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**.

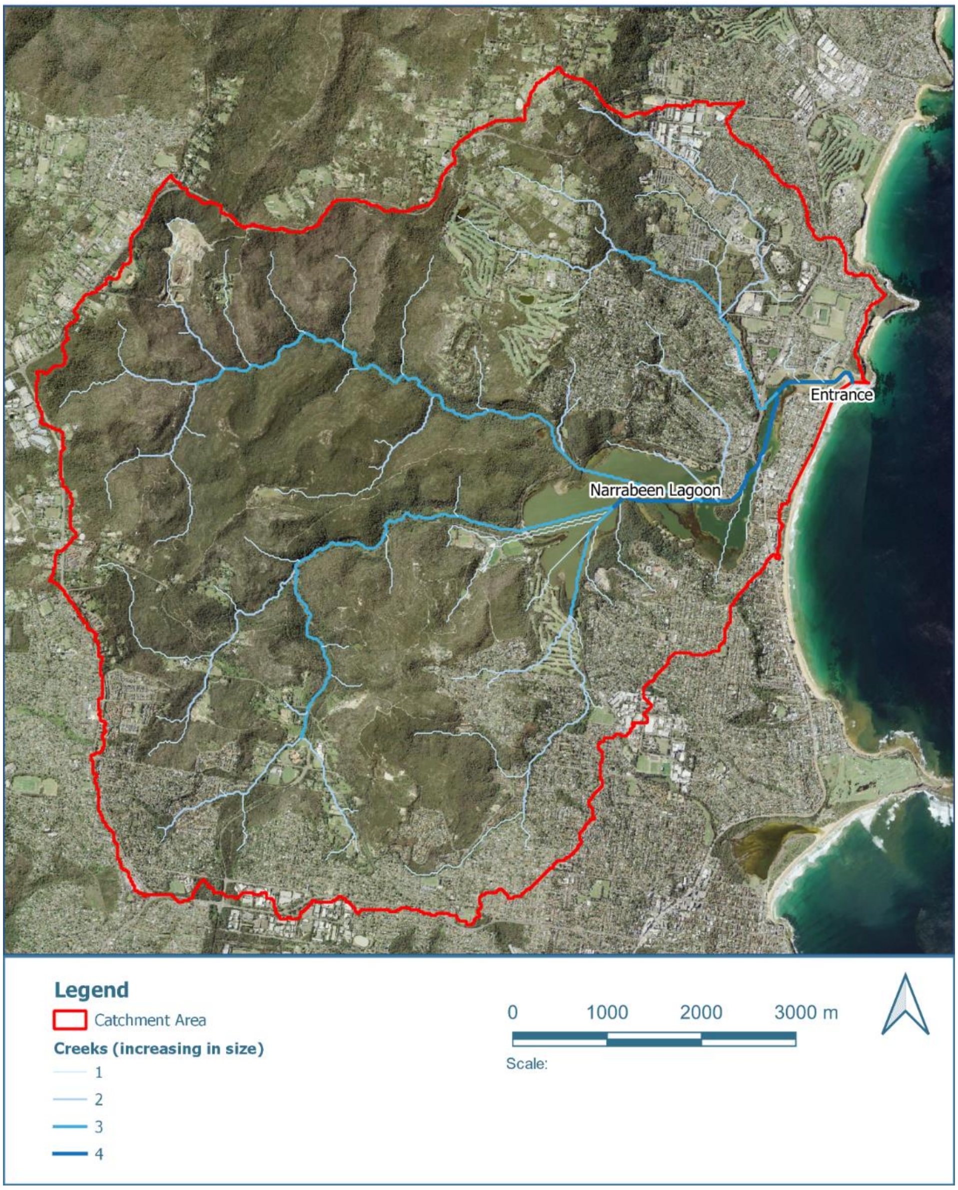

Figure 2-1: Catchment showing major creeks

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 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.

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

Royal HaskoningDHV

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).

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)

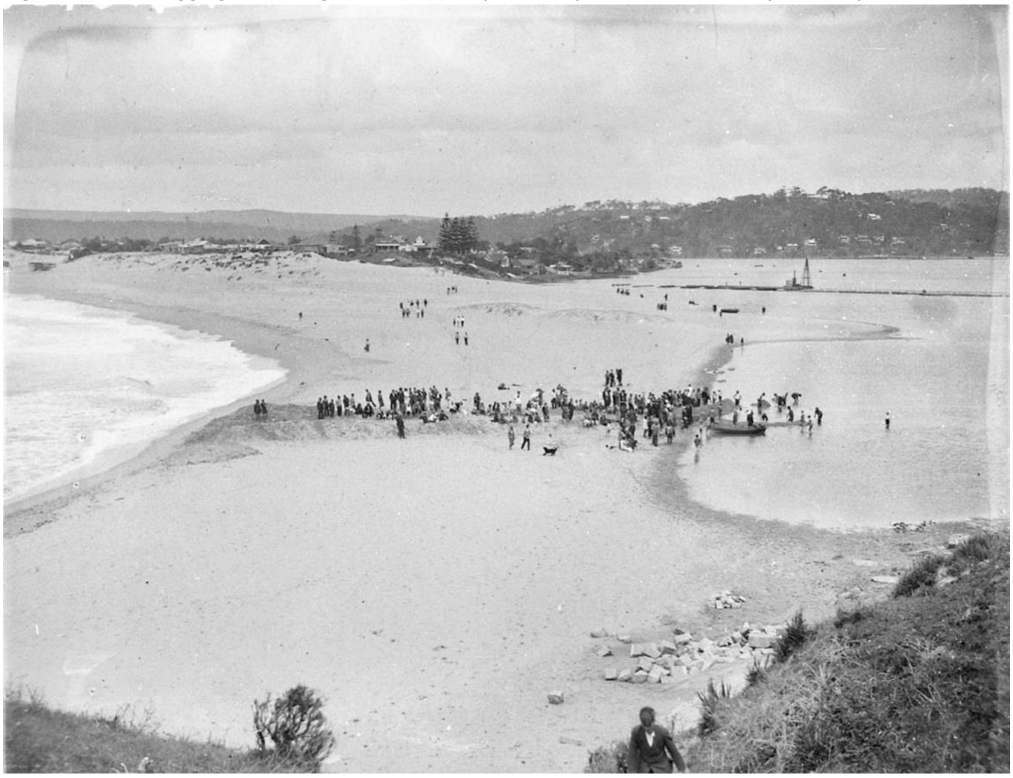

Figure 2-4: View of flood mitigation channel from Narrabeen Headland, April 1927 (Source: State Library of NSW)

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.

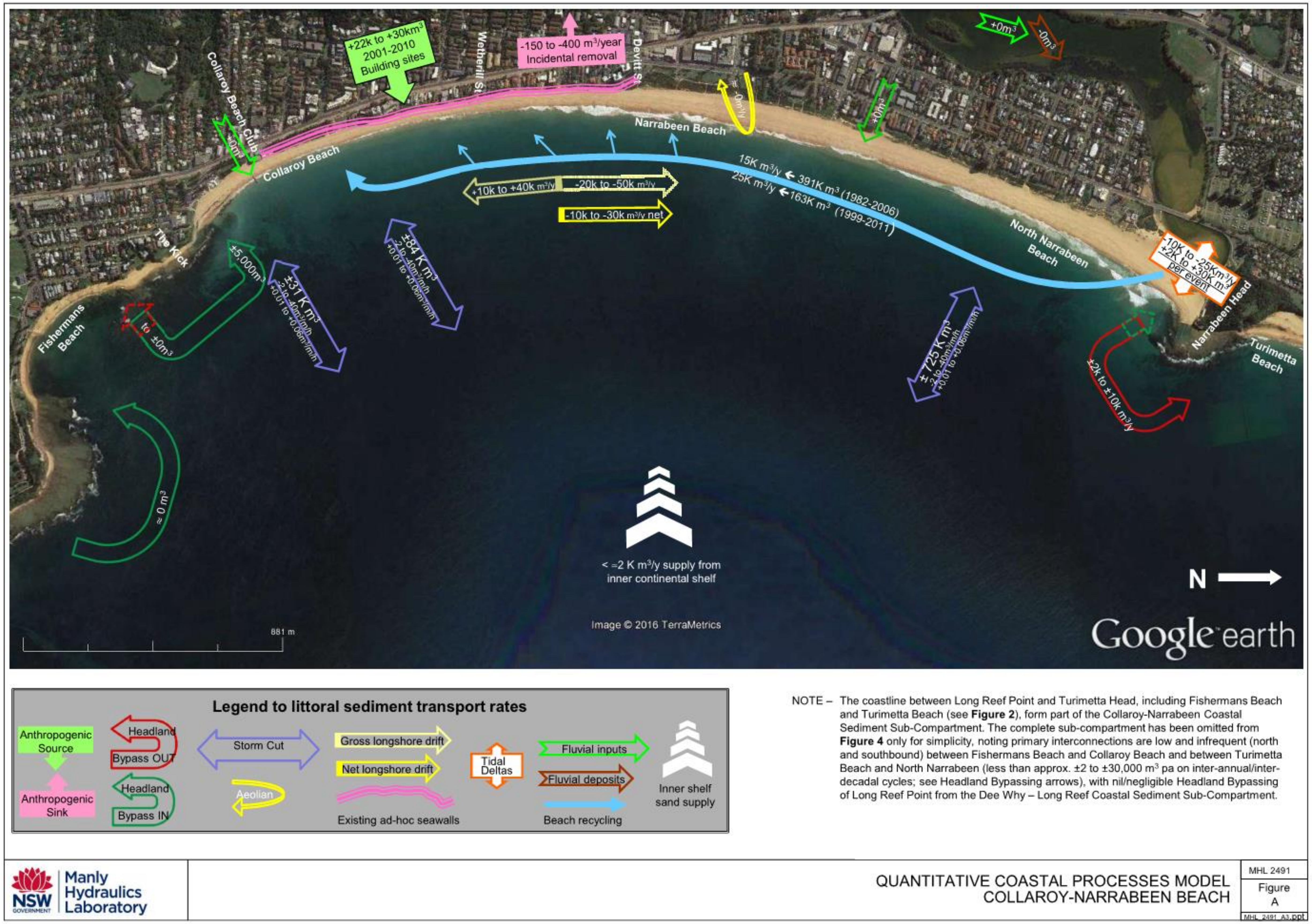

Figure 2-5: Coastal processes model for Collaroy-Narrabeen Beach embayment (Source: Manly Hydraulics Laboratory)

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).

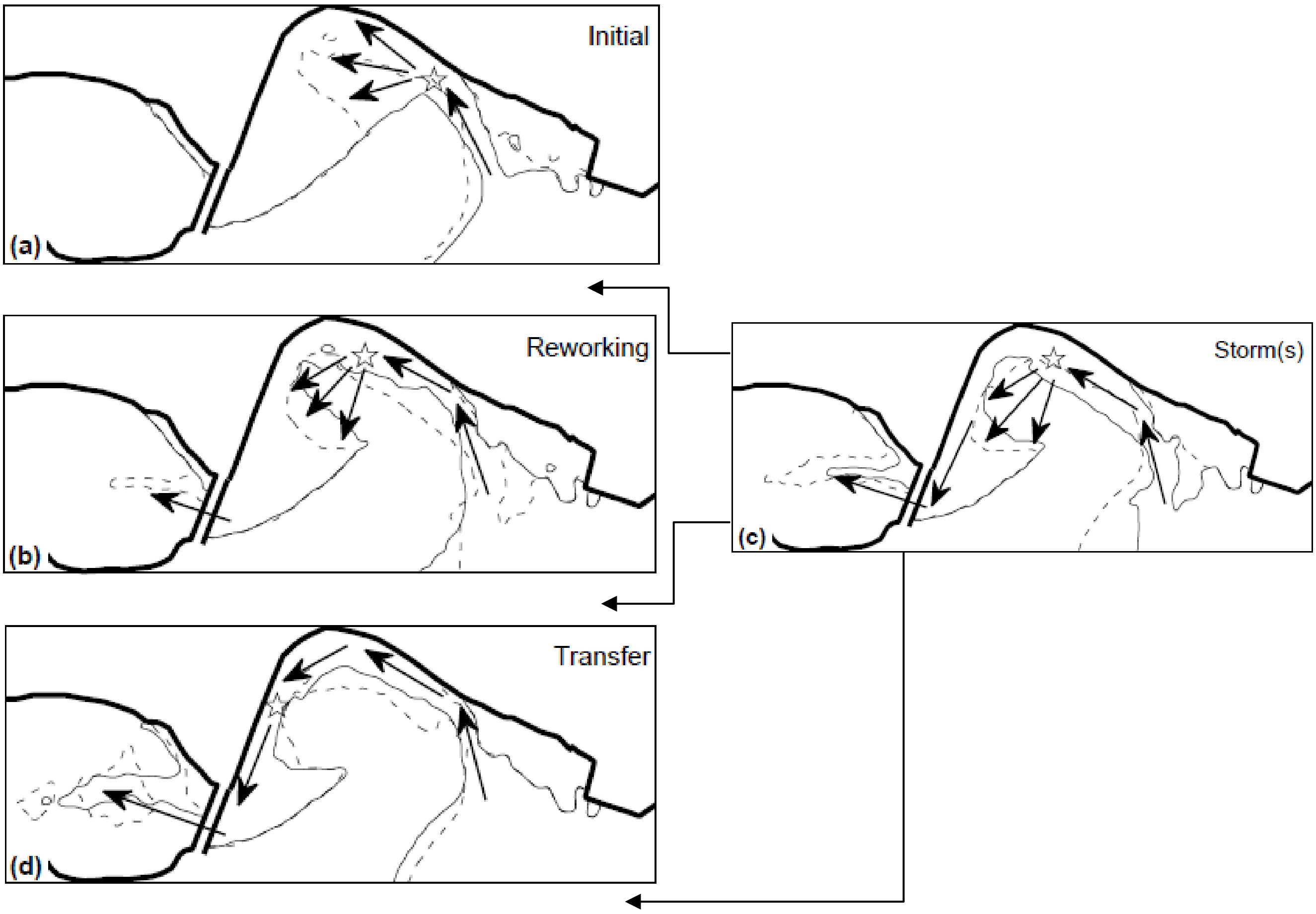

Figure 2-7: Lagoon entrance morphodynamics (Morris, 2010)

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.

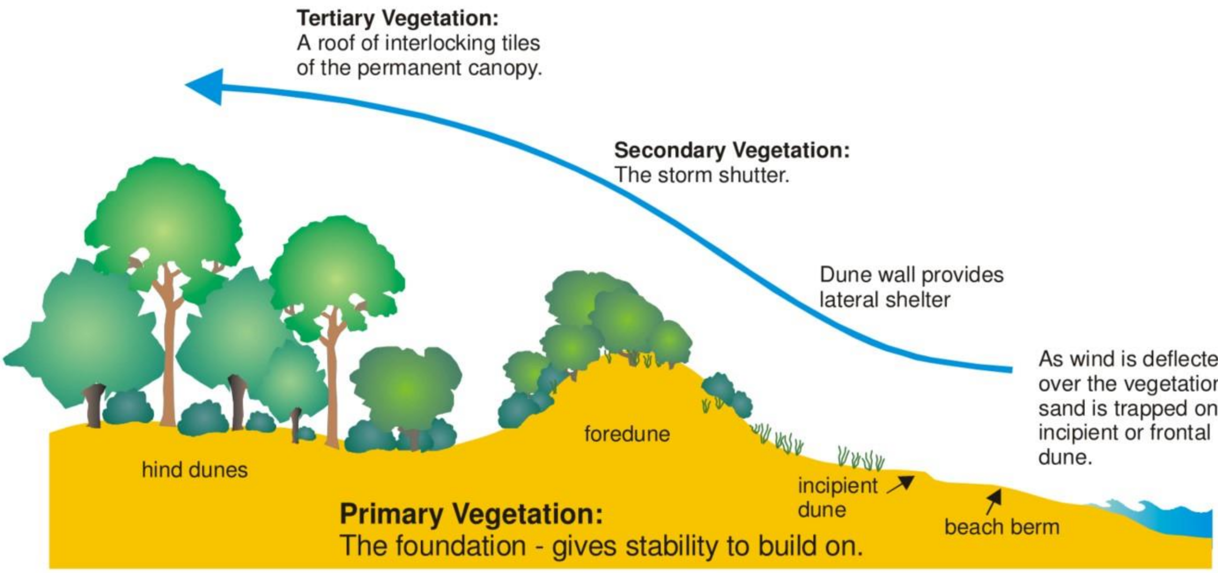

Figure 2-13: Functional model of dune vegetation (DLWC, 2001)

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.

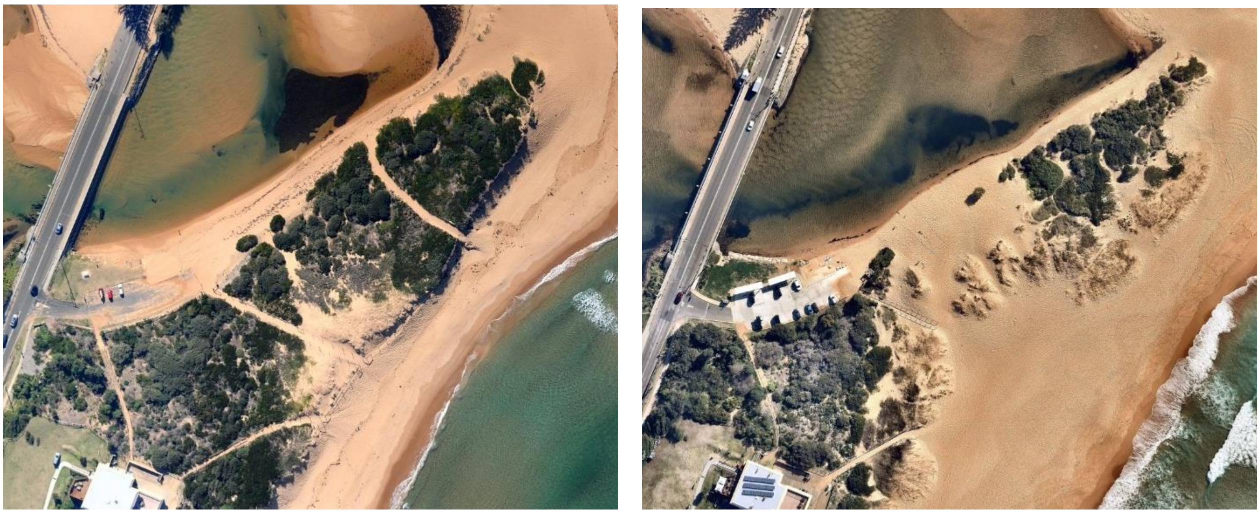

Figure 2-14: Birdwood Park dune aerial photograph comparison – June 2010 (left), August 2021 (right) (Source: Nearmap)

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.

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

[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).