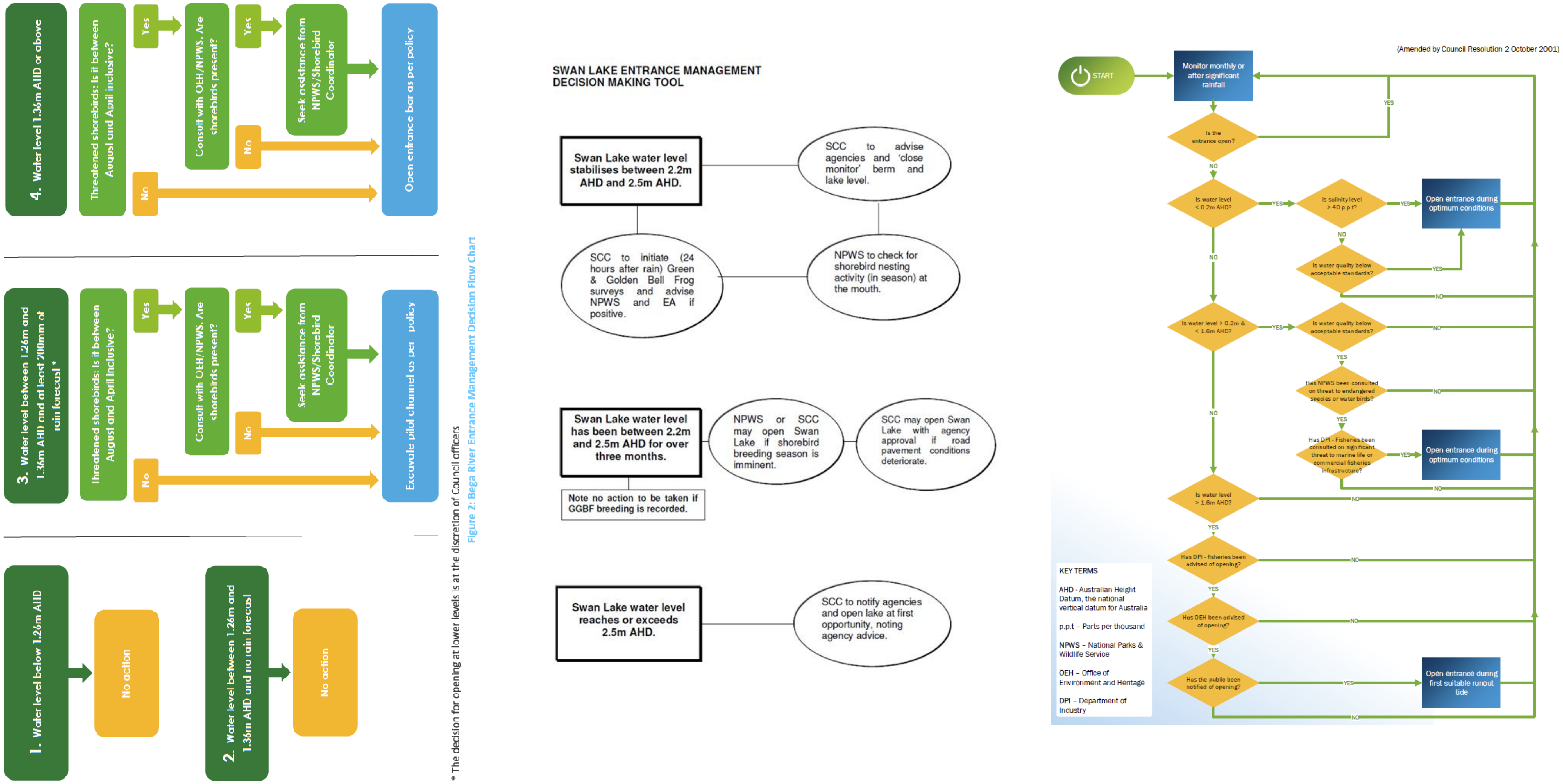

Figure 3-3: Example decision trees for entrance management; Right: Bega Valley Shire Council, Middle: Shoalhaven City Council, Left: Port Macquarie-Hastings Council

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3.3 National ICOLL entrance management

With respect to entrance management, the National Committee on Coastal and Ocean Engineering (NCCOE) has the following guidelines and recommendations (refer **Table 3-2**).

Table 3-2: NCCOE guidelines for entrance management

Management Option	Advantage	Disadvantage	Applicability at Narrabeen Lagoon
Barrage(s) / Tidal Gate	• Protects inland areas from ocean inundation caused by elevated storm surge water levels. • Significantly reduces ingress of sediment.	• Very high capital cost. • High maintenance cost. • Potential major adverse impacts on the estuary entrance and adjacent coastline. • May require pumping to control flooding from upstream. • Altered ecology.	Ultimately does not address fundamental issues at Narrabeen Lagoon. Entrance would remain closed during elevated ocean levels. If this coincides with catchment flooding, properties along foreshore would likely be inundated.
Breakwater(s)	• Increased hydraulic conveyance of entrance successful in keeping entrances open and mitigating flooding. • Exposed to tidal flushing every cycle, likely leading to enhanced water quality.	• Breakwaters constructed on littoral drift coasts have the potential to cause “downdrift” erosion by reducing sediment input and by altering beach alignments through nearshore wave diffraction. • High capital costs. • Can potentially change tidal planes and increase tidal inundation within estuaries and flooding of fringing areas. • Can increase channel velocities and channel bank scour. • Increased sediment deposition within the estuary. • Interrupts alongshore littoral drift which may require installation of sand bypassing system. • Can impact of surf amenity of coastline.	Maintaining surf amenity is a particularly important consideration at North Narrabeen. The potential impacts of breakwaters on surf amenity, the high capital cost and likely ecological impacts within the lagoon from altered tidal exchange result in this option not being feasible.

Management Option	Advantage	Disadvantage	Applicability at Narrabeen Lagoon
Training Wall(s)	• Protect internal estuary channel banks from scour resulting from the increased velocities induced by entrance breakwater construction and/or migration of flood and ebb tide channels. • Can be a flexible solution that is adaptable to prevailing sea level and climate conditions.	• Limited success because the scale of the scour process is very much larger than that of the bank protection works. • Can create localised scour or high velocities. • Increase in the tidal prism (due to more efficient tidal exchange) may destabilise the entrance.	A training wall is already present along the northern bank of the lagoon entrance. The potential impacts of installing a training wall on the southern side of the lagoon entrance on surf amenity, the high capital cost, and likely ecological impacts within the lagoon from altered tidal exchange result in this option not being feasible.
Dredging	• Keep untrained entrances open. • Dredging can allow for maintenance of some exchange of ocean water with the lake and for flood conveyance. Placing sand onto the beaches, in the short term, maintains beach amenity and provides a greater sand buffer to mitigate storm erosion.	• Can become expensive and/or frequent during periods of drought or particular coastal conditions (swell directions, beach rotation). • High long term operation costs. • Potentially disruptive operation.	Dredging (i.e. entrance clearance operations) has been effectively employed as a primary entrance management procedure at Narrabeen Lagoon for over 50 years. Though recently it has been required, in its current form, more frequently due to the prevailing coastal conditions.
Entrance Bypassing Systems	• Can be developed where entrance breakwaters have interrupted the natural transport of littoral drift along the coast. • Flexible systems that can vary from fixed sand pumps located on trestles that extend across the surf zone to shoreline operations using excavators, bobcats and trucks.	• High capital, ongoing and maintenance costs. • Can prevent use of a section of beach.	Entrance bypassing would require prior construction of breakwaters. Given the location of the entrance of Narrabeen Lagoon to the immediate south of several pocket beaches defined by headlands with limited sand exchange (essentially closed systems), an entrance bypassing is not considered to be necessary.

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Management Option	Advantage	Disadvantage	Applicability at Narrabeen Lagoon
Artificial Reefs	• Induce incoming waves to break, thus reducing the wave energy reaching the shore. • Alter currents and hence sediment transport and beach alignment. • Can enhance surf amenity and/or ecology. • Structure is not visible from the beach if always submerged.	• Only suitable for small tidal ranges with low wave variability. • Limited protection during coastal storms. • High capital costs.	May reduce localised wave energy reaching the shore, however littoral drift would still occur along Collaroy-Narrabeen Beach. May increase time for sand to build-up inside entrance. Coastal storm events would still likely result in large ingress of sand to the entrance.

3.4 International ICOLL entrance management

A review of management was undertaken for ICOLLS in South America, America, Africa and New Zealand which showed there are a range of management approaches used worldwide from very active management in New Zealand, cultural management in Africa and a comparative review of the impact of intervention/inaction between 2 ICOLLS in South Africa.

Australia has the highest proportion of ICOLLs in the world at 21%. Outside Australia, ICOLLs occur in larger numbers in New Zealand, South Africa, North Africa and the Mediterranean, the southernmost coasts of South America and the west coast of North America (refer **Figure 3-4**).

ICOLLs around the world are concentrated along microtidal to low mesotidal coastlines in the mid latitudes and predominantly in temperate climates. ICOLLs form at the mouth of rivers with generally low mean annual discharges and typically occur where marine processes dominate (i.e. wave dominated) over fluvial inputs. The distribution of ICOLLs internationally is related to greater wave heights, driven by high intensity winds and longer fetch distances, and is associated with a tidal range of <~3 m, smaller catchments < 2000 km^2 and tidal prisms < 30 x 106 m^3.

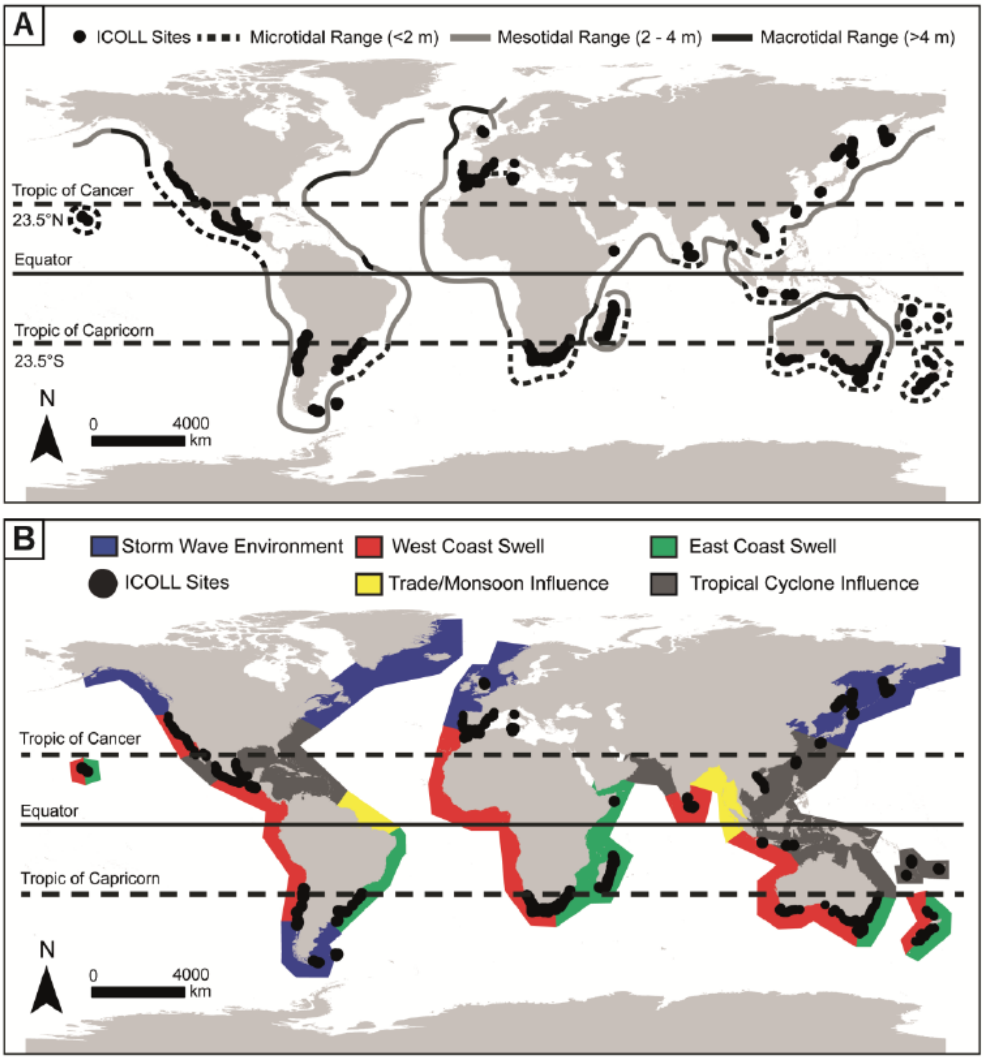

Figure 3-4: Global distribution of ICOLLs (Source: McSweeney et al., 2017)

3.4.1 Applicability at Narrabeen Lagoon

The entrance management of all ICOLLs requires a balance between environmental, social and economic factors. Each system should be carefully considered, and a policy developed that considers flood risk, the health of the ecosystem and public amenity. These factors need to be carefully considered in Narrabeen Lagoon due to the size of the catchment, the degree of development on the adjacent floodplain, and the engaged local community.

As discussed above, where possible, the best management strategy when dealing with ICOLLs is to leave these systems as close to natural and as undisturbed as possible. When ICOLLs are artificially altered there can often be adverse environmental impacts within the natural system. However, flood events within urbanised catchments are often considered to be a valid reason to intervene due to the risk to property, and in some cases risk to life. When managed correctly, the potential negative impacts of artificially altering the behaviour of an ICOLL can be reduced. While entrance management is important to ensure the reduction in flood impacts on properties, these strategies should be carefully managed to ensure minimal negative environmental impact.

In summary, a highly populated lagoon such as Narrabeen Lagoon, with large numbers of properties and assets on the surrounding floodplain, should have appropriate procedures for mechanical opening and entrance clearance which consider long term impacts.

3.5 Priority considerations for Narrabeen Lagoon entrance management

The reviews undertaken in this Section have confirmed that undertaking mechanical openings and entrance clearance operations at Narrabeen lagoon is appropriate as a means of flood mitigation. The entrance clearance operations also aim to maintain or enhance water quality in the Lagoon and to conserve or enhance the biological diversity of the Lagoon system. Key considerations for this assessment include:

- The Narrabeen Lagoon Floodplain Risk Management Plan lists entrance clearance operations, with the included result of facilitating mechanical openings to be done when the lagoon does close, as its highest priority flood mitigation action;
- Community expectations including those of property owners and recreational users;
- The short term mechanical openings are consistent with State, national and international management practices;
- As an ICOLL, the lagoon is a sensitive natural environment and therefore any management process or activity needs to carefully consider the environmental impacts; and,
- The conditions at the entrance are changing all the time, such as with the decadal beach rotations and state of Birdwood Park Dune, and a variety of approaches, or more flexible processes, may be needed to appropriately manage the entrance.

Sections 4, 5 and 6 of this report consider, analyse and evaluate the way that current entrance management activities are undertaken as well as identify alternative options.

The alternative options were developed through engagement with Council and identified industry experts who have a thorough understanding of Narrabeen Lagoon. This initial stage identified, considered and prioritised possible alternatives to ultimately develop a list of viable alternate options that should be evaluated in detail. These options were refined following community consultation via a draft options paper in 2021. Alternative options were considered to address the short and medium term entrance management works that are currently already undertaken, as well as to consider if there may be a suitable longer term solution. It is important that financial, environmental and social aspects are considered when assessing all activities.

Short term management
Short term management needs to carefully consider the emergency response, reducing risk of damage to properties in low-lying areas surrounding the lagoon, as well as the efficiency of the opening to maximise the time the lagoon will stay open, thus minimising the return time for undertaking a new mechanical opening.

Council currently mechanically opens the entrance of Narrabeen Lagoon when the water level reaches 1.0-1.3m above mean sea level. While at this water level the minor flooding is considered to be nuisance flooding, water levels are noticeably high and can cause alarm in the community, especially if they remain elevated for long periods of time. As reported in the community engagement options report "A key outcome of this analysis will be a decision as to whether there is scope to mechanically open the lagoon at lower water levels and, if so, what conditions are required to ensure it is a successful opening." (RHDHV, 2021).

Medium term management
The review of medium term management considered potential improvements and refinements to the existing entrance clearance practices, including planning, design, work methods, and construction operations and management. As reported in the community engagement options report "A key outcome of this review will be to identify whether it is possible to shorten the time between the entrance being completely full of sand and the clearance works starting on site. It will also provide an assessment of the frequency, design and alternative clearance methodologies." (RHDHV, 2021). Dune management at Birdwood Park dune is also an important medium term consideration due to its impact on sand movement in the area.

Long Term Management
The objective of the development of a long term management strategy for Narrabeen Lagoon entrance is to determine if there is a feasible, alternative permanent management option that could be implemented to reduce the frequency, improve the effectiveness of, or eliminate, current short term and medium term management interventions referred to above. Several potential long term entrance management options have been investigated in **Section 6** of this report.

3.5.1 Climate change

Climate change and projected sea level rise pose an issue for the management of the Narrabeen Lagoon entrance. Projected sea level rise scenarios will result in worsening flood conditions due to higher ocean water levels, a higher entrance berm level and higher initial water levels in the lagoon.

The latest IPCC sea level rise predictions are documented within the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate – Chapter 4 Sea Level Rise and Implications for Low-lying Islands, Coasts and Communities (IPCC, 2019). Predictions for the upper bound of the likely range (i.e. 13^{th} to 87^{th} percentile) of sea level rise for the worst case RCP8.5 climate change scenario are 0.08m in 2030 and 0.17m in 2040 relative to the present time. Equivalent predictions for the mid-range RCP4.5 climate change scenario are 0.07m in 2030 and 0.14m in 2040 relative to the present time.

Higher sea levels mean that Council's trigger levels (currently 1.0 to 1.3 m AHD) will require reconsideration in the future and likely will need to be significantly higher to be effective (BMT WBM, 2013), however consideration must be given to the lagoon water level at which inundation becomes problematic for Council and the community.

The 2013 Narrabeen Lagoon Flood Study identified that peak design flood water levels are expected to progressively increase as the impacts of climate change manifest resulting in a worsening of existing flood conditions through higher ocean water levels (tide and storm surge), higher entrance berm and higher initial water levels in the lagoon.

Morris' (2010) investigations into climate change suggested that the natural cycle at which the entrance opens and closes would accelerate leading to decreased periods in which the entrance was open to the ocean. This will impact the frequency and effectiveness of entrance clearance operations.

The report discusses the impacts of climate change in each section as appropriate.

4 Short term closed entrance management

4.1 The need for short term closed entrance management

When Narrabeen Lagoon entrance is closed, significant flooding of the adjacent low-lying floodplain can and does occur due to:

- heavy rain;
- elevated ocean levels in severe storms as a result of astronomical tide;
- storm surge and wave setup; and/or,
- a combination of these factors.

This flooding has the potential to cause major damage to properties surrounding the lagoon foreshore.

Removal of the sand at the blocked entrance allows the lagoon to drain to the ocean (depending on oceanic conditions), thereby reducing risk to properties from flooding due to rainfall. To reduce the impact of flood events in the short-term, the blocked entrance can be broken out using excavators as an emergency measure, subject to certain trigger conditions being satisfied. This is referred to as mechanical opening (refer **Figure 4-1**).

The main objective of mechanically opening the lagoon entrance is to reduce lagoon water levels and prevent flooding of properties in the event lagoon water levels are elevated and moderate to heavy rainfall is forecast.

As mentioned previously, during large storm events, short-term strategies alone will not be able to completely mitigate flood inundation. The reason for this is when catchment flooding occurs in combination with elevated ocean levels or when elevated ocean levels alone present a flood risk, mechanical opening of the lagoon entrance would not reduce the severity of foreshore flooding.

While it is important to consider how management strategies can be improved individually, it should also be considered that the implementation of medium and long term entrance management strategies will have implications in the short-term as well.

4.2 Review of current mechanical opening practices

The existing short term management strategy employed by Council is to mechanically open the lagoon by creating an emergency breakout of the entrance when certain trigger conditions are met. The current procedures from Council's OMS are summarised in **Table 4-1**.

As the entrance berm is scoured away due to outflows resulting from the water level in the lagoon being higher than the ocean level (as discussed below), the lagoon water level lowers and the flood risk is reduced in the short term. However, the success of mechanical opening is dependent on various conditions being met including appropriate levels for lagoon water, entrance berm and ocean water as well as the prevailing tide and wave conditions (refer **Section 4.2.1**, **Table 4-1**).

Mechanical openings are carried out most frequently when the entrance is closed and the lagoon water level is predicted to reach or has reached trigger levels of 1.0m to 1.3 m AHD (refer **Table 4-1**). When water levels exceed 1.3 m AHD, the rising water levels begin to encroach on Wimbledon Avenue, Lagoon Street, and the eastern foreshores of the eastern channel (Manly Hydraulics Laboratory, 1989). At a lagoon water level of 1.0 m AHD a small number of properties begin to be affected (e.g. ponding across driveways in Malcolm Street, Narrabeen) and parts of the Narrabeen Lagoon Multi-Use Trail are impacted. At a lagoon water level of 1.3 m AHD, flooding starts extending over the Mactier Street roundabout and it is considered to be an unacceptable nuisance at a higher water level than this. This leads Council to opening the entrance to alleviate flooding, usually earlier than 1.3 m AHD to ensure flooding doesn't occur. Trigger levels were assessed in the Narrabeen Lagoon Floodplain Risk Management Study, as discussed in **Section 2.4.3**.

The mechanical opening usually involves an excavator digging a 'pilot' channel between the lagoon and the ocean. The pilot channel is occasionally dug a day or two in advance, particularly if the channel needs to be quite long. In such cases, a 'plug' is left at each end of the channel, to maintain the channel until the optimum timing is reached for release of lagoon waters. It is then a simple matter to 'pop' the channel to start the outflow and scouring action. An example of an entrance pilot channel being excavated at Narrabeen Lagoon is shown in **Figure 4-1**. This is a similar practice to that employed at Manly Lagoon when input from rainfall exceeds the capacity of the low flow pipes to drain the lagoon. Note that in short term mechanical openings, particularly in emergency situations, it is intended for the outflow to scour the initial mechanically created pilot channel, widening and deepening it, in an attempt to ensure that it stays open for a longer period.

As discussed in further detail in **Section 5.1**, due to low-lying public infrastructure and private property ICOLLS in NSW are typically opened at a lower levels than their natural breakout range. Often when an ICOLL breaks out naturally, the higher level of water in the lagoon creates an outflow with enough force to scour the sand to widen and deepen the channel, ensuring that future tides and wave action do not immediately deposit enough sand straight back into the entrance to close it. While still lower than natural levels, Council has set the trigger level for mechanical opening at 1.0-1.3 m AHD (supported by experience and expert advice) to ensure that there is a sufficient water level difference, or hydraulic gradient, within the lagoon to overcome ocean tides, scour out a breakout channel and successfully reduce lagoon water levels. If done at a water level lower than 1.0m AHD, Council has experienced that the outflow will not create enough scour at the entrance, resulting in the deposition of sand by wave action that infills the entrance shortly after (within the range of days to weeks) (Cardno, 2019). This poses risks for current and future flood events and affects the overall efficiency of the mechanical opening. As part of this project the potential to mechanically open the entrance at lower levels with numerical breakout modelling has been investigated, the results of which are detailed in **Section 4.4.1**.

It is also noted that, if possible, the entrance of a lagoon should not be broken out during king tides or large spring tides as the water level in the ocean can be higher than the lagoon water level resulting in the movement of sand back into the entrance channel before a stable outflow is established (Coffs Harbour City Council, 2018). However, it is acknowledged that this is not always possible during severe weather events (e.g. East Coast Low) when flooding within the lagoon can coincide with heavy swell and elevated ocean water levels associated with coastal storms (i.e. storm surge and wave setup).

The volume of sand held in the entrance shoals can also have an adverse impact on the effectiveness of a mechanical opening. If an extensive volume of sand exists in shoals located upstream of the artificially created breakout channel, this constricts the outflow and slows the rate at which the water level lowers in the lagoon. This can result in early closure, particularly if the entrance is opened when the lagoon water level is below the trigger levels.

Figure 4-1: Pilot channel excavation, September 2018

4.2.1 Trigger Conditions

The Lagoon Entrance Management Operation Management Standard (OMS 455) identifies several trigger condition scenarios that initiate an emergency response from Council, based upon the water level within the lagoon and forecast rain. When these triggers are reached Council conducts an emergency breakout of the blocked entrance as shown in **Figure 4-1**. The exact timing of the breakout also takes into consideration factors such as the tide and wave conditions. Openings are not usually undertaken at lower water levels as they are not as efficient and do not result in considerable reductions in peak flood levels, as investigated in **Section 4.4.1**.

A summary of the OMS procedures and actions to be taken for the mechanical opening and monitoring of Narrabeen Lagoon based on trigger water levels and other conditions is provided in **Table 4-1**.

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Table 4-1: Narrabeen Lagoon procedures for mechanical openings

Trigger Water Levels	Trigger Conditions	Desirable Conditions	Actions Required
≤1.0 m AHD	Rising water levels and a closed entrance		• Notify contacts opening is likely in next 24-72hrs • Monitor foreshore inundation • Monitor existing and forecast rain and rate of rise of water levels
Scenario 1		• Falling tide • Low wave heights • Low ocean water levels (i.e. storm surge is minimal) • Large ocean tidal range (>1.0m) • Entrance plug is narrow (~80m or less) • These conditions are essential for Scenario 1 to ensure a successful opening	• Decision to mechanically open lagoon is made and notifications sent • Plant and staff mobilised to site • Install warning signs and cordon off area • Excavate breakout channel • Close beach to public for 24 hours
1.0 – 1.3 m AHD	Lagoon has been closed for an extended period of time (months) Potential damage to foreshore vegetation and inundation of foreshore reserves		
Scenario 2			
≥1.3 m AHD	Rain has fallen and / or rain is forecast		

With consideration for the review of ICOLL management up and down the NSW coast, presented in **Section 3**, the current management practices for Narrabeen Lagoon can be considered in-step with those for ICOLLs located in similar catchments, namely other heavily urbanised, flood prone catchments. The implementation of short term management procedures, for the purpose of flood mitigation, that involve mechanical opening of the Lagoon entrance at water levels that are lower than those that would breakout the entrance naturally, is considered comparable to current industry practices.

4.3 Review of emergency response for flood event

In the event that flooding is predicted to have risks to life and property, a coordinated multi-agency emergency response may be required.

Under the state and local Emergency Management Plan, the NSW SES is the appointed combat agency for storm and flood. In large events, Council supports the NSW SES and emergency services through the activation of the Local Emergency Management Officer (LEMO) and establishes an Incident Management Team (IMT). The LEMO and Council's IMT provide assistance to the NSW SES by providing resources including plant and equipment, in addition to the provision of intelligence such as the predicted height, timing and extent of flooding.

The decision to issue an evacuation warning or order is determined by the NSW SES. Other emergency services and supporting agencies, such as Council, assist in the execution of the order by facilitating activities such as door knocking, provision of transport for evacuees, activating evacuation centres and the like.

There is usually limited time in which evacuations can be conducted because the flooding that occurs at Narrabeen Lagoon can usually be characterised as flash flooding, meaning the rise in the lagoon's water level is relatively fast in response to catchment rainfall and significant water level increases can occur in only a few hours (BMT WBM, 2013). The duration of flooding is relatively short, generally draining to the sea within a matter of hours once rainfall intensity and tidal water levels reduce. As such, there is potential for flooding to occur overnight when people are asleep and not aware of evacuation orders. This has key implications for how flooding is managed for Narrabeen Lagoon as a mechanical opening requires excavators to be mobilised and brought to site, then a channel needs to be dug, and subsequently it takes some time for water levels to drop, the rate of which is heavily influenced by the prevailing conditions.

The predisposition for flash flooding and response time for mechanical openings has implications for flood warning and emergency response. To ensure access roads are used before inundation occurs, flood emergency response must be swift. Pre-emptive warnings are occasionally given to residents if a flood is predicted in order to enable the community to prepare and ensure that if evacuation is needed it will be effective. Communication about evacuation includes text messages to the public within the target area.

Council uses a comprehensive flood forecasting system to inform decision making for emergency response. A series of different water level and rainfall gauges are located throughout the catchment and managed by MHL. The gauges record data at 15 minute intervals and send the data via telemetry to a central database. When the water level in the lagoon reaches certain predetermined levels, Council staff receive automated SMS alerts. The collected gauge data are also available to the public on MHL's website.

Flood prediction in ICOLLs is complicated by the highly variable downstream conditions related to tidal behaviour, berm height, entrance dynamics and morphology, and ocean waves. Since 2017, Council has been using Manly Hydraulics Lab's (MHL) bespoke Flood Information Tool (MHLFIT), which integrates these considerations while incorporating near real-time gauge data, Bureau of Meteorology (BoM) rainfall forecasts, tide and antecedent moisture content into its automated predictions of lagoon level for up to three days into the future. The predicted levels are approximate, but with a run of the model taking less than 30 seconds, rapid sensitivity and scenario testing can be completed swiftly. Council also uses information derived from the Narrabeen Lagoon Flood Study TUFLOW Model (BMT, 2013) and the Northern Beaches Council LGA 3Di Model (RHDHV, 2018).

In smaller events also, Council uses the MHLFIT software to predict lagoon water levels and uses this information to assist in developing a suitable response, including deciding if/when the lagoon should be opened.

In addition to assisting the SES, Council provides information to the community about flood events and actions related to the opening of the lagoon through its website (refer **Figure 4-2**) and social media. For example, Council issued Facebook notifications are shown in **Figure 4-3** below.

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Friday, 19 March 2021

Friday 19 March

Narrabeen and Manly Lagoons were both successfully opened yesterday and water is now flowing freely in and out of the entrances.

Great Mackerel, Dee Why and Curl Curl lagoons are also open.

> Significant rainfall is still forecast for across the weekend and people living in low-lying areas should remain on alert and continue to monitor forecasts and warnings.

Council experts will also be monitoring the tides, wind, rainfall, swell and lagoon levels across the weekend and have crews on standby to take whatever additional action is needed.

- SES: https://www.ses.nsw.gov.au/
- Manly Hydraulics Lab: http://www.mhl.nsw.gov.au/users/NBFloodInfo-CurrentConditions
- BOM: http://www.bom.gov.au/

Watch the video below to learn more about how Council manages Narrabeen Lagoon.

Thursday 18 March

While heavy rainfall fell across the Northern Beaches last weekend, the Narrabeen Lagoon didn't reach the level required for a successful opening.

With significant falls predicted across the next three days, Council will pre-emptively open the lagoon today. Although the lagoon is slightly lower than the minimum 1m required, the forecast rainfall should ensure that the entrance opens to the ocean.

A similar pilot channel has been created at Manly and both Dee Why and Curl Curl lagoons are either open or will reopen naturally below trigger levels.

Our experts will continue to closely monitor the tides, wind, rainfall, swell and lagoon levels around the clock, and have crews on standby to take whatever additional action is needed.

> People in low lying areas around our lagoons and waterways should be on alert and monitor forecasts and warnings.

Watch the video below to learn more about how Council manages Narrabeen Lagoon.

Friday 12 March

Update: the pilot channel is now in place and the entrance will be opened when it reaches the trigger level.

While we didn't receive the forecast rainfall over the last few days, there are further falls predicted across the weekend and early next week. Council staff will continue to monitor the lagoon levels around the clock and have machinery on stand-by to open the entrance if the trigger levels are reached.

To learn more about how and when Council opens the lagoon entrance, watch the explainer video below.

Wednesday 10 March 2021

Northern Beaches Council is preparing an entrance channel at Narrabeen Lagoon this morning in preparation for heavy rainfall over the coming days. Heavy machinery is operating at the entrance to today to dig a channel to help open the lagoon once the level rises.

The lagoon is normally opened when levels are between 1m and 1.3m above sea level. The lagoon is now at 0.8m above sea level and approximately 50mm of rain is forecast over the next two days. Council staff will monitor the rainfall and lagoon conditions over the coming days and will open the lagoon when the water levels hit these trigger levels, and tides and ocean conditions allow.

Timing the lagoon opening in large weather events is challenging. To better understand how Council manages the opening of the lagoon, watch this video.

If members of the public have any concerns, please call our Customer Service team on 1300 434 434.

Figure 4-2: Examples of entrance management notifications on Council's website

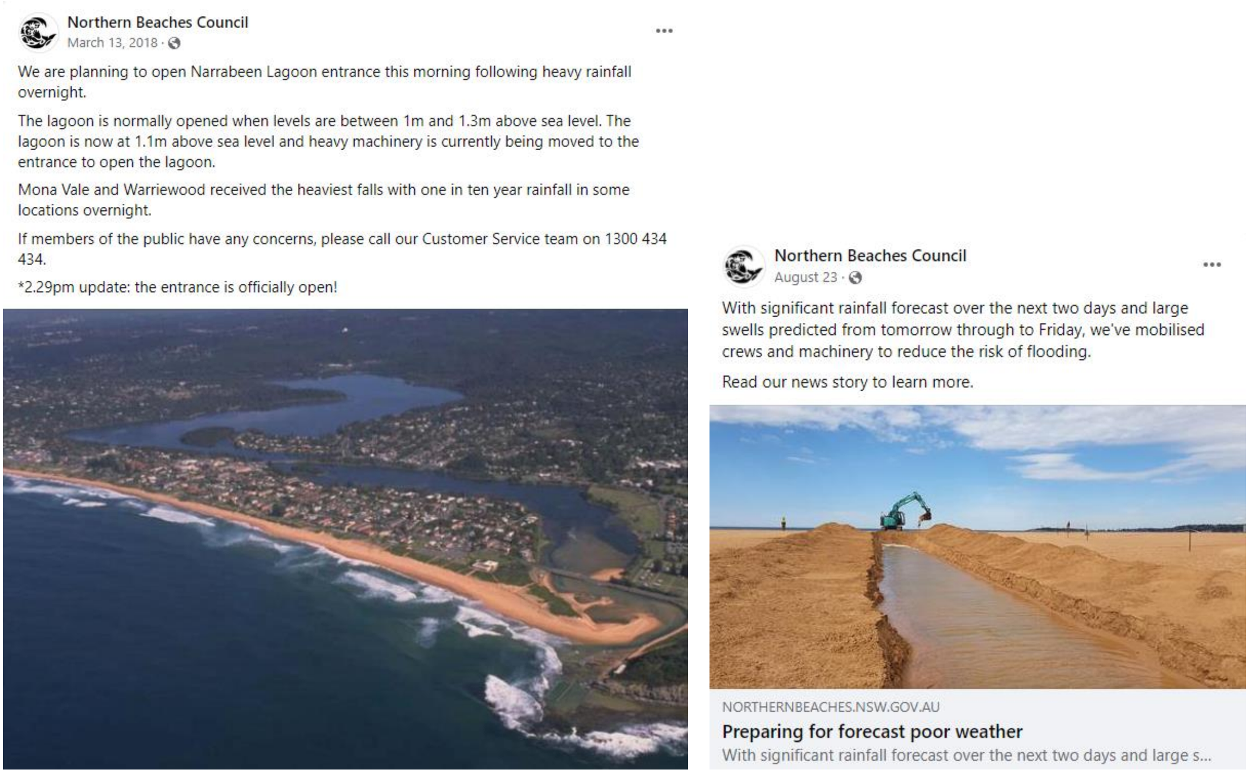

Figure 4-3: Examples of entrance management Facebook notifications

4.4 Options for improving processes

Upon review of the existing short term management strategies at Narrabeen Lagoon and other ICOLLs across the State, several opportunities for improvement and innovation of short term practices have been identified, being:

- trigger condition flexibility;
- pilot channel design;
- expanding entrance breakout data collection; and,
- remote sensing and automation.

Each option is outlined further in the subsequent sections.

4.4.1 Trigger condition flexibility

Currently, the trigger water levels for mechanical breakout are set at 1.0-1.3 m AHD, as outlined in OMS-455 (Warringah Council, 2013), which provides further detail on scenarios that initiate mechanical opening procedures. This report considered if lower trigger water levels could be adopted in certain conditions to better account for the range of dynamic conditions that may be encountered.

At a lagoon level of 1.1-1.2 m AHD, many local residents want Council to open the lagoon, due to concerns about potential flooding if it rains. Some sections of the community call for the lagoon entrance to be opened at a level even lower than 1.0 m AHD, generally when the lagoon has already been closed for a while and they are concerned about water quality.

As discussed previously, Council has adopted the current trigger conditions in order to provide the best possible outcome for a successful entrance breakout that considers several factors, such as: existing water levels, predicted rainfall, tides, entrance berm condition and wave conditions. This does, however, limit the ability of Council to open the lagoon outside of the parameters set in OMS-455 (Warringah Council, 2013).

It was considered if the Lagoon opening procedures could be updated a more flexible, or broader, set of trigger conditions, such as a decision tree style format, could be adopted. An example decision tree style format is provided below (refer **Figure 4-7**). To assess this option, numerical modelling of various breakout scenarios was undertaken for a variety of conditions. These included the lagoon water level at the time of mechanical opening, breakout channel excavation level, tidal phasing, and wave setup. Detailed information on the parameters and outcomes of the modelling is provided in **Appendix C**.

Numerical modelling of the various scenarios indicates that mechanical opening at an initial water level of 1.3m AHD is the most effective and rapid method to reduce lagoon water levels for flood mitigation purposes. This trigger level also corresponds to the initiation of nuisance flooding over the Mactier Street / The Esplanade roundabout. Flooding is considered to be an unacceptable nuisance at a higher water level than this 1.3m AHD trigger level. The historical experience of Council is that initiation of breakouts shortly after high tide is the best practice at Narrabeen Lagoon.

The modelling results showed that mechanical opening at lower initial water levels of 1.0m AHD and 0.8m AHD may be possible, however this results in a much slower build-up of breakout channel discharge which results in a narrower and shallower scour channel and thus the rate at which the water level in the lagoon falls is reduced. In addition, the narrower and shallower scour channel is more susceptible to infilling during this period by sand mobilised by wave action. This quicker infill time means there is a higher chance of a shorter period before another mechanical opening is needed, therefore reducing the overall efficiency of the mechanical opening program. Even though mechanical opening at lagoon water levels of 0.8-1.0 m AHD may be possible, this should only be considered in extenuating circumstances, e.g. catastrophic rainfall forecasts or a devastating pollution/environmental incident event. This action must also be aligned with favourable conditions and when the timing of achieving lowered lagoon water levels or the length of time before the entrance closes again are not critical (i.e. it would be ineffective if the entrance was to close again before the peak flooding has occurred). If this action is undertaken Council should fully document the activity.

Council has previously confirmed in practice that lower trigger levels of 0.6 m AHD are ineffective for entrance breakouts.

In addition to the trigger water level, the modelling indicated that the depth of excavation (bed level) achieved in the pilot channel has an impact on the initiation of breakout scour processes, particularly for the lower water level of 0.8m AHD. This has also been demonstrated in practice with a recent mechanical opening at a water level of 1.1m AHD between 4-6 June 2021 when the entrance had considerable shoaling (refer **Figure 4-4**). The pilot channel was excavated at a relatively shallow bed level to initiate water outflow, however the weak outflow was not sufficient to initiate scour within the channel and the breakout channel subsequently closed during a moderate high tide and low wave conditions. Following this, a mechanical re-opening of the breakout channel by Council two days later on the 8 June 2021 was undertaken at mid tide falling (refer **Figure 4-5** and **Figure 4-6**). This was successful due to a deeper excavation level being achieved that extended further into the lagoon across the flood tide shoal and a broadening of the excavation at the entry point for lagoon waters. As such, it is recommended that mechanical opening at lower lagoon water levels is carried out with the breakout channel excavated as deep as may be practicable and wider at the upstream entry point from the lagoon so as to initiate the breakout with a stronger lagoon outflow that is able to start scouring the breakout channel quicker.

Figure 4-4: 4 June 2021 mechanical opening (photos taken at 10am low tide)

Figure 4-5: 8 June 2021 mechanical re-opening (photos taken at 5pm, 2hrs before high tide)

Figure 4-6: 10 June 2021 mechanical re-opening (photos taken at 4.30pm, mid tide rising)

With consideration of the above modelling outcomes, it is suggested that if Council undertakes mechanical openings at lagoon levels lower than 1.3 m AHD, when conditions are favourable and breakout is considered to be necessary, the lagoon and ocean conditions should be carefully documented and the outcomes monitored and reported (refer **Section 4.4.3**).

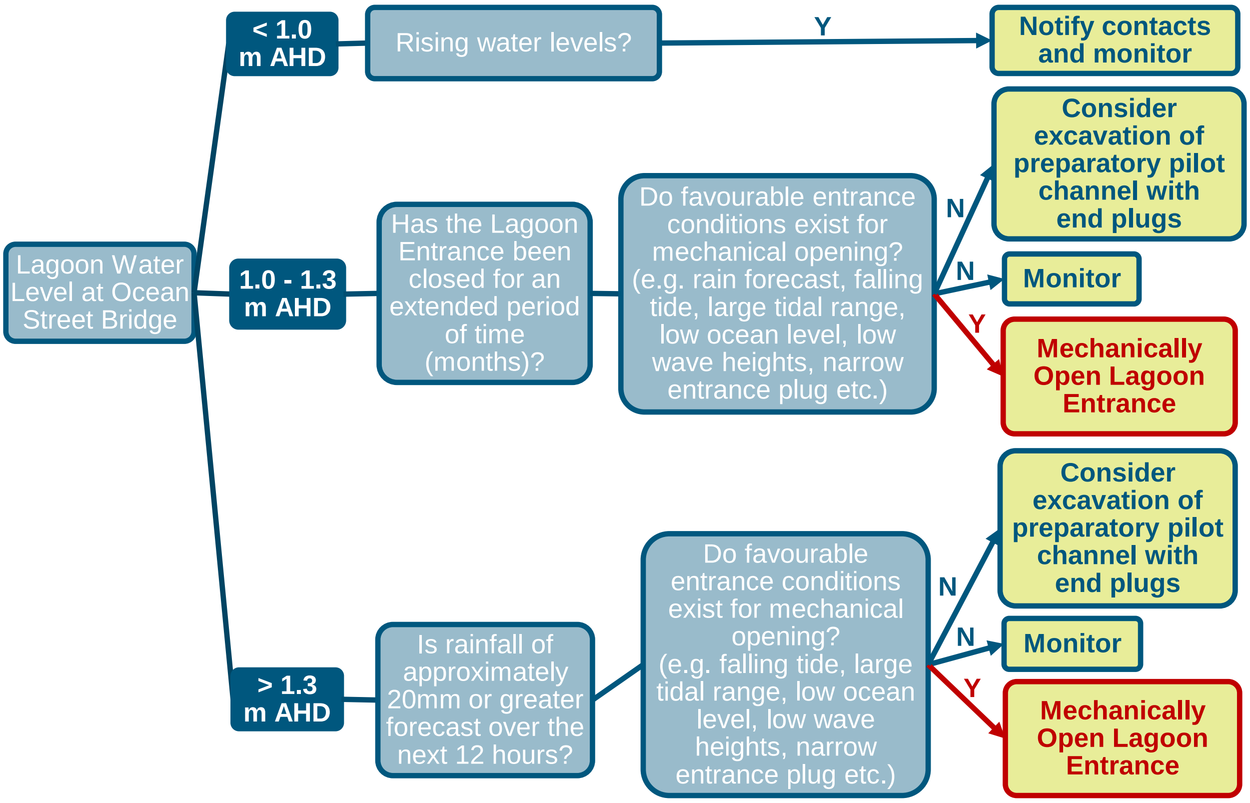

Figure 4-7: Example decision tree for mechanical opening of closed entrance at Narrabeen Lagoon

Ultimately, it is envisioned that a more flexible set of trigger conditions provide good decision making guidance when considering whether or not to undertake mechanical openings in any extenuating scenarios which may be encountered. This would allow Council to confidently refer other parties to the procedures that are being adhered to when assessing the need for mechanical breakout of the entrance.

This decision tree could be published online for the public to view, should Council desire, and the current scenario indicated and updated so that concerned members of the public can view the conditions and decision pathway required to initiate a mechanical opening.

Moreover it is recommended that the trigger levels (1.0 - 1.3 m AHD currently) and emergency procedures are re-assessed within the medium to long term due to sea level rise associated with climate change, as the water level at which an effective breakout can occur will be increased (to ensure there is still an adequate water level difference when the ocean level is higher) whilst the level at which properties become inundated will remain the same.

4.4.2 Pilot channel design

When the lagoon is to be mechanically opened, an excavator enters the beach via Birdwood Park and travels out to the entrance where a pilot channel is excavated. The location of the pilot channel is determined by visually lining up the 'second light pole' (which is the second light from the Swimming Association building at North Narrabeen beach) with the outer most tip of Long Reef (refer **Figure 4-8**). It is well documented that Collaroy-Narrabeen Beach experiences a cycle of beach rotation every ~10 years

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where there is either a net material transport to the northern end of the beach or to the or southern end of the beach. This results in varying beach widths depending on the stage of the cycle (refer **Figure 2-9**). However, it is noted that the channel alignment is currently fixed in the operating procedure, and therefore does not change to reflect the prevailing beach rotation state.

The length of the pilot channel, and therefore amount of sand required to be excavated to achieve the prescribed alignment, can vary significantly depending on whether the beach is rotated/rotating clockwise or anti-clockwise. It is therefore considered that flexibility with respect to both the angle of the pilot channel angle as well as the location should be incorporated into the emergency management procedures. This would allow the pilot channel to be excavated in a position that works more effectively with the natural configuration of the entrance shoals and beach berm at the time of mechanical opening. This is of particular importance during an emergency opening when timely excavation of the pilot channel is required.

Figure 4-9 shows the surveyed entrance bedrock levels in 1976 and plots of the natural tidal channel centreline alignments obtained from review of various Google Earth aerial photographs between 2007 and 2017. **Figure 4-10** shows an approximate overlay of the natural tidal channel centreline alignments onto the 2015 rock surface contour survey. These figures indicate that the natural tidal channel alignment generally follows a SSE orientation and runs through the area of deepest bedrock levels. The natural tidal channel is generally located away from the shallow bedrock area adjacent to the footpath, the Swimming Association building and the ocean pool (visible on the June 2010 image in **Figure 2-9**). It is thought that if the artificial pilot channel followed this general natural alignment corridor to mimic the natural system in a ‘working with nature’ approach this may maximise the available scour depth above bedrock. It is noted that the natural tidal channel centreline alignments shown in **Figure 4-9** and **Figure 4-10** are generally very consistent with the location that Council currently excavates for the pilot channel based on the guidelines in the OMS. The completion of a geophysical survey to accurately determine the bedrock level contours over the entrance area would be useful to define the best location for the pilot channel to maximise the depth of scour. The pilot channel should not be excavated over the northern entrance area where shallow bedrock and a rock shelf exists adjacent to the footpath.

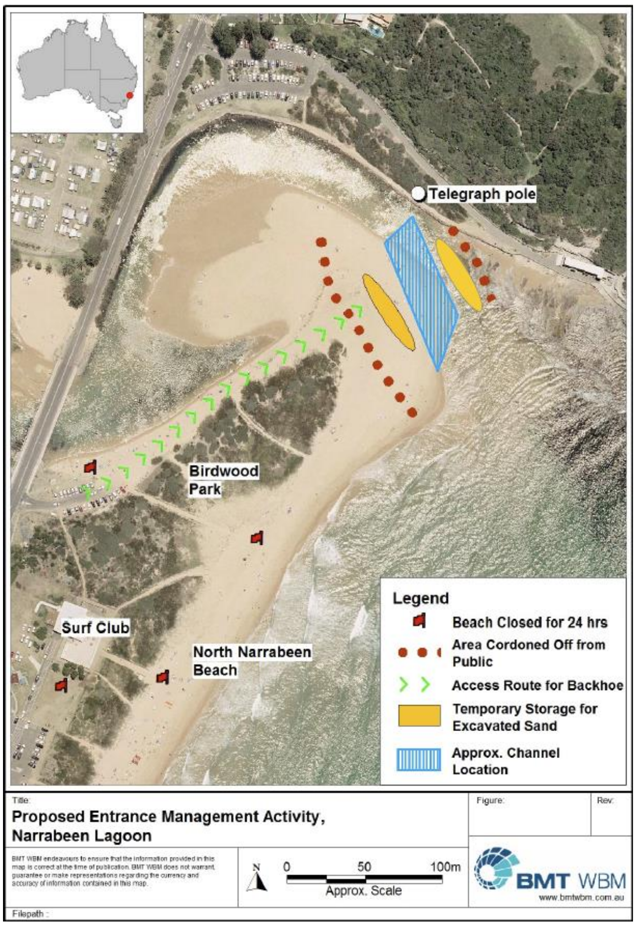

Figure 4-8: Pilot channel alignment in current operating procedure

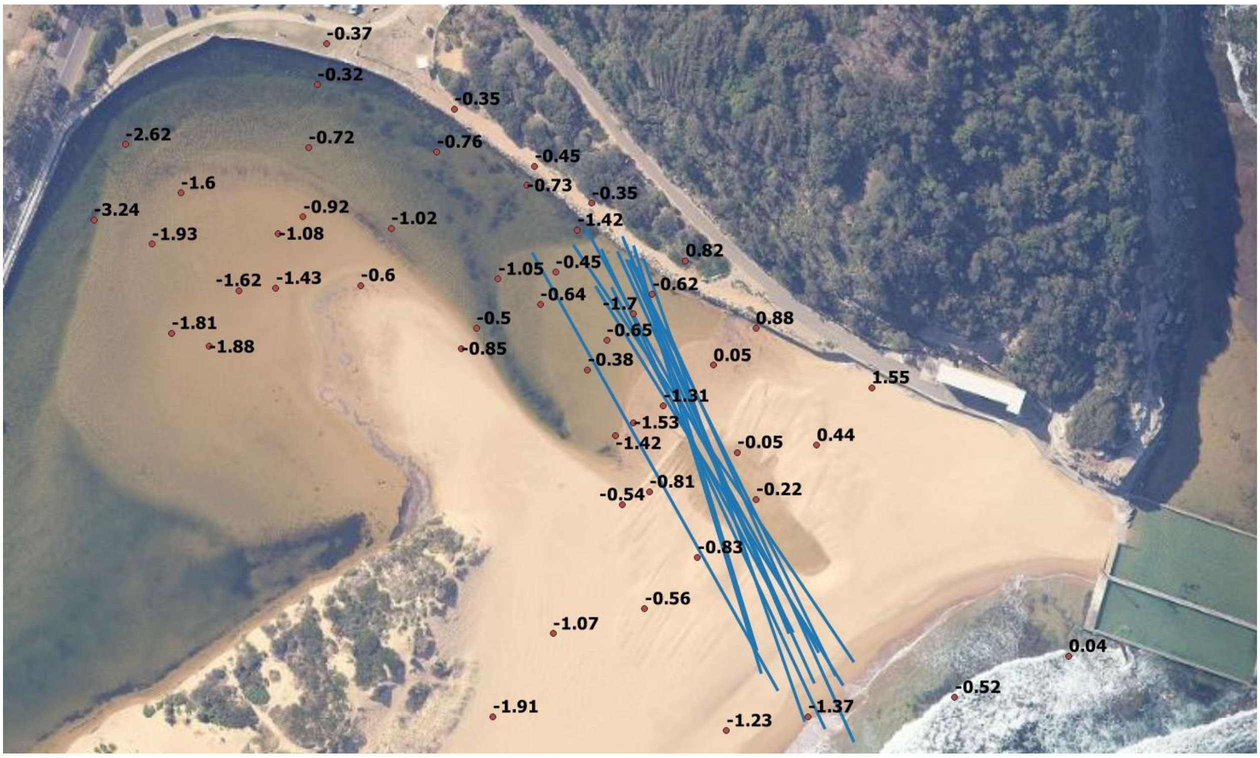

Figure 4-9: Bedrock spot heights from 1976 survey and natural tidal channel alignments

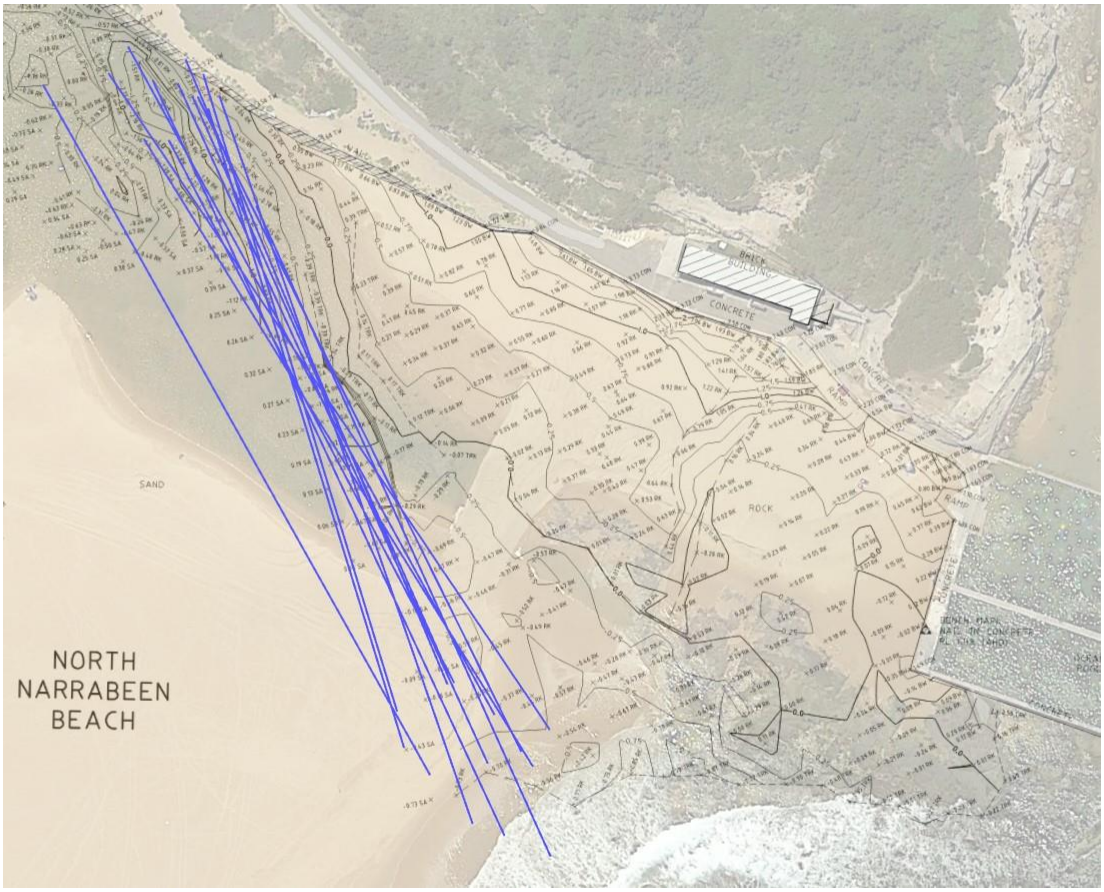

Figure 4-10: Rock surface contours from 2015 survey and natural tidal channel alignments

In addition to following the natural alignment of the tidal channel and lowest bedrock corridor, the extent and position of the 'sand tongue' formed by extension of the flood tide shoal into the lagoon can also influence the location of the breakout channel. Ideally, the pilot channel would be positioned parallel to and northward of the sand tongue to create the shortest possible channel length and enable linkage with deeper water in the natural flood tide channel running adjacent to the northern seawall.

It should be noted that excavation through the 'sand tongue' to shortcut the flow path of lagoon waters around the bend is not recommended. Maintaining the alignment of the dominant flood tide channel adjacent to the northern seawall is preferred in order to mimic the natural system, minimise excavation effort, and to avoid to potential risk of lagoon outflow scouring and undermining the landward side of Birdwood Park Dune resulting in loss of established vegetation and dune area.

As discussed in **Section 4.4.1**, widening of the pilot channel entry point for lagoon waters, extension of the pilot channel across shallow flood tide shoal areas, and excavation as deep as may be practicable is also recommended. A typical pilot channel excavation width of around 2m is recommended to be achieved. Mounds of excavated sand should be scraped away from the edges of the pilot channel to facilitate the breakout process, particularly if opening at a lower lagoon water level. These general recommendations are depicted schematically in **Figure 4-11**.

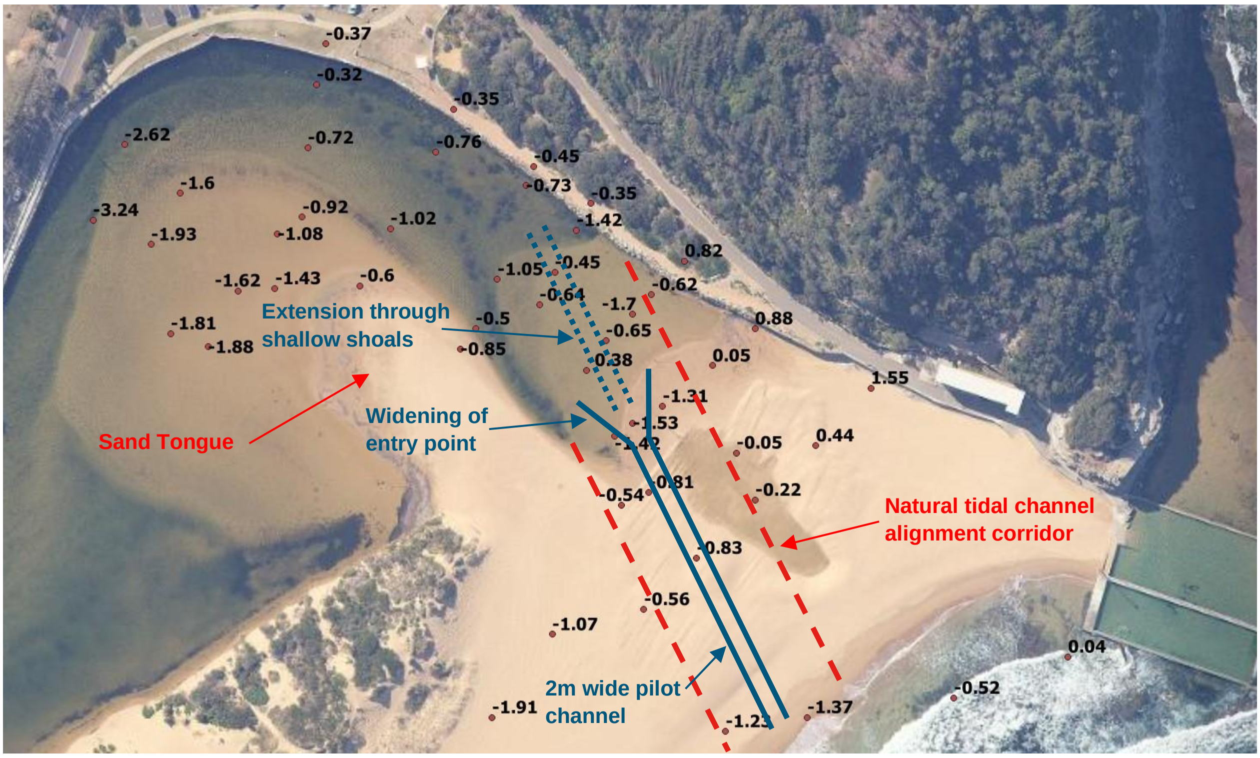

Figure 4-11: Pilot channel recommended arrangement

The option to maintain a complete or partial pilot channel across North Narrabeen Beach to create a (semi) permanent tidal exchange between the lagoon and the ocean or at a minimum lowering the natural breakout water level range by maintaining a lower berm height has been considered. This would be similar to what is done at Queenscliff Beach for Manly Lagoon (refer **Figure 4-12**) and the most efficient way to maintain such a channel may require that an excavator is stored onsite for immediate and regular use, as is the case at Manly Lagoon. This arrangement is not considered to be appropriate at Narrabeen Lagoon as the response of this larger waterbody to rainfall runoff is slower than the smaller catchment and waterway area of Manly Lagoon, so there is more time available for excavation of a pilot channel. As such, having rapid response capability onsite for flood mitigation purposes would provide little benefit.

Figure 4-12: Pilot Channel at Manly Lagoon (January 2020)

4.4.3 Expanding entrance breakout data collection

Council have gained a substantial amount of first-hand knowledge and experience regarding mechanical opening of the lagoon entrance and what conditions are necessary, sufficient and desirable. The dates of mechanical openings and entrance closures have been recorded by Council since 2009 in a database that includes the peak water level in the lagoon (e.g. from the gauge at the Ocean Street Bridge) at the time of opening and captures comments relating to the opening or closure process and decision making. It would be of great benefit for future Council operations to expand the range of data collected and maintained to create a more comprehensive record of mechanical breakouts going forward. This would build up a more comprehensive knowledge database to document Council's first hand understanding of the lagoon entrance breakout dynamics.

Expanded data capture could include:

- additional condition information including water levels, tides, phasing of opening relative to ocean tide, recorded rainfall before and after, rate of water level change, photos, video, etc.
- recording opportunities for improvement, documented after each mechanical breakout, and
- rating operations on their success/effectiveness.

The more informative the database is the more likely that it will be able to be utilised in developing and implementing future, more automated, management options.

4.4.4 Remote sensing and automation

Innovative means of remote sensing are becoming increasingly accessible and cost effective. Examples of such remote sensing include the use of Unmanned Aerial Vehicle (UAV) drones (for photography, videography, and photogrammetric topographic surveys) and solar-battery operated monitoring cameras with a cellular network connection. These low cost technologies provide great opportunities for automated and remote data collection. By conducting routine (e.g. every month or following significant flood or ocean storm events) drone surveys, perhaps even using drones with mounted LiDAR[4], the lagoon entrance berm height and width could be monitored and reported. The data could automatically and regularly update hydrodynamic models that may be used for event forecasting (refer **Section 4.3**). To maximise efficiency the aim could be to capture the maximum extent of entrance shoaling, which would best be done through frequent drone surveys completed at spring low tide. This would provide the most cost effective method of quantitative monitoring of entrance sand volumes and berm levels over time as it is when the lowest sea levels are experienced, and therefore the most land area is exposed. The drone surveys would also provide a useful aerial photo record for short and long term visual monitoring of entrance conditions.

An example of an existing in-situ camera monitoring system and dashboard visualisation, installed in Terrigal NSW, is presented in **Figure 4-13**. A photographic collection is already being catalogued for North Narrabeen, which includes the beach berm, via the CoastSnap station located on North Narrabeen Headland. Collection relies upon community submission of photos via the CoastSnap application to build up a database of images.

Using remote sensing a large amount of useable data can be accumulated for potential automation algorithms (e.g. machine learning) to help refine modelling and improve the accuracy of predictions. It could also be used to inform the best alignment to excavate a pilot channel at a given time. Some options also provide a simple, low cost means of regularly monitoring the lagoon entrance condition and publicly disseminating this information to interested residents (e.g. through the use of online dashboards).

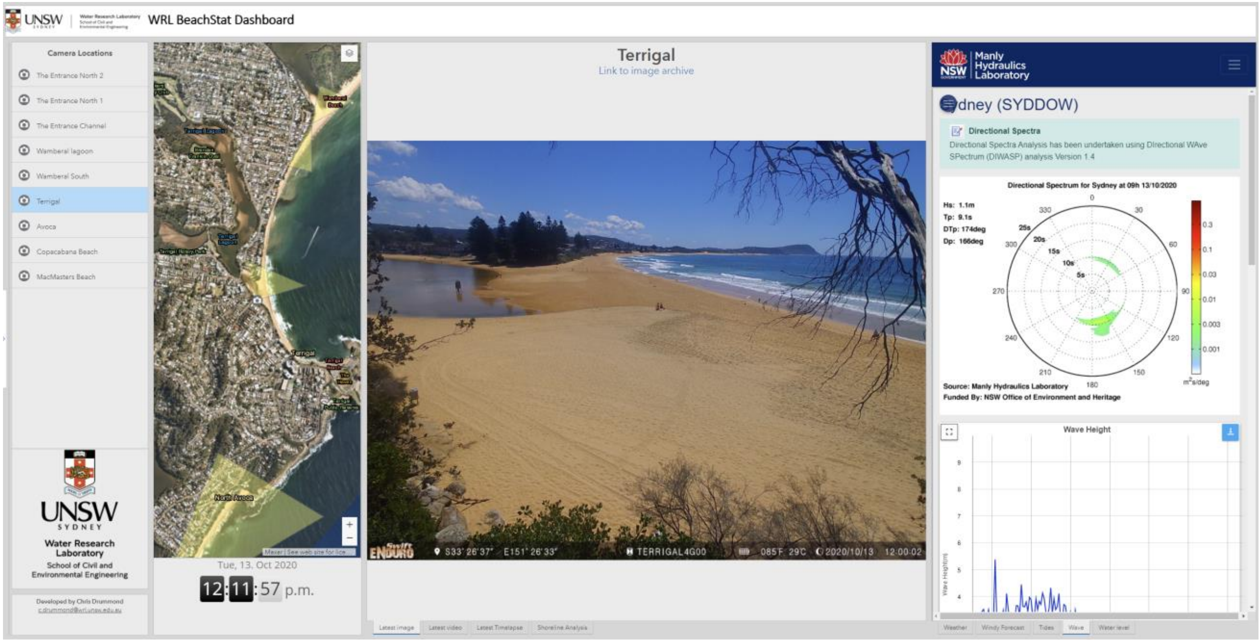

Figure 4-13: Basic ESRI Dashboard Example (UNSW WRL, 2020)

4.5 Recommendations for short term entrance management

In summary, the management of Narrabeen Lagoon can be considered in-step with the generally accepted entrance management strategies implemented for ICOLL's located within heavily urbanised, flood prone catchments elsewhere up and down the NSW coast, as discussed in **Section 3**. These

[4] *Previous investigations by Council into mounted LiDAR have determined that this not a cost effective option.*

conditions warrant the implementation of short term management procedures, for the purpose of flood mitigation, that involve mechanical opening of the Lagoon entrance at water levels that are lower than those that would breakout the entrance naturally.

RHDHV have identified several opportunities for improvement and innovation (refer **Section 4.4**). Outlined below, in order of importance and ease of implementation are the five (5) recommendations put forward for further consideration with respect to the short term management of Narrabeen Lagoon:

1. **Review:**
    - **trigger conditions.** It is envisioned that a more flexible set of trigger conditions could provide good decision making guidance especially when considering undertaking mechanical openings in extenuating scenarios which may be encountered. Council could confidently refer other parties to the procedures that are being adhered to when assessing the need for mechanical breakout of the entrance.
    - **pilot channel design/location.** Refine, and make more flexible, the design guidelines for where the pilot channel is to be excavated, locating it in a position that works more effectively with the natural configuration of the entrance shoals and beach berm at the time of mechanical opening and in the area of lowest bedrock levels if possible. This is of particular importance during an emergency opening when timely excavation of the pilot channel is required. It is noted that completion of a geophysical survey to accurately determine the bedrock level contours over the entrance area would be useful to define the best location for the pilot channel to maximise the depth of scour.
    - **update OMS and REF.** Update Council's existing OMS procedures and REF for lagoon openings based on the above review.

2. **Refine flood forecasting system.** This could include improved automation, supplemented with remote sensing data (refer to next item for further detail).

3. **Enhance the installation and use of remote data collection equipment (e.g. camera, drones, etc.)** to capture more data to help refine modelling and improve the accuracy of predictions. This may also be used to inform the best alignment to excavate a pilot channel at a given time. The additional data could also improve monitoring of lagoon outflow and assessment of the effectiveness of an opening. This may also provide a simple, low cost means of regularly monitoring the lagoon entrance condition and publicly disseminating this information to interested residents (e.g. through the use of online dashboards).

4. **Expand the qualitative and quantitative standardised data captured for each lagoon entrance mechanical opening.** Items to consider including are:
    - additional condition information including water levels, tides, phasing of opening relative to ocean tide, recorded rainfall before and after, rate of water level change, photos, video, etc;
    - recording opportunities for improvement, documented after each mechanical breakout; and,
    - rating operations on their success/effectiveness.

5. **Enhance publicly available information** on Council's website and the MHL flood warning webpage to help the public understand the content and ultimately their understanding of how and why Council manages the Narrabeen Lagoon entrance. Information could include a decision matrix/tree, trigger levels for mechanical openings, and real-time updates on conditions.

5 Medium term entrance management

5.1 The need for sand management

Sand is constantly moving in the vicinity of Narrabeen Lagoon entrance. As described in **Section 2.2**, the lagoon entrance naturally closes due to the littoral movement of sand northwards along Collaroy-Narrabeen Beach, with the volume of sand moving into the entrance exceeding the volume of sand being washed out from the entrance by the outgoing tide. A large amount of sand can move into the entrance very quickly in large swell conditions, particularly during east coast lows. Sand can also be blown over the dune and into the entrance waterway.

Entrance processes such as breakouts and closures are a natural occurrence for an ICOLL like Narrabeen Lagoon. If left unmanaged, the sand in the entrance waterway would keep building up until it becomes choked and the berm is very high. The lagoon level would keep rising behind the berm and eventually the berm would break out naturally, however by then the adjacent floodplain would be flooded. Council intervenes to minimise the potential impact and risk of flooding, as well as to maintain or enhance water quality in the Lagoon and to conserve the biological diversity of the Lagoon system. Removal of the sand improves the hydraulic efficiency of the entrance by reducing the 'shallow water effect' and friction effects from the sand shoals, so that water can flow through more easily.

Typically, after an entrance clearance operation the entrance will stay open for a couple of years before it closes. There will then be a period of time, up to a year or two, when the entrance will close but mechanical opening concurrent with a high enough lagoon water level will open it again, until eventually the entrance waterway upstream to the Ocean Street Bridge and even beyond becomes so choked with sand that mechanical opening is very difficult.

An additional objective during entrance clearance operations is to move the sand back to Collaroy Beach to maintain a buffer for beach erosion and to reduce the impact on properties there from the process of littoral drift.

5.2 Review of current entrance clearance practices

Since 1975, entrance clearance operations have been used as the dominant process to remove sand from a closed lagoon entrance. Accumulated sand is typically removed using heavy machinery and transported south for replenishment of Collaroy Beach, as shown in **Figure 5-1**.

Figure 5-1: Excavators removing the entrance shoals (left), Unloading and regrading of sand for beach replenishment (right)

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Entrance clearance works have been completed approximately every 3-5 years, with the volume of sand removed ranging from 27,400 m^3 to 150,000 m^3 but averaging at approximately 30,000-50,000m^3 per campaign (refer **Table 5-1**).

Table 5-1: Historical Entrance Clearance Operations

Year	Sand Removed (m^3)	Location with Respect to Ocean Street Bridge	Approximate Duration (months)
1975	150,000	-	5
1979	37,500	-	1
1982-83	60,000	-	-
1987	40,000	East	3
1990	30,000	East and West	4
1992-93	56,000	East and West	5
1995	27,500	East and West	4
1999	70,000	East and West	3
2002	40,000	East and West	4
2006	45,000	East and West	3
2011	36,000	East and West	2
2016	38,650	East and West	2
2018	30,900	East and West	3
2021	27,400	East and West	2

Source: Cardno (2017) and Northern Beaches Council

The most recent clearance operations were conducted in Winter/Spring 2016, Spring/Summer 2018, and Spring/Summer 2021.

2016 Entrance Clearance Operation

For the July 2016 entrance clearance operation, it was determined by hydrographic survey that approximately 43,000 m^3 of sand should be removed. The design of the clearance operations allowed for separation between the dredge profile and both the rock training wall and the Ocean Street Bridge to ensure no damage to these structures. Additionally, there was an allowance of a (minimum) 10m separation between operations and seagrass beds. The dredge profile was designed to ensure the works only removed the additional layer of sand that had been recently deposited and did not remove any deeper material (Cardno, 2017).

Entrance clearance works were undertaken over a 9 week period between 1st September to 5th November. A net total of 38,650 m^3 was removed from the lagoon and placed on Collaroy-Narrabeen Beach between Mactier Street and Ramsay Street.

2018 Entrance Clearance Operation

Design of the 2018 Narrabeen Lagoon Entrance Clearance works was undertaken by the University of New South Wales (UNSW) Water Research Laboratory (WRL) and included design profiles for the excavated bed surface within the lagoon entrance channel, as well as the proposed areas of beach replenishment along Collaroy-Narrabeen Beach. Design excavation levels were determined by WRL (2018) by referencing previous survey data from within the lagoon entrance to ascertain where excavation of recently deposited marine sand could take place.

Entrance clearance works at Narrabeen Lagoon and beach replenishment on Collaroy-Narrabeen Beach were undertaken over 11 weeks from the 24th of September to the 7th of December 2018. A net total of 30,872 m^3 was removed from the lagoon and placed on Collaroy-Narrabeen Beach between Goodwin Street and Wetherill Street.

2021 Entrance Clearance Operation

For the July 2021 entrance clearance operation, comparisons were made of the lagoon bathymetry from the post 2018 work survey to the more current pre-clearance survey completed in July 2021. From the differences in bathymetry it was determined that approximately 25,500 m^3 of marine sand had entered the lagoon, with approximately 19,000 m^3 east of the Ocean Street Bridge, and 6,500 m^3 west of the Ocean Street Bridge. Hence, it was decided that 25,000 m^3 should be removed.

An amphibious dredge was used to excavate the sand, which was pumped as a slurry by pipeline to a dewatering basin at the site compound adjacent to the Birdwood Park parking area where a single 23T excavator managed the sand stockpile and loaded trucks for transport to Mactier Street. The amphibious dredge was a change from the excavators used for previous entrance clearance operations. The bulk of sand was removed from the shoal east of the Ocean Street Bridge. West of the bridge, a regime channel was formed approximately 180 m long and 30 m wide, dredged to -1 m AHD.

Entrance clearance works were undertaken over a 9 week period from 22nd September to 15th December 2021. A net total of 27,400 m^3 was removed from the lagoon and placed on Collaroy-Narrabeen Beach between Clarke Street and Robertson Street. At the conclusion of the works, the lagoon was successfully opened with a lagoon water level of 0.8 m AHD.

5.3 Review of pre-clearance planning

Prior to the initiation of an entrance clearance operation, a Review of Environmental Factors (REF) is prepared in accordance with Division 5.1 of the EP&A Act as well as with Council's Lagoon Entrance Management OMS 455 (Warringah Council, 2013). Preparation of the REF also considers any lessons learnt from the previous post-completion report which is prepared subsequent to each entrance clearance campaign.

In undertaking entrance management activities, it is preferable to replicate the natural variability within the opening regime as much as possible to protect ecological processes.

5.3.1 Timing for commencement of works

Undertaking entrance management activities more frequently than needed can have adverse ecological impacts and can also be a waste of Council's limited resources. The decision on when to commence entrance clearance considers the following:

- Field observations and/or computer model information indicate that the duration of open entrance conditions is decreasing.
- The entrance area is choked (i.e. filled with beach sand) from west of the Ocean Street Bridge downstream to the natural rock weir at the entrance.

- The entrance clearance operations should be conducted outside of the main swimming season, particularly outside of the December/January school holidays, to minimise disruption to the recreational users of the lagoon entrance and beach areas.
- Weather conditions – The entrance clearance operations should be conducted outside the peak winter east coast low season to minimise disruption to the removal and placement of sand, and to avoid the need for emergency openings, which can significantly change the sand profile during the clearance works.

5.3.2 Approvals and procurement

The organisation of approvals, licences and permits requires significant resources when preparing to undertake the lagoon entrance clearance works. Required approvals, licences and permits include, but are not limited to approval under Division 5.1 of the EP&A Act 1979 from Northern Beaches Council (requires preparation of an REF) and a Fisheries Permit (for dredging, reclamation, harming marine vegetation and blockage of fish passage). It is noted that under the Crown Lands Management Act 2016, Council reserve trust managers are appointed as Crown land managers for land they previously managed. Councils will now manage Crown land as if it were public land under the Local Government Act 1993. As such, no Landowners consent is required. Notwithstanding, Council maintains an ongoing Crown Lands Licence for dredging in the lagoon entrance area and placement of this material along Collaroy-Narrabeen Beach, which is retained with an annual fee.

The necessary approvals, licences and permits are applied for in advance (if not available to hold indefinitely or for extended periods of time) of undertaking the design of the works, procuring a contractor or mobilising plant. Contractors and the superintendent are engaged with sufficient time for planning and assessment of the proposed work, and to ensure quality, suitability and relevance of their documentation.

5.3.3 Entrance clearance design

The entrance clearance design is determined during the preparation of the REF. It considers the hydraulic efficiency of flow through the entrance, the location of seagrasses and the location of fresh sand deposited since the previous entrance clearance campaign. Excavation is not undertaken in new areas unless acid sulphate soil testing confirms that the sand is clean marine sand. Sediment coring is also used to confirm that the sand is suitable for beach replenishment. The pre-clearance survey should be undertaken as close as possible to the commencement of works, because if the bathymetry changes before works are commenced, the design needs to be revised. This ensures that the design is reflective of lagoon conditions immediately prior to the commencement of works.

The following design criteria are typically applied to define the extent of entrance clearance works (WRL, 2018):

- all batter slopes to be flatter than 1V:6H (vertical:horizontal);
- excavation to be a minimum of 10 m from the lagoon boundary (larger if practical and 20m from any eroding banks);
- excavation to be a minimum of 10 m from seagrass or macroalgae mapped by a recent ecology survey; and,
- all excavation levels to be above historical excavation levels as defined by previous post-clearance surveys.

At the completion of both the 2018 and 2021 entrance clearance campaigns it was observed that large lobes of sand remained on each side of the entrance channel due to the highly accreted state of the beach berm at the time. It is considered that extension of the design footprint to include lowering of the beach berm to the east of the Birdwood Park sand dune would assist in preventing premature ingress of sand back into the lagoon following completion of the clearance works, particularly if the beach berm is in a relatively accreted state. This is confirmed by Morris' (2010) investigation of entrance infilling processes following the 2006 entrance clearance works, which concluded that ingress of material through the entrance is largely dependent on sand availability at the ocean entrance.

In the 2018 entrance clearance campaign, some minor over-excavation by the contractor below design levels was identified during works in some areas both upstream and downstream of Ocean Street Bridge. Over-excavation has the potential to extend into acid sulphate soils and result in excavation of muddy materials that may generate turbidity in the works area and are not suitable for beach replenishment activities. It is important that progress of excavation is regularly checked against the design plan by the Superintendent to minimise the risk of over-excavation.

The amphibious dredge used in 2021 created a lesser impact on the community in terms of noise extent and visual perspective than did the excavators used in previous entrance clearance operations. However, there was an increased risk of delay to the project, due to the methodology relying upon continuous operation of a single dredge and pipeline system. On several occasions, one of these two systems required maintenance works and the project came to a standstill while these works were carried out.

The amphibious dredge methodology was initially forecast to average 333 m^3 per day of marine sand transported to Collaroy-Narrabeen Beach, however the outcome of the works saw an average transport rate of 480 m^3 per day. There were specific areas of the lagoon that provided efficient outputs, and other areas where dredging was slower. Dredging works were slower close to the northern rock wall, as the bedrock level is quite high and poses a risk to damaging the dredge head. The siltier sand in the western shoal travelled more slowly through the pipeline, which slowed down the production rate.

5.3.4 Beach replenishment areas

Beach replenishment areas are determined during the early planning phase of the clearance works, based on the beach profile and where sand is most needed. It is noted that beach replenishment survey data for Collaroy-Narrabeen Beach could be provided by ongoing beach surveys undertaken periodically by the Water Research Laboratory (WRL) by quad bike and drone. In addition to Collaroy-Narrabeen Beach, other areas which are reviewed for replenishment include parts of the Narrabeen Lagoon foreshore, such as adjacent to the Sydney Lakeside Caravan Park or the eroded areas along the southern shoreline of Narrabeen Lagoon.

5.3.5 Traffic management

During development of the REF, a Traffic Management Plan is prepared in consultation with Transport for NSW (TfNSW). This needs to be prepared prior to the works to allow sufficient time to obtain any road occupancy licence/s or permits. This is included by the contractor in the Construction Environmental Management Plan, which is required as per the tender documentation.

Recent entrance clearance campaigns have involved loaded trucks moving in an anti-clockwise loop, via Walsh Street and Pittwater Road, unloading for sand replenishment at the relevant beach access road head and returning to the entrance via Ocean Street. This loop approach shares the traffic load for adjacent properties, but a temporary relaxation of the three-tonne load limit on Walsh Street is required from Council.

Locations for access to the beach are determined based on beach replenishment areas and ease of access. Several road heads are available, including at Mactier St, Wetherill Street, Stuart Street, Ramsay

Street, or the sand ramp at the northern end of Collaroy Beach car park. Of these, the only road head where the beach can be easily accessed due to the existence of traffic lights is at Mactier Street. Previous beach replenishment campaigns have used other road heads, but access via just Mactier Street has been acceptable in recent times due to clockwise beach rotation providing adequate storage capacity around Mactier Street to accommodate beach replenishment volumes.

Beach replenishment at locations south of Mactier Street would require unloaded trucks leaving road heads to either turn left onto Pittwater Road southbound and complete a large loop that would return them to Narrabeen Lagoon (which is inefficient), or to turn right onto Pittwater Road northbound without traffic lights and across several lanes of traffic, which would require a Road Occupancy Licence from TfNSW. Another alternative would be to access the beach via Mactier Street and then transport the sand southward to the desired replenishment location using a chain of excavators, Moxy trucks and dozers.

The Traffic Management Plan also needs to provide details of the movement of vehicles on and off site at Ocean Street.

5.3.6 Community engagement

The relatively large-scale entrance clearance works conducted every 3-5 years result in several impacts on the local community due to the operation of heavy machinery and high use of local roadways for sand transportation. These impacts include, but are not limited to, noise, beach closure, traffic impacts, reduced recreational access, public safety, and lagoon amenity.

It is noted that Council has already prepared a video and website[5] that outline its management of coastal lagoons, including specific content describing the mechanical breakout and entrance clearance operations at Narrabeen Lagoon.

When entrance clearance works are scheduled and the scope of excavation works has been planned out, community engagement material is prepared to inform the community of the scope and purpose of the upcoming clearance works, as well as to aid in their understanding of why the works are required. Information is provided through a number of different avenues. Media releases are prepared, information is uploaded to Council's website and social media as well as emailed out through Council's weekly e-news. Letters are also sent to nearby properties which may be impacted and signage is installed near the works area. It is considered that there could still be some potential to update the information on the website in real time, as the works progress. A dedicated webpage for each entrance clearance campaign may be the simplest way of achieving this.

5.4 Review of entrance clearance works

Processes during entrance clearance works are covered in the Construction Environmental Management Plan (CEMP), which is required to be prepared by the contractor in consultation with Council early in the project and prior to the commencement of works.

Whilst the method and machinery involved in the entrance clearance may vary from one campaign to the next, the following processes should always be considered.

[5] https://www.northernbeaches.nsw.gov.au/environment/coast-and-waterways/lagoons

5.4.1 Maintenance of a closed entrance

During an entrance clearance operation a closed entrance is desirable, to provide safe, stable and predictable operating conditions for sand extraction. If the lagoon entrance is open when works are due to commence, it should be mechanically closed.

During the entrance clearance works, monitoring is undertaken for lagoon water levels, rainfall, ocean conditions and water quality. If it is necessary to mechanically open the lagoon during the works, for the purposes of flood mitigation or to improve water quality, the lagoon should be mechanically closed again once any threat has passed. The lagoon water level after mechanical closure should be not less than 0.4 m AHD for environmental reasons, but may be higher than this if required by the contractor for the efficient operation of machinery.

Details of when and how the lagoon should be opened and closed should also be included in the CEMP, and if the works are being undertaken under contract, it should be ensured that the contractor is aware of their obligations for managing the entrance to reduce flood risk and disruption to the works.

5.4.2 Quality control of excavation depths and extent

During recent entrance clearance operations, contractors have used GPS to determine the depth and extent of excavation, however subsequent survey has found that the GPS did not provide a reliable method for tracking the excavation depths or extent during the works.

Ideally the depth and extent of excavation should be checked independently during the entrance clearance works. This could be done by bathymetric survey, although this is time consuming and slows the progress of the works. However remote sensing and data collection equipment (e.g. UAV[6] topographic beach surveys and USV[7] hydrographic surveys) is gradually becoming more cost effective and time efficient as technology improves.

The CEMP should cover the method of quality control, the process for rectifying excavation that does not match the design plan as well as how this would be costed. The method of quality control would need to consider the method of paying the contractor, which for example could be based on the volume excavated or on a daily rate of excavation.

5.4.3 Public safety management

Public safety should be maintained at all times. Public safety management is covered within the CEMP, prepared prior to the commencement of works. Details of methods of managing pedestrians and waterway users, as well as details of signage for these groups are included.

The work managers need to ensure that the public is kept a safe distance away from the works. During previous entrance clearance campaigns pedestrians have been observed to ignore signage, particularly during haulage of material from the western work area on the upstream side of Ocean Street Bridge. The Superintendent needs to ensure that the contractor is enforcing requirements from the CEMP. This is a constant challenge in a large, public construction area, and consideration should be given to whether this can be improved.

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[6] *Unmanned Aerial Vehicle*
[7] *Unmanned Surface Vehicle*

5.4.4 Water quality management

Water quality management is covered in the CEMP. Monitoring is undertaken by the contractor during the excavation to ensure that water quality meets environmental guidelines and to inform onsite decisions regarding excavation in certain work areas, adjustment of other control measures such as silt curtains, and to provide a formal record of observations, causes and responses to any water quality incidents.

The water quality monitoring comprises periodic (several times per day) visual inspection of lagoon water quality (e.g. water discolouration/plumes) and recording of observations, including the likely cause of any observed water quality degradation (e.g. over-excavation into muddy material, catchment/stormwater inflows etc.). Provision for quantitative spot measurement of water quality (i.e. turbidity in NTU) with a hand-held probe should be retained onsite for investigation of any observed poor water quality.

5.5 Options for improving processes

Upon review of the most recent entrance clearance operations in 2016, 2018 and 2021, it was found that in general the processes were sound, with comprehensive investigation and planning documented in the Review of Environmental Factors and Construction Environmental Management Plan in each case.

There were several areas identified where improvements could potentially be made. These were principally related to entrance clearance design, including the frequency at which entrance clearance is undertaken, the volume of sand removed and the location from which it is removed. Also, it is considered that dune management should be included in medium term planning for entrance management due to its important role in reducing the quantity of sand moving into the entrance waterway.

The method of transporting the sand from the lagoon entrance to Collaroy Beach could also be varied. The option of pumping the sand through a pipeline, which would require a substantial upfront cost to construct, is considered in the Long Term Management section of this report (refer **Section 6**).

In recent times, entrance clearance operations have been completed more frequently (approximately every 3 years) due to the relatively high volume of sand available at the northern end of Narrabeen Beach. This larger volume of sand is due to the process of beach rotation, a decadal process related to the El Nino / La Nina cycle and its influence on wave approach direction and consequently alongshore sand transport. Flexibility is required to allow for a variable frequency of entrance clearance campaigns in response to different stages of the beach rotation cycle.

Discussion of the options below is based on maintaining an open entrance channel for a longer proportion of time overall, however consideration must be given not just to hydraulic efficiency, but also to any environmental, recreational and social impact as well as available budget.

Four options for entrance clearance design are discussed below:

1. Current entrance clearance practice
2. Increased frequency, lesser volume, focus on western shoal
3. Increased frequency, lesser volume, regime tidal channel
4. Dune management

5.5.1 Option 1: Current entrance clearance practice

Council’s management of the lagoon has remained fairly consistent over the last 40+ years, with mechanical openings or emergency breakouts implemented as a short term management option, primarily for flood mitigation purposes, and periodic entrance clearance operations implemented as a medium term management option to remove the bulk of sand which has accumulated in the entrance since the previous entrance clearance operation.

Option 1 is the continuation of the current method of entrance clearance works as described in **Section 5.2** above, comprising the removal of sand every 4 years (on average) from the shoals accumulating immediately upstream (west) and downstream (east) of the Ocean Street Bridge.

Figure 5-2 below shows the area for excavation in the design plan from the REF for the most recent entrance clearance campaign in 2021.

Figure 5-2: Area of excavation for 2021 entrance clearance campaign (Cardno, 2021)

5.5.2 Option 2: Increased frequency, lesser volume, focus on western shoal

During the last 5 years North Narrabeen Beach has been extremely wide due to the larger scale process of beach rotation over the entire Collaroy-Narrabeen embayment. This widening has increased local sand volumes adjacent to the entrance, which in turn has increased the potential for sand transport into the entrance of the lagoon. In addition, the wider beach has effectively increased the length of the entrance channel, which also increases the risk of closure. As a consequence of these factors, entrance clearance operations and emergency openings have needed to be completed more frequently.

The concept of more frequent entrance clearance campaigns has previously been suggested by Morris (2010) as an outcome of a detailed study of entrance sedimentation behaviour, although this study was unrelated to the current issue of increased rate of accretion due to beach rotation.

Morris observed that large-scale clearance of the flood tide shoals to the east and west of Ocean Street Bridge resulted in initial rapid infilling of areas to the east of the bridge due to the associated increase in available sand storage volume. This was then followed by a slower rate of infilling as the system approached closure, during which time expansion of the lower flood tide shoals (east of the bridge) provided a sand source for mobilisation and transport (under the action of tides) of sand upstream to build-up the upper flood tide shoals (west of the bridge).

Morris observed that following rapid infilling of the lower flood tide shoal, a phase of ‘quasi-stability’ evolves where there was found to be minimal impediment to hydraulic efficiency (i.e. with respect to tidal exchange). However, once the upper flood tide shoal begins forming, tidal hydraulic efficiency declines, representing a ‘tipping point’ in entrance stability that ultimately leads to the entrance closing.

As such, it was considered by Morris (2010) that higher frequency, smaller scale strategic removal of sand from the upper (western) shoal could be a more strategic and efficient means of maintaining an open lagoon entrance when compared to a large scale removal of the entire flood tide delta as per the current practice.

Notwithstanding the above findings by Morris, and while it is accepted that throttling of tidal flows by the upper shoals plays a part, it is considered that entrance closure is primarily driven by localised entrance processes: infilling caused by wave action, both in building up the beach berm level from net northerly alongshore transport of sand along Collaroy-Narrabeen Beach and offshore/onshore movement of sand during beach recovery following major coastal storms; wave stirring of sand at the lagoon entrance accompanied by flood tides; and mobilisation of large volumes of sand during major coastal storms (e.g. east coast lows).

For the purpose of comparison with Option 1, which assumes an average removal of 40,000 m^3 every 4 years, a more frequent clearance campaign every 2 years would need to comprise an excavation volume of less than around 15,000 m^3 to achieve the same present value cost over an analysis period of 30 years.

The concept of removing only the western shoal, in accordance with Morris’ findings, assumes that the eastern shoal is not blocked with sand. Option 2 is based on the reduced entrance clearance volume being removed mainly from the western shoal but at a lesser depth/extent than the current practice, but it includes an allowance for a channel through the eastern shoal. **Figure 5-3** below indicates the area that could be considered (in the REF) for this option.

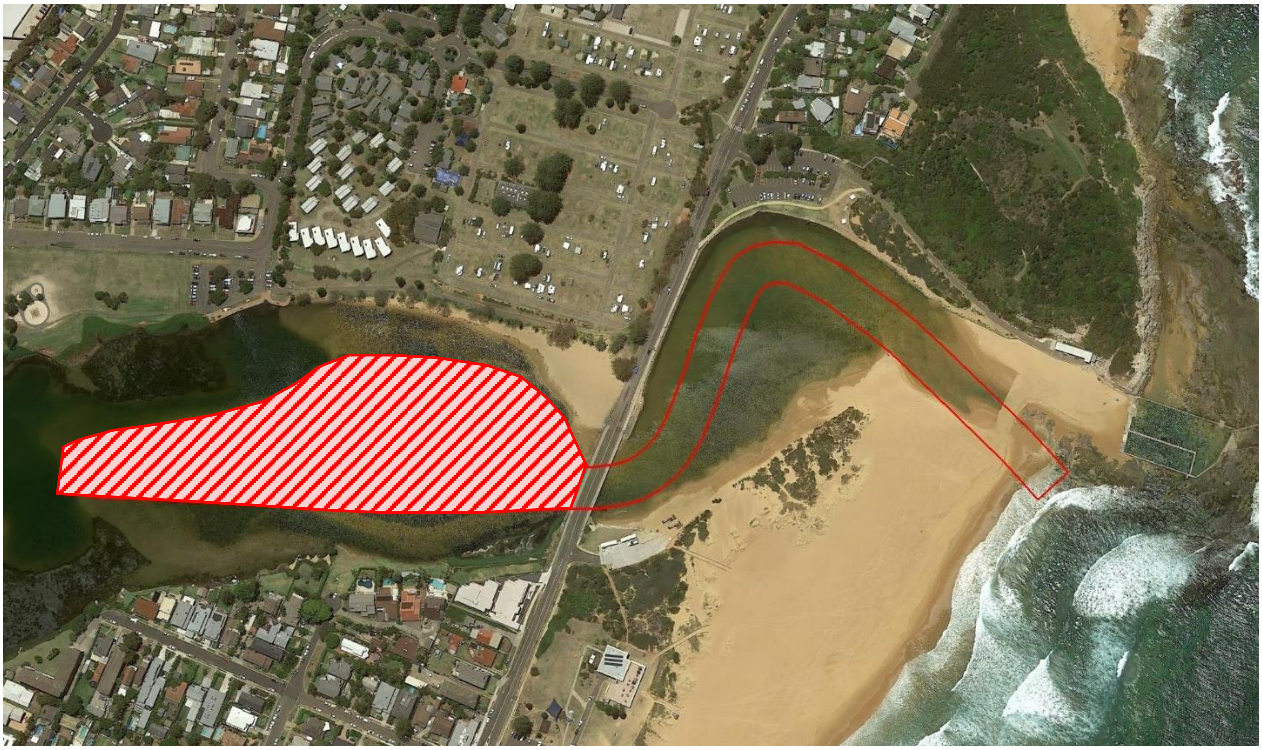

Figure 5-3: Indicative entrance clearance area for Option 2

It is considered that this option may be worth trialling to potentially prolong periods of open entrance conditions, under specific conditions when the entrance channel is well-established through the beach berm and the beach has rotated in an anti-clockwise direction to minimise the beach width adjacent to the entrance. Under other conditions when sand volumes adjacent to and within the entrance are high, this option may be less effective due to the localised entrance processes mentioned above acting to impose entrance closure.

5.5.3 Option 3: Increased frequency, lesser volume, regime tidal channel

It is considered that a reduced entrance clearance volume could be removed in a more targeted excavation footprint compared with Option 2 above. As an alternative method of achieving a smaller scale and more frequent removal of sand, for the purpose of potentially improving the hydraulic efficiency and keeping the entrance in an open condition for a greater percentage of the time, a regime tidal channel could be maintained through both the western and eastern shoals.

Review of recent aerial photographs indicates that the tidal channel under 'normal regime' open entrance conditions (e.g. not broken out wide following flooding) is typically around 30m wide. Measurements undertaken by Morris (2010) over a 2 year period determined that the cross-sectional area of the entrance channel in transects downstream of the Ocean Street Bridge stabilised to 20-25 m^2 (measured below mean sea level). A target regime tidal channel approximately 30m wide and excavated to -1 m AHD[8] or bedrock (whichever is shallower) would achieve a similar hydraulic conveyance.

The excavation depth within the regime tidal channel would be limited to the maximum excavation levels from previous entrance clearance campaigns, to ensure that only recently deposited marine sand is removed. Review of maximum excavation levels within WRL (2018) determined that the deepest

[8] Subject to consideration of maximum excavation levels from previous entrance clearance campaigns, to ensure that only recently deposited marine sand is removed.

excavation upstream of the Ocean Street Bridge was at a level of -1.05m AHD closest to the bridge, which then tapered to -0.4m AHD on the western side of the upstream shoal. The deepest excavation downstream of the bridge was at a level of -0.8m AHD closest to the bridge and then tapered up to a level of -0.5m AHD closest to the entrance. The entrance rock weir at approximately 0m AHD was noted to limit excavation depths adjacent to the tip of Birdwood Park dune.

The southern shoreline of the lagoon upstream of the Ocean Street Bridge has been subject to erosion. The existing channel runs close to the shoreline in this location which has promoted undercutting and greater wave penetration. Positioning the regime tidal channel away from the shoreline in this location, whilst maintaining an alignment that approaches the deepest point in the channel beneath the Ocean Street Bridge, would alleviate erosive pressure on this section of shoreline. An overlay of an indicative regime channel alignment is provided in **Figure 5-4**.

Figure 5-4: Indicative regime tidal channel alignment

It should be noted that this strategy would not increase the hydraulic efficiency of the entrance to the extent that would be achieved with large scale removal of the entire flood tide delta, but would be primarily focused on maintaining an open entrance condition for as long as possible. The availability of an open entrance for a greater percentage of time is nevertheless a flood mitigation benefit.

It should also be noted that when the lagoon water level builds up behind a closed berm, compared with the water level for an open entrance, the larger difference between the lagoon and ocean water levels results in more effective scour when the berm does actually open, and therefore more sand being transported out of the entrance and into the ocean. Increasing the frequency of entrance clearances to maintain the entrance in an open condition means that over time, this could allow a greater build-up of sand within the entrance area surrounding the regime channel than would be the case if the entrance closed and was allowed to remain closed for a period of time.

The maintenance of a regime tidal channel through the upper shoals along the indicative alignment shown in **Figure 5-4** would provide a recreational amenity benefit as the beach area adjacent to Narrabeen Caravan Park, which would be preserved, is a popular swimming area for families. The shallow shoals extending off the beach provide a safe area for children and toddlers to wade and swim. However, reduced lagoon depths in those areas of the upper shoals which are not excavated could prevent the potential use of watercraft in close proximity to the entrance.

This option of a regime tidal channel is further evaluated and analysed in **Section 6.4** of this report.

If the frequency of entrance clearance campaigns is increased to around 2 years, then this would enhance the opportunity to establish a longer-term contractual arrangement with a contractor. This could potentially reduce the costs of the operation if several campaigns are priced competitively in the tender, would improve the time efficiency of the tendering process, may encourage the contractor to invest in bespoke entrance clearance and beach replenishment methodologies, and may improve response times to address shoaled and/or closed entrance conditions if the preferred contractor has committed to mobilise within an agreed time period following Council instruction to commence works.

5.5.4 Option 4: Dune management

Dune Management is generally more of an ongoing, maintenance requirement as opposed to a specific medium term option. Discussion is included here because it may include some earthmoving, which would be done most efficiently in conjunction with entrance clearance works. In addition to maintaining the main body of the dune, dune management includes management of the beach profile on both the western and eastern sides of the dune. However, before dune management becomes a maintenance operation, works are required to establish the dune in a more stable, maintainable state.

The removal of Birdwood Park dune has been suggested during community consultation. However, as mentioned in **Section 2.2.2.1**, Birdwood Park dune has several important functions including:

- stabilising the position of the lagoon entrance channel;
- providing protection from wave washover deposits into the lagoon;
- providing protection to the Ocean Street Bridge and the adjacent foreshore;
- limiting wind-blown sand transport into the lagoon; and,
- helping to retain sand that may otherwise be available for transport into the lagoon entrance under the action of waves and tidal currents.

Maintaining the dune in a state which achieves these functions will not only prolong the time for which the entrance stays open, but will also have other flow on beneficial environmental, social and economic impacts.

Revegetation of the dune

The removal of vegetation in recent years to “lower” the dune, followed by the attempted but unsuccessful establishment of spinifex grass, has contributed to a much higher rate of wind-blown sand entering into the lagoon. The flat beach at the western edge of the dune has disappeared, with the dune sloping straight down to the water’s edge. The presence of a flat beach in this area provides several benefits, including: adding to stability of the toe of the dune to minimise the dune slumping into the lagoon; providing a popular area for families to locate, close to a car park; and providing access for pedestrians and vehicles from the car park around the western edge of the dune.

The existing denuded areas of Birdwood Park dune need to be revegetated to maintain the stability of the dune barrier and limit wind-blown sand transport into the lagoon entrance. It is the intention of Council to revegetate the dune, despite past attempts being unsuccessful, but before works are commenced consideration needs to be given to potentially removing some of the sand which has deposited in recent years on the western side. Earth moving equipment could be used to simply push the sand back over to the eastern side of the dune, in effect reversing the westward progression of the dune. A narrower beach on the eastern side of the dune can also reduce the amount of mobile sand moving northwards and into the lagoon entrance. Depending on the approach and timing of works on the western side of the dune, revegetation works could commence on the eastern side and be undertaken progressively towards the western side. The earlier these initial works are implemented, the less sand will transfer into the lagoon. Survey should be undertaken prior to and immediately after any earthmoving works, to aid with monitoring and future planning. Several lines of survey from the lagoon to the ocean would be appropriate.

Vegetation on the dune should include both groundcover and larger species to in order to optimise stabilisation of the dune. Vegetation should be extended as far north as practicable, to reduce alongshore width of the lagoon entrance berm and hence minimise the area of sand available for wave washover or wind-blown transport into the lagoon. Dune revegetation should be undertaken initially with primary planting of groundcover species such as Spinifex and Pigface. Once these groundcover species are established, they will support the planting of larger species. Secondary planting of shrubs and trees should be undertaken using locally indigenous species to preserve the genetic stock of the area and utilise plants adapted to the local conditions.

Stabilisation of the planting areas during the vegetation establishment period should be achieved with the laying of coir or jute matting. Public access to dune revegetation areas should not be permitted, and discouraged by installation of perimeter dune fencing and signage. Maintenance of the planting area over the initial establishment period for primary and secondary species would include: fertilising; watering; weeding; inspection; removal and replacement of stolen, dead and dying vegetation; maintenance of protective dune fencing and signage; and ongoing stabilisation of any exposed dune surface areas (as required).

In addition to revegetation, consideration could be given to a means of trapping some of the mobile sand on the beach where it is easier to remove, before it is blown up the dune and into the revegetation areas while they are being established. Lowering the dune and revegetating it has proven to be a difficult task, and until it is revegetated, sand will continue to be blown over the dune and into the lagoon entrance. One method of trapping sand could comprise the installation of dune-forming fences along the toe of the dune, to trap some of the mobile sand, and slow down the growth of the dune. Dune-forming fences are most commonly made of a porous material such as a woven synthetic cloth, attached to plain wire strained between treated pine posts. The fences would need to be maintained with the sand removed on a regular basis.

Management of beach east of dune

The beach east of the main dune also needs to be monitored, and investigation made into whether or not the sand should be removed from this area before it travels northwards and into the lagoon entrance. This option is particularly worth considering during periods like the present time, when clockwise beach rotation is causing the sand to build-up at the northern end of Narrabeen Beach at a much faster rate than normal. Consideration could be given to transporting the sand southwards along the beach during winter when there are fewer beach users. This would require investigation into the cost viability and community engagement regarding social impacts.

Once the dune has been restored to a satisfactory profile and vegetation has become established, regular monitoring and maintenance should be undertaken on an ongoing basis, to ensure that the dune continues to achieve the functions listed above.

5.6 Recommendations for medium term entrance management

The artificial removal of sand from the Narrabeen Lagoon entrance (i.e. an entrance clearance) has been used to reduce the impact of flood events and maintain/prolong an open entrance condition at relatively regular intervals (3-5 years) since 1975. The works remove on average about 30,000-50,000 m^3 of sand per entrance clearance operation. These works have been successfully implemented over the course of several decades, with comprehensive investigation and planning documented in the Review of Environmental Factors (REF) and Construction Environmental Management Plan (CEMP) each time. Management actions in the area have been subject to a higher level of interest and discussion by the local community, particularly following a number of storm events over the last decade.

Several opportunities have been identified for improvement and innovation. Outlined below are the recommendations put forward for further consideration with respect to the medium term management of the Narrabeen Lagoon entrance:

- **Review design and frequency of entrance clearance**
  The feasibility of more frequent, smaller scale, strategic removal of sand from the flood tide shoals should be investigated in detail to potentially keep the entrance in an open condition for a greater percentage of the time. This includes consideration of establishing a longer-term program of work that would deliver several entrance clearance campaigns over a fixed period (say 5-10 years), rather than single clearances every 3-5 years. This should reduce the overheads and the time between shoaling and clearances.

  The actual frequency should be flexible, to take into account the different stages of the decadal beach rotation cycle of Collaroy-Narrabeen Beach. More frequent entrance clearance operations would be expected to be required during periods of clockwise beach rotation and less frequent campaigns required during periods of anti-clockwise beach rotation.

  Two options are recommended for consideration and potential trialling, each with a similar net present value to the current practice of clearing the entrance (which for the purpose of comparison, is taken as 40,000 m^3 every 4 years):

  - Increased frequency (2 years), lesser volume (15,000 m^3), focus on western shoal; and,
  - Increased frequency (2 years), lesser volume (15,000 m^3), regime tidal channel.

- **Review processes**
  Review of processes found that in general they were sound, with comprehensive investigation and planning documented in the Review of Environmental Factors and Construction Environmental Management Plan in each case. However the following areas are recommended for more consideration:

  - Enhancement of lagoon process information on Council's website, and project-specific community education platforms for each entrance clearance campaign;
  - Review of payment methods and procurement strategy for contractor with consideration given to potentially engaging a contractor over a longer period of time for multiple, more frequent entrance clearances; and,
  - Review of tracking method for excavation depths and extent during works, as the use of GPS by the contractor has been found to not always be reliable.

- **Maintenance of Birdwood Park dune**
  The maintenance of Birdwood Park dune plays an important role in controlling the movement of wind-blown sand into the entrance waterway. This review has found that to optimise the benefits that the dune can provide, consideration should be given to reshaping, revegetating and then maintaining the dune. The following works are recommended for consideration:

  a) Reshaping of the dune, with relocation of sand which has blown over on to the western side and re-creating a shallow beach on the western side of the dune.

  b) Revegetation of the denuded areas of the dune, to stabilise it and to limit wind-blown sand entering the lagoon. Initial primary planting should comprise groundcover species and once established, should be followed by secondary planting of larger species. Vegetation should also be extended as far north as practicable, to reduce alongshore width of the lagoon entrance berm and hence minimise the area of sand available for wave washover or wind-blown transport into the lagoon. Public access to planting areas should be controlled by installation of perimeter dune fencing and signage.

  c) Maintenance of the dune would be on an ongoing basis and involve not only maintaining the vegetation, but also monitoring the profile of the dune and adjacent beaches, as well as managing sand movement. It is recommended that sand-catching fences are considered for installation along the eastern toe of the dune to slow the growth of the dune and to reduce sand transport into revegetation areas while they are being established. Sand on the eastern beach as well as sand caught in the fences could be transported south, during winter and/or in conjunction with entrance clearance campaigns.

6 Long term entrance management strategy options

6.1 Need for a long term management strategy

Council’s management of the lagoon entrance has remained fairly consistent over the last 40+ years, with mechanical openings or emergency breakouts implemented as a short term management option, primarily for flood mitigation purposes, and entrance clearance operations implemented as a medium term management option every 3-5 years to remove the bulk of sand which has accumulated in the entrance since the previous entrance clearance operation.

During the last 5 years North Narrabeen Beach has been very wide due to the larger scale process of beach rotation over the entire Collaroy-Narrabeen embayment. This widening has increased local sand volumes adjacent to the entrance, which in turn has increased the potential for sand transport into the entrance of the lagoon. In addition, the wider beach has effectively increased the length of the entrance channel, which also increases the risk of closure. As a consequence of these factors, entrance clearance operations and mechanical breakouts have needed to be completed more frequently.

In the longer term, climate change will also impact on the effectiveness of entrance management. Previous studies by Morris (2010) have concluded that climate change impacts such as sea level rise would increase the rate of sand infilling at the lagoon entrance and decrease the duration of open entrance conditions. This may be offset to a small degree by increased rainfall intensity and enhanced ability of flood events to scour the entrance, however it was anticipated that increased sand infilling due to sea level rise would remain the dominant forcing mechanism for entrance conditions. As such, it is anticipated that entrance clearance will be required more frequently to keep the entrance in an open condition for a greater percentage of the time.

A closed entrance and subsequent elevated lagoon water levels can cause community concern and increases Council’s reliance on emergency breakout procedures. In response to this growing concern, Council has investigated a range of options including options requiring high upfront costs for permanent infrastructure, to determine whether there is a better way to reduce flood risk in the longer term. These options could be implemented either in conjunction with or as alternatives to the current entrance clearance practices described in the medium term entrance management section of this report. The investigation has included consultation with a technical expert panel as well as the community, and the options have been assessed from a technical feasibility, economic, environmental and social impact perspective.

6.2 Objectives and prioritised options

The objective of the development of a long term management strategy for Narrabeen Lagoon entrance is to determine if there is a feasible permanent infrastructure option that could be implemented to reduce the frequency or eliminate current short term and medium term management interventions.

An Entrance Management Workshop was convened by Council in December 2019, and involved technical stakeholders and industry experts. The purpose of the workshop was to discuss a range of potential options including options considered in previous studies and ideas provided by community members, with a view to narrowing down the range for detailed investigation. The outcome of this workshop was the identification of the following four potential long term entrance management options:

1. Ebb tide channel;
2. Mobile sand pumping;
3. Rock training wall; and,

4. Low flow pipes.

Council commonly receives requests to consider a permanent opening at Narrabeen Lagoon entrance. The only method to permanently open the lagoon entrance is to build a training wall (or breakwater) with consideration given to removal of the bedrock platform and/or rock sill that act to control natural scour levels and form a hydraulic control for lagoon water levels. Training walls have been built at a small number of coastal lagoons in NSW including Lake Illawarra, Lake Macquarie, and Wallis Lakes. An example rock training wall at Tallebudgera Creek in QLD is shown in **Figure 6-1** below.

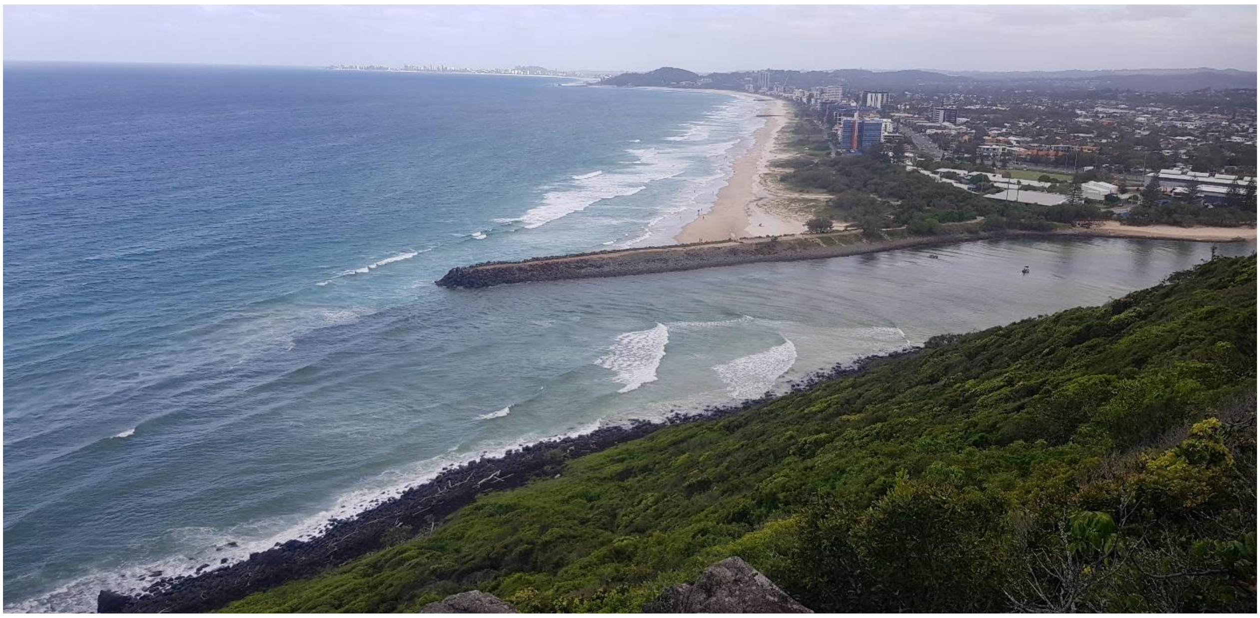

Figure 6-1: Example rock training wall at Tallebudgera Creek entrance

The option of constructing a training wall at the lagoon entrance was discussed in detail by the expert technical panel. Preliminary investigation of a training wall identified a range of significant environmental, recreational, public safety and aesthetic impacts associated with this option which would need justification by an extensive environmental assessment process, and would be unlikely to be supported by the community. These impacts included:

- increased tidal range and lowering of the mean water level and low tide level within the lagoon, resulting in alteration of the frequency of exposure of shallow water areas, and:
    - impacting on the movement of water craft such as kayaks, sailing boats and powered boats within the lagoon; and,
    - having the potential to cause die-off of the seagrass beds in the lagoon, which cover extensive areas within the lagoon and provide habitat for fish sheltering, spawning and foraging. The increased exposure of large areas of tidal flats would also adversely impact benthic species. The die-off of seagrass and increased exposure of tidal flats may also result in generation of odour from rotting vegetation and organic matter in muds, which would impact nearby receptors including foreshore residents and local businesses.
- removal of entrance bedrock would also have an impact on rocky shore ecosystems that may exist on areas of bedrock that are currently exposed either above or below water.

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- broader morphological changes (erosion and accretion) within the lagoon may also occur due to adjustment of the system to the new entrance condition. This would modify the habitat for flora and fauna species, and in some cases may result in loss of foreshore land.
- Birdwood Park is currently used as a relatively sheltered wading and swimming area for children and their families. The increased hydraulic conveyance provided by training walls would likely increase the tidal velocities and water depths in this area, reducing its recreational amenity for young families.
- the surfing break at North Narrabeen was declared a National Surfing Reserve in 2009 and is highly valued by the local community. The implementation of an entrance training wall is likely to materially alter the characteristics of the surfing break due to several effects including:
  - the physical presence of the training wall, limiting access to previously available surfing positions and potentially causing rip currents;
  - modification of shoaling patterns formed near the entrance at times of flooding that are understood to influence surfing conditions; and,
  - accumulation of sand on the southern side of the training wall over time due to northerly littoral drift, and associated impacts on wave breaking patterns.
- an entrance training wall would limit public access to the northern end of the beach and the rock pool.
- several public safety issues that would be created by an entrance training wall, including:
  - public access on to the rock structure crest during hazardous surf conditions;
  - injury caused by surfers impacting the rock structure;
  - strong rip currents along the southern side of the rock structure;
  - strong currents through the entrance channel; and,
  - increase in current velocities and water depths within the lagoon.
- installation of a training wall would result in significant alteration to the visual character and scenic quality of the entrance, which is currently in a relatively natural state. The training wall would be a prominent structure that would be visible from most areas of Collaroy-Narrabeen Beach.

The investigation also identified that even a moderate training wall (reduced length, no entrance bedrock removal) would be twice as expensive as current management practices over a 30 year planning period with a full permanent entrance (including entrance bedrock removal) likely to be over five times more expensive.

It should also be noted that a permanently open estuary would have greater flood impacts in some circumstances, such as when ocean levels are very elevated. If during a flood event the ocean level is higher than the lagoon water level (which can occur due to the combination of astronomical tide, storm surge, and wave setup), then having the ICOLL entrance closed may in fact lessen the flood impact. A permanently open estuary would also likely have greater flood impacts in the long term due to sea level rise as a result of climate change (Coffs Harbour City Council, 2018).

As a result, the training wall option was not considered any further.

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6.3 Description of long term management strategy options

The long term management options considered are described below to a conceptual level of detail that is sufficient for initial assessment. Schematic figures showing the proposed arrangements for the potential management options described below are also provided for reference.

6.3.1 Base case

The ‘base case’ represents the continuation of the current practice of entrance management undertaken by Council and will be used for comparison against other potential management options. The base case comprises the periodic removal of sand shoals accumulating immediately upstream (west) and downstream (east) of the Ocean Street bridge. This operation is referred to as ‘entrance clearance works’ and is completed every 3-5 years and involves the removal of approximately 30,000-50,000 m^3 of sand.

In recent times, entrance clearance operations have been completed more frequently (every 3 years) due to the relatively high volume of sand available at the northern end of Collaroy-Narrabeen Beach. This is due to the process of beach rotation, which is a decadal process related to the El Nino / La Nina cycle and its influence on wave approach direction and consequently alongshore sand transport.

The base case adopted to represent the average long term excavated volume and frequency for entrance clearance campaigns is 40,000 m^3 every 4 years. In practice, the future entrance management regime would need to provide flexibility to allow for a variable frequency of entrance clearance campaigns in response to different stages of the beach rotation cycle (as discussed in **Section 5.6**).

The works are normally completed by excavators that load the sand into dump trucks for road transport to the south for replenishment of Collaroy-Narrabeen Beach (refer **Figure 5-1**). The lagoon entrance is artificially closed during the entrance clearance operations. Accessible road heads of the side streets along Pittwater Road (e.g. Mactier Street, Wetherill Street, Ramsay Street) and the northern end of the Collaroy beachfront carpark (opposite Jenkins Street) can be used to access the beach for back dumping of sand, which is subsequently regraded with earthmoving equipment operating on the beach.

6.3.2 Ebb tide channel option

When the Narrabeen Lagoon entrance is open, it is subject to tidal influences. The ebb tide is the tidal phase during which the tidal current is flowing seaward out of the lagoon, and the flood tide is the tidal phase during which the tidal current is flowing inland into the lagoon.

An ebb tide channel is the naturally formed underwater channel which forms as the tide flows out of the lagoon. Depending on various factors such as water velocity, direction and sand grain size, a submerged wall structure may be able to deflect and focus the energy of the ebb tide to enhance natural channel scour and potentially keep the entrance open longer if ebb tide currents are able to transport sand out of the lagoon and into the ocean.

The ebb tide channel option involves the enhancement of an ebb tide dominant channel by installing submerged control structures downstream of Ocean Street perpendicular to the left hand bank (looking downstream) (refer to **Figure 6-2** for conceptual arrangement).

This option could potentially be achieved with a series of half-tide (i.e. height set at average water level between high and low tides in the lagoon) training walls formed by low-level rock structures, that would consistently direct ebb tide flows along a channel through the main area of entrance sand accumulation (flood tide delta). This option may need to be supported by periodic sand removal with earthmoving equipment, but would aim to harness the natural power of the ebb tide to maintain an ebb tide dominant channel in a 'working with nature' approach.

This option could be implemented by installation of two rubble mound structures located:

- on the northern side of Ocean Street Bridge, adjacent to the caravan park; and,
- on the bend in the existing tidal channel running along the sandstone block seawall.

The rubble mound structures would be constructed from durable sandstone rock that is suitable for the marine environment and would have a design life of over 40 years. The crest of the rock mound structures would be at the half tide level, which is approximately +0.4m AHD according to analysis of the water level record from the gauge at the Ocean Street Bridge. The rock mounds would be approximately 1 m high above the seabed level and have crest width of approximately 3.5 m, maximum sideslopes of 1V:1.5H, and would extend around 60 m at right angles across the existing tidal channel running against the sandstone block seawall. This would result in the rock mounds requiring around 1,000 tonnes of rock for their construction.

It would be possible to trial this option by forming temporary training walls with sand-filled geotextile tubes. Based on recent application of geotubes at Stockton Beach, these structures would be 20 m long (3 geotubes needed for training wall length of 60 m), 3.5 m wide and 1.4 m high, and have a volumetric capacity of around 98 m^3. The geotubes could be laid in position and then hydraulically pumped with slurrified sand sourced from the surrounding ebb tide shoals.

To give the ebb tide channel option the best chance of success, an entrance clearance operation would need to be conducted immediately prior to construction. This would include the initiation of the preferred ebb tide channel alignment by over excavation in the area off the ends of each training wall.

The effectiveness of the proposed half tide training walls to create an ebb tide channel was evaluated within the Delft3D numerical model used for the Narrabeen Lagoon Floodplain Risk Management Study (Cardno, 2019). The half tide training walls were incorporated into the model grid representing the open entrance bathymetry from the post entrance clearance survey completed in December 2018.

The modelling demonstrated that the flood tide current speed peaks at a greater value than the ebb tide. This indicates an upstream bias in the sand transport potential suggesting that under normal tidal conditions the entrance area is generally subject to infilling processes.

The modelling examined the difference between the existing open entrance conditions (i.e. without half-tide training walls) and with the half-tide walls installed. The modelling results indicated that the walls would not be effective in generating the desired increase in ebb tide currents to maintain an ebb tide dominated entrance channel thereby keeping the lagoon open. As such, the ebb tide channel option is not considered to be a technically feasible entrance management option and has been eliminated from further consideration. The results also suggested that in the event that some additional ebb tide scour did occur at the outer end of the half tide walls the eroded sand would have settled only a short distance downstream. Full details and results of the ebb tide channel option modelling are provided in **Appendix D**.

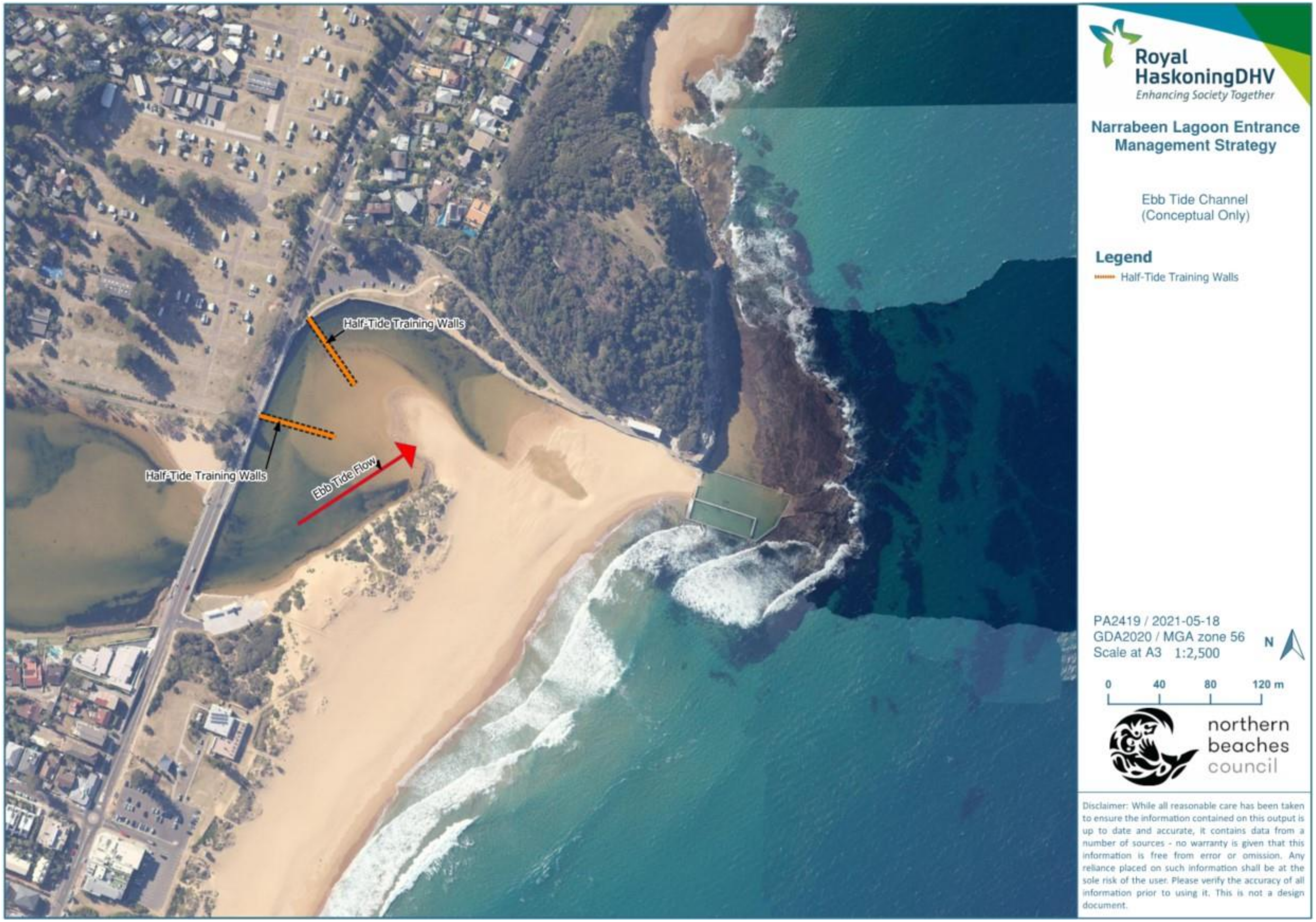

Figure 6-2: Ebb tide channel option conceptual arrangement

6.3.3 Mobile sand pumping option

An alternative to the historical practice of using dump trucks to transport excavated sand to beach access points at road heads at the southern end of Collaroy-Narrabeen Beach, is the establishment of a semi-permanent mobile sand pumping system (refer to **Figure 6-4** for conceptual arrangement). Such a system would facilitate pumping of excavated sand as a slurry within a pipeline along the beach to selected discharge points for subsequent redistribution and regrading by earthmoving equipment. The primary benefit of this system is the elimination of intensive truck traffic along local streets during entrance clearance operations, which would provide a reduction in associated impacts to local residents including traffic congestion and noise.

It is important to note that this option is not a different concept of permanently maintaining an open lagoon, but rather a different sand transport mechanism to remove and transport the sand during periodic entrance clearance operations.

The mobile sand pumping system would comprise a mobile hopper that is positioned on the beach berm adjacent to the lagoon entrance area. The mobile hopper could be mounted on a sled and pulled into different locations as required. Alternatively, proprietary tracked equipment exists, such as the Slurrytrak system (designed and built by CGC Group) which was implemented for sand bypassing at the Dawesville and Mandurah Inlets in Western Australia (refer **Figure 6-3**). The mobile hopper is fed with sand, placed into the hopper by several excavators, and with seawater pumped from the adjacent waterbody. The hopper is fitted with screens to filter out oversize material and a slurry pump at the base of the hopper is used to pump the sand slurry through a flexible connection pipeline to a primary pumping station.

Figure 6-3: Slurrytrak system operating at Dawesville and Mandurah Inlets, Western Australia

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Figure 6-4: Mobile sand pumping option conceptual arrangement

The primary pumping station in the case of the Narrabeen Lagoon mobile sand pumping option would be located some 400m away within the reserve area adjacent to the North Narrabeen Beach carparking area and SLSC building. The temporary pumping station would comprise a portable unit that could be initially purchased by Council and then stored in a depot between clearance operation when it would be transported by truck float and lifted into position.

The primary pumping station would comprise a jet pump fitted inside a protective housing and would connect to the buried permanent delivery pipeline. The delivery pipeline would comprise a 200 mm diameter HDPE pipe that would be installed within public land at the rear of the dunes. Pipe segments would be supplied and welded together within a shallow trench (approximately 1 m deep) within the dunes and could be weighed down with concrete 'staples' if positioned within the coastal hazard zone. Once the pipework is laid, the trench would be backfilled and dune vegetation would be restored over the footprint of disturbance (approximately 5 m wide) along the pipeline alignment.

The buried permanent delivery pipeline would extend over a length of around 1,700 m from Birdwood Park to the foreshore reserve at Devitt Street where it would connect to a temporary booster station. The temporary booster station could be a similar portable unit to the primary pumping station and would be owned and maintained by Council.

A temporary pipeline would be installed from the booster station at Devitt Street to the particular replenishment site(s) on the beach, for the most efficient delivery of sand to the intended location. The maximum length of temporary pipeline required would be 1,100 m in the event replenishment was carried out as far south as the northern end of the Collaroy Beach carpark (opposite Jenkins Street). The temporary pipeline would comprise 12 m lengths of 200 mm diameter HDPE pipe that are hauled into position on the beach and bolted together with flanged connections. The pipe lengths could be dismantled and stored within a Council depot between clearance operations.

Alternatively, the sand could be deposited at Devitt Street by the pump and pipeline and then manually reworked to the southern end of the beach as required by excavators and trucks.

An inherent risk with placement of a pipeline along the active beach is the possible occurrence of coastal storms and associated wave action and beach erosion, which could result in dislodgement or damage to the pipeline. A recent example of this occurring is the damage to the Jimmys Beach (Port Stephens) sand transfer system (refer **Figure 6-5**) caused by large swell and beach erosion, although it should be noted that this is a permanent installation. The sand pumping contractor would need to continually monitor storm and swell forecasts and have the capability to rapidly disassemble and remove the temporary pipeline if required.

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Figure 6-5: Damage to Jimmys Beach sand transfer system by large swell in 2019 (Source: Newcastle Herald, 5 June 2019)

To facilitate discharge of the sand slurry at discrete locations along the beach, offtake pipe outlets with isolation valves would need to be installed at key locations. To provide maximum flexibility for beach replenishment activities it is proposed that up to four (4) discharge points could be installed at accessible road heads at Mactier Street, Wetherill Street, Ramsay Street and at the northern end of the Collaroy Beach carpark (opposite Jenkins Street).

Discharge of sand slurry onto the beach would be managed by site supervision and operation of an excavator on the beach to rework the material over the beach profile and create sand bunds as necessary to facilitate water quality control from the slurry discharge (refer **Figure 6-6**). Sections of the beach would need to be closed to public access for the duration of pumping operations.

It is noted, that as with the 'base case' entrance clearance methodology, mobile sand pumping operations could also be undertaken at an increased frequency and involve a lower volume of sand excavation. That is, 15,000 m^3 removed every 2 years.

Figure 6-6: Management of sand slurry discharge within a bunded beach area at The Entrance, Central Coast

6.3.4 Low flow pipes option

The low flow pipe option involves the installation of a series of large underwater pipes at the lagoon entrance to provide some release of rainfall runoff into the lagoon (mitigation of build-up in lagoon water level and thus benefit to lagoon flooding), and to allow tidal exchange between the lagoon and the ocean when the entrance is otherwise closed for prolonged periods by sand ingress (refer to **Figure 6-7** for conceptual arrangement). A similar scheme has been implemented at the entrance to Manly Lagoon (refer **Figure 6-8**).

Figure 6-7: Low flow pipes option conceptual arrangement

The installation of low flow pipes at Narrabeen Lagoon could be achieved by directional drilling of conduits through the entrance bedrock platform. The inlet of the low flow pipes could be positioned at the bend in the tidal channel running adjacent to the northern seawall. At this location the bed levels within the entrance channel are relatively stable at around -0.6 m AHD, being a sufficient distance away from the more dynamic downstream areas opposite Birdwood Dune where extensive shoaling occurs. The adjacent foreshore reserve area beside the northern carpark is also accessible for plant and equipment.

Discussions with directional drilling contractors has determined that the maximum size of pipeline that can be installed has an 800mm diameter and that a clearance of at least 1 m is required below the top of bedrock to the top of the pipe. As such, for a proposed pipe inlet invert level of approximately -0.6 m AHD (the stable channel bed level referred to above) the pipe invert would need to grade down to -2.5 m AHD to provide sufficient clearance of the top of the pipe below the potential minimum top of bedrock level of -0.7 m AHD along the pipeline alignment. This top of bedrock level is indicative only as it is based on spot heights from an entrance rock shelf survey undertaken by NSW Public Works Department in 1976.

The technical feasibility of directional drilling would be subject to detailed field investigation of the top of rock levels and competency of the entrance bedrock material. Geological mapping indicates that North Narrabeen Headland and the surrounding rock platform is part of the Narrabeen Group of sedimentary rocks and comprises interbedded sandstones, claystones and shales.

Three 800 mm diameter pipelines spaced at a distance of 1-2 m apart could be installed and extend over a distance of around 400 m to a submerged outlet through the face of the rock outcrop drop-off beyond the ocean pool.

The inlets and outlets of the pipes would have a concrete headwall structure and be covered with stainless steel grating to reduce public safety risks for recreational activity (e.g. swimming) and the ingress of debris and vegetation (e.g. kelp). To further enhance public safety, the pipe inlets could be positioned through the face of the northern seawall (which may require localised seawall reconstruction) rather than being positioned within a headwall structure within the tidal channel. This would also improve constructability and reduce capital costs as the directional drilling could be completed from land rather than potentially requiring the expensive construction of a coffer dam structure for an in-channel installation.

The practicality of ongoing maintenance of the low flow pipes would require careful consideration and could be problematic if build-up of marine growth and/or ingress of large volumes of sand, debris and vegetation (e.g. kelp) significantly reduces the capacity of the pipes or results in complete blockage. Similar to the Manly Lagoon low flow pipes, vertical access chambers could be provided at intervals along the pipeline length to facilitate access for inspection and cleaning equipment. The access chambers would need to protrude above typical beach berm levels and would have a visual impact on the existing natural setting. Regular inspection of the pipelines would need to be undertaken by remote CCTV methods. It is assumed that routine pipe cleanout would need to be undertaken at least on an annual basis and potentially after significant coastal storm events. Maintenance of the proposed 400m length of low flow pipelines at Narrabeen Lagoon entrance represents significant cost and operational risk for the low flow pipes option.

The existing TUFLOW flood model was used to simulate the low flow pipe option (3 x 800 mm diameter pipes) under closed entrance conditions over a 20 day period of tides for initial water levels in the lagoon of 1.3 m AHD and 0.3 m AHD. The modelling showed that under tide only conditions with no catchment inflows the low flow pipes are able to reduce the lagoon water level from 1.3 m AHD to 0.4 m AHD in around 20 days. Over a further 20 days the lagoon water level reduces to 0.2-0.3 m AHD.

If the initial water level in the lagoon is 0.3m AHD, the water level reduces 0.1m to 0.2m AHD over the 20 day simulation period. It is noted that lowering of lagoon water levels to these levels for prolonged periods of time would have potential environmental impacts relating to reduced recreational amenity and drying of seagrass beds (refer **Section 6.4.3.2** and **Section 6.4.3.3**). Analysis of historical lagoon water level records from the Narrabeen Bridge (Pittwater Road) tide gauge has determined that water levels below 0.2m AHD and 0.1m AHD occur very rarely under the existing management regime. Furthermore, when these low water levels occur the duration of events is relatively short with an average duration of less than 6 hours.

As such, prolonged lowering of the lagoon water level to these levels has not occurred previously and the lower lagoon water levels, particularly during periods of minimal catchment inflow, is likely to have a significant impact on lagoon ecology and the overall recreational amenity of the lagoon.

From the modelling, it can be concluded that the installation of low flow pipes has the potential to lower lagoon water levels during periods of entrance closure. However, further assessment of their long term performance by modelled simulation of their performance using actual water level and flooding records is required.

It is also noted that the installation of low flow pipes would have no influence on lagoon entrance closure behaviour. As such, any installation of low flow pipes would be implemented independently of future periodic entrance clearance operations. Full details and results of the low flow pipes option modelling are provided in **Appendix D**.

Figure 6-8: Existing low flow pipes at Manly Lagoon beneath the beach berm at Queenscliff Beach

6.4 Evaluation and analysis of long term management options

The evaluation and analysis of management options for the longer term, whether they be in conjunction with or alternative to the current medium term entrance clearance practices, is described below for each option with regard to a variety of impacts including economic, flood risk, social and environmental. The option of increasing the frequency of entrance clearances with a reduced excavation volume, as discussed in the medium term entrance management section of this report, has also been evaluated.

As part of this process a Cost Benefit Analysis (CBA) was also undertaken by Marsden Jacob Associates to inform the economic evaluation of the various long term management options under consideration. The CBA is a complex process that identifies the economic benefits and costs of the investment options to all stakeholders, including Council, other agencies and businesses and community. The CBA is based on an assessment of market and non-market economic benefits and costs.

The following five (5) options were considered in the CBA:

- **Option 1 – Base Case:** continuation of the current periodic (4 yearly) entrance clearance by excavation and trucking, with a volume of 40,000 m^3 per campaign
- **Option 2 – Excavation and Trucking at reduced intervals:** periodic entrance clearance by excavation and trucking, with an increased frequency (2 yearly) and reduced volume of 15,000 m^3 per campaign, with focus on maintaining a regime tidal channel
- **Option 3 – Mobile Sand Pumping:** periodic (4 yearly) entrance clearance by mobile sand pumping system, with a volume of 40,000 m^3 per campaign
- **Option 4 – Mobile Sand Pumping:** periodic entrance clearance by mobile sand pumping system, with a 2 yearly frequency and reduced volume of 15,000 m^3 per campaign, with focus on maintaining a regime tidal channel
- **Option 5 – Installation of Low Flow Pipes:** installation of low flow pipes plus periodic entrance clearance by excavation and trucking, with a 2 yearly frequency and reduced volume of 15,000 m^3 per campaign, with focus on maintaining a regime tidal channel

The CBA considered infrastructure costs, project costs and flood damage costs. The CBA results identify the incremental difference between the costs and benefits of each option case compared with the base case to help identify a preferred option. The details of the CBA, including Whole of Life cost estimates prepared by Muller Partnership, are provided in **Appendix E**.

The results of the analysis show whether the incremental difference between continuing with current long term entrance management regime (i.e. Option 1 – Base Case) and implementing a new management option will generate a net benefit.

6.4.1 Base case

6.4.1.1 Economic

Capital and Operating Costs

Costs associated with the base case (CBA Option 1) comprise the ongoing costs of periodic entrance clearance operations using the existing methodology of excavating and trucking by a contractor, procured through a tender process undertaken for each campaign. Whole of Life cost estimates prepared by Muller Partnership (refer **Appendix E**) and additional cost estimates provided by Council for project management, contract administration and design indicate that the net present value of the base case over a 30 year analysis period is $7.8M[9]. If entrance clearance operations were completed at an increased frequency of 2 years and with a lower volume of sand removal (15,000 m^3 per campaign, refer **Section 5.5.3**) then the cost would marginally increase (for more detail refer to **Appendix E**).

Reduction of Flood Risk to Property

To allow comparative evaluation of flood risk between management options, flood modelling has been undertaken with the Delft3D morphodynamic model used for the Narrabeen Lagoon Floodplain Risk Management Study (Cardno, 2019). For the base case, the closed entrance and open entrance conditions represent the upper and lower bounds of flood risk within the lagoon foreshore areas. These were represented by the following two flood modelling scenarios:

[9] *Based on a discount rate of 7%.*

1. Closed and shoaled entrance condition, initial lagoon water level 1.3m AHD, beach berm level 1.3m AHD
2. Open entrance condition, post-entrance clearance campaign, initial lagoon water level 0.3m AHD[10]

Flood modelling results for various Average Recurrence Intervals (ARIs) for the above scenarios were compared against the ground levels and floor levels for the list of 2041 properties used for the flood damages analysis within the Narrabeen Lagoon Floodplain Risk Management Study. The number of properties subject to above ground and above floor flooding is summarised in **Table 6-1** and **Table 6-2** respectively. These results demonstrate that open entrance conditions significantly reduce the number of properties subjected to above ground level flooding for events up to the 100 year ARI, however this diminishes for larger events up to the Probable Maximum Flood (PMF). Open entrance conditions provide a significant reduction of properties subjected to above floor level flooding in all events other than the PMF.

Table 6-1: Above ground level flooding results summary for Base Case

Entrance Condition	No. Properties with Above Ground Level Flooding				
ARI	PMF	1000yr	100yr	20yr	5yr
Closed	1235	980	913	842	753
Open	1182	912	771	504	343

Table 6-2: Above floor level flooding results summary for Base Case

Entrance Condition	No. Properties with Above Floor Level Flooding				
ARI	PMF	1000yr	100yr	20yr	5yr
Closed	1171	862	673	531	318
Open	1057	694	377	102	61

It should be noted that under the current regime of entrance clearance operations the entrance is open approximately 75% of the time and closed for 25% of the time. In addition, the modelled open entrance condition represents the best possible time for flooding to occur, namely shortly after the entrance has been subjected to an entrance clearance campaign. In practice, although the entrance may be considered to be open, the degree of shoaling at the entrance would vary. As such, the flood risk to property would also vary between the modelled 'open' and 'closed' entrance conditions results during the period when the entrance shoals are building to the point of entrance closure. It is estimated based on recent experience that the entrance could be in a fully open state (i.e. post entrance clearance condition, before progressive shoaling occurs) for around 6-9 months within the 4 year period between entrance clearance campaigns. As such, under the base case, the entrance has been assumed to be fully open for 15% of the time, closed for 25% of the time, and in an intermediate state for the remaining 60% of the time.

The above percentages for entrance conditions under the base case were applied to the flood damage analysis undertaken by Marsden Jacob Associates (refer **Appendix E**). It was determined that the Annual Average Damage (AAD) cost for the base case was $4.3M.

[10] *Typical mean water level within lagoon under open entrance conditions when water levels are controlled by the natural rock weir at the lagoon entrance (BMT WBM, 2013).*

Flood modelling was also undertaken for CBA Option 2, which is for excavation and trucking at reduced intervals. This option is for an increased frequency (2 yearly) and lower volume entrance clearance scenario focused on excavation of a regime tidal channel through the lagoon entrance shoals, as described in **Section 5.5.3** of this report. The results for the entrance open condition are provided in **Table 6-3** and **Table 6-4**, and indicate that there is a slight increase in flood risk due to the increased constriction to flood flows caused by retaining the shoals adjacent to the regime tidal channel.

It was considered that increasing the frequency of entrance clearance campaign to a 2 yearly interval would keep the entrance in an open condition for a greater percentage of the time. For analysis purposes, it was assumed that under this entrance clearance regime the entrance could be fully open for 40% of the time, closed for 15% of the time, and in an intermediate state for the remaining 45% of the time. It was determined that the AAD for this scenario was $3.7M, providing a reduction in flood damages relative to the base case. A sensitivity analysis was also undertaken to test these assumptions (refer **Appendix E**).

Table 6-3: Above ground level flooding results summary for Increased Frequency / Lower Volume Entrance Clearance (regime tidal channel)

Entrance Condition	No. Properties with Above Ground Level Flooding				
ARI	PMF	1000yr	100yr	20yr	5yr
Closed	1235	980	913	842	753
Open	1206	935	821	574	371

Table 6-4: Above floor level flooding results summary for Increased Frequency / Lower Volume Entrance Clearance (regime tidal channel)

Entrance Condition	No. Properties with Above Floor Level Flooding				
ARI	PMF	1000yr	100yr	20yr	5yr
Closed	1171	862	673	531	318
Open	1105	723	488	128	64

The results of the CBA study identified CBA Option 2, for excavation and trucking at an increased frequency of two years with a reduced volume of 15,000m^3, as the preferred option based on net present value (NPV) outcome, compared with the other options. CBA Option 2 has the highest NPV of $6.38 million. A Benefit Cost Ratio cannot be calculated for this option because the Present Value of Costs is lower than the Base Case and thus cost savings are a benefit. This option reduces the flood damage costs by approximately $6.5 million compared with the Base Case (CBA Option 1).

6.4.1.2 Social

Recreational Amenity

Narrabeen Lagoon and its adjacent foreshore areas support a wide range of recreational activities including swimming, surfing (entrance area), wind surfing, sailing, stand-up paddle boarding, canoeing/kayaking, fishing, walking/jogging/cycling, golf (Cromer Golf Course) and passive recreation (e.g. picnicking, BBQs, cafés, restaurants). The condition of the lagoon entrance has an impact on most of these activities as outlined in **Table 6-5** and **Table 6-6**.

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Table 6-5: Impact of open lagoon conditions on recreational amenity

Activity	Advantages	Disadvantages
Swimming	• Improved water quality and clarity	• Variable water depth due to tides • Unsafe swimming conditions at entrance due to tidal flow velocities • Less beach area available across the entrance berm area for passive recreation
Surfing	• Ebb tide current can assist with paddle out	• Dangerous to cross entrance during high flow conditions
Wind surfing, sailing, canoeing, kayaking, stand-up paddle boarding	• Improved water quality and clarity at the entrance for recreation	• Variable water depth due to tides • Lower water levels in general across the lagoon reducing area for sailing and windsurfing
Fishing	• Improved catches from ocean fish entering lagoon via the entrance channel	
Walking, jogging, cycling	• Narrabeen Lagoon Trail less likely to be subject to inundation	
Golf	• Cromer Golf Course less likely to be subject to inundation	
Passive recreation	• Visual amenity of entrance improved • Foreshore access to cafes/restaurants (e.g. The Boatshed and Limani Seafood) less likely to be subject to inundation	• Variable water depth due to tides • Exposed seagrass beds during periods of very low water levels, resulting in low visual amenity and unpleasant odour

Table 6-6: Impact of closed lagoon conditions on recreational amenity

Activity	Advantages	Disadvantages
Swimming	• Stable water level • Safe swimming area at entrance • Large area available for passive recreation across the entrance berm area • Dry access from the northern carpark and North Narrabeen ocean pool to patrolled area of North Narrabeen Beach	• Recreational water quality impacted by catchment runoff • Increased water depth following catchment runoff events • Visual amenity of lagoon water adversely impacted
Surfing	• Dry access to North Narrabeen Beach is available from northern carpark	
Wind surfing, sailing, canoeing, kayaking, stand-up paddle boarding	• Stable water level • Increased water depth	• Recreational water quality impacted by catchment runoff

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Activity	Advantages	Disadvantages
	• Improved foreshore launching conditions	
Fishing		• Lagoon entrance closed to ocean fish passage
Walking, jogging, cycling		• Sections of Narrabeen Lagoon Trail are inundated and made inaccessible when lagoon water levels are elevated
Golf		• Areas of Cromer Golf Course susceptible to inundation when lagoon water levels are elevated
Passive recreation	• High water level improves visual amenity of the wider lagoon	• Water quality impacted by catchment runoff • Access to foreshore areas including cafes/restaurants can be limited by inundation

Based on the community consultation completed to date, it is understood that there is a general preference for the lagoon entrance to be in an open condition more often than the current average of 75% of the time. This sentiment is particularly strong in relation to the recreational amenity of the entrance area for swimming activities enjoyed in popular lagoon beach areas for families at Birdwood Park and adjacent to Narrabeen Caravan Park, where a preference was expressed for an open entrance providing regular tidal flushing with ocean water to maintain both water quality and clarity.

During entrance clearance operations, recreational amenity is temporarily adversely impacted by occupation of the lagoon entrance, Birdwood Park and sand replenishment locations along Collaroy-Narrabeen Beach by construction equipment and sand excavation and placement operations. These impacts extend for a period of 3-4 months every 4 years and can be minimised by scheduling entrance clearance operations outside of peak periods for lagoon and beach usage (e.g. outside of summer school holidays).

Public Safety

Public safety concerns associated with the base case are mainly related to the potential swimming hazards associated with an open entrance condition, particularly in the period after an entrance clearance operation. These hazards include deeper water within the excavated lagoon areas where shallow shoals used to exist and increases in flow velocity due to increased tidal exchange. Tidal velocities increase through downstream constrictions such as the Ocean Street Bridge and along the ebb tide channel adjacent to the northern seawall. However, as the entrance is open 75% of the time on average the local community has experienced these conditions before and is therefore familiar with the risks posed mainly to young children at the popular Birdwood Park swimming area.

The entrance clearance operation itself does pose some risk to public safety with public areas at the lagoon entrance and beach replenishment locations being occupied with construction plant and equipment and increased local road traffic. However, this can be adequately managed with worker supervised exclusion zones, traffic management measures, and scheduling of entrance clearance operations outside of peak periods for lagoon and beach usage (e.g. outside of summer school holidays).

Aesthetics
Periodic entrance clearance operations to re-establish or enhance open entrance conditions are considered to improve aesthetics of the entrance to the lagoon by facilitating exchange of clear ocean water into the lower portion of the lagoon to improve water clarity around the entrance area. The visual amenity of the entrance is also improved when it is open and tidal exchange with the ocean occurs, as opposed to an elevated beach berm blocking the continuity of the waterway. This management approach also maintains the natural aesthetic of the entrance, without the introduction of any additional hard structures.

Community Support
As noted previously, it is understood that the community is generally supportive of maintaining an open entrance for a greater proportion of the time. However, the increased road traffic generated by periodic entrance clearance campaigns is a common issue for local residents for the current methodology of excavation and trucking.

6.4.1.3 Environmental

Water Quality
As discussed in **Section 2.1.2**, monitoring of recreational water quality in Narrabeen Lagoon over the last 5 years indicates that the ‘beach suitability grade’ given through the State of the Beaches report to Bilarong Reserve is generally ‘poor’. This is due to elevated levels of bacteria, particularly following low levels of rainfall. This site is located away from the lagoon entrance and is not well flushed by ocean water.

The ‘beach suitability grade’ given to Birdwood Park is generally ‘good’, although there have been periods of ‘poor’ grading (i.e. 2015-2016 and 2016-2017) that were noted to be associated with entrance closure for extended periods. DPIE advised that the site had generally good water quality during dry weather but elevated enterococci levels were measured following low levels of rainfall. It was recommended that swimming be avoided during and following rainfall, and when the lagoon is closed.

Beachwatch also monitors water quality at North Narrabeen Beach, which is generally ‘good’. However, it was noted that the water may be susceptible to pollution after rain due to discharge from Narrabeen Lagoon causing elevated enterococci levels.

It is evident that water quality in the vicinity of the lagoon entrance is generally ‘good’ but can be adversely affected by periods of rain and closed entrance conditions. Periodic entrance clearance operations to re-establish or enhance open entrance conditions act to increase tidal exchange and flushing of areas around the lagoon entrance with ocean water. This generally improves water clarity and water quality after rainfall events at the popular swimming spots at Birdwood Park and along the foreshore adjacent to the caravan park (upstream of Ocean Street bridge). However, this effect diminishes over time as the entrance infills with sand and progressive shoaling limits tidal exchange to the point of entrance closure.

The water quality at poorly flushed areas in the upper reaches of the lagoon (i.e. Bilarong Reserve) is unlikely to improve significantly as a result of entrance clearance activities due to their considerable distance away from the entrance.

Ecology
Periodic entrance clearance operations to re-establish or enhance open entrance conditions result in tidal exchange of ocean water into the lagoon and maintenance of open entrance water levels. When the lagoon entrance is open and scoured to exposed bedrock, the natural rock weir (at approximately 0m AHD) at the entrance acts as a hydraulic control for water levels in the lagoon. Previous studies have

reported that under these conditions water levels in the lagoon are maintained at approximately 0.2-0.4m AHD (BMT WBM, 2013) and that mean water levels are of the order of 0.38m AHD during spring tide periods and 0.2m AHD during neap tide periods (MHL, 1989).

When the entrance is closed by build-up of the beach berm to natural levels of 2m AHD or higher, water levels in the lagoon can increase to above 1m AHD with inflows from catchment runoff events until the lagoon entrance is mechanically opened (i.e. excavated channel breakout) at trigger levels between 1m AHD and 1.3m AHD. As the entrance is closed approximately 25% of the time, the water level regime in the lagoon varies gradually between these two states and the ecology generally adapts to accommodate these changes in water depth, salinity, water temperature and water clarity.

Previous studies (WBM Oceanics, 2001) have determined that seagrass beds within the lagoon suffered a decline in the 1960s and 1970s. This was attributed to rapid urban development, unsewered areas, historical dredging practices, poor light conditions due to high water turbidity, nutrient enriched inflow water, and periodic low salinity levels causing seagrass beds to be restricted to shallower water depths.

If entrance clearance operations were completed at an increased frequency of two years, keeping the entrance in an open condition for a greater percentage of the time, this may have ecological effects on the lagoon as a whole. This would change the natural state of the lagoon from its historic condition of being a mainly closed body of water only open to the ocean for short periods of time due to flood, to being mainly open to the ocean and only being closed for short periods. Currently the lagoon is completely closed for approximately 25% of the time, and the ecology appears to have adapted to this situation. Further studies would be required to estimate the overall impact of having the lagoon open for a greater percentage of the time and its impact on water quality, vegetation communities and fish habitat.

The entrance of the lagoon is a dynamic area with progressive shoaling and active sand transport limiting the stability of seagrass beds, or benthic and rocky reef habitat. Nonetheless, there are procedures in place for periodic entrance clearance operations to minimise harm to local ecology by applying a 10 m buffer distance between these operations and mapped seagrass bed areas, installing floating booms and silt curtains around seagrass beds within the lagoon entrance channel, and limiting excavation to recently deposited marine sand to minimise turbidity generation.

6.4.2 Mobile sand pumping

6.4.2.1 Economic

Capital and Operating Costs

Costs associated with mobile sand pumping (CBA Options 3 and 4) comprise the ongoing costs of periodic entrance clearance operations using the alternate methodology of pumping the excavated sand as a slurry to beach replenishment locations along Collaroy-Narrabeen Beach and the dewatering and shaping of the sand. The permanent pipeline would be initially installed along the beach and the capital costs of purchase of the temporary pipeline, main pumping station and booster station would also be incurred. It is assumed that these assets would be stored in a Council depot between operations and that the pumping stations would need to be replaced every 15 years after their working life expires.

Whole of Life cost estimates for the mobile sand pumping option prepared by Muller Partnership (refer **Appendix E**) and additional cost estimates provided by Council for project management, contract administration and design indicate that the net present value of entrance clearance operations through sand pumping undertaken at a 4 year frequency (40,000 m^3 per campaign as per the base case) over a 30 year analysis period is $11.6M[11]. If pumping operations were completed at an increased frequency of 2

[11] *Based on a discount rate of 7%.*

years and with a lower volume of sand removal (15,000 m^3 per campaign, refer **Section 5.5.3**) then the cost would marginally increase (for more detail refer to **Appendix E**). Both of these cost estimates are considerably higher than for the base case.

Although a Council facilitated scheme has been adopted for the purposes of the cost benefit analysis, the economic ranking of mobile sand pumping should be reviewed if pricing is available from a 100% contractor delivered scheme (contractor supplies, installs and removes pumps and pipelines and associated equipment each operation and Council does not purchase pipelines and pumps) that may be considered for future entrance clearance operations. The outcomes of the current entrance clearance operation which partly involves sand pumping would be expected to also inform further consideration of the mobile sand pumping option.

Reduction of Flood Risk to Property

The reduction in flood risk to property provided by periodic entrance clearance campaigns using the mobile sand pumping method would be equivalent to that described for the base case method in **Section 6.4.1.1**, as it is simply just a different mechanism to remove and transport the sand during entrance clearance operations.

6.4.2.2 Social

Recreational Amenity

The benefits to recreational amenity of periodic entrance clearance and potentially increasing the percentage of the time that the entrance is open by undertaking more frequent operations would be similar to that described in **Section 6.4.1.2**.

The level of temporary disruption to recreational activities around the lagoon entrance during entrance clearance activities would also be similar to the base case. However, it would be expected that a greater footprint would be occupied on the beach by sand bunding and water management associated with discharge of the sand slurry at discrete locations along Collaroy-Narrabeen Beach. In addition, installation of the temporary pipeline for up to a kilometre length along the back of the beach berm would also result in occupation of a portion of the useable beach area for the duration of the works. The occupation of land by pump stations would result in visual disturbance to public recreation areas and their operation may cause noise impacts if appropriate sound dampening measures are not implemented.

Public Safety

The discussion of public safety matters for the base case (refer **Section 6.4.1.2**) is also relevant for periodic mobile sand pumping operations.

It is considered that the mobile sand pumping operations would pose higher public safety risks at the beach replenishment locations along Collaroy-Narrabeen Beach due to the nature of sand bunding and water management associated with discharge of the sand slurry. However, this could be managed by strict enforcement of worker supervised exclusion zones and scheduling of entrance clearance operations outside of peak periods for beach usage (e.g. outside of summer school holidays). The reduction of local road traffic associated with the mobile sand pumping operation in comparison to the base case (i.e. haulage truck movements) would provide a benefit to public safety for both vehicles and pedestrians.

Aesthetics

The mobile sand pumping methodology would result in similar aesthetic outcomes at the lagoon entrance and the beach replenishment sites to the base case (refer **Section 6.4.1.2**). However, the occupation of beachfront areas with pipework and pumping stations would have an increased visual impact.

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Community Support
Community support for the mobile sand pumping methodology was evidenced during community consultation held in early 2021, due to the preference for maintenance of natural aesthetics at the lagoon entrance, open entrance conditions, and the benefit of significantly reducing construction traffic on local roads during entrance clearance operations in comparison to the base case.

6.4.2.3 Environmental

Entrance clearance operations undertaken with the alternate mobile sand pumping methodology would have similar water quality and ecology outcomes as the base case (refer **Section 6.4.1.3**). However, it is noted that there is potential for increased turbidity in the nearshore zone at beach replenishment locations if the discharge of sand slurry is not managed effectively. This potential impact is typically managed by establishment of a seaward sand bund to direct the sand slurry discharge along the beach over a sufficient length to facilitate settling of finer sediments to achieve acceptable water quality for discharge of return water into the ocean. In conjunction with adjustment of the slurry discharge location, earthmoving equipment is used to continually rework deposited sand and to maintain the sand bund (refer **Figure 6-6**).

6.4.3 Low flow pipes

6.4.3.1 Economic

Capital and Operating Costs
The objective of the low flow pipes (CBA Option 5) at the lagoon entrance is to mitigate the build-up in lagoon water level when the entrance is closed by letting it flow to the ocean through the pipes, and thus reduce potential lagoon flooding risks. It should be noted that as the low flow pipes themselves would have no influence on lagoon entrance closure behaviour, periodic entrance clearance operations would still be required as part of this management option.

Costs associated with low flow pipes comprise the initial capital costs of installation of the intake and outlet structures and the pipework itself, and the ongoing operational costs of annual pipe inspection and cleanout of obstructions (e.g. sand, kelp, debris etc.). It is noted that the inherent uncertainty associated with the ongoing costs of pipe inspection and cleanout and the potential for pipe blockage, represents a significant cost and operational risk for the low flow pipes option.

Whole of Life cost estimates prepared by Muller Partnership (refer **Appendix E**) for low flow pipes and periodic entrance clearance as well as additional cost estimates provided by Council for project management, contract administration and design indicate that the net present value of the installation and operation of the low flow pipes option over a 30 year analysis period is $15.9M[12] (for more detail refer to **Appendix E**).

Reduction of Flood Risk to Property
As discussed in **Section 6.3.4**, the benefit provided by installation of the low flow pipes is the maintenance of tidal exchange during closed entrance conditions and release of catchment inflows, resulting in a lowering of the lagoon water level, which may represent an improved initial water level condition prior to a design flood event. The lower initial water level in the lagoon provides a reduction in the peak flood level and associated flood damages.

For the low flow pipes, the closed entrance and open entrance conditions represent the upper and lower bounds of flood risk within the lagoon foreshore areas. These were represented by the following two flood modelling scenarios:

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[12] *Based on a discount rate of 7%. Includes 50% contingency on capital cost and 20% contingency on operating costs.*

1. Closed and shoaled entrance condition, initial lagoon water level 0.6 m AHD[13], beach berm level 1.3m AHD
2. Open entrance condition, regime tidal channel, initial lagoon water level 0.3 m AHD[14]

Flood modelling results for various Average Recurrence Intervals (ARIs) for the above scenarios were compared against the ground levels and floor levels for the list of 2041 properties used for the flood damages analysis within the Narrabeen Lagoon Floodplain Risk Management Study (Cardno, 2019). The number of properties subject to above ground and above floor flooding is summarised in **Table 6-7** and **Table 6-8**, with the closed entrance modelling results for the base case also included for comparison. These results show that, based on the adopted initial water level condition, the low flow pipes provide significant reduction in properties experiencing above ground and above floor level flooding in flood events up to 20 year ARI and that this benefit diminishes for less frequent flood events.

Table 6-7: Above ground level flooding results summary for Low Flow Pipes

Entrance Condition	No. Properties with Above Ground Level Flooding				
ARI	PMF	1000yr	100yr	20yr	5yr
Closed (base case)	***1235***	***980***	***913***	***842***	***753***
Closed	1222	974	900	787	635
Open	1206	935	821	574	371

Table 6-8: Above floor level flooding results summary for Low Flow Pipes

Entrance Condition	No. Properties with Above Floor Level Flooding				
ARI	PMF	1000yr	100yr	20yr	5yr
Closed (base case)	***1171***	***862***	***673***	***531***	***318***
Closed	1151	833	647	410	165
Open	1105	723	488	128	64

Similar to the base case, the flood risk to property would vary between the modelled ‘closed’ and ‘open’ entrance conditions results in periods when the entrance shoals are building to the point of entrance closure. It was assumed that periodic entrance clearance operations would still be required as the installation of low flow pipes would have no influence on lagoon entrance closure behaviour. For analysis purposes, it was assumed that a more frequent 2 yearly entrance clearance regime would be applied and that the entrance could be fully open for 40% of the time, closed for 15% of the time, and in an intermediate state for the remaining 45% of the time. It was determined that the AAD for this scenario was $3.2M, providing a significant reduction in flood damages relative to the base case (where AAD = $4.3M). It should be noted that the reduction in flood damages was most significant for lower ARI events (e.g. 5 year and 20 year ARI), however these events would occur more often.

[13] Lowered initial water level condition able to be achieved given sufficient time for tidal exchange without significant catchment runoff inflows into the lagoon.
[14] Typical mean water level within lagoon under open entrance conditions when water levels are controlled by the natural rock weir at the lagoon entrance (BMT WBM, 2013).

6.4.3.2 Social

Recreational Amenity

The installation of a pipe intake structure at the lagoon entrance would impact on recreational amenity by introduction of a potential obstruction for passive recreational craft (e.g. stand-up paddle boards, canoes, kayak etc.) and swimming activities, depending on the final location of the intake. Localised currents around the intake structure under certain conditions may create a safety hazard for swimming activities and would need to be assessed. It is however noted that the potential location of the intake structure at the bend in the tidal channel running adjacent to the northern seawall is at a significant distance away from the popular swimming areas for families at Birdwood Park and along the foreshore adjacent to the caravan park.

The low flow pipes would allow tidal exchange between the lagoon and the ocean when the entrance is otherwise closed for prolonged periods. This would be expected to enhance the recreational amenity in the immediate vicinity of the lagoon entrance area during closed conditions by improving water clarity with inflow of ocean water and facilitating tidal flushing of rainfall runoff thereby improving any associated poor water quality.

There is potential for the low flow pipes to significantly lower lagoon water levels, particularly during prolonged periods of minimal catchment inflow. This would likely impact the recreational amenity within the lagoon for activities that rely on adequate water depth such as swimming and use of passive recreational craft (e.g. wind surfing, sailing, canoeing, kayaking, stand-up paddle boarding).

Public Safety

As noted above, the introduction of a pipe intake structure may create a potential safety hazard for passive recreation activities. This risk is partially mitigated by the distance of the pipe intake away from popular areas and the provision of stainless steel grating over the pipe intake and outlet points. However, the residual risk of the structure as an obstruction or area where localised currents may exist would still need to be addressed. The public would need to be adequately informed of the hazard with warning signage provided in the vicinity of the pipe intake and outlet locations (near the ocean pool) and also at popular nearby swimming locations.

Aesthetics

The low flow pipes themselves would be installed generally out of sight below the bedrock surface and beach berm, and the submerged outlet structure would be located offshore of the ocean pool. A noticeable feature of the scheme would be the pipe intake structure, although the visual impact of this could be minimised by incorporating the pipe intake into the face of the existing northern seawall structure. Vertical access chambers for maintenance access would need to be provided at intervals along the pipelines and would likely protrude above typical beach berm levels. This feature would have a visual impact on the existing natural setting.

Community Support

Community support for installation of low flow pipes was low relative to other options based on feedback received during community consultation held in early 2021.

6.4.3.3 Environmental

Water Quality

As noted previously, the installation of low flow pipes would be expected to improve water quality within the immediate lagoon entrance area, particularly during periods of prolonged entrance closure. During closed entrance conditions, the pipes would facilitate tidal flushing of rainfall runoff and improve any associated poor water quality that may have otherwise impacted popular swimming areas in the immediate vicinity.

Ecology

The tidal exchange provided by low flow pipes during closed entrance conditions would be expected to improve water clarity, which is beneficial to the maintenance of seagrass beds within the lagoon entrance area.

The pipes may also maintain a route for fish passage and recruitment at times of entrance closure. The viability of the low flow pipes for these purposes would depend on further assessment and design. It is noted that shafts of natural light were incorporated in the design of the low flow pipes extension at Manly Lagoon to aid in fish passage and recruitment.

As noted in **Section 6.4.1.3**, the natural rock weir at the entrance acts as a hydraulic control for water levels in the lagoon. Installation of low flow pipes would alter this natural water level control and would potentially lower the water levels generally experienced in the lagoon during prolonged periods with no catchment inflow (refer **Section 6.3.4**). This could have detrimental impacts on the large areas of seagrass beds established on extensive shallow sand banks located mainly within the central and western areas of the lagoon (refer **Figure 6-9**). Significant areas of shallow seagrass beds include:

- the nearshore area on the eastern shoreline between Loftus Street and Malcom Street;
- the nearshore area adjacent to Mactier Street and Wheeler Park, and extending into the central area of the lagoon opposite Bilarong Reserve;
- the nearshore area adjacent to Jamieson Park and Pipeclay Point;
- the nearshore area between the western end of Bilarong Reserve and Deep Creek; and,
- in the south-western corner of the lagoon, in the nearshore area to the east of South Creek.

The above seagrass areas include shallow banks with bed levels of 0-0.2m AHD. These areas would be adversely impacted and subject to seagrass die-off if a general lowering of mean lagoon water levels resulted in more frequent or more extended exposure of seagrass beds at low tides.

If the water level of the lagoon was permanently lowered due to the low flow pipes, this may have significant ecological effects on the lagoon as a whole. Currently the lagoon is completely closed for approximately 25% of the time, which lends to higher water levels, and the ecology appears to have adapted to this situation. Further studies would be required to estimate the overall impact on the lagoon of having significantly lower lagoon water levels all of the time, including the impact on water quality, seagrass beds, riparian vegetation communities, fish and birds, and recreational amenity.

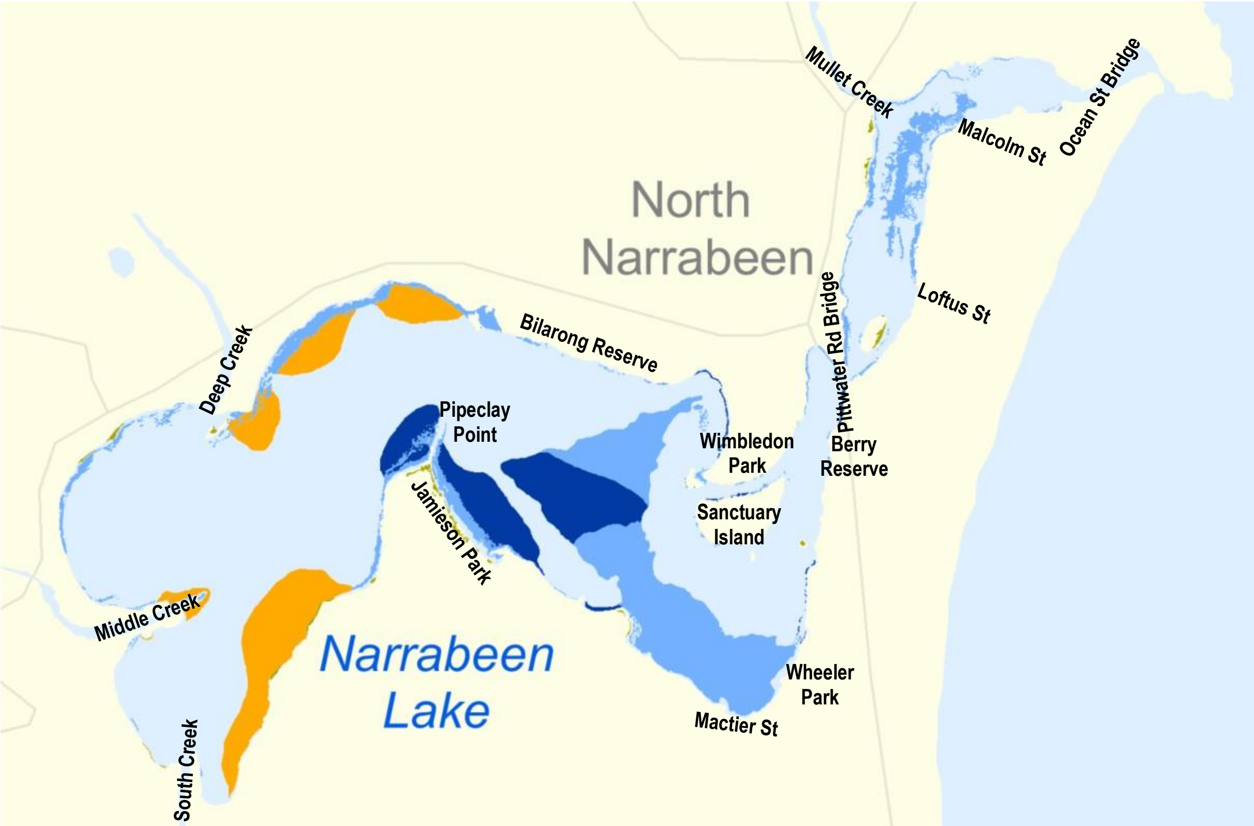

Figure 6-9: Seagrass beds within Narrabeen Lagoon, Light blue = Zostera, Dark blue = Zostera/Halophila, Orange = Halophila (NSW Government, 2005)

6.5 Summary assessment of long term management options

A summary of the assessment of long term management options against various economic, social, and environmental criteria discussed in **Section 6.4** is presented below in **Table 6-9**.

Table 6-9: Summary assessment of long term management options

CRITERIA	Option 1 – Base Case	Option 2 – Excavation and Trucking (2 yearly)	Option 3 – Mobile Sand Pumping (4 yearly)	Option 4 – Mobile Sand Pumping (2 yearly)	Option 5 – Installation of Low Flow Pipes + Excavation and Trucking (2 yearly)
ECONOMIC					
Feasibility	Yes	Yes	Yes	Yes	Feasibility subject to detailed investigation of rock levels and competency for directional drilling, and assessment of long term hydraulic performance in reducing lagoon water levels.
Capital and Operating Costs	As per existing.	Low Marginal increase if reduced sand removal volumes can be achieved.	High Could potentially be reduced with 100% contractor delivered scheme.	High Could potentially be reduced with 100% contractor delivered scheme.	High Significant cost risk associated with ongoing maintenance requirements.
Reduction in Flood Risk to Property	As per existing.	Moderate Subject to assumed increase in open entrance conditions.	As per existing.	Moderate Subject to assumed increase in open entrance conditions.	Significant Subject to confirmation of long term hydraulic performance
Net Present Value (NPV, $’000)	-	6,380	-3,450	790	5,523
Benefit Cost Ratio (BCR)	-	n/a	0.00	1.14	1.69

CRITERIA	Option 1 – Base Case	Option 2 – Excavation and Trucking (2 yearly)	Option 3 – Mobile Sand Pumping (4 yearly)	Option 4 – Mobile Sand Pumping (2 yearly)	Option 5 – Installation of Low Flow Pipes + Excavation and Trucking (2 yearly)
SOCIAL					
Recreational Amenity	As per existing. Impacts subject to open or closed entrance condition.	Positive impact if increase in open entrance conditions can be achieved. Increased temporary disruption during entrance clearance campaigns from occupation of lagoon entrance/Birdwood Park and sand trucking and placement operations at sand replenishment locations.	As per existing. Increased temporary disruption during entrance clearance campaigns from occupation of lagoon entrance/Birdwood Park, installation of pipeline along beach, and management of sand slurry discharge.	Positive impact if increase in open entrance conditions can be achieved. Increased temporary disruption during entrance clearance campaigns from occupation of lagoon entrance/Birdwood Park, installation of pipeline along beach, and management of sand slurry discharge.	Potential improvement in entrance area water clarity from tidal flushing during closed entrance conditions. Potential adverse impacts from lowered lagoon water levels. Increased temporary disruption during entrance clearance campaigns from occupation of lagoon entrance/Birdwood Park and sand trucking and placement operations at sand replenishment locations.
Public Safety	Minor impact, managed with existing worker supervised exclusion zones, traffic management measures, and scheduling outside of peak periods.	Minor impact, managed with existing worker supervised exclusion zones, traffic management measures, and scheduling outside of peak periods.	Minor impact, managed with existing worker supervised exclusion zones, traffic management measures, and scheduling outside of peak periods.	Minor impact, managed with existing worker supervised exclusion zones, traffic management measures, and scheduling outside of peak periods.	Moderate impact, subject to configuration of pipe alignment, intake structure, and access chambers.
Aesthetics	Positive impact, maintains existing natural open entrance condition.	Positive impact if increase in open entrance conditions can be achieved.	Positive impact, maintains existing natural open entrance condition.	Positive impact if increase in open entrance conditions can be achieved.	Moderate impact, subject to configuration of pipe alignment, intake structure, and access chambers.
Community Support	Supported, but increased local road traffic is main complaint.	Supported, but increased local road traffic is main complaint.	Supported, due to potential reduction of local road traffic.	Supported, due to potential reduction of local road traffic.	Low, relative to other options.

CRITERIA	Option 1 – Base Case	Option 2 – Excavation and Trucking (2 yearly)	Option 3 – Mobile Sand Pumping (4 yearly)	Option 4 – Mobile Sand Pumping (2 yearly)	Option 5 – Installation of Low Flow Pipes + Excavation and Trucking (2 yearly)
ENVIRONMENTAL					
Water Quality	Entrance clearance campaigns improve water clarity and quality locally around the lagoon entrance area due to increased tidal exchange and flushing associated with open entrance conditions.	Positive impact if increase in open entrance conditions can be achieved.	Entrance clearance campaigns improve water clarity and quality locally around the lagoon entrance area due to increased tidal exchange and flushing associated with open entrance conditions.	Positive impact if increase in open entrance conditions can be achieved.	Positive impact locally around the lagoon entrance from tidal flushing during closed entrance conditions, and if increase in open entrance conditions can be achieved.
Ecology	As per existing, ecology adapts to gradual changes in water level regime associated with open, intermediate and closed entrance conditions.	Positive impact at entrance if increase in open entrance conditions can be achieved. The lagoon being open for a greater percentage of the time may result in changes to the water quality and water level regime, requiring the ecology in the broader lagoon to adapt.	As per existing, ecology adapts to gradual changes in water level regime associated with open, intermediate and closed entrance conditions.	Positive impact at entrance if increase in open entrance conditions can be achieved. The lagoon being open for a greater percentage of the time may result in changes to the water quality and water level regime, requiring the ecology in the broader lagoon to adapt.	Potential lowering of lagoon water levels during prolonged periods with no catchment inflow could have detrimental impacts on large areas of seagrass beds established on extensive shallow sand banks.

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6.6 Recommendations for long term entrance management

Council has investigated a range of options including options requiring high upfront costs for permanent infrastructure, to determine whether there is a better way to reduce flood risk in the longer term. These options could be implemented either in conjunction with or as alternative to the current entrance clearance practices described in the medium term entrance management section of this report. The investigation has included consultation with a technical expert panel as well as the community, and the options have been assessed from a technical feasibility, economic, environmental and social impact perspective.
These options have been compared with the Base Case option, which comprises the continuation of the current entrance clearance practices as described in the medium term entrance management section of this report.

The following conclusions and recommendations are made with respect to long term entrance management:

- Entrance clearance operations involving excavation and trucking (as per the base case current practice) is the more economically beneficial option in comparison to the mobile sand pumping option, based on current costing assumptions for installation of a permanent pipeline partially along the beach and Council purchase and maintenance of all assets (i.e. permanent and temporary pipeline and pumps).

- The economic ranking of mobile sand pumping should be reviewed if lower cost pricing is available from a contractor delivered scheme (Contractor supplies, installs and removes pumps and pipelines and associated equipment each operation and Council does not purchase pipelines and pumps).

- The installation of low flow pipes with excavation and trucking every two years has a positive cost benefit analysis, but less so than more frequent entrance clearance operations. However, given the potential environmental impacts of this option associated with lagoon water level lowering (both recreational amenity and ecological impacts) and the likely operational challenges associated with pipe access and maintenance, it is recommended that this option is not pursued any further.

- Hydrodynamic modelling identified that the installation of half-tide walls would not be effective in generating the desired sustained increase in ebb tide currents to maintain an ebb tide dominated entrance channel. Therefore, the ebb tide channel option is not considered to be a technically feasible entrance management option and has been eliminated from further consideration.

7 Implementing the Strategy

The draft Narrabeen Lagoon Entrance Management Strategy considers how Council currently manages the Narrabeen Lagoon entrance and whether improvements could be implemented. The draft Strategy reviewed the activities Council currently employs, namely mechanical openings and entrance clearance operations, and identified, analysed and evaluated possible alternative options. The draft Strategy presents a prioritised set of recommendations for implementation that are expected to improve the management of the entrance both in terms of efficiency and outcomes.

Table 7-1 below outlines the suggested prioritised implementation strategy and recommendations going forward for management of the Narrabeen Lagoon entrance. Options for the Short Term relate to mechanical opening of the lagoon for flood mitigation purposes and options for the Medium / Long Term relate to managing large volumes of sand in the longer term, with a view to maintaining an open entrance for as long as is practicably possible. These options are still in draft form, for consideration by the community during public exhibition.

Table 7-1: Draft Entrance Management Strategy prioritised recommendations

Management Option Type	Option Description	Recommendation	Priority
Short term	Maintain mechanical opening of the lagoon entrance for the primary purpose of flood mitigation	Develop a flexible set of trigger conditions to allow for openings to be undertaken in a wider range of conditions, including extenuating scenarios.	High
		Refine guidelines for where the pilot channel is to be excavated, locating it in a position that works more effectively with the natural configuration of the entrance. Review and update Council's OMS procedures and REF for lagoon openings.	High
		Enhance collection of data, including through the use of remote data sensing equipment, and use this data to refine flood forecasting, improve the location of the entrance channel etc. and evaluation of the success of entrance openings.	Medium
		Enhance publicly available information on Council's website and the MHL flood warning webpage to support understanding of how and why Council manages the Narrabeen Lagoon entrance. Information could include a decision matrix/tree, trigger levels for mechanical openings, and real-time updates on conditions.	Medium
Medium / Long Term	Continue periodic entrance clearance operations	Review design and frequency of entrance clearance operations on an ongoing basis, with consideration for factors including beach rotation and climate change. Investigate more frequent, smaller scale, strategic removal of sand from the flood tide shoals. Consider trialling a focus on the western shoal or a regime tidal channel.	High

Management Option Type	Option Description	Recommendation	Priority
	Mobile sand pumping option	Review mobile sand pumping if lower cost pricing is available from a contractor delivered scheme rather than Council purchasing pipes and pumps.	Low
	Review processes for entrance clearance	Review payment methods and procurement strategy for contractor; and Review tracking method for excavation depths and extent during works.	Medium
	Reshape, revegetate and maintain Birdwood Park dune	Reshape the dune, with relocation of sand away from western side and re-creation of the beach on the western side of the dune.	High
		Revegetate the denuded areas of the dune, to stabilise it and to limit wind-blown sand entering the lagoon. Extend the vegetation as far north as practicable, to reduce alongshore width of the lagoon entrance berm to reduce sand entering lagoon.	High
		Maintain the dune. Maintain the vegetation, monitor the profile of the dune and adjacent beaches and manage sand movement. Consider sand-catching fences.	Ongoing

Glossary

Aeolian	Pertaining to wind transported sediment.
Amenity	Those features of an estuary that foster its use for various purposes, e.g. clear water and sandy beaches make beach-side recreation attractive.
Amphibious dredge	Type of excavator that can perform dredging while afloat on soft terrain such as swamp, wetland, and shallow water. Can be fitted with a dredge head and pump to enable pumping of dredged material as a slurry through floating pipework to a nearby dewatering basin.
Australian Height Datum (AHD)	A standard national surface level datum approximately corresponding to mean sea level.
Annual Exceedance Probability (AEP)	The chance or likelihood that an event of a nominated size or greater (e.g. flood discharge) will occur in any year.
Average Recurrence Interval (ARI)	The average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that periods between exceedances are generally random. That is, an event of a certain magnitude may occur several times within its estimated return period.
Acid Sulfate Soils (ASS)	Acid sulfate soils (ASS) are naturally occurring sediments and soils containing iron sulfides (mostly pyrite). When these sediments are exposed
Algae	Non-rooted aquatic plants, specifically non-vascular photosynthetic organisms with unicellular reproductive organs, including phytoplankton and seaweeds.
Bathymetry	The measurement of water depth at various places in a body of water.
Beach berm	The landward crest of the beachface.
Beach replenishment	Artificial emplacement of sand to improve beach amenity and/or increase protection for backshore assets.
Benthic organisms	Organisms living in or on the bed of a waterbody.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.

Design Flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. For example some roads may be designed to be overtopped in the 1% AEP flood event.
Directional drilling	A trenchless construction method used to install pipes underground without disturbing the ground surface.
Discharge	Volumetric flow rate of water, typically measured in terms of cubic metres per second (m3/s).
Dredging	The excavation of material from a water environment.
Ebb tide	The outgoing tidal movement of water within an estuary.
Ecosystem	A community of living organisms, together with the environment in which they live and with which they interact.
El Nino-Southern Oscillation (ENSO)	The oscillation between the El Niño climate phase and the La Niña phase, usually over several years.
Entrance berm (beach berm)	A deposit of sand across the entrance to an estuary.
Entrance clearance	Large scale artificial removal of sand within the lagoon entrance area by excavators and trucks or other means (e.g. amphibious dredge).
Epifauna	The aggregate of animals that live on the surface of the bottom of an ocean, river or lake, or are attached to other aquatic organisms or submerged rocks.
Estuary	An enclosed or semi-enclosed body of water having an open or intermittently open connection to coastal waters in which water levels vary in a periodic fashion in response to ocean tides.
Fauna	Any mammal, bird, reptile or protected amphibian.
Flash Flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which caused it.

Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Flood tide	The incoming tidal movement of water within an estuary.
Fluvial	Pertaining to non-tidal flows.
Foreshore	The area of shore between low and high tide marks and land adjacent thereto.
Geographical Information Systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
Habitat	The places in which an organism lives and grows. Many estuarine organisms require different habitats at different stages of their life cycles.
Half tide level	The average of successive high tide and low tide levels.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrographic survey	The survey of physical features present underwater, involving the measurement of water depth and bed levels to a reference height datum (e.g. AHD).
ICOLL	Intermittently Closed / Open Lake or Lagoon.
Invert	The base interior level of a pipe.
Littoral drift	Wave, current and wind processes that facilitate the transport of sediments along a shoreline.

Littoral zone	An area of the coastline in which sediment movement by wave, current and wind action is prevalent.
Macroalgae	Small to large attached algae of several types (red, brown and green). Green algae may become detached and accumulate in shallow waters.
Mangroves	An intertidal plant community dominated by trees.
Marine sediments	Sediments in coastal waters moved along the coast by littoral processes.
Marinisation	Process of increasing salinity within an estuary.
Mechanical opening	Artificial initiation of a lagoon breakout under closed entrance conditions by the creation of a pilot channel through the entrance berm with excavators.
Morphology	The study of spatial and temporal variations in the form and structure of the earth's surface.
Morphodynamic	The mutual interaction of coastal morphology with hydrodynamic agents (tides, currents, waves). This interaction takes place through sedimentation, erosion and sediment transport processes.
Neap tides	Tides with the smallest range in a monthly cycle. Neap tides occur when the sun and moon lie at right angles relative to the earth (the gravitational effects of the moon and sun act in opposition on the ocean).
NTU	Nephelometric Turbidity Units (measurement unit for turbidity)
Numerical model	A mathematical representation of a physical, chemical or biological process of interest. Computers are often required to solve the underlying equations.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood (PMF)	The flood calculated to be the maximum that is likely to occur.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a more detailed explanation see Average Recurrence Interval.
Runoff	That proportion of rainfall that drains off the land's surface.

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Salinity	The total mass of dissolved salts per unit mass of water. Seawater has a salinity of about 35 g/kg or 35 parts per thousand.
Scour	Localised erosion of bed or bank material due to flowing water.
Seiching	Resonant (or near-resonant) standing oscillations in a semi-enclosed water body caused by incoming long-period waves.
Shear stress	The stress exerted on the bed of an estuary by flowing water. The faster the velocity of flow the greater the shear stress.
Shoals	Shallow areas in an estuary created by the deposition and build-up of sediments.
Slurry	A watery mixture of insoluble matter, e.g. sediment or sand mixed with water.
Spring tides	Tides with the greatest range in a monthly cycle, which occur when the sun, moon and earth are in alignment (the gravitational effects of the moon and sun act in concert on the ocean).
Stage	Water level within a river or stream with respect to a chosen reference height.
Storm surge	The increase in coastal water levels caused by the barometric and wind setup effects of storms. Barometric setup refers to the increase in coastal water levels associated with the lower atmospheric pressures characteristic of storms. Wind setup refers to the increase in coastal water levels caused by an onshore wind driving water shorewards and piling it up against the coast.
Swash	Up and down propagation of bores formed after collapse of waves on the beach. Swash is the decelerating uprush phase and backwash is the accelerating downrush phase.
Swash zone	Zone where wave bores run up and down the beach face.
Surf zone	The surf zone (or breaker zone) is the zone where waves break as a consequence of depth limitation and surf onshore as wave bores. The width of the surf zone varies depending on the wave conditions and water level.
Tidal delta	The build-up of shoals in the lower reaches of an estuary due to the gradual accumulation of marine sands transported into the estuary through its entrance.

Tidal exchange	The proportion of the tidal prism that is flushed away and replaced with 'fresh' coastal water each tide cycle.
Tidal planes	A series of water levels that define standard tides, e.g. 'Mean High Water Spring' (MHWS) refers to the average high water level of Spring Tides.
Tidal prism	The total volume of water moving past a fixed point on an estuary during each flood tide or ebb tide.
Tidal propagation	The movement of the tidal wave into and out of an estuary.
Tidal range	The difference between successive high water and low water levels. Tidal range is maximum during Spring Tides and minimum during Neap Tides.
Tides	The regular rise and fall in sea level in response to the gravitational attraction of the sun, moon and planets.
Training walls	Walls constructed at the entrances of estuaries to improve navigability.
Turbidity	Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is a measurement of the amount of light that is scattered by material (e.g. suspended sediment) in the water when a light is shined through the water sample. Turbidity is measured in nephelometric turbidity units (NTU).
Washover	The portion of swash uprush that overtops the crest of a berm.
Water clarity	A measure of the transmission of light through water.
Water Quality	The suitability of the water for various purposes, as measured.
Wave setup	Super-elevation of the water surface due to the onshore mass transport of water by wave action.

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Appendix A: Literature List

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Table A-1: Available Literature

Title	Year	Author(s)
Narrabeen Lagoon – Investigation of a Permanent Entrance	1977	Department of Public Works, NSW Hydraulics Laboratory
Narrabeen Lake – Flood of August 1986	1986	Manly Hydraulics Laboratory
Narrabeen Lagoon Entrance Study	1989	Manly Hydraulics Laboratory
Narrabeen Lagoon Entrance Sand Fluidisation Scheme Pilot Study	1991	Public Works Department, NSW Manly Hydraulics Laboratory
Collaroy/Narrabeen Beach Nourishment Investigations	1993	Patterson Britton & Partners Pty Ltd
Narrabeen Lagoon – Estuary Processes Study	2001	WBM Oceanics Australia
Narrabeen Lagoon – Estuary Management Plan	2002	WBM Oceanics Australia
Management and Monitoring of an ICOLL Entrance Clearance	2007	Cameron, D.W. , Morris, B.D., Collier, L., and Mackenzie, T Water Research Laboratory, University of New South Wales
Alternative Management Strategies for Clearing Narrabeen Lagoon Entrance	2009	Manly Hydraulics Laboratory
Coastal Inundation at Narrabeen Lagoon – Optimising adaptation investment	2010	AECOM Australia Pty Ltd
Warringah Lagoons Review of Environmental Factors – Supplementary Information	2010	BMT WBM Pty Ltd on behalf of Warringah Council
Entrance Management of Narrabeen, Dee Why and Curl Curl Lagoons	2010	BMT WBM Pty Ltd on behalf of Warringah Council
Infilling and sedimentation mechanisms at intermittently open-closed coastal lagoons	2010	Thesis by B. Morris, at The University of New South Wales
Narrabeen Lagoon Plan of Management	2011	SMEC
The Risky Business of ICOLL Entrance Management	2012	K. Stephens, J. Murtagh
Aquatic Recreation Usage Study of Narrabeen Lagoon	2013	Alan Ginns and Andrew Ginns, Gondwana Consulting
Narrabeen Lagoon Flood Study	2013	BMT WBM Pty Ltd
OMS-455 Lagoon Entrance Management	2013	Warringah Council
Narrabeen Lagoon Entrance Clearance	2017	Cardno
June 16 Event Modelling Results	2018	Cardno

Title	Year	Author(s)
Assessment of present beach rotation at Collaroy-Narrabeen Beach	2019	Water Research Laboratory UNSW
Narrabeen Lagoon Floodplain Risk Management Plan	2019	Cardno
Narrabeen Lagoon Floodplain Risk Management Study	2019	Cardno

Appendix B: Review of State, National and International ICOLL Entrance Management

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Review of NSW ICOLL Entrance Management

In addition to the broader ICOLL best practice procedures, a review of individual entrance management policies of ICOLLs across the NSW coast has been undertaken.

The review of policies from other NSW Councils made it apparent that there are many similar lagoon entrance management philosophies up and down the NSW coast (refer **Table B-1**). All councils had set appropriate trigger levels, based on a range of factors to ensure that floods were mitigated as efficiently as possible, as part of their estuary management plans. These councils all had detailed procedures for monitoring ICOLL entrances. All trigger levels were considered carefully for each ICOLL and set to ensure a reduction in flood risk while conserving the ecosystems within the lake based on current water depths and future rainfall. However, differences arose in respect to the factors that impacted either the trigger water level or when artificial intervention was allowed. Some of these differences are summarised below:

- Greater Taree Council had salinity and water quality indicators impacting the trigger levels due to the oyster and shellfish production requirements.
- Port Macquarie-Hastings Council had triggers impacted by salinity levels.
- In Bega Valley Council and Shoalhaven City Council, while there were still triggers to open entrances to avoid flooding, this was impacted by endangered shorebird nesting. The mechanical opening of the entrance could only be operated during months where shorebirds did not nest and after surveying that the mechanical openings would not impact their nesting. The Shoalhaven River had similar reasons for trigger levels being set as Narrabeen, as they were based on the water level in the river (head difference) to ensure scouring of the pilot channel.

Individual trigger levels were set for all ICOLLs (refer **Table B-1**) and carefully considered based on a number environmental, social and economic factors. Example entrance management decision trees for Bega, Port Macquarie and Shoalhaven Councils are provided in **Figure B-1**.

Table B-1: Selected NSW entrances – short term response trigger levels and entrance management policies

Responsible	Entrance	Warning Trigger Level (m AHD)	Emergency Trigger Level (m AHD)	Entrance Management Policies
Bega Valley Shire Council	Back Lake	1.2	1.4	• Decision tree for management decision(s) (refer **Figure B-1**) • Minimal intervention in the long term; returning to a 'natural as possible' breakout regime. • Progressive and opportunistic raising of assets to levels above 3m AHD. • Progressive and opportunistic removal of assets that are currently affected by inundation close to or just above the trigger level. • Maintaining a buffer of no new development within close proximity to and below an elevation of 3.0m AHD around water body.
	Bega River	1.26	1.36	
	Curalo Lagoon	1.0	1.2	
	Cuttagee Lake	1.8		
	Wallagoot Lake	1.2	1.4	
	Wallaga Lake	1.1	1.25	
Mid Coast Council (Formerly Greater Taree City Council)	Farquhar Inlet	2.0		• (TBC[15]) Triggers for entrance opening works (Excavation of Notch through Berm): 1. A flood level of 1.6m AHD is reached at the Farquhar Inlet gauge 2. Salinity levels at Farquhar Inlet fall to below 12 ppt 3. Closure of the Scotts Creek shellfish harvest area for more than 120 consecutive days, combined with a weekly rainfall reading at Taree Airport greater than 80mm • (TBC) Dredging of temporary pilot channel to connect main river water body and entrance. • (TBC) Dredging of permanent pilot channel, including Training wall, to connect main river water body and entrance.
Central Coast Council (Formerly Gosford City Council)	Wamberal Lagoon	2.4		• Artificial opening of lagoon entrance at predefined trigger water levels to prevent flooding of surrounding properties. • reduction in catchment pollution via stormwater runoff through implementation of vegetated buffer zones and WSUD features.
	Terrigal Lagoon	1.23		
	Avoca Lagoon	2.09		
	Cockrone Lagoon	2.53		
	Pearl Beach	2.75		
Wollongong City Council	Fairy Lagoon	1.3	1.6	• Artificial opening of lagoon entrance at predefined trigger water levels to prevent flooding of surrounding properties. • (TBC) Maintaining a 'dry notch' (i.e. a low or 'saddle' point in the beach adjacent to the entrance which the Lagoon can preferentially flow across).
	Towradgi Lagoon	1.4	1.6	
Shoalhaven City Council	Burrill Lake	1.1	1.2	• Decision tree based on water level for management decision(s) (refer **Figure B-1**)
	Currarong Creek	n.a.		
	Lake Conjola	1.0	1.2	
	Shoalhaven River	2.5	3.0	
	Swan Lake	2.2	2.5	
	Tabourie Lake	1.17		
Coffs Harbour City Council	Woolgoolga Lake	1.6		• Scenario decision trees based on water level for management decision(s)
Port Macquarie-Hastings Council	Lake Cathie	1.2	1.6	• Decision tree based on water level for management decision(s) (refer **Figure B-1**)

[15] *To Be Confirmed.*

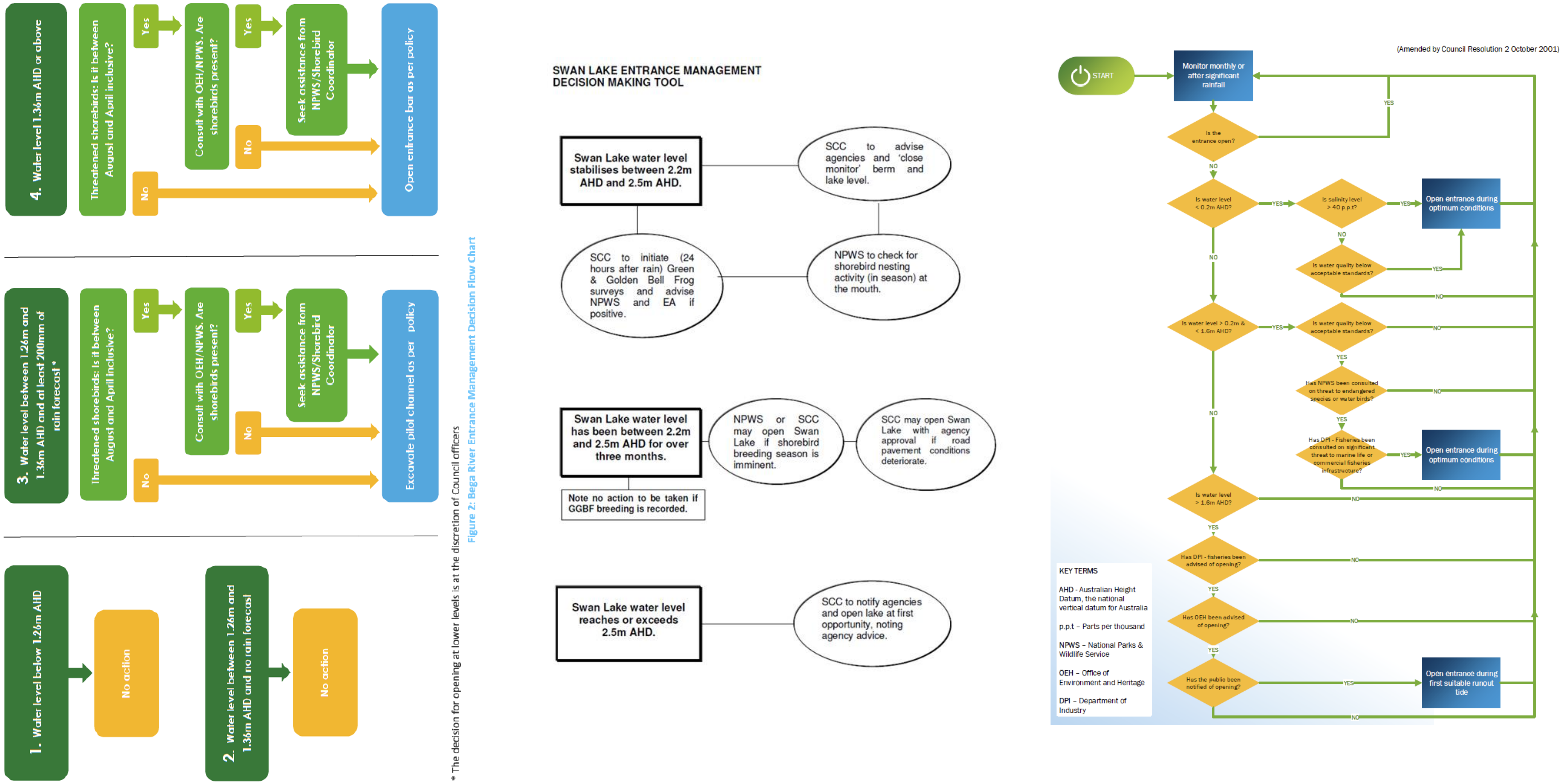

Figure B-1: Example decision trees for entrance management; Right: Bega Valley Shire Council, Middle: Shoalhaven City Council, Left: Port Macquarie-Hastings Council

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Review of National ICOLL Entrance Management

With respect to entrance management, the National Committee on Coastal and Ocean Engineering (NCCOE) has the following guidelines and recommendations (refer **Table B-2**).

Table B-2: NCCOE guidelines for entrance management

Management Option	Advantage	Disadvantage	Applicability at Narrabeen Lagoon
Barrage(s) / Tidal Gate	• Protects inland areas from ocean inundation caused by elevated storm surge water levels. • Significantly reduces ingress of sediment.	• Very high capital cost. • High maintenance cost. • Potential major adverse impacts on the estuary entrance and adjacent coastline. • May require pumping to control flooding from upstream. • Altered ecology.	Ultimately does not address fundamental issues at Narrabeen Lagoon. Entrance would remain closed during elevated ocean levels. If this coincides with catchment flooding, properties along foreshore would likely be inundated.
Breakwater(s)	• Increased hydraulic conveyance of entrance successful in keeping entrances open and mitigating flooding. • Exposed to tidal flushing every cycle, likely leading to enhanced water quality.	• Breakwaters constructed on littoral drift coasts have the potential to cause “downdrift” erosion by reducing sediment input and by altering beach alignments through nearshore wave diffraction. • High capital costs. • Can potentially change tidal planes and increase tidal inundation within estuaries and flooding of fringing areas. • Can increase channel velocities and channel bank scour. • Increased sediment deposition within the estuary. • Interrupts alongshore littoral drift which may require installation of sand bypassing system. • Can impact of surf amenity of coastline.	Maintaining surf amenity is particularly sensitive at North Narrabeen. The potential impacts of breakwaters on surf amenity, the high capital cost and likely ecological impacts within the lagoon from altered tidal exchange result in this option not being feasible.

Management Option	Advantage	Disadvantage	Applicability at Narrabeen Lagoon
Training Wall(s)	• Protect internal estuary channel banks from scour resulting from the increased velocities induced by entrance breakwater construction and/or migration of flood and ebb tide channels. • Can be a flexible solution that is adaptable to prevailing sea level and climate conditions.	• Limited success because the scale of the scour process is very much larger than that of the bank protection works. • Can create localised scour or high velocities. • Increase in the tidal prism (due to more efficient tidal exchange) may destabilise the entrance.	A training wall is already present along the northern bank of the lagoon entrance. The potential impacts of installing a training wall on the southern side of the lagoon entrance on surf amenity, the high capital cost, and likely ecological impacts within the lagoon from altered tidal exchange result in this option not being feasible.
Dredging	• Keep untrained entrances open. • Dredging can allow for maintenance of some exchange of ocean water with the lake and for flood conveyance. Placing sand onto the beaches, in the short term, maintains beach amenity and provides a greater sand buffer to mitigate storm erosion.	• Can become expensive and/or frequent during periods of drought or particular coastal conditions (swell directions, beach rotation). • High long term operation costs. • Potentially disruptive operation.	Dredging (i.e. entrance clearance operations) has been effectively employed as a primary entrance management procedure at Narrabeen Lagoon for over 50 years. Though recently it has been required, in its current form, more frequently due to the prevailing coastal conditions.
Entrance Bypassing Systems	• Can be developed where entrance breakwaters have interrupted the natural transport of littoral drift along the coast. • Flexible systems that can vary from fixed sand pumps located on trestles that extend across the surf zone to shoreline operations using excavators, bobcats and trucks.	• High capital, ongoing and maintenance costs. • Can prevent use of a section of beach.	Entrance bypassing would require prior construction of breakwaters. Given the location of the entrance of Narrabeen Lagoon to the immediate south of several pocket beaches defined by headlands with limited sand exchange (essentially closed systems), an entrance bypassing is not considered to be necessary.

Management Option	Advantage	Disadvantage	Applicability at Narrabeen Lagoon
Artificial Reefs	• Induce incoming waves to break, thus reducing the wave energy reaching the shore. • Alter currents and hence sediment transport and beach alignment. • Can enhance surf amenity and/or ecology. • Structure is not visible from the beach if always submerged.	• Only suitable for small tidal ranges with low wave variability. • Limited protection during coastal storms. • High capital costs.	May reduce localised wave energy reaching the shore, however littoral drift would still occur along Collaroy-Narrabeen Beach. May increase time for sand to build-up inside entrance. Coastal storm events would still likely result in large ingress of sand to the entrance.

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Review of International ICOLL Entrance Management

ICOLLs around the world are concentrated along microtidal to low mesotidal coastlines in the mid latitudes and predominantly in temperate climates. ICOLLs form at the mouth of rivers with generally low mean annual discharges and typically occur where marine processes dominate (i.e. wave dominated) over fluvial inputs. The distribution of ICOLLs internationally is related to greater wave heights, driven by high intensity winds and longer fetch distances, and is associated with a tidal range of <~3 m, smaller catchments < 2000 km^2 and tidal prisms < 30 x 106 m^3.

Australia has the highest proportion of ICOLLs in the world at 21%. Outside Australia, ICOLLs occur in larger numbers in New Zealand, South Africa, North Africa and the Mediterranean, the southernmost coasts of South America and the west coast of North America (refer **Figure B-2**). International case studies of ICOLL management for some of these areas are summarised in the following sections.

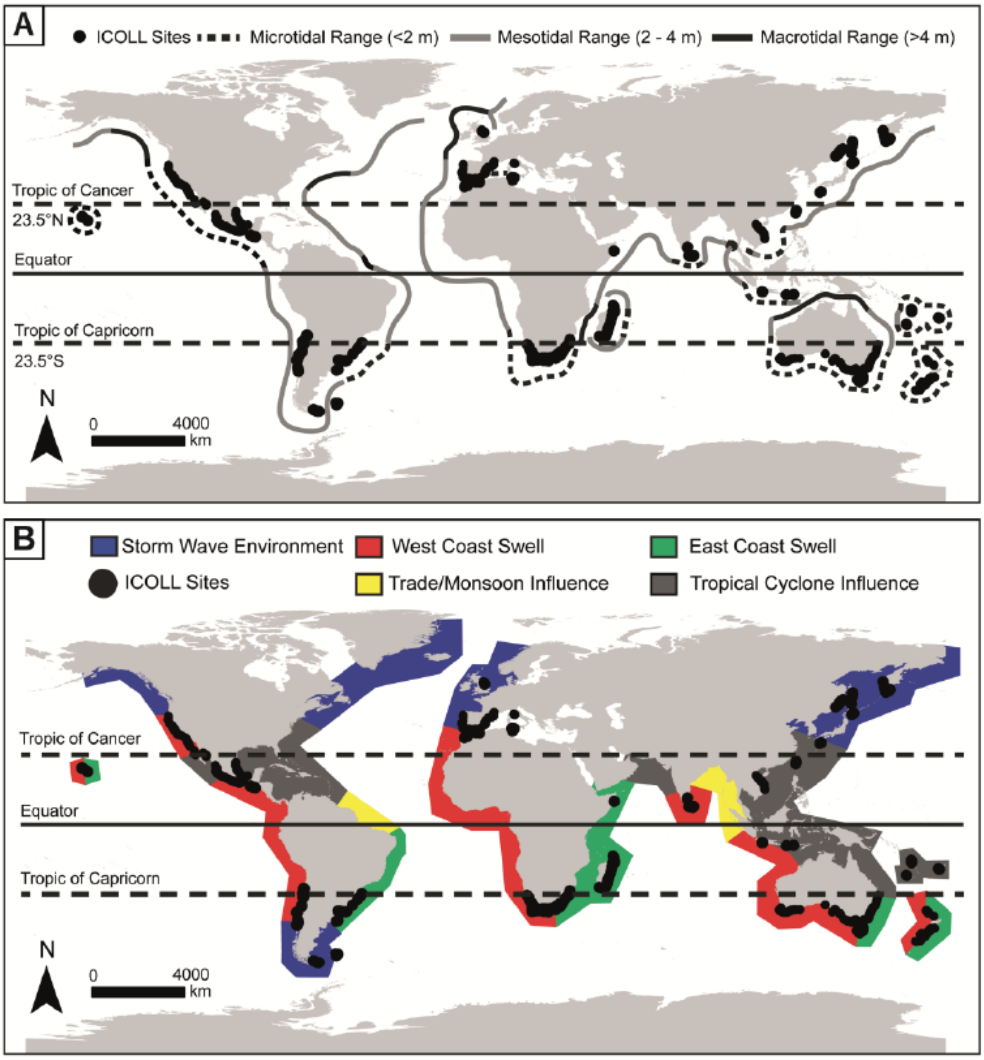

Figure B-2: Global distribution of ICOLLs (Source: McSweeney et al., 2017)

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New Zealand

The levels of most coastal lakes in New Zealand's South Island are human-controlled using a variety of mechanisms such as: direct excavation; breakout at maintained beach crest levels; or by culverts and pipes (Kirk & Lauder, 2000). Excavations are usually carried out by mobilised plant which breaches the beach barrier (or berm) at a predefined maximum water level within the lagoon. Openings are maintained for a variable length of time until sea conditions close the entrance. If closure occurs before lagoon water levels have lowered to a level considered to be satisfactory it is usual for repeated excavation to occur.

Under human management, lagoon maximum water levels have been reduced and the range of levels has contracted. Lagoons have not only reduced in area, and become reduced in volume and in average depth, but they have also become very much less active environments for physical processes (because fetches for wave action, seiching, current formation, etc., have also been reduced). Furthermore, the distribution of plants, animals (e.g. nesting sites for birds) has become adjusted to these new, artificial water level regimes.

South Africa

A comparative case study between two lagoon outlets in KwaZulu-Natal, South Africa highlighted the importance of appropriate entrance management (Guastella et al. 2014). A timely artificial breaching of the lagoon outlet/entrance at Margate Beach prevented large infrastructure loss, whilst the application of a 'do nothing' approach at Amanzimtoti resulted in costly infrastructural loss (i.e. derailing of a goods train), injury and the potential for loss of life. In both cases, the institution of a short term policy for artificial breaching was recommended. Emergency breaching was highlighted as the preferable solution over permanent diversions. Live webcams were also noted as an opportunity to examine the baseline and before and after intervention scenarios to use and apply the knowledge gained for future potential intervention.

It was ultimately noted that although artificial breaching of river mouths may have an adverse effect on the natural functioning of these sensitive systems, in some critical cases it is politically/socially unavoidable. Each case needs to be assessed individually, based on sound scientific input. Artificial breaching should only be done if absolutely necessary and from a hydrodynamic point of view it is preferable to allow water levels to rise and breach the bar naturally.

A further example of an ICOLL is provided in the Bot River. For the past over 100 years the estuary has been opened to the sea every 2 to 5 years by artificial means, resulting in a great variability of physical conditions and low diversity of organisms that occupy the estuary permanently.

Africa

Muni-Pomadze lagoon, Ghana is an example of an ICOLL on the north-west coast of the African continent (Davies-Vollum et al., 2017). There are both traditional and ad-hoc local practices that influence lagoon opening. Information from a focus group discussion confirmed that traditional opening ceremonies have taken place at the end of the rainy season to prevent rising lagoon water from flooding homes on the lagoon barrier and eastern shore. The ceremonies involved dredging of the low, unstable barrier to create an outlet to the ocean that allowed impounded lagoon waters to drain. Once the lagoon was breached, It was noted that the openings could be maintained by individual ad-hoc actions of fishermen who drove canoes through the tidal inlet during low tide.

South America

Laguna de Rocha is a lagoon located on the Atlantic coast of Uruguay. It is one of a series of lagoons that exists along the Uruguayan and Brazilian coasts. Artificial opening of the Lagoon has been proposed to be managed by the use of a consensual decision model (Conde et al., 2015) to balance the inputs from stakeholders (refer **Figure B-3**).

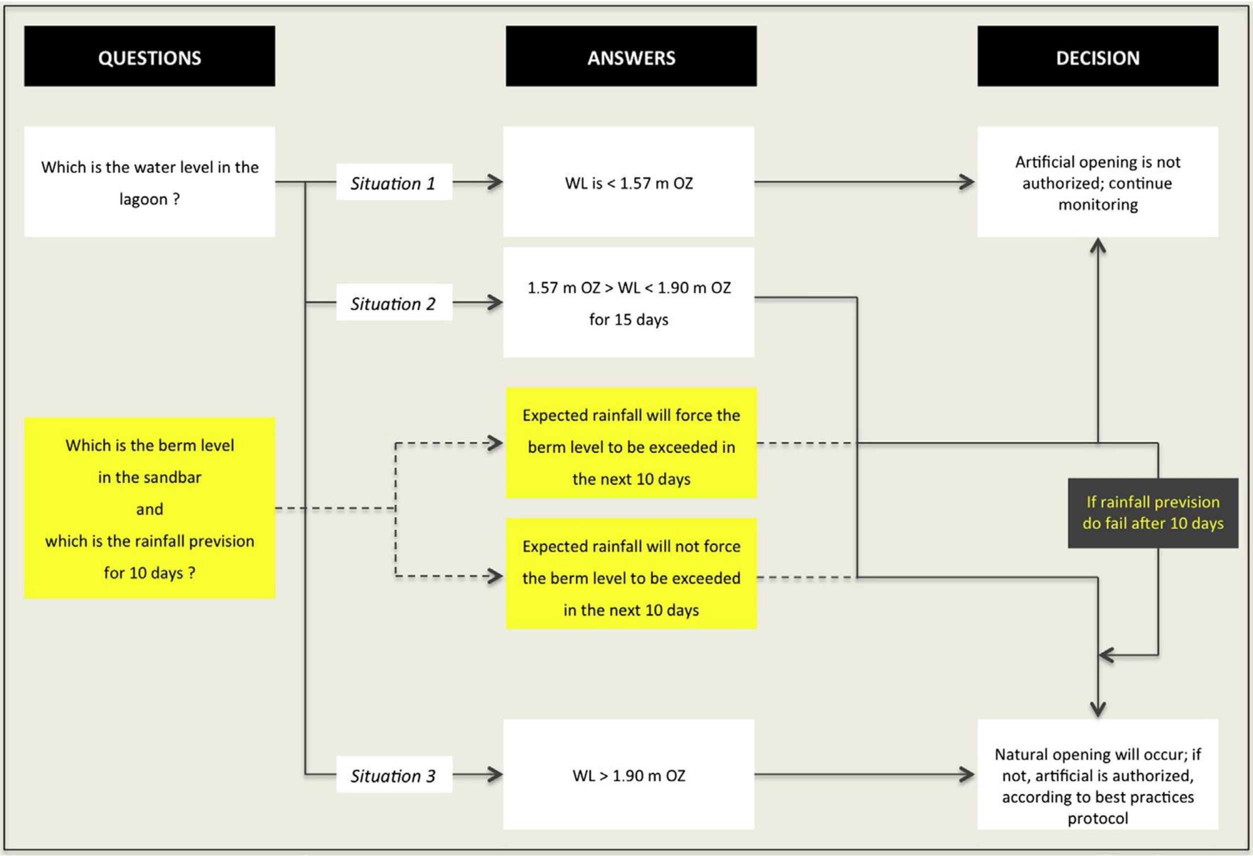

Figure B-3: Proposed decision-making model for the artificial opening of Laguna de Rocha sandbar

RHDHV International Experience

As an international consultancy, RHDHV has had the opportunity to work on coastal lagoon projects all over the world. RHDHV utilised its international network of engineers and scientists to investigate any relevant short-term entrance management policies that may be applicable to Narrabeen Lagoon. RHDHV engineers and scientists have undertaken a wide range of projects from morphological studies all the way through to detailed design of entrance management options (such as breakwaters) in locations such as:

- Israel;
- Tunisia;
- Columbia; and,
- South Africa.

However, with respect to short term entrance management, no additional or innovative policies were identified.

Appendix C: Lagoon Breakout Modelling

General

Mechanical opening of the lagoon is currently considered when lagoon water levels are between 1.0 m AHD to 1.3 m AHD subject to certain favourable conditions existing at the lagoon entrance. The current trigger water levels and conditions have been derived from best first-hand knowledge.

RHDHV has undertaken numerical modelling of various mechanical opening configurations to test the relative effectiveness of entrance breakouts under different conditions including:

- lagoon water level (or Initial Water Level) at the time of mechanical opening;
- breakout channel excavation bed level;
- tidal phasing; and,
- wave setup.

The Delft3D moveable bed morphology model that was developed for analysis of management options for the Narrabeen Lagoon Floodplain Risk Management Study (Cardno, 2019) was obtained for use in the analysis of options for the current entrance management strategy investigation. The model grid and bathymetry levels within the original model were retained for initial breakout runs, as was the ocean tide boundary condition comprising a +0.6 m AHD to -0.6 m AHD sinusoidal tidal signal (close to the mean tidal range) over a 30 hour simulation period.

A sand thickness was defined within the model to limit entrance scour to the bedrock level, which is an important process for breakout modelling at Narrabeen Lagoon where the bedrock is periodically exposed by entrance scour processes. Some anomalies were identified from review of the sand thicknesses within the original Deft3D model in comparison to the surveyed bedrock spot heights obtained from the lagoon entrance rock shelf survey undertaken by Public Works Department on 23rd April 1976 (Manly Hydraulics Laboratory, 1989). These anomalies were subsequently corrected by incorporating the surveyed bedrock surface into the model to define sand thickness relative to the entrance bathymetry.

The model bathymetry at the lagoon entrance comprised a grid of approximately 8m x 8m cells. Hence, the initial breakout channel was modelled to be 8m wide to approximate the typical width of around 5m that is achieved soon after excavation and initiation of the breakout flow (the initial excavation width in practice is approximately 2m). The original model bathymetry comprised a uniform 1.3 m AHD level across the beach berm area, which was used to represent the ‘closed and shoaled’ entrance condition for the ‘base case’ within the Narrabeen Lagoon Floodplain Risk Management Study (Cardno, 2019). This was modified to a more natural beach berm level of 2.0 m AHD in several of the final model runs to test the sensitivity of mechanical entrance opening to initial beach berm levels.

Several initial water levels within the lagoon were adopted for modelling of mechanical entrance opening scenarios. These comprised water levels representing the upper and lower bounds of the current trigger level range at 1.3 m AHD and 1.0 m AHD and a lower water level below existing triggers of 0.8 m AHD.

A number of output points were defined throughout the lagoon within the model (refer **Figure C-1**). Additional model output points were defined at the approximate start and end of the breakout channel alignment to assist with assessment of breakout processes (refer **Figure C-2**).

Figure C-1: Delft3D model output locations within lagoon

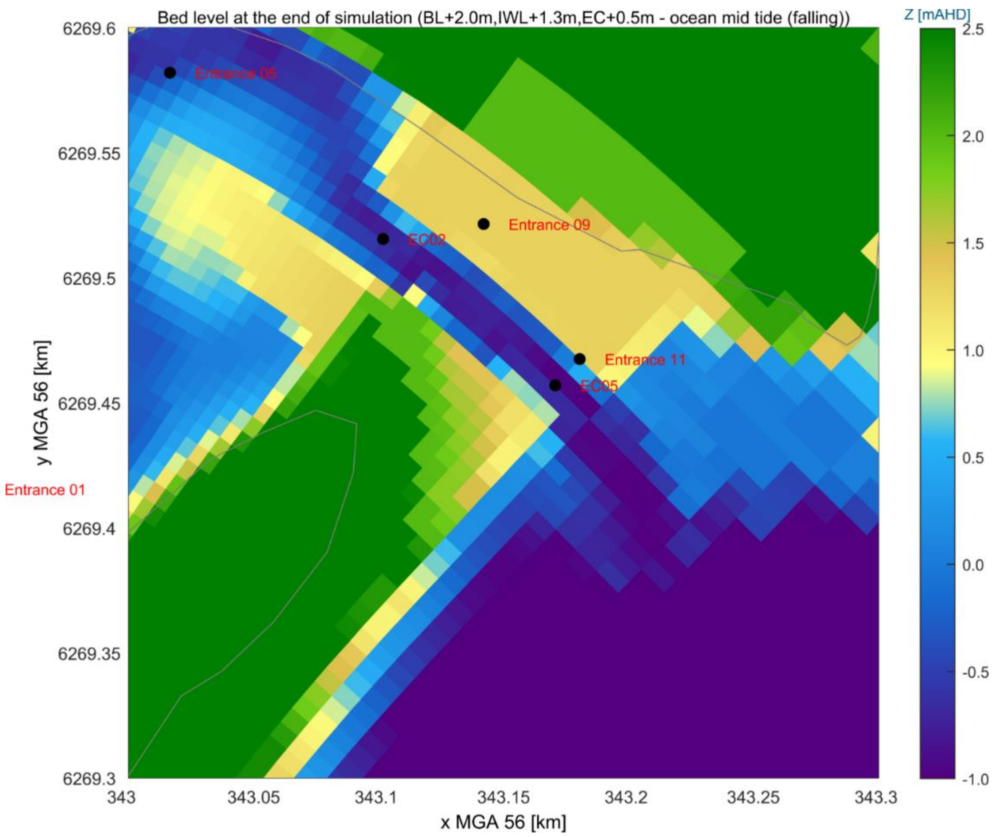

Figure C-2: Delft3D model output locations along breakout channel

The results from the modelling of various scenarios with each of these initial water levels as the starting condition for initiation of breakout processes is discussed below.

Initial Water Level = 1.3 m AHD

Model simulations for initial water level 1.3 m AHD were undertaken with the breakout channel bed level set at 0.5 m AHD, which was considered to be a reasonable excavation level that could be achieved in practice without groundwater causing slumping of the lower portion of the channel. Modelling of the initiation of breakout at different phases of the tide was undertaken by allowing the model to stabilise between t=0 and t=1hr before bed erosion was activated within the simulation to coincide with the following four different ocean tidal phases; mid tide rising, high tide, mid tide falling, and low tide.

The results of these simulations are summarised in **Table C-1** and indicate that, for the circumstances that were modelled, initiating the breakout at ‘mid tide falling’ produces the most rapid increase in channel discharge with the peak discharge being achieved after around 8 hours. **Figure C-3** shows that the breakout channel development occurring during the falling tide enables the peak channel discharge to be achieved at or around high tide and is then sustained at 25-30 cum/s until the next high tide occurs. This results in lagoon water levels falling at an earlier stage, although the maximum rate of water level falling is similar for all tidal phases (refer **Figure C-4**). The breakout channel scour level achieved at the end of the simulation (t=30hrs) was also similar at -0.90 to -0.98 m AHD, apart from the low tide simulation which achieved a slightly higher scour level of -0.79 m AHD. Notwithstanding, all simulations were considered to be successful breakouts with mid tide falling being indicated as the preferred tidal phase for initiation of breakout due to favourable timing of the early peak discharge development with the next falling tide.

Table C-1: Initial Water Level 1.3 m AHD Channel Breakout Results with Different Tidal Phasing

Tidal Phase	Initial Water Level (m AHD)	Entrance Channel Level (m AHD)	Peak Discharge (cum/s)	Timing of Peak Discharge (hrs from t=1hr)	Max. Rate of WL Falling (m/hr)*	Breakout Scour Level (t=30hrs)^
Mid Tide Rising	1.3	0.5	31.6	12.5	0.036	-0.98
High Tide	1.3	0.5	32.5	10.5	0.036	-0.90
Mid Tide Falling	1.3	0.5	31.2	8.0	0.036	-0.95
Low Tide	1.3	0.5	31.0	14.0	0.036	-0.79

* Measured at model output location Northern Basin 04

^ Measured at output location EC05

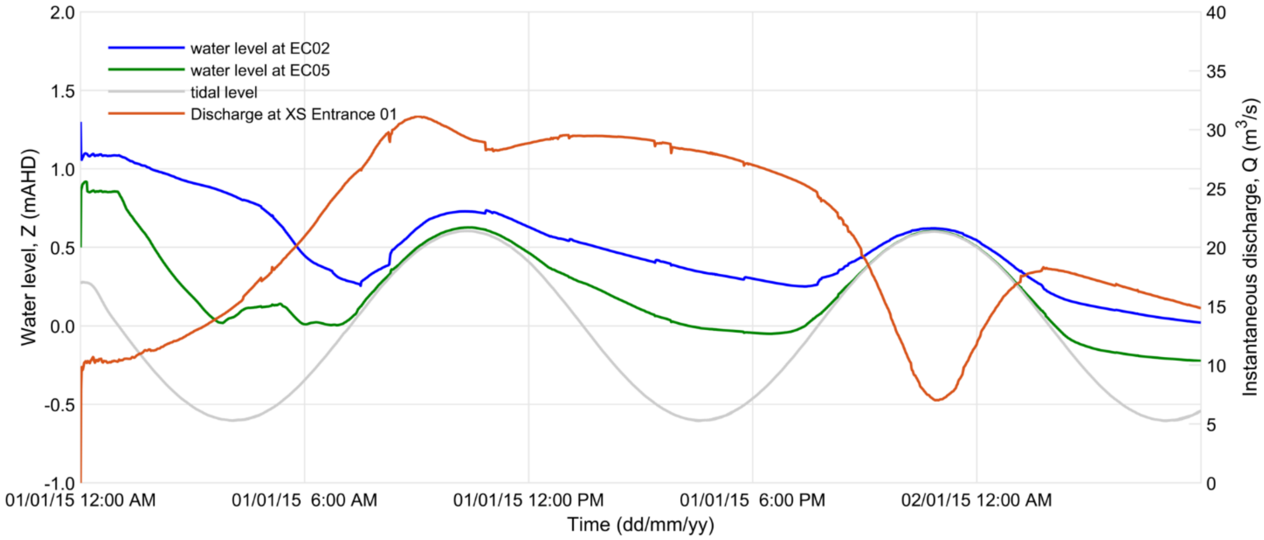

Figure C-3: Breakout Channel Discharge and Water Level – IWL 1.3, BC 0.5, Mid Tide Falling

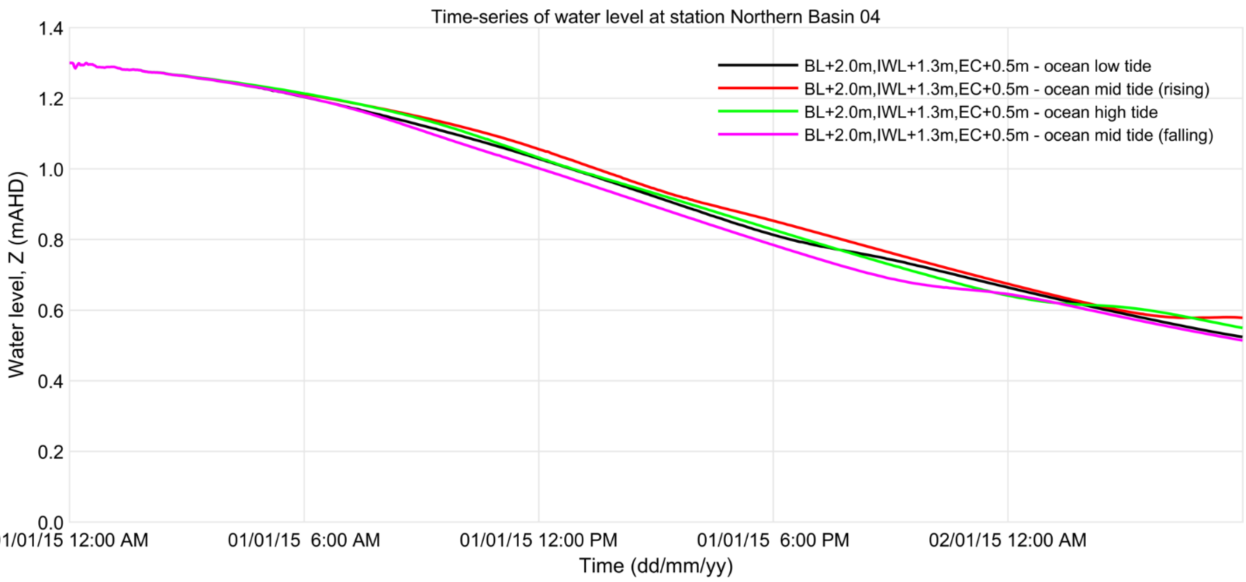

Figure C-4: Lagoon Water Level at Northern Basin 04 – IWL 1.3, BC 0.5

Additional simulations were undertaken to assess the impact of wave setup and beach berm level on breakout processes. It was considered that a wave setup of 0.2m and a beach berm level of 2.0 m AHD would represent the typical low ocean swell and naturally closed entrance berm conditions under which a breakout could be initiated. The results of these simulations are summarised in **Table C-2** and indicate that the inclusion of 0.2m wave setup on the ocean tide signal lowers the peak discharge and rate of water level falling (as would be expected due to the reduced lagoon to ocean head difference), and raises the resultant breakout channel scour level slightly (refer **Figure C-5**) but does not impact on the overall effectiveness of the breakout. The inclusion of a higher 2.0 m AHD beach berm in the entrance bathymetry did not have any significant impact on the breakout outcomes.

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Table C-2: Initial Water Level 1.3 m AHD Channel Breakout Results with Wave Setup and Berm Level 2.0 m AHD

Tidal Phase	Berm Level (m AHD)	Wave Setup +0.2m (Y/N)	Peak Discharge (cum/s)	Timing of Peak Discharge (hrs from t=1hr)	Max. Rate of WL Falling (m/hr)*	Breakout Scour Level (t=30hrs)^
Mid Tide Falling	1.3	N	31.2	8.0	0.036	-0.95
Mid Tide Falling	1.3	Y	27.3	7.5	0.033	-0.82
Mid Tide Falling	2.0	Y	27.4	7.5	0.034	-0.87

* Measured at model output location Northern Basin 04
^ Measured at output location EC05

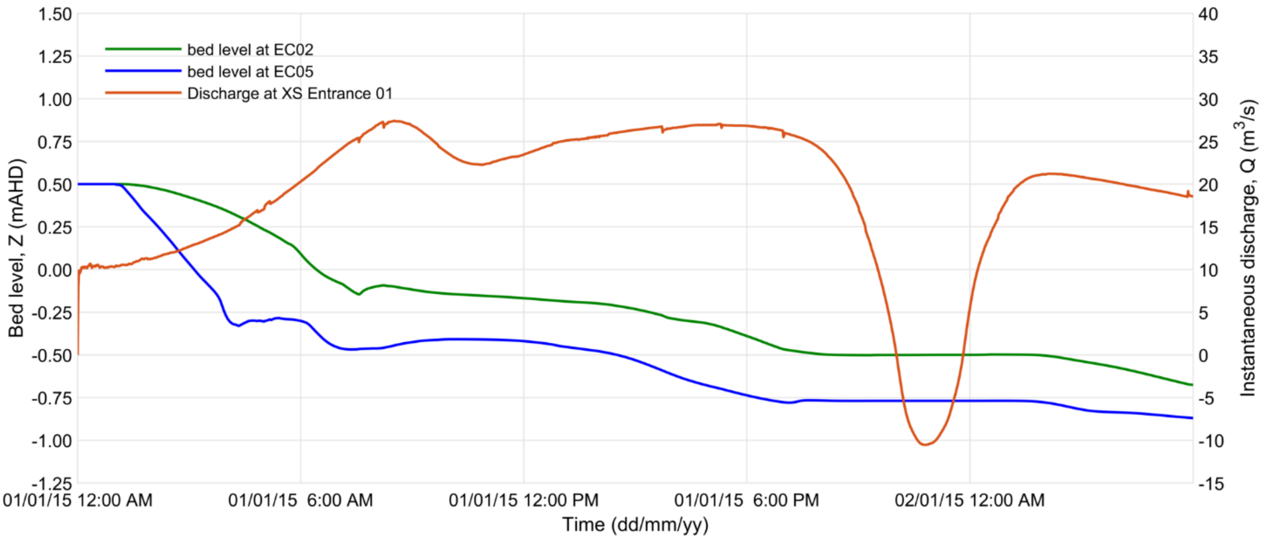

Figure C-5: Breakout Channel Bed Level Variation – IWL 1.3, BC 0.5, Mid Tide Falling, 0.2m wave setup

Plots showing the entrance area bathymetry initial conditions (t=0) and the resultant scour channel at the end of the simulation (t=30hrs) for the initial water level of 1.3 m AHD, beach berm at 2.0 m AHD, and 0.2m wave setup are provided in **Figure C-6**. This shows that the resultant scour channel is around 36m wide.

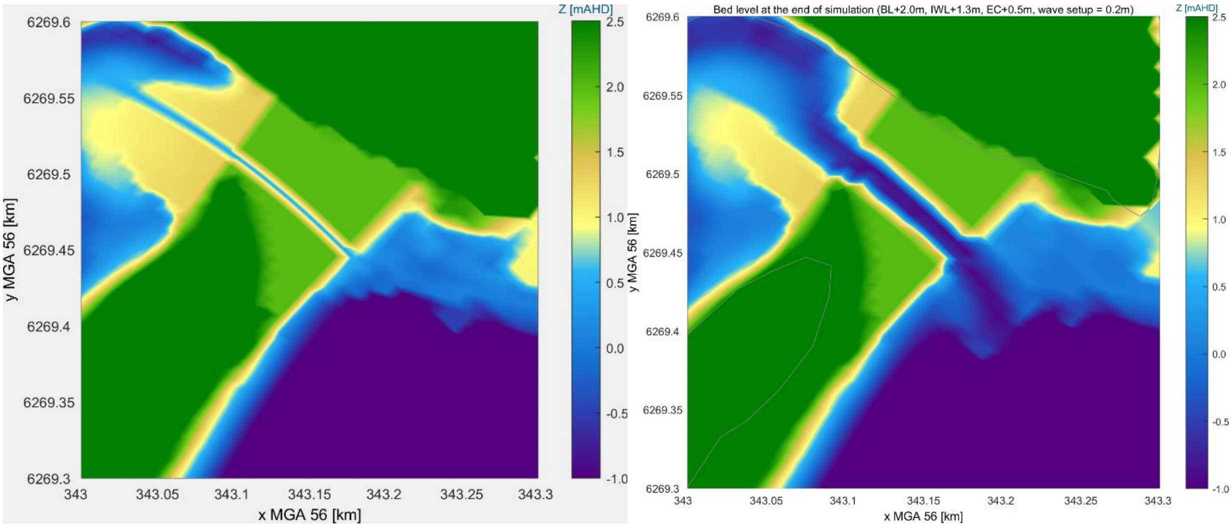

Figure C-6: Initial (left) and final (right) entrance bathymetry – IWL 1.3, BC 0.5, berm 2.0, 0.2m wave setup

Initial Water Level = 1.0 m AHD

The results of model simulations completed for an initial lagoon water level at 1.0 m AHD are summarised in **Table C-3**. The breakouts achieved at this trigger level were generally weaker than those at 1.3 m AHD. For the initial model run with the breakout channel excavation bed level set at 0.5 m AHD (refer **Figure C-7**), the peak discharge achieved was 50% lower and took longer to develop (20hrs), the rate of lagoon water level falling was slower, and the scour level in the channel was shallower. Lowering the breakout channel excavation level to 0.2 m AHD (refer **Figure C-8**) increased the speed of the breakout process with a higher peak discharge being achieved within 7hrs, with corresponding increases in the channel scour level and rate of lagoon water level falling.

The final model runs including 0.2m wave setup are considered to be the most realistic simulations as they include the effects of wave action and a more achievable channel excavation level at 0.5 m AHD. As shown in **Figure C-9**, the inclusion of wave setup significantly slows down the rate of discharge development in the channel. The breakout channel discharge at the end of the simulation is relatively low at 10.7 cum/s and is still rising at a low rate in between high tide periods. The resultant rates of lagoon water level falling (around 0.01m/hr) are significantly lower than those achieved at a trigger level of 1.3 m AHD and a shallower scour level (-0.2 m AHD) is also achieved (refer **Figure C-10**). Additional model runs were undertaken for breakout initiation at different tidal phases, however this did not significantly change the rate of breakout development or outcomes. **Figure C-11** shows that the scour channel at the end of the simulation is approximately 20m wide.

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Table C-3: Initial Water Level 1.0 m AHD Channel Breakout Results

Tidal Phase	Berm Level (m AHD)	Breakout Channel Level (m AHD)	Wave Setup +0.2m (Y/N)	Peak Discharge (cum/s)	Timing of Peak Discharge (hrs from t=1hr)	Max. Rate of WL Falling (m/hr)*	Breakout Scour Level (t=30hrs)^
Mid Tide Falling	1.3	0.5	N	14.2	20.0	0.016	-0.46
Mid Tide Falling	1.3	0.2	N	21.3	7.0	0.024	-0.81
Mid Tide Falling	1.3	0.5	Y	10.7	29.0	0.009	-0.21
Mid Tide Falling	2.0	0.5	Y	10.7	29.0	0.013	-0.21

* Measured at model output location Northern Basin 04

^ Measured at output location EC05

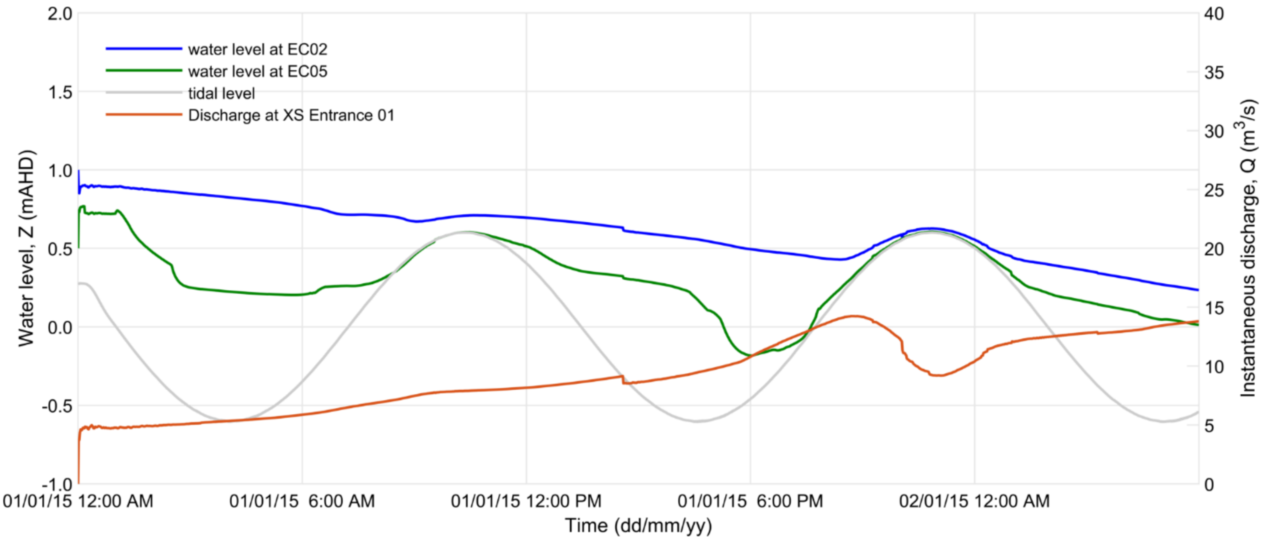

Figure C-7: Breakout Channel Discharge and Water Level – IWL 1.0, BC 0.5, Mid Tide Falling

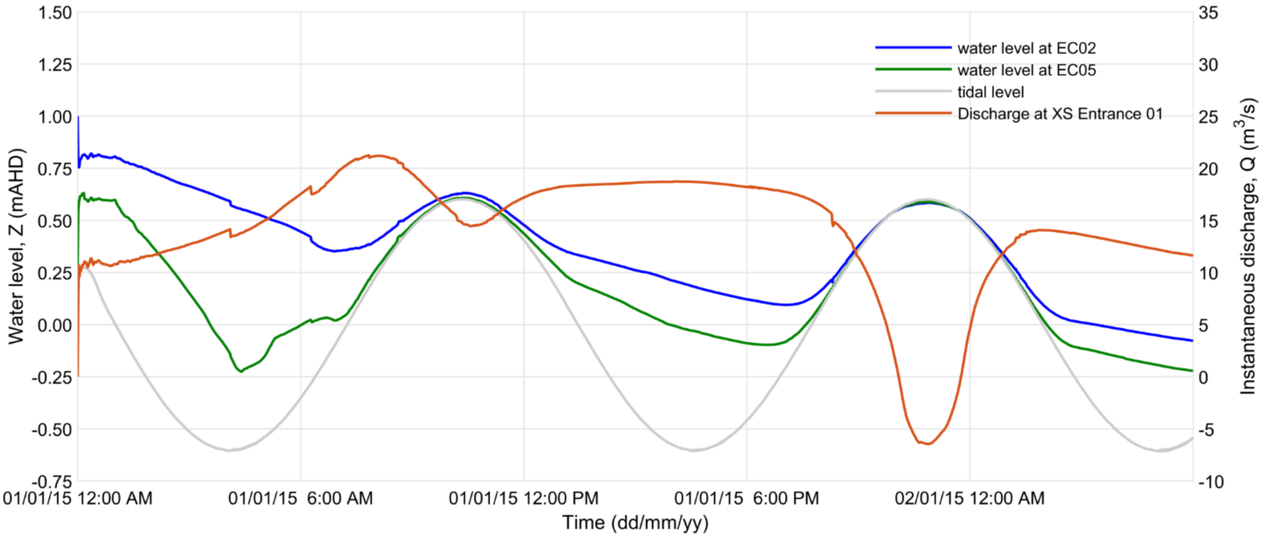

Figure C-8: Breakout Channel Discharge and Water Level – IWL 1.0, BC 0.2, Mid Tide Falling

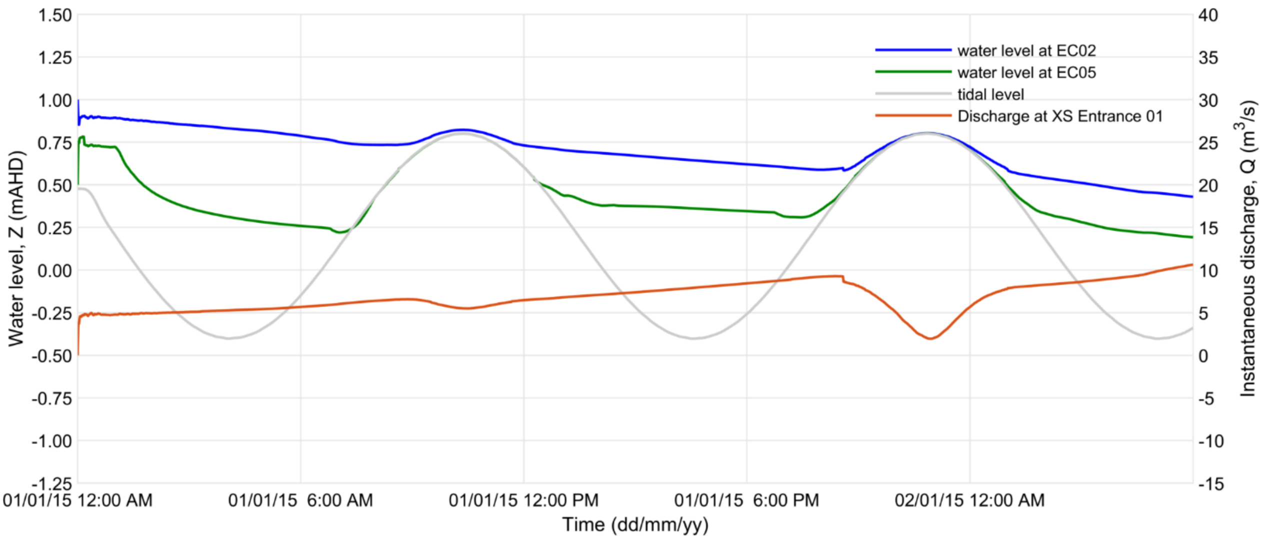

Figure C-9: Breakout Channel Discharge and Water Level – IWL 1.0, BC 0.5, Mid Tide Falling, 0.2m wave setup

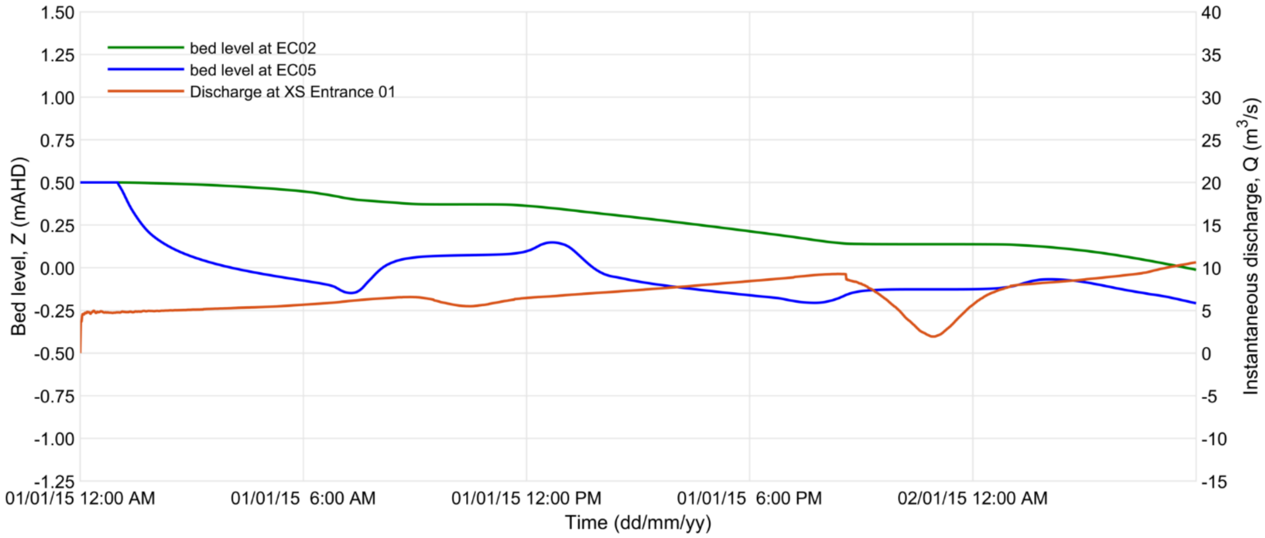

Figure C-10: Breakout Channel Bed Level Variation – IWL 1.0, BC 0.5, Mid Tide Falling, 0.2m wave setup

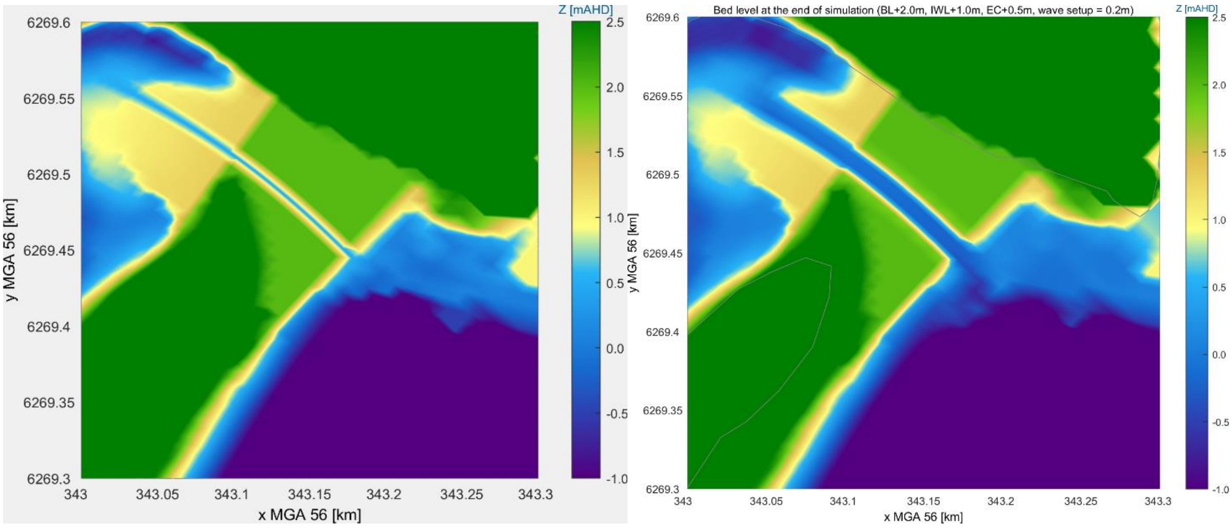

Figure C-11: Initial (left) and final (right) entrance bathymetry – IWL 1.0, BC 0.5, berm 2.0, 0.2m wave setup

Initial Water Level = 0.8 m AHD

The results of model simulations completed for an initial lagoon water level at 0.8 m AHD are summarised in **Table C-4**. The initial model run with the breakout channel excavation bed level at 0.5 m AHD (refer **Figure C-12**) demonstrated that the breakout channel would not become established at this excavation level. Excavation of a deeper breakout channel down to 0.2 m AHD was required to initiate the breakout process (refer **Figure C-13**). However, the breakout achieved was still weak when compared to the 1.3 m AHD trigger level with slower development of peak discharge, lower peak discharge, lower rate of lagoon water level falling and shallower channel scour level. The inclusion of wave setup to simulate more realistic ocean boundary conditions significantly impacted (adversely) the rate of channel discharge increase (refer **Figure C-14**).

Similar behaviour to the breakouts at a 1.0 m AHD trigger level was demonstrated, with a slow rise in channel discharge in between high tide periods that was still rising at the end of the simulation (t=30hrs). The breakout channel scouring process was also slow and stagnated during high tide periods (refer

Figure C-15). Additional model runs were undertaken for breakout initiation at different tidal phases, however this did not significantly change the rate of breakout development or outcomes. **Figure C-16** shows that the scour channel at the end of the simulation is approximately 20m wide.

Table C-4: Initial Water Level 0.8 m AHD Channel Breakout Results

Tidal Phase	Berm Level (m AHD)	Breakout Channel Level (m AHD)	Wave Setup +0.2m (Y/N)	Peak Discharge (cum/s)	Timing of Peak Discharge (hrs from t=1hr)	Max. Rate of WL Falling (m/hr)*	Breakout Scour Level (t=30hrs)^
Mid Tide Falling	1.3	0.5	N	1.8	-	0.002	0.27
Mid Tide Falling	1.3	0.2	N	11.9	19	0.015	-0.58
Mid Tide Falling	1.3	0.2	Y	12.4	29	0.014	-0.47
Mid Tide Falling	2.0	0.2	Y	12.4	29	0.017	-0.47

* Measured at model output location Northern Basin 04

^ Measured at output location EC05

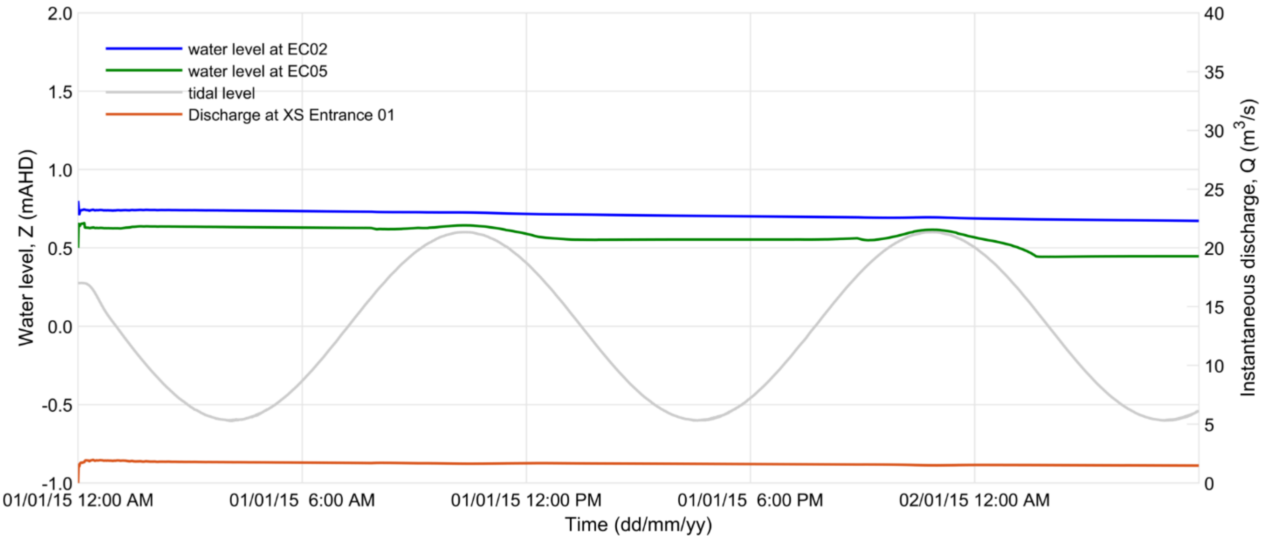

Figure C-12: Breakout Channel Discharge and Water Level – IWL 0.8, BC 0.5, Mid Tide Falling

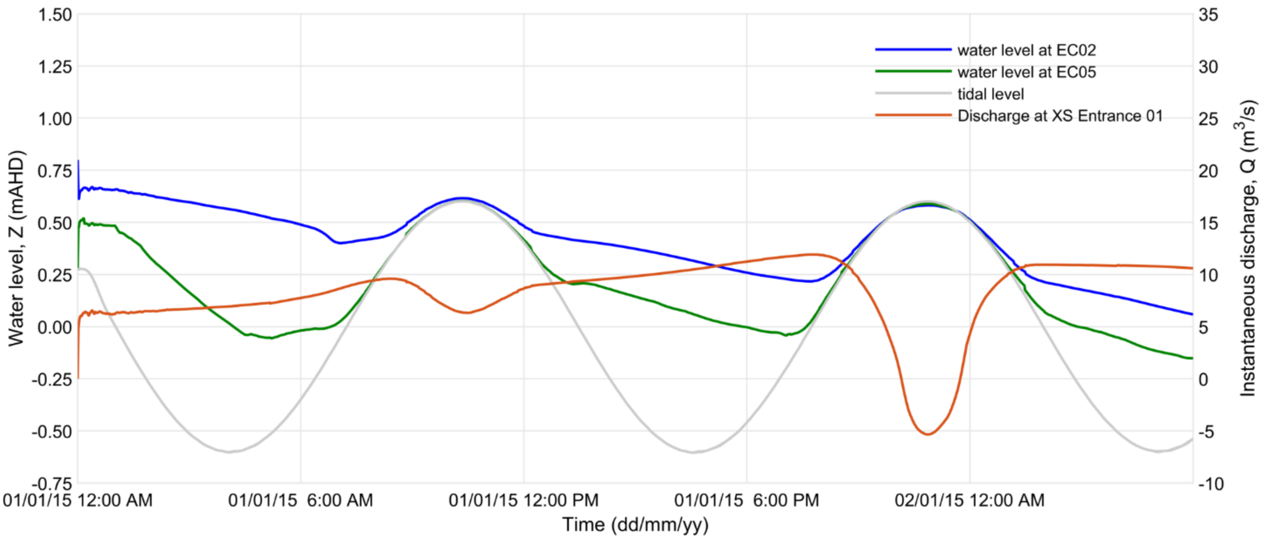

Figure C-13: Breakout Channel Discharge and Water Level – IWL 0.8, BC 0.2, Mid Tide Falling

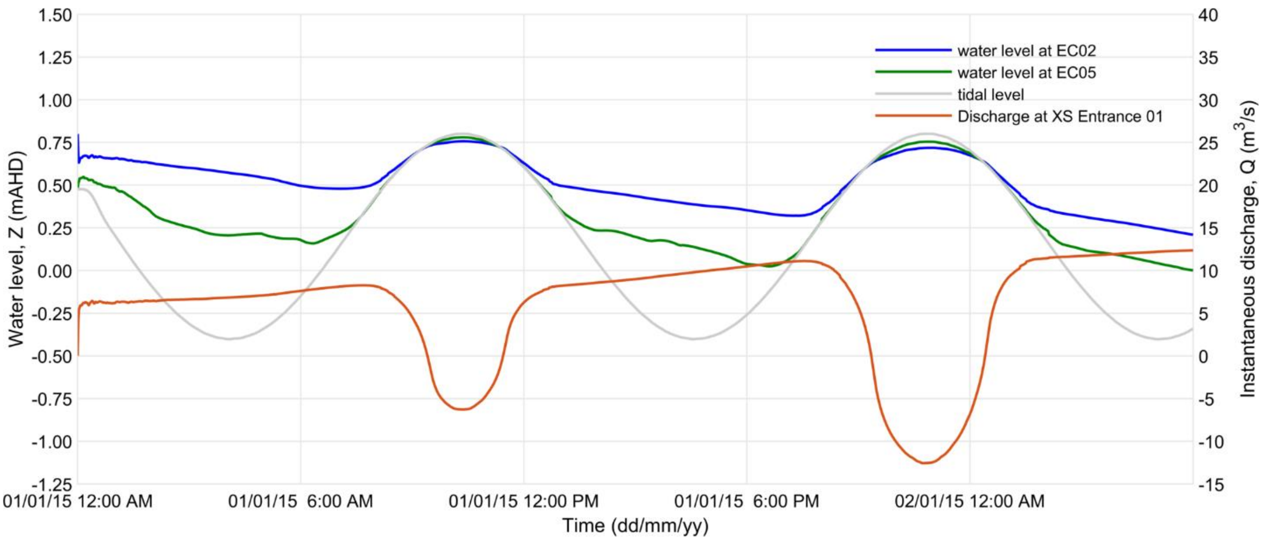

Figure C-14: Breakout Channel Discharge and Water Level – IWL 0.8, BC 0.2, Mid Tide Falling, 0.2m wave setup

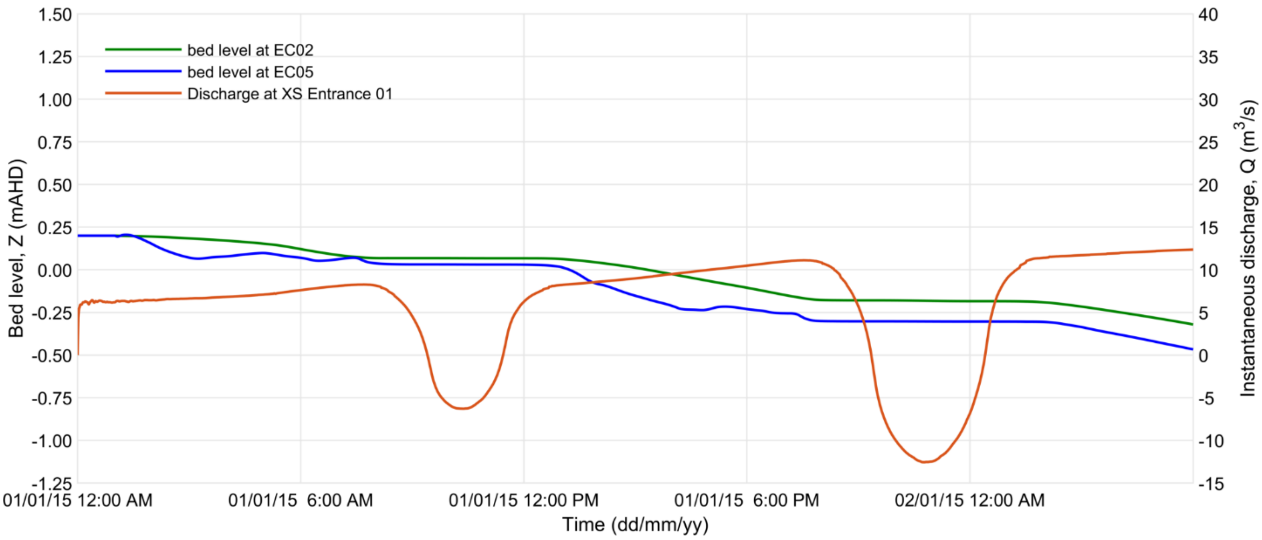

Figure C-15: Breakout Channel Bed Level Variation – IWL 0.8, BC 0.2, Mid Tide Falling, 0.2m wave setup

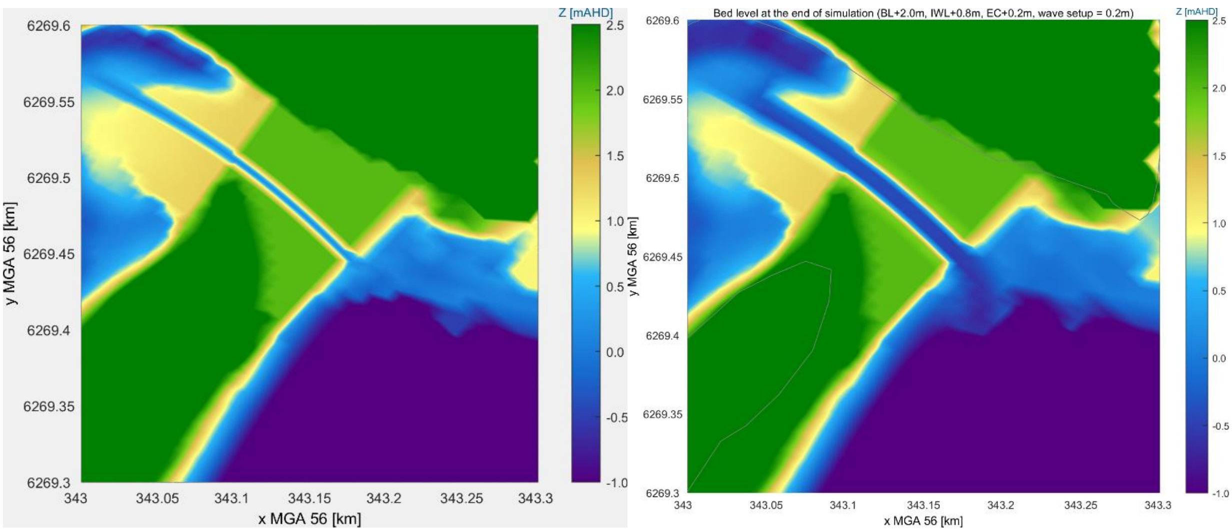

Figure C-16: Initial (left) and final (right) entrance bathymetry – IWL 0.8, BC 0.2, berm 2.0, 0.2m wave setup

Conclusions

A summary of the main conclusions from modelling simulations of breakout behaviour under various conditions is provided in the points below:

- Initial Water Level = 1.3 m AHD
  - Breakout channel bed level at 0.5 m AHD can initiate breakout.
  - Breakout is relatively strong with peak discharge achieved within 7-8 hours.
  - Initiation of breakout at mid tide falling allows the peak discharge to be achieved close to the next high tide so it can be sustained as the tide falls again (refer to further discussion below).

- Initial Water Level = 1.0 m AHD
  - Breakout channel bed level at 0.5 m AHD can initiate breakout.

- Breakout is weaker with slower build-up of channel discharge and lagoon water level fall rate. As a result, timing with tidal phasing is not as important.
- An extended period of time is required for lagoon drainage and channel scour to occur. Consequently, the narrower and shallower scour channel is more susceptible to infilling during this period by sand mobilised by wave action.

- Initial Water Level = 0.8 m AHD
  - Breakout could not be initiated with channel bed level at 0.5 m AHD. A lower excavation level of 0.2 m AHD was required, which may be difficult to achieve in practice due to slumping within the channel.
  - Breakout is weaker with slower build-up of channel discharge and lagoon water level fall rate. As a result, timing with tidal phasing is not as important.
  - An extended period of time is required for lagoon drainage and channel scour to occur. Consequently, the narrower and shallower scour channel is more susceptible to infilling during this period by sand mobilised by wave action.

It should be noted that although the modelling provided valuable insights and indicated that breakout initiation at mid tide falling provided favourable results, the historical experience of Council is that the commencement of breakout shortly after high tide is the best practice at Narrabeen Lagoon to achieve successful breakouts. This allows time for the scour channel to fully develop so that by low tide the lagoon is at peak discharge and as the tide then rises the resistance to emptying the Lagoon has the least effect on flood levels. As such, it is recommended that the historical practice of initiating breakouts shortly after high tide is continued.

Appendix D: Modelling of Long Term Management Strategy Options

Ebb tide Channel Modelling Discussion

The effectiveness of the proposed half tide training walls was evaluated within the Delft3D model used for the Narrabeen Lagoon Floodplain Risk Management Study (Cardno, 2019). The half tide training walls were incorporated into the model grid representing the open entrance bathymetry from the post entrance clearance survey completed in December 2018.

The Delft3D fixed bed model was run for a month long period with tides from December 2017, which had a large spring-neap tide range. The modelling results for water level, current speed and direction at output location 'Entrance 010', positioned inside the lagoon entrance channel (refer **Figure D-1**), are presented in **Figure D-2**. The strong asymmetry between flood and ebb tides current speed demonstrates that the flood tide current speed peaks at a greater value than the ebb tide. This indicates an upstream bias in the sand transport potential suggesting that under normal tidal conditions the entrance area is generally subject to infilling processes, as noted earlier (pending the movement and availability of material within the littoral zone).

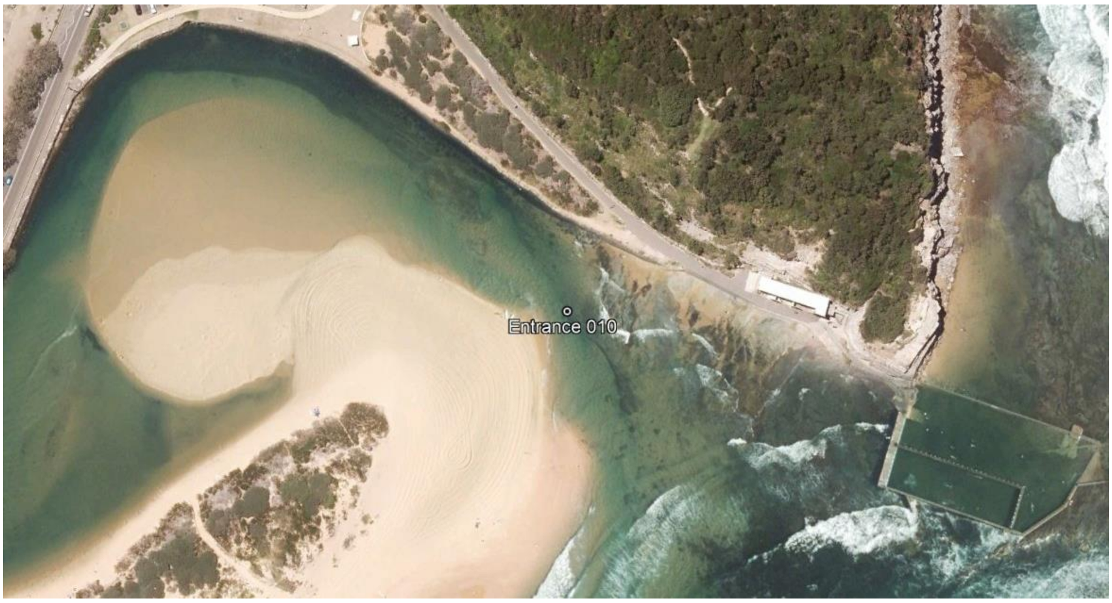

Figure D-1: Delft3D model output location Entrance 010

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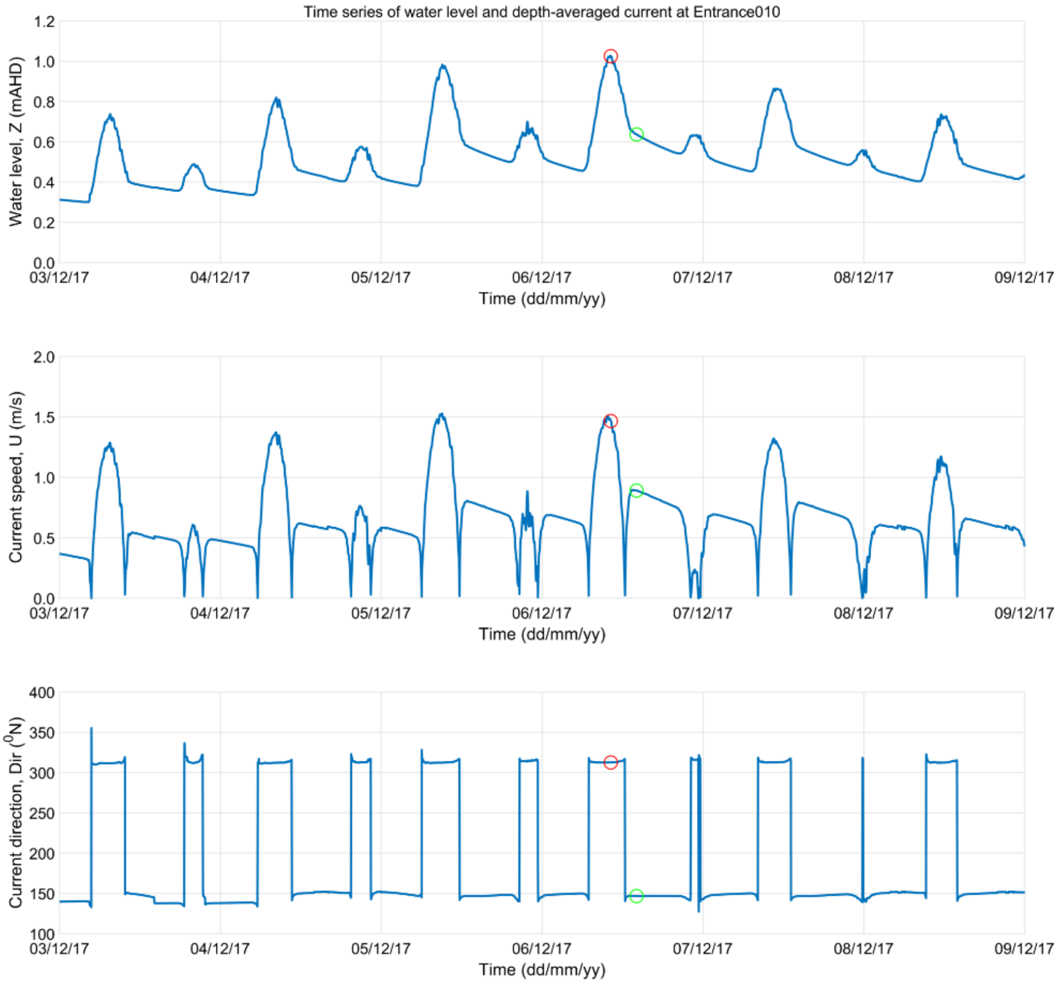

Figure D-2: Water level, current speed and direction at Entrance 010 for Ebb Tide Channel modelling

The Delft3D morphological model adopted a typical sand particle size diameter of 0.3 mm, which has a critical bed shear stress for mobilisation of 0.19 N/m^2. The bed shear stress at the peak current speed during the modelled flood and ebb tides within the fixed bed model simulation are presented in **Figure D-3**. The bed shear stress during flood tides shows potential sand mobilisation and transport in the entrance channel adjacent to Birdwood Dune and under the Ocean Street Bridge. The ebb tide results show sand transport potential only within the entrance channel and the area located just offshore of the beach berm. It is noted that the uncoloured areas within the ebb tide plot indicate that bed shear stress in these areas of the entrance are below the critical value for sand mobilisation during ebb tides.

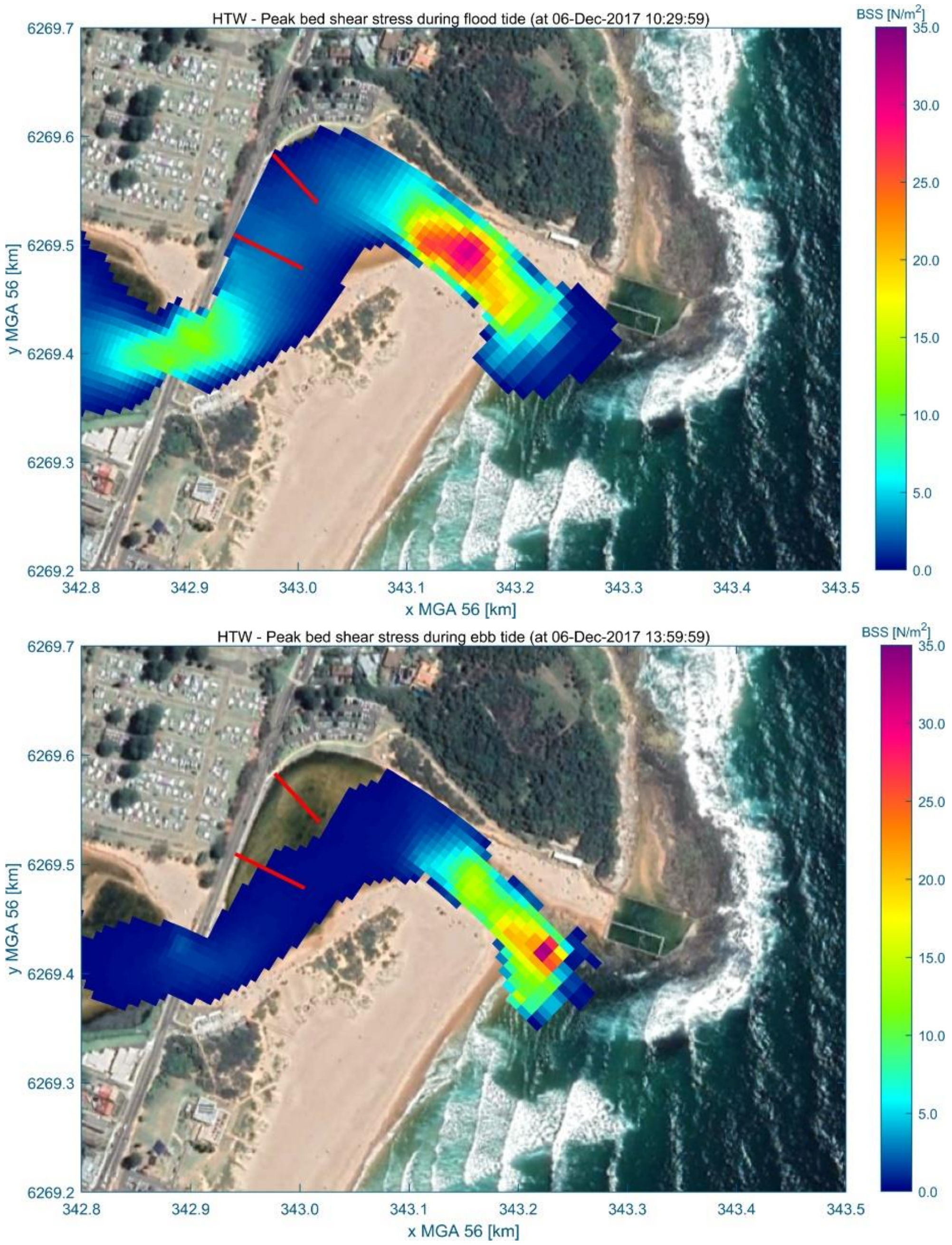

Figure D-3: Bed shear stress at peak flood (upper) and peak ebb (lower) tide currents for Ebb Tide Channel option modelling

The difference in modelled bed shear stress between the existing open entrance conditions (i.e. without half-tide training walls) and with the half-tide walls installed is presented in **Figure D-4** and **Figure D-5**. These results indicate that the installation of half-tide walls create an increase in flood tide bed shear stress around the end of the walls and a reduction in the lee of the walls. However, the area of bed shear stress increase is limited to localised areas around the ends of the walls. The ebb tide plot (refer **Figure D-5**) shows that there is no bed shear stress difference created by the half-tide walls, indicating that the walls are not effective in generating the desired increase in ebb tide currents to maintain an ebb tide dominated entrance channel. As such, the ebb tide channel option is not considered to be a technically feasible entrance management option and has been eliminated from further consideration. The results also suggest that in the event some additional ebb tide scour did occur at the outer end of the half tide walls the eroded sand would have settled only a short distance downstream.

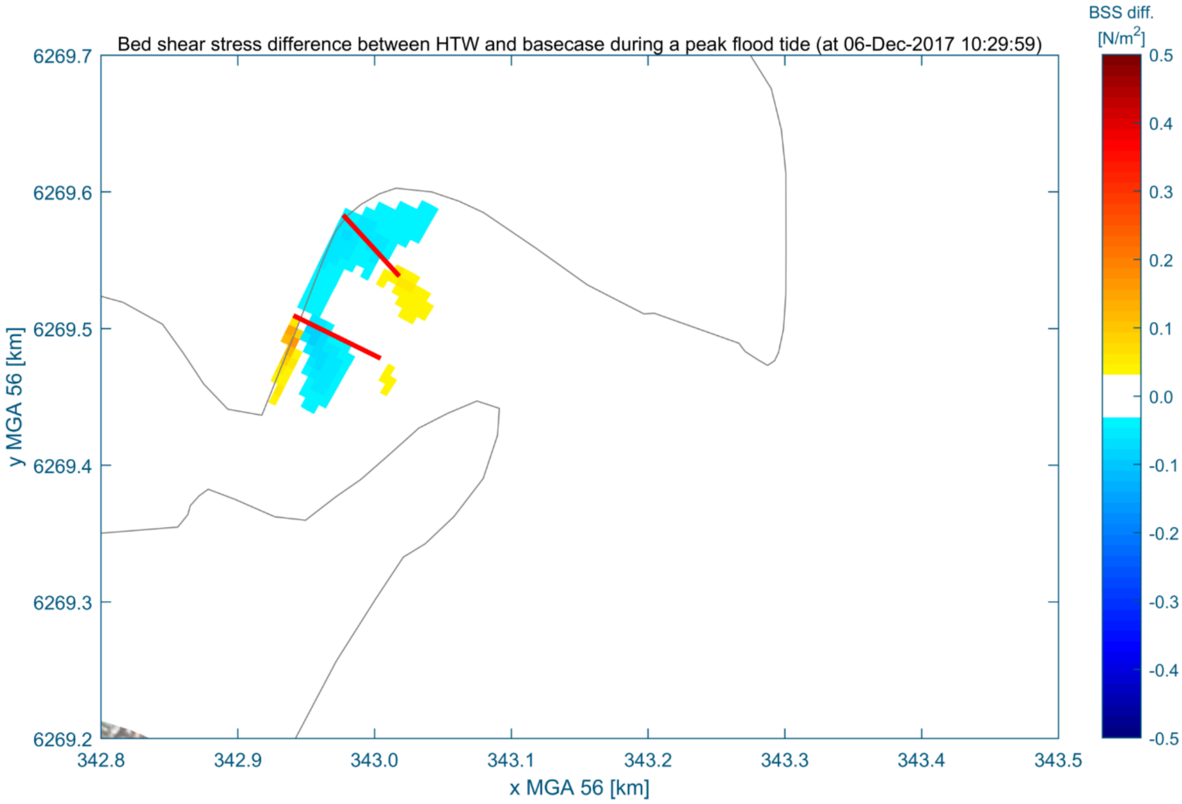

Figure D-4: Bed shear stress difference plot at peak flood tide for Ebb Tide Channel modelling

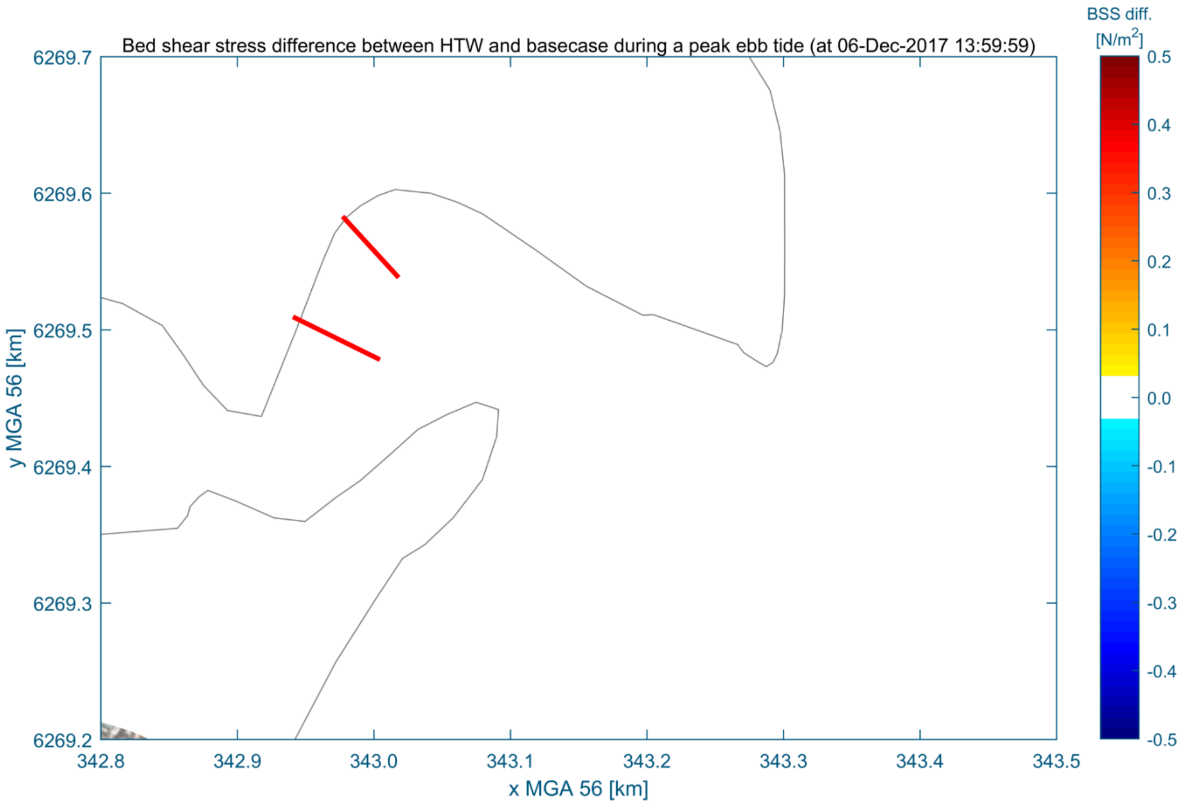

Figure D-5: Bed shear stress difference plot at peak ebb tide for Ebb Tide Channel modelling

Low Flow Pipes Modelling Discussion

The existing TUFLOW flood model was used to simulate the low flow pipe option as it includes a robust representation of pipe hydraulics. The model results from simulation of the low flow pipes (3 x 800 mm diameter pipes) under closed entrance conditions[16] over a 20 day period of tides are presented in **Figure D-6** for initial water levels in the lagoon of 1.3m AHD and 0.3m AHD. These plots show that under tide only conditions with no catchment inflows the low flow pipes are able to reduce the lagoon water level from 1.3 m AHD to 0.4 m AHD in around 20 days. The peak discharge through the pipes over this period is in the order of 2 m³/s. Over a further 20 days the lagoon water level reduces to 0.2-0.3 m AHD.

If the initial water level in the lagoon is 0.3m AHD, the water level reduces 0.1 m to 0.2 m AHD over the 20 day simulation period. It is noted that lowering of lagoon water levels to these levels for prolonged periods of time would have potential environmental impacts relating to reduced recreational amenity and drying of seagrass beds (refer **Section 6.4.3.2** and **Section 6.4.3.3**). Analysis of historical lagoon water level records from the Narrabeen Bridge (Pittwater Road) tide gauge has determined that water levels below 0.2 m AHD and 0.1 m AHD occur very rarely under the existing management regime at 4% and 0.4% occurrence respectively. Furthermore, when these low water levels occur the duration of events is relatively short with an average duration of less than 6 hours. As such, prolonged lowering of the lagoon water level to these levels has not occurred previously and is likely to have a significant impact on lagoon ecology.

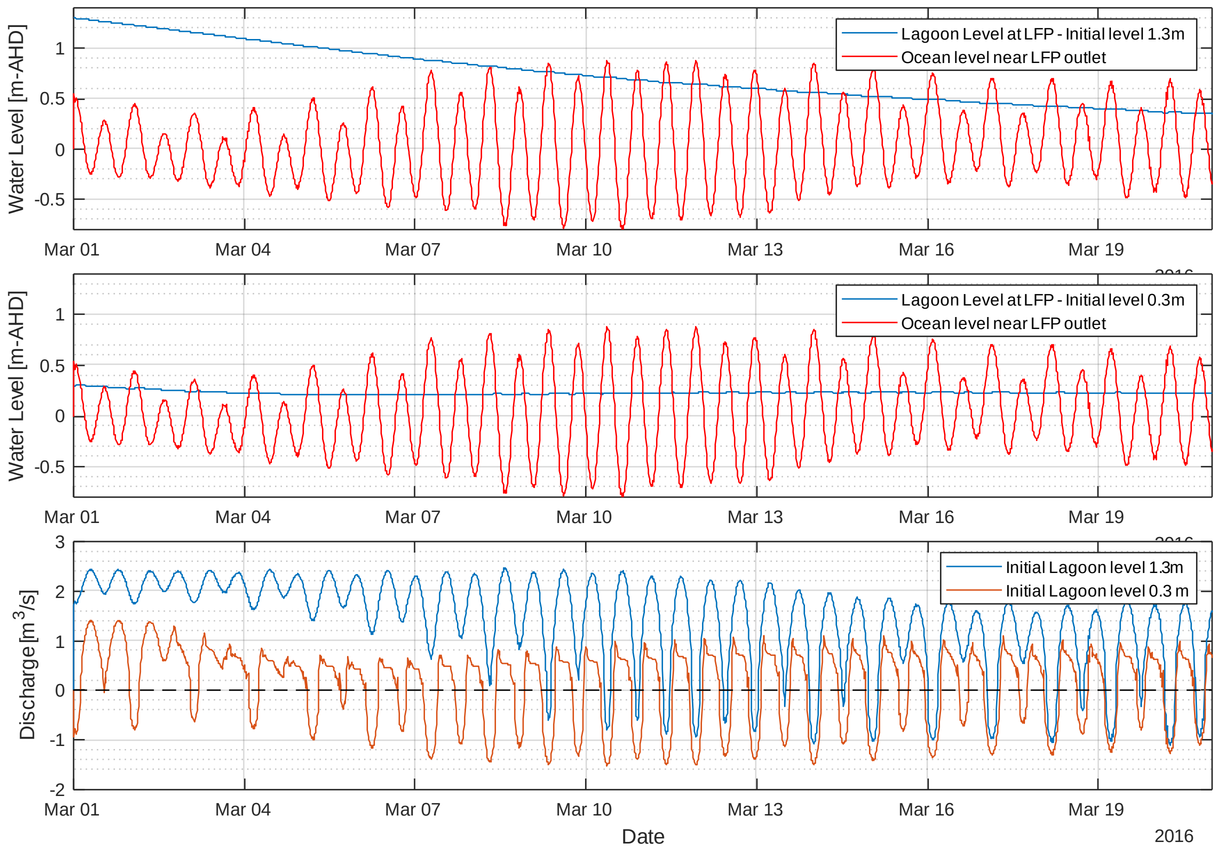

Figure D-6: Low flow pipe (LFP) modelling results, Water level variation IWL=1.3 m AHD (top), Water level variation IWL=0.3 m AHD (middle), Discharge through pipes (bottom)

[16] *Beach berm level set at 1.3m AHD within the model to represent a closed and shoaled entrance condition.*

To investigate the potential for the low flow pipes to reduce lagoon water levels during a long period of closure, a stage-discharge relationship was developed from the results of the model runs presented in **Figure D-6**. The stage, or driving head, is computed as the lagoon water level minus the ocean water level such that positive numbers represent an ebb tide. The stage-discharge relationship is shown in **Figure D-7** and was applied to the lagoon water levels during the long dry period from July 2005 to January 2007.

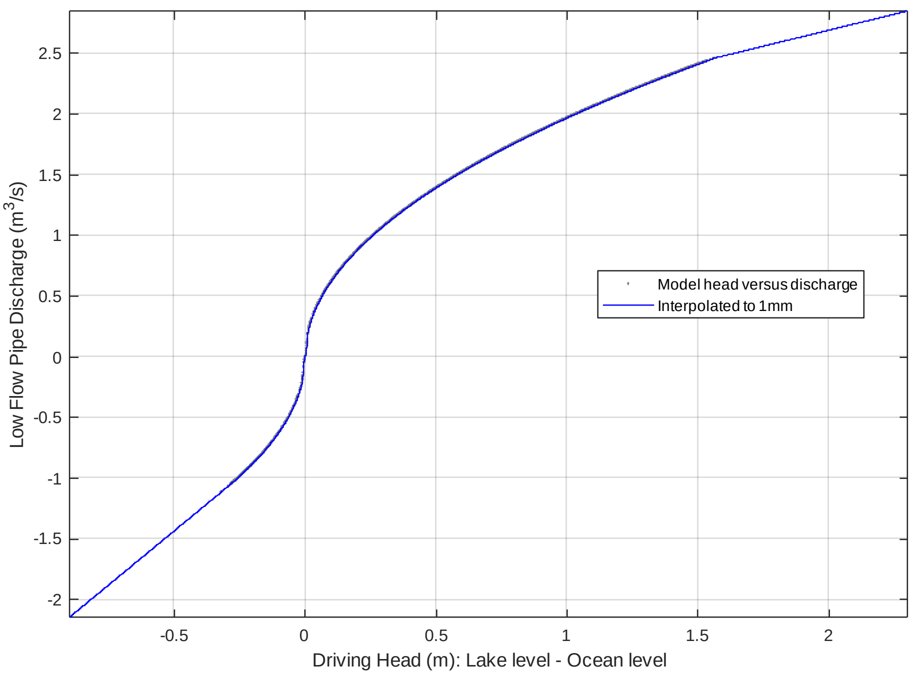

Figure D-7: Stage discharge relationship for proposed Low Flow Pipes configuration

The driving head is presented in **Figure D-8** and indicates the strong spring-neap cycle and the potential large head for flow out of the lagoon (positive head). The potential low flow pipe instantaneous and low-pass filtered discharge estimated from the stage-discharge relationship is also shown in **Figure D-8**. This indicates that the driving head between the lagoon and ocean water levels provides significant potential to transport water out of the lagoon during periods of entrance closure.

The potential decrease in water level that the low flow pipes could provide may be estimated using the following equation:

$$\frac{dVol_{Lagoon}}{dt} = Q_{Catchment} - Q_{Evap,Ground\ Losses} - q(\Delta h)_{LFP}$$

Where $dVol_{Lagoon}/dt$ is the rate of change of the Lagoon water volume at each time, $Q_{Catchment}$ is the discharge entering the lagoon from the catchment, $Q_{Evap,\ Ground\ Losses}$ is the discharge lost from the lagoon due to evaporation from the water surface and groundwater losses, and $q(\Delta h)_{LFP}$ is the discharge into (flood tide) and out of (ebb tide) the lagoon via the low flow pipes.

The lagoon volume at any time may be estimated from the water level and the water level/volume curve shown in **Figure D-9**. Integrating the low flow pipe discharge over a dry month gave a typical volume of water lost from the lagoon of about 500,000 to 700,000 m^3 equating to a water level decrease of around 10 to 20 cm.

It can be concluded that the installation of low flow pipes has the potential to lower lagoon water levels during periods of entrance closure. However, further assessment of their long term performance by modelled simulation of their performance using actual water level and flooding records is required. This would test the key assumption that sufficient time is always available before a flood event for the initial lagoon water level to lower to an equilibrium level of 0.3 m AHD (e.g. this may not be achieved if several flood events occur in close succession). To allow for this uncertainty an initial water level of 0.6 m AHD has been adopted in the flood modelling of the low flow pipes under closed entrance conditions completed for the purposes of the Cost Benefit Analysis (refer **Appendix E**).

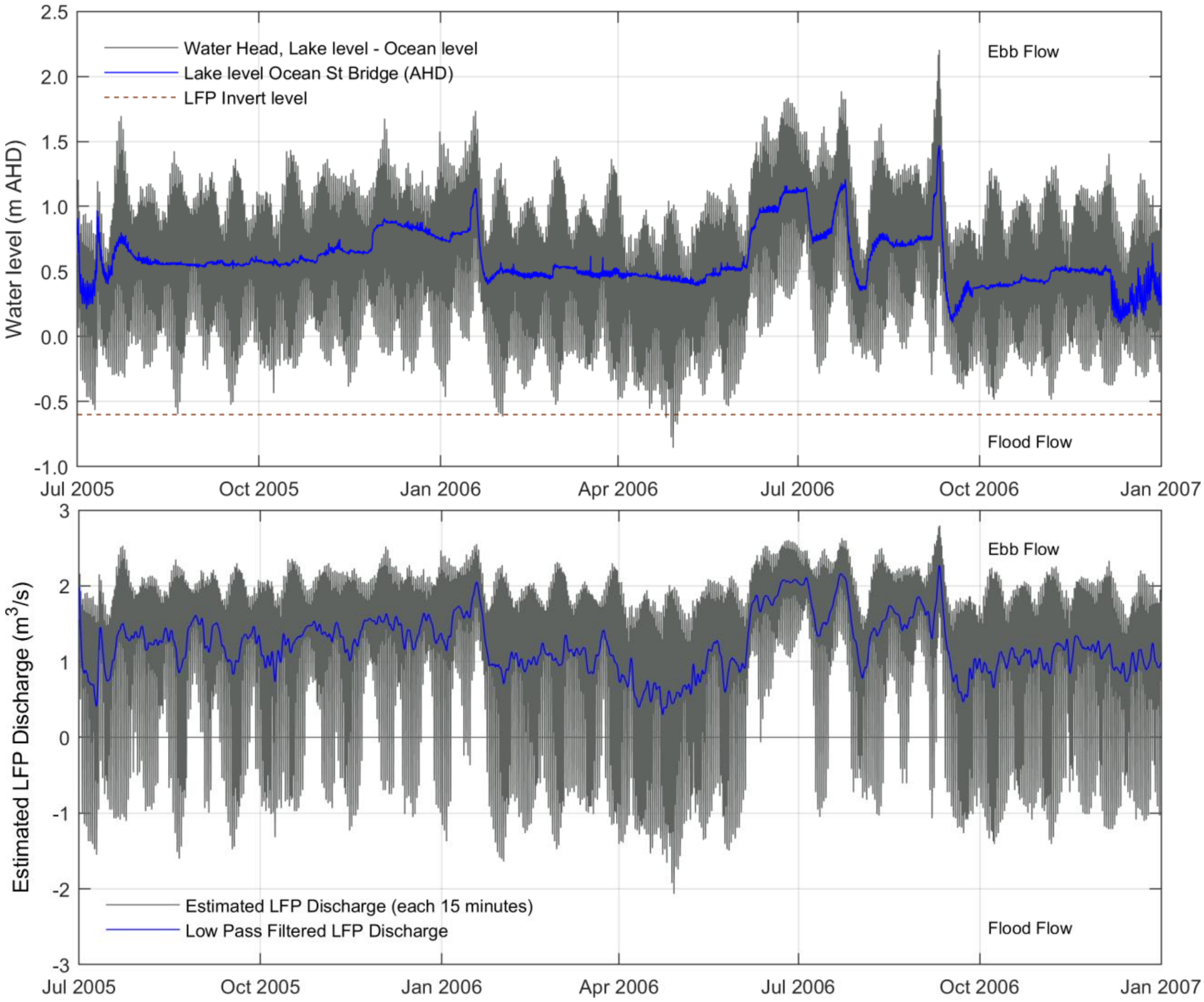

Figure D-8: July 2005 to January 2007 Low Flow Pipe (LFP) Simulation – Water level and driving head (upper), Discharge (lower)

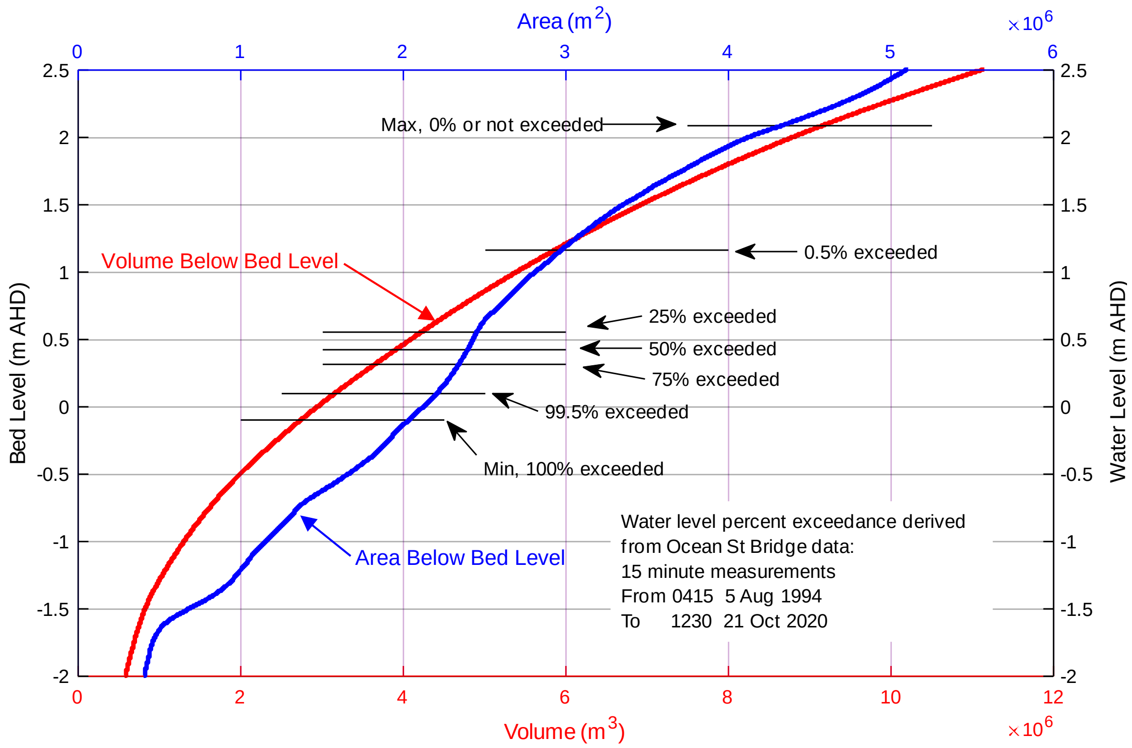

Figure D-9: Narrabeen Lagoon storage volume (red) and surface area (blue) versus bed level, and percent exceedance water levels

Appendix E: Cost Benefit Analysis

General

A Cost Benefit Analysis (CBA) has been undertaken by Marsden Jacob Associates to inform the economic evaluation of the various long term management options under consideration.

The analysis has been undertaken in accordance with NSW Government Guidelines for Cost-Benefit Analysis (TPP17-03). The CBA is the most comprehensive of the economic appraisal techniques and is the preferred method of analysis for most State and Commonwealth agencies responsible for economic management.

The CBA identifies the economic benefits and costs of the investment options to all stakeholders, including Council, other agencies and businesses and community. The CBA is based on an assessment of market and non-market economic benefits and costs.

The results of this analysis are summarised in the following sections.

Options Considered

The following five (5) options were considered in the CBA:

- **Option 1 – Base Case:** continuation of the current periodic (4 yearly) entrance clearance by excavation and trucking, with a volume of 40,000 m^3 per campaign
- **Option 2 – Excavation and Trucking at reduced intervals:** periodic entrance clearance by excavation and trucking, with an increased frequency (2 yearly) and reduced volume of 15,000 m^3 per campaign, with focus on maintaining a regime tidal channel
- **Option 3 – Mobile Sand Pumping:** periodic (4 yearly) entrance clearance by mobile sand pumping system, with a volume of 40,000 m^3 per campaign
- **Option 4 – Mobile Sand Pumping:** periodic entrance clearance by mobile sand pumping system, with a 2 yearly frequency and reduced volume of 15,000 m^3 per campaign, with focus on maintaining a regime tidal channel
- **Option 5 – Installation of Low Flow Pipes:** installation of low flow pipes plus periodic entrance clearance by excavation and trucking, with a 2 yearly frequency and reduced volume of 15,000 m^3 per campaign, with focus on maintaining a regime tidal channel

Generic Assumptions and Constraints

The economic analysis uses the following assumptions and parameters:

- 7% real discount rate with sensitivities of 3% and 10%, in accordance with NSW Government guidelines
- 30 year analysis period
- all cost and benefit values are in 2020 dollars

Cost Assumptions

Infrastructure Cost

The capital and operating costs associated with each of the five CBA options were prepared by Muller Partnership and are summarised in **Table E-1** in accordance with how they align with the cost items presented in the cost benefit analysis. The costs associated with each option are explained further below.

Table E-1: Cost assumptions used in CBA from Muller Partnership (2021)[17]

Cost Item	**Option 1** Excavation and Trucking (4 yearly)	**Option 2** Excavation and Trucking (2 yearly)	**Option 3** Mobile Sand Pumping (4 yearly)*	**Option 4** Mobile Sand Pumping (2 yearly)*	**Option 5** Low Flow Pipes
Capital cost					
Pipelines	-	-	$528,200	$528,200	$4,171,400
Pump Station	-	-	$425,000	$425,000	-
Other Capex	-	-	$707,800	$707,800	$1,040,600
Capex contingency (Options 1-4 = 20%, Option 5 = 50%)	-	-	$332,200	$332,200	$2,606,000
Ongoing cost					
Maintenance (per campaign)	$2,148,000	$1,152,000	$2,610,000	$1,725,600	$1,192,200
Pump replacements (every 15 years)	-	-	$480,000	$480,000	-

Note: * Costs for Options 3 and 4 are based on installation of a permanent pipeline to Devitt Street and Council purchase, storage and maintenance of temporary pipeline and pumping stations for periodic use by mobile sand pumping contractors.

Option 1 and Option 2 – Excavation and Trucking

Option 1 and Option 2 use the same long term entrance management methodology but at different frequencies. Option 1 assumes the entrance is cleared by excavation and trucking of 40,000 m^3 of sand every four years. The frequency of entrance clearance is increased and sand volumes are reduced under Option 2, with 15,000 m^3 being excavated and trucked to Collaroy Beach every two years.

There are no capital costs, or upfront costs, associated with either Option 1 or 2. Maintenance costs, the cost of manual entrance clearance by excavation and trucking, is assumed to occur:

- Under Option 1 every 4 years at a total cost of $2.15 million, incl. a 20% contingency; and,

[17] *Muller Partnership, 2021, Narrabeen Lagoon Entrance Management concept Design Estimates and whole Of Life Assessments (Rev 2), 7 June.*

- Under Option 2 every 2 years at a total cost of $1.15 million, incl. a 20% contingency.

The maintenance costs are lower for Option 2 compared to Option 1 primarily because of the smaller volume of sand removed per campaign.

Option 3 and Option 4 – Mobile Sand Pumping

Option 3 and Option 4 involve implementation of mobile sand pumping infrastructure, but at different frequencies. Option 3 assumes that the entrance is cleared by pumping about 40,000 m^3 of sand to Collaroy Beach every four years. The frequency of entrance clearance is increased and the sand volumes reduced under Option 4, with 15,000 m^3 being pumped to Collaroy Beach every two years.

The upfront capital costs associated with Option 3 and 4 are $1.99 million (incl. a 20% contingency) because the same methodology is used for both options. The costs include pipelines, pump stations, other capital expenses, such as site preparation, remediation and preliminaries and margins, as well as a 20% contingency on all these costs.

In addition, both options include a cost of $480,000 every 15 years for the replacement of pumps.

Maintenance costs for both Option 3 and Option 4 are estimated at $2.61 million and $1.73 million, respectively, per campaign including contingencies. Maintenance includes temporary pipeline assembly, pipeline and pump operation and other costs such as site preparation and remediation.

Option 5 – Low Flow Pipes

This option involves the installation of low flow pipes at the lagoon entrance to provide some release of rainfall runoff and allow tidal exchange between the lagoon and the ocean when the entrance is otherwise closed by sand ingress. The low flow pipes would be implemented in conjunction with periodic entrance clearance campaigns, assumed to be completed on average every 2 years with excavation and trucking.

The upfront capital costs under Option 5 amount to $7.82 million, including a 50% contingency. This covers the installation of the low flow pipes as well as site preparation and remediation.

Maintenance costs associated with Option 5 total $1.19 million per campaign. This includes the maintenance cost of the low flow pipes, such as annual cleanouts of pipelines (about $14,250 incl. contingency) and 2 yearly inspections of the pipelines (about $25,920 incl. contingency). In addition, the maintenance costs include periodic entrance clearance campaigns. The costs for these are the same as for Option 2 ($1.15 million).

Other Costs

All options incur additional costs for project management, contract administration and design, and preparation of a Review of Environmental Factors (REF). Council advised the following additional costs per entrance clearance campaign:

- $40,000 per campaign for project management and contract administration; and,
- $60,000 per campaign for seagrass mapping, design and REF preparation.

In addition, the economic cost of trucking sand to Collaroy Beach was estimated by Marsden Jacob Associates using the Transport for NSW (TfNSW) Economic Parameter Values. The economic cost takes into account congestion costs and other externalities, such as air pollution, greenhouse gas (GHG) emissions and noise pollution, arising from trucking of sand from the Narrabeen Lagoon entrance to Collaroy Beach. The economic costs associated with trucking the sand are estimated to be:

- \$80,671 for 40,000 m^3 of sand per campaign under Option 1; and,
- \$30,252 for 15,000 m^3 of sand per campaign under Option 2.

These estimates assume that bogie trucks are used, which are classified as Medium Rigid (Vehicle Class 4) and have a capacity of 10 tonnes. Loaded trucks leave Birdwood Park carpark, turn right onto Ocean Street and then take the next left into Walsh Street to access Pittwater Road and ultimately Mactier Street (a travel distance of about 4.1 km, refer **Figure E-1**). This is done to minimise trafficking of heavily loaded trucks on local roads such as Ocean Street. Empty trucks leave Mactier Street, turn right at the lights onto Pittwater Road and then turn into Ocean Street heading north to Birdwood Park (a travel distance of about 2.3 km, refer **Figure E-2**). Approximately 8,000 round trips are made under Option 1 and 3,000 round trips under Option 2.

The cost of urban congestion and urban externalities for Class 4 vehicles were sourced from TfNSW:

- Urban congestions costs are \$1.3464 per vehicle kilometre; and,
- Urban externalities, including air pollution, GHG emissions and noise pollutions, are \$0.2292 per vehicle kilometre.

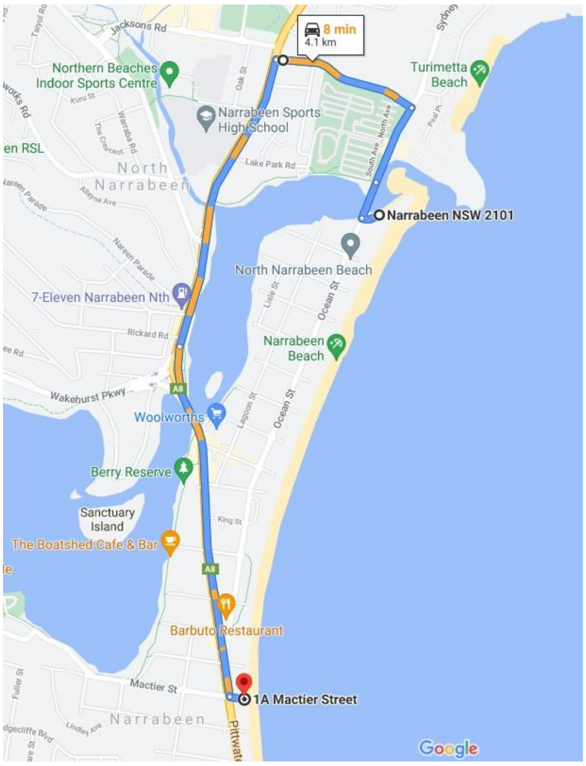

Figure E-1: Trucking route for loaded trucks from Narrabeen Lagoon Entrance to Mactier Street / Collaroy Beach

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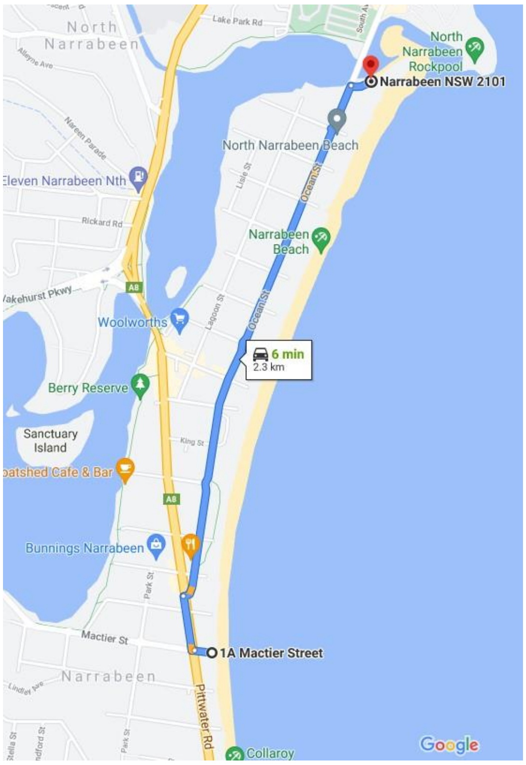

Figure E-2: Trucking route for empty trucks from Mactier Street / Collaroy Beach to Narrabeen Lagoon Entrance

Flood Damage Cost Assessment

Flood Modelling

Flood modelling of the site was undertaken with the Delft3D model used for the Narrabeen Lagoon Floodplain Risk Management Study (Cardno, 2019). Five different design flood events (5 year, 20 year, 100 year, 1000 year ARI events as well as the probable maximum flood) were modelled to assess the extent and depth of flooding and associated impacts (e.g. numbers and types of properties affected and depth of flooding).

Flood modelling was completed for open and closed lagoon entrance conditions, and varying assumptions regarding the initial lagoon water level, presence of low-flow pipes and entrance clearance strategy. The cost benefit analysis was based on application of flood modelling results from several scenarios, referred to as Model Run 1, 3, 4 and 6 (see below).

- Model Run 1 – closed and shoaled entrance (berm level 1.3m AHD, initial water level of 1.3m AHD)
- Model Run 3 – open entrance post entrance clearance campaign before progressive shoaling occurs (initial water level of 0.3 m AHD)
- Model Run 4 – closed and shoaled entrance with low flow pipes in place (berm level 1.3 m AHD, initial water level of 0.6 m AHD)
- Model Run 6 – regime tidal channel (initial water level of 0.3 m AHD)

The lagoon entrance can close relatively quickly, i.e. within a few months, after an entrance clearance campaign. As such, assumptions were required regarding the probability of entrance conditions, i.e. the proportion of time the entrance will be open (post entrance clearance condition, before progressive shoaling occurs), closed, or in a state in between, to calculate an expected value of annual average damage costs. The probabilities applied in the CBA model, as discussed earlier, are shown in **Table E-2**.

Table E-2: Entrance condition probabilities by CBA option

CBA Option	Entrance Open	In between	Entrance closed
Option 1 – Excavation & Trucking (4 years)	15%	60%	25%
Option 2 – Excavation & Trucking (2 years)	40%	45%	15%
Option 3 – Mobile Sand Pumping (4 years)	15%	60%	25%
Option 4 – Mobile Sand Pumping (2 years)	40%	45%	15%
Option 5 – Low Flow Pipes (2 years)	40%	45%	15%

Flood Damage Costs

Flood damage costs for residential and commercial buildings for the five different design flood events were established using NSW Floodplain Risk Management Guidelines – Residential Flood Damage (DECC (now DPIE), 2007) for residential properties and the Victorian Rapid Appraisal Method for Floodplain Management (Flood RAM) (DSE, 2009) for commercial and industrial properties.

Both the NSW Floodplain Risk Management Guidelines (Residential Flood Damage) and VIC Flood RAM are very similar methodologies for the rapid and consistent evaluation of floodplain management measures in a benefit cost analysis framework. Both the NSW and VIC methodologies enable estimates of flood damages to be made for an area without the need for excessive amounts of detailed property data. It ensures consistency and hence comparability across different evaluations.

Residential Cost Curves

Building damage costs for residential buildings is a function of overfloor inundation and building type. Building damage costs are higher for single-storey dwellings. Similarly, the value of contents lost depends on overfloor inundation depths. **Table E-3** outlines the damage cost curves or equations for the three residential building types considered:

1. single storey house, low set / slab on ground
2. two storey house, low set / slab on ground
3. single storey house, high set[18] (i.e. built on elevated foundations)

Information on the types of properties and their ground and floor levels was provided by Council and used to determine the above ground and overfloor inundation depths under the different design flood events and lagoon entrance conditions.

[18] *A high-set building is usually defined as a building with a floor level of at least 1.5 metres above ground level.*

Table E-3: Residential building (structural) and content damages ($2020)

Building Type	Depth of overfloor inundation (m)	Structural Damage ($)	Content Damage ($)
Single-Storey Residential – low set	0 < x ≤ 2	y = 18,467 + 6,833 x	y = 24,758 + 24,758 x
	x > 2	y = 18,467 + 6,833 x	y = 74,273
Single-Storey Residential – high set	-1.5 < x < 0	y = 23,268 + 10,456 x	y = 0
	0 ≤ x ≤ 2	y = 23,268 + 10,456 x	y = 24,758 + 24,758 x
	x > 2	y = 23,268 + 10,456 x	y = 74,273
Double-Storey Residential	0 < x ≤ 2	y = 12,927 + 4,783 x	y = 17,330 + 17,330 x
	2 < x ≤ 2.6	y = 12,927 + 4,783 x	y = 51,991
	x > 2.6	y = 20,314 + 7,516 x	y = 81,700

Note: y = estimated damage; x = overfloor depth (m)

Clean-up costs and external damages were accounted for in addition to building and content damages. Estimates recommended in the NSW Floodplain Risk Management Guidelines were adjusted so that they reflect 2020 year values. Clean-up costs were assumed to be $6,602 per flood affected property. External damages were assumed to be $11,058 per flood affected property. Additional accommodation costs were estimated at $1,089 per flood affected property.

Figure E-3 shows the combined damage cost by overfloor flood depth for the three types of residential buildings.

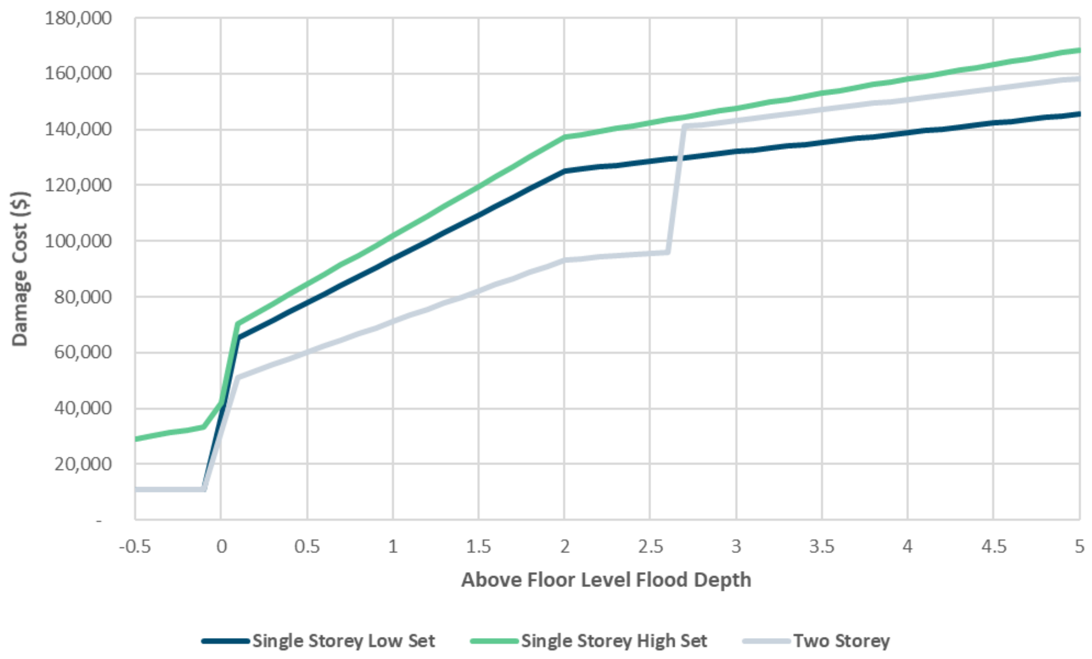

Figure E-3: Residential damage cost curves by building type

Information on building type and floor area of residential properties was provided with the flood mapping data and consisted of detailed survey undertaken during the Narrabeen Lagoon Floodplain Risk Management Study and Plan (Cardno, 2019).

Commercial Cost Curves

Damage cost estimates for commercial buildings depend on the depth of overfloor inundation, floor area of the building and content values. Content values are categorised in low, medium or high value contents.

The potential and actual damage cost estimates for medium value content are shown in **Table E-4**. Clean up costs were accounted for in addition to building and content damage and were estimated as 40% of building and content damage (DSE, 2009).

Information on the floor area and type of content value of commercial and industrial properties was provided by Council.

It is important to distinguish between potential and actual damage when assessing flood damage. Actual damage cost estimates should be used in analyses where there is evidence that property owners will have time to prepare for the flood event.

- potential damage is the damage that would occur if no remedial action is undertaken and the exposure to the flood event is not reduced.
- actual damage is the damage that occurs after actions have been taken to reduce the exposure to the flood event (e.g. sand bagging, removing valuable items, etc.).

Actual damage cost estimates were used in the analysis, as it was assumed that property owners would have time to prepare for the flood event.

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Table E-4: Commercial building and content damage (medium value contents) ($2020)

Depth of overflood inundation (m)	Actual Damage ($/sqm)	Potential Damage ($/sqm)
3.00	298.6	679.5
2.70	298.6	679.5
2.40	298.6	679.5
2.10	298.6	679.5
1.80	239.2	544.1
1.50	224.0	508.7
1.20	179.7	407.5
1.00	149.3	339.1
0.90	141.7	322.7
0.60	118.9	272.1
0.50	112.6	254.3
0.30	84.8	193.6
0.20	74.7	170.8
0.10	56.9	127.8
0.05	40.5	91.1
0.00	22.8	50.6
-0.30	0.0	0.0

Annual Average Damage Costs

The Annual Average Damage (AAD) was calculated using a probability approach based on the flood damages calculated for each design flood event for each of the four Model Runs (corresponding to different lagoon entrance conditions). Flood damages were calculated for each property and design flood event based on the damage curves shown above.

The flood damage curve for each Model Run was estimated by summing the damage costs for each design flood event for all buildings and properties. The flood damage curve (or loss-probability curve) is based on the flood damage costs for a range of flood events / probabilities. Damage costs were interpolated between known data points (e.g. between the 5 year ARI and 20 year ARI). Data points outside the range of the data sample were not extrapolated.

The area under the flood damage curve represents the AAD (refer to example in **Figure E-4**). The AAD is estimated by integrating the area below the flood damage curve or calculating the area under the curve.

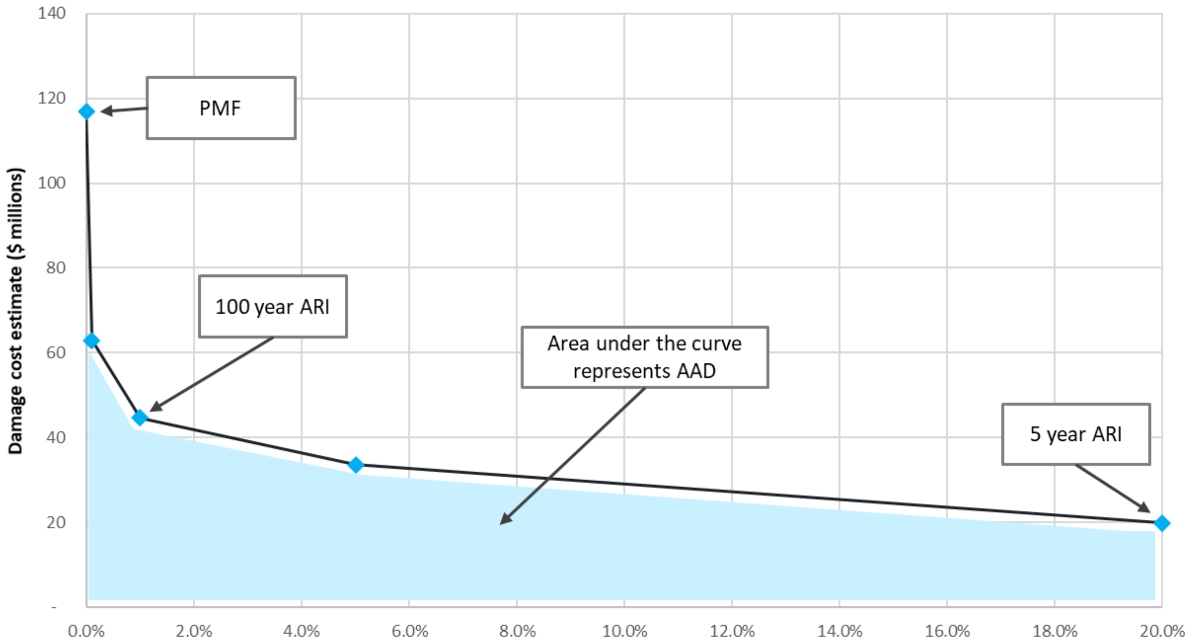

Figure E-4: Flood damage curve and annual average damage (AAD) under Model Run 1

The AAD for each of the Model Runs are presented in **Table E-5** for residential and commercial/industrial properties.

Table E-5: Expected value of annual average damage for each Model Run (in $'000s)

CBA Option	Total AAD	AAD Residential	AAD Commercial
Model Run 1 – Entrance Closed	$6,147	$5,532	$616
Model Run 3 – Entrance Open post major clearance	$1,946	$1,695	$251
Model Run 4 – Entrance Closed with low-flow pipes	$4,636	$4,142	$494
Model Run 6 – Entrance Open regime tidal channel	$2,287	$2,008	$279

It is noted that the AAD estimates shown above differ somewhat from the estimates previously presented in Cardno (2019) due to adjustment to $2020 values and the different methodology used for commercial and industrial properties.

Entrance condition probabilities were then applied to the AAD for the respective Model Runs to calculate the expected value of AAD for each of the five CBA options. The AAD for each CBA option are shown in **Table E-6**.

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Table E-6: Expected value of annual average damage for each CBA option (in $'000s)

CBA Option	Total expected value AAD
Option 1 – Excavation & Trucking (4 years)	$4,257
Option 2 – Excavation & Trucking (2 years)	$3,735
Option 3 – Mobile Sand Pumping (4 years)	$4,257
Option 4– Mobile Sand Pumping (2 years)	$3,735
Option 5 – Low Flow Pipes (2 years)	$3,168

CBA Results

The CBA results identify the incremental difference between the costs and benefits of the Option cases compared with the base case (business as usual case). The results of the analysis show the incremental difference between continuing with current long term entrance management regime (i.e. Option 1) and implementing a new management option to demonstrate whether a change in management will generate a net benefit from a whole of society perspective.

Option 2, excavation and trucking every two years, is the preferred option based on net present value (NPV) outcome. The NPV of each Option is ranked and displayed in **Figure E-5**. Option 2 has the highest NPV of $6.38 million. A Benefit Cost Ratio (BCR) cannot be calculated for this option because the Present Value of Costs is lower than the Base Case and thus cost savings are a benefit . This option reduces the flood damage costs (avoided AAD cost) by $6.5 million compared with the base case.

Option 5, low flow pipes with excavation and trucking every two years, is economically beneficial, indicating that more frequent entrance clearance operations involving smaller volumes is beneficial if low flow pipes are found to be technically feasible and the cost assumptions do not change to the extent to render the options unviable economically. Option 5 has an NPV of $5.5 million. However, given the potential environmental impacts of this option associated with lagoon water level lowering (both recreational amenity and ecological impacts, refer **Section 6.4.3.2** and **Section 6.4.3.3**) and the likely operational challenges associated with pipe access and maintenance (refer **Section 6.3.4**), it is recommended that this option is not pursued any further.

Option 4, mobile sand pumping every 2 years, has an NPV of $0.8 million so it is marginally beneficial, where Option 3 is not economically beneficial. While mobile sand pumping (Option 4) reduces the flood damage costs (avoided AAD cost) by $6.5 million compared with the base case it requires significant upfront capital and high ongoing maintenance costs compared with Option 2. The economic merit of Option 4 could potentially be improved if pricing is available from a fully contractor delivered scheme (no Council purchase of pipeline and pumps), if this resulted in a lower cost outcomes. It is noted that the current entrance clearance campaign (September – December 2021) partly involves sand pumping (together with trucking) and the technical, commercial and social outcomes of this campaign could inform further consideration of the Mobile Sand Pumping option.

The detailed base case analysis results are presented in **Table E-7** followed by the detailed analysis of the incremental difference between options in **Table E-8**. Where a cost is negative, it denotes a benefit because the cost in the Option case is lower than in the base case (reflecting avoided costs). A benefit cost ratio cannot be calculated for Option 3 because the present value of costs is negative.

It is noted that in the longer term, climate change would also impact the effectiveness of the options under consideration. Previous studies by Morris (2010) have concluded that climate change impacts such as sea level rise would increase the rate of sand infilling at the lagoon entrance and decrease the duration of open entrance conditions in the future. Increased storm frequency and changes in offshore wave heights were determined to have a minor influence on entrance infilling, with sea level rise being the dominant driving force for changes in sedimentation patterns. This may be offset to a small degree by increased rainfall intensity and enhanced ability of flood events to scour the entrance, however it was anticipated that increased sand infilling due to sea level rise would remain the dominant forcing mechanism for entrance conditions. As such, management options that involve an increased frequency of entrance clearance campaigns (i.e. Option 2, 4 and 5) are expected to be more effective in combating the long term impacts of sea level rise, with more frequent entrance clearance anticipated to keep the entrance in an open condition for a greater percentage of the time.

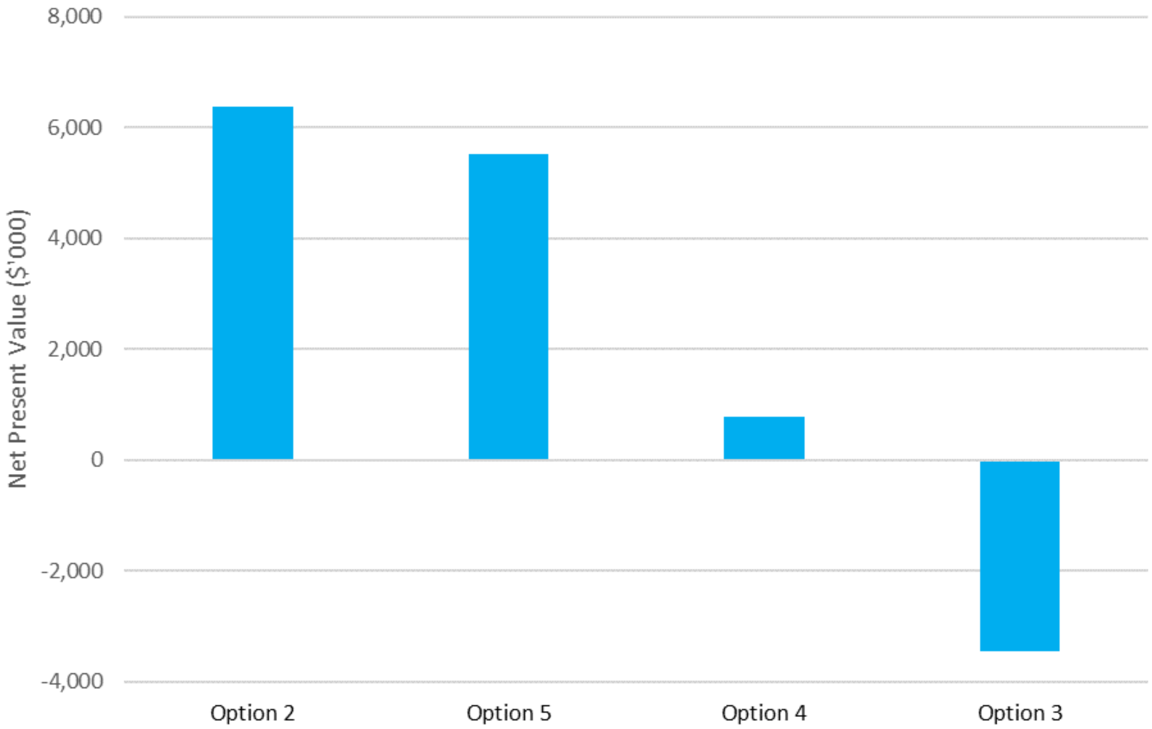

Figure E-5: Ranked Incremental Net Present Value of Options (7% discount rate)

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Table E-7: Base Case (Option 1) costs in present value terms (7% discount rate)

Cost Item	Base Case (Option 1) PV Cost (in $'000)
Capital costs	$0
Ongoing costs Maintenance (incl. council staff, seagrass mapping, REF prep) and economic cost of trucking	$8,126
Flood damages Residential and commercial	$52,825
Cost total (present value terms)	**$60,950**

Table E-8: Incremental results for options (in $'000 - 7% discount rate)

Cost Item	Option 2 Excavation and Trucking (2 yearly)	Option 3 Mobile Sand Pumping (4 yearly)*	Option 4 Mobile Sand Pumping (2 yearly)*	Option 5 Low Flow Pipes
Incremental costs				
Capital cost (incl. contingency)	0	1,863	1,863	7,307
Maintenance cost (2 years Option 2,4,5; 4 years Option 3)	-106	1,612	3,573	237
Replacement cost (every 15 years)	0	237	237	0
Council staff	117	20	122	357
Seagrass mapping, design, REF preparation	175	0	175	175
Economic cost of trucking	-87	-281	-281	-87
Incremental Cost (PV)	**99**	**3,450**	**5,690**	**7,989**
Avoided incremental cost / benefits				
Avoided AAD cost	6,480	0	6,480	13,512
Incremental Benefit (PV)	**6,480**	**0**	**6,480**	**13,512**
Net Present Value	**6,380**	**-3,450**	**790**	**5,523**
BCR	**n/a**	**0.00**	**1.14**	**1.69**

Sensitivity Testing

The CBA is necessarily based on a series of assumptions, which means that there is a degree of uncertainty around the results. Sensitivity testing has been undertaken to clarify which assumptions can materially change the results. The following sensitivity tests have been undertaken:

- **discount rates** of 3% and 10%
- shorter and longer **analysis periods** of 20 and 50 years
- changes in **capital costs** of both a 10% increase and decrease
- changes in **maintenance costs** of both a 10% increase and decrease
- changes in **entrance condition** probabilities (refer to **Table E-9**)

Table E-9: Entrance condition probabilities sensitivity test

Option	Base Assumption	Sensitivity
Option 1 and 3	Open – In Between – Closed 15% - 60% - 25%	Open – In Between – Closed 25% - 50% - 25%
Option 2, 4 and 5	Open – In Between – Closed 40% - 45% - 15%	Open – In Between – Closed 25% - 60% - 15% 40% - 40% - 20% 25% - 55% - 20%

Sensitivity analysis results are presented in **Table E-10** and **Table E-11**. The results show that:

- Option 2 and Option 5 are both sensitive to changes in discount rates, primarily driven by the annual flood damage costs and the impact of valuing future flood damages at a high (lower discount rate) or lower (higher discount rate) rate. The low discount rate assumes future costs have a more similar value to today whereas the higher discount rate assumes future costs should be valued less than today.
- Using a lower discount rate (3%) changes the ranking of Option 2 and 5, where Option 5 becomes preferred. Lowering the discount rate increases the value of benefits in the future. None of the sensitivities change which options are net beneficial.
- Shortening the analysis period only has a marginal impact on all options. Option 5 has the largest change associated with both increasing and decreasing the analysis period because of the effect it has on the payback period of the initial capital investment. Given the expected asset life of the low flow pipes is at least 50 years, it is expected the 50 year analysis period is realistic for this option.
- The capital and maintenance cost estimate sensitivity of plus 10% increases the overall contingency from 20% to 30% (Options 1-4) and 50% to 60% (Option 5). The options are not highly sensitive to a further change in the capital or maintenance cost estimates, largely because the flood damage costs are much more significant.

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Table E-10: Sensitivity analysis results (NPV in $'000)

Sensitivity	**Option 2** Excavation and Trucking (2 yearly)	**Option 3** Mobile Sand Pumping (4 yearly)*	**Option 4** Mobile Sand Pumping (2 yearly)*	**Option 5** Low Flow Pipes
Under central case assumptions	***6,380***	***-3,450***	***790***	***5,523***
Discount rate of 3%	9,884	-4,514	2,023	12,477
Discount rate of 10%	4,953	-3,008	313	2,746
20 year analysis period	5,317	-3,166	305	3,516
50 year analysis period	6,966	-3,601	962	6,831
Capital cost +10%	6,380	-3,605	635	5,036
Capital Cost - 10%	6,380	-3,295	945	6,010
Maintenance cost + 10%	6,389	-3,604	473	5,503
Maintenance cost - 10%	6,372	-3,296	1,108	5,543

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Table E-11: Sensitivity analysis results for entrance condition probabilities (NPV in $'000s)

Sensitivity	**Entrance Condition** Open – in between – closed	**Option 2** Excavation and Trucking (2 yearly)	**Option 3** Mobile Sand Pumping (4 yearly)*	**Option 4** Mobile Sand Pumping (2 yearly)*	**Option 5** Low Flow Pipes
Under base assumptions Options 1 and 3 Options 2, 4 and 5	***15% – 60% – 25% 40% – 45% – 15%***	***6,380***	***-3,450***	***790***	***5,523***
Options 1 and 3 Options 2, 4 and 5	25% – 50% – 25% 40% – 45% – 15%	3,774	-3,450	-1,816	2,916
Options 1 and 3 Options 2, 4 and 5	15% – 60% – 25% 25% – 60% – 15%	2,788	-3,450	-2,803	3,336
Options 1 and 3 Options 2, 4 and 5	15% – 60% – 25% 40% – 40% – 20%	5,183	-3,450	-407	4,794
Options 1 and 3 Options 2, 4 and 5	15% – 60% – 25% 25% – 55% – 20%	1,590	-3,450	-4,000	2,608
Options 1 and 3 Options 2, 4 and 5	25% – 50% – 25% 25% – 60% – 15%	181	-3,450	-5,409	730
Options 1 and 3 Options 2, 4 and 5	25% – 50% – 25% 40% – 40% – 20%	2,576	-3,450	-3,014	2,187
Options 1 and 3 Options 2, 4 and 5	25% – 50% – 25% 25% – 55% – 20%	-1,016	-3,450	-6,607	1

7 June 2021

Haskoning Australia Pty Ltd
Level 14, 56 Berry Street
NORTH SYDNEY NSW 2060

ATTENTION: MATT POTTER

Dear Matt,

**RE: NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
CONCEPT DESIGN ESTIMATES & WHOLE OF LIFE ASSESSMENTS (R2)**

As per your updated request and feedback dated 4th June 2021, Muller Partnership has updated our Concept Design Estimates for 5 No. Options and their associated Whole of Life Assessment for the proposed capital and maintenance costs for the Narrabeen Lagoon Entrance Management and enclose our report.

Please note, the Whole of Life Assessments are based on the updated Concept Design Estimates prepared by Muller Partnership dated 07 June 2021. The estimated costs herein are current day costs. The whole of life tables below shows future escalated costs.

Please take note of our Assumptions (Item 4.0) and Exclusions (Item 5.0) which have been based on the information provided.

Should you have any queries or require any further information please do not hesitate to contact *Simon Dwyer* or the undersigned.

Yours faithfully
MULLER PARTNERSHIP

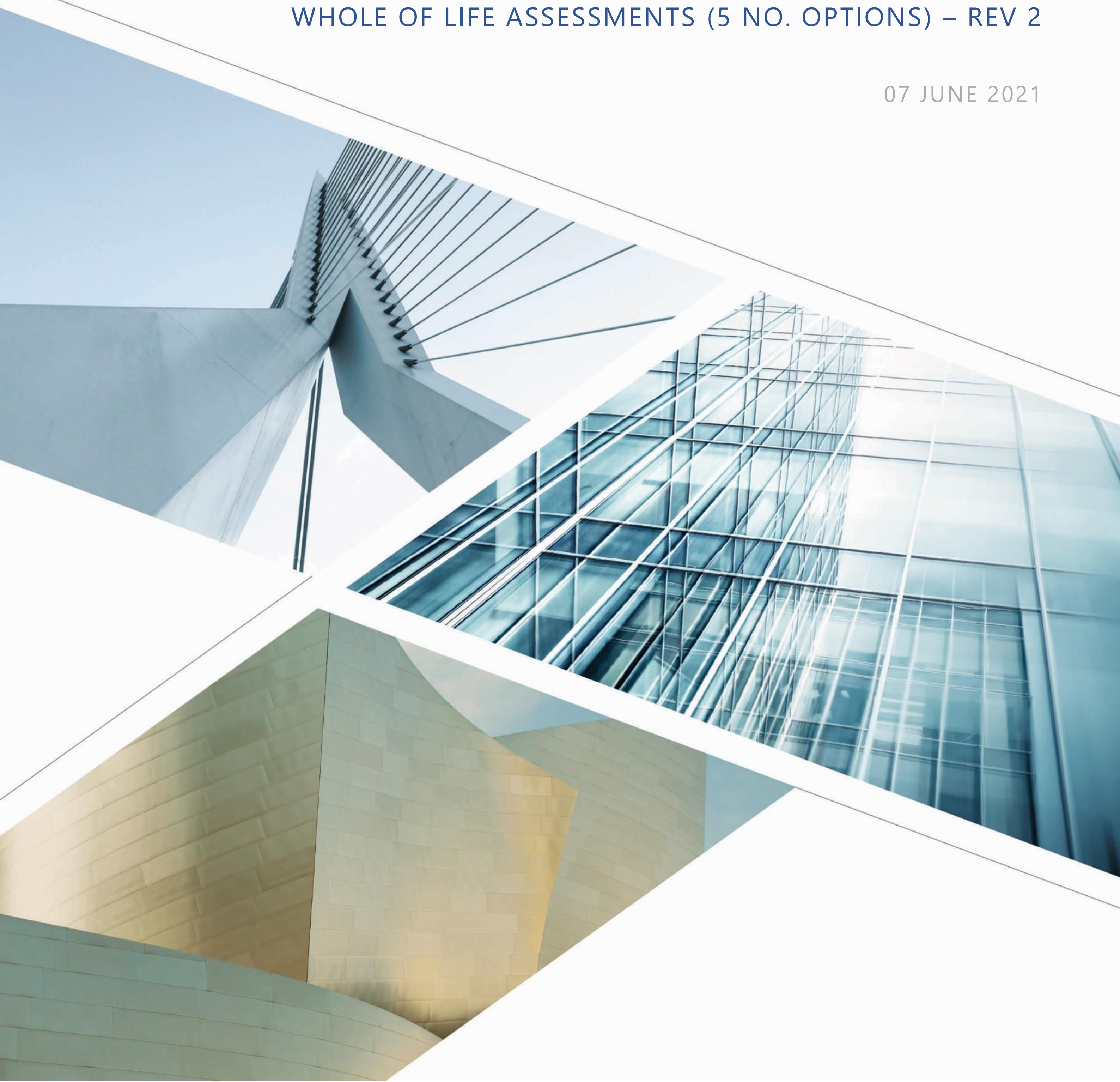
GRANT MULLER –**CHIEF EXECUTIVE**
GM:SD – 21170 – Narrabeen Lagoon Entrance Management (Rev 2)

MULLER partnership

Newcastle | Sydney | Melbourne

NARRABEEN LAGOON ENTRANCE MANAGEMENT
CONCEPT DESIGN ESTIMATES AND
WHOLE OF LIFE ASSESSMENTS (5 NO. OPTIONS) – REV 2

07 JUNE 2021



Disclaimer

Muller Partnership have prepared this report in part on the basis of information supplied to it in the ordinary course of business by Mr Matt Potter of Royal Haskoning DHV.

Whilst all reasonable professional care and skill have been exercised to validate its accuracy and authenticity, Muller Partnership is unable to provide any Guarantee in that regard, and will not be liable to any party for any loss arising as a result of any such information subsequently being found to be inaccurate, lacking authenticity or having been withheld.

This report is only intended for use by Royal Haskoning DHV and Muller Partnership accepts no responsibility to other parties who use opinions or information contained herein. They do so at their own risk.

In acting as Quantity Surveyor for Royal Haskoning DHV, Muller Partnership's liability is limited to the scope of services and value limit, as defined in their Professional indemnity insurance cover. A copy is available on request.

This report covers only the items as contained in this report. Should Royal Haskoning DHV require additional items or areas of assessment, these should be specifically requested and will be actioned as agreed between the parties.

The construction costs are current as at the date of this assessment only. The values assessed herein may change significantly and unexpectedly over a relatively short period (including as a result of general market movements or factors specific to the particular property). We do not accept liability for losses arising from such subsequent changes in values.

Document history & status

Revision	Date	Description	By	Review	Approved
0	27/05/2021	Concept Design Estimates & Whole of Life Assessments (5 No. Options)	SD	GM	GM
1	01/06/2021	Concept Design Estimates & Whole of Life Assessments Update	SD	GM	GM
2	07/06/2021	Concept Design Estimates & Whole of Life Assessments Update	SD	GM	GM

CONTENTS

Glossary of Key Terms

Preliminaries & Margin	The Preliminaries and Margin Allowance is an allowance for the builders' margin and their establishment and management of the site. This item will therefore include for items such as site fencing & amenities, site foreman, head office overheads, insurances, cranage, site cleaning, OH&S management, QA, etc.

1.0 EXECUTIVE SUMMARY

Project Description

Generally, the scope of work in the provided Concept Design documentation includes 5 No. management options for the Narrabeen Lagoon Entrance comprising capital and maintenance activities including the following:

Excavation and Trucking (Once Every 4 Years) - Option 1:

- Bulk excavation of 40,000 m3 of sand at Narrabeen Lagoon Entrance and trucking to Collaroy-Narrabeen Beach.
- Unloading and spreading of sand at Collaroy-Narrabeen Beach to maintain environmental profile.

Excavation and Trucking (Once Every 2 Years) - Option 2:

- Bulk excavation of 15,000 m3 of sand at Narrabeen Lagoon Entrance and trucking to Collaroy-Narrabeen Beach.
- Unloading and spreading of sand at Collaroy-Narrabeen Beach to maintain environmental profile.

Mobile Sand Pumping (Once Every 4 Years) - Option 3:

- Capital costs for purchasing temporary primary pumping station, booster station, permanent delivery pipeline and temporary delivery pipeline.
- Construction of a permanent delivery pipeline comprising DN200 HDPE pipework across 1,700m.
- Maintenance works comprising mobile sand pumping including installation / assembly of temporary delivery pipeline, temporary primary pumping station and temporary booster station.
- Bulk excavation and 'SlurryTrak' sand pumping of 40,000 m3 of sand from Narrabeen Lagoon Entrance and pumping to Collaroy-Narrabeen Beach to be discharged at 4 No. outlet locations to be undertaken every four years.
- Disassembly of temporary infrastructure and storing to Council requirements.
- Ongoing maintenance of temporary primary pumping and booster stations.
- Replacement of temporary primary pumping and booster stations every 15 years.

Mobile Sand Pumping (Once Every 2 Years) Option 4:

- Capital costs for purchasing temporary primary pumping station, booster station, permanent delivery pipeline and temporary delivery pipeline.
- Construction of a permanent delivery pipeline comprising DN200 HDPE pipework across 1,700m.
- Maintenance works comprising mobile sand pumping including installation / assembly of temporary delivery pipeline, temporary primary pumping station and temporary booster station.
- Bulk excavation and 'SlurryTrak' sand pumping of 15,000 m3 of sand from Narrabeen Long Entrance and pumping to Collaroy Beach to discharged at 4 No. outlet locations to be undertaken every two years.
- Disassembly of temporary infrastructure and storing to council requirements.
- Ongoing maintenance of temporary pump and booster stations.
- Replacement of temporary primary pumping and booster stations every 15 years.

Low Flow Pipes - Option 5:

- Construction of 3 No. 800mm dia low flow pipes including horizontal directional drilling through bedrock from Narrabeen Lagoon Entrance to submerged outlet at edge of rock shelf.
- Construction of a new intake and outlet structure to support associated low flow pipes.
- CCTV pipe inspection of low flow pipes and routine cleanout to remove debris.

Cost Overview

A summary of the Concept Design Estimates are as follows:

Excavation & Trucking (Once Every 4 Years) - Option 1

Ref	Description	$/ Excl. GST
1.0	**Maintenance Works – 4 Year Frequency**	
2.0	General	$517,600
3.0	Site Preparation	$25,000
4.0	Excavation, Trucking and Spreading	$1,040,000
5.0	Remediation	$75,000
6.0	Preliminaries and Margin (8%)	$132,400
7.0	Maintenance Works Contingency (20%)	$358,000
8.0	**Maintenance Works – 4 Year Frequency - Option 1 Total (Excl GST)**	**$2,148,000**

Excavation & Trucking (Once Every 2 Years) - Option 2

Ref	Description	$/ Excl. GST
1.0	**Maintenance Works – 2 Year Frequency**	
2.0	General	$308,400
3.0	Site Preparation	$25,000
4.0	Excavation, Trucking and Spreading	$480,000
5.0	Remediation	$75,000
6.0	Preliminaries and Margin (8%)	$71,600
7.0	Maintenance Works Contingency (20%)	$192,000
8.0	**Maintenance Works – 2 Year Frequency - Option 2 Total (Excl GST)**	**$1,152,000**

Mobile Sand Pump (Once Every 4 Years) - Option 3

Ref	Description	$/ Excl. GST
1.0	**Capital Works**	
2.0	General	$521,800
3.0	Site Preparation	$21,250
4.0	Permanent Delivery Pipeline	$448,700
5.0	Temporary Delivery Pipeline	$79,500
6.0	Temporary Primary Pumping Station	$262,500
7.0	Temporary Booster Pumping Station	$162,500
8.0	Remediation	$42,500
9.0	Preliminaries and Margin (8%)	$122,250
10.0	Capital Works Contingency (20%)	$333,000
11.0	**Capital Works – Option 3 Total (Excl GST)**	**$1,994,000**
12.0	**Maintenance Works – 4 Year Frequency**	
13.0	General	$631,600
14.0	Site Preparation	$55,700
15.0	Excavation - SlurryTrak	$800,000
16.0	Temporary Delivery Pipeline Assembly	$147,000
17.0	Temporary Primary Pumping Station Assembly & Operation	$138,000
18.0	Temporary Booster Pumping Station Assembly & Operation	$138,000
19.0	Pump Station Maintenance	$20,000
20.0	Remediation	$83,550
21.0	Preliminaries and Margin (8%)	$161,150
22.0	Maintenance Works Contingency (20%)	$435,150
23.0	**Maintenance Works – 4 Year Frequency - Option 3 Total (Excl GST)**	**$2,610,000**
24.0	**Maintenance Works – 15 Year Frequency**	
25.0	Primary Pumping Station & Booster Replacement	$400,000
26.0	Maintenance Works Contingency (20%)	$80,000
27.0	**Maintenance Works – 15 Year Frequency – Option 3 Total (Excl GST)**	**$480,000**

Mobile Sand Pump (Once Ever 2 Years) - Option 4

Ref	Description	$/ Excl. GST
1.0	**Capital Works**	
2.0	General	$521,800
3.0	Site Preparation	$21,250
4.0	Permanent Delivery Pipeline	$448,700
5.0	Temporary Delivery Pipeline	$79,500
6.0	Temporary Primary Pumping Station	$262,500
7.0	Temporary Booster Pumping Station	$162,500
8.0	Remediation	$42,500
9.0	Preliminaries and Margin (8%)	$122,250
10.0	Capital Works Contingency (20%)	$333,000
11.0	**Capital Works – Option 4 Total (Excl GST)**	**$1,994,000**
12.0	**Maintenance Works – 2 Year Frequency**	
13.0	General	$424,200
14.0	Site Preparation	$55,700
15.0	Excavation - SlurryTrak	$360,000
16.0	Temporary Delivery Pipeline Assembly	$147,000
17.0	Temporary Primary Pumping Station Assembly & Operation	$120,500
18.0	Temporary Booster Pumping Station Assembly & Operation	$120,500
19.0	Pump Station Maintenance	$20,000
20.0	Remediation	$83,550
21.0	Preliminaries and Margin (8%)	$106,550
22.0	Maintenance Works Contingency (20%)	$288,000
23.0	**Maintenance Works – 2 Year Frequency - Option 4 Total (Excl GST)**	**$1,726,000**
24.0	**Maintenance Works – 15 Year Frequency**	
25.0	Primary Pumping Station & Booster Replacement	$400,000
26.0	Maintenance Works Contingency (20%)	$80,000
27.0	**Maintenance Works – 15 Year Frequency – Option 4 Total (Excl GST)**	**$480,000**

Low Flow Pipes - Option 5

Ref	Description	$/ Excl. GST
1.0	**Capital Works**	
2.0	General	$479,400
3.0	Site Preparation	$1,250
4.0	Intake & Outlet Structure	$69,000
5.0	Low Flow Pipes	$4,102,400
6.0	Remediation	$2,500
7.0	Preliminaries and Margin (12%)	$557,450
8.0	Capital Works Contingency (20%)	$1,042,000
9.0	**Capital Works – Option 5 Total (Excl GST)**	**$6,254,000**
10.0	**Maintenance Works**	
11.0	Pipe Inspection & Routine Cleanout	$31,000
12.0	Preliminaries and Margin (8%)	$2,500
13.0	Maintenance Works Contingency (20%)	$6,500
14.0	**Maintenance Works – Option 5 Total (Excl GST)**	**$40,000**

We note the attached estimate is for construction costs only and does not allow for items such as property acquisition, finance costs, escalation, design & documentation or planning & authority fees & charges or Client-Side Project Management. Please refer to the Qualification, Assumptions and Exclusions sections of this report for further details.

The purpose of this report is to inform Royal Haskoning DHV of the potential whole of life costs associated with the proposed options. Muller Partnership has developed maintenance costs based on the provided documentation / project brief and assumptions in Section 4.0.

Based on the information provided, the assumed maintenance requirements have been quantified within a Whole of Life [WoL] model in order to determine the current Net Present Value. The results can be seen in the tables below outlining the duration and discounted rate to allow Royal Haskoning DHV to understand the potential budgets.

Whole of Life Model Result

A summary of the Whole of Life Model Results (NPV) is as follows:

Excavation & Trucking (Once Every 4 Years) - Option 1

		Duration			
		NPV	10 Years	20 Years	30 Years
Total Cost		$2,148,000	-	-	-
Discounted Rate	4.0%	-	$5,471,027	$8,939,815	$10,494,105
	7.0%	-	$4,830,105	$6,915,219	$7,576,388
	10.0%	-	$4,310,249	$5,588,869	$5,875,489

Excavation & Trucking (Once Every 2 Years) - Option 2

		Duration			
		NPV	10 Years	20 Years	30 Years
Total Cost		$1,152,000	-	-	-
Discounted Rate	4.0%	-	$4,763,481	$7,981,519	$10,155,509
	7.0%	-	$4,112,235	$6,102,484	$7,065,730
	10.0%	-	$3,590,060	$4,841,836	$5,278,303

Mobile Sand Pump (Once Every 4 Years) - Option 3

		Duration			
		NPV	10 Years	20 Years	30 Years
Total Cost		$5,084,000	-	-	-
Discounted Rate	4.0%	-	$8,565,446	$13,047,083	$15,083,778
	7.0%	-	$7,732,871	$10,429,017	$11,287,124
	10.0%	-	$7,050,342	$8,703,888	$9,072,728

Mobile Sand Pump (Once Every 2 Years) - Option 4

		Duration			
		NPV	10 Years	20 Years	30 Years
Total Cost		$4,200,000	-	-	-
Discounted Rate	4.0%	-	$9,054,260	$14,142,256	$17,547,461
	7.0%	-	$8,024,765	$11,169,095	$12,666,975
	10.0%	-	$7,191,584	$9,166,901	$9,841,398

Low Flow Pipes - Option 5

		Duration			
		NPV	10 Years	20 Years	30 Years
Total Cost		$6,294,000	-	-	-
Discounted Rate	4.0%	-	$6,222,595	$6,363,879	$6,455,933
	7.0%	-	$6,024,163	$6,110,943	$6,151,690
	10.0%	-	$5,840,961	$5,895,183	$5,913,618

2.0 SCHEDULE OF INFORMATION

Muller Partnership has used the following information in compiling our Concept Design Estimates and Whole of Life Assessment:

- Cost Options Narrative word document prepared by Royal Haskoning DHV identifying the project brief and proposed manage options received 18 May 2021;
- Narrabeen Lagoon Entrance Management Strategy drawings (3 No.) prepared by Royal Haskoning DHV dated 18 May 2021;
- 2018 Narrabeen Lagoon Entrance Clearance Actual Sand Removal Costs;
- Indicative Cost Estimates (Excel Format) for Excavation & Trucking works prepared by Royal Haskoning DHV received 18 May 2021;
- Alternative Management Strategies for Clearing Narrabeen Lagoon Entrance Report (MHL1737) prepared by NSW Department of Commerce and dated June 2009;
- E-mail correspondence between RHDHV and Brent Cooper of CGC Group relating to costing information for SlurryTrak works dated November 2020;
- Indicative Cost Estimates (Excel Format) for Mobile Sand Pumping works prepared by Royal Haskoning DHV received 18 May 2021;
- E-mail correspondence between RHDHV and Michael Daley of Daley Directional Drilling relating to costing information for Low Pipe drilling works dated September 2020;
- E-mail correspondence from RHDHV relating to costing information for Low Pipe drilling works as provided by H&M Drilling dated September 2020;
- Email and phone correspondence with Matt Potter of Royal Haskoning DHV, confirming scope of works, frequency of maintenance options, project brief and report feedback (May – June 2021).

All rates used within our Concept Design Estimates and Whole of Life Assessments have been gathered from our in-house databases as well as being constructed from first principles namely labour, materials and waste to reflect current market and project specific value.

3.0 METHODOLOGY

The methodology used to develop the budget for Whole of Life Assessment can be separated into a few steps. These steps include the determination of inspections and maintenance costs and the development of the WoL model to consider various discounted rates and Net Present Value (NPV).

The Whole of Life models are based on routine management and inspections regime as listed in Section 4.0 Assumptions. The results of the WoL model shows the results of 4%, 7%, and 10% discount rates on the Net Present Value [NPV] across a range of durations of 10 years, 20 years and 30 years.

The Whole of Life Assessment has been based upon the following assumptions:

- Frequency of works in relation to excavation / trucking and sand pumping as advised by RHDHV;
- Full replacement of pump stations every 15 years for mobile sand pumping options as advised by RHDHV;
- Assumed pump station maintenance to be undertaken by council every 4 years (Option 3) or every 2 years (Option 4);
- Assumed CCTV pipe inspection to be undertaken every 2 years to Low flow pipes (Option 5);
- Assumed routine pipe cleanout to be undertaken every year to Low flow pipes (Option 5).

4.0 ASSUMPTIONS

We have made the following assumptions in the preparation of our Concept Design Estimates and Whole of Life Assessments:

1. The works will be competitively tendered to a number of suitable qualified contractors on a lump sum basis;
2. The Contractor will have clear uninterrupted access to the site;
3. Project durations have been calculated based on historic data provided and in-house calculations;
4. Assumed quantities of excavation required as advised by RHDHV;
5. Assumed no testing of excavated material is to be undertaken;
6. Assumed no work relating to disposal or remediation of contaminated materials is to be undertaken;
7. Assumed extent of site clearance required for each management option;
8. Assumed extent of remediation and re-vegetation to be undertaken;
9. Assumed extent of existing service location / protection and sediment controls required for each management option;
10. Assumed pipe material for low flow pipes in Option 5;
11. Assumed design details of headwalls / stainless steel grates to intake / outlet structure in Option 5;
12. Assumed no encasing or sleeving pipe is required to drilling in Option 5;
13. Assumed specification of pumps and booster assemblies required and operational costs associated whilst works are undertaken.

5.0 EXCLUSIONS

Within the following Concept Design Estimates and Whole of Life Assessments the acronym 'EXCL' means work that has ***not*** been included in our estimate. We specifically note the following exclusions from the estimated cost:

1. GST;
2. Changes in market conditions;
3. Authority fees and charges / legal fees;
4. Delay costs including latent conditions;
5. Works outside normal hours;
6. Aboriginal and Heritage impacts;
7. Services diversions;
8. De-watering;
9. Testing of excavated material;
10. Contamination and / or remediation;
11. New services / replacement of existing;
12. Works outside the specified site area;
13. Client-Side Project Management;
14. Authority's fees and charges & legal fees;
15. Delays resulting from approvals such as Environmental/ Authorities;
16. Property acquisition;
17. Finance costs;
18. Design and documentation fees;
19. Planning Fees;
20. Works to the existing rock batters;
21. Shotcrete to the rock batters;
22. Construction contingency.

APPENDIX A – CONCEPT DESIGN ESTIMATES (5 NO. OPTIONS)

NARRABEEN LAGOON ENTRANCE
MANAGEMENT OPTIONS
EXCAVATION & TRUCKING - OPTION 1
JUNE 2021

MAIN COST SUMMARY

Ref	Description	%	Cost / m2	Sub Total	Total
1.0	MAINTENANCE WORKS - 4 YEAR FREQUENCY				
2.0	GENERAL	24.10		517,600	517,600
3.0	SITE PREPARATION	1.16		25,000	25,000
4.0	EXCAVATION, TRUCKING AND SPREADING	48.42		1,040,000	1,040,000
5.0	REMEDIATION	3.49		75,000	75,000
6.0	PRELIMINARIES AND MARGIN (8%)	6.16		132,400	132,400
7.0	MAINTENANCE WORKS CONTINGENCY (20%)	16.67		358,000	358,000
8.0	MAINTENANCE WORKS - 4 YEAR FREQUENCY - OPTION 1 TOTAL (EXCL GST)				*2,148,000*
		100.00		2,148,000	2,148,000

NARRABEEN LAGOON ENTRANCE
MANAGEMENT OPTIONS
EXCAVATION & TRUCKING - OPTION 1
JUNE 2021

MULLER partnership

ESTIMATE DETAILS

Ref	Description	Quantity	Unit	Rate	Amount
1.0	MAINTENANCE WORKS - 4 YEAR FREQUENCY				
	1				
				Total :	
2.0	GENERAL				
	General				
	1 Site establishment and demobilisation	1.00	Item	100,000.00	100,000.00
	2 Contractors supervision	12.00	Weeks	10,000.00	120,000.00
	3 Survey and set out of works by registered surveyor	8.00	Davs	1,800.00	14,400.00
	4 Location of services	1.00	Item	10,000.00	10,000.00
	5 Protection of services	1.00	Item	25,000.00	25,000.00
	6 Traffic control to Narrabeen Lagoon Entrance and Collaroy Beach	12.00	Weeks	18,600.00	223,200.00
	Sediment & Erosion Controls				
	7 Allow for sediment fencing, berms and environmental controls as required	1.00	Item	25,000.00	25,000.00
				Total :	*517,600.00*
3.0	SITE PREPARATION				
	Site Clearance				
	1 Allow for general site clearing and preparation to undertake works	50,000.00	m2	0.50	25,000.00
				Total :	*25,000.00*
4.0	EXCAVATION, TRUCKING AND SPREADING				
	Bulk Excavation				
	1 Allow for bulk excavation of sand at Narrabeen Lagoon Entrance	40,000.00	m3	8.00	320,000.00
	2 Allow to load and truck sand to Collaroy / Narrabeen Beach	40,000.00	m3	10.00	400,000.00
	3 Allow to unload and spread sand across Collaroy / Narrabeen Beach	40,000.00	m3	8.00	320,000.00
				Total :	*1,040,000.00*
5.0	REMEDIATION				
	Remediation Works				
	1 Allow for minor remediation works to Narrabeen Lagoon Entrance once sand excavation has been undertaken	50,000.00	m2	1.50	75,000.00

ESTIMATE DETAILS

Ref	Description	Quantity	Unit	Rate	Amount
				Total :	75,000.00
6.0	PRELIMINARIES AND MARGIN (8%)				
				Total :	
7.0	MAINTENANCE WORKS CONTINGENCY (20%)				
	1				
				Total :	
8.0	MAINTENANCE WORKS - 4 YEAR FREQUENCY - OPTION 1 TOTAL (EXCL GST)				
	1				
				Total :	

NARRABEEN LAGOON ENTRANCE
MANAGEMENT OPTIONS
EXCAVATION & TRUCKING - OPTION 2
JUNE 2021

MAIN COST SUMMARY

Ref	Description	%	Cost / m2	Sub Total	Total
1.0	MAINTENANCE WORKS - 2 YEAR FREQUENCY				
2.0	GENERAL	26.77		308,400	308,400
3.0	SITE PREPARATION	2.17		25,000	25,000
4.0	EXCAVATION, TRUCKING AND SPREADING	41.67		480,000	480,000
5.0	REMEDIATION	6.51		75,000	75,000
6.0	PRELIMINARIES AND MARGIN (8%)	6.22		71,600	71,600
7.0	MAINTENANCE WORKS CONTINGENCY (20%)	16.67		192,000	192,000
8.0	MAINTENANCE WORKS - 2 YEAR FREQUENCY - OPTION 2 TOTAL (EXCL GST)				*1,152,000*
		100.00		1,152,000	1,152,000

NARRABEEN LAGOON ENTRANCE
MANAGEMENT OPTIONS
EXCAVATION & TRUCKING - OPTION 2
JUNE 2021

MULLER partnership

ESTIMATE DETAILS

Ref		Description	Quantity	Unit	Rate	Amount
1.0		MAINTENANCE WORKS - 2 YEAR FREQUENCY				
	1					
					Total :	
2.0		GENERAL				
		General				
	1	Site establishment and demobilisation	1.00	Item	100,000.00	100,000.00
	2	Contractors supervision	5.00	Weeks	10,000.00	50,000.00
	3	Survey and set out of works by registered surveyor	3.00	Davs	1,800.00	5,400.00
	4	Location of services	1.00	Item	10,000.00	10,000.00
	5	Protection of services	1.00	Item	25,000.00	25,000.00
	6	Traffic control to Narrabeen Lagoon Entrance and Collaroy Beach	5.00	Weeks	18,600.00	93,000.00
		Sediment & Erosion Controls				
	7	Allow for sediment fencing, berms and environmental controls as required	1.00	Item	25,000.00	25,000.00
					Total :	308,400.00
3.0		SITE PREPARATION				
		Site Clearance				
	1	Allow for general site clearing and preparation to undertake works	50,000.00	m2	0.50	25,000.00
					Total :	25,000.00
4.0		EXCAVATION, TRUCKING AND SPREADING				
		Bulk Excavation				
	1	Allow for bulk excavation of sand at Narrabeen Lagoon Entrance	15,000.00	m3	10.00	150,000.00
	2	Allow to load and truck sand to Collaroy / Narrabeen Beach	15,000.00	m3	12.00	180,000.00
	3	Allow to unload and spread sand across Collaroy / Narrabeen Beach	15,000.00	m3	10.00	150,000.00
					Total :	480,000.00
5.0		REMEDIATION				
		Remediation Works				
	1	Allow for minor remediation works to Narrabeen Lagoon Entrance once sand excavation has been undertaken	50,000.00	m2	1.50	75,000.00

ESTIMATE DETAILS

Ref	Description	Quantity	Unit	Rate	Amount
				Total :	75,000.00
6.0	PRELIMINARIES AND MARGIN (8%)				
				Total :	
7.0	MAINTENANCE WORKS CONTINGENCY (20%)				
	1				
				Total :	
8.0	MAINTENANCE WORKS - 2 YEAR FREQUENCY - OPTION 2 TOTAL (EXCL GST)				
	1				
				Total :	

NARRABEEN LAGOON ENTRANCE
MANAGEMENT OPTIONS
MOBILE SAND PUMPING - OPTION 3
JUNE 2021

MAIN COST SUMMARY

Ref	Description	%	Cost / m2	Sub Total	Total
1.0	CAPITAL WORKS				
2.0	GENERAL	10.26		521,800	521,800
3.0	SITE PREPARATION	0.42		21,250	21,250
4.0	PERMANENT DELIVERY PIPELINE	8.83		448,700	448,700
5.0	TEMPORARY DELIVERY PIPELINE	1.56		79,500	79,500
6.0	TEMPORARY PRIMARY PUMPING STATION	5.16		262,500	262,500
7.0	TEMPORARY BOOSTER PUMPING STATION	3.20		162,500	162,500
8.0	REMEDIATION	0.84		42,500	42,500
9.0	PRELIMINARIES AND MARGIN (8%)	2.40		122,250	122,250
10.0	CAPITAL WORKS CONTINGENCY (20%)	6.55		333,000	333,000
11.0	CAPITAL WORKS - OPTION 3 TOTAL (EXCL GST)				*1,994,000*
12.0	MAINTENANCE WORKS - 4 YEAR FREQUENCY				
13.0	GENERAL	12.42		631,600	631,600
14.0	SITE PREPARATION	1.10		55,700	55,700
15.0	EXCAVATION - SLURRYTRAK	15.74		800,000	800,000
16.0	TEMPORARY DELIVERY PIPELINE ASSEMBLY	2.89		147,000	147,000
17.0	TEMPORARY PRIMARY PUMPING STATION ASSEMBLY & OPERATION	2.71		138,000	138,000
18.0	TEMPORARY BOOSTER PUMPING STATION ASSEMBLY & OPERATION	2.71		138,000	138,000
19.0	PUMP STATION MAINTENANCE	0.39		20,000	20,000
20.0	REMEDIATION	1.64		83,550	83,550
21.0	PRELIMINARIES AND MARGIN (8%)	3.17		161,000	161,000
22.0	MAINTENANCE WORKS CONTINGENCY (20%)	8.56		435,150	435,150
23.0	MAINTENANCE WORKS - 4 YEAR FREQUENCY - OPTION 3 TOTAL (EXCL GST)				*2,610,000*
24.0	MAINTENANCE WORKS - 15 YEAR FREQUENCY				
25.0	PUMP STATION & BOOSTER REPLACEMENT	7.87		400,000	400,000
26.0	MAINTENANCE WORKS CONTINGENCY (20%)	1.57		80,000	80,000
27.0	MAINTENANCE WORKS - 15 YEAR FREQUENCY - OPTION 3 TOTAL (EXCL GST)				*480,000*
		100.00		5,084,000	5,084,000

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NARRABEEN LAGOON ENTRANCE
MANAGEMENT OPTIONS
MOBILE SAND PUMPING - OPTION 3
JUNE 2021

ESTIMATE DETAILS

Ref	Description	Quantity	Unit	Rate	Amount
1.0	CAPITAL WORKS				
	1				
				Total :	
2.0	GENERAL				
	General				
1	Site establishment and demobilisation	1.00	Item	100,000.00	100,000.00
2	Contractors supervision	10.00	Weeks	10,000.00	100,000.00
3	Survey and set out of works by registered surveyor	6.00	Davs	1,800.00	10,800.00
4	Location of services	1.00	Item	15,000.00	15,000.00
5	Protection of services	1.00	Item	25,000.00	25,000.00
6	Traffic control to both ends of permanent pipeline construction	10.00	Weeks	18,600.00	186,000.00
	Sediment & Erosion Controls				
7	Allow for sediment fencing, berms and environmental controls along length of permanent pipeline construction	1.00	Item	85,000.00	85,000.00
				Total :	521,800.00
3.0	SITE PREPARATION				
	Site Clearance				
1	Allow for general site clearing and preparation to undertake works [NB: Assumed 5m clearance of permanent pipeline]	8,500.00	m2	2.50	21,250.00
				Total :	21,250.00
4.0	PERMANENT DELIVERY PIPELINE				
	Permanent Delivery Pipeline				
	Excavation				
1	Allow for detailed excavation to permanent delivery pipeline trench including backfilling once pipework has been laid	1,360.00	m3	120.00	163,200.00
	Pipework				
2	Supply and lay DN200 HDPE pipework into trench	1,700.00	m	150.00	255,000.00
3	Allow for bends, junctions, tees, couplers and other fittings as required for pipework [NB: Assumed 10% costs of pipework]	1.00	Item	25,500.00	25,500.00
	Connection				

ESTIMATE DETAILS

Ref	Description	Quantity	Unit	Rate	Amount
4.0	PERMANENT DELIVERY PIPELINE				(Continued)
4	Allow to connect pipeline to temporary pumping station and booster assembly as required	2.00	No	2,500.00	5,000.00
				Total :	448,700.00
5.0	TEMPORARY DELIVERY PIPELINE				
	Temporary Delivery Pipeline				
1	Allow for supply and delivery of DN200 HDPE pipe to Council depot as required [NB: Temporary laying of pipe taken in maintenance works]	1,100.00	m	65.00	71,500.00
2	Ditto isolation valves and offtake pipe outlets to suit temporary delivery pipeline	4.00	No	2,000.00	8,000.00
				Total :	79,500.00
6.0	TEMPORARY PRIMARY PUMPING STATION				
	Temporary Primary Pumping Station				
1	Allow for supply and delivery of mobile / temporary primary pumping station to Council depot [NB: Provisional - Temporary assembly / installation & disassembly taken in maintenance works]	1.00	Item	250,000.00	250,000.00
	On-Site Plinth				
2	Allow to construct permanent on-site plinth to support installation and assembly of temporary pumping station	50.00	m2	250.00	12,500.00
				Total :	262,500.00
7.0	TEMPORARY BOOSTER PUMPING STATION				
	Temporary Pumping Station Booster				
1	Allow for supply and delivery of mobile / temporary pumping station booster to Council depot [NB: Provisional - Temporary assembly / installation & disassembly taken in maintenance works]	1.00	Item	150,000.00	150,000.00
	On-Site Plinth				
2	Allow to construct permanent on-site plinth to support installation and assembly of temporary booster station	50.00	m2	250.00	12,500.00
				Total :	162,500.00
8.0	REMEDIATION				
	Remediation Works				

ESTIMATE DETAILS

Ref		Description	Quantity	Unit	Rate	Amount
8.0		REMEDIATION				(Continued)
	1	Allow for minor remediation works to permanent delivery pipeline once works have been completed	8,500.00	m2	5.00	42,500.00
					Total :	42,500.00
9.0		PRELIMINARIES AND MARGIN (8%)				
					Total :	
10.0		CAPITAL WORKS CONTINGENCY (20%)				
	1					
					Total :	
11.0		CAPITAL WORKS - OPTION 3 TOTAL (EXCL GST)				
	1					
					Total :	
12.0		MAINTENANCE WORKS - 4 YEAR FREQUENCY				
	1					
					Total :	
13.0		GENERAL				
		General				
	1	Site establishment and demobilisation	1.00	Item	100,000.00	100,000.00
	2	Contractors supervision	14.00	Weeks	10,000.00	140,000.00
	3	Survey and set out of works by registered surveyor	9.00	Davs	1,800.00	16,200.00
	4	Location of services	1.00	Item	10,000.00	10,000.00
	5	Protection of services	1.00	Item	25,000.00	25,000.00
	6	Traffic control to Narrabeen Lagoon Entrance and Collaroy Beach	14.00	Weeks	18,600.00	260,400.00
		Sediment & Erosion Controls				
	7	Allow for sediment fencing, berms and environmental controls as required	1.00	Item	80,000.00	80,000.00
					Total :	631,600.00
14.0		SITE PREPARATION				

ESTIMATE DETAILS

Ref	Description	Quantity	Unit	Rate	Amount
14.0	SITE PREPARATION				
	Site Clearance				
1	Allow for general site clearing and preparation to undertake works [NB: Assumed 5m clearance of temporary pipeline and surrounding areas of pump station assembly areas]	55,700.00	m2	1.00	55,700.00
				Total :	*55,700.00*
15.0	EXCAVATION - SLURRYTRAK				
	Bulk Excavation - SlurryTrak				
	Plant Mobilisation				
1	Allow for mobilisation of plant equipment [NB: Refer to 'General' Trade for Details]	1.00	Item		INCL
	Excavation Works - SlurryTrak				
2	Allow for bulk excavation of sand at Narrabeen Lagoon Entrance with SlurryTrak operation into mobile sled with connection pipe (Approx 400mm long) to temporary primary pumping station	40,000.00	m3	15.00	600,000.00
	Excavation Works - Excavator				
3	Allow for bulk spreading of sand slurry to maintain beach profile at temporary outlets installed at Collaroy Beach	40,000.00	m3	5.00	200,000.00
				Total :	*800,000.00*
16.0	TEMPORARY DELIVERY PIPELINE ASSEMBLY				
	Temporary Delivery Pipeline - Assembly				
1	Allow for delivery and assembly of DN200 HDPE pipe from Council depot to Collaroy Beach as required [NB: Supply of temporary delivery pipeline taken in Capital Works]	1,100.00	m	90.00	99,000.00
2	Ditto isolation valves to suit and offtake pipe outlets to suit temporary delivery pipeline	4.00	No	700.00	2,800.00
	Temporary Delivery Pipeline - Disassembly				
3	Allow to carefully disassemble DN200 HDPE pipe and store at Council depot	1,100.00	m	40.00	44,000.00
4	Ditto isolation valves to suit and offtake pipe outlets	4.00	No	300.00	1,200.00
				Total :	*147,000.00*
17.0	TEMPORARY PRIMARY PUMPING STATION ASSEMBLY & OPERATION				
	Assembly				

ESTIMATE DETAILS

Ref	Description	Quantity	Unit	Rate	Amount
17.0	TEMPORARY PRIMARY PUMPING STATION ASSEMBLY & OPERATION				*(Continued)*
1	Allow for delivery of primary pumping station from Council depot and assembly on site as required	1.00	Item	54,000.00	54,000.00
	Operation				
2	Allow for operating costs of pump station whilst works are undertaken	12.00	Weeks	2,500.00	30,000.00
	Disassembly				
3	Allow to carefully disassembly and store primary pumping station at Council depot	1.00	Item	54,000.00	54,000.00
				Total :	*138,000.00*
18.0	TEMPORARY BOOSTER PUMPING STATION ASSEMBLY & OPERATION				
	Assembly				
1	Allow for delivery of pumping station booster from Council depot and assembly on site as required	1.00	Item	54,000.00	54,000.00
	Operation				
2	Allow for operating costs of booster station whilst works are undertaken	12.00	Weeks	2,500.00	30,000.00
	Disassembly				
3	Allow to carefully disassembly and store pumping station booster at Council depot	1.00	Item	54,000.00	54,000.00
				Total :	*138,000.00*
19.0	PUMP STATION MAINTENANCE				
	Pump Station Maintenance				
1	Allow for routine inspections and maintenance undertaken by Council of temporary primary pumping station and pumping station booster [NB: Assumed to be undertaken every 4 years before campaign begins]	2.00	No	10,000.00	20,000.00
				Total :	*20,000.00*
20.0	REMEDIATION				
	Remediation Works				
1	Allow for minor remediation works to temporary delivery pipeline once works have been completed	55,700.00	m2	1.50	83,550.00
				Total :	*83,550.00*
21.0	PRELIMINARIES AND MARGIN (8%)				

ESTIMATE DETAILS

Ref	Description	Quantity	Unit	Rate	Amount
				Total :	
22.0	MAINTENANCE WORKS CONTINGENCY (20%)				
1					
				Total :	
23.0	MAINTENANCE WORKS - 4 YEAR FREQUENCY - OPTION 3 TOTAL (EXCL GST)				
1					
				Total :	
24.0	MAINTENANCE WORKS - 15 YEAR FREQUENCY				
1					
				Total :	
25.0	PUMP STATION & BOOSTER REPLACEMENT				
1	NB: Assumed full replacement of pumping station and booster station every 15 years		Note		
	Temporary Primary Pumping Station				
2	Allow for supply and delivery of mobile / temporary primary pumping station to Council depot [NB: Provisional - Temporary assembly / installation & disassembly taken in maintenance works]	1.00	Item	250,000.00	250,000.00
	Temporary Pumping Station Booster				
3	Allow for supply and delivery of mobile / temporary pumping station booster to Council depot [NB: Provisional - Temporary assembly / installation & disassembly taken in maintenance works]	1.00	Item	150,000.00	150,000.00
				Total :	400,000.00
26.0	MAINTENANCE WORKS CONTINGENCY (20%)				
				Total :	
27.0	MAINTENANCE WORKS - 15 YEAR FREQUENCY - OPTION 3 TOTAL (EXCL GST)				
1					
				Total :	

NARRABEEN LAGOON ENTRANCE
MANAGEMENT OPTIONS
MOBILE SAND PUMPING - OPTION 4
JUNE 2021

MAIN COST SUMMARY

Ref	Description	%	Cost / m2	Sub Total	Total
1.0	CAPITAL WORKS				
2.0	GENERAL	12.42		521,800	521,800
3.0	SITE PREPARATION	0.51		21,250	21,250
4.0	PERMANENT DELIVERY PIPELINE	10.68		448,700	448,700
5.0	TEMPORARY DELIVERY PIPELINE	1.89		79,500	79,500
6.0	TEMPORARY PRIMARY PUMPING STATION	6.25		262,500	262,500
7.0	TEMPORARY PUMPING STATION BOOSTER	3.87		162,500	162,500
8.0	REMEDIATION	1.01		42,500	42,500
9.0	PRELIMINARIES AND MARGIN (8%)	2.91		122,250	122,250
10.0	CAPITAL WORKS CONTINGENCY (20%)	7.93		333,000	333,000
11.0	CAPITAL WORKS - OPTION 4 TOTAL (EXCL GST)				*1,994,000*
12.0	MAINTENANCE WORKS - 2 YEAR FREQUENCY				
13.0	GENERAL	10.10		424,200	424,200
14.0	SITE PREPARATION	1.33		55,700	55,700
15.0	EXCAVATION - SLURRYTRAK	8.57		360,000	360,000
16.0	TEMPORARY DELIVERY PIPELINE ASSEMBLY	3.50		147,000	147,000
17.0	TEMPORARY PRIMARY PUMPING STATION ASSEMBLY & OPERATION	2.87		120,500	120,500
18.0	TEMPORARY BOOSTER PUMPING STATION ASSEMBLY & OPERATION	2.87		120,500	120,500
19.0	PUMP STATION MAINTENANCE	0.48		20,000	20,000
20.0	REMEDIATION	1.99		83,550	83,550
21.0	PRELIMINARIES AND MARGIN (8%)	2.54		106,550	106,550
22.0	MAINTENANCE WORKS CONTINGENCY (20%)	6.86		288,000	288,000
23.0	MAINTENANCE WORKS - OPTION 4 TOTAL (EXCL GST)				*1,726,000*
24.0	MAINTENANCE WORKS - 15 YEAR FREQUENCY				
25.0	PUMP STATION & BOOSTER REPLACEMENT	9.52		400,000	400,000
26.0	MAINTENANCE WORKS CONTINGENCY (20%)	1.90		80,000	80,000
27.0	MAINTENANCE WORKS - 15 YEAR FREQUENCY - OPTION 4 TOTAL (EXCL GST)				*480,000*
		100.00		4,200,000	4,200,000

ESTIMATE DETAILS

Ref		Description	Quantity	Unit	Rate	Amount
1.0		CAPITAL WORKS				
	1					
					Total :	
2.0		GENERAL				
		General				
	1	Site establishment and demobilisation	1.00	Item	100,000.00	100,000.00
	2	Contractors supervision	10.00	Weeks	10,000.00	100,000.00
	3	Survey and set out of works by registered surveyor	6.00	Davs	1,800.00	10,800.00
	4	Location of services	1.00	Item	15,000.00	15,000.00
	5	Protection of services	1.00	Item	25,000.00	25,000.00
	6	Traffic control to both ends of permanent pipeline construction	10.00	Weeks	18,600.00	186,000.00
		Sediment & Erosion Controls				
	7	Allow for sediment fencing, berms and environmental controls along length of permanent pipeline construction	1.00	Item	85,000.00	85,000.00
					Total :	*521,800.00*
3.0		SITE PREPARATION				
		Site Clearance				
	1	Allow for general site clearing and preparation to undertake works [NB: Assumed 5m clearance of permanent pipeline]	8,500.00	m2	2.50	21,250.00
					Total :	*21,250.00*
4.0		PERMANENT DELIVERY PIPELINE				
		Permanent Delivery Pipeline				
		Excavation				
	1	Allow for detailed excavation to permanent delivery pipeline trench including backfilling once pipework has been laid	1,360.00	m3	120.00	163,200.00
		Pipework				
	2	Supply and lay DN200 HDPE pipework into trench	1,700.00	m	150.00	255,000.00
	3	Allow for bends, junctions, tees, couplers and other fittings as required for pipework [NB: Assumed 10% costs of pipework]	1.00	Item	25,500.00	25,500.00
		Connection				

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ESTIMATE DETAILS

Ref	Description	Quantity	Unit	Rate	Amount
4.0	PERMANENT DELIVERY PIPELINE				(Continued)
4	Allow to connect pipeline to temporary pumping station and booster assembly as required	2.00	No	2,500.00	5,000.00
				Total :	448,700.00
5.0	TEMPORARY DELIVERY PIPELINE				
	Temporary Delivery Pipeline				
1	Allow for supply and delivery of DN200 HDPE pipe to Council depot as required [NB: Temporary laying of pipe taken in maintenance works]	1,100.00	m	65.00	71,500.00
2	Ditto isolation valves and offtake pipe outlets to suit temporary delivery pipeline	4.00	No	2,000.00	8,000.00
				Total :	79,500.00
6.0	TEMPORARY PRIMARY PUMPING STATION				
	Temporary Primary Pumping Station				
1	Allow for supply and delivery of mobile / temporary primary pumping station to Council depot [NB: Provisional - Temporary assembly / installation & disassembly taken in maintenance works]	1.00	Item	250,000.00	250,000.00
	On-Site Plinth				
2	Allow to construct permanent on-site plinth to support installation and assembly of temporary pumping station	50.00	m2	250.00	12,500.00
				Total :	262,500.00
7.0	TEMPORARY PUMPING STATION BOOSTER				
	Temporary Pumping Station Booster				
1	Allow for supply and delivery of mobile / temporary pumping station booster to Council depot [NB: Provisional - Temporary assembly / installation & disassembly taken in maintenance works]	1.00	Item	150,000.00	150,000.00
	On-Site Plinth				
2	Allow to construct permanent on-site plinth to support installation and assembly of temporary booster station	50.00	m2	250.00	12,500.00
				Total :	162,500.00
8.0	REMEDIATION				
	Remediation Works				

ESTIMATE DETAILS

Ref	Description	Quantity	Unit	Rate	Amount
8.0	REMEDIATION				(Continued)
	1 Allow for minor remediation works to permanent delivery pipeline once works have been completed	8,500.00	m2	5.00	42,500.00
				Total :	42,500.00
9.0	PRELIMINARIES AND MARGIN (8%)				
				Total :	
10.0	CAPITAL WORKS CONTINGENCY (20%)				
	1				
				Total :	
11.0	CAPITAL WORKS - OPTION 4 TOTAL (EXCL GST)				
	1				
				Total :	
12.0	MAINTENANCE WORKS - 2 YEAR FREQUENCY				
	1				
				Total :	
13.0	GENERAL				
	General				
	1 Site establishment and demobilisation	1.00	Item	100,000.00	100,000.00
	2 Contractors supervision	7.00	Weeks	10,000.00	70,000.00
	3 Survey and set out of works by registered surveyor	5.00	Days	1,800.00	9,000.00
	4 Location of services	1.00	Item	10,000.00	10,000.00
	5 Protection of services	1.00	Item	25,000.00	25,000.00
	6 Traffic control to Narrabeen Lagoon Entrance and Collaroy Beach	7.00	Weeks	18,600.00	130,200.00
	Sediment & Erosion Controls				
	7 Allow for sediment fencing, berms and environmental controls as required	1.00	Item	80,000.00	80,000.00
				Total :	424,200.00
14.0	SITE PREPARATION				

ESTIMATE DETAILS

Ref	Description	Quantity	Unit	Rate	Amount
14.0	SITE PREPARATION				
	Site Clearance				
1	Allow for general site clearing and preparation to undertake works [NB: Assumed 5m clearance of temporary pipeline and surrounding areas of pump station assembly areas]	55,700.00	m2	1.00	55,700.00
				Total :	*55,700.00*
15.0	EXCAVATION - SLURRYTRAK				
	Bulk Excavation - SlurryTrak				
	Plant Mobilisation				
1	Allow for mobilisation of plant equipment [NB: Refer to 'General' Trade for Details]	1.00	Item		INCL
	Excavation Works - SlurryTrak				
2	Allow for bulk excavation of sand at Narrabeen Lagoon Entrance with SlurryTrak operation into mobile sled with connection pipe (Approx 400mm long) to temporary primary pumping station	15,000.00	m3	17.00	255,000.00
	Excavation Works - Excavator				
3	Allow for bulk spreading of sand slurry to maintain beach profile at temporary outlets installed at Collaroy Beach	15,000.00	m3	7.00	105,000.00
				Total :	*360,000.00*
16.0	TEMPORARY DELIVERY PIPELINE ASSEMBLY				
	Temporary Delivery Pipeline - Assembly				
1	Allow for delivery and assembly of DN200 HDPE pipe from Council depot to Collaroy Beach as required [NB: Supply of temporary delivery pipeline taken in Capital Works]	1,100.00	m	90.00	99,000.00
2	Ditto isolation valves to suit and offtake pipe outlets to suit temporary delivery pipeline	4.00	No	700.00	2,800.00
	Temporary Delivery Pipeline - Disassembly				
3	Allow to carefully disassemble DN200 HDPE pipe and store at Council depot	1,100.00	m	40.00	44,000.00
4	Ditto isolation valves to suit and offtake pipe outlets	4.00	No	300.00	1,200.00
				Total :	*147,000.00*
17.0	TEMPORARY PRIMARY PUMPING STATION ASSEMBLY & OPERATION				
	Assembly				

ESTIMATE DETAILS

Ref		Description	Quantity	Unit	Rate	Amount
17.0		TEMPORARY PRIMARY PUMPING STATION ASSEMBLY & OPERATION				*(Continued)*
	1	Allow for delivery of primary pumping station from Council depot and assembly on site as required	1.00	Item	54,000.00	54,000.00
		Operation				
	2	Allow for operating costs of pump station whilst works are undertaken	5.00	Weeks	2,500.00	12,500.00
		Disassembly				
	3	Allow to carefully disassembly and store primary pumping station at Council depot	1.00	Item	54,000.00	54,000.00
					Total :	*120,500.00*
18.0		TEMPORARY BOOSTER PUMPING STATION ASSEMBLY & OPERATION				
		Assembly				
	1	Allow for delivery of pumping station booster from Council depot and assembly on site as required	1.00	Item	54,000.00	54,000.00
		Operation				
	2	Allow for operating costs of booster station whilst works are undertaken	5.00	Weeks	2,500.00	12,500.00
		Disassembly				
	3	Allow to carefully disassembly and store pumping station booster at Council depot	1.00	Item	54,000.00	54,000.00
					Total :	*120,500.00*
19.0		PUMP STATION MAINTENANCE				
		Pump Station Maintenance				
	1	Allow for routine inspections and maintenance undertaken by Council of temporary primary pumping station and pumping station booster [NB: Assumed to be undertaken every 2 years before campaign begins]	2.00	No	10,000.00	20,000.00
					Total :	*20,000.00*
20.0		REMEDIATION				
		Remediation Works				
	1	Allow for minor remediation works to temporary delivery pipeline once works have been completed	55,700.00	m2	1.50	83,550.00
					Total :	*83,550.00*
21.0		PRELIMINARIES AND MARGIN (8%)				

ESTIMATE DETAILS

Ref	Description	Quantity	Unit	Rate	Amount
				Total :	
22.0	MAINTENANCE WORKS CONTINGENCY (20%)				
	1				
				Total :	
23.0	MAINTENANCE WORKS - OPTION 4 TOTAL (EXCL GST)				
	1				
				Total :	
24.0	MAINTENANCE WORKS - 15 YEAR FREQUENCY				
	1				
				Total :	
25.0	PUMP STATION & BOOSTER REPLACEMENT				
	1 NB: Assumed full replacement of pumping station and booster station every 15 years Temporary Primary Pumping Station		Note		
	2 Allow for supply and delivery of mobile / temporary primary pumping station to Council depot [NB: Provisional - Temporary assembly / installation & disassembly taken in maintenance works] Temporary Pumping Station Booster	1.00	Item	250,000.00	250,000.00
	3 Allow for supply and delivery of mobile / temporary pumping station booster to Council depot [NB: Provisional - Temporary assembly / installation & disassembly taken in maintenance works]	1.00	Item	150,000.00	150,000.00
				Total :	400,000.00
26.0	MAINTENANCE WORKS CONTINGENCY (20%)				
				Total :	
27.0	MAINTENANCE WORKS - 15 YEAR FREQUENCY - OPTION 4 TOTAL (EXCL GST)				
	1				
				Total :	

NARRABEEN LAGOON ENTRANCE
MANAGEMENT OPTIONS
LOW FLOW PIPES - OPTION 5

JUNE 2021

MAIN COST SUMMARY

Ref	Description	%	Cost / m2	Sub Total	Total
1.0	CAPITAL WORKS				
2.0	GENERAL	7.62		479,400	479,400
3.0	SITE PREPARATION	0.02		1,250	1,250
4.0	INTAKE & OUTLET STRUCTURE	1.10		69,000	69,000
5.0	LOW FLOW PIPES	65.18		4,102,400	4,102,400
6.0	REMEDIATION	0.04		2,500	2,500
7.0	PRELIMINARIES AND MARGIN (12%)	8.86		557,450	557,450
8.0	CAPITAL WORKS CONTINGENCY (20%)	16.56		1,042,000	1,042,000
9.0	CAPITAL WORKS - OPTION 5 TOTAL (EXCL GST)				*6,254,000*
10.0	MAINTENANCE WORKS				
11.0	PIPE INSPECTION & ROUTINE CLEANOUT	0.49		31,000	31,000
12.0	PRELIMINARIES AND MARGIN (8%)	0.04		2,500	2,500
13.0	MAINTENANCE WORKS CONTINGENCY (20%)	0.10		6,500	6,500
14.0	MAINTENANCE WORKS - OPTION 5 TOTAL (EXCL GST)				*40,000*
		100.00		6,294,000	6,294,000

MULLER partnership

NARRABEEN LAGOON ENTRANCE
MANAGEMENT OPTIONS
LOW FLOW PIPES - OPTION 5

JUNE 2021

ESTIMATE DETAILS

Ref		Description	Quantity	Unit	Rate	Amount
1.0	CAPITAL WORKS					
	1					
					Total :	
2.0	GENERAL					
		General				
	1	Site establishment and demobilisation	1.00	Item	100,000.00	100,000.00
	2	Contractors supervision	14.00	Weeks	10,000.00	140,000.00
	3	Survey and set out of works by registered surveyor	9.00	Davs	1,800.00	16,200.00
	4	Location of services	1.00	Item	15,000.00	15,000.00
	5	Protection of services	1.00	Item	25,000.00	25,000.00
	6	Traffic control	14.00	Weeks	11,300.00	158,200.00
		Sediment & Erosion Controls				
	7	Allow for sediment fencing, berms and environmental controls as required	1.00	Item	25,000.00	25,000.00
					Total :	479,400.00
3.0	SITE PREPARATION					
		Site Clearance				
	1	Allow for general site clearing and preparation to undertake works	500.00	m2	2.50	1,250.00
					Total :	1,250.00
4.0	INTAKE & OUTLET STRUCTURE					
		Intake Structure				
	1	Allow for supply, delivery and installation of pre-cast concrete headwalls to intake structure	2.00	No	8,000.00	16,000.00
	2	Supply and install stainless steel grates to intake structure	2.00	No	3,000.00	6,000.00
	3	Ditto stainless steel safety handrail to enhance public safety	10.00	m	500.00	5,000.00
		Outlet Structure				
	4	Allow for supply, delivery and installation of pre-cast concrete headwalls to outlet structure including difficult access constraints	2.00	No	15,000.00	30,000.00
	5	Supply and install stainless steel grates to outlet structure including difficult access constraints	2.00	No	6,000.00	12,000.00
					Total :	69,000.00

ESTIMATE DETAILS

Ref		Description	Quantity	Unit	Rate	Amount
5.0	LOW FLOW PIPES					
		Plant Equipment				
	1	Mobilisation and demobilisation of plant equipment	1.00	Item	100,000.00	100,000.00
		Launch Pit				
	2	Allow for launch pit excavation to lagoon entrance to allow for drilling including shoring as required	1.00	No	28,000.00	28,000.00
		Underboring / Drilling				
	3	Allow for minimum 800mm bore hole directionally drilled through bedrock [NB: 3 No. pipes across 414m length]	1,242.00	m	2,400.00	2,980,800.00
		Pipe Supply and Pulling				
	4	Supply and install DN800 HDPE pipe including pulling through bore hole as required [NB: Assumed pipe material]	1,242.00	m	800.00	993,600.00
					Total :	*4,102,400.00*
6.0	REMEDIATION					
		Remediation Works				
	1	Allow for minor remediation works to permanent delivery pipeline once works have been completed	500.00	m2	5.00	2,500.00
					Total :	*2,500.00*
7.0	PRELIMINARIES AND MARGIN (12%)					
					Total :	
8.0	CAPITAL WORKS CONTINGENCY (20%)					
	1					
					Total :	
9.0	CAPITAL WORKS - OPTION 5 TOTAL (EXCL GST)					
	1					
					Total :	
10.0	MAINTENANCE WORKS					
	1					

ESTIMATE DETAILS

Ref	Description	Quantity	Unit	Rate	Amount
				Total :	
11.0	PIPE INSPECTION & ROUTINE CLEANOUT				
	Pipe Inspection				
1	Allow for CCTV pipe inspection to identify any issues or debris [NB: Assumed to be undertaken every 2 years]	1.00	Item	20,000.00	20,000.00
	Pipe Routine Cleanout				
2	Allow for pipe maintenance and cleanout to be undertaken by Council [NB: Assumed to be undertaken every year]	1.00	Item	11,000.00	11,000.00
				Total :	31,000.00
12.0	PRELIMINARIES AND MARGIN (8%)				
				Total :	
13.0	MAINTENANCE WORKS CONTINGENCY (20%)				
1					
				Total :	
14.0	MAINTENANCE WORKS - OPTION 5 TOTAL (EXCL GST)				
1					
				Total :	

APPENDIX B – WHOLE OF LIFE ASSESSMENTS (5 NO. OPTIONS)

NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
EXCAVATION AND TRUCKING (4 YEAR) - OPTION 1

MULLER partnership

			1	2	3	4	5	6
Year		**Units**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
CAPITAL COSTS ($ 2021)								
Capital costs	Excl.	$						
TOTAL CAPITAL COSTS	-	$	-	-	-	-	-	-
OPERATING COSTS ($ 2021)								
Labour & other operating costs	Excl.	$						
TOTAL OPERATING COSTS		$	-	-	-	-	-	-
MAINTENANCE COSTS ($ 2021)								
Based on the Concept Design Estimate dated 07 June 2021.								
General								
Site establishment and demobilisation	Frequency of every 4 years	$	$ 100,000			$ 100,000		
Contractors supervision		$	$ 120,000			$ 120,000		
Survey and set out of works by registered surveyor		$	$ 14,400			$ 14,400		
Location of services		$	$ 10,000			$ 10,000		
Protection of services		$	$ 25,000			$ 25,000		
Traffic control to Narrabeen Lagoon Entrance and Collaroy Beach		$	$ 223,200			$ 223,200		
Sediment & Erosion Controls								
Allow for sediment fencing, berms and environmental controls as required		$	$ 25,000			$ 25,000		
Site Clearance								
Allow for general site clearing and preparation to undertake works		$	$ 25,000			$ 25,000		
Excavation, Trucking and Spreading								
Allow for bulk excavation of sand at Narrabeen Lagoon Entrance		$	$ 320,000			$ 320,000		
Allow to load and truck sand to Collaroy / Narrabeen Beach		$	$ 400,000			$ 400,000		
Allow to unload and spread sand across Collaroy / Narrabeen Beach		$	$ 320,000			$ 320,000		
Remediation Works								
Allow for minor remediation works to Narrabeen Lagoon Entrance once sand excavation has been undertaken		$	$ 75,000			$ 75,000		
Preliminaries & Margin		$	$ 132,400			$ 132,400		
Maintenance Works Contingency		$	$ 358,000			$ 358,000		
TOTAL MAINTENANCE COSTS		$	2,148,000	-	-	2,148,000	-	-
TOTAL MAINTENANCE PV 4%		$	2,065,385	-	-	1,836,119	-	-
TOTAL MAINTENANCE PV 7%		$	2,007,477	-	-	1,614,728	-	-
TOTAL MAINTENANCE PV 10%		$	1,952,727	-	-	1,423,538	-	-
LIFECYCLE COSTS		$	2,148,000	-	-	2,148,000	-	-
TOTAL PV 4%		$	$ 2,065,385	$ -	$ -	$ 1,836,119	$ -	$ -
TOTAL PV 7%		$	$ 2,007,477	$ -	$ -	$ 1,614,728	$ -	$ -
TOTAL PV 10%		$	$ 1,952,727	$ -	$ -	$ 1,423,538	$ -	$ -

NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
EXCAVATION AND TRUCKING (4 YEAR) - OPTION 1

MULLER partnership

7	8	9	10	11	12	13	14	15	16	17	18
2027	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
	$ 100,000				$ 100,000				$ 100,000		
	$ 120,000				$ 120,000				$ 120,000		
	$ 14,400				$ 14,400				$ 14,400		
	$ 10,000				$ 10,000				$ 10,000		
	$ 25,000				$ 25,000				$ 25,000		
	$ 223,200				$ 223,200				$ 223,200		
	$ 25,000				$ 25,000				$ 25,000		
	$ 25,000				$ 25,000				$ 25,000		
	$ 320,000				$ 320,000				$ 320,000		
	$ 400,000				$ 400,000				$ 400,000		
	$ 320,000				$ 320,000				$ 320,000		
	$ 75,000				$ 75,000				$ 75,000		
	$ 132,400				$ 132,400				$ 132,400		
	$ 358,000				$ 358,000				$ 358,000		
-	2,148,000	-	-	-	2,148,000	-	-	-	2,148,000	-	-
-	1,569,523	-	-	-	1,341,634	-	-	-	1,146,835	-	-
-	1,207,900	-	-	-	903,572	-	-	-	675,919	-	-
-	933,983	-	-	-	612,787	-	-	-	402,049	-	-
-	2,148,000	-	-	-	2,148,000	-	-	-	2,148,000	-	-
$ -	**$ 1,569,523**	**$ -**	**$ -**	**$ -**	**$ 1,341,634**	**$ -**	**$ -**	**$ -**	**$ 1,146,835**	**$ -**	**$ -**
$ -	**$ 1,207,900**	**$ -**	**$ -**	**$ -**	**$ 903,572**	**$ -**	**$ -**	**$ -**	**$ 675,919**	**$ -**	**$ -**
$ -	**$ 933,983**	**$ -**	**$ -**	**$ -**	**$ 612,787**	**$ -**	**$ -**	**$ -**	**$ 402,049**	**$ -**	**$ -**

NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
EXCAVATION AND TRUCKING (4 YEAR) - OPTION 1

MULLER partnership

19	20	21	22	23	24	25	26	27	28	29	30
2039	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**	**2046**	**2047**	**2048**	**2049**	**2050**
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
	$ 100,000				$ 100,000				$ 100,000		
	$ 120,000				$ 120,000				$ 120,000		
	$ 14,400				$ 14,400				$ 14,400		
	$ 10,000				$ 10,000				$ 10,000		
	$ 25,000				$ 25,000				$ 25,000		
	$ 223,200				$ 223,200				$ 223,200		
	$ 25,000				$ 25,000				$ 25,000		
	$ 25,000				$ 25,000				$ 25,000		
	$ 320,000				$ 320,000				$ 320,000		
	$ 400,000				$ 400,000				$ 400,000		
	$ 320,000				$ 320,000				$ 320,000		
	$ 75,000				$ 75,000				$ 75,000		
	$ 132,400				$ 132,400				$ 132,400		
	$ 358,000				$ 358,000				$ 358,000		
-	2,148,000	-	-	-	2,148,000	-	-	-	2,148,000	-	-
-	**980,319**	-	-	-	**837,981**	-	-	-	**716,310**	-	-
-	**505,623**	-	-	-	**378,232**	-	-	-	**282,937**	-	-
-	**263,784**	-	-	-	**173,069**	-	-	-	**113,551**	-	-
-	2,148,000	-	-	-	2,148,000	-	-	-	2,148,000	-	-
$ -	**$ 980,319**	**$ -**	**$ -**	**$ -**	**$ 837,981**	**$ -**	**$ -**	**$ -**	**$ 716,310**	**$ -**	**$ -**
$ -	**$ 505,623**	**$ -**	**$ -**	**$ -**	**$ 378,232**	**$ -**	**$ -**	**$ -**	**$ 282,937**	**$ -**	**$ -**
$ -	**$ 263,784**	**$ -**	**$ -**	**$ -**	**$ 173,069**	**$ -**	**$ -**	**$ -**	**$ 113,551**	**$ -**	**$ -**

NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
EXCAVATION AND TRUCKING (2 YEAR) - OPTION 2

MULLER partnership

			1	2	3	4	5	6
Year		**Units**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
CAPITAL COSTS ($ 2021)								
Capital costs	Excl.	$						
TOTAL CAPITAL COSTS	-	$	-	-	-	-	-	-
OPERATING COSTS ($ 2021)								
Labour & other operating costs	Excl.	$						
TOTAL OPERATING COSTS		$	-	-	-	-	-	-
MAINTENANCE COSTS ($ 2021)								
Based on the Concept Design Estimate dated 07 June 2021.								
General								
Site establishment and demobilisation	Frequency of every 2 years	$	$ 100,000		$ 100,000		$ 100,000	
Contractors supervision		$	$ 50,000		$ 50,000		$ 50,000	
Survey and set out of works by registered surveyor		$	$ 5,400		$ 5,400		$ 5,400	
Location of services		$	$ 10,000		$ 10,000		$ 10,000	
Protection of services		$	$ 25,000		$ 25,000		$ 25,000	
Traffic control		$	$ 93,000		$ 93,000		$ 93,000	
Sediment & Erosion Controls								
Allow for sediment fencing, berms and environmental controls as required		$	$ 25,000		$ 25,000		$ 25,000	
Site Clearance								
Allow for general site clearing and preparation to undertake works		$	$ 25,000		$ 25,000		$ 25,000	
Excavation, Trucking and Spreading								
Allow for bulk excavation of sand at Narrabeen Lagoon Entrance		$	$ 150,000		$ 150,000		$ 150,000	
Allow to load and truck sand to Collaroy / Narrabeen Beach		$	$ 180,000		$ 180,000		$ 180,000	
Allow to unload and spread sand across Collaroy / Narrabeen Beach		$	$ 150,000		$ 150,000		$ 150,000	
Remediation Works								
Allow for minor remediation works to Narrabeen Lagoon Entrance once sand excavation has been undertaken		$	$ 75,000		$ 75,000		$ 75,000	
Preliminaries & Margin		$	$ 71,600		$ 71,600		$ 71,600	
Maintenance Works Contingency		$	$ 192,000		$ 192,000		$ 192,000	
TOTAL MAINTENANCE COSTS		$	1,152,000	-	1,152,000	-	1,152,000	-
TOTAL MAINTENANCE PV 4%		$	1,107,692	-	1,024,124	-	946,860	-
TOTAL MAINTENANCE PV 7%		$	1,076,636	-	931,182	-	805,379	-
TOTAL MAINTENANCE PV 10%		$	1,047,273	-	848,291	-	687,116	-
LIFECYCLE COSTS		$	1,152,000	-	1,152,000	-	1,152,000	-
TOTAL PV 4%		$	$ 1,107,692	$ -	$ 1,024,124	$ -	$ 946,860	$ -
TOTAL PV 7%		$	$ 1,076,636	$ -	$ 931,182	$ -	$ 805,379	$ -
TOTAL PV 10%		$	$ 1,047,273	$ -	$ 848,291	$ -	$ 687,116	$ -

NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
EXCAVATION AND TRUCKING (2 YEAR) - OPTION 2

MULLER partnership

7	8	9	10	11	12	13	14	15	16	17	18
2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
$ 100,000		$ 100,000		$ 100,000		$ 100,000		$ 100,000		$ 100,000	
$ 50,000		$ 50,000		$ 50,000		$ 50,000		$ 50,000		$ 50,000	
$ 5,400		$ 5,400		$ 5,400		$ 5,400		$ 5,400		$ 5,400	
$ 10,000		$ 10,000		$ 10,000		$ 10,000		$ 10,000		$ 10,000	
$ 25,000		$ 25,000		$ 25,000		$ 25,000		$ 25,000		$ 25,000	
$ 93,000		$ 93,000		$ 93,000		$ 93,000		$ 93,000		$ 93,000	
$ 25,000		$ 25,000		$ 25,000		$ 25,000		$ 25,000		$ 25,000	
$ 25,000		$ 25,000		$ 25,000		$ 25,000		$ 25,000		$ 25,000	
$ 150,000		$ 150,000		$ 150,000		$ 150,000		$ 150,000		$ 150,000	
$ 180,000		$ 180,000		$ 180,000		$ 180,000		$ 180,000		$ 180,000	
$ 150,000		$ 150,000		$ 150,000		$ 150,000		$ 150,000		$ 150,000	
$ 75,000		$ 75,000		$ 75,000		$ 75,000		$ 75,000		$ 75,000	
$ 71,600		$ 71,600		$ 71,600		$ 71,600		$ 71,600		$ 71,600	
$ 192,000		$ 192,000		$ 192,000		$ 192,000		$ 192,000		$ 192,000	
1,152,000	-	1,152,000	-	1,152,000	-	1,152,000	-	1,152,000	-	1,152,000	-
875,425	-	809,380	-	748,317	-	691,861	-	639,665	-	591,406	-
696,573	-	602,466	-	521,073	-	450,676	-	389,789	-	337,129	-
556,564	-	450,817	-	365,161	-	295,781	-	239,582	-	194,062	-
1,152,000	-	1,152,000	-	1,152,000	-	1,152,000	-	1,152,000	-	1,152,000	-
$ 875,425	$ -	$ 809,380	$ -	$ 748,317	$ -	$ 691,861	$ -	$ 639,665	$ -	$ 591,406	$ -
$ 696,573	$ -	$ 602,466	$ -	$ 521,073	$ -	$ 450,676	$ -	$ 389,789	$ -	$ 337,129	$ -
$ 556,564	$ -	$ 450,817	$ -	$ 365,161	$ -	$ 295,781	$ -	$ 239,582	$ -	$ 194,062	$ -

NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
EXCAVATION AND TRUCKING (2 YEAR) - OPTION 2

MULLER partnership

19	20	21	22	23	24	25	26	27	28	29	30
2039	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**	**2046**	**2047**	**2048**	**2049**	**2050**
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
$ 100,000		$ 100,000		$ 100,000		$ 100,000		$ 100,000		$ 100,000	
$ 50,000		$ 50,000		$ 50,000		$ 50,000		$ 50,000		$ 50,000	
$ 5,400		$ 5,400		$ 5,400		$ 5,400		$ 5,400		$ 5,400	
$ 10,000		$ 10,000		$ 10,000		$ 10,000		$ 10,000		$ 10,000	
$ 25,000		$ 25,000		$ 25,000		$ 25,000		$ 25,000		$ 25,000	
$ 93,000		$ 93,000		$ 93,000		$ 93,000		$ 93,000		$ 93,000	
$ 25,000		$ 25,000		$ 25,000		$ 25,000		$ 25,000		$ 25,000	
$ 25,000		$ 25,000		$ 25,000		$ 25,000		$ 25,000		$ 25,000	
$ 150,000		$ 150,000		$ 150,000		$ 150,000		$ 150,000		$ 150,000	
$ 180,000		$ 180,000		$ 180,000		$ 180,000		$ 180,000		$ 180,000	
$ 150,000		$ 150,000		$ 150,000		$ 150,000		$ 150,000		$ 150,000	
$ 75,000		$ 75,000		$ 75,000		$ 75,000		$ 75,000		$ 75,000	
$ 71,600		$ 71,600		$ 71,600		$ 71,600		$ 71,600		$ 71,600	
$ 192,000		$ 192,000		$ 192,000		$ 192,000		$ 192,000		$ 192,000	
1,152,000	-	1,152,000	-	1,152,000	-	1,152,000	-	1,152,000	-	1,152,000	-
546,788	**-**	**505,536**	**-**	**467,397**	**-**	**432,135**	**-**	**399,533**	**-**	**369,390**	**-**
291,583	**-**	**252,190**	**-**	**218,119**	**-**	**188,651**	**-**	**163,164**	**-**	**141,121**	**-**
157,190	**-**	**127,324**	**-**	**103,132**	**-**	**83,537**	**-**	**67,665**	**-**	**54,809**	**-**
1,152,000	-	1,152,000	-	1,152,000	-	1,152,000	-	1,152,000	-	1,152,000	-
$ 546,788	**$ -**	**$ 505,536**	**$ -**	**$ 467,397**	**$ -**	**$ 432,135**	**$ -**	**$ 399,533**	**$ -**	**$ 369,390**	**$ -**
$ 291,583	**$ -**	**$ 252,190**	**$ -**	**$ 218,119**	**$ -**	**$ 188,651**	**$ -**	**$ 163,164**	**$ -**	**$ 141,121**	**$ -**
$ 157,190	**$ -**	**$ 127,324**	**$ -**	**$ 103,132**	**$ -**	**$ 83,537**	**$ -**	**$ 67,665**	**$ -**	**$ 54,809**	**$ -**

NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
MOBILE SAND PUMPING (4 YEARS) - OPTION 3

MULLER partnership

				1	2	3	4	5	6
Year			**Units**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
CAPITAL COSTS ($ 2021)									
Based on the Concept Design Estimate dated 07 June 2021.									
General	Upfront Capital Costs								
Site establishment and demobilisation			$	$ 100,000					
Contractors supervision			$	$ 100,000					
Survey and set out of works by registered surveyor			$	$ 10,800					
Location of services			$	$ 15,000					
Protection of services			$	$ 25,000					
Traffic control to both ends of permanent pipeline construction			$	$ 186,000					
Sediment & Erosion Controls									
Allow for sediment fencing, berms and environmental controls along length of permanent pipeline construction			$	$ 85,000					
Site Preparation									
Allow for general site clearing and preparation to undertake works	Assumed 5m clearance of permanent pipeline length		$	$ 21,250					
Permanent Delivery Pipeline									
Excavation									
Allow for detailed excavation to permanent delivery pipeline trench including backfilling once pipework has been laid			$	$ 163,200					
Pipework									
Supply and lay DN200 HDPE pipework into trench	1700m long		$	$ 255,000					
Allow for bends, junctions, tees, couplers and other fittings as required	Assumed 10% costs of pipework		$	$ 25,500					
Connection									
Allow to connect pipeline to temporary pumping station and booster assembly as required			$	$ 5,000					
Temporary Delivery Pipeline									
Allow for supply and delivery of DN200 HDPE pipe to council depot as required	Temporary laying of pipe taken in maintenance works		$	$ 71,500					
Ditto isolation valves and offtake pipe outlets to suit temporary delivery pipeline	Temporary assembly of isolation valves taken in maintenance works		$	$ 8,000					
Temporary Primary Pumping Station									
Allow for supply and delivery of mobile / temporary primary pumping station to Council depot	Assembly / installation & disassembly taken in maintenance works		$	$ 250,000					
Allow to construct permanent on-site plinth to support installation and assembly of temporary pumping station	Assumed details		$	$ 12,500					
Temporary Booster Pumping Station									
Allow for supply and delivery of mobile / temporary booster pumping station to Council depot	Assembly / installation & disassembly taken in maintenance works		$	$ 150,000					
Allow to construct permanent on-site plinth to support installation and assembly of temporary booster station	Assumed details		$	$ 12,500					
Remediation Works									
Allow for minor remediation works to permanent delivery pipeline once works have been completed	Assumed 5m clearance of permanent pipeline length		$	$ 42,500					
Preliminaries and Margin			$	$ 122,250					
Capital Works Contingency			$	$ 333,000					
TOTAL CAPITAL COSTS		1,994,000	$	1,994,000	-	-	-	-	-
OPERATING COSTS ($ 2021)									
Labour & other operating costs		Excl.	$						
TOTAL OPERATING COSTS			$	-	-	-	-	-	-

NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
MOBILE SAND PUMPING (4 YEARS) - OPTION 3

MULLER partnership

			1	2	3	4	5	6
Year		**Units**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
MAINTENANCE COSTS ($ 2021)								
Based on the Concept Design Estimate dated 07 June 2021.								
General								
Site establishment and demobilisation	Frequency of every 4 years	$	$ 100,000			$ 100,000		
Contractors supervision		$	$ 140,000			$ 140,000		
Survey and set out of works by registered surveyor		$	$ 16,200			$ 16,200		
Location of services		$	$ 10,000			$ 10,000		
Protection of services		$	$ 25,000			$ 25,000		
Traffic control to Narrabeen Lagoon Entrance and Collaroy Beach		$	$ 260,400			$ 260,400		
Sediment & Erosion Controls								
Allow for sediment fencing, berms and environmental controls as required		$	$ 80,000			$ 80,000		
Site Clearance								
Allow for general site clearing and preparation to undertake works	Assumed 5m clearance of temporary pipeline and surrounding areas of pump station assembly	$	$ 55,700			$ 55,700		
Excavation - Slurry Trak								
Plant Mobilisation	Mobilisation of plant equipment taken in General trade above		INCL			INCL		
Excavation Works - SlurryTrak								
Allow for bulk excavation of sand at Narrabeen Lagoon Entrance with SlurryTrak operation into mobile sled with connection pipe (Approx. 400mm long) to temporary primary pumping station		$	$ 600,000			$ 600,000		
Excavation Works - Excavator								
Allow for bulk spreading of sand slurry to maintain beach profile at temporary outlets installed at Collaroy Beach		$	$ 200,000			$ 200,000		
Temporary Delivery Pipeline - Assembly								
Allow for delivery and assembly of DN200 HDPE pipe from Council depot to Collaroy Beach as required	Supply of temporary delivery pipeline taken in Capital Works	$	$ 99,000			$ 99,000		
Ditto isolation valves to suit and offtake pipe outlets to suit temporary delivery pipeline		$	$ 2,800			$ 2,800		
Temporary Delivery Pipeline - Disassembly								
Allow to carefully disassemble DN200 HDPE pipe and store at Council depot		$	$ 44,000			$ 44,000		
Ditto isolation valves to suit and offtake pipe outlets		$	$ 1,200			$ 1,200		
Temporary Primary Pumping Station Assembly & Operation								
Assembly								
Allow for delivery of primary pumping station from Council depot and assembly on site as required		$	$ 54,000			$ 54,000		
Operation								
Allow for operating costs of pump station whilst works are undertaken		$	$ 30,000			$ 30,000		
Disassembly								
Allow to carefully disassembly and store primary pumping station at Council depot		$	$ 54,000			$ 54,000		
Temporary Booster Pumping Station Assembly & Operation								
Assembly								
Allow for delivery of booster pumping station from Council depot and assembly on site as required		$	$ 54,000			$ 54,000		
Operation								
Allow for operating costs of pump station whilst works are undertaken		$	$ 30,000			$ 30,000		
Disassembly								
Allow to carefully disassembly and store booster pumping station at Council depot		$	$ 54,000			$ 54,000		
Pump Station Maintenance								
Allow for routine inspections and maintenance undertaken by Council of temporary primary pumping station and booster pumping station	Assumed to be undertaken every 4 years before campaign begins	$	$ 20,000			$ 20,000		
Pump Station & Booster Replacement								
Allow for supply and delivery of mobile / temporary primary pumping station to Council depot [NB: Provisional - Temporary assembly / installation & disassembly taken in maintenance works]	Assumed full replacement every 15 years	$						
Allow for supply and delivery of mobile / temporary pumping station booster to Council depot [NB: Provisional - Temporary assembly / installation & disassembly taken in maintenance works]	Assumed full replacement every 15 years	$						
Remediation								
Allow for minor remediation works to temporary delivery pipeline once works have been completed		$	$ 83,550			$ 83,550		
Preliminaries and Margin		$	$ 161,150			$ 161,150		
Maintenance Works Contingency		$	$ 435,150			$ 435,150		
TOTAL MAINTENANCE COSTS		$	**2,610,150**	-	-	**2,610,150**	-	-
TOTAL MAINTENANCE PV 4%		$	**2,509,760**	-	-	**2,231,167**	-	-
TOTAL MAINTENANCE PV 7%		$	**2,439,393**	-	-	**1,962,142**	-	-
TOTAL MAINTENANCE PV 10%		$	**2,372,864**	-	-	**1,729,818**	-	-
LIFECYCLE COSTS		$	**4,604,150**	-	-	**2,610,150**	-	-
TOTAL PV 4%		$	**$ 4,427,067**	**$ -**	**$ -**	**$ 2,231,167**	**$ -**	**$ -**
TOTAL PV 7%		$	**$ 4,302,944**	**$ -**	**$ -**	**$ 1,962,142**	**$ -**	**$ -**
TOTAL PV 10%		$	**$ 4,185,591**	**$ -**	**$ -**	**$ 1,729,818**	**$ -**	**$ -**

MULLER partnership

7	8	9	10	11	12	13	14	15	16	17	18
2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-

NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
MOBILE SAND PUMPING (4 YEARS) - OPTION 3

7	8	9	10	11	12	13	14	15	16	17	18
2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
	$ 100,000				$ 100,000				$ 100,000		
	$ 140,000				$ 140,000				$ 140,000		
	$ 16,200				$ 16,200				$ 16,200		
	$ 10,000				$ 10,000				$ 10,000		
	$ 25,000				$ 25,000				$ 25,000		
	$ 260,400				$ 260,400				$ 260,400		
	$ 80,000				$ 80,000				$ 80,000		
	$ 55,700				$ 55,700				$ 55,700		
	INCL				INCL				INCL		
	$ 600,000				$ 600,000				$ 600,000		
	$ 200,000				$ 200,000				$ 200,000		
	$ 99,000				$ 99,000				$ 99,000		
	$ 2,800				$ 2,800				$ 2,800		
	$ 44,000				$ 44,000				$ 44,000		
	$ 1,200				$ 1,200				$ 1,200		
	$ 54,000				$ 54,000				$ 54,000		
	$ 30,000				$ 30,000				$ 30,000		
	$ 54,000				$ 54,000				$ 54,000		
	$ 54,000				$ 54,000				$ 54,000		
	$ 30,000				$ 30,000				$ 30,000		
	$ 54,000				$ 54,000				$ 54,000		
	$ 20,000				$ 20,000				$ 20,000		
								$ 250,000			
								$ 150,000			
	$ 83,550				$ 83,550				$ 83,550		
	$ 161,150				$ 161,150				$ 161,150		
	$ 435,150				$ 435,150			$ 80,000	$ 435,150		
-	2,610,150	-	-	-	2,610,150	-	-	480,000	2,610,150	-	-
-	1,907,211	-	-	-	1,630,292	-	-	266,527	1,393,580	-	-
-	1,467,785	-	-	-	1,097,979	-	-	162,412	821,346	-	-
-	1,134,933	-	-	-	744,630	-	-	99,826	488,552	-	-
-	2,610,150	-	-	-	2,610,150	-	-	480,000	2,610,150	-	-
$ -	$ 1,907,211	$ -	$ -	$ -	$ 1,630,292	$ -	$ -	$ 266,527	$ 1,393,580	$ -	$ -
$ -	$ 1,467,785	$ -	$ -	$ -	$ 1,097,979	$ -	$ -	$ 162,412	$ 821,346	$ -	$ -
$ -	$ 1,134,933	$ -	$ -	$ -	$ 744,630	$ -	$ -	$ 99,826	$ 488,552	$ -	$ -

MULLER partnership

19	20	21	22	23	24	25	26	27	28	29	30
2039	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**	**2046**	**2047**	**2048**	**2049**	**2050**
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-

NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
MOBILE SAND PUMPING (4 YEARS) - OPTION 3

MULLER partnership

19	20	21	22	23	24	25	26	27	28	29	30
2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
	$ 100,000				$ 100,000				$ 100,000		
	$ 140,000				$ 140,000				$ 140,000		
	$ 16,200				$ 16,200				$ 16,200		
	$ 10,000				$ 10,000				$ 10,000		
	$ 25,000				$ 25,000				$ 25,000		
	$ 260,400				$ 260,400				$ 260,400		
	$ 80,000				$ 80,000				$ 80,000		
	$ 55,700				$ 55,700				$ 55,700		
	INCL				INCL				INCL		
	$ 600,000				$ 600,000				$ 600,000		
	$ 200,000				$ 200,000				$ 200,000		
	$ 99,000				$ 99,000				$ 99,000		
	$ 2,800				$ 2,800				$ 2,800		
	$ 44,000				$ 44,000				$ 44,000		
	$ 1,200				$ 1,200				$ 1,200		
	$ 54,000				$ 54,000				$ 54,000		
	$ 30,000				$ 30,000				$ 30,000		
	$ 54,000				$ 54,000				$ 54,000		
	$ 54,000				$ 54,000				$ 54,000		
	$ 30,000				$ 30,000				$ 30,000		
	$ 54,000				$ 54,000				$ 54,000		
	$ 20,000				$ 20,000				$ 20,000		
											$ 250,000
											$ 150,000
	$ 83,550				$ 83,550				$ 83,550		
	$ 161,150				$ 161,150				$ 161,150		
	$ 435,150				$ 435,150				$ 435,150		$ 80,000
-	2,610,150	-	-	-	2,610,150	-	-	-	2,610,150	-	480,000
-	1,191,238	-	-	-	1,018,276	-	-	-	870,426	-	147,993
-	614,409	-	-	-	459,610	-	-	-	343,812	-	54,684
-	320,539	-	-	-	210,305	-	-	-	137,981	-	20,553
-	2,610,150	-	-	-	2,610,150	-	-	-	2,610,150	-	480,000
$ -	$ 1,191,238	$ -	$ -	$ -	$ 1,018,276	$ -	$ -	$ -	$ 870,426	$ -	$ 147,993
$ -	$ 614,409	$ -	$ -	$ -	$ 459,610	$ -	$ -	$ -	$ 343,812	$ -	$ 54,684
$ -	$ 320,539	$ -	$ -	$ -	$ 210,305	$ -	$ -	$ -	$ 137,981	$ -	$ 20,553

NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
MOBILE SAND PUMPING (2 YEARS) - OPTION 4

MULLER partnership

			1	2	3	4	5	6
Year		**Units**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
CAPITAL COSTS ($ 2021)								
Based on the Concept Design Estimate dated 07 June 2021.								
General	Upfront Capital Costs							
Site establishment and demobilisation		$	$ 100,000					
Contractors supervision		$	$ 100,000					
Survey and set out of works by registered surveyor		$	$ 10,800					
Location of services		$	$ 15,000					
Protection of services		$	$ 25,000					
Traffic control to both ends of permanent pipeline construction		$	$ 186,000					
Sediment & Erosion Controls								
Allow for sediment fencing, berms and environmental controls along length of permanent pipeline construction		$	$ 85,000					
Site Preparation								
Allow for general site clearing and preparation to undertake works	Assumed 5m clearance of permanent pipeline length	$	$ 21,250					
Permanent Delivery Pipeline								
Excavation								
Allow for detailed excavation to permanent delivery pipeline trench including backfilling once pipework has been laid		$	$ 163,200					
Pipework								
Supply and lay DN200 HDPE pipework into trench	1700m long	$	$ 255,000					
Allow for bends, junctions, tees, couplers and other fittings as required	Assumed 10% costs of pipework	$	$ 25,500					
Connection								
Allow to connect pipeline to temporary pumping station and booster assembly as required		$	$ 5,000					
Temporary Delivery Pipeline								
Allow for supply and delivery of DN200 HDPE pipe to council depot as required	Temporary laying of pipe taken in maintenance works	$	$ 71,500					
Ditto isolation valves and offtake pipe outlets to suit temporary delivery pipeline	Temporary assembly of isolation valves taken in maintenance works	$	$ 8,000					
Temporary Primary Pumping Station								
Allow for supply and delivery of mobile / temporary primary pumping station to Council depot	Assembly / installation & disassembly taken in maintenance works	$	$ 250,000					
Allow to construct permanent on-site plinth to support installation and assembly of temporary pumping station	Assumed details	$	$ 12,500					
Temporary Pumping Station Booster								
Allow for supply and delivery of mobile / temporary pumping station booster to Council depot	Assembly / installation & disassembly taken in maintenance works	$	$ 150,000					
Allow to construct permanent on-site plinth to support installation and assembly of temporary booster station	Assumed details	$	$ 12,500					
Remediation Works								
Allow for minor remediation works to permanent delivery pipeline once works have been completed	Assumed 5m clearance of permanent pipeline length	$	$ 42,500					
Preliminaries and Margin		$	$ 122,250					
Capital Works Contingency		$	$ 333,000					
TOTAL CAPITAL COSTS	1,994,000	$	1,994,000	-	-	-	-	-
OPERATING COSTS ($ 2021)								
Labour & other operating costs	Excl.	$						
TOTAL OPERATING COSTS		$	-	-	-	-	-	-

NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
MOBILE SAND PUMPING (2 YEARS) - OPTION 4

MULLER partnership

			1	2	3	4	5	6
Year		**Units**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
MAINTENANCE COSTS ($ 2021)								
Based on the Concept Design Estimate dated 07 June 2021.								
General								
Site establishment and demobilisation	Frequency of every 2 years	$	$ 100,000		$ 100,000		$ 100,000	
Contractors supervision		$	$ 70,000		$ 70,000		$ 70,000	
Survey and set out of works by registered surveyor		$	$ 9,000		$ 9,000		$ 9,000	
Location of services		$	$ 10,000		$ 10,000		$ 10,000	
Protection of services		$	$ 25,000		$ 25,000		$ 25,000	
Traffic control		$	$ 130,200		$ 130,200		$ 130,200	
Sediment & Erosion Controls								
Allow for sediment fencing, berms and environmental controls as required		$	$ 80,000		$ 80,000		$ 80,000	
Site Clearance								
Allow for general site clearing and preparation to undertake works	Assumed 5m clearance of temporary pipeline and surrounding areas of pump station assembly	$	$ 55,700		$ 55,700		$ 55,700	
Excavation - Slurry Trak								
Plant Mobilisation	Mobilisation of plant equipment taken in General trade above		INCL		INCL		INCL	
Excavation Works - SlurryTrak								
Allow for bulk excavation of sand at Narrabeen Lagoon Entrance with SlurryTrak operation into mobile sled with connection pipe (Approx. 400mm long) to temporary primary pumping station		$	$ 255,000		$ 255,000		$ 255,000	
Excavation Works - Excavator								
Allow for bulk spreading of sand slurry to maintain beach profile at temporary outlets installed at Collaroy Beach		$	$ 105,000		$ 105,000		$ 105,000	
Temporary Delivery Pipeline - Assembly								
Allow for delivery and assembly of DN200 HDPE pipe from Council depot to Collaroy Beach as required	Supply of temporary delivery pipeline taken in Capital Works	$	$ 99,000		$ 99,000		$ 99,000	
Ditto isolation valves to suit and offtake pipe outlets to suit temporary delivery pipeline		$	$ 2,800		$ 2,800		$ 2,800	
Temporary Delivery Pipeline - Disassembly								
Allow to carefully disassemble DN200 HDPE pipe and store at Council depot		$	$ 44,000		$ 44,000		$ 44,000	
Ditto isolation valves to suit and offtake pipe outlets		$	$ 1,200		$ 1,200		$ 1,200	
Temporary Primary Pumping Station Assembly & Operation								
Assembly								
Allow for delivery of primary pumping station from Council depot and assembly on site as required		$	$ 54,000		$ 54,000		$ 54,000	
Operation								
Allow for operating costs of pump station whilst works are undertaken		$	$ 12,500		$ 12,500		$ 12,500	
Disassembly								
Allow to carefully disassembly and store primary pumping station at Council depot		$	$ 54,000		$ 54,000		$ 54,000	
Temporary Pumping Station Booster Assembly & Operation								
Assembly								
Allow for delivery of booster pumping station from Council depot and assembly on site as required		$	$ 54,000		$ 54,000		$ 54,000	
Operation								
Allow for operating costs of pump station whilst works are undertaken		$	$ 12,500		$ 12,500		$ 12,500	
Disassembly								
Allow to carefully disassembly and store pumping station booster at Council depot		$	$ 54,000		$ 54,000		$ 54,000	
Pump Station Maintenance								
Allow for routine inspections and maintenance undertaken by Council of temporary primary pumping station and booster pumping station	Assumed to be undertaken every 2 years before campaign begins	$	$ 20,000		$ 20,000		$ 20,000	
Pump Station & Booster Replacement								
Allow for supply and delivery of mobile / temporary primary pumping station to Council depot [NB: Provisional - Temporary assembly / installation & disassembly taken in maintenance works]	Assumed full replacement every 15 years	$						
Allow for supply and delivery of mobile / temporary pumping station booster to Council depot [NB: Provisional - Temporary assembly / installation & disassembly taken in maintenance works]	Assumed full replacement every 15 years	$						
Remediation								
Allow for minor remediation works to temporary delivery pipeline once works have been completed		$	$ 83,550		$ 83,550		$ 83,550	
Preliminaries and Margin		$	$ 106,550		$ 106,550		$ 106,550	
Maintenance Works Contingency		$	$ 288,000		$ 288,000		$ 288,000	
TOTAL MAINTENANCE COSTS		$	1,726,000	-	1,726,000	-	1,726,000	-
TOTAL MAINTENANCE PV 4%		$	1,659,615	-	1,534,408	-	1,418,646	-
TOTAL MAINTENANCE PV 7%		$	1,613,084	-	1,395,156	-	1,206,671	-
TOTAL MAINTENANCE PV 10%		$	1,569,091	-	1,270,964	-	1,029,481	-
LIFECYCLE COSTS		$	3,720,000	-	1,726,000	-	1,726,000	-
TOTAL PV 4%		$	$ 3,576,923	$ -	$ 1,534,408	$ -	$ 1,418,646	$ -
TOTAL PV 7%		$	$ 3,476,636	$ -	$ 1,395,156	$ -	$ 1,206,671	$ -
TOTAL PV 10%		$	$ 3,381,818	$ -	$ 1,270,964	$ -	$ 1,029,481	$ -

7	8	9	10	11	12	13	14	15	16	17	18
2027	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-

MULLER partnership

7	8	9	10	11	12	13	14	15	16	17	18
2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
$ 100,000		$ 100,000		$ 100,000		$ 100,000		$ 100,000		$ 100,000	
$ 70,000		$ 70,000		$ 70,000		$ 70,000		$ 70,000		$ 70,000	
$ 9,000		$ 9,000		$ 9,000		$ 9,000		$ 9,000		$ 9,000	
$ 10,000		$ 10,000		$ 10,000		$ 10,000		$ 10,000		$ 10,000	
$ 25,000		$ 25,000		$ 25,000		$ 25,000		$ 25,000		$ 25,000	
$ 130,200		$ 130,200		$ 130,200		$ 130,200		$ 130,200		$ 130,200	
$ 80,000		$ 80,000		$ 80,000		$ 80,000		$ 80,000		$ 80,000	
$ 55,700		$ 55,700		$ 55,700		$ 55,700		$ 55,700		$ 55,700	
INCL		INCL		INCL		INCL		INCL		INCL	
$ 255,000		$ 255,000		$ 255,000		$ 255,000		$ 255,000		$ 255,000	
$ 105,000		$ 105,000		$ 105,000		$ 105,000		$ 105,000		$ 105,000	
$ 99,000		$ 99,000		$ 99,000		$ 99,000		$ 99,000		$ 99,000	
$ 2,800		$ 2,800		$ 2,800		$ 2,800		$ 2,800		$ 2,800	
$ 44,000		$ 44,000		$ 44,000		$ 44,000		$ 44,000		$ 44,000	
$ 1,200		$ 1,200		$ 1,200		$ 1,200		$ 1,200		$ 1,200	
$ 54,000		$ 54,000		$ 54,000		$ 54,000		$ 54,000		$ 54,000	
$ 12,500		$ 12,500		$ 12,500		$ 12,500		$ 12,500		$ 12,500	
$ 54,000		$ 54,000		$ 54,000		$ 54,000		$ 54,000		$ 54,000	
$ 54,000		$ 54,000		$ 54,000		$ 54,000		$ 54,000		$ 54,000	
$ 12,500		$ 12,500		$ 12,500		$ 12,500		$ 12,500		$ 12,500	
$ 54,000		$ 54,000		$ 54,000		$ 54,000		$ 54,000		$ 54,000	
$ 20,000		$ 20,000		$ 20,000		$ 20,000		$ 20,000		$ 20,000	
								$ 250,000			
								$ 150,000			
$ 83,550		$ 83,550		$ 83,550		$ 83,550		$ 83,550		$ 83,550	
$ 106,550		$ 106,550		$ 106,550		$ 106,550		$ 106,550		$ 106,550	
$ 288,000		$ 288,000		$ 288,000		$ 288,000		$ 368,000		$ 288,000	
1,726,000	-	1,726,000	-	1,726,000	-	1,726,000	-	2,206,000	-	1,726,000	-
1,311,618	-	1,212,665	-	1,121,177	-	1,036,591	-	1,224,913	-	886,082	-
1,043,650	-	902,653	-	780,704	-	675,231	-	746,420	-	505,108	-
833,879	-	675,442	-	547,108	-	443,158	-	458,784	-	290,756	-
1,726,000	-	1,726,000	-	1,726,000	-	1,726,000	-	2,206,000	-	1,726,000	-
$ 1,311,618	$ -	$ 1,212,665	$ -	$ 1,121,177	$ -	$ 1,036,591	$ -	$ 1,224,913	$ -	$ 886,082	$ -
$ 1,043,650	$ -	$ 902,653	$ -	$ 780,704	$ -	$ 675,231	$ -	$ 746,420	$ -	$ 505,108	$ -
$ 833,879	$ -	$ 675,442	$ -	$ 547,108	$ -	$ 443,158	$ -	$ 458,784	$ -	$ 290,756	$ -

19	20	21	22	23	24	25	26	27	28	29	30
2039	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**	**2046**	**2047**	**2048**	**2049**	**2050**
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-

NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
MOBILE SAND PUMPING (2 YEARS) - OPTION 4

MULLER partnership

19	20	21	22	23	24	25	26	27	28	29	30
2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
$ 100,000		$ 100,000		$ 100,000		$ 100,000		$ 100,000		$ 100,000	
$ 70,000		$ 70,000		$ 70,000		$ 70,000		$ 70,000		$ 70,000	
$ 9,000		$ 9,000		$ 9,000		$ 9,000		$ 9,000		$ 9,000	
$ 10,000		$ 10,000		$ 10,000		$ 10,000		$ 10,000		$ 10,000	
$ 25,000		$ 25,000		$ 25,000		$ 25,000		$ 25,000		$ 25,000	
$ 130,200		$ 130,200		$ 130,200		$ 130,200		$ 130,200		$ 130,200	
$ 80,000		$ 80,000		$ 80,000		$ 80,000		$ 80,000		$ 80,000	
$ 55,700		$ 55,700		$ 55,700		$ 55,700		$ 55,700		$ 55,700	
INCL		INCL		INCL		INCL		INCL		INCL	
$ 255,000		$ 255,000		$ 255,000		$ 255,000		$ 255,000		$ 255,000	
$ 105,000		$ 105,000		$ 105,000		$ 105,000		$ 105,000		$ 105,000	
$ 99,000		$ 99,000		$ 99,000		$ 99,000		$ 99,000		$ 99,000	
$ 2,800		$ 2,800		$ 2,800		$ 2,800		$ 2,800		$ 2,800	
$ 44,000		$ 44,000		$ 44,000		$ 44,000		$ 44,000		$ 44,000	
$ 1,200		$ 1,200		$ 1,200		$ 1,200		$ 1,200		$ 1,200	
$ 54,000		$ 54,000		$ 54,000		$ 54,000		$ 54,000		$ 54,000	
$ 12,500		$ 12,500		$ 12,500		$ 12,500		$ 12,500		$ 12,500	
$ 54,000		$ 54,000		$ 54,000		$ 54,000		$ 54,000		$ 54,000	
$ 54,000		$ 54,000		$ 54,000		$ 54,000		$ 54,000		$ 54,000	
$ 12,500		$ 12,500		$ 12,500		$ 12,500		$ 12,500		$ 12,500	
$ 54,000		$ 54,000		$ 54,000		$ 54,000		$ 54,000		$ 54,000	
$ 20,000		$ 20,000		$ 20,000		$ 20,000		$ 20,000		$ 20,000	
											$ 250,000
											$ 150,000
$ 83,550		$ 83,550		$ 83,550		$ 83,550		$ 83,550		$ 83,550	
$ 106,550		$ 106,550		$ 106,550		$ 106,550		$ 106,550		$ 106,550	
$ 288,000		$ 288,000		$ 288,000		$ 288,000		$ 288,000		$ 288,000	$ 80,000
1,726,000	-	1,726,000	-	1,726,000	-	1,726,000	-	1,726,000	-	1,726,000	480,000
819,233	-	757,427	-	700,284	-	647,452	-	598,605	-	553,444	147,993
436,868	-	377,847	-	326,800	-	282,649	-	244,463	-	211,436	54,684
235,512	-	190,765	-	154,520	-	125,161	-	101,380	-	82,118	20,553
1,726,000	-	1,726,000	-	1,726,000	-	1,726,000	-	1,726,000	-	1,726,000	480,000
$ 819,233	$ -	$ 757,427	$ -	$ 700,284	$ -	$ 647,452	$ -	$ 598,605	$ -	$ 553,444	$ 147,993
$ 436,868	$ -	$ 377,847	$ -	$ 326,800	$ -	$ 282,649	$ -	$ 244,463	$ -	$ 211,436	$ 54,684
$ 235,512	$ -	$ 190,765	$ -	$ 154,520	$ -	$ 125,161	$ -	$ 101,380	$ -	$ 82,118	$ 20,553

NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
LOW FLOW PIPES - OPTION 5

MULLER partnership

			1	2	3	4	5	6
Year		**Units**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
CAPITAL COSTS ($ 2021)								
Based on the Concept Design Estimate dated 07 June 2021.								
General	Upfront Capital Costs							
Site establishment and demobilisation		$	$ 100,000					
Contractors supervision		$	$ 140,000					
Survey and set out of works by registered surveyor		$	$ 16,200					
Location of services		$	$ 15,000					
Protection of services		$	$ 25,000					
Traffic control		$	$ 158,200					
Sediment & Erosion Controls								
Allow for sediment fencing, berms and environmental controls as		$	$ 25,000					
Site Preparation								
Allow for general site clearing and preparation to undertake works		$	$ 1,250					
Intake Structure								
Allow for supply, delivery and installation of pre-cast concrete headwalls to intake structure		$	$ 16,000					
Supply and install stainless steel grates to intake structure		$	$ 6,000					
Ditto stainless steel safety handrail to enhance public safety		$	$ 5,000					
Outlet Structure								
Allow for supply, delivery and installation of pre-cast concrete headwalls to outlet structure including difficult access constraints		$	$ 30,000					
Supply and install stainless steel grates to outlet structure including difficult access constraints		$	$ 12,000					
Low Flow Pipes								
Plant Equipment								
Mobilisation and demobilisation of plant equipment		$	$ 100,000					
Boring Pit								
Allow for pit excavation to lagoon entrance to allow for boring		$	$ 28,000					
Underboring / Drilling								
Allow for minimum 800mm bore hole directionally drilled through bedrock [NB: 3 No. pipes across 414m length]		$	$ 2,980,800					
Pipe Supply and Pulling								
Supply and install DN800 HDPE pipe including pulling through bore hole as required [NB: Assumed pipe material]		$	$ 993,600					
Remediation Works								
Allow for minor remediation works to permanent delivery pipeline once works have been completed		$	$ 2,500					
Preliminaries and Margin		$	$ 557,450					
Capital Works Contingency		$	$1,042,000					
TOTAL CAPITAL COSTS	6,254,000	$	6,254,000	-	-	-	-	-

NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
LOW FLOW PIPES - OPTION 5

MULLER partnership

			1	2	3	4	5	6
Year		**Units**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
OPERATING COSTS ($ 2021)								
Labour & other operating costs	Excl.	$						
TOTAL OPERATING COSTS		$	-	-	-	-	-	-
MAINTENANCE COSTS ($ 2021)								
Based on the Concept Design Estimate dated 07 June 2021.								
Pipe Inspection								
Allow for CCTV pipe inspection to identify any issues or debris	Assumed to be undertaken every 2 years	$	$ 20,000		$ 20,000		$ 20,000	
Pipe Routine Cleanout								
Allow for pipe maintenance and cleanout to be undertaken by Council	Assumed to be undertaken every year	$	$ 11,000	$ 11,000	$ 11,000	$ 11,000	$ 11,000	$ 11,000
Preliminaries and Margin		$	$ 2,500		$ 2,500		$ 2,500	
Maintenance Works Contingency		$	$ 6,500		$ 6,500		$ 6,500	
TOTAL MAINTENANCE COSTS		$	40,000	11,000	40,000	11,000	40,000	11,000
TOTAL MAINTENANCE PV 4%		$	38,462	10,170	35,560	9,403	32,877	8,693
TOTAL MAINTENANCE PV 7%		$	37,383	9,561	32,333	8,269	27,965	7,152
TOTAL MAINTENANCE PV 10%		$	36,364	9,000	29,455	7,290	23,858	5,905
LIFECYCLE COSTS		$	6,294,000	11,000	40,000	11,000	40,000	11,000
TOTAL PV 4%		$	$ 6,051,923	$ 10,170	$ 35,560	$ 9,403	$ 32,877	$ 8,693
TOTAL PV 7%		$	$ 5,882,243	$ 9,561	$ 32,333	$ 8,269	$ 27,965	$ 7,152
TOTAL PV 10%		$	$ 5,721,818	$ 9,000	$ 29,455	$ 7,290	$ 23,858	$ 5,905

NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
LOW FLOW PIPES - OPTION 5

MULLER partnership

7	8	9	10	11	12	13	14	15	16	17	18
2027	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**
-	-	-	-	-	-	-	-	-	-	-	-

NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
LOW FLOW PIPES - OPTION 5

MULLER partnership

7	8	9	10	11	12	13	14	15	16	17	18
2027	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**
-	-	-	-	-	-	-	-	-	-	-	-
$ 20,000		$ 20,000		$ 20,000		$ 20,000		$ 20,000		$ 20,000	
$ 11,000	$ 11,000	$ 11,000	$ 11,000	$ 11,000	$ 11,000	$ 11,000	$ 11,000	$ 11,000	$ 11,000	$ 11,000	$ 11,000
$ 2,500		$ 2,500		$ 2,500		$ 2,500		$ 2,500		$ 2,500	
$ 6,500		$ 6,500		$ 6,500		$ 6,500		$ 6,500		$ 6,500	
40,000	11,000	40,000	11,000	40,000	11,000	40,000	11,000	40,000	11,000	40,000	11,000
30,397	8,038	28,103	7,431	25,983	6,871	24,023	6,352	22,211	5,873	20,535	5,430
24,187	6,186	20,919	5,350	18,093	4,627	15,648	4,002	13,534	3,461	11,706	2,994
19,325	4,783	15,653	3,874	12,679	3,138	10,270	2,542	8,319	2,059	6,738	1,668
40,000	11,000	40,000	11,000	40,000	11,000	40,000	11,000	40,000	11,000	40,000	11,000
$ 30,397	**$ 8,038**	**$ 28,103**	**$ 7,431**	**$ 25,983**	**$ 6,871**	**$ 24,023**	**$ 6,352**	**$ 22,211**	**$ 5,873**	**$ 20,535**	**$ 5,430**
$ 24,187	**$ 6,186**	**$ 20,919**	**$ 5,350**	**$ 18,093**	**$ 4,627**	**$ 15,648**	**$ 4,002**	**$ 13,534**	**$ 3,461**	**$ 11,706**	**$ 2,994**
$ 19,325	**$ 4,783**	**$ 15,653**	**$ 3,874**	**$ 12,679**	**$ 3,138**	**$ 10,270**	**$ 2,542**	**$ 8,319**	**$ 2,059**	**$ 6,738**	**$ 1,668**

NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
LOW FLOW PIPES - OPTION 5

MULLER partnership

19	20	21	22	23	24	25	26	27	28	29	30
2039	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**	**2046**	**2047**	**2048**	**2049**	**2050**
-	-	-	-	-	-	-	-	-	-	-	-

NARRABEEN LAGOON ENTRANCE MANAGEMENT OPTIONS
LOW FLOW PIPES - OPTION 5

MULLER partnership

19	20	21	22	23	24	25	26	27	28	29	30
2039	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**	**2046**	**2047**	**2048**	**2049**	**2050**
-	-	-	-	-	-	-	-	-	-	-	-
$ 20,000		$ 20,000		$ 20,000		$ 20,000		$ 20,000		$ 20,000	
$ 11,000	$ 11,000	$ 11,000	$ 11,000	$ 11,000	$ 11,000	$ 11,000	$ 11,000	$ 11,000	$ 11,000	$ 11,000	
$ 2,500		$ 2,500		$ 2,500		$ 2,500		$ 2,500		$ 2,500	
$ 6,500		$ 6,500		$ 6,500		$ 6,500		$ 6,500		$ 6,500	
40,000	11,000	40,000	11,000	40,000	11,000	40,000	11,000	40,000	11,000	40,000	-
18,986	5,020	17,553	4,642	16,229	4,291	15,005	3,968	13,873	3,668	12,826	-
10,124	2,589	8,757	2,239	7,574	1,937	6,550	1,675	5,665	1,449	4,900	-
5,458	1,351	4,421	1,094	3,581	886	2,901	718	2,349	581	1,903	-
40,000	11,000	40,000	11,000	40,000	11,000	40,000	11,000	40,000	11,000	40,000	-
$ 18,986	**$ 5,020**	**$ 17,553**	**$ 4,642**	**$ 16,229**	**$ 4,291**	**$ 15,005**	**$ 3,968**	**$ 13,873**	**$ 3,668**	**$ 12,826**	**$ -**
$ 10,124	**$ 2,589**	**$ 8,757**	**$ 2,239**	**$ 7,574**	**$ 1,937**	**$ 6,550**	**$ 1,675**	**$ 5,665**	**$ 1,449**	**$ 4,900**	**$ -**
$ 5,458	**$ 1,351**	**$ 4,421**	**$ 1,094**	**$ 3,581**	**$ 886**	**$ 2,901**	**$ 718**	**$ 2,349**	**$ 581**	**$ 1,903**	**$ -**

Appendix F: Stage 1 Community and Stakeholder Engagement Report

Community and Stakeholder Engagement Report

Narrabeen Lagoon Entrance Management Strategy (Stage 1 of 2)

Impact level: 2

Consultation period: 10 February to 28 March 2021

Contents

1. Summary

This report outlines the stage one community and stakeholder engagement conducted as part of the Narrabeen Lagoon Entrance Management Strategy project from 10 February to 28 March 2021.

We asked for your thoughts and suggestions on the potential ways the entrance could be managed in the future. We presented an options paper that outlines the way we currently manage the entrance and long-term options being considered. We encouraged discussion and did not limit responses to voting on entrance management options.

This consultation highlighted the diversity of opinion in the local community about the key issues and management objectives for Narrabeen Lagoon. Community feedback also revealed a high level of local and historic knowledge and sense of public ownership of Narrabeen Lagoon.

A variety of themes were identified within the submissions. While no individual theme was represented in the majority of submissions, the two most common themes were:

- Support for further investigation and potential implementation of a sand pumping scheme
- Options that maximise the duration of lagoon entrance open conditions should be prioritised

1.1. Key outcomes

Total unique responses	111	
How responses were received	Online Your Say submission form Email/written submissions[1]	Completions: 98 Received: 14
Feedback themes	• Support for further investigation of a sand pumping scheme to be installed at Collaroy-Narrabeen Beach. • The entrance of Narrabeen Lagoon should be open as much as possible.	• Support and requests for dredging of the western basin/main waterbody of Narrabeen Lagoon. • Improvements to entrance clearance. • Improvements to Council's emergency response arrangements. • Suggested alternative options.

[1] One respondent provided their submission online via the Your Say form and via email.

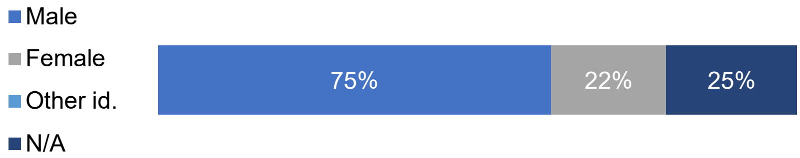
1.2. How we engaged

Have Your Say	Visitors: 3112 Visits: 4115	Av. time onsite: 1m22s
Videos	Explainer video: 1	Views: 4,619
Print media and collateral	Letterbox drop: Properties that received letters were in the 2097, 2099, 2101 and 2102 postcodes. Site signs: Yes	Distribution: Letters were sent to 3,100 properties. Number: 4 signs installed in prominent locations around the lagoon foreshore and close to the entrance.
Electronic direct mail (EDM)	Community Engagement (fortnightly) newsletter: 3 Council (weekly) e-News: 3	Distribution: 20,000 subscribers Distribution: 150,000 subscribers
	External stakeholder email	Distribution: 23 external stakeholders were emailed with project details inviting comment. The external stakeholders included all 163 watercraft permit holders for Narrabeen Lagoon.
Face-to-face	Drop-in sessions were available on three different days: Monday 1 March 2-5pm Wednesday 10 March 4-6pm Saturday 20 March 9am-12pm	Bookings: 5
Phone	Calendly phone appointments were offered on two different days: Thursday 4 March (6-9pm) Tuesday 9 March (9am-12pm)	Bookings: 0

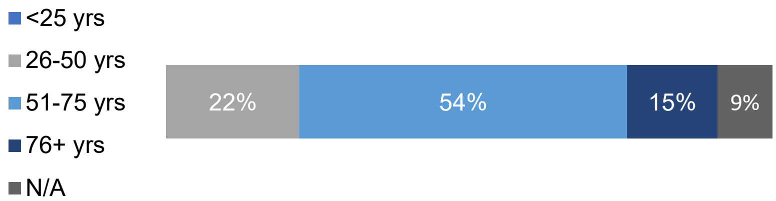
Key stakeholder engagement	Meetings: Presentation at a pre-standing Surfrider meeting	Attendance: 10

1.3. Who responded[2]

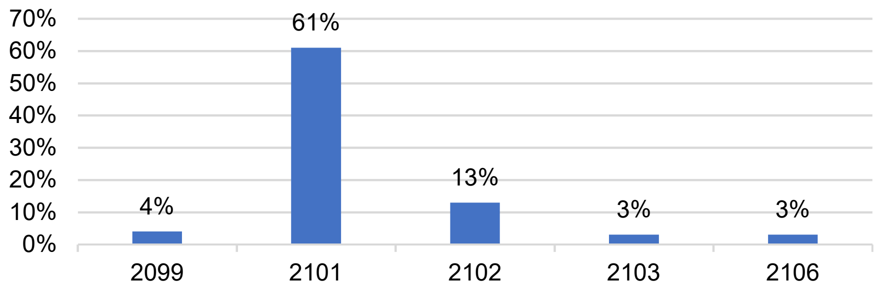
Gender



Age groups



Postcodes



2. Background

Narrabeen Lagoon is one of the Northern Beaches' greatest natural and recreational assets. However, it is also prone to flooding and Council has been managing the entrance of the lagoon to reduce the risk of flooding for close to half a century.

An Entrance Management Strategy is being developed to confirm the best long-term management options for managing sand deposition in the entrance. This will enable a best practice and formalised approach.

Council expedited a preliminary review of the feasibility of a breakwall. It was determined that it was not a feasible option and was therefore excluded from the Options Paper as reported to Council at its meeting on 27 October 2020.

The project's impact level two Community and Stakeholder Engagement Plan was devised on a two-stage approach:

- Stage 1: Public consultation on the options paper to gather input from the community regarding the different options we are investigating.

[2] Demographic data was gathered by request only. The data represented only includes those respondents who provided this detail.

- Stage 2: Public exhibition of the draft Entrance Management Strategy to ensure it is supported by a broad cross-section of the community.

This report outlines the community and stakeholder engagement conducted as part of stage one.

3. Engagement objectives

Our community engagement objectives were to:

- build community and stakeholder awareness of participation activities
- provide accessible information so community and stakeholders can participate in a meaningful way
- identify community and stakeholder concerns, local knowledge and values.

4. Engagement approach

Stage one community and stakeholder engagement for Narrabeen Lagoon Entrance Management Strategy was conducted over a six-week period, from 10 February 2021 to 28 March 2021, and consisted of a series of activities that provided opportunities and platforms for community and stakeholders to contribute.

The engagement was planned, implemented and reported in accordance with Council's Community Engagement Matrix (2017).

The engagement approach was designed to understand the community's feedback on the way we currently manage the entrance and long-term options being considered.

A project webpage[3] was established on our have your say platform with information provided in an accessible and easy to read format. The project page included an explainer video about Narrabeen Lagoon Entrance. We encouraged people to learn more about Narrabeen Lagoon entrance and how Council currently manages this complex issue. We also broke down the video into shorter section should people want to jump to a particular section.

We trialled a new online format to present the options paper and linked people to it from the project page. The online document allowed people to view the information alongside various graphics.

The project page also included some background information, and links to the relevant Council report and webpages.

The project was promoted via onsite signage, resident and stakeholder notifications, our Council E-News and community engagement newsletter.

Feedback was captured through an online comment form embedded onto the have your say project page. An open-field comments box provided community members a space to outline their feedback.

Email and written comments were also invited. Contact details for the project manager were provided as a channel for the community to ask any questions about this project.

There was a lot of technical information contained in the options paper and we wanted to support you as best we can during this consultation.

[3] https://yoursay.northernbeaches.nsw.gov.au/narrabeen-lagoon-entrance-management-strategy

We provided opportunities for people to book a face to face meeting with the project team at the Narrabeen Coastal Environment Centre. As an alternative, we offered bookings for a telephone appointment. We were agile in our approach and, when some face to face meetings had to be postponed due to an emergency entrance management procedure, offered to meet or call the community members at a separate time.

Results provide responses across a spectrum of demographics, expertise, experience and understanding of our local government area.

4.1. Reaching diverse audiences

We worked with our Community Development team (liaisons to our multicultural communities and not-for-profit organisations/community services) and utilised their platforms and networks to share information, increase project exposure and awareness, and reach a diverse audience. An article about the project was included in Council's Religious and Cultural Leaders Newsletter.

5. Findings[4]

This consultation highlighted the diversity of opinion in the local community about the key issues and management objectives for Narrabeen Lagoon. Community feedback also revealed a high level of local and historic knowledge and sense of public ownership of Narrabeen Lagoon.

A variety of themes were identified within the submissions. The table below outlines the most common themes along with Council's responses. Other themes raised are shown in a graph below and all verbatim comments can be read in the Appendix section.

In their submissions, some people told us that they appreciated the way we had presented the information and felt they had learned a lot by watching the explainer video on the Your Say page.

Table 1: An outline of the most common themes and Council's response

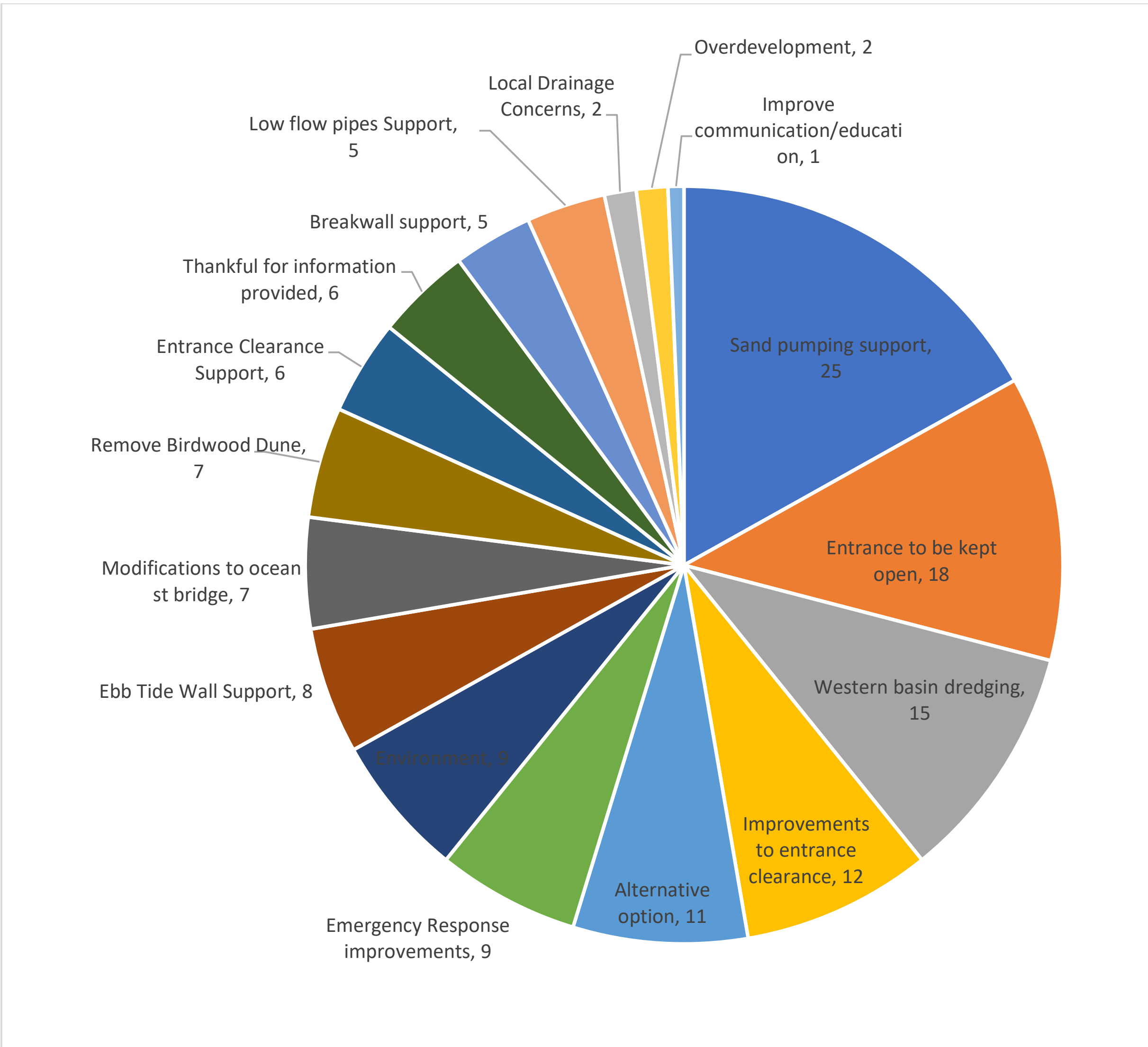
Theme	What we heard	Council's response
Support for further investigation of a sand pumping scheme to be installed at Collaroy-Narrabeen Beach	The most common response that was received from the community was general support for further investigation and discussion on the potential benefits of a mobile sand pumping scheme at Collaroy-Narrabeen Beach. The specific reason for preferencing this option varied, with responses including flood benefits, amenity improvements and potential improved tidal flushing.	The assessment of options in the Narrabeen Lagoon entrance management strategy includes consideration of economic, social and environmental factors. Whilst ultimately recommended options need to be economically and technically feasible, understanding the level of community support for an option informs the likely future acceptance and preference of options.

[4] Community and stakeholder views contained in this report do not necessarily indicate a commitment to a particular course of action.

The entrance of Narrabeen Lagoon should be open as much as possible	A number of submissions outlined the numerous benefits associated with the entrance of Narrabeen Lagoon being open. These benefits related to differing factors including flood risk reduction, improved amenity and improvements to water quality through increased tidal flushing.	Flooding in Narrabeen Lagoon can be driven by rainfall in the catchment, large swell events in the ocean or a combination of both. However rainfall in the catchment is the dominant form of flooding and an open lagoon reduces but does not eliminate this flood risk. A key objective of the Entrance Management Strategy is to improve the duration of open entrance conditions at Narrabeen Lagoon in recognition of the abovementioned flood benefits in addition to secondary water quality and amenity improvements.
Support and requests for dredging of the western basin/main waterbody of Narrabeen Lagoon.	Submissions were received which requested investigation of dredging of the main waterbody of Narrabeen Lagoon. The submissions outlined a range of potential benefits, including recreational amenity, water quality and flood risk.	Dredging of the main waterbody of Narrabeen Lagoon for recreational purposes has previously been investigated by the former Warringah Council. There are unlikely to be any significant flood benefits of dredging the bed of Narrabeen Lagoon in the main waterbody. The management of Narrabeen Lagoon entrance is undertaken primarily as a flood risk reduction action. As dredging of the main waterbody of Narrabeen Lagoon will not significantly impact flood levels it is not recommended for further investigation as part of this strategy.
Improvements to entrance clearance	Submissions were received which outlined a number of potential improvements to the existing entrance clearance management regime. These include changes or increases to the design footprint, for the clearance to be undertaken more regularly,	The draft Narrabeen Lagoon Entrance Management Strategy has considered this feedback and has recommended trialing more frequent, lower volume clearances to

	for traditional dredges to be used in lieu of excavators.	produce more prolonged open entrance conditions. In relation to the utilisation of traditional dredges, the Narrabeen Lagoon entrance clearance works currently underway are trialing a dredging approach in response to community feedback.
Suggested alternative options	A range of alternative entrance management options were suggested by the community. These included: • Installation of flood gates under Ocean Street bridge • Pumping of ocean water into Narrabeen Lagoon when the entrance is closed • Modifications to the beach and use of groyne structures • Underground pipelines at Mactier Street	The alternative options were reviewed by the consultants undertaking the study for whether they should be included in the assessment of long term management options. Options involving pumping of ocean water into the lagoon or installing pipelines under Mactier Street were found to be technically or economically unfeasible to achieve the desired outcome. Other options such as groynes would have unacceptable social and amenity impacts on Collaroy-Narrabeen Beach.
Improvements to Council's emergency response arrangements	A number of submissions were received which outlined potential improvements to Council's emergency response procedures including the mechanical opening of the lagoon. The suggestions included opening the lagoon at a lower trigger level or maintaining pilot channels or machinery at Narrabeen Lagoon.	The submissions have been considered and investigations were undertaken on opening Narrabeen Lagoon entrance at lower trigger levels. The results found that a lower trigger level may be successful if the conditions are optimum and this is recommended in the draft Strategy. The maintenance of a constant pilot channel or machinery stationed at Narrabeen Lagoon entrance was not found to be justified as there is sufficient response time to use external contractors.

The following pie graph shows all the themes and number of respondents who mentioned a theme in their response. Please note a number of individual responses were grouped into multiple themes.



Appendix 1 Verbatim community and stakeholder responses*

Part A: online submissions

Number	Submission
1	Dear Sir/Madam, I would to support the option for the mobile sand pumping. I've been a local resident for the last 24 years and a volunteer surf lifesaver for the last 15 years at North Narrabeen surf club, so I know the entrance to the lagoon quite well. The ebb tide flow option would be ugly and invasive, The half tide training walls would rapidly silt up and block the current deepest trench of the lagoon entrance, which is also the best snorkelling area in the lagoon. The area alongside the current wall at that point is also home to and provides shelter to most of the fish in the lowest part of the lagoon (hence the good snorkelling). If the water was flowing across the mid point in that area it would be a barren and featureless desert, The low flow pipes would look disgusting, rapidly block up and, critically, would not support marine life in that stretch. They definitely would not allow fish to swim in and out of the lagoon and would also end up heavily littered. They would also be really dangerous for swimmers and children in times of heavy rain and floods - there would be no escape point for anyone trapped in them as they'd work like a giant storm water drain! Thankfully you have ruled the break-wall out and the mobile sand pumping definitely looks like the best option. It works well in other parts of the country, has a minimal impact visually, keeps all the sand transporting trucks off the road, can target specific areas of sand build up, should come in at a reasonable cost, would keep the entrance clear and also retain the current trench alongside the road wall, home to most of the fish life and also the only decent snorkelling and swimming area in the whole lagoon.

Personal details have been redacted where possible. Spelling and grammatical errors have been amended only where misinterpretation or offence may be caused.

2	RE LONG-TERM OPTIONS Re Mobile Sand Pumping The Mobile Sand Pumping Option would require pumping sand over a distance greater than 2km., which is a long distance The pipeline would be a permanent installation, require booster stations and a mobile hopper connected to the end of the pipeline. If the pipeline was installed along the top of the existing foredune it would be a physical intrusion that would mar the beach area. If the pipeline was installed through a cut and cover operation along Ocean Street it would be out of sight but require extensive infrastructure. A particular concern is the impact of the mobile hopper and pipeline on the amenity, safety and recreational use of the beach. It is possible the disruption at Narrabeen Lagoon entrance would be ongoing due to the mobile hopper. Since 2015 there has been a greater accumulation of sand at the northern end of the Collaroy / Narrabeen Beach that would favour the Mobile Sand Pumping. However, the Beach rotation pattern could reverse this trend so that more sand is accumulated at the southern end of the beach (Collaroy Beach). If so, the pipeline would be less effective, as mechanical intervention would not be required to progressively transfer sand from North Narrabeen to Collaroy Beach. A pipeline on or near the foredune is likely to be vulnerable to coastal erosion or storm damage. Re Ebb-Tide Channel I support the trial of this option by forming temporary training walls with sand-filled geotextile bags. This would be a relatively inexpensive option and is worth trialling prior to a more expensive or permanent option, such as the 2km pipeline. The adverse recreational and aesthetic impacts of the Ebb-Tide Channel could be mitigated via design measures that provide better outcomes for recreation and aesthetic amenity. Re Installation of low flow pipes I do not support this option. The low flow pipes at the entrance of Manly Lagoon are an artificial intrusion at the Lagoon Entrance that spoil the natural amenity of Queenscliff Beach. The significant capital cost, together with the adverse impact on environment and aesthetics, hopefully will rule out this option.
3	The situation at the entrance to Narrabeen Lagoon would benefit from the introduction of management procedures which attempt to avoid short-term horizon emergency action. This is a guiding principle for any such situation. The current medium-term horizon procedures have to be continued with until long-term horizon, permanent management structures can be installed. I believe that the idea for a pipeline to pump sand and water away from the entrance and south to the Collaroy/Narrabeen beaches to be good one, and that a trial of 'training walls' to direct the water flow out of the lagoon is well worth trying.
4	The introductory video certainly answered most of our questions. Suggestion that similar videos could/should be run at local cinemas to get the "accurate" message on this natural phenemenon and reduce politicisation of this issue. Stress the high cost of alternate options trying to "tackle' a natural phenomenon. Keep updating information and please advise just what % of the local community actually view, read and responded to these managemnt options. Congratulations on a clear and factual presentation.

5	Narrabeen Lake covers approximately 2.2 square kilometers - agreed? There has been a t least 221 years of European faming, timber felling and agricultural pursuits within the run-off area to Narrabeen Lake - agreed? So, with 221 years of land clearing silt run-off into the lake at least half of the lake floor is covered with at least 500 millimeters of silt - agreed? The other half of the lake floor nearest the ocean, has, on average least one metre of extra sand - agreed? So what is preventing council from dredging the estimating one point seven million tonnes of sand, washing it and selling the clean sand to concrete companies? (Approx nett revenue $13.2m at current raw price). Alternatively, dredge and pump the sand in a controlled exercise 500 to 750 metres out into the ocean to form a flatter sea floor out from the coastline so big waves break further out to sea. (Similar to what was done at Copacabana Beach at Rio back in the thirties). From a health and safety point of view the balance of lake could be dredged of silt, pesticides, herbicides and fertilizer to prevent algal blooms that infest the waterwat.
6	I am responding to your request for submissions on Council's Narrabeen Lagoon Entrance Management Strategy. My main concern about the existing strategy is the significant delay that sometimes occurs before action is taken to reopen the lake. I suggest that peak use periods, such as school holidays, and the length of time that the lake has been closed ought to be major indicators for action to be taken to reopen the lake. In the past the lake has sometimes remained closed during school holidays. This has seriously detracted from the community's enjoyment of the lake and impacted upon the visitors to our area staying in the camping area. Any future strategy should include measures to ensure that the lake remains open during the holiday periods and is not closed for months at a time. I am not an expert on the practicalities of the proposed long term strategies but, from a lay perspective, I believe that the they do not improve at all on the system currently in place. All of the proposals would have a detrimental impact on the natural beauty of the region.
7	Hello, Well done council for considering this important issue and engaging with the public in this way. At this stage based on the options paper, the mobile sand pumping option seems the best option by far. I understand that this also operates successfully at Noosa Heads. No doubt there will be engineering challenges to be solved but intuitively the initial cost and disruption would be more than offset by the longer term benefits and savings. At the next stage it would be good to see more detail on environmental/ecological considerations.

8	I know that the lagoon mouth problem has been happening since the causeway was built for the first bridge. My family lived on Narrabeen Peninsula since before it was built. Do you have any feedback on the current management of Narrabeen Lagoon entrance during wet weather events? A. The operators of the diggers and the actions of the others involved cannot be faulted. They are professional and efficient. The big problem is that they are working on an unnatural situation caused by the blocking of the main channel of the lagoon by a road over the top of a man-made causeway. What other practices would you like to see the Council adopt? A. The Council needs to extend the bridge north not quite as far as where McKenzie Parade used to join Ocean Street but far enough to allow the main channel to run along its natural course unhindered by having to do a complete change of direction into an s bend thereby losing all its momentum and dropping suspended sand too soon. What are your thoughts on the periodic clearance works in the Narrabeen Lagoon entrance? A. Presently they are necessary but not sufficient to alleviate the risk of flooding to the overdeveloped floodplains and swamps in the Warriewood Valley. Do you have any feedback on how to improve the process or alternatives Council should consider? A. Re-route the main channel of the lagoon so it goes straight out to sea without being blocked and made to go in an S bend. Extend the bridge to allow the main channel to flow as a natural coastal system How do you want Narrabeen Lagoon entrance managed long-term? A. Opening as required to stop flooding the overdeveloped areas of the swamp and flood plain. What are the key considerations in determining which option to select? A. Taking a few of the caravan park sites back to allow the channel to flow as it did before someone thought they knew better than nature Working out how to extend the bridge without disturbing traffic flow along Ocean Street and Sydney Road. Alleviating pollution caused by removing the causeway and making sure none of it gets into the sea or blocks “Shark Alley”
9	I sm owner and resident at the lagoon waterfront [redacted] lagoon street. I have been living there for much more than 10 years and some of my neighbours have been living here for well in excess of that. From our experience with flood events and excessive rainfall periods combined with high tide events we respectfully request that the lagoon needs to be kept open whenever such events occur and well prior to it. Whenever the lagoon is open our houses are not threatened by heavy rainfalls and floods like recently. water raises but stays comfortably lower than our doorsteps to living rooms and patios towards the lagoon like last week. but when the lagoon is closed for too long and heavy rainfalls and tides occur, water raises in the lagoon too high and reaches our downstairs living rooms as it happened 1-2 years ago. it is crucial that you keep the lagoon open.
10	To get the entrance as close to the original path it took before 1974 (the storm)Perhaps working models of pre 74 and currently to get some kind of gauge as to which would be better and or idears could be tested before applied to the real deal .In essence the current version would be the control study. Expensive but what’s the option.
11	Build a large break wall and an artificial reef somewhere near narrabeen surf club

12	I believe the current process of allowing it to be 1 mtr above sea level is making the lake and lagoon worse and over time has caused this problem This needs to stop Every time the entrance is opened yes water goes out and some sand but more sand comes in causing a build up towards the bridge as water volume is not there as lake and lagoon has silted over If you go for a swim at the entrance when opened the sand is like quicksand More sand is coming in rather than out There is insufficient water flow due to the volume of sand in the lake and lagoon just look at the sand build up on the east and west side of Ocean street bridge If the sand in the lake and lagoon was removed therefore increasing water volume then when the entrance is opened and sand taken away not pushed up against the pool you may find the flushing theory would work I remember when the entrance where the rocks are at high tide being 2 Mtrs deep at least sailing with centre boards down This will be an expensive process but perhaps the sand can be sold. Maybe a cement company can do it for the sand Start dredging East and West side of bridge Then moving along creating a deep Chanel
13	I believe you should open the entrance of the lagoon as nature intended. Clear the entrance, take away all the sand at the mouth of the entrance, including the sand next to the surf club, which was man moved to there.. Bit expensive, but u will get good flow in and out of the lagoon. .cheers.
14	Council should seek, and heed, the advice of an experienced Coastal Engineer, such as Angus Gordon. Having been involved in a not dissimilar issue at Jimmy's Beach on the Mid North Coast, I would strongly recommend against using a Jet-Flow pump to shift the necessary sand. It is expensive to install, inflexible in its operation and expensive to operate, with significant establishment and disestablishment costs. It also requires a suitably qualified operator. The Mandurah alternative is far more practical, although it's designed to shift far greater volumes than required here, so it may prove to be expensive. In the long run, I suspect that a continuation of existing practices may prove to be the most cost-effective option on a DCF basis. It does require constant monitoring and the appropriate preventative action, as pointed out in the Options papers. In the end, the decision should rest on an analysis of the respective capital and operating costs.
15	Why don't you start, Dredgeing Narrabeen lake like they used to do years ago the lake is not very deep
16	I support a trial of an ebb tide channel and also the low flow pipes. For what it is worth, I'd also support a break breakwall. Would be interested in seeing an alternate video, an explainer, that provides a thorough explanation of historic decisions made, a timeline of events over the last century or so. Namely of the Narrabeen lagoon, the topography of the surrounding areas, and changes made, particularly the flood plain, changes to the entrance, and Pittwater Rd construction from Collaroy to Nth Narrabeen.
17	Like the idea of pumping the sand up the beach to keep the lagoon permanently open. Thank you for your time and energy to fix this once and for all.

18	Short Term - I support the investigation, and hopefully implementation, of more frequent mechanical opening of the entrance to deliver greater amenity/recreational benefits as well as longer duration tidal flows to support ecological processes and lagoon health. Medium Term - I support more frequent mechanical sediment removal and relocation (this will also help bolster, and hide, the seawalls existing and now under construction at South Narrabeen/Collaroy (terrible pointless short term responses - just bite the bullet and go for property buy-backs and parkland !) Long Term - I support sand pumping as the only viable option, and one with the greatest net benefit, However the pipeline should be located along Ocean Street (to be better protected against storm action) and I have concerns about the visual impacts of the pumping station shown on the dune near the lagoon entry (if this is to be a permanent or intrusive feature). Ebb tide rock training walls are not supported - due to their significant adverse recreational and aesthetic impacts (and I very much doubt that they will be effective). Low-flow pipes or a channel is definitely not supported - ugly and ineffectual. Breakwall - I wholeheartedly agree with not further considering this option - no, just no ! Thanks for the opportunity to comment. But not keen on the on-line options paper only approach (instead of a downloadable version) - as such an "ephemeral" document is not reassuring (or a good look) in terms of later accountability and transparency in decision-making.
19	As a resident for over 21 years I have watched the Lagoon levels rise and fall on a daily basis. In my view when the entrance is open there is very little tidal movement and little erosion around the waters edge. When closed it is a different matter. The level gradually rises and additional erosion occurs. eg along side the stormwater drain at Octavia Street where the lake edge has eroded some 750cm exposing old bottles, rusty metal and asbestos over the years. The drain is also a great measuring device for water levels. When the level reaches the top of the drain the lagoon should be opened. Recently the levels reached well over the top (over the adjacent seat concrete base) before quickly falling when Council opened the lagoon. In my opinion notwithstanding everything stated by you and your experts the best way you can prevent flooding and maintain a healthy lagoon environment is to keep the entrance open. If you keep it open we will not have repeats the flooding which occurred on 28/10/2013, 21/4/2015 and 5/6/2016

20	In any solution, the lake needs to be regarded as a living thing, not merely as an open stormwater drain. The estuary geography of the lake means that it requires an influx of saltwater to live and thrive and for this to happen an effective opening as well as channels to allow and promote tidal water flow both in and out of the lake need to be established and maintained. Bear in mind the mullet and prawn runs that require open access to the ocean from the lake in order to maintain health stocks of both and those higher up the food chain that rely on them, including the larger fish, pelicans, eagles and fisherman that the lake is famous for. Over the past 10-12 years, during the last 2 major clearance operations with the excavators and trucks clearing sand to both sides of the Ocean St bridge, the sand banks in both areas was flattened out with no channels re-established, therefore in effect chocking the lake and all but eliminating water influx into the lake during a rising tide. Water needs to flow into the lake on a rising tide and out on a falling tide to maintain its health and water quality. A reduced or restricted tidal flow in and out of the lake leaves the entrance susceptible to closure as sand is not being washed away from the entrance on a falling tide. In regards the medium term proposals, the mechanical breakout should include the excavation of a decent channel from the entrance, continue adjacent to the Ocean St rockwall, under the Ocean St bridge and along the southern bank of the lake west of the Ocean St bridge to a point near the end of Malcolm St opposite the Lake Park playground. That would promote tidal water flow both in and out of the lake. With the long term proposals, the Ebb tide training walls would be unnecessary if a channel was excavated in the sandflat in conjunction with the mechanical breakout at the entrance. The lake tried to do this itself in the last week during the flooding rains, so some mechanical assistance would easily achieve the desired result. The low flow pipes or channel would require too much rock excavation and I suspect would be close to the pool which is not ideal. The mobile sand pumping option seems ok, but a few points here include:- -the proposed nominal discharge points, are they on the beach or offshore -how temporary is the "temporary primary pumping station" and what's is visual impact -we assume the mobile hopper and connecting pipe will come and go as needed -running the discharge pipes south along the beach in the foredune. How will that go on the beach south of Goodwin St which was heavily eroded in the past few winter storms
21	We are lakefront residents at the end of Albemarle Street Narrabeen, we would like to compliment council for the way the Narrabeen Lagoon entrance was managed during the heavy March 2021 rainfall. The lagoon water rose over the banks however not to the extent that properties were flooded nd evacuations were required, as we have experienced many times before. We would like to see a 24 hour 7 day a week way of communicating with council during extreme weather events to offer feedback from local residents and also receive updates from council as to what action has been taken with opening up the lake entrance, perhaps this could take the form of a monitored Facebook group. We would also like council to consider the drainage around the lagoon, for example the base of Albemarle St the pine needles from neighbouring trees wash down the street straight into the drain at the end of the street where they block the drain and don't allow for the excess water to drain, causing more flooding issues. We report this continuously to council but it is never monitored enough to combat the problem when needed. Perhaps there is a another type of drainage system council could consider that would be more effective.
22	Council's management of Narrabeen Lagoon has been severely lacking for several years. Instances of flooding, pollution and algal blooms have become increasingly prevalent. The only way to maintain the good health of the lagoon for both the environment and residents is to to keep it permanently open to the sea. To do this Council should look into some more inexpensive and environmentally friendly ways to focus the ebb-tide, such that it consistently maintains an erosional channel.

23	Current Management: Thank goodness the Lagoon entrance was opened this weekend (20th March 2021). It is interesting that despite the torrent of water pouring out through the entrance the Lagoon levels are still high because there has been so much rain. I have watched and listened over the last 50 years and I am pleased that Council is heeding the scientists and engineers who have been studying our beaches and lagoons over that time and I do hope it continues. Periodic Clearance: This is obviously something that needs to be done and Collaroy/Narrabeen beach benefits as well. It does appear to be an ongoing battle though and 6,000 truck movements is a lot of noise and possibly wear and tear on the roads and the budget. Long term Management: There are some interesting ideas proposed. I am glad that the breakwall idea has been dropped. These man made interferences (like seawalls on the beaches) can bring unwanted consequences. This is why I support the idea of trialing an ebb tide flow system using sandbags first. As for piping the sand from the entrance to the beaches - if it really is a feasible option and doesn't need ugly infrastructure, then perhaps it is a good idea. I am not an expert on any of these matters but I am an interested and concerned resident. I appreciate the effort that Council makes to keep us all informed and the opportunity to have a say. Please continue this as well as listening to the experts.
24	I have been a resident of Nareen Pde, a particularly flood prone area, for more than 50 years. To the rear of my home is a narrow water course which runs into the nareen creek which runs into the lagoon system. There have been multiple floods to homes in our street over the 50 yrs and it is crucial that the lagoon entrance is open to allow water to escape during periods of heavy rainfall. However and IN ADDITION it is VITAL that the water courses and nareen creek are also kept clean of debris, silt, fallen trees and overgrowth to allow water flow to escape and not be blocked and build up causing unnecessary flooding of people's yards and homes. This attention to the waterways and creek is NOT occurring and there is a now permanent blockage of silt, undergrowth, weeds,debris etc which prevents free flow out to the lagoon. When I was a child(30-40years ago) the nareen creek was regularly cleaned/ dredged to keep it clear and flowing. At the least council should engage regular creek clearing if not dredging to improve flow and help safeguard properties from damaging flood waters. I believe this is required.
25	I know Councils is trying to find the answer to keeping the Entrance open, But unfortunately they continue to go down the wrong path. The last big mistake, was the massive sand hill they installed to stop the sand building up in the lake entrance. (and we can see how that worked) My family and I has lived in the same street for over 120 yrs and my grandfather worked on the first dredging operation in early 1900 and I have fished,surfed,sailed and swam in this prestige area all my life. Looking at the councils aerial photos it clearly shows, which way the the water wants to flow and the way that the sand builds up in an arc from the pool south to Collaroy. What I feel is needed (after years of observation) to keep the entrance open is to: 1: Remove the sand hill and restore it back to its original flat beach to the carpark (south side of Bridge) 2: Install Lge sand bag wall ,no higher than .5 m above top of the flat sand beach and stop at the maximum arc of sand at surf edge, A Line of deep water is shown on your aerial photo and should be followed with a sand bag wall as above. 3: Sand that has already been washed in should be retained and used to restore the sandy beach that was removed by previous council at the car park on the North western break wall. I have seen this sand bag wall process used at Cotton tree Qld and it has worked well and has not impacted on the environment or destroyed surf conditions . I am available to discuss my thoughts if council wishes.

26	Hi, I believe the short term solution is only a band- aid throughout the year and does not fix the problem with erosion, water level height/depth and does not improve conditions which may reduce the risk of flooding for residents living in and around flood prone areas such as Lake Park Road, Malcolm Street, Wellington Street, Devitt Street, Mactier Street & Pittwater Road both sides of the bridge. I feel the medium term solution would work best for everyone, if the lagoon was dredged on a yearly basis, In the past, when dredged the sand was depositied at Collaroy Beach and naturally with wind, swell direction and tide moved north protecting the residents and beaches at South Narrabeen, Narrabeen & North Narrabeen from damage and erosion. Further impacts to the the high amounts of sand in the lagoon have been the high amount of construction in the area and amounts of silt from building site entering the lagoon, the Surfrider foundations removal of the dune vegetation while good , depending on the wind, in particular if on shore deposits large amounts of sand in the lagoon. The long term solution of dredging similar to the Gold Coast would be ideal. I have seen recently, the erosion in areas of the lagoon, Middle & Deep Creek are full of sand. Areas at the back of Cromer Golf Course have seen rising water levels and the loss of trees. Near the boatshed Mactier, Ocean Street Briger and Lake Park the water height is extremely low. In Darius Avenue, a drain (outside [redacted] that constantly floods at the drop of minor rainfall. In 10 years I have been evacuated twice. The impact on residents is severe, this needs to be a priority for Council not only to improve water quality for recreation, improve the environment and for the health and safety of the residents. If there is another large environmental impact similar to 2009 & 2017 which is highly dependent on tides the impact of flooding could be significantly worse and endanger lives.
27	Hi I am a 50yr resident living near the lake and used the lake in many different ways over the years. I think the problem isn't at the lake's entry to the sea, the entire lake needs to be part of the approach to maintaining a healthy waterway. Fundamentally the volume of water contained has been reduced due to mainly silt & run off from developments & natural influences from surrounding areas feeding into the lake. Deep Creek was never really deep but now is very shallow. The flow of Deep & Middle Creek is incredibly restricted. My father commuted along the Wakehurst Parkway every day for 25+ years through the 70s, 80s & 90s without many flood events restricting the flow of traffic. It is now happening 3-5 times a year where we get a few days rain. The lake still floods when the lake is open. I learnt how to sail dinghies & windsurfers with centre boards (removable keels) on the lake. That pastime is not possible on the larger portions of the lake now. I stopped windsurfing on the lake because of how shallow is was getting. I know of three life changing spinal cord injuries from windsurfing of the lake. I learnt how to fish in the creeks & deeper sections of the lake. There was once a time when high powered speed boats would tow water skiers on the western portion of the lake. The reason the lake gets flooded after just a few days of rain is because volume of water & flow of water is just not enough to store & disperse the rain events. I agree the the outlet needs attention but you have to consider the entire waterway.
28	On viewing the short video it seems the Council is doing what they can. In the long term it is like Collaroy beach and houses should not have been built on the foreshore of either area. It would be best to acquire these properties and not be so controlled by the ocean, drainage and weather. As this would be so expensive and elevated roads would need to be put in place it seems the best thing is to continue as the Council is doing. (Collaroy beach houses should have been acquired, removed and dunes stabilised
29	1.We recommend the immediate purchase of an excavator to be standing by at all times to open the lagoon entrance in case of flooding.. 2. Need to appoint a person to the council able to predict possible flooding because of a high tide and high rainfall predicted at the SAME time..then opening up the entrance BEFORE the build up of lake water.. Our home has been badly flooded twice ..once in 2016 and again in 2020..The repercussions and expense involved months of restoring woodwork, replacing electrical items like fridges and dishwasher and our garden.... We know these could have been prevented as on BOTH occasions as soon as the entrance to the lagoon was opened later in the day, the water rushed out of the house like a river ...leaving us with

	a disaster area..This indicates that the council was far too late with opening up the entrance.. 3...Earlier this year another high tide with heavy rainfall caused complete flooding of the cul-de-sac at the bottom of Robertson Road ... As we were becoming really concerned re another flooding of our home, I rang the council. ...I was told that they were getting a bulldozer in to open up the entrance ASAP.....I asked why this could not have been requested much earlier but he didn't know....SURELY someone should be taking responsibility for to ensure the opening is cleared when or before it is likely to be required... 4. Flooding of our lagoon has caused a great deal of erosion of its banks and soil resulting in many beautiful trees being lost....Also many of the footpaths already need repairing along the walkways ..eg already near the Boatshed....Eventually the footpaths will need reinforcement or replacement at more cost .. Surely prevention of flooding is reliant on prediction of the tides and expected rainfall....If we as elderly seniors can do this then surely the council could employ someone responsible to excavate the entrance before flooding occurs.. 5.. Please consider this option as many of others involves a great expense..
30	Ref 2020/683379 Narrabeen Lake: I feel one of the easest way to help with the problem of flooding would be to have a permant small electric powered dredge pumping silt that has washed into the lake over the years of from develpment around it. By deeping it would allow more water volume and the sand from the entrance could be pumped back onto the beach.
31	re Narrabeen Lagoon Entrance Management Strategy. I am concerned about the water quality in the lagoon due to lack of care of the feeder streams, canals etc. The lagoon is a wonderful asset for the Northern Beaches and is popular for water activities such as swimming , fishing and boating. I would hesitate to eat anything caught in the lake and am also concerned about the potential for swimmers both human and canine(see dog parks) contracting bacterial and viral diseases etc. Surely part of the plan to maintain this unique environment should also consider maintaining the feeder creeks to maintain life and prevent pollution of the lagoon itself. Nareen Creek , east of Narroy Road used to be cleared regularly by Pittwater Council, however, it had been ignored by the NBC until very recently when a somewhat haphazard attempt to remove weed and improve flow was made. Unfortunately the upper reaches have not been touched, apart from the occasional spraying of glyphosate which leads to piles of dead weed blocking the creek and poisoning the water. Amphibians in particular are adversely affected by such a poison let alone reptiles, fish and water birds. Nareen Creek is a unique environment for amphibians, reptiles and birds. I have myself rescued a long necked turtle that got flooded out last year onto the main road. Unfortunately during droughts the it becomes a toxic swamp with algae limiting the oxygen levels. it needs to be dredged to remove the long standing weed, fallen trees and other rubbish which result in flooding of the local area. I understand that the creek was developed when the Nareen Park originally a swamp was drained and the land level raised with junk from the tip ,some of which was toxic resulting in a toxic sludge and weeds that are difficult to recycle. Surely some effort should be made to return this creek to the condition it was some years ago when Pittwater Council made a concerted effort to clean it up and improve water quality and flow. Necessary in order to reduce flooding and contaminating our lagoon. I would certainly like to see the lagoon open to the ocean to improve water quality and facilities, however, would also like to see a greater effort to improve the water quality of all the sources running into the lake. Thank you for allowing me to address my concerns.

32	Periodic opening and pehaps more regular (every 3 yrs) dredging would seem like the best way forward. Permanent pipes or pumping will severely impact the amenity, as well as being a safety issue.
33	Opening the Lagoon permanently is a great idea and well done!!! It is great for marine life, bird life, mammals and related wildlife. It is also great for tourists and residents and helps to minimise flooding which is a real risk for residents. Now if NBC is going to be fair, equitable and really a local government it MUST do the same for the Manly Lagoon at Queenscliff - it MUST be permanently opened up wider to stop the pollution build up, marine life degradation and most importantly - reduce the high flood risk for all the residents !!! Open up Manly lagoon NOW!!
34	Could you please permanently open the lagoon entrance and dredge the lagoon to a suitable depth so that we can actually use it. Stop fluffing around with temporary solutions and worrying about the short term water quality affect at the beach.
35	Dear Narrabeen Lagoon Entrance Management Strategy Team. Firstly, thank you for the explanatory video re the behavior sand at the entrance to the lagoon. Well done. I'm contacting you with a question. Quite apart from the important issues about effectively managing potential flooding issues. What is the current thinking re dredging the further reaches of the lagoon? As I recall, several years ago there were serious plans to dredge the lagoon. Why was the proposal shelved? While I'm absolutely NOT suggesting a return to the water-skiing of the 70's. (God forbid.) I AM concerned about the lake gradually silting-up. I've lived in the area for over 30 years and have seen changes to that effect. I recall that during the discussions about dredging, some of the experts foresaw that without dredging - the lagoon would gradually silt-up. Apparently, it would in turn, eventually become a swamp and then decades later cease to be a waterway. I look forward to your response.
36	The sand dune north of the surfclub needs to go to allow the lagoon to naturally shift entrances as it did prior to human interference. When the excavators dig at the entrance the dune just supplies more sand via slipping. Have you tried digging a hole at the beach? The surrounding sand just refills the hole. I would also like to see the artificial reef at south narrabeen revisited.
37	I believe that break walls at regular intervals should be constructed along the beach between Collaroy and North to prevent the rapid north migration of sand along the beach. These are the practices would you like to see Council adopt. The periodic clearance works in Narrabeen Lagoon entrance is essential to reduce flooding of properties around the perimeter of Narrabeen Lagoon. This is how I want Narrabeen Lagoon entrance managed long-term and the key considerations in determining which option to select include 1. the amount of sand that is required to be removed 2. the frequency between sand removal intervals 3. the present cost and future costs

38	Firstly thank you for the opportunity to make a submission. The info provided in the proposal was very enlightening and shows the complexity of opening the lake. The policy of opening when the lake is high and heavy rain is predicted (as is happening, I believe, this week) is a great step. I am not sure this was done in the flooding last February. The issue raised is the sand from the beach daming the lake. What if you created a concrete open channel between the lake and sea that could always be kept open using a bobcat.... don't laugh I am only a novice!!!!
39	Hi Hi believe the Dune that was put in front of the entrance after the 74 storm needs to be removed and the first 500 m of the lake entrance requires to be dredged so that the flow to the back of the lake can be kept.
40	As the in going tide, deposits more sand than the out going, [except when sufficient rain removes sand, as it increases the out going tide] The obvious answer is to pump seawater into the lake with the in coming tide therefore increasing the sand removal as it goes out. This could be worked out to equal the in coming tide or more if necessary. Pumping water would be cheaper than pumping sand and could be turned off when not needed. The S bend created by building the sandhill could also be removed by shortening the sandhill by at least one third, if not half. This would make the flow more direct and powerfull. An artificial reef could be constructed at the narrabeen gardens using sand bags slowing sand movement along the beach and help stop erosion. We need to think outside the box.
41	Hi I've had a look at the different options and it looks like a difficult problem to solve. It may be worth considering flood proofing the edges of the lagoon so that if the lagoon is closed it will not have as significant an impact. I'm glad to see that the breakwall has been disregarded. As a keen and frequent surfer at North Narrabeen I would not like to see any solution that damages the surf break, This is an iconic surf break that is not just know in Australia but around the world. With the WSL tour holding an event at North Narrabeen this year the profile will only continue to be raised. Any solution that is adopted need to protect and even enhance the surfing characteristics of North Narrabeen.
42	I am of the opinion that a pumping station situated amongst the dunes and only operating mid week would be a great option. Also I have had thoughts that dual pipes extended to the rock shelf with appropriate safety sceening would allow water movement without sand entry to the lake and the excess sand in the lake itself could be moved to create more dunes and beach.
43	Hi, The entrance to the lake was re directed by council around 20 years ago to run along the edge of the rock wall to then meet the ocean close to the very Nth corner of the beach near the pool. This has lead to the lake closing much more frequently, because the rock shelf which the water has to flow over is the shallowest at that part of the beach, therefore the water can not create a trench which is deeper than just a few inches on the low tide, so a little bit of sand will easily block the entrance. Prior to the change of water flow, which I mentioned the water used to flow out next to the sand dune. The flow would hug the sand dune side of the lake area east of the bridge and flow to the ocean next to the dune. This would allow the water flow through the entrance to be deeper because the rock shelf on the bottom sits lower there and therefore the entrance used to close up much less frequently. All the would need to happen is redirect the flow of water along the back of the sand dune and open the entrance to the ocean close to the dune next to time allow the water to dig out a deeper channel and now become blocked so easily. The entrance always closed from time to time in my lifetime, but it was much less frequent for the 2 decades I've been around, prior to the changes made when the water flow was redirected to hug

	the stone wall. It's a simple change to redirect it back to how it was previously and will allow the water to flow more freely, rather than over the shallowest part of the rock shelf on the bottom.
44	Long Term Solution. This is a bit of a different concept to those mentioned by the council and others. Although , it does have a slight similarity to the "low ebb flow pipe" at entrance. A look at the lake on Google Earth shows that about at Mactier Street the peninsula is almost at it's minimum width separating the ocean from the lake. A large underground pipe connecting the lake to the ocean could be constructed . If it had a backflow restrictor fitted high tide water could enter the lake via this pipe. As the tide goes out , the backflow restrictor stops the water going back to the ocean via the pipe. The only outflow option the lake would have is via the entrance. The extra water flowing out would help keep the opening from clogging.
45	Short Term management: As stated by the council , mechanical opening of the lake is carried out when the water height reaches 1.2 to 1.3 m above sea level. I think this level is too high. I live down the street from the Lakepark Road boat ramp where there is a council water height gauge. I look at the gauge on a fairly regular basis. About 3 years ago there was substantial flooding of North Narrabeen caused by a very heavy rain event. At that time , the lake had been closed for months. The water height was .9 m . Heavy rains occurred (as predicted by the weather bureau) . The council waited for the 1.2 water height and the lake was mechanically opened. Unfortunately the lake opening takes about a day to fully establish itself. During that time the lake level rose and flooding occurred causing much damage. Had the lake been opened and reduced the .9 m to .3 or .6 m the flooding probably would not of occurred or flooding would have been to a less extent. Opening the lake at .9 m may not create the "perfect" opening but the worst outcome is that it has to be reopened again. The cost of mechanical opening of the lake is nothing compared to the cost and danger of a flood.
46	1) The actual lagoon should be dredged annually to provide safe channels for boating etc - the lagoon has generally gotten shallower overall over the last 40 years that I have been a resident 2) The entrance to lagoon would then only need to be manually opened by tractor(s) as & when deemed appropriate. 3) The dredged (and dug out #2) sand can be repurposed on DY - Collaroy - Sth Narrabeen beaches.
47	I have lived in Warringah all my life and directly on the lake for 20 years. The council seems to not be taking into account 1970s wholesale changes to the entrance position (now blocked by the North Narrabeen SLSC sandhill 'extension'); and the massive increase in siltation due to opening up housing areas in the catchment such as Red Hill. Short-term - Clearly the water levels being used must be adjusted down so as to not leave water sitting too high in & around the lake. As your options paper itself states "water levels are noticeably high and can cause alarm in the community". This should not happen and causes flooding to paths , gardens and housing at the current high levels. The only time I have seen 'true' flooding was since then in June 2016 and Feb 2020. The main reason for that I believe was teh lake was closed and sitting at way too high a level. If had been drained EARLIER than on the day (!) of the well-forecast storm events, the lake could have been able to take a greater rain 'load'. Medium-term - The clearances are becoming required too frequently since the 2015 rotation meaning too much cost for residents. Although absolutely necessary to clarify what is what of the peninsula's greatest tourist attractions, a more permanent solution must be found. Long-term: Having read the options paper, and briefly researched the options, I believe the sand-pumping stations must be the way to go - for cost-benefit and aesthetics, let alone a good solution.
48	I have been a Narrabeen resident and surfer for over 25 years and have listened to the various points of view regarding the management of the lake entrance during that time,and I've been present when most openings have taken place . The transport of sand to Collaroy every few years at considerable cost has been a necessary undertaking--my property is one that flooded in 2016 due a combination of factors from king tides to large swells and the lake not being opened early enough. Due to a prominence of south swells and the depth of the rock shelf we will continue to see the entrance closed up on a regular basis, so I believe it would be in our best interests (and for the continued good health of the lagoon) if the sand were to be pumped down to Collaroy via pipes through the sand dune , and this could be done when considered necessary without reliance on copious amounts of rain to keep the channel clear. With climate change influencing our coastal waters this is not a problem that will get better on it's own,and the sooner we address it the

	better.Can I also say I thought the video was excellent and summed up the situation overall very well
49	The major dredging works that occur every 4 years is a huge waste of our Council Rates. The entrance always closes up anyway. Just open the lagoon up when it closes. It shouldnt even take 1 day to do- more like a couple of hours with a single excavator. This is far wiser - cost saving & minimal (if at all) disruption.
50	The major floods in the area were because the lake was opened too late. I strongly believe the lake should be always kept open.
51	None of the proposed long term solutions contain sufficient information to enable effective feedback by the community. The traffic light system used for key aspects of each solution has no supporting information to show the basis for setting the traffic light colour for that particular aspect of the solution. Based on initial searches and reading relating to the potential effects of sand pumping, the current council view in this presentation that the environmental impact is low does not seem to align with community concerns raised in Mandurah WA with respect to the effects of sand pumping there. See news article Mandurah Mail newspaper dated February 5 2019 by Kaylee Meerton. The current council practices appear to work albeit they are expensive and don’t appeal to everybody. From the previous council flood mitigation workshops it became evident that a long term solution was difficult implement due to the inadequate development practices surrounding the lagoon over many many decades. That being said a long term solution should not be dismissed. As a user of the lagoon I have noticed over recent years a continuing build up of sediment across the entire expanse of the lagoon to the point that previous parts of the lagoon that were once deep are now very shallow not just near the entrance but also at far ends of the lagoon. Has there been any consideration into the impact the changes in depth of the lagoon are also contributing to the problems at the entrance. The other issue raised by the council staff with respect to the causes adding to the closure of the lagoon entrance was the obstruction of natural outflow from the lagoon caused by the Ocean Street bridge with its artificial break wall. Has consideration been given to implementing changes to this structure to provide a more direct path for outflow from the lagoon which may assist the natural process of sand clearing under the right conditions. Modern bridge building techniques should be able to do away with the need for such a large rock wall on the northern end of the bridge. I appreciate this problem is very complex and requires careful study over a long period to find the best overall solution that balances environmental impacts, flood mitigation and cost. A significant amount of information is required by the community, if the community is to provide effective feedback on any long term solution.
52	I live locally at the end of lagoon street and like many people walk the lake regularly and enjoy kayaking and fishing, I am in the fortunate position to observe the lake day in day out and by doing so I gain a good insight into the health and issues impacting the lake. In my view I would like council to spend more time on the "medium term options described" and in doing so pay particular attention to the frequency of the medium term options and extent of the medium term options. By this I mean that more time and more equipment will be required in order to achieve an effective removal of sand to the east and west of the Ocean street bridge. The failure to remove sand adequately or delays in medium term options has meant that the sand build up to the west of the bridge is now greater than at anytime previously in history and the impact of this causes reduced flow, damage to weed beds habitat on south western side of the lake is large and the lake as become more susceptible to flooding and poor water quality. I would urge council when undertaking the next sand removal that their is a concentrated effort on both the eastern and western side of the ocean street bridge and that the depth and scale of the excavation in increased and extended. What this achieves will be a reduction (for a period of the time) reduction in the need for short term measures, it will maintain habitat without losing more weed beds, it will promote flow in the lake, improve water quality, improve aesthetics once the work is undertaken and improve health for both marine life and water users. I would like to discuss this further with council officers and I am flexible as to whether to meet at council offices or on site. I feel passionate about this subject and I applaud council for giving residents the opportunity to input thoughts.
53	There must be a better way to keep the entrance open then the present policy of removing sand by excavators. Perhaps a breakwater could be built on the southern side of the entrance to stop the sand moving north and closing the entrance. The water course should be straightened to what it was prior to the bridge being built. Hopefully these measures will help to reduce the future ongoing costs and prevent flooding along the banks.

54	I am a long term resident of the area going back beyond Council's 50 years management of the lake..my recollection is of a healthy lake system which was open more frequently than now. I would like to know if council 's old records show a similar build up in the "old days". If not, does the build up of sand in the Western end of the lake (due to surrounding residential development) contribute in any way to what's happening at the entrance.If that can be established, dredging to the west may be helpful. I also question whether dumping the spoil a kilometre away doesn't cause this aggregation to occur much more frequently. Your Lake Management Plan seems centred on flooding concerns...not a word on the health of the lake...SURELY more frequent openings would help and maybe dredging the western end would provide a larger, deeper volume of water, that would give more regular water temperatures (particularly in summer) and a better aquatic environment.
55	As a long term resident of Narrabeen over the years I’ve become more and more aware of the the importance of our lagoon which is so so beautiful when she’s in full flight/flow I believe it’s offers so much more to the community when open whether it be recreationally or environmentally. The risks when closed can be very scary for our community that have to live with the constant threat of flooding, and the damage it causes. When a child I recall the dredging in multiple locations which assisted in the flow of fresh ocean water to the lagoon which has left a life time of memories, but when closed the smell the colour of the water was horrible and pelican itch is horrendous. I am and will always support the lagoon being opened as much as possible and fully support the possible sand pumping which is very similar to which is conducted on the far north coast of NSW and other locations throughout Australia
56	Go with the sand pumping to Collaroy. On the Gold Coast at the Spit they run a pumping facility from one side of the break wall to the other - being South Stradbroke Island, they also do it from south of the Tweed river to Greenmount. Pipes go in permanently (hidden/buried) along the dunes to south Collaroy and are turned on intermittently
57	Re: How do you want Narrabeen Lagoon entrance managed long-term? What are the key considerations in determining which option to select? As a long term resident of Narrabeen, 35 years and an active surfer and participant in the North Narrabeen boardriders club, I would like to say the the direction of the long term sand pumping to keep the lagoon open and replenish the sand on Collaroy beach is the favoured option from what council is considering. Key Considerations: 1. Keeping the entrance open as much as possible for all lagoon recreational activities 2. Keeping the surfing banks in the best possible form for this unique natural surfing resource Thank you for respecting this great surfing beach and ditching any prospect of an entrance break wall. This would prove disastrous for the unique natural resource.
58	Thank you for the opportunity to respond - I do not support building a breakwall (I know you've discounted the option), nor creating the ebb tide channel nor the low flow pipe - these options would significantly interrupt how people use the lagoon entry at the moment. I can support the mobile sand pumping option on the proviso that the permanent pipe is buried and does not run across the top of the dunes. I actually do not support protecting the buildings in Collaroy / Narrabeen. They should never have been built on the sand dune. I would prefer Council to use it's funds to buy back these properties, demolish them and restore the sand dune. Once again thank you for the opportunity to provide feedback.
59	We think there were less problems many years ago when the lakes entrance was more of a straight line from the bridge to the ocean rather than curving around. There is a sand hill in the way now that could be moved over. Maybe this will give better flow with less blockages,

60	First Council must accept that the current setup from the ocean st bridge to the entrance is a man made problem and any environmental concerns should take into consideration that we are not altering a natural environment if we make major changes. I believe 2 issues are causing most of the blocking of the lagoon they are 1, the rock wall on the nth side attempts to direct the flow 90 degrees thus slowing the water flow and creating a great eddy in the central basin east of the bridge where sand builds up and slowly creeps nth east until the lagoon closes. 2, the dune east of the bridge is man made and provides an un natural build up of sand that also creeps nth and blocks the entrance. During the medium term clearance programmes the accuracy of the excavator operators has varied enormously and has at times looked random and inconsistent leaving large holes next to untouched areas which also slows flow and creates eddys. When the openings occur the sand is often piled metres high directly next to the opening on both sides almost inviting an immediate re closure. if it was carted away it would lengthen the time it stays open. Often when a major clearance is finished little attention seems to be given to the width of the opening which can be the difference between months or years. If the large dune was reduced to the minimum required to offer protection and graded to the sth , there would not be a ready supply to move nth and block it. This dune has grown many many times larger than when it was constructed and is many times larger than is required and in my opinion IS the problem. I would like to offer a potential solution that could be trialled very easily and with minimum cost and may negate the need for the more expensive solutions. next time a major clearance is done as well as the removal of sand you could relocate sand from the area nth east of bridge by dragging or pushing it east thus widening the channel and increasing the flow that will itself remove sand from the entrance. Also clear the sand from under the bridge all the way along its length and create more flow to move sand. rather than counting cubic metres or truck loads to measure effectiveness, monitor the excavator operators to maximise the operations success by accuracy of removal. Once an operation is complete you would only need minimal sand re location from the sth side of entrance by very small plant equipment such as a bobcat/ small loader etc or even councils own beach rake approx 100m to the sth, sth west to prevent build up. Re train councils tractor operator?? to operate a bobcat on inclement days when ovals can not be mowed and no work is done. This is an easy cost effective alternative to the major works up for discussion. When the rock pool is cleaned of sand it is often dumped on the nth side of lagoon and adds to the clogging. I have been in and out and across the entrance as a local surfer, swimmer and Councils Lifeguard on Nth Narrabeen Beach for over 45 yrs and feel very strongly that the dune on sth side should be reduced massively directly sth of entrance and less so as you head sth and most of the problems will be reduced. In summary Open and clear the sand as normal on next major operation with an emphasis on accuracy and widening. Following that, implement a regular entrance maintenance programme to stop build up. Make the maintenance a priority and the length of time between major clearances will become further apart. Change the focus from major costly operations to targeted intelligent and informed maintenance which will over time be a much cheaper and effective way to manage the Lagoon.

61	Firstly, it was a revelation to look at and listen to the council video on the opening and closing of the Narrabeen Lagoon icoll. I was heartened to hear this and to know that science determines the opening and closing of the lagoon, not just upset property owners fearful of flooding, who lobby local councillors into pressuring Council to open the entrance. You mention that the environmental health of the Lagoon is important and as such feeds into the equation of when to open the Lagoon too. My concerns are:- *water quality of the lagoon and the causes contributing to this! Are the causes being identified and addressed within the whole lagoon catchment - not just having an open the lagoon mentallity to this problem . What is going on in the catchment to pollute the lagoon and sometimes even give it an odour? Does engineering talk to the environmental department about all of this?. * my second concern is about the salinity of the Lagoon . I am sure that there must be a connection between salinity in the lagoon, fish stock and types of fish etc and the magnificent occurrence of birdlife in the lagoon catchment with a particular focus of mine on the black swan colony and pelicans who call the lagoon, home. Obviously too pollution levels will affect the occurrence of these birds. So have studies been done on what conditions favour the occurrence of these large, iconic birds and does this information feed into the frequency of lagoon opening events??? Perhaps the one metre rule is too low? A lagoon by definition opens to the ocean periodically and is not a lake . It is a sensitive total environment that needs to be managed well when sitting in an urban area. Obviously there are demands on this management plan which have to balance flooding risks, passive and active recreation and the delicate natural ecosystem. The frequency of opening and closing of the lagoon should not just be determined by the flood risk . I would like to see the management of this enjoy a wider scope and be the result of engineering and the environment and recreation consulting with each other and learning from each other . PS occasionally boats with outboard motors and manned by usually younger males, speed through the lagoon on the beach side. These sorts of activities along with unleashed dogs on the foreshores should be stopped promptly because of the detrimental effect they have on Lagoon shoreline, fauna and birdlife .
62	The problem created many years ago was building the bridge. Unfortunately the opening underneath the bridge needed to be a whole lot wider and until this is rectified the lagoon entrance is always going to have blockage problem. The sand dune built in front of the bridge by man has compounded the problem but unfortunately until the bridge entrance is wider it probably has to be left as it is. If the opening was wider natural process at the lagoon entrance would work properly. Consideration should be given also a bit of dredging further inside the lagoon as this may assist in water quality. (don't forget man has compounded the silting up of the lagoon)
63	Can the channels that run under the bridges at Ocean St and Pittwater Rds be increased to allow better flow of water to the Ocean? This would prevent water backing up at these bottle necks when there is risk of flooding
64	Thank you for councils commitment and service regarding maintaince of lagoon entrance. as a former resident of Ocean St North narrabeen work has been done with consideration and minimally disruptive. maybe divert traffic off ocean st at rats park onto Pittwater Rd north narrabeen residents to use lagoon st during sand movement. Liked the trial of moving sand actually on the beach using small bulldozers not sure how effective it was. glad not considering pipe as at queenscliff. Was concerned by flooding due to big storms and tides 2016 ??? when the Lake was closed and filthy (maybe not scheduled for another yr ??? but it needed opening prior to excessive rain and storms, easy to say in hindsight and not knowing logistics planning required for sand excavation. Pro active communication evacuation alert storm tidal flooding last year and reading council info given me more understanding. Praise for all you do for us to enjoy preserve protect maintain our precious local natural environment.

65	Hi, I don’t live in the northern beaches, but I did grow up there, and own a property in Bilgola .It’s interesting that you seem to be having similar issues with Narrabeen Lake Entrance to those we have up here on the mid north coast with Lake Cathie. I’m not sure if the issues are exactly the same, but it seems that in periods of drought, lake entrances tend to silt up, and people living around the lake start to complain about water quality. Attempts here to open the lake when the lake level is low have generally failed ie the sea soon seals the dredged entrance up. Flooding is less of a problem here as the lake is smaller, but maybe it is more of a problem in Narrabeen because there are 2 large creeks with big catchments feeding into the lake, and maybe there has been more development at lower levels around the lake (and the ongoing problems with Wakehurst Parkway.) The real problem with both of these lake systems is a history of inappropriate development around the lakes which doesn’t allow them to regulate themselves in a natural way (a similar problem in a way to the coastal erosion issue, where the problem is excessive development too close to the sea.) If you want to retain the natural features ie lake systems and beaches for all to enjoy into the future, then planned retreat and restoration to as close to the original, natural features as possible, is really the only way, expensive and locally unpopular as it would be, with landholders being appropriately compensated, given they were allowed to build etc in inappropriate places. Another example is Sand or Sandy Point at Palm Beach. I can recall when there was a continuous sandy beach all the way around, with only modest houses set back from the beach. Successive attempts by landholders to retain their own properties have resulted in increasing erosion of the public asset in order to preserve the private land. There, that’s my 2 cents worth
66	In the long term, the problems of managing Narrabeen ICOLL entrance must be viewed more broadly. The entrance is a small part of a larger dynamic water system encompassing all of Narrabeen Lakes system, including tributaries, together with the coastal area extending from North Narrabeen to Collaroy beaches. Narrabeen Lagoon is not a natural system. It has been modified to allow for human occupation and movement, and permanent changes have been forced on the lagoon as a result. Some of these are permanent retaining walls; another is the enforced re-location of the entrance to the extreme north end of the beach, north of its natural and historic location some distance further south. It's questionable whether, left to itself, the entrance would move back to its original more southerly position, as existing permanent retaining walls may discourage this. I don't know whether Council's records extend back to the time when the entrance was in its historical position, and what the frequency of closure was for an entrance in that position. But I imagine that possibly in that position the entrance would have been naturally disposed to stay open for longer periods, perhaps even stay open nearly all the time, because a deep entrance was available owing to the absence of the shallow rock floor which obstructs the present entrance position. I wonder whether Council has given any serious thought to the benefits of moving the entrance back to where nature put it? Or has the subject perhaps been avoided like the plague because its effects on the iconic North Narrabeen surf break may be catastrophic. But does anyone even know what would happen? It might even improve the break. Also, the opportunity for a deep entrance would enhance the effects of tidal scouring of the entrance channel, particularly during spring tides, both flood and ebb. Other factors affecting the entrance must include the silted state of the lagoon, particularly but not only in its main expanses west of the Pittwater Road crossing. The former Warringah Council recently examined the problem, but on terms that appeared from the outset bound to render dredging impossible: the central basis of the study required that controlled commercial dredging would not be permitted, and that the costs of dredging must be from the public purse. Blind Freddie could see from Day 1 that the study would find dredging uneconomic - and it did. If NBC would open its mind, commercial dredging under controlled and supervised conditions could permit economic improvement of water flows in the upper lagoon, without necessarily triggering destruction of the all-important sea grass beds. And detailed consideration may establish ways in which dredging, perhaps between the two main bridges, could benefit water flows in the entrance. The film clip makes the point that sand dredged when the entrance is opened is distributed elsewhere on the beach - no doubt at considerable expense. The vexed question of coastal erosion is being managed simply by replacing the missing sand. Is that responsible management? It becomes a recurring expenditure, at varied intervals; and emergencies happen with little warning - and under conditions where it's impossible to start replacing the lost sand until the cause of the sand loss abates. I have seen permanent stone groynes erected on long stretches of beach like

	ours, in Queensland, on the Gold Coast. Set about 600 metres apart, they work well, the beach stays put - and so do the houses. I have never seen groynes even mentioned in discussion of beach erosion in NSW. Do they spoil the surf break too? They don't seem to have that problem in Queensland. The issue is not just the Narrabeen Lagoon Entrance: it is all of the lagoon, and the coastline adjacent to the entrance. I urge people far better qualified than I am to open their eyes and look at a bigger picture. Narrabeen Lagoon has been fiddled with over the last 100 years, generally with some benefits but some unforeseen effects too. It needs fine tuning by people with both imagination and ingenuity. Don't follow the text-book solution: look for economical and original solutions. And for heaven's sake, get away from this crazy business of trucking millions of tons of sand from A to B only to see it washed away again.
67	Of those options the low flow pipes seem the better. In my opinion they should dredge around Jamieson Park as they used to.
68	The long term mobile pumping of sand seems okay if it more cost effective than the current trucking methodology. I do not like the other two options as they will likely have significant long term impacts. In the 10years living at Narrabeen I haven't seen the water quality in the lake deteriorate when the entrance is closed. Is this a myth or does data exist? I would like to see the homes raised and foreshore assets protected rather open the entrance regularly.
69	Please keep Narrabeen Lagoon open at all times. I have lived on the Lagoon edge for 27 years and the only time it floods is if the lagoon is closed, as soon as it is opened the water drains away. I also feel the water is cleaner when it is tidal and children swim close to the Woolworths Car Park. A high level of rain water could cause pollution, and possibly contain fecal matter from run off water.
70	hello Environment management in the last two years I noticed that the Mullet Creek which runs into the lagoon underneath Pittwater Road, has been a brownish colour and only a few fish can be seen now and one or two ducks, where as there used to be hundreds of fish and dozens of ducks enjoying their environment...my impression is that lots of polutant is flowing into Mullet Creek from it's source and a large part of the lagoon is hence discoloured when it used to be crystal clear...one reason is of course the lagoon outlet is most often blocked by sand and should be kept open at all times... surely it would NOT cost a huge amount for a grader to move the washed-in sand once a week or how often it needs to be done......I imagine that " once a year sand clearing " would cost lots more with countless truck loads and sand scooping machines operating there for 2 weeks or more...we need crystal clear water in the creeks and lagoon...voila !
71	I am impressed by the way the NBC is approaching this issue. I learned a great deal from the "explainer" video, such that I appreciate that this is a complex issue best addressed by the relevant technical experts in consultation with those members of the community who re immediately affected and the NBC itself. My only comment would be as to how the proposed solution(s) will relate to the wider lagoon management issues such as seagrass health and maintaining the public amenity of the lagoon.
72	Whilst we are not exposed to flooding risk at the perimeter of the lagoon, we have an interest in flood mitigation more generally. In the rain event in 2016, water prevented access to Gondola Road at Pittwater Road and water flooded Gondola road up to the intersection with Venetian Road. I assume that the source of the buildup was stormwater and not flood from the lagoon. The option papers are excellent and clearly describe the various options under consideration. It is interesting to learn that the natural state of the lagoon mouth is closed and natural opening is the exception. Our preference is for more frequent removal of sand from the lagoon entrance and depositing of sand on Narrabeen-Collaroy beaches. Not only does this replenish sand on those beaches, it deepens the lagoon near its entrance providing some protection against flood

73	We live near the Lagoon and only ever swim on an incoming tide when the water quality is good. While this is excellent after the council have removed the sand from the whole lagoon area it is a diminishing affect. The better the flow the more sand is brought in and the gradual deterioration until we are where we are now. At this time the levels of sand are such that even if the entrance is open it is temporary. It is a problem and water quality is a major concern for everyone for all accept the 12 months after clearing. So my suggestions would include. Need to have clean ocean water pumped into the lagoon west of the caravan park all year round. Slowing of the in tide and the flow of sand would be helpful to reduce the rapid silting of the lagoon There will still need to be some major works to remove sand at regular intervals. This is a major resource growing in popularity every year and the water quality is a health hazard for us and our grand children. Thank you
74	After reviewing / reading the information provided by council and being a local resident and user of the local water areas, I am in strong support of a stronger initial investment for best effect; and also potentially lower maintenance cost. I'm not sure if the cost indicators are based on initial cost or overall cost (initial + ongoing maintenance) But a more permanent solution would seem best with the Ebb Tide Channel (Without knowing the mobile sand pumping situation in terms of running and maintenance costs. If that was not prohibitive in maintenance then possibly that is also a genuine option to select) Beyond protecting the primary issue of flooding of local areas, the area is heavily used all year round - from the back of the lake to the front of the lake, and it would be beneficial to provide and ensure a clean and safe environment. Thanks for taking the time to provide the preliminary information and opportunity to provide feedback
75	The entrance to the lagoon is not natural. Man made the problem. (ICOLL and berm situation). Pumping seems the best long term solution and this has been discussed for decades!
76	I believe that the current method of opening the entrance prior to or during a heavy rainfall event using a large digger is most likely the most effective way to alleviate the flooding events. As long as the opening are done in a timely manner I expect that the flooding issues will best be managed this way. Long term options will still see the lake opening cover up with sand so it would still need to be carted away during extended dry periods.
77	As a resident near the lake I support Council's short, medium and long-term planning options. Council's short-term strategy must ensure that the safety of homes adjacent to the lake is protected during storm events and future flooding must be avoided. Council's plans must be nimble enough to ensure that this is the number one priority. To achieve this aim, the lagoon's entrance would need to be open more permanently. I support a permanent opening. Whilst a break-wall has been discounted, this would appear to be the only permanent long-term option. Surely the capital costs upfront now would be repaid by avoiding ongoing works?
78	At last the Council is considering a permanent solution to the silting up of the lagoon entrance. The Mobile Sand Pumping idea is by far the best option. The proposal indicates diggers to remove sand. Why would a subtle dredge not be a better idea? The diggers stir the surrounding water and are difficult to keep depth consistent, often exposing sharp shells that were buried deeper below the sand surface. Would this operate all year round or only in the of season? When the bridge was replaced many years ago the replacement bridge was shortened and allowed reclaiming area on the western side of Ocean St . By making the entrance channel meander further it slows the flow thus depositing sand. Could pipes be installed under the road on the north side of the entrance bridge t allow an improved direct route for the flow to the west side of the bridge? It would also be desirable for more sand to be removed from the west side. This has continued to shallow and the existing hollows near Pelican path that have been longstanding fishing sites are almost gone now! Any correspondence with local fisherman will support this observation. Hopefully a good decision is reached quickly and not bogged down with more obscure studies and red tape which is often the case. This area is too important to delay further. Thank you for the opportunity to comment..

79	Siltation of all our lagoons has reduced the head of water that maintain their flow. The pumping option has the benefit to remove sediment and in turn increase the volume of water. Additional, the pumping option is also portable so could be deployed to the address the water quality issues at Curl Curl and Dee Why Lagoons. I believe an overarching management plans for all our lagoons should be in place. In my opinion Curl Curl Lagoon has the greatest need of attention.
80	It would be helpful if the council could produce a video with the detailed options for short, Medium and long term stratergies. I personally feel the council has done a fantastic job (to date) with the lake managment however I feel the council need to improve on the communication platforms they share their messaging. I am also happy to discuss further Kind regards
81	I support the option to create flow pipes in combination with periodical mechanical opening of the lagoon to maintain a mechanism to keep the lagoon clean and useable as one of the rare water-access areas for families with children and dogs.
82	Mobile sand pump option looks interesting, but then I read a bit about it in Mandura WA https://www.mandurahmail.com.au/story/5888089/community-raise-concerns-over-sand-bypassing-in-mandurah/ and locals are complaining that it brings a lot of silt up and makes water really murky. Our sand looks cleaner, so it may not be such a problem, but would be interesting to know more. 1) how long will it take to pump necessary quantities of sand (40 000 cubic m?) to Collaroy 2) how likely this murky water issue is estimated to take place at Collaroy? Thanks
83	Hi, please keep the lakes entrance open by whatever means. Thank you.
84	I would like to see the lagoon go back to the ‘old days’ of management. Bring back dredging. When there was dredging full time the lagoon was much better. It was deep, people were able to do water sports. Bring in a private contractor like before, that way it would cost the Council nothing.
85	Please make sure the lagoon is opened regularly. Sometimes the creek that is parallel to Garden Street is so stagnant. My dog drinks it and gets sick.
86	Definitely not a permanent Breakwall or Low Flow pipe, please. I favour the sand-pumping option supported by Ebb Tide Flow management but need much, much more information on the sand-pumping element including noise abatement and control; maintenance regime; environmental effects; public safety;etc. etc. Whilst I feel for the contractors who will lose business, the current periodic short and (in particular) medium-term remedial measures cause far too much environmental damage to be justified or sustained. Those truck movements should be stopped as soon as possible I also need to know more about the modelling that has taken place on the Ebb Tide Flow management. Please keep me posted. Thanks
87	I support Councils current short and medium term management of the Narabeen lagoon entrance and I support the creation of an ebb flow channel and mobile sand pumping as longer term options. I do not support the low flow pipe option.

88	After reviewing the information provided, and being a local resident (emerald st) who uses the lagoon almost daily for either myself or my wife and 3 kids, I believe the option of pumping sand down to the southern end sounds like the most suitable option overall. I do believe this would also have a positive impact on the sea life, protection of houses on the mid-south beach strip, and could possibly improve the quality of consistent surf (think snapper and Kirra). All of these would be significant positives for narrabeen and the northern beaches. I hope my comments can be taken into consideration.
89	Thanks for providing such great detail and numerous options for consideration. I'm opposed to anything that looks unnatural such as breakwalls and similar man-made 'crude' options. The mobile pumped sand option appears to be the best in terms of the key considerations.
90	why dont we dredge the back part of the lake therefore making it wider for better use for boaties and kayaks alike and also the lake would hold more water i.e more water coming in and out less chance of blocking up the front
91	I know and understand the current entrance management strategy, based as it is on sound engineering, which I support. That said I have observed in the period since the last clearance a welcome finer tooth approach to utilising interim breakouts and better temporal alignment of lagoon water level and optimal tides on an opportunistic response to these conditions as they present. This has resulted in an interim benefit in terms of overall cyclical water quality as well as improved recreational benefit in between each 3-5 year major reduction of the broad crested weir of marine sand infill, West and East of the road bridge (the stone wall abutments of which appear to be in need of maintenance). One thing I would advocate is more accurate measuring of removed quantities by means of a temporary weighbridge for each truckload. I say this because the present method of quantity assessment relying as it does on x amount of loader buckets per truck load seems to me to overstate the quantity actually loaded out on the 6,000 truck trips, due to the fact that the sand is worked up by machinery possibly three times before it makes it onto the truck. It would be most interesting to see how the data based on cubic measure stacks up by cross checking some loaded trucks on the Kimbriki Tip weighbridge to determine whether this is a significant discrepancy. Such a check would also benefit in terms of having a better measure of the true amount of sand transferred to Collaroy,
92	After being evacuated in February 2020 flood we are pleased that council has been maintaining/monitoring the entrance opening and closing
93	Stop putting sand from building cites on the beach, wouldn't say it was a regular occurrence, I saw 80 x 10 tone loads of pristine sand, emptied at South Narrabeen, due to Southerly conditions the sand eventually ends up at North Narrabeen lake entrance, and when they clear the entrance, it gets reintroduced at South Narrabeen, have you ever seen a dog chase it's tail?!?! No one beats the ocean
94	I have lived in North Narrabeen intermittently for 31 years. I also own a home within the flood zone (medium risk). Both sets of my grandparents moved North Narrabeen in the 1950s and my parents (have never left!) still live in North Narrabeen. My favourite memories growing up include swimming across the Narrabeen Lagoon entrance. I hope the Lagoon entrance can be maintained and enjoyed by my own children and generations to come. I would like to see the least environmental and aesthetic impact on the lagoon (i.e. as close to nature as possible). Based on the report provided, I believe the mobile sand pumping option shows the most promise, however further investigations by Council is required before a preferred option can be selected.

	Please see below comments on the Narrabeen Lagoon Entrance Management Strategy.
	
	• Why has the ‘do nothing’ option not been reported? This would give the community an understanding of why the lagoon entrance requires management and the impact of not intervening.
	• How is Council managing the development of the catchment and the quantity and quality of stormwater? This directly impacts the quality of the water in the lagoon and potential for flooding.
	• Consideration should be given to the long term option of mechanically opening the lagoon when required (ie no dredging) as proposed by Professor Andrew Short in the Pittwater Life magazine, March 2021, page 8.
	• What has been the impact of the construction of the Narrabeen (Ocean St) Bridge and foreshore realignment on the behaviour of the lagoon? Would the replacement and realignment of the bridge alleviate sediment build up at the entrance?
	• The option of a breakwall should be included in the report to satisfy the community that it has been considered as an option and to compare it against the other options presented.
	• General: the traffic light analysis requires a key to clarify how the options have been scored. In particular, for subjective criteria (environment, aesthetics etc.). Council should also provided the indicative cost of each option and whether there will be any impact on residents rates.
	• Mobile Sand Pumping
	  o The diagram shows the pipe continuing to Collaroy Beach car park, however there is no discharge point shown at this location. Is this an error?
	  o Council should provide further information; diagrams, photos etc. of the permanent infrastructure (pumping stations, discharge points etc) to enable to community to assess the aesthetic impact of this option.
	  o Preference should be to bury the pipeline.
	  o Is there a cost savings by selecting this option (i.e. reduction in truck transportation of sand to Collaroy)? Otherwise what is the benefit of this option?
	• Ebb-Tide Channel
	  o this option requires a diagram to show the dimensions of the wall relative to the lagoon (including tide levels).
	  o It is unclear how this option has been rated low environmental impact, considering the impact to fish schools and sea grass in the localised area.
	• Low Flow Pipes
	  o this option should not be considered on its own, as the report states that additional measures would be required.
	  o The report has a photograph of an open concrete channel, however the option description is for pipes? If it is an open channel, this option would have a high recreational impact, as it would prevent swimmers from crossing the lagoon entrance.
	  o Not withstanding, this option should be dismissed due to the high cost and environmental impact.

95	To Whom it may concern My memories of how the lagoon or as we knew it ” lake” are a distant remnant to the way the Lagoon has silted up today. A scan through Near Maps from 2009 to today show that the sand east and west of the bridge has never really been removed, the depths marginally changed by the excavation process undertaken every 4-5 years as Council has stated. I have a deep love of the lake/lagoon from my childhood and to this day I fish the area both inside and on the beach. I have a keen interest in the environmental condition as this provides great fishing. All the other water based activities that occur in the catchment benefit from a healthy system, this is under pressure with all the development in the catchment areas from Belrose to Ingleside and Warriewood.

This man-made interference requires better management by Council and artificial intervention is imperative now that the catchment is no longer in a Natural State. Every year the Lagoon is putrid and Water quality low during the summer months, I cannot remember when there were really good water flows in the last 10 years. The cycles of closure are frequent and opening only occurring around high rainfall, even prior to 2016.
I am no expert in marine engineering however I do take note of when the entrance is opened and within three weeks its closed, the current practice is not effective. In my opinion the opening is excavated too far south of the existing rock shelf and a deep scour as stated doesn't really occur. At the time of opening if you tried creating the trench in a line that runs straight from the sea wall to just south of the pool the wave action may not close the opening so quickly and more sand will be displaced over the rocks.
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Short Term - Medium Term Management
Removal of the sand build up East and West of the bridge to allow greater water holding capacity during rainfall events, this would in turn potentially create a greater flow when opening is required. The sand build up at the moment is high and requires at least double the normal amount removed otherwise the same results will be repeated.
Long Term Management
The sand pumping option appears to be the best offered however there is no strategy for removal of sand West of the bridge.
The other options on face value appear to be hit and miss and provide minimal effectiveness.
Thank you for the opportunity to provide an opinion, this is a difficult problem to find a solution to . I hope that Council will adopt an effective strategy that won't be a temporary resolution, one that will be cost effective over the long term. T
he enjoyment financial and benefits to the community will be worth the expenditure.

96

<u>Narrabeen Lagoon Entrance Management Strategy Submission</u>
This submission by Cromer Golf Club is to provide feedback to Northern Beaches Council on the Narrabeen Lagoon Entrance Management Strategy project and the management options outlined.

1. Cromer Golf Club (CGC) is located at the south-western edge of the Narrabeen Lagoon (the Lagoon), bordering the lagoon between Middle Creek and South Creek. The boundary of the golf course broadly runs along the western edge of South Creek from the lagoon almost to Toronto Avenue in Cromer.
2. CGC has a water licence which permits the annual extraction of approximately 70ML of water from South Creek.

3. This water is extracted at the weir across South Creek. The weir is located near the entrance to the walking track on South Creek Road. This entrance to the walking track is close to the point where South Creek Road turns in to Rose Avenue.
4. The area of the golf course adjacent to the Lagoon and for most of the length of South Creek is relatively low-lying. In periods when the Lagoon entrance is closed these areas of the golf course are frequently subjected to flooding, water damage, debris from creek overflow and a decline in water quality from Lagoon water 'leaking' upstream into creek water. These issues are exacerbated during heavy rain events.
5. Even without heavy rain events, when the Lagoon level approaches the "one metre higher than mean sea level" threshold the Lagoon water backs up into South Creek and its tributary streams and can create localised water accumulation.
6. The costs of flooding, other water damage and the deterioration of creek water quality are significant and include:
    a. Closure of the golf course (loss of income from green fees, cart hire, food & beverage sales). Based on our 2020 operations, for each day the course is closed our earning reduce by almost $4,000. This is the equivalent of the annual subscription fees of one member, which then needs to be replaced.
    b. Repair of damage to the course (including labour, debris removal, loss of course materials and equipment, replacement of sand, soil, and turf). As an example, the repairs following flooding after the rain event in February 2020 resulted in an insurance claim under our existing policies of over $200k.
    c. Outside of the claim noted in item b), smaller flooding results in labour cost to rectify damaged playing surfaces.
    d. Loss of amenity (including inability to service our members, deterioration of playing surfaces, impact of poor Lagoon water quality e.g. odour, impact on course flora and fauna).
    e. Loss of productivity (the inability of course staff to undertake scheduled work and their diversion to course repair activities, which has a consequential affect on amenity to our members).
    f. Insurance costs (higher premiums and deductibles, assuming suitable insurance policies can be secured).
7. CGC is seeking a Lagoon entrance management strategy for Narrabeen Lagoon, which reduces the number of :
    a. major flooding events on the golf course.

	b. days in which the lagoon level remains below the level of “one metre higher than mean sea level” but sufficiently high to cause Lagoon water to back up into South Creek and its tributary streams. This causes: i. low level local flooding, which reduces playability and access of golf carts to the course. ii. contamination of CGC’s primary water source, often requiring the use of low quality bore water, and consequent deterioration of our primary turf surfaces. 8. CGC would support Council **short-term** entrance management options, including: a. Reducing the “one metre higher than mean sea level” threshold to a level below 1 metre to ensure an acceptable Lagoon height is maintained and which avoid regular localised water accumulation and contamination of creek water. b. More regular mechanical breakout operations. c. A structured communication with stakeholders (including CGC) on the level of the Lagoon and timing of mechanical breakout operations. 9. CGC would support Council **medium-term** entrance management options, including: a. Removal of sand and marine sediment from the Lagoon entrance. While this does not immediately affect Lagoon flows at CGC it will improve consequential water levels at the western edge of the Lagoon. b. Desilting the Lagoon, particularly at the Western end of the Lagoon. c. Raising the height of the South Creek weir to make it ‘flood-proof’ and restrict Lagoon water from ‘leaking’ upstream with consequential effects on South Creek water quality. 10. CGC would support Council any of the **long-term** entrance management options which places a priority on reducing the amount of time the Lagoon is closed and enables entrance clearance operations to be more easily undertaken. While acknowledging a lack of detailed technical knowledge the: a. ‘Ebb-tide channel’ option seems to achieve this objective. b. ‘Mobile sand pumping’ seems a viable alternative. c. The installation of low flow pipes has the disadvantage of high cost and a lower impact on the duration of open entrance conditions.
97	NL 4008 Called the “Anti-Flood Sand Fuse” Revised 9-10-2018 A low cost, Water Level Adjuster and Flood Water Evacuation Device Designed by, [redacted] in Sept. 2006 as a modification of a mechanical valve Gate System I had also designed in 1990's known as The Pearly Gates, Anti-Flood and Water level Controlling Device. Located, slightly under, adjacent and parallel to the west of the Ocean Street Bridge. It is constructed wholly of the local lagoon sand of the north-western corner area of the bridge. This is sand that has been washed into the lagoon from the sea beach. The structure is a sand ridge about 12 metres wide at its base with a flat and level top. It’s highest span section, (Span 1) is adjacent the most northern of the six bridge spans. It's lowest span section is towards the southern end of the bridge. Spans 1 & 2 will rarely need to be

	reconstructed. Spans 3 & 4 will at times become “PROGRESSIVELY SPENT” when they become eroded during a Potential Flood Event. They get washed out to sea when rising flood-waters spill over their tops. This rapid progressive erosion, allows for the rapid evacuation of the Head of Water backing up from the Bridge. There may or may not be pre-emptive mechanical erosion required, if given forward knowledge of a large downpour? It can be done as a precaution. (This is a stylised Side Elevation View detailing the SAND FUSE installation within the SIX available BRIDGE SPANS as viewed from the Western side) of The Ocean Street Bridge Narrabeen North End South End North Abutment of Bridge Span 1 1.6m AHD …............. Sand Fuse Span 2 1.5m AHD .... Sand Fuse Span 3 1.4m AHD …............. Sand Fuse Span 4 1.3m AHD …............. Sand Fuse Span 5 0.0m AHD water No Fuse Span 6 0.0m AHD water No Fuse South Abutment of Bridge Sand ridge graded height levels vary for each of the SIX bridge spans. Further consideration to the design height of the Sand Anti-Flood Fuse. The heights of the sand ridges across the four northern spans to decrease in height of each one progressively by 10cm towards the southern end.................... The Bridge has SIX spans. Northern-most (Span 1) 1.6m AHD. Sand level (Span 2) 1.5m AHD. Sand level (Span 3) 1.4m AHD. Sand level * (Span 4) 1.3m AHD. * Sand level (Span 5) 0.0m AHD. Requires only seabed levelling with 20kg size rocks Southern-most (Span 6) 0.0m AHD. Requires only seabed levelling with 20kg size rocks *1.3m AHD is selected, because it is the arbitrary height deemed by Warringah Council (in about 2000) to mechanically open the Lagoon's entrance to prevent flooding. Before that, 1.4m AHD was the chosen level. (to lower Rapid Flood event risk.) It is assumed that there will be no need for any sand fuses to be installed in the two southern-most bridge spans. Only some seabed levelling work (rock fill). At least one span is to remain open to allow fish movements. The determination of the (Span 5) will be made after the results of observations of the systems performance with it left open. Also the ultimate determination of individual sand fuse heights during the initial “Break in” period of the system. Spent Fuses will need to be reconstructed as soon as possible after flood waters have subsided. A west-ward 40kg bag-size Sandbag wall extension to the wall partition between span 4 & 5 may be required to prevent an Eddy forming, with an aggressive scouring action, attacking the fuses. [redacted] Anti-Flood Sand Fuse (AFSF), Benefits. Revised 28-1-2015 AFSF complements the Training Wall at Narrabeen Lagoon Entrance. It fulfils the duties of the omitted and missing essential component of the Training Wall, that is: A Water Level Control Device. It partially repairs the unforgivable Environmental Vandalism done to the Natural, Shale Rock Weir at the Lagoon Entrance when in the 1980's. Some rock was excavated at the Entrance Area, that was essential to maintain Optimum Water Levels to a perched by 600mm lagoon. Levels essential for the marine life. That life had evolved to live in within the unchanged lagoon, since the last Ice Age. It offers an alternative and better solution to that of replacing the excavated rock. That rock removal actually assists flood water evacuation. Now it's absence benefits, the Anti -Flood Sand Fuse's effectiveness. It can provide adequate water levels to provide water cover to Zostera Sea Grass Beds, that can only survive within a narrow zone of water depth. As the lagoon's seabed topography of the seagrass beds is in the shape of Plateaus, the water level parameters are very narrow. The Optimum Level at High Tide is 0.6 m AHD. This is the historic water level evolved and set for the lagoon to remain a healthy Coastal Lagoon environment for it's inhabitants. It is also the desired water level for humans that Fish, Sail, Row, swim, and live with Narrabeen Lagoon. It is only when the Lagoon drains excessively, due to drought or the absence of an Entrance Intruded Beach Sand Plug. That the amenity of the lagoon suffers and complaints of shallow water are heard. Nobody is complaining of shallow water in January 2015 because there is a massive sand plug retaining the lagoon's water. Unfortunately in this condition Flood Risk is extremely high and the migrated sand must be removed, for only that reason and to return it to the Collaroy / Narrabeen Beach. The Anti-Flood Sand Fuse prevents flooding & property damage.. It progressively erodes

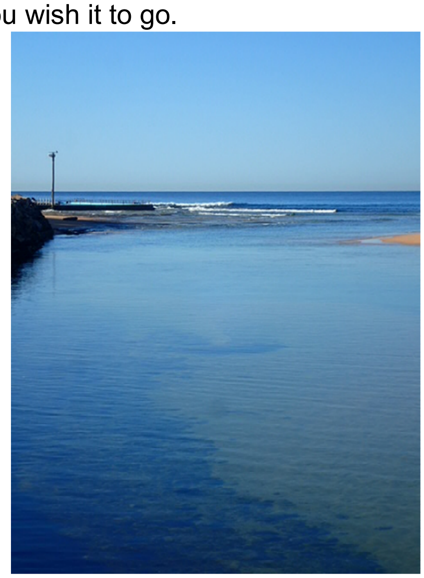
	whenever water levels rapidly rise above predetermined levels. This rapidly evacuates head waters that have built up upstream from the Ocean Street Bridge. The existing and now free-flowing Training Wall then directs the flood water efficiently to sea. Road closures due to flooding prevented. Note, Wakehurst Parkway Flooding is mostly caused by vegetation choked feeder streams to Middle Creek, regardless of the Lagoon Water Levels. The Anti-Flood Sand Fuse prevents the Ingress of Intruding Beach Sand. Because the Sand Fuses constrict the tidal inflow, the inflow water velocity east of the Ocean St Bridge is controlled and lowered to where beach sand is not swept up and transported west-ward up to and beyond the bridge. This also reduces the frequency of expensive Mechanical Sand Clearance Operations. Operations then, only required on the east side of the bridge, adjacent to the Entrance & beach. If the beach sand intrusion into the lagoon is reduced, then the migrating sand remains within the headland boundaries of the Collaroy / Narrabeen beaches. Sand Nourishment demand to the beach will reduce. Beach properties can sit at a lower risk level of being eroded. This issue also needs to be addressed. I will describe why before I return to the Anti Flood Sand Fuse topic. Sand Stabilisation Experimental Programs undertaken over the last 40 years have completed their Operational Life Cycle and need to be redone. (Dunes Bulldozed, to a low and flat profile and be replanted with suitable plants. The next 40 year cycle.) They are no longer protecting Beach Front properties, but are placing them at a heightened risk of being impacted by wave action. Over the 40 years, Sand Dune Vegetation has been, progressively trapping and holding wind blown sand. Plants overgrow sand buried plants repeatedly and this action sculpts the Sand Beach to become steeper than normal. The beach has become much narrower, with most of the available sand stacked up very high at the back of the beach. When a storm event happens, wave action against a steep beach undermines and erodes faster than a flatter, sloping broad beach buffer. Back to the AFSF topic. As the AFSF will protect the Marine Habitat and marine nursery areas, marine life will flourish. The lagoon will regain it's reputation, as a Top Fishing & Prawning Spot. When a marine area is in pristine condition, it's tourism value increases dramatically. Businesses, boat hire, water sports, tackle shops, Real Estate rentals, general retailers in the area and the Narrabeen Caravan Park will all benefit. [redacted] How best to make it happen? 28-1-2015 The AFSF is relatively cheap to construct, when costed as a parcel of “Extra Work” when the Sand Clearance Operation Contract is under way. Indeed, it may benefit the excavators by restricting unwanted water flow to the areas of their work. I'm sure the Excavators will wish to first construct the AFSF and their Sand Coffer Dam, prior to Entrance Sand removal. It is thought that Modelling Trials of the AFSF device (in miniature and/or computer) is a costly waste, as there is nothing to be lost by actually making the device on site. ….. Requirements: DPI NSW Fisheries, Permission to modify a navigation Channel. Council: DA A sufficient volume of Local Intruded Beach Sand, stockpiled beside the North-West corner of the Ocean Street Bridge, next to the Caravan Park and the Pelican Walking Pathway. Amounting to enough volume of sand to construct the 14 metre wide x slightly less than 2.0m high sand ridge wall. The length being slightly under 60 metres. Plus have an equal amount of additional Stockpiled sand, handy at that location for initial and ongoing adjustments and replacement of any “Spent” eroded Sand Fuses. The Four Stepped Design, of the device enables easy “ Drive over DRY”access to Spent Fuse locations via the North-Western shoreline area. Site Supervisor. Plus 2 x Assistants Surveyors x 2 (required to assist in accurately sculpting the Fuse Heights) It is suggested that 5 Water-level Marker Ruler Strips be attached or painted on the west sides of Bridge Span dividing walls. To be used when “Fine tuning the Optimum Operating Heights of the Sand Fuses and when reconstructing spent fuses. Bulldozer operator. Assistants to perform fitting barricades, sand fitting in span 4 end, site security etc Excavator (low height and/or long reaching tool) suitable to fit and work under the spans of the bridge. In

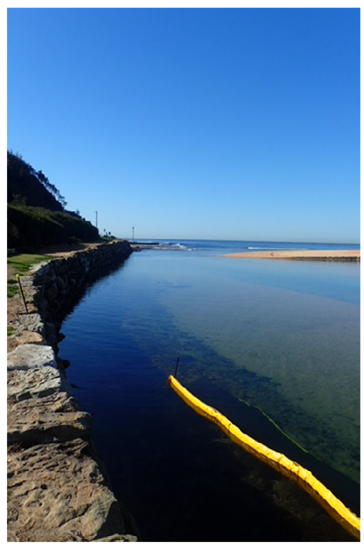
	the event of a failure of the Sand Fuse Device to perform in preventing flood water escaping. It (the sand ridges) could be dismantled within a couple of hours at minimal cost, or simply left to self erode. If it works. Everybody wins..... If it fails in some way.........it didn't cost much..........it will not have damaged anything. It's design can be useful in designing mechanical Lagoon Entrance Water Flow controlling devices, and/or replacement of the natural rock weir. Please note, Earlier documents state 1.4M AHD as the arbitrary water level to mechanically Break Open the entrance that was revised to be 1.3m AHD. In about year 2000 by (NLJE & FM C'tee) of combined P.W.C. & W. Councils. [redacted] 9-10-2018 …... .... Edit 5-11-2018 If the (AFSF) is constructed following the November 2018 works. It be noted that if around 500 x 20Kg sandbags be placed in the voids between the Bridge wall between span 4 and span 5. With some of the bags extending that bridge wall to the west, to arrest eddy currents erosion of the sand fuse. The specifications of the 20Kg capacity, sandbags: made of UV Stabilised Woven and coated Poly Fabric. Of equal Specifications of Rheem Canvacon 14SS 14 x 14 weaves per inch of HDPE and coated on both sides with LDPE. Rot proof sewing thread and/ or welded seams. End closures being Stainless Steel Tie Wire Twists, fitted securely. Edit 6-11-2018 Following Site Meeting with NBC's Todd Dickinson & Duncan Howley. Prior to the wind up of the Major Sand Works in Mid December 2018. The construction of the (AFSF) device is desired to prevent repeats of rapid sand reentry per previous Earthworks. Roughly two volumes of Sand Fuse, Construction and maintenance Sand are required to remain at the North west area location of the Ocean St Bridge. Required sand. Sand Fuse Length = 60m Width of base 14m maximum height for the calculation (say 2.0m high). This equates to 1,680 cubic metres of sand. Plus, sand to fill 500 x 20Kg Sand Bags being 10,000 Kg (…....................cubic metres) Total sand requirement (..=..cubic metres) [redacted] 6-11-2018
98	Dear Northern beaches Council Floodplain Planning & Response Team We have met members and been in email correspondence with your team since our house was flooded during a 2016 ECL weather event and then nearly again a few years ago. We live on the lagoon and swim, surf, fish on or near it daily. We like to think we are keen observers and in fine tune with the different stages of water quality as well as conscious of the state of the local Fauna and sea life in accordance to water quality. Despite being an 'ICOLL, with the modern pressures of urban runoff having the lagoon with a mostly open entrance now seems to be the generally agreed community consensus. Two major flooding events in last 8 years would have been prevented with an open entrance and a better council strategy at the time. With global warming incorporating sea-level rise and increased extreme weather events now a reality & scientifically accepted, it is time to find the best lagoon solution factoring in a worst-case scenario. Objectives? *Mitigate flooding and closure of Wakehurst parkway that restricts emergency services access to NB Hospital. *Mitigate flooding to surrounding residential and commercial areas within the lagoon flood plains. *Maintain and improve lagoon water quality to benefit of fauna, sea life as well as human recreational use. **-Path of least resistance (could also be the Path of lowest council expenditure)** We have had regular and cordial email correspondence with Valerie Tulk since a major flooding event that affected us directly but us and many in the community remain frustrated by council continuing to open lagoon entrance south of what is the now naturally occurring channel.

When we mean “now naturally occurring channel” Is the natural flow since the stone seawall was installed on the northern side of the entrance from ocean St bridge North and East terminating near the swimming club amenities building. As far as we have been able to determine the current bridge and sandstone wall was installed 1954. This Sandstone wall is key in the puzzle to keeping the entrance channel deeper and maintaining as open longer. And in all correspondence, we have had and everything we have read this wall has never been considered a factor in determining entrance position, direction, shape or depth. Maximizing flow velocity and scour effect is vital to the entrance self-managing. The wall will always direct flow along the N side scouring down to the sandstone and cutting out sand from the North across to the more southerly side. When the lagoon last naturally broke it was in this position and the entrance maintained as open for an extended period.

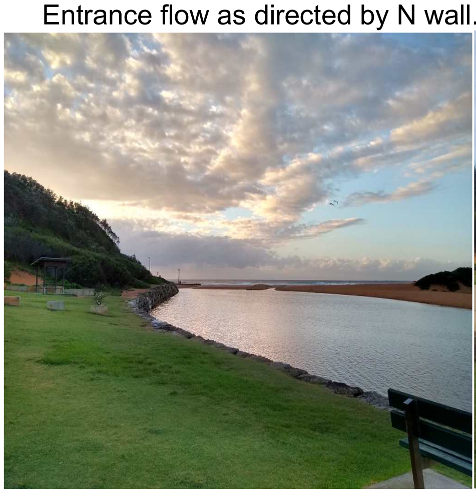
Continually opening the lagoon south at the closest point between lagoon and ocean shoreline creates a shallow meandering low velocity mostly sand entrance. This hinders the lagoon getting a good flush and usually closes over within 4- 6 weeks.

Please for just once can council try the path of least resistance and help remove sand on the N where it’s evident the water wishes to travel. Many of us think you may be surprised at how effective nature will do the job. If you wish to keep digging the channel too far south, then you need to look at reshaping the stone wall to direct the current where you wish it to go.





Entrance flow as directed by N wall.



Natural N flow Vs S manual opening Shallow S low velocity entrance

	 Manually opening Southern side of entrance [redacted] Regards the other proposals being considered to maintain entrance the only other viable and realistic option we support will be dry sand mining pumping sand back to replenish South Narrabeen Beach, especially once Collaroy seawall is finalised ,as modelling shows wall will accelerate longshore drift. We would appreciate your feed back to our suggestions.

Part B: emailed submissions

Number	Submission
1	Good afternoon, My husband and I were away when we received the information about the Narrabeen Lagoon strategy. Our opinion is as follows. The whole lake needs to be dredged as it is too shallow which is a major problem for flooding. Council said years ago that they were going to dredge the lake and have not done it. We have made several phone calls over the years but that goes no where. This email is also probably a waste of time but it is all we can do to keep urging council to clean up the lake property. Narrabeen lakes is the highlight of the area and it is such a shame to see it in such poor state. People will be able to walk across it soon and won't need a kayak or paddle board. Please consider doing more than just the entrance that millions of dollars is spent on with no long term effect. I hope somebody that really cares reads this email. Thanking you
2	Re Narrabeen Lagoon Entrance Management strategy As a resident directly impacted by the lagoon issues, it seems that there is no way to predict in advance when any rain may impact a closed entrance through sand build up then our suggestion is to take steps to keep it open on a permanent basis. I have seen 3rd would countries that have had a more organized dredging system than we have had here is one of Australians most advanced cities. • Implement a proper dredging system with a replanned purpose • Put a rockwall on the northern side to assist in permanent opening • The maintenance is not being done correctly as it stands now • Without the lake being open at all times it creates public liability for an unclean waterway • The sand level keeps rising in the lake due to no real plan to maintain it

	• On a yearly basis there should be sonar measuring to take place that verifies the min max depths • Take the sand out via dredging and sell the sand This is a public area with hundreds of houses impacted by a lack of planning and or a lack of ongoing maintenance.
3	Please find the ATTACHED Document, **Anti-Flood Sand Fuse Device, 4008** , outlining an entrance Management concept that utilizes the Local beach sand to control Lagoon Water levels and Entrance Area water velocity. I look forward to answering any questions that you may ask me about the Anti-Flood Sand Fuse Device. Plus the related Collaroy / Narrabeen Beach Sand issue. Thank You, *(submission appears above in the online submissions table)*
4	Hello I live in Narrabeen and have done for the last 7 years. Since living hear we have been frequent users of the path around the lake, Jamieson park and also the lagoon entrance at North Narrabeen. We have missed entire summers of being able swim in the lagoon with our young children as the entrance was closed and with no rain forecast, council never opened the lagoon which meant the water was polluted with signs up saying don't swim. We have known about the current reactive strategy for some time where by the lagoon is only opened when there is risk of flooding. Unfortunately this wasn't done to my recollection during the storms of 2016 which led to wide spread flooding. Additionally we know the council has been 'lookokg into' an overall management strategy for some time. There a numerous benefits of having the lagoon open and flowing all year round, better fishing, recreation, water flow - the southern end of the lake feels like stagnant water! I feel that it is time for council to be open and transparent with what the proposed options are and a committed timeline to make a decision the a committed plan to implement. Ultimately what I am saying is stop kicking the can down the road and make a decision!
5	What about putting a pipe from the ocean to the lagoon under the sand so the water flows back and forth deep under the sand then it won’t matter if the sand builds up. Make the pipe low enough so it would be unusual for it to be exposed. That way the water will flow in and out of the lake via the submerged pipe. Regards to Narrabeen lagoon opening and closing strategy to north Narrabeen beach. How about putting a pipe deep under the (mouth)entrance so that the water can flow back and forth from the lake to the ocean and back. It would be a big pipe and deep enough to work. The pipe would be deep enough for it to be an unusual event for it to be exposed. Therefore the sand can do what ever nature intends and it won’t effect the flow of water out of the lagoon and into the lagoon from the ocean.

6	It appears that around every 2 years the Council undertakes some form of Floodplain Risk Management Review, study or review for the management of the Narrabeen Lake entrance. The last report was the Cardno report in 2018/2019 which followed up Cardno's 2016 report. In 2013 there was another study prepared by BMT WBM with many more studies over the previous 20 years Within the last review, Cardno reported on some 20 potential structural options for flood reduction and lake entrance clearance. Each one of these past reports have indicated that if the lake entrance is open then the flood risk is almost zero. That is why **EARLY** mechanical breakout has proved successful. Neither the latest Cardno report nor any of the previous reports have investigated the positioning of the entrance. **No report has considered moving the current entrance to be in a straight line of the Ocean St Bridge as it was prior to Council moving it to its current position it in the early 1970's. (50 YEARS AGO) In particular removing the "S" shape bend from the western side of Ocean St Bridge to the lake entrance.** **Additionally, no previous report has analysed the effect of the "S" bend on the outgoing water flow in its own right and whether the elimination of the "S" shape bend would assist in Berm removal and improved scouring at the entrance.** **The "S" bend acts as a restrictor to the outgoing water flow and this is ONE major factor in the entrance closing.** Additionally, each of the previous reports including council's current information video state that a certain level of water is required to force the Berm build up to be pushed back out to sea, **however no analysis has considered pumping additional seawater into the lake to give it the necessary force to do this on the outgoing tide. The low flow pipe solution is not the answer.** **SO WHY HAVE THE FINER POINTS OF ADDING WATER TO THE LAKE AND THE RELOCATION OF THE ENTRANCE NOT BEEN A POINT OF ANALYSIS BY COUNCIL AND THESE PAST REPORTS?** **A REVIEW MUST BE CARRIED OUT IMMEDIATELY INTO THESE 2 OPTIONS INDEPENDENT OF EACH OTHER AND COMBINED TOGETHER PRIOR TO ANY DECISION BEING MADE.** Implementation of the above actions would mean that the little alcove beach at the east side of the Ocean St bridge would be sacrificed however this is a small price to pay for a solution that provides better outcomes for the entrance remaining open. The loss of this beach area would be more than compensated with the forming of a much larger beach along the north retaining wall on the opposite side of the channel. **Summary** The solution to the issue is basic. What is needed is an unrestricted flow of outgoing water that is equal to or greater than the flow of incoming water (on a daily or periodic basis) thus ensuring there is no Berm buildup.
7	Re Narrabeen Lake flooding. I have lived in Parukala Place for 60years and have observed the actions of Narrabeen lakes over that period. Darius Ave / Parukala Place have never flooded in that 60 years when the lake entrance has been open. The only time we flood is when the council is tardy in opening the lake, sometimes 12 to 24 hours after the water has started rising in the above streets. The frequency of flooding has not increased, but of late the severity has. At 1 to 1.3 on the gauge in the lake, the level the council opens the lake, the water has already started to rise in Darius Ave. Allowing for the delay in the council opening the lake we are well and truly flooded by the time the lake is opened. My observations over the past 60 years has convinced that if the lake is open the tide seems to have very little effect on the lake flooding. On my most recent trip North I noticed that the mouth to the two most norther rivers have big gantries across them with large pipes extending down into the river bed and an exhaust pipe going to adjacent northern beach. While this might not be the most picturesque solution it must work keeping the

	mouths open. We in the above streets will be extremely grateful for any method that you come up with to keep the entrance open.
8	I'm a resident of Narrabeen for the last 40 years and live at [redacted] Mactier St. We paddle board in the Lagoon daily and know it well. I have read all the information that you have provided and thank you for the overview. I have watch the lagoon over the years and seen the impact on Lagoon / sand / vegetation with floods and the current management. The stone wall built at the entrance many years ago made a big improvement in the flow of sand at the entrance making it easier to open. I do not agree with the policy that the lagoon needs to be a particular height before the entrance can be opened. Having the entrance open 99% of the time improves the water quality, prevents local flooding even if this is just the pathways around the lake which are now in constant use. I would like to see the entrance cleared using small diggers on a monthly basis. That way if there is a heavy rain fall it is not a major problem to open the Lagoon. At present sand is taken back to Collaroy just to be washed back down to Narrabeen. But sand is also washing out of the Lagoon and you can see the damage to the shore line with all the fallen trees ending up in the lagoon. Why can sand not be placed also on the lake shore line to protect the tree line? Particularly in well used public areas. To stop sand being washed down from Collaroy, rock wall structures could be placed in a couple of places out into the sea to slow down the massive sweep of current that runs during big surf conditions. I have attached some google maps photos of LA beaches in the USA where this technique is used to great effect. Although the initial cost maybe greater the long term benefit would save a lot of money and help the homes and the sea wall that currently being erected in Collaroy. We use to dredge the lagoon this has now stopped – it was looked at a few years ago but it was said the cost was too high. The report at that time showed that a major cost was paid to the marine department for removal of sea weed psm. The sand could also be sold. This is crazy that a government dept should be charging a cost for service to the public when it is not for commercial gain. This should be looked at. The Lagoon depth is also reducing due the erosion of the shore line. This effect must make it harder for a volume of water to help flush the entrance of the Lagoon. I trust these thought are of help to you in planning the future management of the Lagoon.
9	A few points on the Narrabeen lagoon entrance management strategy Options: Short Term - the mechanical opening periodically works fine for me. There seems to be unnecessary carry on by the community regarding water on footpaths etc, but as a resident it does no actual harm and is reality of living in a flood plain. Equally amenity of the lake for swimming etc is not a reason to open the lake. We have more beach pools and patrolled

<table>
<tr><td></td><td>beaches and council run swim centres than anywhere in the world. Its madness to open the lake just for swimming amenity. With so many other options nearby

Long term:
1. Ebb tide channel looks promising as it is more passive once constructed. It might change surf conditions, but its subjective whether it will improve or worsen the abnks, in any given swell condition. I think it has a lower aesthetic and recreation impact than indicated by RHK, and could add low tide fishing or swimming options. Nippers will be jumping off them, racing around them etc depending on material and sand profile.
2. Mobile sand pumping is my 2nd favorite. However is not as 'passive' as an ideal permanent solution
3. Low flow pipes – waste of money. Literally dozens of swimming options within metres of the lake. Not a good use of money for the release of a few sea lice.

Entrance Clearance:
Would support less intrusive approaches, including running dump trucks along the beach (to reduce road traffic on the Coll-Narra stretch) , and or running at night on the beach when there are much less users. This might be a cheaper, and possible to do more frequently, but shorter duration. Ie before the sand gets under the bridge.

Keep up the good work council!</td></tr>
<tr><td>10</td><td>I refer to Council's recent publication re current and possible future options for the Management of Narrabeen Lagoon Entrance and request for comments and suggestions in this regard.

The Study advises that the main problem with opening the closed entrance is caused by the lack of rainwater to raise the surface level of the lagoon to above that of the adjacent sea level. All of Council's past opening operations have relied on the heavens to open up to deliver the necessary volumes of rainwater to achieve Council's aims. As your publication advises it once took four years for nature to complete this task. There is however an alternate abundant supply of water immediately available nearby - the Pacific Ocean.

One of the suggestions contained in your publication is for the provision of a Low Flow pipeline to provide gravity-fed sea water to assist with the reduction of stagnation of the lagoon waters at times when the entrance is closed. The nearby rockpool is re-filled after regular cleaning by the use of a pump located generally at the seaward end of the suggested Low Flow pipeline. Is it possible that this pump, or additional/alternate pumps, could be connected to the intended Low Flow pipeline to provide a continuous inflow of seawater to the lagoon when required to raise the surface level to that needed (RL 1.3) for a "breakout" ?

Obviously a large pump/pipeline system would be required to sufficiently raise the lagoon's water level. Council's hydraulics specialists would I'm sure be able to calculate and provide the necessary sizing details and resultant timing. A suitable pump system could however provide Council with some temporal certainty toward achieving the end result and therefore Council, rather than nature, would be in control of the Lagoon entrance.

It may well prove however that the pumping system and/or time required to sufficiently raise the level of the whole lagoon is far too great to be considered a rational undertaking. There is however a possible truncated option to this concept.

Photo '18 Oct 2018' in your document shows that a temporary sand barrier has been constructed just upstream of the entrance to assist with sand removal operations. If a similar sand barrier was also provided adjacent to the Ocean Street bridge at the time of carrying out the pumping operations it would isolate that area and vastly reduce the required water volume, and hence time, necessary to raise the surface level to that required for normal mechanical opening procedures.</td></tr>
</table>

	Would that volume however provide enough impetus to widen an initially mechanically cut pilot channel and sufficiently open the entrance? Could the water level in this isolated section be raised above R.L.1.3 (but below the adjacent roadway) to assist by providing additional required volume? Once again this is an exercise for Council's specialists or possibly the Manly Hydraulics Laboratory. Should it be determined that this will provide an insufficient volume of water for the purpose, consideration could be given to constructing the sand barrier somewhere further upstream (extended along the banks to prevent property and Caravan Park flooding) to a location where calculations show that the desired result can be achieved. Following successful entrance opening the upstream barrier would be removed to allow for tidal flows to the whole lagoon. Weather patterns and predictions would of course need to be monitored during such an exercise to avert possible flooding from overfilling. I feel that Council's consideration of the provision of sand pumping via a buried pipeline along the beach to Collaroy is a much preferred option to the trucking of removed sands. Excavation/dredging similar to that currently adopted would however still be required to deliver sands to the pump's location. Whilst a pipeline and pumping will be an initially more expensive exercise it should provide Council with a permanent, efficient, suitable and locally preferable method of sand transferal and result in long-term financial savings. Is it somehow possible that the same pump used for sand transfer could also be utilised in the provision of the above suggested inflow? Additional benefits can accrue from the existence of a permanent sand transfer system. Your Study advises that there has been over recent years progressive widening of North Narrabeen beach which increases the volume of sand at the Lagoon entrance, with more extensive and frequent clearance and opening operations becoming necessary. Sand buildup has forever been occurring at the northern end of the beach, due to natural littoral drift transporting suspended sands from the southern (Collaroy) end. On irregular occasions storm-surge erosion at the southern end of the beach increases this sand loss resulting in the need for its rapid replacement. The existence of a readily available permanent system for the return of lost sand would therefore enable quick response as needed and assist resolution of three connected ongoing problems :- the entrance closure; lagoon sand buildup; and beach erosion. If found necessary, the excess northern sand could be pumped back south independently of any other lagoon management requirements. Regrettably it would appear too late to coordinate pipeline construction with stabilisation works currently being undertaken along part of the southern region of the beach. With regard to the suggested Ebb-Tide channel it is possible that the proposed semi-submerged training walls may adversely affect inflow and be somewhat counter-productive. They could also become a hazard for recreational pursuits. Should more frequent and controlled entrance openings and a more permanent sand removal and transfer system become available the need for such works may be negated. There are further issues associated with this matter. In the past, sand removal has extended only to a point generally in line with the eastern boundary of Lagoon Street leaving a large bank of sand upstream. Future works should be extended to remove this additional built-up sand. Previously suggestions have been made to remove the entrance rock shelf. This shelf acts as a weir controlling water outflow. It's removal would at low tides lower the water level of the whole lagoon resulting in exposure of formerly constantly submerged areas and seagrasses. This option should be rejected out of hand. There are some submerged oystershell encrusted rocks (remnants of the adjacent seawall construction) in the main entrance channel which should be removed for the protection of unwary swimmers. Whilst appreciating that Northern Beaches Council is seeking solutions to long-standing problems, your publication is only the latest of many similar ones put out by former Warringah and Warringah/Pittwater Councils jointly. These have been based on, or accompanied by, various reports prepared by independent consultants, special Council Committees and public

	submissions. They have however resulted in only minor changes to the basic principles of relying on rainfall and trucking. Some sand removal process improvements have however been progressively introduced. These include upgraded equipment and techniques, the creation of one-way truck movements, to reduce traffic flow inconvenience, and provision of perimeter silt control fencing to combat suspended sediment transfer, caused by tidal flow movement, for sea grasses protection. In this regard it was later found more practical to provide an entrance barrier (as per Photo '18 Oct 2018') to eliminate tidal movements thereby obviating the need for the erection and dismantling of the fencing. Regrettably, although some method adjustments resulted from submissions to previous Councils investigations, no advice, announcements, or follow-up publications were provided to the public of any decisions taken. Only observation at the time of the next works gave any indication of adopted management changes. It is time that the same old "Same Old" methods of "Pray For Rain" and "Bring In The Trucks" solutions were abandoned. It is earnestly hoped that your Council can finally determine and implement more suitable methods of dealing with these longstanding entrance management problems. Once Council's investigations are completed details of the results of your Study and intended future actions should be published. In appreciating the extensive costs associated with any manner in which these problems are resolved the former Councils' documents made reference to the possibility of State (and/or Federal ?) Government financial assistance for the overall project. Could that still be available ? I would appreciate the opportunity to meet with Council's officers to further discuss and explain my thoughts on these issues. I refer to my submission of 26th February re the suggested concept of creating an isolated section of the lagoon, by the provision of a sand weir near or upstream of the Ocean Street bridge, to assist with opening of the entrance. As an alternative to pumping seawater into the isolated dammed area via a "low flow" pipeline, a more suitable method may be to pump water from the remaining larger upstream section of the lagoon over the sand weir to achieve the required elevated level. Once again this is a matter for Council's hydraulics specialists to calculate volumes and levels to ensure no environmental damage is occasioned to either section of the temporarily divided lagoon. It could however result in the lagoon itself being utilised when needed to solve its own perennial problem.
11	I think that Council need to investigate as an alternative solution, moving the north embankment back of the Ocean Street Bridge - so then the lake/lagoon is more open to the ocean instead of going around a curve. This would bring the entrance back to how it was before the bridge - this is evidenced by early photos, as well as 'heresay' I've heard a few times, that having filled in the north side of the road into the lagoon to make the bridge shorter it has severely impacted the natural flow of water in and out of the lake/lagoon.
12	To whom it may concern, I would like to state my support for the 2019/07/04 Draft Narrabeen Floodplain Risk Management study, where they laid out a proposal to extend the bridge opening. This proposal could be a reasonable compromise to correct the blunder of the current bridge having been built in the wrong location and thus minimising the self scouring effects of the lagoon entrance. I have had the pleasure of living at [redacted] Ocean St back in the early 1990's, and speaking with the very elderly resident at [redacted] Ocean St who had lived there all his life. He informed me that the most recent bridge had been built on the south side of the opening to maximise the size of the camping ground area on the north bank of the lagoon, and the lagoon no longer drained properly. Hasn't Council now outlayed sufficient funds with repeated opening of the channel to realise it might be more cost effective in the long term to open up the drainage channel so it flows faster and more directly out of the opening, and would likely require less interference by man once it

	was returned to a state more closely resembling the original? One only needs to look at the older stock photos on the web to realise the original width of the opening and that the main body of deep water was heavily biased to the north of the lagoon arm. And if you have made it this far through my email, thank you for giving me the time.
13	Only 3 suggestions. 1. A 1 meter rock wall around the entire lake. 2. Raise the road height, by a meter, in the Wakehurst Parkway that floods all the time, 3. Dig a deeper trench at the lake outlet. In the last 2 floods, the water level has reached the same, several meter mark, from my garage door. I assume that is because that is the level height of the outlet to the ocean, possibly. It is all up to you if you want to fix the problems or just pass the buck.
14	Of course the lagoon will flood because it full of sand. It is so shallow you can nearly walk from one side to the other in some areas. My daughter has stopped using her paddle board in the lake because it bottoms out. The lake was always open or opened regularly to keep it healthy. Stop listening to minority green groups and dredge it get a bit of depth in the lagoon and maybe it wont flood as often. It will be able to handle heavy rainfall.

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beaches
council