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)

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.

[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.