Hydrosphere Consulting

Ballina Shire Council

Shaws Bay Dredging Options Assessment and Dredge Plan

April 2018

Final Report

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Cover photo: Proposed East Beach nourishment area at Shaws Bay.

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18-012 SHAWS BAY DREDGING OPTIONS ASSESSMENT AND DREDGE PLAN

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1. INTRODUCTION

Shaws Bay is a popular recreational area of great importance to the local community and visitors alike. The Bay provides a sheltered waterway which is ideal for activities such as swimming, paddle boarding, snorkelling and fitness training, with recreational anglers also utilising the area. The Bay is used year-round and will continue to get busier as a result of the Shire's growing population with significant visitor pressure during holiday periods. Shaws Bay also has significant environmental values there are numerous competing challenges for this waterway. Fundamental to maintaining a balanced and healthy environment in Shaws Bay is need to ensure that water quality in the Bay is maintained, public amenity and carrying capacity are optimised whilst ensuring that important ecological areas are protected.

1.1 Dredging objectives

The Shaws Bay CZMP (Hydrosphere 2013) recommends a suite of actions working towards protecting and maximising the future value of the Bay. As part of the implementation of this CZMP, Hydrosphere Consulting is undertaking an investigation into the feasibility of dredging Shaws Bay on behalf of Ballina Shire Council (BSC) with the primary aims of:

- Reducing siltation;
- Improving tidal flushing and reducing water quality risks;
- Maintaining foreshore access to deep water; and
- Improving foreshore beaches.

In doing this, there are several significant anticipated benefits and it is important that any future dredging is undertaken in a way that maximises these benefits, whilst balancing numerous technical, ecological, legislative and financial factors.

1.2 Investigation structure

The investigation into dredging feasibility has been divided up into three broad stages:

1. Baseline Surveys and Data Analysis. This is provided as a separate report (Hydrosphere 2018) which provides the background and main objectives of the project. This stage also documents key information necessary to define the dredging proposal through provision of an updated hydrographic survey, definition of the target dredging area, characterisation of the target sediments and the suitability for beach nourishment within the Bay as well as survey of target areas for the presence of seagrass which may influence the feasibility of dredging;
2. Dredging Options Assessment and Detailed Plan (this report) to identify and evaluate the best detailed methodology for dredging, considering agency stakeholder input, environmental, technical and financial constraints; and
3. Preparation of documentation required for works approval (due for completion June 2018). This will include identification of the approvals pathway, preparation of assessment documentation and applications for permits required. This stage of work is intended to progress the project to the point where tenders for the physical works can be requested.

1.3 Historical dredging of Shaws Bay

Dredging of Shaws Bay has previously been undertaken to provide fill, combat the infilling of the Bay and for local (on-site) beach nourishment. Dredging of the Bay was carried out in the 1960s to provide fill for the construction of Compton Drive, which now borders the Bay to the north.

In the mid-1970s targeted dredging of the Bay was completed which involved pumping dredged sand onto the foreshore, predominantly along the western banks, to form beaches (PBP 2000b). This involved the use of a cutter suction dredge which pumped directly to the beach via a 12 inch delivery line. Observations at the time indicated that the spoil was dark in colour and not visually appealing as beach sediment. However after two to three months the sediment was reported to have bleached naturally creating the desired foreshore appearance.

Dredging of the Bay was also carried out twice in the 1980s (1982 & 1986) using a similar method. This involved the removal of material to a depth of 12 feet (~-3-4m AHD) within the Bay which was utilised as beach nourishment (PBP 2000b). This dredging program predominately targeted the northwest corner of the Bay. Dredging carried out in 1986 resulted in minimal material being extracted due to limited sediment depositional areas-above the 3-4m target depth. Prior to the commencement of these dredging programs, excavation was undertaken along both sides of the northern section of the training wall. It was noted that this improved water circulation between the Bay and the Richmond River and allowed for flushing of the Bay during dredge operations.

Following the 1980s dredging, wind generated waves gradually transported sand from the nourished beaches back into the deeper sections of the Bay in a northerly direction. In the 1990s a long-reach excavator was used to again pull sand back onto the beach areas (PBP 2000b). Since then, the shoreline has become relatively stable although localised erosion and sediment inputs continue to contribute to infilling of the Bay.

2. CONSTRAINTS AND KEY CONSIDERATIONS

The CZMP states the overall goal for the management of Shaws Bay is “to improve the recreational amenity of Shaws Bay and to ensure that the habitat and ecological values of the Bay are maintained within an acceptable range”. In evaluating the best options for dredging it is important that each element of the project is optimised to best contribute to this goal.

It is also important to consider the environmental, legislative, technical and social constraints that may be imposed on the project. These are outlined in Sections 2.1 to 2.4 below and will be further assessed in detail as part of the Review of Environmental Factors which will be undertaken during Stage 3 of this project

2.1 Environmental

The following describe key environmental aspects for consideration in the project. Environmental impacts and measures to address these risks will be assessed as part of Stage 3 (Environmental impact assessment and approvals) and will be incorporated into a Dredging Management Plan to be implemented by the contractor.

2.1.1 Marine vegetation

Marine/estuarine vegetation is a key ecosystem feature within Shaws Bay. The extent of seagrass, mangroves and saltmarsh has been assessed as part of the Shaws Bay CZMP and the recent baseline survey (Hydrosphere Consulting 2018). These communities are ecologically important in numerous ways and are recognised as providing habitat structure, sediment stability and a food resource for a wide array of estuarine fauna. Marine vegetation also helps promote settlement of suspended solids, thus effectively ‘filtering’ turbid water and also is recognised as a significantly contributing to carbon sequestration in the form of ‘blue carbon’.

Dredging of Shaws Bay has the potential to impact seagrass (*Zostera* and *Halophila*; Plate 1) communities both directly and indirectly via dredging, pipeline placement, beach nourishment, plume generation and geomorphic effects. Direct impacts on estuarine vegetation will require a permit from DPI-Fisheries and monetary or habitat compensation in accordance with the department’s *Policy and guidelines for fish habitat conservation and management* (DPI 2013). Direct impacts to seagrass beds, where approved, will require monetary compensation in the order of $108/m². Compensation may also be required as a result of any indirect impacts to estuarine vegetation. Because of the high ecological value of seagrass and the significant requirements for compensation this factor is one of the main constraints on dredging within the Bay.

Plate 1. *Zostera* and *Halophila* seagrasses in close association at Shaws Bay

Avoidance of marine vegetation during dredging is necessary to avoid direct impacts, however it is also important to ensure that slumping of sediments and unanticipated impacts on seagrass does not occur at the dredge area boundaries. To avoid this it is necessary to incorporate 'batters' in the dredging design which provide a shallow gradient between the natural surface and the floor of the dredge cut. The previous (prior to the 2013 update) *Policy and guidelines for fish habitat conservation and management* promoted a 1 in 6 slope requirement for dredge batters. This specification has subsequently been removed, partly due to recognition that natural slopes are often steeper than this, but also to ensure that proponents consider this issue and determine the most appropriate mitigation. For the current study, batters of 1 in 6 were considered appropriate for Area 2, however a steeper 1 in 4 slope for Area 1 was considered sufficient given existing bed slopes in this area, some of which are close to 1 in 1 slope.

Whilst the proposed dredging areas have been designed to avoid significant impacts on seagrass, a key component of the project will be the expansion of East Beach which will impact an area of up to 660m² of fringing seagrass in this location. Preliminary discussions with DPI-Fisheries have indicated that although this proposal is consistent with the CZMP, this is still regarded as a large quantity of marine vegetation which would require significant steps toward habitat creation and protection in other parts of the Bay (which is also recommended in the CZMP) and should be incorporated into the works plan for this project.

The recent baseline survey (Hydrosphere Consulting 2018) identified that some areas of the bed of Shaws Bay are blanketed in dense growth of the green macroalga *Microdictyon umbilicatum.* This green macroalga does not appear to attach to the substrate and its location is influenced by tidal currents. It is not reported to be of ecological significance and incidental removal of this species during dredging is not considered likely to require a permit.

2.1.2 Benthic macroinvertebrates

Dredging in Shaws Bay will invariably result in an impact on benthic macroinvertebrates. No specific invertebrate surveys have been undertaken as part of this study, however limited previous sampling was undertaken as part of the estuary processes study (PBP 2000). This winter survey showed that the majority of macroinvertebrates generally consisted of polychaete worms and various species of whelks (gastropoda). Sampling at that time was undertaken from a range of sites, several of which coincide with the proposed dredging locations/depths of the current project as shown in Table 1.

Table 1. Macroinvertebrates previously recorded by PBP (2000) in dredge areas 1 and 2

Dredge Area	Site	Depth	Sediment Description	Macroinvertebrate count
1	B22	3m	Anoxic Muddy Sand	Nil
1	B23	LWM	Slightly Muddy Sand	5 Bivalves
1	B24	LWM	Clean Sand	5 Polychaetes
2	B13	2m	Muddy Shelly Sand	32 Gastropods
2	B14	2.5m	Anoxic Muddy Sand	Nothing alive, many dead gastropods

Generally, the results of the PBP (2000) survey indicated that polychaete worms were nearly always associated with the clean sand, whereas the gastropods were in higher abundances where mud was present. This corresponds with observations during seagrass surveys undertaken for the current study (Hydrosphere 2018) where large numbers of gastropods were evident grazing in seagrass areas, which were typically silty, whereas few live animals were observed on bare sand offshore from the seagrass.

A study undertaken by Hydrosphere (2016) evaluated the response of the benthic macroinvertebrate community to sub-tidal dredging within the Brunswick River estuary, which forms part of the Cape Byron Marine Park. Sampling was undertaken within dredging and reference areas, prior to and on two occasions after dredging. The results of this work also showed a prevalence of polychaetes on sandy sediments, although crustaceans (primarily various crabs, amphipods) and sometimes small bivalves were also found in relatively high abundances. The results of this study indicated that the benthic macroinvertebrate community recovered rapidly and in fact had higher diversity on the first post-dredging survey (February 2016), but then regained very similar levels to the pre-dredge survey (July 2015) by the 1 year anniversary (July 2016). The study concluded on a general level that the sub-tidal benthic macroinvertebrate population was generally sparse, recovered quickly following dredging and appeared to be more influenced by seasonal recruitment events than physical disturbance.

Intertidal beaches in Shaws Bay were also sampled by PBP (2000). The sample sites corresponding to the proposed nourishment areas contained relatively high number of polychaetes as well as occasional amphipods and gastropods. The beach works associated with the current proposal will include machinery movements and burial of existing beach sediments. Whilst no directly comparable study has been identified to date, it is considered that the results of intertidal infauna monitoring undertaken for ocean beach scraping provide some insights into the likely impacts. A study by Smith *et al*. (2011) determined that the effect of beach scraping on a north coast ocean beach was not discernible even one day after the impact event. Although recovery is likely to take longer than this within the less dynamic confines of Shaws Bay, this once again indicates that benthic macroinvertebrates are highly responsive and will readily colonise new habitats quickly.

It is concluded that whilst impacts on benthic macroinvertebrates are unavoidable, the scale of impact is likely to be relatively low and temporary. Despite this, it will be important to consider this factor in the impact assessment for the project (Stage 3) and determine avoidance and mitigation measures where appropriate.

2.1.3 Sediment quality

A detailed sediment investigation of the potential dredge target areas was also completed as part of the Stage 1 baseline assessment (Hydrosphere Consulting 2018). This investigation identified that the sediment at the proposed target areas was predominantly comprised of sand-size fractions ideal for beach nourishment. However, the investigation also identified that sections of the Shaws Bay bed contained surface silt often with high levels of organic coverage, which was confirmed during field component of the seagrass assessment. This silt and organic matter is not suitable for beach nourishment and will need to be separated from sand destined for foreshore management. The sediment investigation also identified the presence of PASS in the majority of sediment layers which needs to be taken into consideration with regards to required treatment and end use options. An ASS management plan will need to be developed and implemented prior to dredging. No other contaminates of concern were detected.

The presence of silt contained within some of the sediments of Shaws Bay has the potential to impact the water quality of waterbody. The disturbance of the sediments during both the dredging and dewatering phases could generate turbid sediment plumes which could impact seagrass beds, detract from the aesthetic values of the Bay and be counter to the overall objectives for management. The dredging and dewatering methodologies adopted for the project must take into account and mitigate potential releases with particular reference to total suspended solids.

2.1.4 Geomorphology

The rate and location of sediment infill in the Bay is a key consideration with regards to selection of target areas and depths as well as quantity of material to be dredged. Infill of the Bay and dredged areas is inevitable, with the average rate of infill per year estimated at 876m^3 (Hydrosphere 2013). Sedimentation is not evenly distributed within the Bay with key areas of infill being the northern section of the east arm, the eastern foreshore of the Bay adjacent to the Discovery Holiday Park and the northern half of the main waterbody. Dredging of these depositional areas must take into account the rate at which they will infill and therefore the estimated quantity of material to be dredge to meet the desired outcomes of the project.

It is also important to consider the likely stability of the edges of the dredged area. It is common practice on land to provide batters for excavated areas, and batters are used in dredging situations to ensure stability of nearby structures (e.g. training walls), reduce ad hoc slumping, and provide better protection for nearby aquatic habitats as discussed in section 2.1.1.

2.1.5 Mitigation of key environmental risks

The key environmental risks and a range of potential mitigation measures are listed in Table 2. It should be noted that this table does not provide an exhaustive listing of all the risks, nor all the potential management options, instead it is included to provide an understanding of the relative advantages or disadvantages of commonly utilised strategies that may be applied at Shaws Bay.

It is intended that the full range environmental risks, and appropriate associated mitigation measures are highlighted in Stage 3 of this project and documented in a Dredging Management Plan to be implemented by the contractor.

Table 2. Advantages and disadvantages of mitigation measures for key environmental risks

Environmental risk	Potential mitigation	Advantages	Disadvantages
Marine vegetation impacts (primarily seagrass)	Avoidance and standoff distances	Removes/significantly reduces risks to marine vegetation. Improves dredging efficiency as clogging of dredge head is reduced and hydro-cyclone efficiency improved. Avoids compensatory habitat costs.	Large standoff distances would significantly restrict the amount of Area 1 that could be dredged. Not compatible with offshore extension of East Beach.
	Incorporate batters to reduce edge slumping	Mimics natural bed slopes. Reduces the risks of burial or undercutting of nearby habitats. Reduces turbidity.	Increases overall footprint of the dredge site. Reduces the efficiency of dredging and volume of sand per area.
	Greater protection of remnant areas	Protection of high value areas is usually more efficient than creation of new areas.	Does not necessarily increase habitat area and may not be considered as adequate compensation.
	Creation of offset (compensatory) areas	Allows dedicated habitat areas to be created in locations that best fit the strategic use of the precinct. Can satisfy legislative obligation for provision of offsets. Creates additional area as new areas are usually required to adopt a replacement ratio greater than 1 : 1.	Suitable areas need to be utilised which can affect public use and amenity. Significant cost associated with creation, maintenance and monitoring.
	Protection of water quality (mainly turbidity) but also flushing/flow	Removes a significant potential impact on seagrass particularly. Good water quality is a key community requirement.	Greater expense and project complexity to manage turbidity. Increased flushing is difficult to achieve without affecting marine vegetation in the first place.
Benthic macroinvertebrate community impacts	Avoidance of high abundance areas	Beneficial for organisms. Reduces organic and shell load to be dealt with during dewatering.	Difficult to avoid completely as shallow substrates are the key target to achieve the aims of the project.
Turbidity and Acid Sulfate Soil	Use of suction style dredges	Ensures that sediment and surrounding water are entrained in the slurry and treated away	Greater volume of water needs to be managed.

Environmental risk	Potential mitigation	Advantages	Disadvantages
		from the dredging site. Highly compatible with sediment screening/separation by hydro-cyclone which is a recognised ASS treatment strategy.	Placement cannot be directly to deposition sites due to water quality constraints.
	Avoidance of muddy substrates	Reduces volume of unsuitable material that needs to be disposed of (i.e. reduced transport and tip fees). Reduced likelihood of high macroinvertebrate impacts (as mud is usually associated with seagrass).	Lack of removal of mud can be viewed as wasted opportunity to 'clean up' and area.
	Terrestrial dewatering and water quality management	Allows for strict control away from the waterway. Allows for better transport by truck, dumper, etc.	Increases overall project footprint (temporarily). Higher overall cost.
	Use of silt curtains	Can isolate sensitive areas from potential impact. Provides a secondary line of defence against accidental/unanticipated discharges.	Not suitable as a primary silt containment strategy as subsequent removal of silt is problematic. Silt curtains are less effective in areas of tidal movement or deep water. Take significant effort to deploy. Large curtains cannot be deployed too close to sensitive areas due to potential for movement and habitat damage.
	Chemical treatment of PASS/ASS (e.g. lime)	Provides additional certainty of ASS risk reduction. Standard and well understood mitigation measure.	Additional costs and project complexity. Increased lime content is not desirable for beach material. Liquid neutralising agents do not provide residual mitigation.
Sediment quality (for beach placement)	Target similar sediment types to native beach material	Achieves a number of goals such as ecological and geomorphic compatibility, social acceptability. Reduces sediment processing requirements and ensures	Reduces flexibility in the range of areas that would be targeted for dredging.

Environmental risk	Potential mitigation	Advantages	Disadvantages
		greater percentage of beneficial reuse.	
	Separation of fines	Improves overall amenity, reduces ASS risk, reduces presence of non-native sediments.	Requires hydrocyclone or settling ponds at additional expense. Requires separate containment and subsequent disposal of fines.
	Screening of shell, debris and organics	Improves overall amenity, reduces ASS risk, reduces presence of non-native sediments.	Requires screening and additional slurry pump to remobilise screened sand. Requires separate stockpiling and subsequent disposal.
Geomorphology	Ensure dredging depth makes accommodation for future infill	Provides or additional buffer that extends timeframe until repeat dredging is required. Reduces the possibility of seagrass colonisation in dredge area.	Increases the width of batters (and hence footprint). Increases volume and short-term dredging costs. Produces excess sediment which may require off-site transport.
	Include batters on cut areas	Achieves numerous advantages as discussed for marine vegetation.	Dredging inefficiency as discussed for marine vegetation.

2.2 Legislative

It is important to understand the approvals pathway for the project as well as key legislative triggers that may influence the project. The relevant legislation has been reviewed and will be detailed in the Stage 3 REF documentation. This review concluded:

- Under Division 25, Clause 129 of the *State Environmental Planning Policy (Infrastructure) 2007* (Infrastructure SEPP) foreshore management such as dredging and beach nourishment to improve tidal flows and foreshore stabilisation may be carried out by or on behalf of a public authority without consent on any land. The proposed dredging works are being undertaken for the purpose of waterway and foreshore management which aims to source clean sand for foreshore management (i.e. beach nourishment and erosion control) while promoting tidal flow within the Bay.
- BSC is the proponent and determining authority responsible for deciding whether to approve or proceed with the activity. An environmental assessment is required in accordance with Part 5 of the *Environmental Planning and Assessment Act, 1979* (EP&A Act) and Section 111 of the Act, which requires that the proponent (BSC) take into account to the fullest extent possible all matters affecting or likely to affect the environment due to the proposed activity.

- The proposed dredging areas fall with the “Coastal Protection” zone under *State Environmental Planning Policy No. 71 – Coastal Protection* (SEPP 71). The matters outlined in Clause 8 of this SEPP, must be taken into account by the consent authority;
- The proposed volume to be dredged is <30,000m³ per year and therefore an Environmental Protection Licence is not required from NSW EPA under the *Protection of the Environment Operations Act 1997* (POEO Act);
- BSC will be required to consult with DPI-Fisheries and to obtain relevant permits if required, in particular the Section 201 permit dredging or reclamation works and Section 205 permit to harm marine vegetation under Part 7 of the *Fisheries Management Act 1994*;
- The NSW EPA requires that wastes generated by the project are classified according to the risks to the environment and human health to facilitate appropriate management and disposal. Once a waste has been properly classified, appropriate management options for it can be considered, as required under the *Protection of the Environment Operations Act 1997* (POEO Act 1997) and its associated regulations.
- For any waste material to be used for beneficial purposes off-site, rather than waste disposal, a Waste Recovery Order and Exemption will be required. These are issued by the NSW EPA in accordance with clause 91, 92 and 93 of *the Protection of the Environment Operations (Waste) Regulation 2014*.

2.3 Physical and logistical

There are a number of physical and logistical constraints that have been taken into consideration during the development of the proposed dredge plan. These include:

- Overlying sludge and organic material within the Bay;
- Submerged objects including the buried Telstra cable and rock outcrops;
- The size and type of dredge required for the project and relevant launch and recovery access points;
- Land availability and suitability around the Bay to process recovered sediment (i.e. separation of material, dewatering and treatment of PASS);
- Potential location for stockpiling recovered sand, on and offsite, for future beach nourishment;
- Physical properties of the sediment that may restrict processing and disposal options; and
- Transportation of recovered sediment (sand) to beach nourishment or storage locations.

2.4 Social and community

A number of social and community related considerations have been taken into account during the development of the proposed dredge plan. These relate to the impacts the project may have on Bay users and the associated economic benefit of the Bay. The Bay is a highly utilised resource and therefore the following has been considered:

- The proposed timing of the project taking into account times of peak Bay usage (i.e. school holidays, main swimmer season and nippers season);
- The commercial business that border and utilise the Bay including the two major caravan/holiday parks and the Shaws Bay Hotel;
- The recreational and community facilities boarding or in vicinity of the Bay including park facilities, BBQ areas, Bay access areas, bike paths, cafes, Marine Rescue Tower and Ballina Surf Club; and
- Noise, vibration, dust and traffic effects on nearby residents.

3. STAKEHOLDER CONSULTATION

Documented detail stakeholder consultation will be contained within the REF documentation (Stage 3). Relevant agencies, organisations, committees, businesses, clubs and affected local residents will be informed of the project and provided with a means to provide feedback on the project. These comments will be taken into consideration when finalising the project methodology and preparing the REF. Initial consultation has commenced involving discussions regarding potential dredging scenarios or legislative and licensing required with council (proponent), Crown Lands, NSW Department of Primary Industries – Fisheries (DPI-Fisheries), NSW Environmental Protection Agency (EPA) and the Office of Environment and Heritage (OEH). The discussion with council and these agencies have assisted in assessing appropriate dredging options.

Letter of advice will be issued to the following stakeholders outlining the aims of the project and proposed dredge plan.

- Agencies/Committees/Councils:
    - Ballina Shire Council;
    - NSW DPI-Fisheries;
    - NSW Office of Environment and Heritage (OEH);
    - Department of Industry – Crown Lands;
    - Jali LALC
    - A and B Ward Committees;
- Business:
    - Shaws Bay Hotel;
    - Reflections Holiday Parks – Shaws Bay;
    - Discovery Parks – Ballina (Ballina Lakeside Holiday Park);
- Clubs:
    - Ballina Lighthouse and Lismore Surf Lifesaving Club;
    - Kawaihae Outriggers Canoe Club;
    - Shaws Bay Hotel Fishing Club;
    - Ballina Angling Club;
    - Titanic Winter Swimmers Club.
- Local residents

4. OPTIONS EVALUATION

A range of scenarios were considered in the evaluation of dredging options for Shaws Bay. Potential options were identified not only based on the most appropriate dredging technology available but also based on other key factors including extent and depth of material to be extracted, dewatering strategies, disposal and re-use of dredged material including quantities required for current and future foreshore management works (i.e. beach nourishment and erosion control) and waste disposal requirements, potential sediment stockpile options, site layout and potential future dredging requirements.

4.1 Dredging extent and volumes

An initial dredge plan was developed during Stage 1 of the study based on the key aims of the project, the outcomes of the hydrographic survey (Hydrosphere Consulting 2018) and understanding of geomorphic processes operating within the Bay. The initial plan targeted two key areas of sediment accumulation, the East Arm Depositional Delta (Area 1) and Main Bay Shallows (Area 2), however an additional three sites as listed in Table 3 are also discussed below:

Table 3: Estimated dredging volumes

Target Area	Target Bed Level (m AHD)	Sediment Volume (m^3)	Dredge Footprint (m^2)
Area 1 – East Arm Depositional Delta	-2.0 to -2.5	1,800 to 3,600	<6,600
Area 2 – Main Bay Shallows	-2.0 to -2.5	1,900 to 5,500	<7,600
Area 3 – East Arm	-1.0	3,100	6,600
Area 4 – Northern Section	-3.5	1,400	3,400
Area 5 – Training Wall Mangroves	-0.3	260	466

4.1.1 Area 1 – East Arm depositional delta

This area is on the down-drift margin of the East Arm deposition delta which has formed through continued erosion of the East Arm northern bank and continued re-mobilisation of bed sediments in the this section of the Bay. The depositional delta has built up over time as a series of sand lobes, corresponding to the varying position of the flood-tide channel.

As the channel migrates generally in a northerly direction, the seagrass colonises sand to the south. This has the effect of stabilising the bed and consolidating the southern extent of the channel. Seagrass exacerbates siltation on the southern side, reducing water levels and results in a further bias of tidal flows along this northern bank and reduces water exchange with the rest of the Bay.

Dredging of Area 1 is constrained by a significant amount of seagrass growth on the delta sediments. The objective is to dredge the seagrass-free sediments at the end of the delta in a bid to stop the further expansion of the delta and to access the good quality sand resource at this location for the planned foreshore management works. The Area 1 dredging will encompass a small section near the training wall that is currently mangrove-free. This is intended to ensure that water remains deep in this location to ensure westward expansion of mangroves along the wall does not occur and that any tidal exchange that does occur in this location remains unimpeded.

The depth of dredging in this location is intended to ensure that the water remains deep enough to limit the expansion of seagrass growth in north and westerly direction at this point and to act as a partial sink for additional sediments. Seagrass in the Bay grows to a bed elevation down to around -1.5m AHD and the -2.5m AHD target is considered to provide sufficient depth. The depth of dredging could be reduced (say to -2.0m AHD) but would provide reduced certainty over the longer-term efficacy of the work.

4.1.2 Area 2 – Main Bay shallows

This area was identified in the Shaws Bay CZMP as the depositional area for sediments and occurs in an area with outcropping rock. Despite the presence of rock, the majority of sediment cores in this target area (Hydrosphere 2018a) only encountered sand to well below the target dredging level of -2.5m. This depth was selected for similar reasons as Area 1, in that there is concern that this area will become shallow enough to promote significant seagrass growth. Such growth could lead to accelerated siltation and shallowing within this popular swimming area and a reduction in tidal exchange between the main part of Shaws Bay and the Northern Section. Again, the target depth could be reduced to -2.0m AHD, however greater longevity of the work will be achieved at the greater depth, with the sediment supply and hence risk of infilling of the connecting channel reduced. It is inevitable that some patches of Area 2 will not be fully dredged due to the unknown extent of outcropping rock and hence the actual volume of sand won from this area will be less than estimated but will still be significant.

4.1.3 Area 3 – East Arm

The East Arm has gradually widened over time as the northern bank eroded. The sediment generated from this erosion has led to lateral expansion but gradual shallowing of the East Arm as well as development of the down-drift depositional delta (Area 1). The shallowing of the East Arm has resulted in vibrant seagrass growth over a large area, but also restricted depth for swimming and increased restriction of ebb tide flows. Community members often raise the prospect of dredging within the East Arm with the expectation of addressing these issues.

An indicative dredging footprint and target depth were evaluated in considering this site. The footprint as shown in Figure 2 was selected to best avoid existing seagrass and mangroves whilst still providing a considerable increase in channel cross-section, with the main aim of reducing restriction of tidal flows between the East Arm and the main section of the Bay. This alignment was also considered most likely to avoid the significant silt build up that occurs in association with the seagrass and would also provide deeper water that was accessible to swimmers utilising Fenwick Park. Alternative options (e.g. channelising towards the southern side) were also explored, but were considered to increase the risk of the issues discussed below.

Foreshore improvement works that have recently been undertaken along the East Arm have created areas of more channelised flow and deeper water for recreation. In doing so, it was observed that areas of channel scour near the ends of new groynes had exposed areas of heavy underlying silt which had not previously been detected. The silt in these relatively small areas will be scoured and replaced by sand over time, however the presence of this material is indicative of the risk of encountering more expansive silt within the East Arm. With this underlying silt, as well as organics, shell and surface silt associated with seagrass which is within the identified dredging footprint, it is highly likely that most sediment from the East Arm would be worthless as beach nourishment material and would likely require off-site landfill disposal. Such disposal is counter to the aims of the project and is prohibitively expensive.

In addition to this, the seagrass of the East Arm forms one of the larger contiguous meadows in the Richmond River catchment and, along the northern margin, is in excellent health. Despite the community’s general desire to keep seagrass growth under control, it should be recognised that seagrass in the East Arm does play an important role in the health of the Bay and helps to ‘filter’ water coming into the Bay. The seagrass supports a large array of fish life and is a popular area for activities such as high-tide snorkelling and paddle boarding.

Securing the necessary permits to destroy this volume of seagrass is unlikely. DPI-Fisheries also require up-front, direct payment of compensation relating to destruction of seagrass, with a cost for this area likely to be significant. Combined with the transport and landfill fees to dispose of the material, the significant water quality risk associated with exposure of large areas of silt and the relative difficulty in dredging vegetated areas due to clogging of cutter heads, etc. this option is not recommended.

4.1.4 Area 4 – Northern Section

The Northern Section is most removed from the tidal exchange with the Richmond River, is more sheltered and somewhat isolated from the main circulation of the Bay. There are also a number of stormwater inputs and overland runoff occurs from a large section of the Bay’s catchment. Although generally acceptable, this section of the Bay does have poorer water quality than the rest of the Bay.

Maintaining open tidal exchange with the Northern Section is vital to ensuring the ongoing ecological condition of this area, which was highlighted in the Shaws Bay CZMP as being ideal for an ecological precinct, but is also important for protecting public health and ensuring that stagnation issues within the Northern Section do not affect the rest of the Bay.

Dredging of the Northern Section, including the connecting strait to the main Bay was considered during this project. Existing bathymetry reveals that the bathymetry is conducive to efficient flushing, with no 'dead spots' or deep holes which may accumulate excessive organic matter. Similarly, the main connecting channel is relatively deep and appears to be sufficiently scoured by exiting tidal flushing. Further dredging to deepen the central portion of the Northern Section as well as the channel is possible, however this would have the effect of increasing the Northern Section sub-tidal volume and could potentially reduce the proportion of water that is exchanged over each tidal period. In addition, it would be necessary to ensure that the maximum depth within the Northern Section would be replicated through the narrow channel area. Inspection of the bathymetric data for this area showed that it would not be possible to maintain appropriately sloped batters for a deeper channel in this area without risking destabilisation of the narrow Western Foreshore Beach as well as the high value saltmarsh and mangrove occurring on the eastern sand point.

Infrastructure searches also revealed that there is reportedly a telecommunications cable running transversely across the narrowest part of the channel. A local cable locating service reported that this cable has not been able to be located during numerous previous physical investigations and it is reported as being out of service. This indicates that the cable is not likely to pose a constraint to dredging, but could still pose a hazard to dredging equipment and is best avoided.

Overall dredging of the Northern Section is not considered to be a priority to achieve the aims of the project and is therefore not recommended.

4.1.5 Area 5 – Training Wall Mangroves

The continued establishment of mangroves along the inside of the training wall continues to be a key concern for some of the community due to build-up of silt that has occurred in this location and the potential effect of blocking tidal exchange with the Richmond River estuary. The CZMP discusses this issue and recommends the ongoing maintenance of juvenile mangrove to limit expansion of this mangrove stand, but could not justify the removal of the mature mangroves based on the information available.

This issue was re-examined in the current study. A survey was undertaken of the western-most half of the mangrove stand to determine the current bed level in this location and potential dredging volumes involved. The resulting cross-sections (see Figure 5 and Figure 6 in Appendix 1) show a typical maximum bed level of around +0.4m AHD against the wall, tapering to around 0m AHD where seagrass becomes dominant. Surface substrate varies from sand and shell, which occurs at locations where tidal flows currently occur through the wall, through to deep mud typically at the boundary with the seagrass and it likely that sub-surface sediments are very similar. The amount of organic matter is variable but generally high.

To fully remove the sediments in this area, dredging would most likely need to be undertaken by excavator and would entail the removal of the mature mangroves trees, roots as well as sediments. As discussed in section 4.2.1, such excavation would generally entail high levels of risk of turbidity, particularly for the seagrass which grows immediately adjacent to the mangroves, so some damage to this vegetation would be inevitable. It is also clear that the sediments in this area are not suitable for beach nourishment purposes and that the only likely option for disposal would be to landfill. The material was not tested but almost certainly will be highly sulfidic potential acid sulfate soil.

The improvements in tidal flushing likely to result from mangrove removal and dredging in this area are still unknown. The hydrodynamics of the Bay were previously investigated as part of the Shaws Bay Process Study Report (PBP 2000b) which was prepared in conjunction with the Shaws Bay Estuary Management Plan (PBP 2000a). This report collated data, undertook field investigations and conducted modelling into tidal level variation between the Richmond River and Shaws Bay, tidal level variation within the Bay, distribution of flow through the training wall, tidal velocity, tidal prism and overall flushing times of the Bay. These investigations identified the following:

- High tide levels are very similar between both waterbodies indicating relatively unimpeded movement of water through the training wall;
- Low tide levels do not corresponded between the two waterbodies with Shaws Bay low tides truncated at approximately -0.3m AHD creating a ponding effect;
- Tidal levels within the main body of the Bay and the East Arm vary by 0.1m indicating a sizable incoming flow along the East Arm. However tidal levels between the River and the East Arm also vary indicating a reasonably significant head loss with regards water passing through the training wall, also supported by the lag in high tide levels between the waterbodies (30-45min);
- Limited tidal flow through the training wall between the western end and the eastern end of the mangrove stand. The highest flow areas occur east of the mangrove stand but taper off with distance eastwards;
- The estimated exchange of water between the two waterbodies is approximately 130,000m^3 for spring tides and 90,000m^3 for neap tides, which is approximately 30% and 23% respectively of the total Shaws Bay volume; and
- Tidal flushing of the East Arm of the Bay is on a daily bases while the northern sections can range from 5-8 days. This is considered to be very good in comparison to other NSW estuaries.

Examination of tidal plots presented in the Shaws Bay processes study suggests that there is virtually complete penetration of all high tides from the Richmond River estuary into Shaws Bay. This indicates that the training wall is relatively porous at these levels and that there is little room for improvement of high tide water exchange available. Conversely, low tide within Shaws Bay remains ponded above the low tide levels within the main estuary by a relatively impermeable sill within the structure of the training wall. Although this reduces the tidal prism of the Bay and hence flushing rates, this ponding effect is highly beneficial for water quality in the Bay as generally only incoming (oceanic) water penetrates into the Bay. The two waterbodies remain effectively separated at low tide when poorer quality water from the Richmond River catchment would otherwise also mix into Shaws Bay. The effect is often visible during periods of wet weather such as shown by Plate 2. Any lowering of the ponded low tide level in Shaws Bay is not recommended as it would not only interfere with the selective exchange discussed above, but also would have implications for the fringing ecological communities within the Bay which are adapted to the current tidal regime.

Although full-scale removal of the mangroves is not warranted on the available information, there is concern that the efficiency of tidal exchange is worsening since the PBP studies in 2000. There is a need to collect contemporary data on tidal exchange, replicating the original methods in order to gain further insight into this issue. Should such studies confirm, there is potential to implement small scale field trials to further evaluate the likely efficacy of mangrove removal.

Plate 2. Aerial view showing catchment flood waters in the lower Richmond River with retained oceanic water within Shaws Bay

Source: Google Earth 25/8/16.

4.1.6 Other dredging concepts

A range of additional opportunities for dredging have been raised either during previous stakeholder consultation or as a result of field observations. These are listed below and have been considered but have been dismissed in accordance with the comments provided in Table 4.

Table 4: Alternative/additional options for dredging scenarios

Option	Description	Comment
1) 'Vacuum' overlying algae prior to dredging target areas	The removal of green macroalga *Microdictyon umbilicatum* that blankets a large proportion of the dredge target areas, in particular Area 1, 2, and 4, prior to dredging of sediments.	The proposed dredging and dewatering methodology should incorporate a screen to separate coarse organics such as Microdictyon. The need to undertake special procedures to deal with blanketing Microdictyon may be influenced by the dredging contractor's equipment and detailed proposal for the works.
2) Vacuum overlying silt prior to dredging target areas	The removal of silt that blankets a large proportion of the dredge target areas prior to dredging of sediments.	Whilst it was observed that the silt generally was overlying the cleaner sandy material in Shaws Bay, there is a risk of encountering silt at other depths and it is considered that hydro-cyclone separation of all dredged material is warranted (see section 4.4.3). This negates the need for any pre-dredging of silt.
3) Vacuum overlying algae and silt for entire Bay	The removal of both the green macroalga *Microdictyon umbilicatum* and silts that blankets a large proportion Shaws Bay prior to dredging sediments.	Bed disturbance for the whole Bay is not recommended as this will have a negative influence on benthic macroinvertebrate communities and is not warranted to achieve the aims of this project.
4) Excavation of northern section of training wall	The excavation on both sides of the northern section of the training wall prior to dredging to promote tidal flushing of the Bay.	This strategy has been utilised previously to improve tidal flushing of the Bay but is not considered necessary as water quality management for contemporary dredging of Shaws Bay will need to be significantly more stringent that in the past. The option to dredge the training wall mangroves is discussed in section 4.1.5.
5) Dredge deeper to access additional clean sand	Dredge Area 1 to a target depth -3.5m AHD to access a larger source of clean sand for foreshore management.	Although cleaner sands are generally found at depth within Shaws Bay (see Hydrosphere 2018), the recommended dredging plan already is likely to generate an excess of suitable sandy material.
6) Removal of rock located within target areas	The removal of boulders located within the dredge target Areas 1 and 2 prior, during or after dredging.	Area 1 contains a number of boulders in, potentially part of old rock walls or used for sediment containment, or simply stray rocks from the training wall construction. Movement of these rocks would require barge mounted excavators or similar to access the waterway. The Area 2 rock is likely to be outcropping bedrock and would require significant effort to remove. In both cases rock removal is not considered necessary to achieve the aims of the project and do not warrant the significant expense and effort required.

4.2 Dredge types

A range of dredging technologies is available for dredging in shallow waterways such as Shaws Bay. The options fall into two broad categories being either mechanical excavation or suction dredging.

4.2.1 Mechanical

Mechanical excavation involves the use of grabs or buckets to dig sediments in a similar manner to terrestrial excavation methods. Inevitably, the act of mechanical excavation will result is significant bed mobilisation, leading to high levels of local turbulence, large turbid plumes and often inefficient transfer and spillage of the sediment being moved.

Where the area to be dredged is close to shore, long-reach excavators are often used to draw the sediment towards the shore, either for deposition at that location or to be loaded onto trucks for transport. Long-reach excavators are used in locations where there is good shoreline access, the area to be dredged is relatively confined and there are good quality sediments which reduce the risk of turbidity related impacts. Crane mounted drag-line excavation can be used where further reach into the waterbody is required. These systems are typically larger than a long-reach excavator and therefore require better accessibility but suffer from the same shoreline constraints as for typical excavators. Where there are shoreward constraints such as marine vegetation, bankside trees, infrastructure, power lines, etc. the use of excavators and drag-lines becomes limiting and other strategies need to be employed.

Barge-mounted or amphibious mechanical dredges can be used to give better coverage and flexibility. For enclosed waters, such dredges are necessarily small, to allow transport and launching and hence are more advantageous in constricted areas. These types of dredges are often configurable in different ways to allow use of clam-shell style grabs, excavator buckets, or suction-cutter heads. This style of equipment is most useful where low volumes of material are to be dredged and for mechanical dredging, these are usually accompanied by a floating pontoon where dredged material is deposited and can be transferred.

Although mechanical excavation has been used in the past at Shaws Bay, this was at a time where the shorelines had been more regularly groomed by such activity and there was significantly less marine vegetation and foreshore development. The current environment at Shaws Bay is likely to be siltier than in the past due to the lack of sediment disturbance as well as on-going inputs from Richmond River floods and stormwater inlets. The environment could also be considered to be more sensitive to turbidity due particularly to the higher abundance of seagrass in most areas of the Bay. Community and agency expectations regarding turbidity and sedimentation effects are also more stringent and the likelihood of acceptance of a large-scale mechanical dredging operation in Shaws Bay is low.

4.2.2 Suction

Suction type dredges rely on hydraulic or mechanical fluidisation of the sediment at the suction head and pumping of the resulting sediment slurry via pipeline either to the ultimate fill destination or to dewatering facilities for processing. The advantage of this technology is that turbid plume generation is minimised as turbid water is drawn into the pipeline through continuous pumping and a properly assembled system will have minimal leaks, thereby maximising the containment of sediment. The percentage solids (sediment) that is pumped with the water is varied according to the distance of pumping and sediment type, but is often in the order of 15-20%. Hence a key disadvantage of suction dredging in estuaries is the large volume of salty water that is transferred ashore and the scale of the dewatering exercise and water management required.

There are numerous variations on the suction dredge concept. Trailing suction dredges are more common on large scale dredges operating in deeper waters. Smaller suction only dredges tend to work more efficiently by ‘pot-holing’, which creates a deep cone. Sediment continues to slump into the hole hence allowing the dredge to pump more material, prior to the dredge being moved to the next location nearby. This creates an uneven bed and is best used in areas where the sediment is loosely consolidated and mobile.

Other variations on suction dredges include auger dredges. This type is often used in robotic applications for clearing of tailings ponds and consists of a horizontal feed screw auger which directs mobilised sediment to a central suction point. Such dredges are often fitted with caterpillar tracks to make them independently manoeuvrable on the bed of the waterway and can be operated in shallow water.

The most common application of suction dredge technology used in shallow estuarine waters in NSW is the cutter-suction style of dredges which have a revolving cutter head to cut and mobilise the sediment. The advantage is that a range of sediment types, levels of compaction and density can be accommodated. Cutter-suction dredges are often operated to swing from side to side whilst slowly winching forward thereby sawing a swathe through the dredge area. This creates a more predicable bed form at a consistent cut depth. Cutter-suction dredges suffer when there is a large amount of debris or vegetation (e.g. seagrass) within the dredging area as this material will tend to foul the cutter head, necessitating periodic shutdown of the dredge and clearing of debris.

Dredging contractors consulted during this project assessment favoured the use of cutter-suction technology for the scope of this project due to the material present and the sediment processing technique likely to be required to guarantee a clean sand output. This technology will minimises plume generation during the agitation of any overlying silt. The cutter component of the dredge may need to be isolated to prevent damage to the dredge when operating nearing submerged rocks within the Bay.

4.3 Dredged material end use and disposal options

A key component to a dredging project is consideration of the intended use of the dredged material and its suitability for that purpose. The Stage 1 report (Hydrosphere 2018) demonstrated that the vast majority of the sediments within dredge areas 1 and 2 were marine sands but there were some areas containing silt as well as some likelihood of surface organic material.

Section 4.1 identifies the potential for a significant volume of sand (up to 9,100m^3) to be generated if dredging to the target extents and target depths is achieved. The sections below discuss the options for the beneficial use and/or disposal of the material generated.

4.3.1 Beach nourishment

Beach nourishment is considered a high-value beneficial end-use of dredged material. Beach nourishment is a common use of dredged sediments, however the material must meet environmental criteria and community expectations before it can be considered fit for this purpose.

The key considerations in this regard are:

- Grain size distribution and mineralogy;
- Aesthetic considerations (colour, odour, feel);
- Presence of shell, organics or other debris;
- Contamination status; and
- Acid sulfate (pyrite or oxidisable sulfur) content.

Uncontaminated quartz sand is highly sought after for beach nourishment, however the presence of some silt as well as high oxidisable sulfur content and occasional high shell amounts in the Shaws Bay sediments means that the sediment should undergo screening and fines separation before the material would be regarded as suitable for use on public beaches.

4.3.1.1. Shaws Bay beach nourishment

In achieving the overall management goal of the Shaws Bay CZMP and keeping in line with the dredging project aims, foreshore management in the form of on-site beach nourishment and erosion control in selected areas is an obvious end-use for the dredged material.

Five locations have been identified within Shaws Bay that require erosion control and/or would benefit from beach nourishment (Appendix 1 - Figure 3). These locations have been selected as they are either highly utilised currently or are anticipated to receive higher usage in the future as a result of strategic planning and facility locations around the Bay. Most areas contain some active erosion.

These 5 locations are:

1. Western foreshore – this beach will receive increased use due to the recent upgrade of the parking and shared path arrangements at this site as well as upgraded access ramp and park facilities. The revetment wall at the back of the beach is too high to allow safe access directly to the beach from the park area and the beach is under-utilised because of this and the lack of beach available at high tide. Placement of sand on this beach will increase public safety near the revetment wall, increase the carrying capacity of the beach and provide additional areas at elevations suitable for saltmarsh growth.
2. East Beach – this area was identified in the CZMP as the main beach for enhancement and is a key component in the strategy to improve public access to areas of better water quality within Shaws Bay. Overland runoff through this area has resulted in erosion gully behind the bank, and there is some foreshore erosion. Placement of sand on this beach will increase public safety through mitigation of erosion scars while increasing the carrying capacity and usability of this section of foreshore.
3. South Pop Denison Park beach – this beach is currently highly utilised due to ease of accessibility within Pop Denison Park and the facilities currently available (i.e. carpark close to foreshore and covered BBQ area). Usage is expected to increase following the proposed improvement of facilities within the Park as part of the CZMP. This beach is used as an access point to the Bay by community members undertaking water based activities. Placement of sand on this beach will mitigate erosion issues present as a result of high usage and overland runoff, increase carrying capacity of the beach and improve accessibility to the water.
4. Middle Pop Denison Park beach – Overland runoff has resulted in active erosion of the area evident by the presence of erosion scars. Placement of sand on this beach will improve public safety, mitigate erosion issues, increase carrying capacity of the beach and provide areas for additional saltmarsh growth.
5. North Pop Denison Park beach – this beach is currently utilised by the community and visitors due to ease of access and the facilities available (i.e. carpark and undercover picnic area). Erosion mitigation is required and this beach is planned to be surrendered in the long-term as part of the ecological zone is Shaws Bay.

The estimated sediment required for on-site foreshore management of the five identified locations is approximately 2,000m^3. This quantity is what would be required to return the locations back to a desired state that would improve the amenity of the foreshore, remove safety hazards and mitigate erosion issues and could feasibly be placed with a low level of impact on fringing marine vegetation. With this level of nourishment, these locations will likely require some future maintenance to combat natural process such as overland runoff, wind driven waves and tidal movement.

As there is the potential to dredge more sediment than required for the five proposed on-site foreshore management locations, alternatives/additional options have been considered. In addition to the first five priority sites further beach nourishment opportunities have been identified as follows:

6. The northern bank of the East Arm. Improvement works, as part of the Shaws Bay CZMP, are currently being implemented which will result in the improved amenity of this section through beach nourishment and erosion control. The works here include the establishment of three beaches bounded by rock groynes and it is anticipated that these beaches will require maintenance beach nourishment 'top ups' periodically into the future. It is likely that some sand from dredging would be beneficially placed at these locations but this will depend on the circumstances at the time of dredging.
7. Offshore expansion of East Beach. Widening of this beach would be highly beneficial as a key strategy in the CZMP was to increase public accessibility and use of this beach. A widened beach would be in close proximity to one of the areas to be dredged and therefore would provide deep water access near the beach. The offshore expansion of the beach would require the placement of approximately 3,800m³ along this section of foreshore (Figure 4 Appendix 1). This option would be dependent on obtaining a permit to harm marine vegetation from NSW DPI-Fisheries and providing the required compensation for the areas of impact. Initial consultation with the departmental officers indicates that a balanced proposal, which incorporates aspects of both beach amenity improvement and substantial steps towards establishment of the northern ecological zone would be considered favourably. This option could impact up to 660m² of seagrass beds resulting in a potential compensation value of over $70,000 (Appendix 1 - Figure 4).
8. Longitudinal expansion of East Beach southwards along the eastern foreshore in front of the Discovery Caravan Park. Beaches in this area are currently in relatively good condition and do not warrant significant nourishment at this time, but should be re-considered at the time of dredging.

Beach nourishment within Shaws Bay would include dredging, dewatering (included ASS treatment if required) and transportation of material to the placement locations. All these factors are inter-linked, however the most influential factor is the method by which sand would be delivered to the target beaches. This is discussed further in section 4.5.

Given that the beach nourishment activities in Shaws Bay will occur within the same site (geomorphological unit) as the origin of the dredged sediments, it is unlikely that a Specific Waste Recovery Order and Exemption would be required to permit this end use.

4.3.1.2. Off-site beach nourishment

The use of dredged material for off-site foreshore management is a potential option. Erosion and recession of open coast beaches as a result of extreme or irregular weather events, sediment budget deficiencies or sea-level rise can result in substantial loss of beach amenity, shoreline recession or coastal inundation within the Ballina Shire. The Ballina Coastline CZMP has been prepared with the goal of addressing these issues along the Ballina Coastline and identifies priorities for management. The additional sand generated by the dredging of Shaws Bay could be utilised in addressing management actions identified in this CZMP, as appropriate, at the time of dredging.

A Specific Resource Recovery Order and Exemption from the NSW EPA will be required for dredged material used for beach nourishment outside of Shaws Bay. Discussions with NSW EPA have indicated a Waste Recovery Order and Exemption for the dredged material would be possible if the sediment is used for beneficial purposes and is compatible with the receiving environment. The elevated oxidisable sulfur status of the Shaws Bay sediments is not necessarily an impediment to obtaining these approvals (as it was in the past), particularly if sediment cyclone separation and ASS monitoring/mitigation is undertaken prior to transport.

4.3.1.3. On-site stockpiling for later nourishment

To allow for ongoing future foreshore management of Shaws Bay, additional sediment in the form of clean sand will be required. Natural processes such as tides and overland runoff will result in the inevitable transport of sediment from proposed erosion control and beach nourishment locations back into deeper parts Shaws Bay and it is envisaged that periodic foreshore management of these locations will be required in order to meet the long-term goals and management actions of the Shaws Bay CZMP. Dredging of the Bay could generate a substantial volume of sand that would be in excess of the requirements for initial on-site foreshore management. A potential scenario is to stockpile this sediment in an appropriate location following dewatering and ASS management. This will provide a reliable source of clean sand for foreshore management without having to undertake repeat dredging in Shaws Bay when additional sand is required for beach maintenance.

The key considerations for on-site stockpiling at Shaws Bay include:

- Proximity to potential future foreshore management locations;
- Modification of and impact to community-utilised land; and
- Requirements for a Waste Recovery Order and Exemption.

This investigation has identified a number of indicative stockpiling locations around Shaws Bay. The estimated area and storage capacity of each potential location has been calculated based on a stockpile height of 1m and as displayed in Table 5 which also provides an outline of the relative advantages and disadvantages of each potential stockpiling location. Based on this initial assessment, locations SP1 and SP4 prove the more favourable locations, however both sites present issues in terms of stockpile integration with the existing landscape, the need to cover the stockpile, most likely with seeded grass and hence the difficulties in re-disturbing the site to recover stockpiled sand when it is required.

Overall, the on-site stockpiling option is problematic and is ideally avoided.

Table 5: Advantages and disadvantages of potential on-site stockpile locations

Location	Advantages	Disadvantages
SP1 – North Pop Denison Park – 5,000m³	• Not near residential properties; • Secluded and likely in a low traffic area of the park; • Potential dewatering site; and • Relatively close to foreshore management locations.	• Difficult to integrate into existing landform; • Will require coverage (e.g. grass) which would interfere with future use. • Both disadvantages are common to all sites below.
SP2 – Southeast Pop Denison Park – 5,000m³	• Not near residential properties; • Relatively close to foreshore management locations; • Easy access for plant machinery for redistributing sediment; and • Large storage capacity.	• Potentially a highly utilised area of the park and likely to interfere with new playground development; • Substantial impact on community parklands.
SP3 – West Shaws Bay Foreshore Reserve – 3,250m³	• Close to foreshore management locations on the East Arm; and • Significant storage capacity.	• Potentially a highly utilised area of the park following the East Arm improvement works; • Adjacent to residential properties; and • Substantial impact on foreshore reserve.

Location	Advantages	Disadvantages
SP4 – East Shaws Bay Fenwick Park – 2,110m³	• Close to foreshore management locations of the East Arm; • Potential dewatering site; and • Potentially a low traffic area of the reserve. • Readily incorporated into current landscape (against wall)	• Adjacent to residential properties; and • Will alter foreshore reserve. • Truck movements for transfers.
SP5 – Compton Drive Reserve – 2,220m³	• Not near residential properties.	• Substantial distance from potential dewatering sites; • Restricted access and need to transfer material across the road; • High utilisation of the park by dog walkers, etc.

4.3.1.4. Off-site stockpiling for later nourishment

Instead of on-site stockpiling of dredged sediments, the material could potentially be stored off-site at an appropriate location. This would provide a reliable source of clean sand for both on and off-site foreshore management in accordance with both the Shaws Bay and Ballina Coastline CZMPs. The key considerations for off-site stockpiling include:

- Suitability of material and potential environmental impacts (i.e. sediment type, contamination, PASS and salinity);
- Location and suitability of potential stock piling locations;
- Proximity to potential future foreshore management locations;
- Impact and modification of Council land;
- Additional environmental assessment requirements;
- Requirement for a Waste Recovery Order and Exemption.

Discussions with Council officers have identified ‘Council Depot 2’ as a suitable location for stockpiling clean sand as this depot is often used for temporary holding of materials for wide variety of Council projects. Sand can be stored at this location until required for management actions in accordance with requirements at Shaws Bay or for use in implementing other foreshore management activities such as with the Coastline CZMP. A Waste Recovery Order and Exemption will be required for any material transported off-site.

4.3.2 Raising low-lying land

Dredged material is often utilised for fill of low-lying land. Potential low-lying land includes areas identified within the Ballina Shire for future developments and Council managed land. Land located in North Ballina has been identified for future expansion of the Southern Cross Industrial Estate and will require raising in order to achieve appropriate design levels. Suitable dredged material from Shaws Bay could be used for fill within this area.

The main considerations for use of the dredged material as fill are:

- Suitability of material (i.e. sediment type, contamination, PASS and salinity);
- EPA waste classification;
- Requirement for a Waste Recovery Order and Exemption.
- Environmental considerations and project approvals at the fill site;

The use of dredged material for fill raises several potential issues including acid sulfate soil risk, potential contamination and salinity. The proposed dredge sediments have been identified as containing PASS. This not only raise practical issues, such as treatment (application, cost etc.) but also legislative issues (i.e. sediment classification and additional approvals or exemptions). Discussion with EPA identified their preference for the environmentally beneficial use of dredge material, this being foreshore management and not land fill. The raising of low lying land is considered a second priority beneficial use, and should only be considered if beach nourishment, for whatever reason, is not pursued.

4.3.3 Disposal options

Beneficial reuse of any dredged material is inherently attractive and is consistent with the policy objective of several regulatory agencies but is also necessary to fully meet all of the aims of the project. Nevertheless, beneficial use is often a more expensive and logistically complex than simple disposal and warrants discussion for the following options.

4.3.3.1. Shaws Bay benthic placement

Dredged material could potentially be redistributed within the Bay, providing an alternative to terrestrial storage or use of dredged sediments. This would be achieved by using dredge to either mechanically move or pump sediments from the areas to be dredged directly to areas which are deep enough to accept additional fill.

Key considerations of Bay placement include:

- Marine vegetation;
- Benthic habitat and fauna;
- Water quality (e.g. oxidisation of sulfides, de-oxygenation, acidification, turbidity, & contaminants);
- Potential for additional approvals from OEH, EPA or DPI-Fisheries;
- Infill rates and influence on sediment processes; and
- Placement area bathymetry.

The only potential placement location for this scenario is the south-western section of the Bay. This is the deepest area of the Bay with a maximum depth of -6.5m AHD. Filling of this section is not considered desirable or appropriate for numerous reasons including:

- The key advantage of this method is simplicity, which inherently provides less opportunity for containment or control. Significant plumes of poor quality water would be expected and containment of such a plume in deep water is difficult as large drop silt curtains are highly susceptible to failure with any tidal currents. Surrounding seagrass and other habitats could be affected and nearby beaches are also likely to be silt affected – hence reducing social amenity.

- The value of the deep water habitats of Shaws Bay is not well known. Large fish including threatened species are known to occur in the Bay although their exact habitat dependencies are not known. Although siltation and deposition of organics is likely to already to occurring in these deeper habitats, the complete smothering of the bed in these locations may give rise to unacceptable impacts.

- A significant part of the dredging proposal is to reduce the continued infilling of this deep area by the dredging of Area 1. The deep area of Shaws Bay is already acting as a sediment sink and artificially reducing this capacity is counter-productive.

- The social acceptability of this option is likely to be low. Community members have specifically commented on the inherent value of the deep/open waters of the Bay. Disposal of sediment in this way will be seen as a poor alternative to the alternative beneficial uses available.

Overall, this option is not recommended.

4.3.3.2. Disused quarries and burrow pits

Filling of large borrow pits and disused quarries utilising dredged sediment has been considered as an option for sediment disposal for this project. A number of large borrow pits and quarries are located within the Shire which could potentially be utilised. As such locations are generally not approved waste facilities, waste classification of the material, confirming ENM status following ASS treatment would be required. This would necessarily involve ASS treatment, stockpiling and testing of material prior to transfer off site.

This method of disposal is potentially considered to be beneficial reuse but is a low value use of this material. Based on the aims of the project, the source and requirements for funding as well as discussions with NSW EPA, this option in not considered viable and would prove challenging to gain approval for.

4.3.3.3. Waste landfill

The vast majority of the dredged material is considered suitable for beneficial use as beach nourishment fill during foreshore management works. There is however some overlying silt, shell material and organics that will be separated from the sand prior to use. The shell and larger organics will be screened and collected as a pile near the base of the hydro-cyclone (see section 4.4.3), which can then be directly loaded onto a truck, whereas the silt will most likely be captured with a geobag (see section 4.4.4), which would be later split and loaded once sufficient dry for handling.

It is envisaged that unwanted dredged material from this project could be placed in landfill at a suitable waste facility, however all waste material will require waste classification prior to disposal. The NSW EPA requires that wastes are classified according to the risks to the environment and human health to facilitate appropriate management and disposal. Once a waste has been properly classified, appropriate management options for it can be considered, as required under the *Protection of the Environment Operations Act 1997* (POEO Act 1997) and its associated regulations. The waste classification is determined by chemical assessment. Based on the outcome of this assessment, the waste is classified as either:

- 'General solid waste' – may be disposed of in regular landfill,
- 'Restricted solid waste' – an Immobilisation Approval is required prior to disposal at regular landfill. This may involve further treatment and/or testing to show that the contaminant is locked up and will not leach out of the spoil; or
- 'Hazardous waste' – cannot be disposed of and must be treated.

The EPA's waste classification guidelines (DECCW, 2009) include threshold values for various contaminants.

Disposal of waste can result substantial costs and therefore the project must aim to reduce the amount of waste generated.

4.3.4 Option comparison

The following table highlights the advantages and disadvantages of each dredge material end use or disposal scenario.

Table 6: Advantages and disavantage of dredged material end use scenarios

Option	Advantages	Disadvantages
On-site foreshore management	• Beneficial use; • Addresses Shaws Bay CZMP management actions; • Close proximity to potential dredge targets and dewatering sites; and • Relatively low cost.	• Need for screening, silt separation and ASS management; • Access and transfer to foreshore management locations is required.

Option	Advantages	Disadvantages
Off-site foreshore management	• Beneficial use; • Addresses Ballina Coastline CZMP management actions; and • Retains a stockpile to allow for regular maintenance of priority beaches.	• Need for screening, silt separation and ASS management; • EPA waste classification & requirement for a Waste Recovery Order and Exemption; • Potential stockpiling of sediment until required.
On-site stockpiling	• Provides a reliable source of clean sand for future foreshore management to address Shaws Bay CZMP management actions; • Relatively low cost to store; and • Close proximity to foreshore management locations.	• Need for screening, silt separation and ASS management; • EPA waste classification & requirement for a Waste Recovery Order and Exemption; and • Stockpile management and access to stockpiles in the future.
Off-site stockpiling	• Provides a reliable source for future foreshore management to address either Shaws Bay or Ballina Coastline CZMP management actions; and • Relatively low cost to store. • Existing facilities allow for efficient access to stockpile in the future	• Need for screening, silt separation and ASS management; • Additional transport costs; • EPA waste classification & requirement for a Waste Recovery Order and Exemption.
Shaws Bay Placement at depth	• No ASS management required; • No dewatering requirements; and • No additional transport requirements.	• Significant water quality issues (plume generation); • Ecological impacts; • Cannot be utilised easily for future foreshore management; and • Only partially addresses project requirements.
Disused quarries and burrow pits	• Potentially considered beneficial use, however considered less beneficial than other scenarios such as foreshore management.	• ASS management • EPA waste classification & requirement for a Waste Recovery Order and Exemption; • Not addressing management actions of CZMPs or in line with funding or aim of the project; • Additional approvals for disposal; and • Transportation costs.
Raising low-lying land	• Beneficial use, however considered less beneficial than other scenarios with foreshore management component; and • Contributes to substantial amount of fill required for developments in the Ballina Shire due to flood risks.	• ASS management; • EPA waste classification & requirement for a Waste Recovery Order and Exemption; • Not addressing management actions of CZMPs; • Additional approvals or exemptions; • Transportation costs; and • Long lead time.

Option	Advantages	Disadvantages
Waste landfill	• None.	• Waste classification is required; • Expensive; • No beneficial use; • Not addressing management actions of CZMPs; and • Premature filling of existing waste landfill sites.

4.4 Sediment placement and dewatering methods

There are a number of dewatering techniques available for high fluid content slurries, which are generated when utilising cutter-suction dredging technologies. In general it is advantageous to minimise dewatering such that the overall duration of works can be shortened and the footprint of processing areas can be reduced. Considerable research has been directed to dewatering techniques, not only for the dredging industry but also for other applications such as the drying of bio-solids from wastewaters or for environmental remediation projects. The most common technologies applicable to the current project are:

- Open air bunds/confined settlement areas where a combination of drainage under gravity and natural evaporation achieves sediment drying;
- Hydro-cyclone/centrifuge technology where the slurry is separated due to differential densities accentuated by high rotational (i.e. “g”) forces; and
- Geo-textile tubes (herein referred to as “geobags”) where hydrostatic pressure within a semi-permeable geo-textile container forces the liquid fraction out whilst retaining the solids within the geo-textile.

The selection of the preferred strategy governs a number of variables in the approach to the works, location of equipment and dewatering facilities as well as the issues, benefits and costs associated with any dredging activities.

4.4.1 Direct placement on foreshore

A potential option which removes the need for a dedicated or centralised dewatering facility is to directly pump dredged material onto the proposed on-site foreshore management areas without any additional processing. Material would be dredged, via mechanical or suction methods, and directly deposited onto the foreshore. Excess water contained within the material would flow directly back into the Bay mainly by surface flow.

As the return flow is uncontrolled, there is minimal opportunity to regulate the quality of discharge water and high suspended solid loads are likely to occur. This inevitably raises the requirement for plume containment using silt curtains, however this is often counter-productive as it leads to concentration of silt with no effective way for removal.

The presence of potential acid sulphate soils (PASS) throughout the areas to be dredged is another key consideration and indicates that an acid sulphate soil management plan would need to be prepared and implemented with detailed monitoring and treatment protocols. Once again, uncontrolled discharge from unbunded placement areas is problematic as this provides little opportunity for management intervention in controlling water quality.

Sediment quality is also difficult to control. During dredging, it is possible to encounter lenses of siltier material. If suction dredging, the nature of the material being dredged is not visible until it exits the dredge pipe, which could be up to 400m in length. By the time that poor quality sediment is detected, it is likely that a significant amount has already been deposited on the beach, which would necessitate either mechanical removal, burial or acceptance of a sub-optimal outcome.

Although direct uncontained deposition of dredged material on the beaches would prove the easiest and cheapest to implement, the potential impacts to the surrounding habitats, additional management requirements and overall project risks are considerable. Uncontained deposition is not recommended.

4.4.2 Bunded (contained) settlement areas

This strategy is an extension of the direct placement method and involves the pumping of dredged material into bunds that are created at the deposition sites. The bunds are typically constructed of the native sand at that location and then enlarged as additional dredged material is generated at the site. Plate 3 shows a typical bund, but at a larger scale than would be undertaken as Shaws Bay. The bund contains excess water from dredging and allows any fines settle out of the water before discharge back to the Bay. Discharge occurs either by seepage through the sandy bund walls/floor, or more typically for hydraulic dredging, the flow rates are too high, and discharge is via an overflow.

The bunding option provides the opportunity to contain water flow to allow better control of water quality and also allows for mechanical mixing of the beach sediments by excavator allowing homogenisation and incorporation of any minor silt that is delivered by the dredge.

Despite the advantages compared to unconfined placement, the use of bunds is still problematic, particularly within the confines of the Shaws Bay precinct. The area required to construct a bund results in a wide footprint that cannot be easily accommodated on a narrow beach. The dewatering areas available for this project are insufficient to meet this requirement without substantial impacts to adjoining marine vegetation in most locations.

Another issue with sand bunds is that they are initially efficient in allowing seepage of excess water through the bund walls, hence yielding good quality filtrate, however, once even minor amounts of silt accumulate within the bund, the bund walls become clogged and all discharge occurs via the overflow. As additional silt accumulates, the bund needs to become proportionally bigger to ensure that silt is not re-mobilised within the pond, leading to high turbidity discharges.

Plate 3. Large scale bunded beach area receiving dredged sand

4.4.3 Dewatering using hydro-cyclone

This option avoids the need for open dewatering bunds and relies on dredged material being pumped directly to a portable slurry separation plant. In this technology, the dredged material is pumped tangentially into cone-shaped vessels, where the centrifugal forces provide separation of the coarser material from the liquid and fine fractions. The efficiency of the cyclone can be managed to some degree to optimise the degree of separation of sand and silt. This effectively ‘cleans’ the sand to yield a low-silt product. As a hydro-cyclone efficiently dewaters the sand, there is very little free water and the sand would typically be suitable for immediate transport, hence limiting stockpile volumes.

Another important benefit of this technique is that it is relatively easy to utilise screens to separate coarse material (shell, organics, glass, etc.) in the processing stream to remove these undesirable components. In this case, the slurry from the dredge is first passed over an inclined screen of (say) 10mm mesh size. The screened sediment drops into a hopper, whilst the screenings slide off the screen into a heap which is disposed of separately. The sediment within the hopper is then re-fluidised and pumped through the cyclone with sand discharged at one point and the silty water discharged separately. As the large debris and organics are removed prior to the cyclone, the efficiency and running time of the cyclone is greatly improved, thus resulting in better dewatering and silt separation.

Additionally, it is often the case that the sulfidic (PASS) content in estuarine sediments is associated with the finer sediment fractions. By efficiently separating the sand from the silt, much of the PASS content is potentially removed and has a high probability of remediating this material. As such, the use of hydro-cyclone technology can be a key component in the acid sulfate soils management strategy and is an approach recommended in the *Queensland Acid Sulfate Soil Technical Manual* (Dear *et al*., 2002).

Overall, hydro-cyclone technology is ideally suited to the Shaws Bay sediments and provides a methodology to separate the overlying silt (high fines) from the heavier sandy sediments. The main drawback is that the liquid component containing residual fines would still need to be separated utilising other means prior to releasing water back to the waterway. This discharge from the cyclone can be treated in traditional open bunds (see section 4.4.2 which discusses a number of disadvantages) however silt would need to be recovered mechanically for disposal. A better approach is to utilise geobags (section 4.4.4) to further process this silty water, capture the fines and provide for better water quality management prior to discharge back to the Bay.

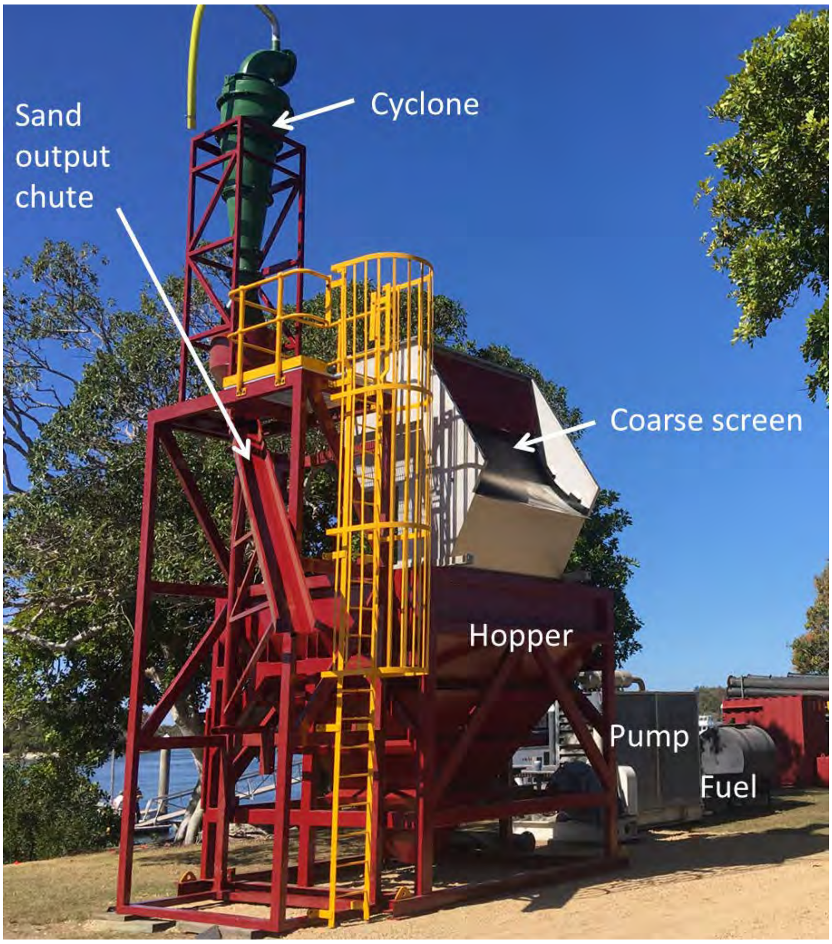


Plate 4. Partially assembled hydro-cyclone plant showing key components

4.4.4 Dewatering using geobags

Geobags (or geotubes) have been successfully used to dewater and contain dredged material in a broad range of projects. This method involves pumping dredged sediments into a geotextile pillow-like container which allows excess water to filter through, whilst retaining the solid fraction. A higher water to sediment ratio is generally pumped to allow distribution of the sediment within the tube (particularly with sandy sediments which are prone to clogging), and to allow efficient mixing with polymers that are added (at least for fine sediments) to increase flocculation and settlement rates. Pumping of material into the geotextile tube continues until the tube is full, whereby pressure within the tube forces water through the semi-permeable membrane, whilst retaining virtually all solids within the tube. As required, additional dredged material is pumped in after each settlement cycle, thereby progressively filling the tube to capacity. A number of geotextile tubes can be employed, so that dredging can either be undertaken continuously whilst some tubes are dewatering whilst others are being filled or to ensure that the filling rate can match the rate of material generation during dredging.

The key advantage of the strategy is the ability to dewater and contain finer sediment fractions. This reduces the footprint of the works area (compared to bunds) and allows the easy containment of the residual fines. This is suitable option for the proposed works due to the presences of silt, organic matter and PASS within the sediments. Following dewatering via hydro-cyclone the remaining residual fines could be pumped directly into a geobag(s). The geobag area would require containment in the form of a low-level bund, lined with impermeable material. This area will capture the filtrate from the geobag(s) which is monitored (primarily for turbidity and pH) and then treated (e.g. with lime) if required, prior to discharging back into the Bay. When properly sized, the surrounding bund acts a safeguard against spillage of sediment from the geobag in the case of an accident, and is considered an effective method to prevent water quality issues in the form turbidity plumes or the discharge of acidic waters.

Once the contents of the geotube(s) have sufficiently dewatered, the geotextile is split open to reveal a relatively firm muddy material which can be loaded separately onto trucks for disposal. In the case of the Shaws Bay sediments, with an average mud (silt and clay) content of around 0.1%, the actual volume of silt likely to be generated is estimated to be around 9m³ (1 truck load).

Plate 5. Example of geobag containment

Source: geodredging.com

4.4.5 Pre-dewatering ASS management

Prior to dewatering and processing of dredge material, to reduce the potential for acid generation as a result of PASS, material can be injected with calcium carbonate slurry (lime) to act as a neutralising and buffering agent. This substance is injected directly into the dredge pipeline mixing through the material neutralising the sediment and essentially removing the potential risk of post processing acid generation. The dredge material will require testing during the initial stages of the project to determine if a neutralising agent is required as part of ASS management and if so the quantity required. This method may not be required due to the already high neutralising capacity of the sediments within the Bay however could be applied if required, ideally prior to hydro-cyclone processing.

4.5 Dewatering/processing sites

A range of locations have been considered for dewatering and processing activities to be undertaken around the Bay. As the favoured dewatering/processing method is by hydro-cyclone using slurry pumped from the dredge, it is advantageous to locate the dewatering site close to the proposed dredging areas. There is however, a need to consider a range of constraints:

- Proximity to dredging area. Long pumping distances reduce the proportion of solids that can be transferred without risking pipe clogging and at extended distances (typically 1km) necessitate in-line booster pumps to be utilised. Both of these factors increases the cost and efficiency of dredging and are ideally minimised;

- Proximity to a suitable water discharge area. Any hydraulic dredging will entail significant volumes of water which needs to be discharged back to the environment. Gravity return may be possible in some sites immediately adjacent to the water, otherwise pumped return will be necessary, in which case the distance should be as short as possible;
- As any truck transport of processed sand will require stockpiling and loading of material, a significant amount of contiguous space is required to accommodate the footprint of the stockpile, provide manoeuvring room for loading, ensure that trucks can enter and exit the site efficiently and accommodate other space consuming components of the operation such as geobags (with bunds), shell and debris screening etc.;
- Trucks will need to be able to safely enter and leave the site. Although traffic control is likely to mandatory, long sight-lines at intersections and low-traffic volumes are desirable. Trucks should have sufficient turning room available on site whilst maintaining appropriate standoff distances from sensitive vegetation. A wheel wash facility at the site exit is likely to be required to ensure that soil from site is not drawn out onto nearby roads.
- The site should be a far removed from residential properties, holiday parks and recreational areas as practical. Operations at the site will result in noise from pumps, trucks, excavators, etc. There will be temporary visual impact as well as the potential for dust, traffic and access disruption. The trucking route should be minimised and reduce transit through residential areas as much as possible.
- The processing site should be as close to the main beach nourishment areas as practical, ideally such that double handing of material (e.g. stockpile-loader-truck-excavator-dumper-beach) is minimised by direct transfers to the intended location (e.g. stockpile-loader-dumper-beach);
- Suitable routes for the slurry pipeline (and discharge return) need to be available;

Considering these constraints, four sites were considered worth further consideration:

1. South-eastern end of Shaws Bay in the vicinity of the Marine Rescue tower carpark. This section of reserve is relatively unvegetated (following sinkhole remediation works undertaken in early 2018) and provides reasonable truck access that can avoid the majority of the residential areas (by following Lighthouse Parade). The pipeline route could be either along the park or the waterway, and discharge would be into a temporarily bunded section of the extreme south-east of the Shaws Bay East Arm. This is considered the best location for discharges due to the relatively high exchange with the Richmond River, but the slurry pipeline length would be approach 1km (from dredge area 2) and would traverse the recently rejuvenated Fenwick Park area. Truck routes are also longer to the deposition area on the Western Foreshore and all transfers to East Beach would need to involve truck transport. The site is significantly smaller than the Pop Denison Park sites listed below.
2. Western end of Fenwick Park. This site is very close to dredging area 1 and less than 500m from dredging area 2. The site is next to residential cabins of the Discovery holiday park and is immediately behind new beaches and vegetation planting established as part of the East Arm foreshore improvement works. The truck routes to this site maximise the traverse of residential areas and some trees on site would need to be removed to allow track access to the main works area. All sand would need to be trucked to the deposition areas, with the minor exception of some sand that could be utilised to top up the East Arm beaches.
3. Pop Denison Park central section. This site has significant area available and is accessible from the northern end of Fenwick Drive, hence avoiding the majority local residential road. The site is the closest to the main deposition areas of East Beach and Pop Denison Park, thereby allowing direct dumper access to these areas and significantly reducing truck loading and movements. The site also a short combined slurry pipeline length (marginally more than western Fenwick Park) but is further removed from nearby residents. Excess water would be discharged to the East Beach area which

receives good tidal flushing. A key disadvantage of this site is the planned redevelopment of this area for recreation, which may occur prior to dredging taking place.

4. Pop Denison Park north. This site may involve both the eastern and western sides of the Pop Denison Park access road, although the bulk of the works would be undertaken the eastern side. This side is preferred as it for improved truck access and much larger area for works and will allow the access road and park facilities to remain open to the public for a greater period of time. The western side of the road could still be utilised (e.g. for a final containment/treatment of water prior to discharge) but the benefits of doing so may depend on the contractor's equipment and final methodology. This site has longer pipeline transfer routes than the central Pop Denison site but has the advantage of being contained in a low-use are of the park and is further removed from residents. Water discharge would probably (although not necessarily) be into the northern section of the Bay, which is less flushed than the East Beach site, hence highlighting the importance of water quality management for discharges.

Overall, the Pop Denison Park central section is the preferred site on technical grounds, however the uncertainty over the timing of this project in relation to playground redevelopment at this site is a key constraint. Given that the northern Pop Denison Park site shares many of the same advantages and offers the potential to use both the water side and eastern sections of the Park, this site is recommended as the preferred location.

4.6 Transfer of dredged material to end use locations

Following the processing and dewatering of dredge material, the transfer of sediments to foreshore management, stockpiling or waste disposal locations (landfill) will be required. The following section outlines the transportation methods assessed.

4.6.1 Shaw Bay Beaches

4.6.1.1. Direct placement

The direct placement of dredged sediments is previously discussed in Section 4.4.1, which outlines the strategy of pumping material directly from the dredge to on-site foreshore management areas. The strategy would eliminate transportation requirements post processing but would limit the volume to be dredged to what can be utilised locally for foreshore management. Although the utilisation of dredge material for on-site beach nourishment is a key aim of this project and addresses Shaws Bay CZMP management action, the composition of material restricts usability without any additional processing. The fines (silt), shell and other organic content will result in water quality and beach amenity impacts if directly placed on the foreshore. Plume generation could result in impacts to seagrass beds while the decomposition of organic matter and darker colouration of the sediments may result in community backlash, though bleaching of sediments will occur over time. This method is not considered a viable option without the prior removal of fines and organic material before foreshore placement.

4.6.1.2. Direct pumping post processing

Following the processing of the dredged material via methods such as hydro-cyclone or open bund dewatering, the sediment extracted for foreshore management could be pumped directly to the selected management areas around Shaws Bay. This method requires the re-fluidisation of dredge material prior to pumping directly to desired beach locations.

As the material is pre-processed, the sediment and resulting water quality is likely to be good, however the distance for pump back of the material is likely to require large pumps with the slurry at relatively low proportions of solids, hence transferring significant volumes of water. At the deposition site, it will be necessary to control the flow of excess water and runoff to protect the seagrass which is downslope of most of the deposition areas. This would typically be done by use of bunds on the beaches similar to those described in section 4.4.2 but can be smaller on account of the better quality sediment.

The advantage of re-distributing material via this method is the ability to access all foreshore management locations without additional impacts to the surrounding terrestrial environment (i.e. truck access).

4.6.1.3. Barge transfer

The transfer of sediment to on-site foreshore management locations via barge is a potential option. Sediment extracted during the processing and dewatering stages could be transferred to a barge via appropriately sized earth moving equipment. The barge would be loaded at a temporary loading ramp/wharf and ideally the sand stockpile generated by the hydro-cyclone would therefore be located nearby. The only location for this to occur is considered to be within the northern section of Shaws Bay, utilising the northern-most section of the parkland adjacent to the water.

The barge can be manoeuvred to the foreshore management locations and the sediment redistributed as required. This method has the advantage of providing ease of access to all foreshore management locations, removes the impact of additional terrestrial access points and allows for targeted foreshore management. However the cost, logistics and double handling of material, with the potential for plume generation or smothering of seagrass beds as result of spills, makes this option hard to implement.

4.6.1.4. Overland transport

For deposition sites in close proximity to the sand stockpile and where roads in public use can be avoided, earth moving machinery can be utilised to transfer material in a way that minimises double-handling of material. Side or front dumpers (Plate 6a) are highly agile can carry significant volumes (typically 5-10t capacity) directly between the processing site (i.e. northern Pop Denison Park) and East Beach and the other Pop Denison Park sites. Such a traverse is at the limit of what would be considered economical for the transfer of this much material, however utilising this strategy allows flexibility, avoids double-handling and is relatively low impact compared to heavier equipment.

An even more flexible alternative is a rubber tracked carrier (, often referred to by a common brand name Morooka (Plate 6b). Such a vehicle can traverse all ground, even soft sand, has a soft footprint due to the rubber tracks and come in numerous configurations up to a maximum payload of 15t. The advantage of a tracked carrier is the that material can be delivered precisely to the location required with only light contouring required to finalise the desired beach profile.

Plate 6. (a) Front dumper and (b) Morooka tracked carrier

Source: dumpers.co.nz (2018) and marookarental.com (2018)

Some overland transport will be involved for all transport options (excepting barge transfer) in order to move material onto East Beach. The landward side of this beach is predominately Coastal Cypress Pine EEC and only limited clearing of low value vegetation in fringe areas of this forest have been planned as part of improvements to Pop Denison Park and the use of specialist dumpers/carriers is considered the best option for undertaking these transfers.

4.6.1.5. Road transport

Depending on the dredge targets, depth and end use scenarios selected, a large majority of the sediment may need to be transferred to off-site foreshore management or stockpile locations. This is in addition to any on-site transportation requirements. Waste material extracted during the processing stage will also need to be transported to an appropriate waste facility for disposal. Road transport is a suitable option both for on- and off-site transportation of dredge materials to specified end use locations. By moving all material via one transportation methodology minimise additional equipment (i.e. barge or pumps) required for the project and reduces costs. Trucks of an appropriate size (i.e. single body trucks) could be utilised to transport material to on-site foreshore management locations (access areas are restricted in size) while trucks of a more substantial nature (i.e. truck and dog) used for off-site transportation if required. Although this is a preferred method there are a number of issues that need to be addressed given the potential number of truck movements that may be required:

- Noise and vibration issues for the transport routes. Route planning and restriction of transport hours to minimise impact on residents would be required;
- Potential damage to local roads and council/community land infrastructure;
- The impact on local traffic and the risk of increased traffic accidents. A traffic management plan will need to be prepared and implemented; and
- Impacts on vegetation and surrounding substrate at both the loading a disposal locations.

4.7 Off-site stockpiling or nourishment

The only feasible way to moving dredged material off-site is through on-site dewatering and road transport. Even direct pumping of sand to the nearest ocean beach (Lighthouse Beach) is not considered feasible due to the requirement for silt separation and screening of shell content prior to placement.

All material not utilised on-site will need to be transported off-site to the selected foreshore management or stockpile location. Depending on the on-site beach nourishment options, dredge targets and depths selected the amount requiring transportation off-site could be up to 7,000m³ of sand. This amount would require a substantial number of truck movements, placing additional stress on local roads, therefore it is beneficial to maximise on-site use of the extracted material. A detailed traffic management plan will be required to address any issue relating to off-site truck movements, and details the exact truck route to be followed.

5. RECOMMENDED SCENARIO

The following sections discuss the preferred integrated scenario for dredging of Shaws Bay, with a summary of options provided in Table 7.

Table 7: Summary of preferred scenario components

Component	**Recommendation**
Dredge Type:	Cutter-Suction
Dredge Extents:	Areas 1 and 2
Dredging Volume	Up to 9,100m³ (at -2.5m AHD), but recommended to be limited to the requirements of local beach nourishment (nominally 5,900m³ at -2.25m AHD)
Dewatering Method:	Hydro-cyclone with pre-screen for shell, organics and foreign material
Dewatering/ Processing Area:	Northern Pop Denison Park, east of the road.
Silt containment:	Bunded geobag(s)
Silt, shell and organics disposal:	Landfill - waste disposal in accordance with waste classification to be confirmed at time of dredging.
End use:	1. Nourishment (foreshore management) of Shaws Bay beaches, options 1 to 7 (i.e. maximise on-site use); 2. Off-site stockpiling at Council Depot #2 until required for beach nourishment in accordance with Ballina Coastline or Shaws Bay CZMPs.
Sand delivery method:	Transport in the form of dumpers/carriers (foreshore management locations 2, 3, 4, 5 and 7) and trucks (foreshore management locations 1, 6 and off-site stockpiling).

5.1 Dredge type

Dredging utilising cutter-suction technology is the preferred methodology for this project as it limits plume generation during dredging and allows for efficient transfer of material for processing, without spillage. Due to the presence of overlying organic matter and buried rocks within proposed dredge targets the cutter component my need to be isolated at certain locations. A cutter-suction dredge is highly compatible with the preferred sediment dewatering and processing option. This type of dredge is readily available on varying scales and a preferred methodology of dredging contractors consulted during this process. The dredge would most likely need to be launched by crane which could be achieved from the hardstand area at the northern end of the western foreshore.

5.2 Dredging areas and volumes

To address the goal and management actions of the Shaws Bay CZMP with regards to foreshore management, siltation and promoting tidal flushing of the Bay, dredging of Areas 1 (East Arm Depositional Delta) and 2 (Main Bay Shallows), is recommended.

The maximum depth of dredging for both these areas is nominated as -2.5m AHD equating to a combined volume of approximately 9,100m³. This amount is likely to reduce due to the presence of rock within Area 2. In order to balance the needs for localised beach nourishment a reduced cut depth is recommended (-2.25m AHD). This results in an estimated volume of 5,900m³, which (when accounting for production loss due to Area 2 rock) is likely to very closely match the required sand volume.

Area 2 should be dredged first and the resultant volume monitored, with the dredging depth for Area 1 and 2 modified accordingly (between -2.0 and -2.5m AHD) to ensure the desired beach nourishment volume has been achieved.

5.3 Dewatering and silt containment

Due to the presence of PASS, overlying silt and organic material within the target areas, a multi-faceted dewatering and processing strategy is the preferred option. This will entail initial screening of the dredged material though a 10mm grating which is intended to remove shell, coarse organic matter and other debris. The screened sediment would then be pumped through a hydro-cyclone to separate the sand from the silt and liquid fraction. Dewatered sand would then be available for use transport. The remaining silt slurry is to be directed to a geobag, where it will gradually dewater. The geobag will be within a sealed bund, and filtrate from the bag will be monitored and discharged back to Shaws Bay. The recommended location for sediment dewatering is at the northern end of Pop Denison Park, east of the park access road as shown in Figure 7, Appendix 1. A secondary settlement bund, with gravity drainage back to the Bay could be established on the western side of the park access road to 'polish' the discharge water and allow gravity discharge to the Bay if desired.

5.4 End uses

Local (Shaws Bay) beach nourishment is the preferred end use and it recommended that dredging volumes are adjusted to match the optimal beach profiles. Sand used for beach nourishment should be placed between the constraints of the existing seagrass and saltmarsh, except for East Beach, where it is recommended that the beach be significantly widened.

There is the potential to increase the dredging volume to provide excess (~3,200m^3) sand which could be stockpiled for future use. Council's Depot #2 is the recommended stockpile location.

5.5 Sand delivery and waste disposal

Road transport is considered the preferred option for transporting material to the Western Foreshore, East Arm (if required) as well as any off-site stockpile and disposal locations. This is a cost effective and logistically appropriate option for transporting dredge material. Truck loading would be undertaken as shown in Figure 7, with trucks entering and leaving the site via Fenwick Drive. A wheel wash facility is likely to be required to avoid material being dragged out onto the public road by trucks.

Truck access to the Western Foreshore location would be at the northern end extent of the current footpath, where a handstand area allows unimpeded access to the edge of the revetment wall.

Waste material (i.e. shell, silt and organics) is to be transported via trucks to appropriate waste facility. A traffic management plan will be required for these options to address all road safety issues and identify appropriate truck routes. Traffic management will be required to ensure safe turning at this location and appropriate separation of vehicles, bikes and pedestrian traffic from work vehicles.

5.6 Additional Studies

In line with the recommendation outlined in Stage 1 of this dredging study (Hydrosphere Consulting 2018) further work should be undertaken to determine if tidal flushing of the Bay can be improved by removing or altering the mangrove stand and associated sediment along the northern side of the training wall. The removal of these mature mangroves to encourage tidal flushing was identified as an option during the development of the Shaws Bay CZMP and continues to be of interest to stakeholders. It has been recommended that a small scale field trail be undertaken prior to any major works occurring, however, in order to accurately assess the likely benefits of mangrove removal, the understand of the hydrodynamics of Shaws Bay should be updated.

The following scope of work is recommended:

1. Replicate, as reasonably possible, the hydrodynamic studies undertaken during the pervious process study (PBP 2000b), with focus on comparative tidal levels between the Bay and the Richmond River estuary over a range of tidal scenarios (i.e. similar to Figure 1);

2. Evaluate any differences between contemporary and earlier studies and determine the rate of degradation (if any) since that time, possibly through re-modelling of tidal exchange results;
3. If confirmed by this investigation, develop and implement a small-scale field trail aimed at increasing tidal exchange through the training wall, taking the following into consideration:
    - The parameters required to conduct tidal exchange and flushing simulations;
    - The ability to measure parameters over an extend period of time in a relatively controlled environment;
    - The scalability of the design;
    - The potential environmental impact of trial; and
    - Permits and approvals required.
4. Results of trial used to further simulate tidal exchange and flushing times and the potential impacts of substantially altering or removing the mangrove stand; and
5. If the simulations indicates the potential for increased tidal exchange and flushing, development of a detail proposal and design for altering the mangroves stand. This will entail an environmental assessment investigating the potential impacts of altering tidal exchange and flow within the Bay and seek approvals and permits required.

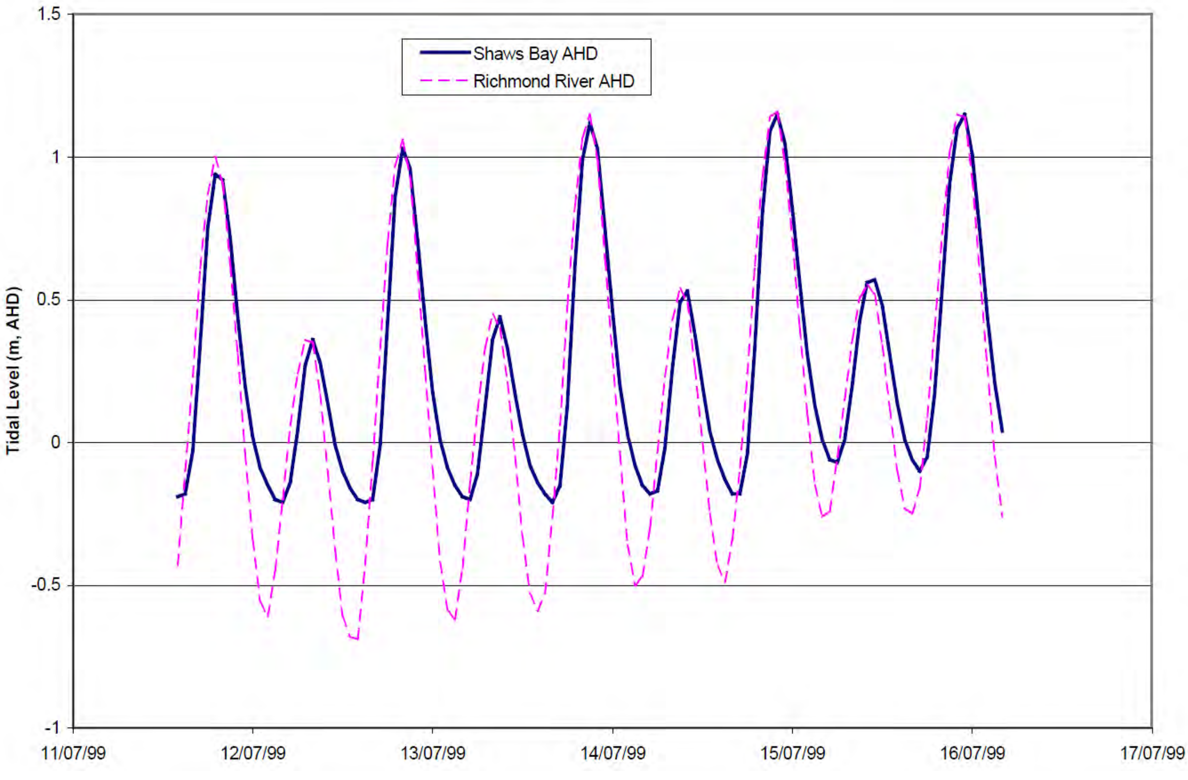


Figure 1: Comparison of tidal levels between Shaws Bay and Richmond River (PBP 2000b)

6. CONCLUSIONS

Dredging of Shaws Bay and utilising the dredged material for beach nourishment as recommended in the Shaws Bay CZMP is considered feasible using standard dredging techniques and equipment as outlined in the recommended scenario (section 5). This study has identified and evaluated numerous options to achieve the goals of the CZMP, taking into account the project's environmental, legislative, logistical and social constraints and considerations.

The following steps to progress the project are recommended:

1. Broader stakeholder consultation on the basis of the recommended scenario to gain an updated comments, concerns and suggestions regarding the proposed project;
2. Preparation of a Review of Environmental factors in in accordance with Part 5 of the *Environmental Planning and Assessment Act, 1979*;
3. Prepare and submit applications for a permit to harm marine vegetation and dredging and reclamation under Part 7 of the *Fisheries Management Act 1994*;
4. Development of a Dredging Management Plan, which amongst other things, comprehensively details environmental risks and mitigation strategies to be employed by the contractor; and
5. Develop and commence a study to update current understanding of Shaws Bay with regards to tidal exchange through the training wall and water circulation within the Bay.

REFERENCES

Dear, S.E., Moore, N.G., Dobos, S.K., Watling, K.M. and Ahern, C.R. (2002) Soil Management Guidelines. In Queensland Acid Sulfate Soil Technical Manual. Department of Natural Resources and Mines, Indooroopilly, Queensland, Australia.

DECCW (2009). Waste Classification Guidelines Part 1: Classifying Waste.

DPI (2013) Policy and guidelines for fish habitat conservation and management. Update 2013. Department of Primary Industries Policy Number TI-O-138.

Hydrosphere Consulting (2013) Coastal Zone Management Plan for Shaws Bay. Report for Ballina Shire Council.

Hydrosphere Consulting (2016) Brunswick River Dredging – post-dredging monitoring Spring 2016. Report for Department of Industry – Lands.

Hydrosphere Consulting (2018) Shaws Bay Dredging Baseline Surveys and Data Analysis, Report for Ballina Shire Council.

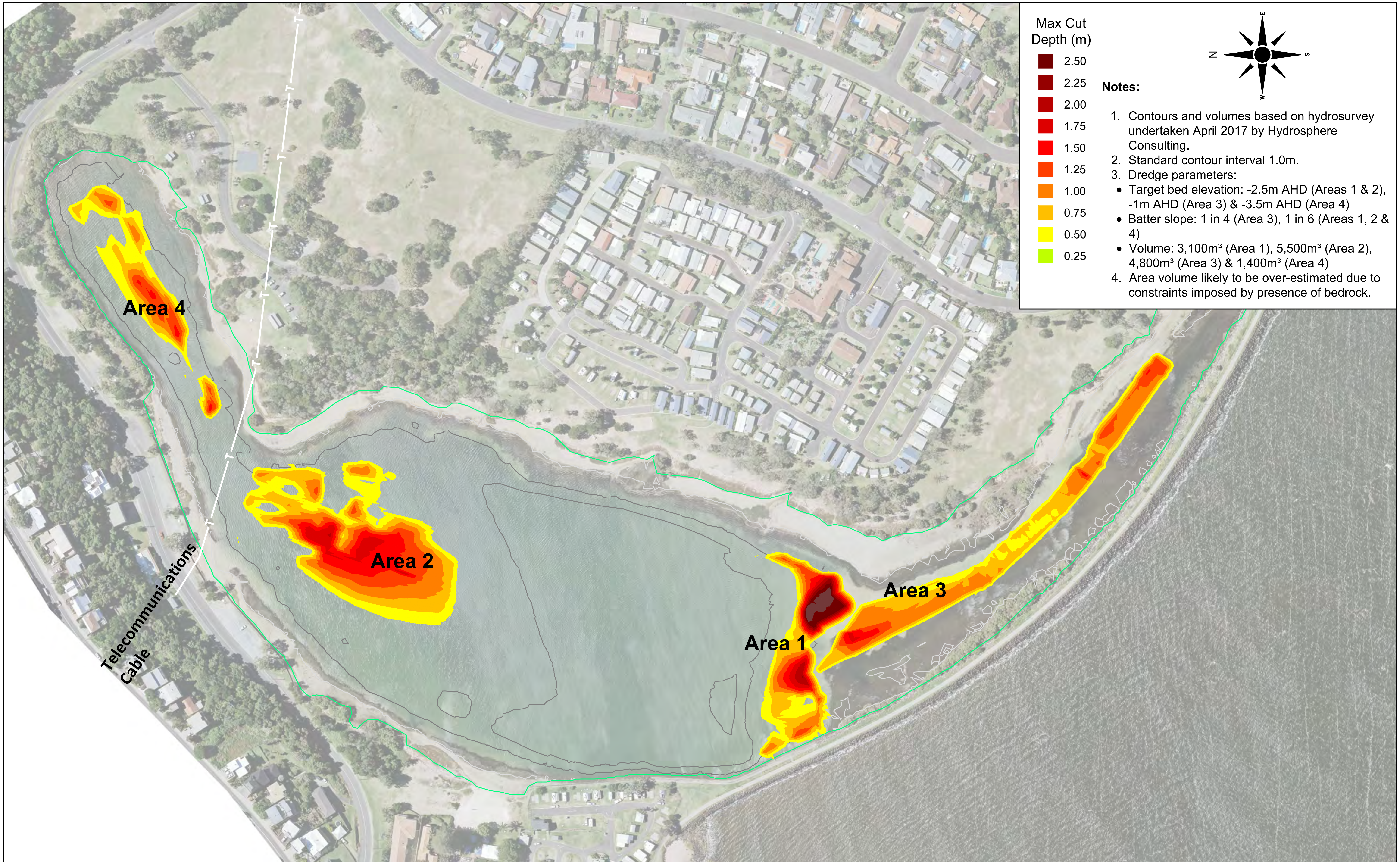
PBP (2000a) Shaws Bay Estuary Management Plan, Volume 2 - Estuary Management Plan, Issue No. 3, Final, prepared for Ballina Shire Council

PBP (2000b) Shaws Bay Estuary Management Plan, Volume 1 - Estuary Processes Study, Issue No. 4, Final, prepared for Ballina Shire Council

Smith, S.D.A., Harrison, M.A. and Rowland, J. (2011) The effects of beach scraping on the infauna of New Brighton beach, northern NSW. Report prepared for Byron Shire Council. National Marine Science Centre, Southern Cross University, Coffs Harbour. June 2011.

WBM Oceanics Australia (2003), *Ballina Shire Coastline Hazard Definition Study Final Report,* Prepared for Ballina Shire Council

APPENDIX 1: DRAWINGS



Notes:

1. Contours and volumes based on hydrosurvey undertaken April 2017 by Hydrosphere Consulting.
2. Standard contour interval 1.0m.
3. Dredge parameters:
   - Target bed elevation: -2.5m AHD (Areas 1 & 2), -1m AHD (Area 3) & -3.5m AHD (Area 4)
   - Batter slope: 1 in 4 (Area 3), 1 in 6 (Areas 1, 2 & 4)
   - Volume: 3,100m³ (Area 1), 5,500m³ (Area 2), 4,800m³ (Area 3) & 1,400m³ (Area 4)
4. Area volume likely to be over-estimated due to constraints imposed by presence of bedrock.

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HYDROSPHERE CONSULTING P.O. BOX 7059 BALLINA NSW 2478 WWW.HYDROSPHERE.COM.AU	Hydrosphere Consulting Strategy in Water & Environment	0 100 200 Metres	BALLINA SHIRE COUNCIL SHAWS BAY DREDGING TARGET AREAS	18-012	2018-02-15	REV 0	RC	FIGURE 2 SHEET 1 OF 1

REVISION

Y:\18-012 Shaws Bay Dredging\Drawings\Dredging scenarios working.dwg

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Strategy in Water & Environment

SCALES

0 60 120

Metres

CLIENT: BALLINA SHIRE COUNCIL

JOB NUMBER: 18-012

SHAWS BAY DREDGING
ON-SITE FORESHORE MANAGEMENT

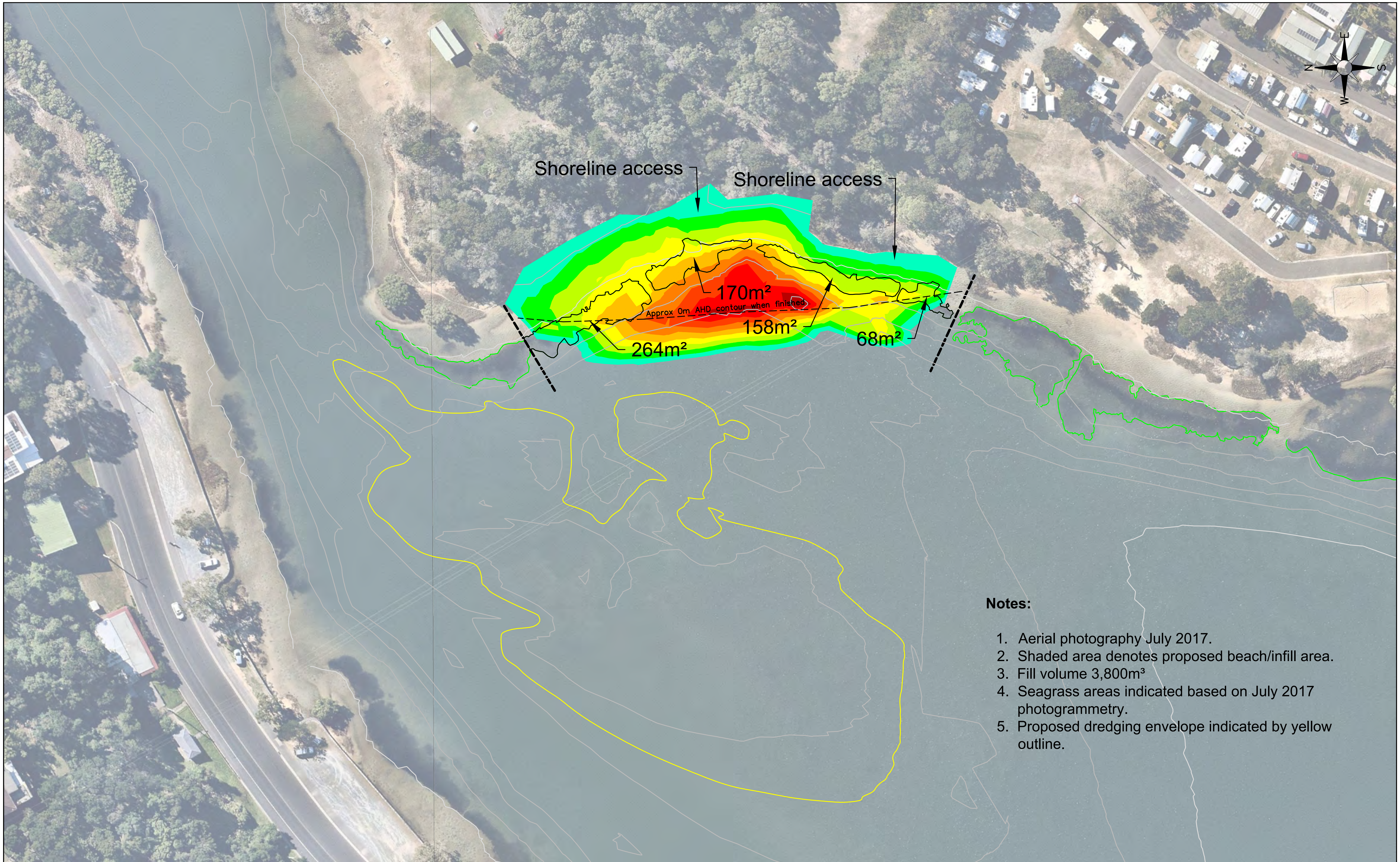
REVISION	DATE	DESCRIPTION	DRAWN
	2018-02-15	REV 0	RC

DRAWING NUMBER

FIGURE 3

SHEET 1 OF 1

Y:\18-012 Shaws Bay Dredging\Drawings\Fill plan_working.dwg

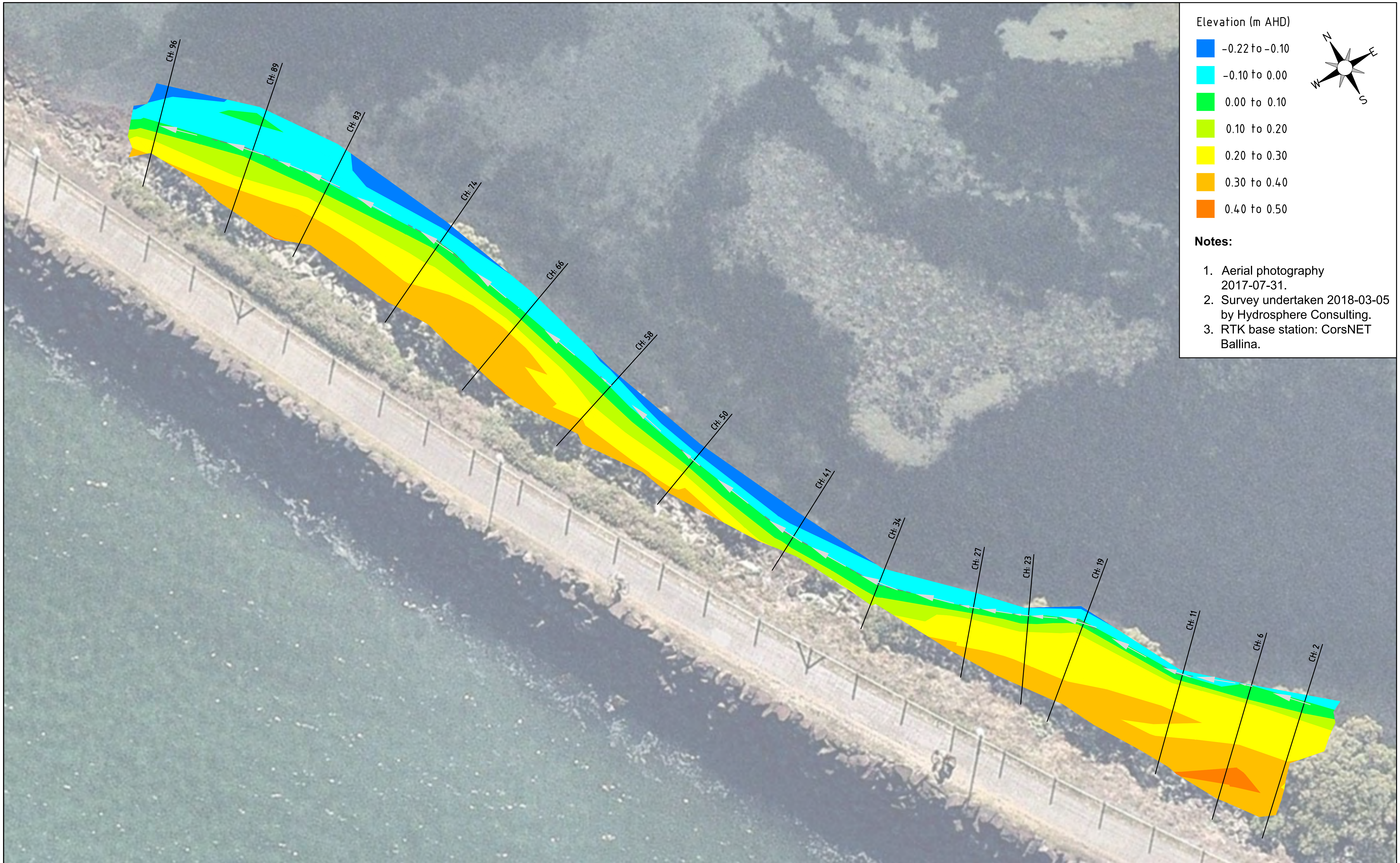


Notes:

1. Aerial photography July 2017.
2. Shaded area denotes proposed beach/infill area.
3. Fill volume 3,800m³
4. Seagrass areas indicated based on July 2017 photogrammetry.
5. Proposed dredging envelope indicated by yellow outline.

DRAWING PRODUCED BY:		SCALES	CLIENT	JOB NUMBER	REVISION	DATE	DESCRIPTION	DRAWN	DRAWING NUMBER
HYDROSPHERE CONSULTING P.O. BOX 7059 BALLINA NSW 2478 WWW.HYDROSPHERE.COM.AU	Hydrosphere Consulting Strategy in Water & Environment	0 35 70 Metres	BALLINA SHIRE COUNCIL	18-025		2018-03-19	REV 0	MH	FIGURE 4 SHEET 1 OF 1
			SHAWS BAY DREDGING EASTERN BEACH NOURISHMENT AREA						

Y:\18-012 Shaws Bay Dredging\Drawings\East Beach SG + Fill.dwg

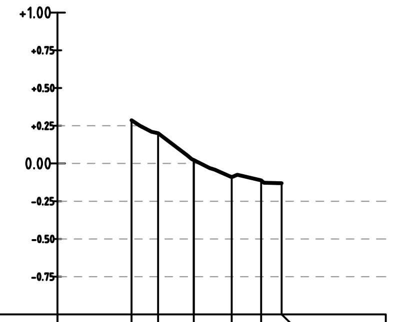


DRAWING PRODUCED BY: HYDROSPHERE CONSULTING P.O. BOX 7059 BALLINA NSW 2478 WWW.HYDROSPHERE.COM.AU	Hydrosphere Consulting — Strategy in Water & Environment	CLIENT: BALLINA SHIRE COUNCIL	JOB NUMBER: 18-012	DRAWING NUMBER
		SHAWS BAY DREDGING TRAINING WALL MANGROVES - SURVEY		FIGURE 5 SHEET 1 OF 2

REVISION	DATE	DESCRIPTION	DRAWN
	2018-03-07	REV 0	MH

Y:\18-012 Shaws Bay Dredging\Drawings\Shaws Mangroves.dwg

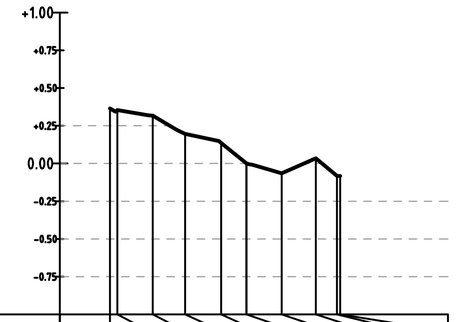
CH: 96.0



Vert. Exag. 5 : 1
Base -1.00m AHD

BED LEVELS	+0.286	+0.201	+0.023	-0.091	-0.111	-0.131
OFFSETS	-2.058	-1.180	0.000	+1.252	+2.228	+2.905

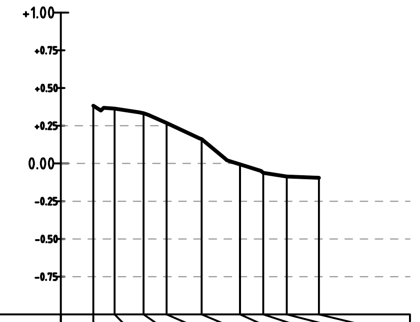
CH: 89.0



Vert. Exag. 5 : 1
Base -1.00m AHD

BED LEVELS	+0.365	+0.354	+0.316	+0.196	+0.136	+0.001	-0.066	+0.034	-0.082	-0.083
OFFSETS	-4.506	-4.262	-3.093	-2.028	-0.836	0.000	+1.166	+2.292	+2.993	+3.097

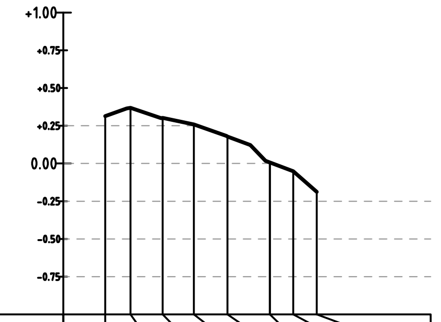
CH: 83.0



Vert. Exag. 5 : 1
Base -1.00m AHD

BED LEVELS	+0.383	+0.363	+0.333	+0.268	+0.161	-0.006	-0.062	-0.087	-0.095
OFFSETS	-4.852	-4.151	-3.190	-2.427	-1.273	0.000	+0.764	+1.544	+2.606

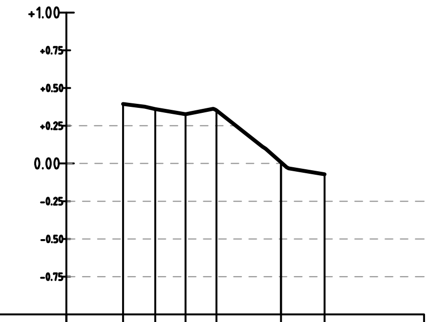
CH: 74.0



Vert. Exag. 5 : 1
Base -1.00m AHD

BED LEVELS	+0.313	+0.369	+0.302	+0.258	+0.178	+0.007	-0.052	-0.188
OFFSETS	-5.445	-4.609	-3.544	-2.515	-1.404	0.000	+0.771	+1.552

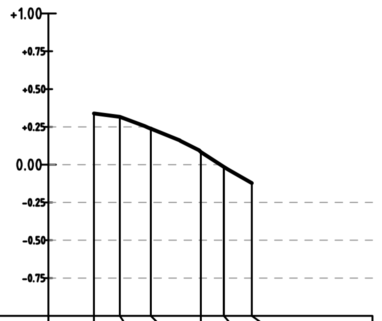
CH: 66.0



Vert. Exag. 5 : 1
Base -1.00m AHD

BED LEVELS	+0.394	+0.361	+0.326	+0.352	+0.008	-0.072
OFFSETS	-5.217	-4.154	-3.152	-2.130	0.000	+1.438

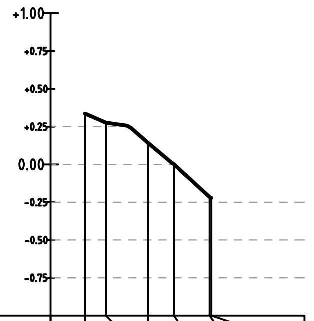
CH: 58.0



Vert. Exag. 5 : 1
Base -1.00m AHD

BED LEVELS	+0.339	+0.317	+0.238	+0.084	-0.015	-0.121
OFFSETS	-4.304	-3.446	-2.418	-0.762	0.000	+0.923

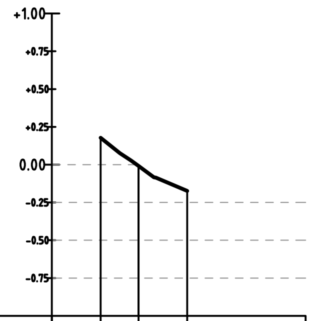
CH: 50.0



Vert. Exag. 5 : 1
Base -1.00m AHD

BED LEVELS	+0.337	+0.277	+0.142	+0.001	-0.216	-0.221
OFFSETS	-2.944	-2.247	-0.849	0.000	+1.180	+1.240

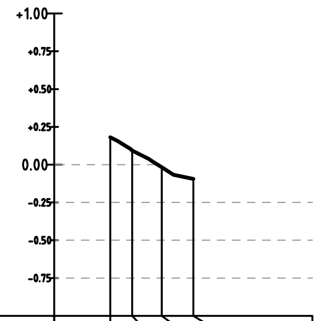
CH: 41.0



Vert. Exag. 5 : 1
Base -1.00m AHD

BED LEVELS	+0.178	-0.009	-0.174
OFFSETS	-1.253	0.000	+1.610

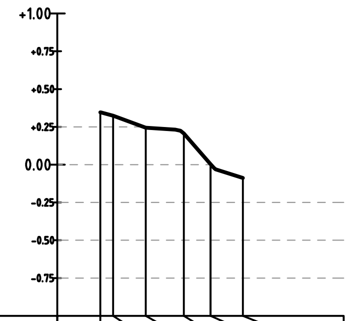
CH: 34.0



Vert. Exag. 5 : 1
Base -1.00m AHD

BED LEVELS	+0.181	+0.093	-0.017	-0.094
OFFSETS	-1.703	-0.978	0.000	+1.051

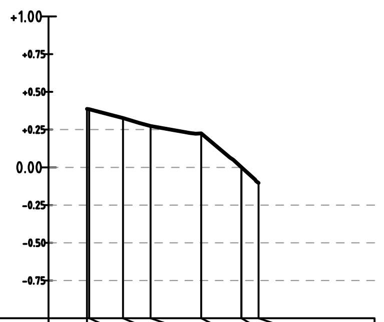
CH: 27.0



Vert. Exag. 5 : 1
Base -1.00m AHD

BED LEVELS	+0.346	+0.324	+0.245	+0.207	+0.003	-0.087
OFFSETS	-3.650	-3.226	-2.146	-0.887	0.000	+1.067

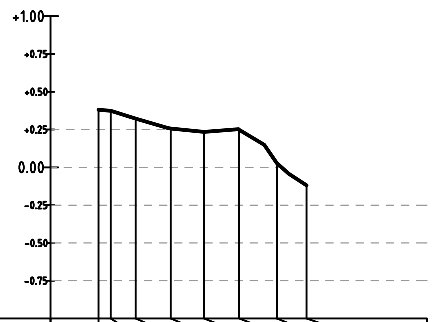
CH: 23.0



Vert. Exag. 5 : 1
Base -1.00m AHD

BED LEVELS	+0.386	+0.385	+0.326	+0.274	+0.225	+0.001	-0.103
OFFSETS	-5.104	-5.032	-3.911	-3.005	-1.330	0.000	+0.566

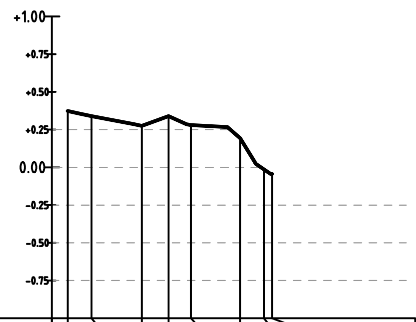
CH: 19.0



Vert. Exag. 5 : 1
Base -1.00m AHD

BED LEVELS	+0.381	+0.374	+0.323	+0.257	+0.234	+0.248	+0.028	-0.119
OFFSETS	-5.896	-5.490	-4.664	-3.506	-2.407	-1.243	0.000	+0.982

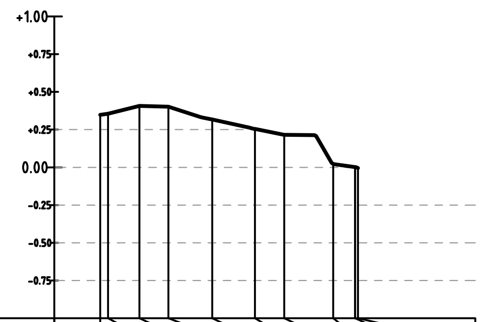
CH: 11.0



Vert. Exag. 5 : 1
Base -1.00m AHD

BED LEVELS	+0.373	+0.339	+0.274	+0.340	+0.280	+0.193	-0.013	-0.044
OFFSETS	-6.473	-5.694	-4.033	-3.145	-2.405	-0.781	0.000	+0.270

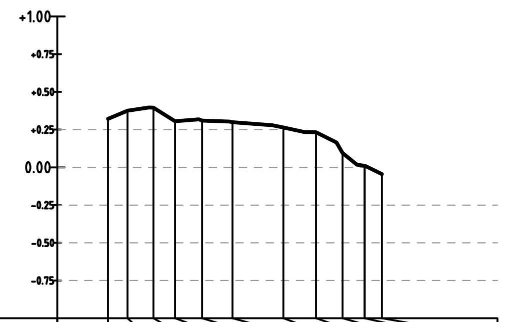
CH: 6.0



Vert. Exag. 5 : 1
Base -1.00m AHD

BED LEVELS	+0.348	+0.355	+0.407	+0.402	+0.317	+0.255	+0.215	+0.021	+0.002	-0.005
OFFSETS	-8.415	-8.159	-7.129	-6.173	-4.726	-3.312	-2.344	-0.727	0.000	+0.096

CH: 2.0



Vert. Exag. 5 : 1
Base -1.00m AHD

BED LEVELS	+0.321	+0.375	+0.396	+0.305	+0.310	+0.299	+0.264	+0.232	+0.095	+0.011	-0.045
OFFSETS	-8.484	-7.838	-6.985	-6.270	-5.374	-4.369	-2.689	-1.605	-0.727	0.000	+0.574

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NOTES

1. Survey undertaken 2018-03-05 by Hydrosphere Consulting.
2. Refer to plan view for section locations.

CLIENT
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JOB NUMBER
18-012

SHAWS BAY DREDGING
TRAINING WALL MANGROVES - SECTIONS

REVISION	DATE	DESCRIPTION	DRAWN
	2018-03-07	REV 0	MH

DRAWING NUMBER

FIGURE 6

SHEET 2 OF 2

Y:\18-012 Shaws Bay Dredging\Drawings\Shaws Mangroves.dwg

Y:\18-012 Shaws Bay Dredging\Drawings\north east loading area.dwg

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SCALES

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Metres

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18-025

SHAWS BAY DREDGING
NORHERN TRUCK LOADING AREA

REVISION	DATE	DESCRIPTION	DRAWN
	2018-03-20	REV 0	MH

DRAWING NUMBER
FIGURE 7
SHEET 1 OF 1