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Halifax Park / Fly Point Sand Accumulation Study

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Halifax Park / Fly Point Sand Accumulation Study

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Prepared For:	Port Stephens - Great Lakes Marine Park
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Title :	Halifax Park / Fly Point Sand Accumulation Study
Author :	David Wainwright
Synopsis :	Over the past year 12 - 18 months, significant sand movement has caused the smothering of valuable sponge gardens at Halifax Park, on the northern tip of Nelson Head in Port Stephens. This report assesses coastal processes in the vicinity of Shoal Bay, Nelson Head and Little Beach, and develops a number of possible management options that may be considered to address the issues. These management options are indicatively costed and assessed.

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1 EXECUTIVE SUMMARY

1.1 Project Background and Aim

Significant sand movement has caused the smothering of valuable sponge gardens at Halifax Park, a renowned SCUBA dive site on the northern tip of Nelson Head within a sanctuary zone of the Port Stephens-Great Lakes Marine Park. During February and March 2011, smothering was also beginning to occur at “The Pipeline” and Fly Point, two other highly regarded dive sites to the west of Halifax Park. The accumulation and spreading of sand from a large dune offshore of Fly Point has been reported from mid-2010 (pers. comm. Dave Harasti, *PSGLMPA*), indicating that the situation has been developing for some time.

A locality plan showing the area of concern is provided as Figure 1-1.

BMT WBM was engaged by the NSW Marine Parks Authority (MPA) to investigate underlying processes and causes of the sand movement and to propose possible solutions to the problems associated with on-going sand accumulation.

The study was to incorporate the following deliverables:

1. The following issues must be addressed in the report;

   a) Feasible options for meeting objectives should be identified both in terms of short term and long term actions that may be required.

   b) The costs and benefits of the options indentified in (a) should be outlined.

   c) Risks associated with the options identified in (a) should be outlined.

   d) The costs, benefits and risks associated with the ongoing maintenance strategies in support of options identified in (a) should be identified.

   e) Where sand removal has been identified as a feasible option in (a) the following should be outlined for each option:

      - The total volume of sand that must be removed for effective remediation;
      - Where the sand must be removed from (location x quantity);
      - The most appropriate methods of removing sand from each location (options);
      - Where the sand can be relocated to;
      - The environmental constraints of each method / option of sand removal and deposition.

2. The provision of relevant data and associated methodology utilized in addressing issues 1 (a)- (e) above.

3. Recommendations for further investigations if considered necessary.

Options for sourcing necessary funds were not canvassed as part of this study.

1.2 Study Approach

Review of available information regarding various environmental processes was required to address the aims of this project, and was essential to the identification of suitable management options.

The methodology adopted for this study involved the following steps:

1. Review and summarise available, relevant background information. Make preliminary conclusions regarding the processes affecting the site;
2. Undertake a site inspection and meeting with stakeholders to discuss the site and project;
3. Validate and refine the preliminary conclusions made regarding the processes affecting the site; and
4. Identify and evaluate solutions that may be adopted, including consideration of both long term and short-term solutions.

Chapter 2 described the outcomes from Steps 1 to 3. Chapter 4 describes the identification and evaluation of management options (Step 4). Chapter 4 presents a recommended strategy for managing the issues at Halifax Park and Fly Point.

1.3 Study Limitations

The study was carried out within cost and time constraints. For these reasons, a number of assumptions were made that potentially limit the outcomes of the study, as follows:

- The study was viewed as a 'scoping' study only, suitable for identifying those options that are most likely to achieve the MPA's site management objectives in a cost effective manner;
- The potential options were considered to a preliminary level of detail only. Additional work and analysis will be required before progressing to detailed design stage of any works;
- The cost estimates are preliminary only, for the purpose of comparing between options. Costs for undertaking the works will depend on the volumes (which need to be confirmed through additional survey), and the options chosen for removal and for disposal of material. No specific contingencies have been included in the costs, and all costs are considered to have an accuracy of about +/-50%; and
- Not all available background data has been reviewed. Only data sets considered of most use to achieving the aims of the study were reviewed or processed, while other data were considered to a cursory level. Overall, there is still a fair degree of uncertainty regarding the environmental processes that are causing the sand accumulation at the dive sites, and much more detailed investigations, including extensive on-site inspections and measurements, would be required to reduce this uncertainty.

Title:

Study Area

Figure: **1-1**

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1.4 Findings of the Study

The main findings from this study are as follows:

- Longshore sand transport has bypassed Nelson Head at times in the past, as indicated by aerial photographs from the 1950's and 1960's, with sand moving westward from Shoal Bay into Little Beach;
- The rate of sand bypassing appears to be greater than previous periods of bypassing, as indicated in available historical aerial photography (i.e. since 1950's);
- This present bypassing is the main reason why the sponge gardens at Halifax Park have been covered by sand,
- The process of sand movement from western Shoal Bay around Nelson Head is complex and involves many different and sometimes opposing factors, such as ongoing erosion in Shoal Bay, stabilisation of Zenith Beach hind dunes, past nourishment of Shoal Bay, and interaction of wave climate changes resulting from broad scale changes in the southern oscillation index (SOI);
- The first priority is to protect marine biodiversity at Fly Point (marine park sanctuary zone), which is potentially at significant risk of being smothered by sand; and
- To reduce the rate of sand bypassing Nelson Head, sand will need to be removed from around western Shoal Bay, including a large sand lobe located to the immediate east of Nelson Head. This is likely to be the most effective short term strategy.

Proposed steps involved in a short term strategy to address the issue involve:

1. Obtain detailed bathymetric and beach survey (**Cost = $30,000 approx**.);
2. Detailed design and environmental assessment for subaerial sand removal from the western end of Shoal Bay beach and from Little Bay beach (total volume approximately 57,000m^3). (**Cost = $150,000 approx**.);
3. Undertake subaerial removal from the western end of Shoal Bay beach and from Little Bay beach (**Cost = $400,000 approx**.);
4. Detailed design and environmental impact assessment for subaqueous dredging at Fly Point and the lobe adjacent to Nelson Head (total volume approximately 80,000m^3). (**Cost = $300,000 approx**.);
5. Undertake the subaqueous dredging at Fly Point and the lobe adjacent to Nelson Head (**Cost = $2.5M approx**.);
6. Ongoing monitoring for a period of at least two years (**Cost = $120,000 approx**[1]).

It is envisaged that the response of the site to the short term dredging, as identified through the monitoring, would leading to a longer term management strategies for the future sustainability of the dives sites in Port Stephens. Some potential actions that could be considered as part of a long term strategy are presented herein, and are not dissimilar to the previously developed, but unimplemented, Shoal Bay Management Plan (MHL, 2001), however, there was insufficient information available to recommend a robust long term strategy for management at this stage.

[1] This monitoring only includes repeated surveys to measure and validate sand transport rates. More detailed monitoring studies may be required as part of studies to support a long term strategy (e.g. ecological studies).

2 ASSESSMENT OF PROCESSES

2.1 Introduction

Processes affecting the transport of sand through the study area have been considered. While the process analysis was not the prime objective of the study, an understanding of such processes is essential to ensure management actions are appropriately targeted. The background data review has also included assessment of water levels and waves insofar as they affect sand transport processes.

Relevant findings, including additional analyses, are summarised in Sections 2.2 to 2.7. Section 2.8 presents a time line of recent events and a conceptual model of processes arising from our review and analyses.

Key background reports reviewed for this study included:

- Lord *et al*. (1995) *Offshore Dredging for Beach Nourishment; Shoal Bay, N.S.W*;
- Watson (1997) *Port Stephens Sand Nourishment Projects Evaluation, Monitoring and Sustainability*
- Frolich (2007) *Recent Morphological Evolution of the Port Stephens Flood Tide Delta*;
- Vila-Concejo et al. (2007) *Flood Tide Delta Morphodynamics and Management Implications, Port Stephens, Australia*
- Austin et al. (2009) *Tidal Hydrodynamics of a micro-tidal, wave-dominated flood tide delta.*
- Harris (2009) *Multi-Scale Morphodynamic Assessment of an Embayed Low Energy Estuarine Beach, Shoal Bay, Port Stephens, NSW*;
- Jiang et at. (2010) *A Hybrid Model of Swash Zone Longshore Sediment Transport on Reflective Beaches*;
- Luzuriaga (2011) *Managing Sand Accretion at Halifax Park, Nelson Bay (Unpublished Masters Project)*

Other data sources also used in the study included:

- Directional wave data collected at Sydney, owned by the Office of Environment and Heritage and managed by the NSW Government’s Public Works Manly Hydraulics Laboratory (1992 to the present);
- Tidal data collected from the permanent water level recording station at Tomaree, near the eastern end of Shoal Bay (owned and administered as for wave data above);
- A variety of historical hydrosurvey information for Port Stephens, collated and provided to BMT WBM by the Office of Environment and Heritage;
- Details of the recent sand removal exercise from Little Beach; and
- Data from a variety of monitoring exercises undertaken by the PSGLMPA during the past year.

2.2 Geomorphology and Bathymetry

A summary of Port Stephen's geomorphological evolution is provided in BMT WBM (2011). Relevant aspects are discussed in this section, along with information more specific to Shoal Bay. The present day (2007) bathymetry of the Port is provided as Figure 2-1 and more detailed bathymetry from the entrance across to Fly Point is provided as Figure 2-2.

The present coastal beaches, eastern basin, flood tide delta and fringing beaches of the Port Stephens estuary have been largely formed since the end of the last ice age around 10,000 years ago. As the sea level rose from its previous glacial low-level, sand was pushed onshore across the continental shelf, eventually depositing within the present beach, dune and estuarine systems. It is possible that some sand is still being supplied from offshore to the present coastline, although this rate would be quite low.

Frolich (2007) argues that the present level of onshore sand supply is insufficient to account for the rate at which the flood tide delta (FTD) is presently moving westward into Port Stephens. The 'prograding' edge of the FTD approximately extends between Corlette in the south to Corrie Island in the north, and incorporates the mouth of the Lower Myall River. Frolich contends that progradation of the FTD is fed from erosion of the seaward ramp of the sand delta inside the heads of Port Stephens, accounting for a lowering of some 0.3 to 0.5 m in this area over the past 50 years.

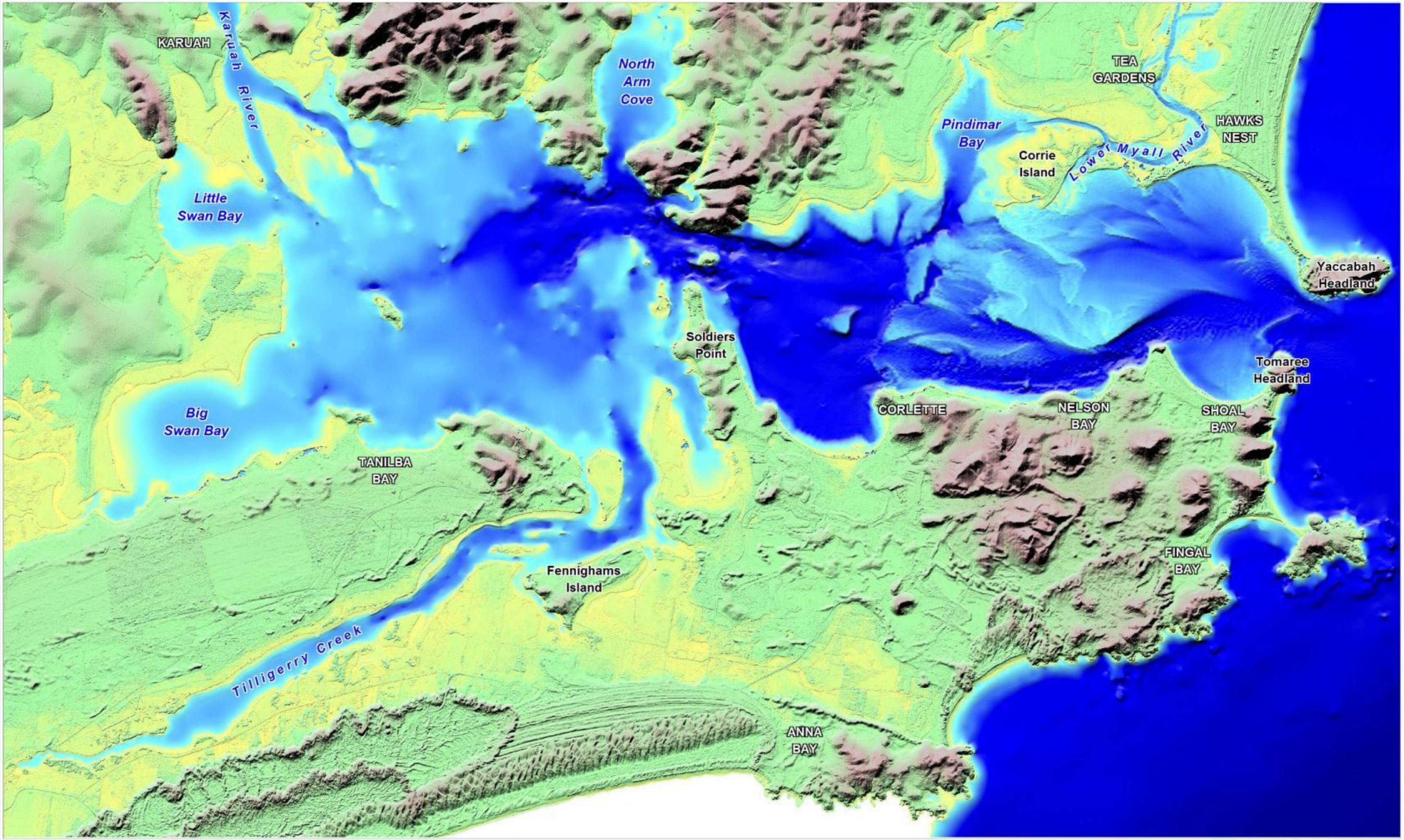
Harris (2009) considered ongoing reworking of the FTD was the main factor contributing to long term recession at Shoal Bay, arguing that the infrequent but severe storm events that ultimately force the recession are affected profoundly by the underlying long term pattern of FTD movement.

The extent of recent bed lowering in Shoal Bay was examined by comparing 1994 and 2007 hydrosurveys (refer Figure 2-3)[2]. This figure shows that most of the change in bathymetry within Shoal Bay over the 13 year period was limited to areas close to Tomaree Headland, and would include changes associated with dredging activities in 1994. Along the shoreline to the west of the main commercial area in Shoal Bay, there is evidence of the nourishment undertaken in the mid to late 1990's. Another feature of note is the apparent movement of the entrance shoal into the mouth of Port Stephens (erosion on ocean side, deposition on western edge). Widespread lowering of the bed of Shoal Bay is not apparent, but cannot be discounted due to the relatively short time period of comparison and potential inaccuracies associated with the hydrosurveys.

Examination of the bathymetry in the Port (Figure 2-1) shows that the broader FTD is separated from sand in Shoal Bay by a continuous channel of at least 10 m depth extending from Nelson Head towards Yacaaba Headland. Significant sand transport between Shoal Bay and the northern parts of the FTD is unlikely due to this disconnection.

Key features of the Shoal Bay bathymetry (Figure 2-2) include:

[2] Interpretation of this comparison must be undertaken with care, as both surveys do not include the beach.



LEGEND

Elevation (m AHD)

- -10
- -1
- 0
- 2
- 50

Title:

Present Day Bathymetry of Port Stephens

Figure: **2-1**

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0 1.25 2.5km

Approx. Scale

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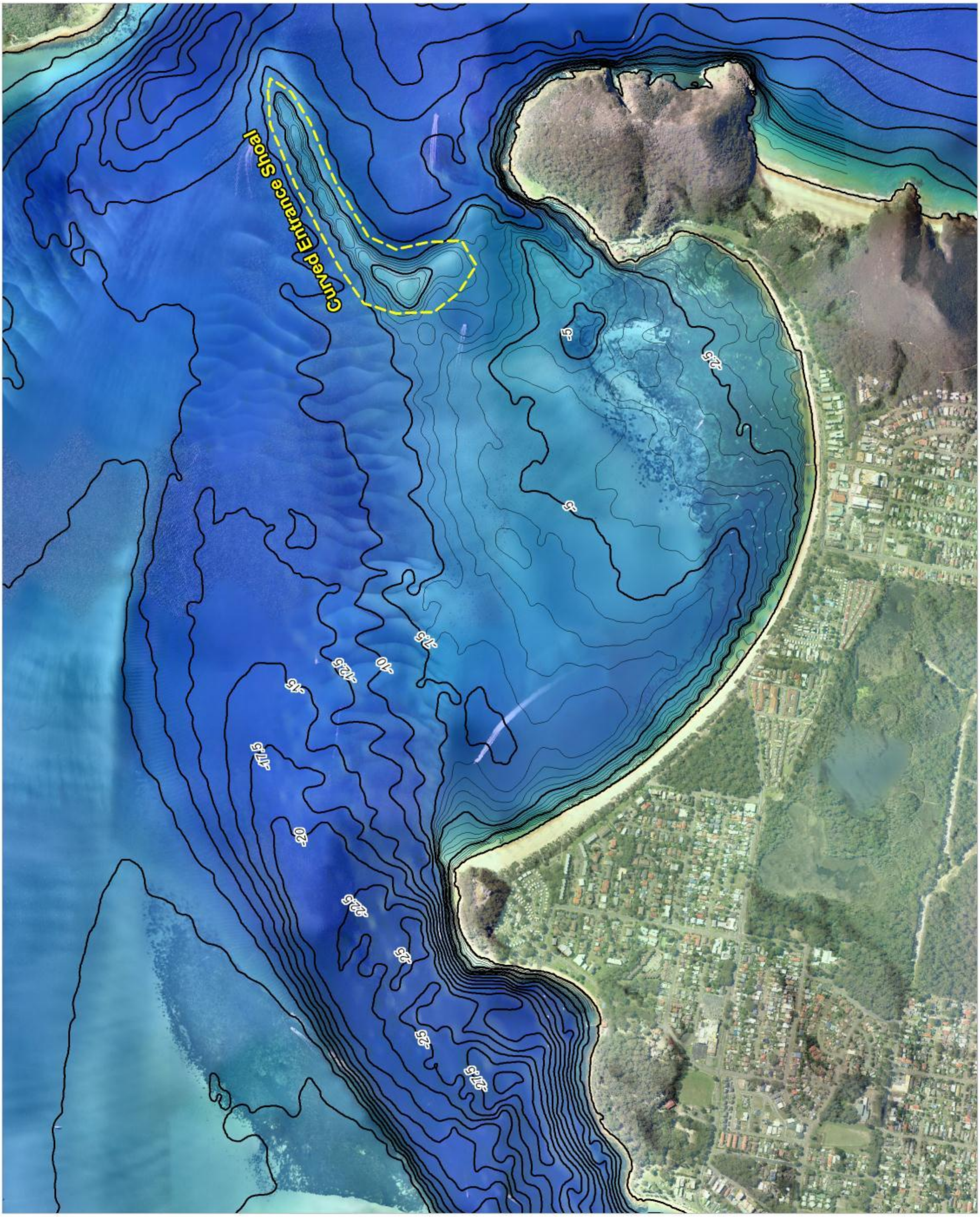

Title:

Bathymetry of Eastern Port Stephens and Around Nelson Head (2007 Hydrosurvey)

Figure: **2.2**

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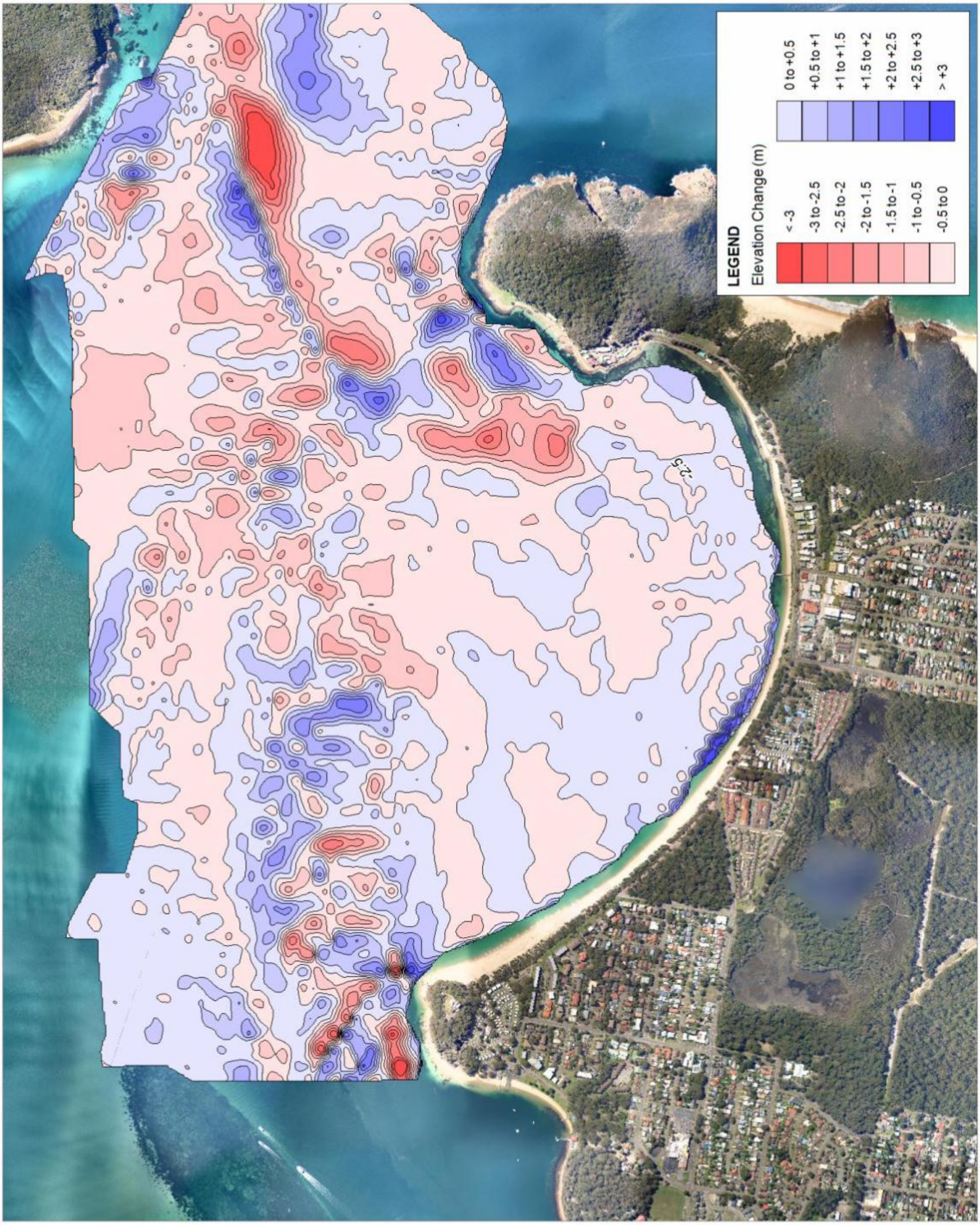

Title:

Change in Bathymetry around Shoal Bay (1994 to 2007)

Figure: **2.3**

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- The bed of Shoal Bay dips in a north westerly direction, with a relict splay, emanating from Zenith Beach, evident in air photographs and bathymetric data. It is hypothesised that in the past, a significant amount of in-filling of Shoal Bay occurred from overwash processes (with lower dunes on Zenith Beach and/or higher sea level in a geological context) and/or Aeolian transport from the open coast into the Shoal Bay embayment;
- Sand is presently being reworked by ocean waves along submerged shoals to the north and east of Tomaree Headland;
- The shoals around Tomaree Headland have an impact on wave refraction patterns. Preliminary wave modelling indicates that these shoals have a focussing effect on wave energy towards the western end of Shoal Bay (refer Section 2.5.2);
- The beach slope between 0 and -5.0 m AHD steepens from east (1V:100H) to west (1V:10H). At the western end, the beach is highly reflective;
- Sand tends to be transported westward along the Shoal Bay shoreline, and is then deposited on a nearshore lobe to the immediate east of Nelson Head. From air photos, it appears that the size of this lobe can vary significantly over time. The lobe is not evident in air photos prior to the 1980s, but is quite prominent in the most recent photos (over the past 10 years or so)[3]. It is unclear whether there has been a shift in the underlying processes causing this sand accumulation, or if it is part of a longer-term cyclical process.

Sand movement in and out of Shoal Bay over the last century is expected to relate to:

1. Aeolian (windborne) transport of sand supplied from the coast (Zenith Beach). Aerial photography from 1963 shows that wind blown sand was moving from Zenith Beach, and contributing to sand deposits in the nearshore zone at eastern Shoal Bay. The mobile sand dunes between Zenith Beach and Shoal Bay have been progressively vegetated and stabilised, with minimum further transport expected from 1990;
2. Seagrass beds have more recently established in areas previously occupied by sand deposits from Zenith Beach. Inspection of later aerial photography shows that these beds are periodically disturbed by wave action, evidenced by splays of sand extending from offshore. OEH has commented that based on shore normal surveys conducted along Shoal Bay (during the 1990s by PWD), the limit of the active sand mobility was determined to be very close to shore and generally above -3m AHD. There also appeared to be no direct evidence of an active sediment pathway from the entrance shoals around Tomaree Headland onto the eastern end of Shoal Bay (pers. comm.. Phil Watson, OEH, 2011).
3. Loss of sand onto the sand lobe to the east of Nelson Head, and along the foreshore to the north and west around Nelson Head. Aerial photographs illustrate periods when minimal or no sand was present at the Nelson Head northern shoreline (1977 – 2001) and periods when a sandy beach is present (1951 – 1966, and 2006 – 2011). When sand is present around the Nelson Head subaerial shoreline, there also appears to be more sand present along Little Beach and further westward.

Estimates from aerial photograph interpretation indicate that Shoal Bay Beach receded around 30 m on average between 1963 and 2006 (Frolich, 2007). Recession was more pronounced at the eastern

[3] It is possible that recent improvements in aerial photography are now able to more easily identify subaqueous features such as nearshore lobes

end (~ 40 m) than at the western end (~20 m). This suggests that volume of new sand into the Shoal Bay sediment compartment (as discussed in Points 1 and 2 above) have been lower than the volume of sand removed from the compartment (Point 3) over the past 50 years.

2.3 Water Levels

Vila-Concejo *et al.* (2007) noted that tidal attenuation inside the estuary is negligible, partly because of the wide mouth (1.24 km). Therefore, ocean water levels can be considered indicative of levels along the shorelines from Shoal Bay through to Fly Point. Results from a tidal planes analysis of the recorded water levels at Tomaree are shown in Table 2-1.

Coastal storms can result in elevated water levels for short periods of time (i.e. barometric storm surge). Maximum water levels at Fort Denison in Sydney (which is considered reasonably consistent with Tomaree) for various recurrence intervals are given in Table 2-2 (DECCW, 2009). Note that these values do not include wave set-up or run-up. For most ocean conditions, the entrance of Port Stephens is sufficiently deep to preclude the need to consider wave set-up (MHL 1999).

Table 2-1 Tidal Planes and Tidal Ranges for Port Stephens (source: MHL, 2009)

Tidal Planes	Water Level (m AHD)
HHWSS	0.979
MHWS	0.603
MHW	0.476
MHWN	0.349
MSL	-0.034
MLWN	-0.418
MLW	-0.544
MLWS	-0.671
ISLW	-0.939
Tidal Ranges	
Mean Neap Range (MHWN-MLWN)	0.766m
Mean Range (MHW-MLW)	1.020m
Mean Spring Range (MHWS-MLWS)	1.274m
Range (HHWSS-ISLW)	1.918m

**Where: Highest High Water Solstice Spring (HHWSS); Mean High Water Spring (MHWS); Mean High Water (MHW); Mean High Water Neap (MHWN); Mean Sea Level (MSL); Mean Low Water Neap (MLWN); Mean Low Water (MLW); Mean Low Water Spring (MLWS); and Indian Spring Low Water (ISLW)*

.

Table 2-2 Elevated Water Levels, Fort Denison, Sydney (BMT WBM 2010)

Average Recurrence Interval (years)	Extreme Water Level (Storm Surge + HHWSS) Sydney (DECCW, 2009) (m AHD)
10	1.35
20	1.38
50	1.42
100	1.44

2.4 Tidal Currents

Based on a review of historical bed form orientations, the channel to the north of Tomaree Headland is dominated by ebb tide currents (Frolich, 2007). Frolich (2007) also identified a continuous ebb dominated channel to the north of Nelson Head and the Shoal Bay embayment, with the exception of the reversal to the north-west of Tomaree headland where flood tides dominate and cause the (westward oriented) curved shape of the entrance shoal (refer Figure 2-2 for location). .

Harris (2009) links stronger shore parallel currents to larger tidal ranges and less energetic waves with shorter periods in Shoal Bay. Short period waves refract less as they approach the shoreline, and therefore approach the shore at a more oblique angle, driving a more intense longshore current.

Austin (2009) described the tidal circulation patterns across the flood tide delta of Port Stephens. Two of Austin's recording sites were in Shoal Bay with the following characteristics:

- S2 – Sontek ADCP installed at average 5.73 m depth at western end of Shoal Bay. 20/12/07 – 14/02/08 (56 days)
- S3 – Sontek ADCP installed at average 3.89 m depth at eastern end of Shoal Bay. 14/02/08 – 28/03/08 (32 days)

Velocities and directions measured during the deployments were depth averaged and analysed for direction to determine characteristics of both the 'flood' and 'ebb' phases. Austin found Site S3 to be ebb dominated, whereas Site S2 was flood dominated. By examining the available readings at S2, Austin noted that currents would consistently revert to a flood direction some 2 hours into the ebb phase. From this, Austin reasons the presence of a clockwise eddy in Shoal Bay, formed by ebb currents separating from Nelson Head. This is consistent with similar patterns observed at other locations where a shallow beach is aligned in close proximity to a strong tidal channel.

Austin's results also indicate flood-tide dominance around the western side of Nelson Head (i.e. from Little Beach around to Nelson Bay), which is somewhat inconsistent with previous findings (Frolich, 2007) that the channel north of Nelson Head was ebb dominated.

Anecdotally, the recent sand movement along the southern shoreline suggests a westward (ie flood-dominant) transport (as indicated by the fact that sand accumulation occurred first at Halifax Park in September/October 2010, then at the Pipeline in February 2011, and then at Fly Point in March 2011). This sequence suggests flood tide currents are at least partly responsible for this sand transport.

2.5 Waves

2.5.1 Offshore Waves

Wave roses for the long term average offshore wave climate for Sydney, which is approximately representative of offshore Port Stephens, are shown on Figure 2-4. The seasonal breakdown of the wave climate is shown on Figure 2-5 (H_s) and Figure 2-6 (T_p).

Figure 2-4 shows that waves are typically between 1-2 m (H_s), with periods of between 8 and 12 seconds (T_p), and approach from South-East to South direction (135 – 180 degrees). The seasonal breakdown shows a tendency for larger and longer period waves approaching from a more southerly direction during winter, transitioning to lower, shorter period waves approaching from a more easterly direction during summer.

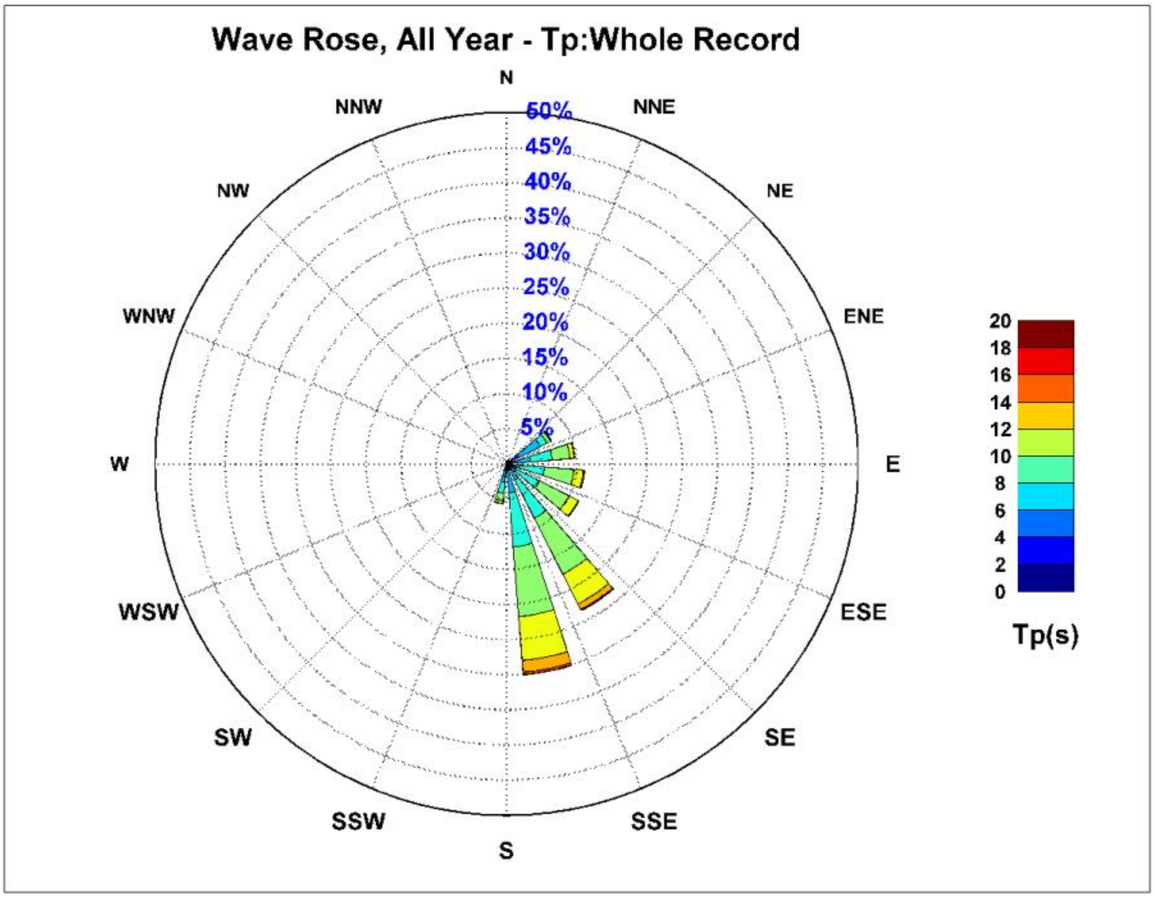
The seasonal climate from each of the last 5 years was also examined. This analysis found that during winter and spring of 2010 and the summer of 2010/2011 the wave climate tended towards more easterly waves when compared to the long term averages. This pattern is expected, following a transition from negative to positive SOI (el-Niño to la-Niña) (Ranasinghe *et al.*, 2004), as occurred during the first half of 2010. The slight change in wave climate is also of some importance when considering exposure of the western end of Shoal Bay to swell waves.

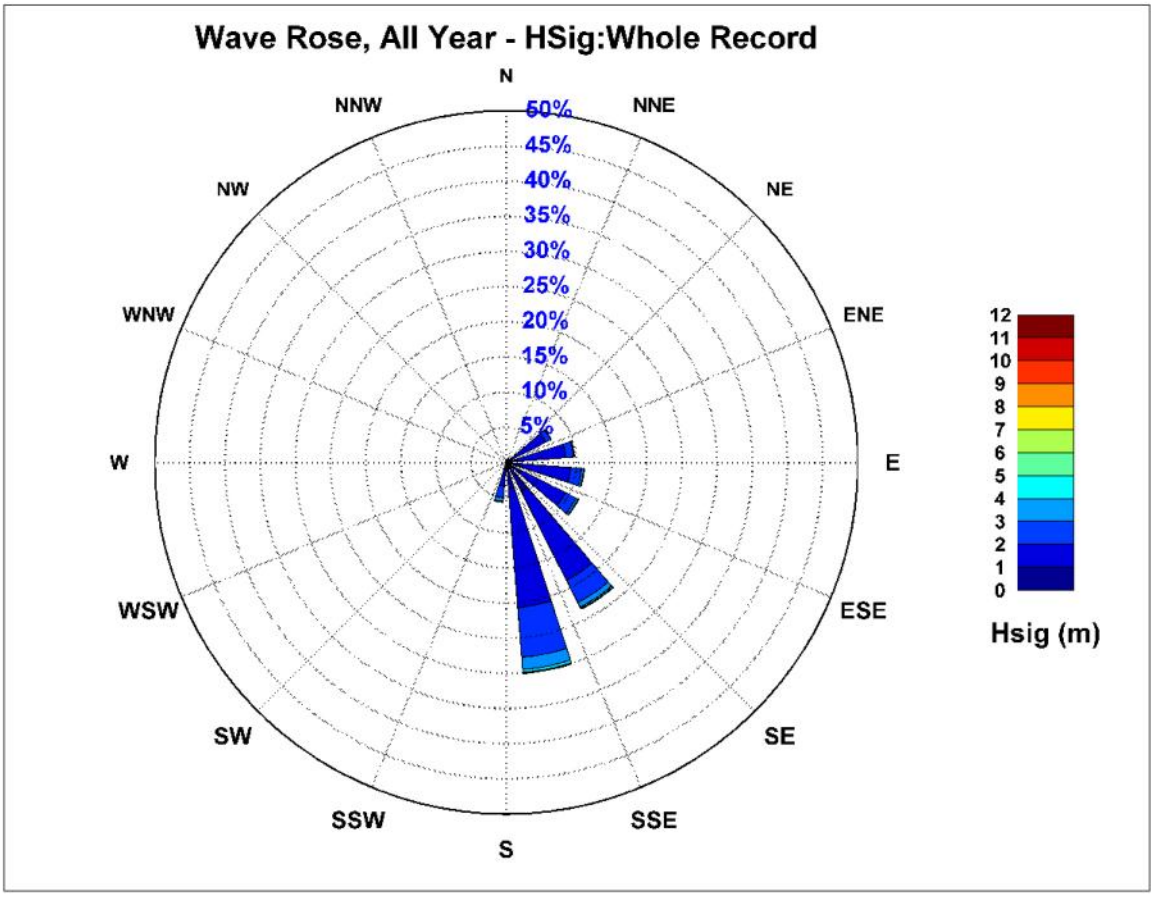
The analysis of wave climate was not exhaustive and did not separate storms, which anecdotal information indicates are the main driving mechanisms for pushing sand from Shoal Bay around Nelson Head. Storm wave refraction patterns and the influence on longshore transport potential is discussed below.

2.5.2 Nearshore Waves

Results from wave model simulations undertaken during a previous study on the Lower Myall River (BMT WBM, 2011) were re-examined in the context of this study. Wave conditions representing a long term average storm (11s, 6.1 m H_s from south of south-east) and a comparable storm resulting from a shift to positive SOI values (11.5s, 6.5 m from south-east) were selected and their simulated patterns of propagation into Shoal Bay are presented as Figure 2-7 Notable features of these modelling results include:

- The entrance shoal north of Tomaree Headland refracts and focuses waves onto the Shoal Bay shoreline. The shoal is known to be active and ongoing changes to this shoal will affect wave propagation into Shoal Bay;
- Waves are focussed onto the western end of Shoal Bay. Storm waves can stir up sediment, making it available for transport along the beach by the dominant east to west tidal currents;
- The refraction patterns result in waves that approach the shoreline at Halifax Park at an oblique angle, ideal for driving sand from east to west; and
- A change to slightly stormier waves (increases in wave height, from more SE than SSE), which may be expected during periods of positive SOI conditions (Ranasinghe *et al*., 2004) results in significantly higher waves at the shoreline in the area of focussing. Ranasinghe *et a*l. (2004) found a doubling in the frequency of storms during periods of positive SOI, so activity along this shoreline could be expected to significantly increase during these times.





Title:

Long Term Average Offshore Wave Climate Roses for Sydney (Tp (Top) and Hs (Bottom))

Figure: **2-4**

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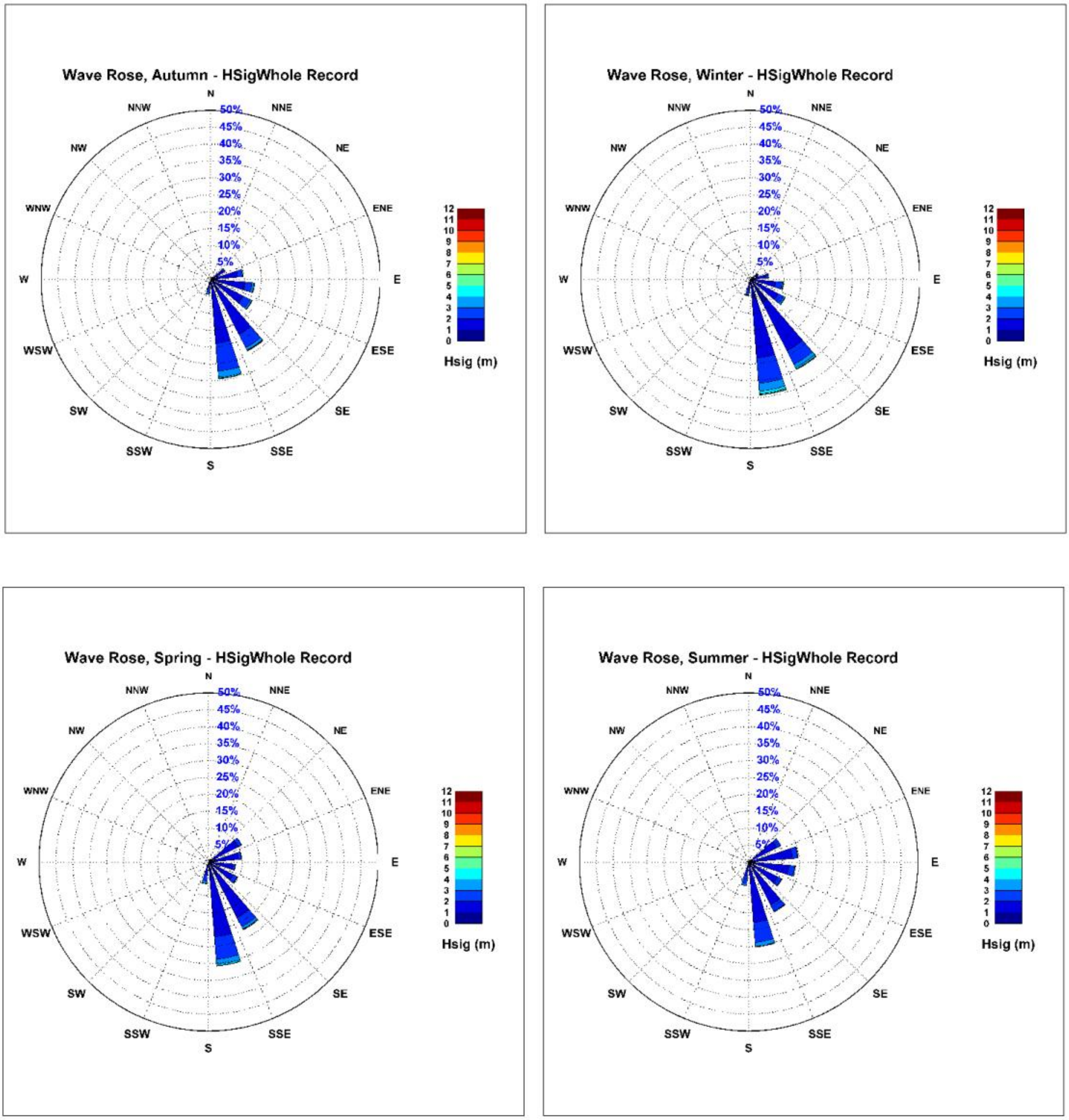

Title:

Seasonal Offshore Wave Climate for Sydney (Hs)

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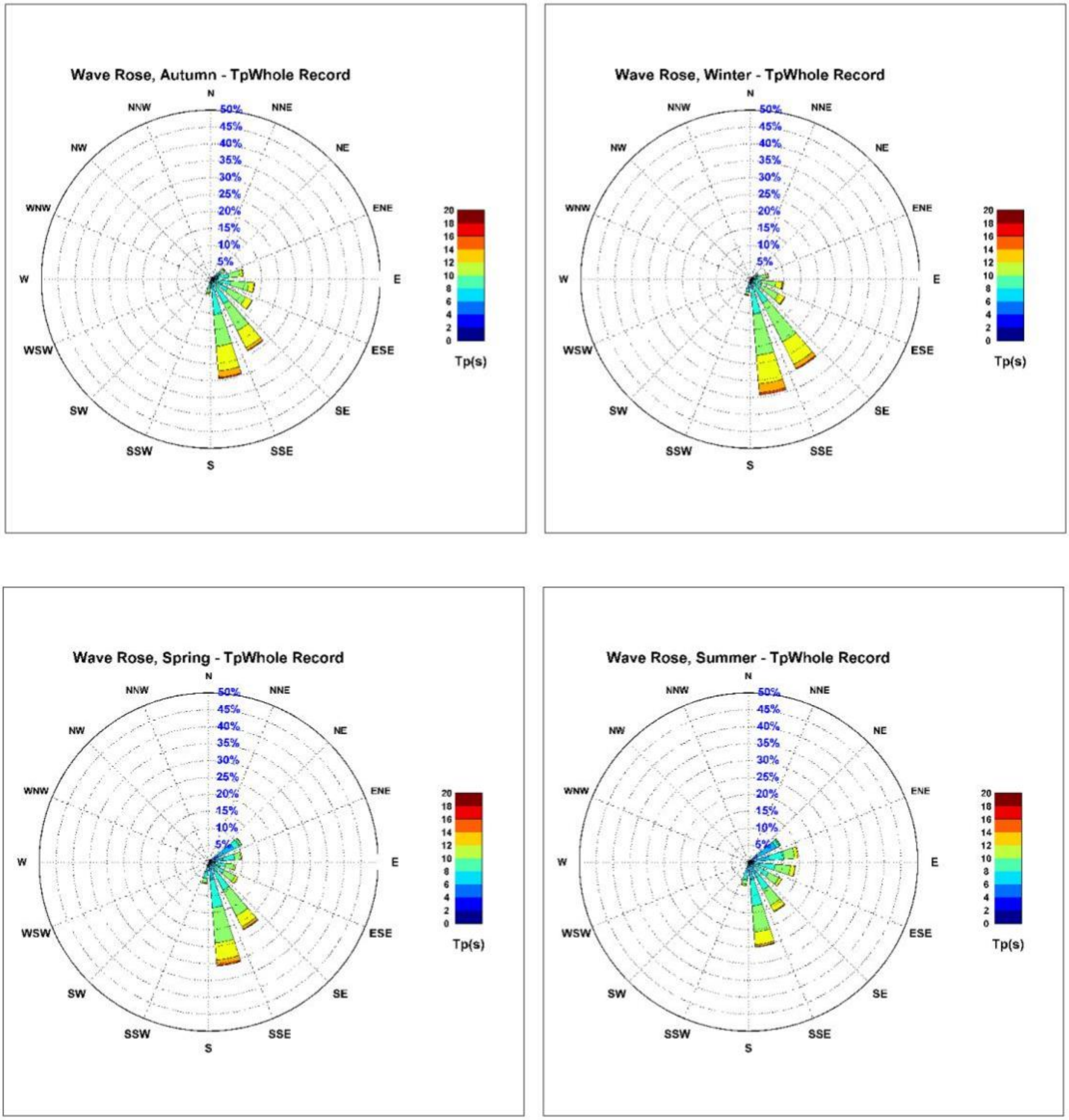

Title:

Seasonal Offshore Wave Climate for Sydney (Tp)

Figure: 2-6

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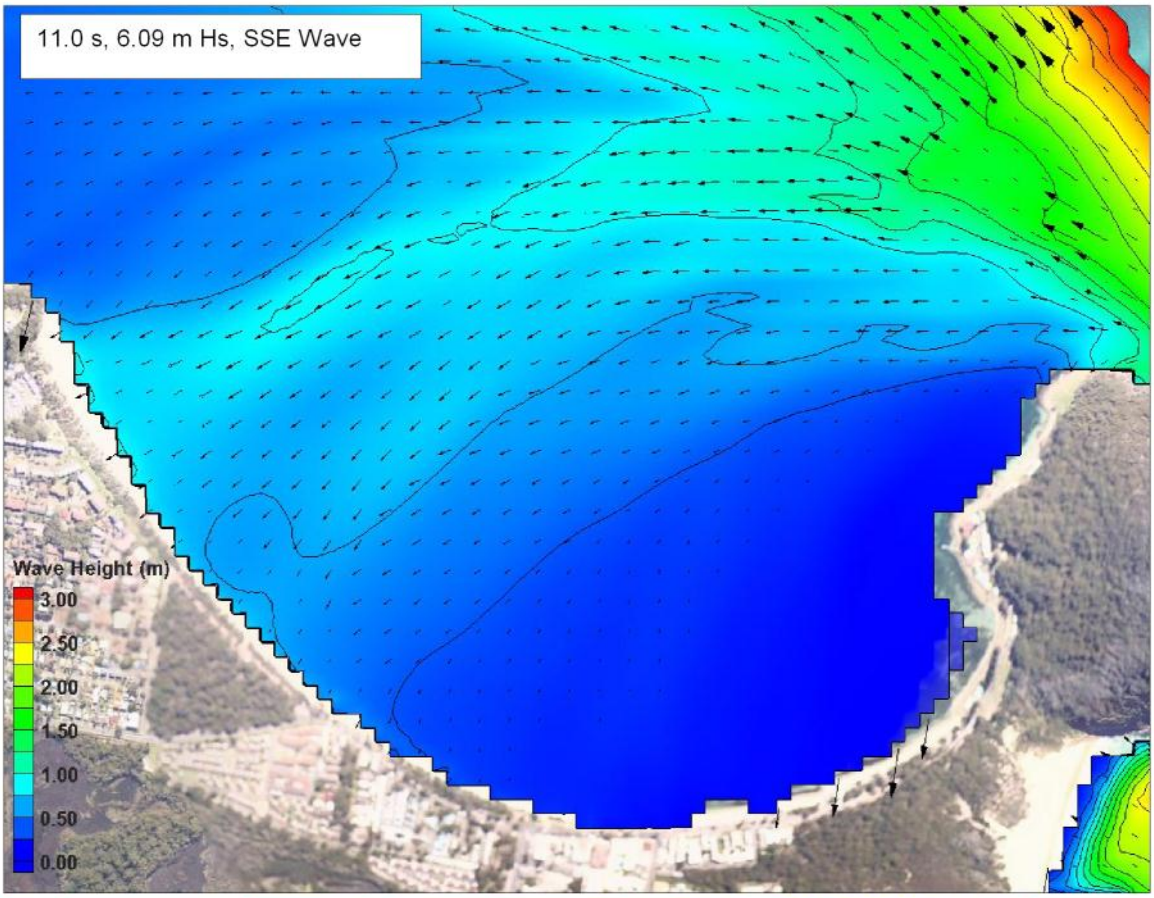

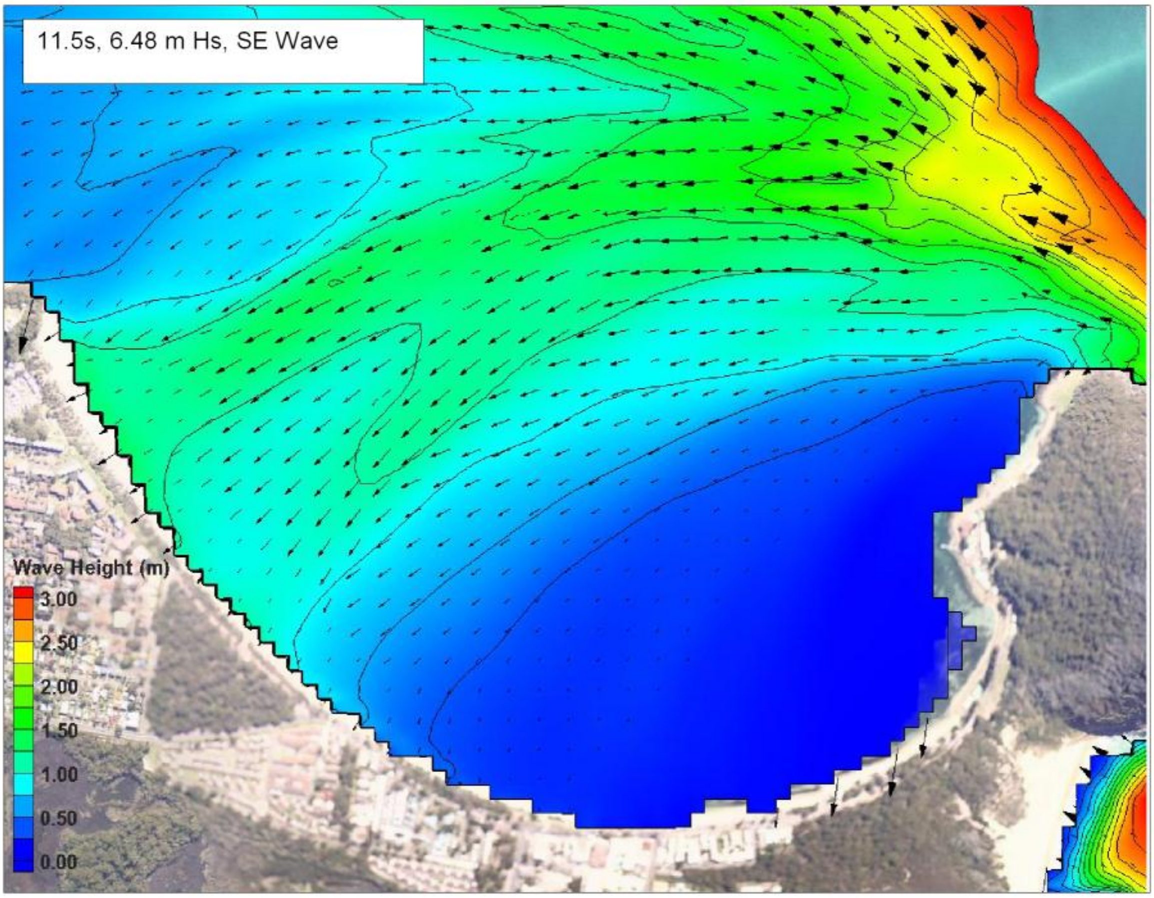

Title:

Comparison of Simulated El-nino (top) and La Nina (bottom) type Storm Waves: Shoal Bay

Figure: 2-7

Rev: A

N

0 375 750m

Approx. Scale

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It is considered that the change in offshore wave climate related to positive SOI conditions during 2010 may be a factor contributing to the mobility of sand in western Shoal Bay and its transport onto the beach at Halifax Park.

The eastern foreshores of Shoal Bay are somewhat protected from oceanic swell under most conditions. The degree of exposure to waves increases with distance westward along the shoreline.

Harris (2009) argues that winds do not contribute significantly to sediment transport and wave dynamics in Shoal Bay, while Frolich (2007) also notes that wind wave power would be significantly lower than storm wave power in the eastern basin (east of Nelson Head). Wind generated waves have therefore not been considered further in this report.

2.6 Sand Movement

2.6.1 Natural Sediment Transport

From a review of historical records and photogrammetric analyses, Watson (1997) concluded that sand moved from east to west along Shoal Bay. Prior to 1970, it appears that sand moved freely from Zenith Beach (i.e. to the south of Tomaree headland) onto the eastern end of Shoal Bay. Progressive stabilisation through revegetation has reduced this sand supply to minimal levels at present. Natural sand movement has therefore altered and it is possible this has affected erosion patterns of the eastern end of Shoal Bay.

Sediments along Shoal Bay have grain sizes around 0.35 – 0.45 mm along the central and eastern sections of the Beach, and from 0.45 to 0.65 mm along the western sections (Harris, 2009). Vila-Concejo *et al.* (2007) noted mean grain sizes of 0.25 mm and 0.75-1.00 mm at the eastern and western ends of Shoal Bay, respectively.

Between May 2008 and May 2009, around 10,000 m^3 of sand was lost from Shoal Bay (Harris, 2011)[4]. Most of this sand was lost from the western areas of the beach during storms between March and May 2009. Harris also notes an average beach recession of approximately 22 metres over the last 40 years (i.e. 0.55 m/yr on average).

As indicated by the proximity of seagrass to the beach, it appears that active sand transport is mostly constrained to the immediate intertidal beach face at the eastern end of Shoal Bay, although towards the western end of Shoal Bay, sand is also active in the shallow subsurface region. This is consistent with the degree of sheltering from swell waves provided by Tomaree Headland, as highlighted in Figure 2-7. As a result, the western end of the beach is wider than the eastern end, and also suggests an overall east to west transport direction. Both anecdotal (refer Section 2.7) and scientific studies (Harris, 2009) indicate that the majority of sand movement occurs during storms.

Based on aerial photograph interpretation, field data collection and regular beach surveys over a period of around 2 years, Harris (2009) found that longshore transport was towards the west over short, medium and long time scales. Harris also found that high energy events triggered erosion along the entire length of Shoal Bay and that all sections of the beach had eroded over the past 4 decades. In the western most section, periods of accretion (1977 – 1991 and 1996 – 1999) were also determined from aerial photography.

[4] Harris' estimate only accounts for volumes above 0.0 m AHD

Harris reported on results from 23 survey transects spaced at around 100 m. Surveys were repeated, albeit irregularly, on 11 occasions between May 2007 and June 2009. Results indicate erosion in the central parts of the beach and accretion along the western end of the beach. Data reproduced by Harris indicate that surveys extended seaward to varying levels between -1.0 m AHD to -2.0 m AHD, and as a result, are unlikely to have picked up the full extent of the active beach profile. Indeed, OEH indicate that sand can be transported alongshore down to depths of -3m AHD, and as such, the surveys may not reflect the true volumetric change experienced by the beach (Pers. Comm., P. Watson, 2011).

Notwithstanding these potential limitations, Harris (2009) identified the following periods of erosion and accretion on Shoal Bay between May 2008 and May 2009:

- July – October 08: accretion;
- October – December 08: erosion back to May 2008 position;
- March – May 09: erosion of around 10,000 m^3 (note, actual volume lost may be higher due to limitations of survey transects). This period contained a single extreme storm accounting for most of the erosion.

The slope of the beach did not vary significantly, although Harris notes that the severe storms between March and May 2009 caused flattening of the beach profile along the entire Bay. Shoreline recession was most pronounced in the central section of the beach (~5 m) and progradation was most pronounced at the western end (~2 m). During March to May 2009, however, approximately 4,500 m^3 of sand was eroded from the western section alone. This quantity is indicative of the amount that may move out of the Shoal Bay compartment during a single storm.

In conclusion, Harris notes that the dominant mechanism driving westward sediment transport is waves acting in conjunction with tidal currents.

MHL (2001) indicate that based on the available data there has been a clear reduction of the beach sand volumes between 1951 and 1978. Since 1978 the sand volumes on the beach have increased, although this can be almost entirely attributed to beach renourishment. MHL (2001) consider the best estimate of the present day sand losses from the beach, which would occur under natural conditions, is approximately 5,000 m^3/year, resulting in a recession of the back beach of approximately 0.2 to 0.4 m/year (not dissimilar to Harris' estimate, as discussed above). Over the past 20 years this recession trend has been masked by the construction of protection structures and beach renourishment (MHL, 2001). In the longer term, and in the absence of any ameliorative works, MHL (2001) considers it is likely that the rate of foreshore recession would increase, and would be compounded by future sea level rise.

The importance of swash zone related transport on steep reflective beaches was discussed in a study on swash zone related sediment transport at Jimmy's Beach by Jiang *et al.* (2010). Where waves break immediately at the shoreface, the transport in this area can account for a large proportion of the littoral transport. The western end of Shoal Bay is a steep reflective beach, and as such, the swash zone is likely to be a key sediment pathway, although further studies at this site would be ideal to investigate this hypothesis further. During storm conditions, it is likely that sediment transport in the surf zone (i.e. seaward of the swash zone) is also important, while during more ambient conditions, transport is mostly restricted to the swash zone (given that all of the wave breaking occurs at the shoreface).

To account for the dominant east to west transport of sand along Shoal Bay, the resultant sand would need to either 1) bypass around Nelson Head, and/or 2) accumulate within the sub-aerial beach and nearshore zone on the updrift side of Nelson Head. Aerial photographs show that a sand lobe to the immediate east of Nelson Head is usually present and varies in size and extent[5]. It is expected that sand transported along the Shoal Bay shoreline is deposited onto this lobe from where a number of processes can then act:

- Strong tidal currents interact with the northern face of the lobe, and can carry sand either east (under ebb tides) or west (under flood tides), depending on the stage of the tide. Eastward oriented sand waves are commonly observed across this shoal, suggesting preferential ebb tide sand transport; and
- Waves approaching this shoal break and stir up sediment. This makes additional sand available for transport by tidal currents. The oblique angle at which swell waves approach this shoal also encourages the transport of sand back onto the Nelson Head shoreline, and subsequently westward along the shoreline towards Halifax Park and Little Beach.

It is also expected that sand accumulated within the sub-aerial beach on the eastern side of Nelson Head is able to be reworked within the upper shoreface around the headland. Aerial photographs dating back to 1951 show a variable upper shoreface beach width on the northern side of Nelson Head, from effectively zero (late 1990s) to a substantial width of more than 10 – 20 metres (1951, 1966, May 2010).

An unpublished master's thesis from Southern Cross University (De Luzuriaga, 2011) presents evidence for a build-up of sand on the western edge of Nelson Head (northern end of Little Beach) between 2006 and September 2009. Interpretation of this information is that in September 2009, there was a continuous feed of sediment from east to west across Halifax Park, evidenced by the presence of sand in the nearshore shallows, which was not present in 2006. The September 2009 level of sand accumulation appears consistent with other historical aerial photographs. A photograph from June 2010 demonstrates a significantly greater amount of sand.

A temporary barrier[6] was installed next to the jetty on Little Beach in December 2009. Its purpose was to ameliorate problems relating to sand accumulation on the Little Beach Boat Ramp. The barrier was removed in June 2010. De Luzuriaga (2011) argues changes in sand levels at Halifax Park between September 2009 and June 2010 were caused by the installation of this barrier. Contrary to De Luzuriaga's conclusion, the primary cause of sand build up at Halifax Park is considered to be an unprecedented level of sand bypassing the western end of Shoal Bay and moving across Halifax Park from east to west. The barrier may have exacerbated sand accumulation within immediately adjacent updrift areas, but is not considered to be the underlying cause of accumulation at Halifax Park.

It is understood that around 300 mm of sand accumulated against the updrift (northern) side of the barrier prior to its removal (pers. comm., Max Haste & Dave Harasti, PSGLMPA). This is significantly

[5] The lobe has been most prominent over the past 10 years or so.
[6] A "Jersey kerb" barrier (typically used for roadworks)

less than the depths of sand accumulation measured around the foreshores of the Halifax Park dive site by De Luzuriaga.

De Luzuriaga measured a continuing increase in sand levels between September and October 2010, following initial falls in sand levels after removal of the barrier in June 2010. The increase corresponds to the intensification of issues at Halifax Park. Further, the depth of sand above the rocks at three transects at the northern end of Little Beach (T1-T3) increased between September and November 2010, after the removal of the barrier. The increase in sand levels apparently occurs in pulses, probably in conjunction with coastal storms that mobilise sand from western end of Shoal Bay.

The sand depth readings from De Luzuriaga (2011) are useful for estimating sand accumulation volumes. Assuming that no sand was present at Halifax Park before the 2010 sand inundation event, it is clear that between 1.0 and 1.2 m of sand had buried the rocky foreshore at Halifax Park before 3 November 2010. Following this, a sand clearing operation was undertaken by Port Stephens Council under permit from the MPA.

2.6.2 Dredging and Artificial Relocation of Sand

In 1986, some 25,000 m^3 of sand was dredged from the Nelson Bay Boat Harbour and used to nourish Shoal Bay beach. By 1994, Shoal Bay required further nourishment, which was met by an additional one-off dredging campaign, with material extracted from the entrance sand shoal of Shoal Bay adjacent to Tomaree Headland (refer Figure 2-3 for relic of dredge hole in current bathymetric profile). Lord *et al*. (1995) describe dredging operations in Shoal Bay in late 1994. They note that the foreshores of Shoal Bay were subject to on-going erosion since the early 1960's and that beach nourishment and foreshore protection works had been undertaken by Port Stephens Council to address the issue. Sand shoals immediately inside Tomaree Headland were identified as a suitable source for nourishment sand. These shoals rise to within 1.0 m of the water surface, and as such, the use of this sand from the shallower shoals was considered advantageous to navigation.

Harris (2009) provides more detail on the history of nourishment at Shoal Bay since 1986, including:

- The 1986 nourishment extended from the boat ramp to 500 m west of the Jetty;
- 'Extensive' shoreline management occurred during the early 1990's associated with erosion around the boat ramp drainage works near the jetty;
- Minor nourishment was undertaken during 1994 (details unknown) prior to the more extensive nourishment described by Lord *et al.* (1995). This major renourishment occurred from the boat ramp to around 700 m west of the Jetty;
- By 1996 nourishment was again periodically required until at least November 1999 (refer Watson, 1997 for details). Harris indicates that an extra 50,000 m^3 may have been placed during this time, although there is significant uncertainty around this figure as highlighted by OEH (Pers. Comm.. P. Watson, OEH, 2011); and
- There were apparently no major nourishment works since November 1999 although Harris notes sand was periodically removed from the western end of the beach to provide nourishment sand in the eroding area during the 2000's.

2.7 Consultation

A meeting with concerned private stakeholders was held at the offices of PSGLMPA on 19 July 2011. Eighteen individuals attended the meeting to discuss the project. Most attendees were either divers or associated with businesses involved in the diving industry. A few other interested residents and Port Stephens Council were also represented.

A broad ranging discussion revealed the following useful information regarding the study area. Interpretation of these issues is also provided, as given below:

- *"Diving has been occurring for at least 30 years at the Halifax Park"*. Local knowledge of the site before this period is less detailed;
- *"The present level of sand inundation is unprecedented over the past 30 years".* Aerial photographs indicate that sand is periodically present around the Halifax Park foreshore, however, the most recent aerial photograph showing sand build up similar to present levels is from 1963 (in appendices to Harris, 2009);
- *"Some of the larger sponges at Halifax Park were estimated to be nearly 50 years old".* This appears consistent with a sand inundation event in the early 1960's. It is understood that these sponges can actually live for up to 100 years (pers. comm. Dave Harasti, PSGLMPA), indicating that, although ages are uncertain, a viable substrate may only have been present during the last 50 years or so;
- *"Before construction of the Marina, sand movement changed direction seasonally along Nelson Bay"*: This is understandable, as longshore drift this far inside Port Stephens may be related to wind waves, and the wind climate changes seasonally. The sites considered in this study (Halifax Park and Fly Point), however, are more likely to be dominated by oceanic swell waves and swift tidal currents;
- *"There are issues at 'The Pipeline' a third site to the west of the Fisherman's Co-op near Nelson Bay Marina".* Subsequent discussions with Dave Harasti (PSGLMPA), who undertook a research project at this site confirmed that notable encroachment of sand occurred in February, 2011. This site is not included in the present study and has not been considered further.
- *"The pattern of sand encroachment at Halifax Park was as follows:*
  - o *Sand began to move onto the foreshore and shallows of Halifax Park initially,*
  - o *The sand continued to build in this area until the shoreward slope became so steep that the sand collapsed onto lower sections of the sponge gardens effectively smothering them;*
  - o *The process continued in this manner with continual supply of sand from western Shoal Bay until the majority of the sponge gardens had been covered in sand.*
  - o *At the present time around 80% of the sponge gardens have been submerged.*
  - o *Prior to significant stormy weather in mid-June 2011, sand was disappearing from the middle slopes of Halifax Park. Following the storm, sand was again covering the rocky substrate."*

  This description concurs with initial understanding of processes from the background information and aerial photography. The conceptual processes are discussed in more detail in Section 2.8.

Importantly, it appears that tidal currents are capable of clearing sand from the site, if supply from the western end of Shoal Bay is moderated.

- *"Sand Inundation at Fly Point is considered an issue".* A number of people concurred with this point. Comment was made, however, indicating that issues at Fly Point occurred here before they occurred at Halifax Park, and suggests a separate process may be acting here. It is expected that the sand is transported to Fly Point by tides, but this would require further assessment to confirm. Discussions with Dave Harasti indicated that markers installed at Fly Point to monitor sand have shown that the presence of sand is intermittent at present. The overall patterns of accumulation are consistent with the movement of 'sand slugs' or 'sand waves' through the site under the influence of tidal currents.
- *"Sponges of around 1.0 m height have been buried by the sand at Halifax Park":* While there is great uncertainty regarding sand depths and spatial variations, it seems that at least 1.0 m of sand is covering the previous sponge garden substrate in some places.

A subsequent meeting was held with government stakeholders on 19 July 2011. Issues discussed at that meeting related more to management options than the physical processes, with considerations included in Section 3.6.

2.8 Time Line of Recent Events and Conceptual Process Model

This section summarises the findings of Chapter 2. Table 2-3 presents a time line of events relevant to the recent sand-bypassing of Nelson Head. This summary has been used to inform the conceptual sand transport processes which are presented in Figure 2-8 and Figure 2-9 for the broader study area and the area immediately around Nelson Head, respectively.

The numbered features in Figure 2-8 and Figure 2-9 are summarised in Table 2-4.

Table 2-3 Time Line of Events

When	What	Why / Details
Before 1960's	Sand may have regularly bypassed Nelson Head	Wind blown sand from Zenith Beach, combined with sand moving onshore from the entrance shoals provided a source of sand to the beach at Shoal Bay. A continuous, wide beach was present in the 1963 aerial photograph, and photography covering the tip of Nelson Head indicates sand along the shoreline at Halifax Park in 1951. It is impossible to know whether this was a cyclic or more typical situation
~ 1970's	Regular diving begins at Halifax Park	Presumably at least some of the rocky substrate existed along the bed of this site, in order to support the sponge gardens and aquatic life for which the site is renowned (Section 2.7). Anecdotal estimates of sponge age indicate that the oldest sponges began growing at this time.
Mid 1960's – 1990's	Northern end of Zenith Beach progressively stabilised with vegetation	This is evident from historical aerial photography
1986	Dredging for the construction of Marina at Nelson Bay.	Shoal Bay had been receding since the 1960's. Insufficient data are available to determine whether this is an ongoing process that has only become a problem since development, or whether it results from a more

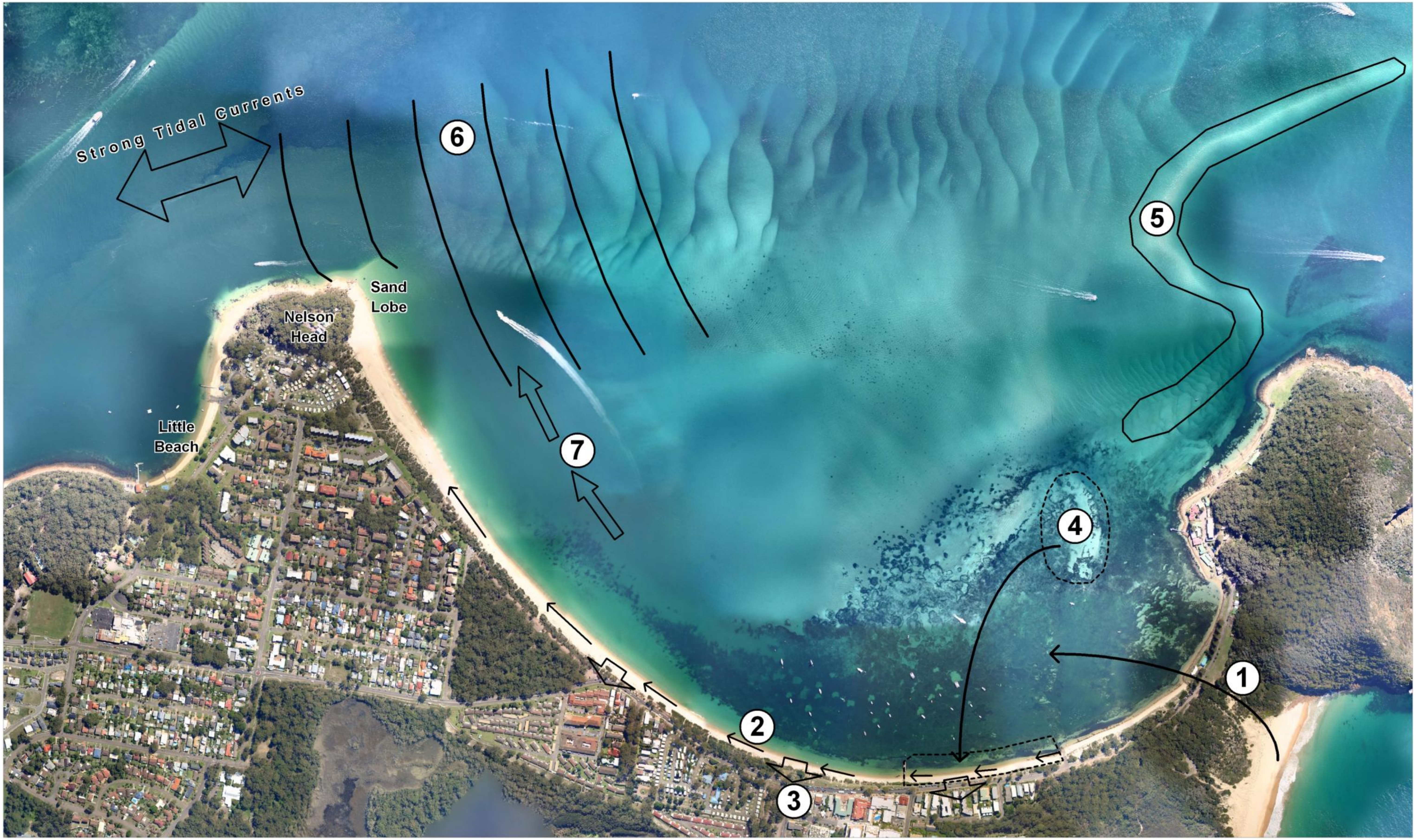
When	What	Why / Details
	25,000 m^3 of spoil used to nourish Shoal Bay from the Boat Ramp to 500 m west of the Jetty.	recent reduction in sand supply from either the coast (i.e. through the entrance to Port Stephens) or across Zenith Beach due to revegetation. Ultimately, Shoal Bay will continue to recede, erosion will continue to be problematic and will need addressing intermittently in the future (refer section 2.6.1).
Early 1990's and early 1994	"Extensive" management works in the vicinity of the Jetty and Boat Ramp	Required to address ongoing erosion along this length of beach. Apparently the sand was sourced from Anna Bay
1994	Second major nourishment exercise.	An estimated 56,000 m^3 of dredged sand from shoals to west of Tomaree headland used to nourish Shoal Bay from the boat ramp to a point 700 metres west of the jetty (refer Section 2.6.2).
1996 - 1999	Possible periodic re-nourishment (extents and volumes uncertain)	The effect of 1994's nourishment exercise had diminished by 1996 and periodic works were required to again protect assets from erosion.
Early 2000's	Occasional re-nourishment, but no major campaigns	Refer Section 2.6.2.
Early 2000's	Sand lobe to the immediate east of Nelson Head becomes more prominent	Sand transported westward along the Shoal Bay shoreline is directed onto the nearshore sand lobe. Sand on this lobe is then likely to moved directly into the deeper tidal channel where it would be redirected under the influence of ebb and flood tides, or is reworked back onto the shoreline under the influence of large swell waves.
2001	Development of Shoal Bay Management Plan	Refer Section 3.1, the Management Plan calls for periodic (twice yearly) removal of sand from the western end of the beach, and placement on the eastern foreshore, as a means of managing long term recessionary trends. Approximately 5,000m^3/yr of sand is recommended for transfer.
2006 - 2008	Resumption of sand bypassing around Nelson Head	Air photos from this time onwards show the development of a sandy beach along the northern shoreline of Nelson Head, with sand continuing to move alongshore across the upper shoreface into the Little Beach embayment.
December 2009	Problems at Little Beach boat ramp lead to the installation of a barrier to stop longshore drift	Apparently, the continued supply of sand across Halifax Park was contributing to longshore drift southwards along Little Beach. From interpretation of available information, it appears that a lobe of sand had formed off the north-western point of Nelson Head, and that wind waves from a northerly direction wrap around the headland to push sand southwards. Seasonally, this would be most prevalent during summer.
June 2010	Barrier at Little Beach removed	Concerns were raised that the barrier was causing sand to build up at Halifax Park.
July 2010	Eyewitness accounts indicate that a 'dune' offshore of Fly Point began to grow in height	This is based on an account from Dave Harasti, who dived this site on a monthly basis during recent years, as part of PhD research work. Data relating to this is limited, as only survey data from 2007 is available. If related to the accumulation of sand offshore of the western end of Shoal Bay, it seems that sand has been moved here tidally. However, research by the University of Sydney indicates that flows between Halifax Park and Fly Point are dominated by ebb tides, and transport from Halifax Park to Fly Point is not supported by such a theory.
Autumn 2010	The Southern Oscillation Index becomes positive, beginning a "La Nina"	La Nina events are associated with statistically stormier weather. In New South Wales, these events are correlated with larger waves and a doubling of the frequency of coastal storms (Ranasinghe et al., 2004). Furthermore, waves come from a more easterly direction and are more

When	What	Why / Details
	event	capable of attacking the western end of Shoal Bay (Section 2.5.2) This event has subsequently evolved into one of the most significant La Nina events of the past century.
September October 2010	Significant sand moves from Shoal Bay, inundating the Sponge Gardens at Halifax Park	The movement of sand does not appear to be correlated to a particular storm in the record at Sydney, although there were significant storms (H_s>4 m) during August, 2010. The pattern is consistent with an overwhelming build-up of sand offshore of the western end of Shoal Bay, followed by movement of a slug of sand onshore by tides and more moderate waves. Eyewitness accounts say: o *Sand began to move onto the foreshore and shallows of Halifax Park initially,* o *The sand continued to build in this area until the shoreward slope became so steep that the sand collapsed onto lower sections of the sponge gardens effectively smothering them;* o *The process continued in this manner with continual supply of sand from western Shoal Bay until the majority of the sponge gardens had been covered in sand.*
November, 2010	Port Stephens Council moves an estimated 20,000 m^3 of sand using land based machinery	This comprised some 7,000 m^3 of sand from the lower beach profile at Shoal Bay and 13,000 m^3 from Little Beach and above Halifax Park. At both locations, the sand was moved higher up on the beach profile, and some of the Little Beach sand was trucked eastwards to nourish Shoal Bay. In the following months, sand continued to accumulate at Halifax Park.
March, 2011	Inundation of sponges recorded at Fly Point	PSGLMPA records the inundation of sponge beds at Fly Point. However, this was not permanent and in follow up inspections, the sand was gone (but the sponge beds had been wiped out at this particular location).
June – July, 2011	Before the middle of June, sand was beginning to disappear from the middle levels of Halifax Park. However, following a storm in the middle of June, the sand had returned.	This was followed by a period of stormy weather in the second half of July, when an estimated 5,000 to 10,000 m^3 of sand was lost from the westernmost 500 m of Shoal Bay (pers. comm. Max Haste PSGLMPA).
August 2011	Continued inundation of Halifax Park	Aug inspections of Halifax Park dive site reveal most significant sand inundation event thus far as a consequence of the July storms.

Table 2-4 Sand Movement Processes, Figures 2-8 and 2-9

ID	Description
	<u>Figure 2.8</u>
1	Prior to the 1960's sand from Zenith Beach contributed to the overall sand budget of Shoal Bay. This supply has subsequently stopped through progressive vegetation of the dune between 1960 and 1990.
2	Numerous researchers have found that the dominant direction of sand transport along the Shoal Bay shoreline is from east to west
3	While the entire length of Shoal Bay has receded over the past 40-50 years, effects at the eastern end have been most severe, partly due to the proximity of development and the presence of assets such as the boat

ID	Description
	ramp and jetty. Major nourishment campaigns were undertaken in this area during 1986 and 1994. Periodic, minor relocation from western/central portion to eastern end has occurred for many years.
4	During late 1994, some 56,000 m^3 was extracted from this location to nourish the shoreline at eastern Shoal Bay
5	The curved entrance shoal has a significant impact on wave refraction patterns, particularly along the western end of Shoal Bay. A comparison of hydrosurveys from 1994 and 2007 indicates that this shoal moved some 150 – 200 m into Port Stephens over that period. The ongoing change associated with this shoal will impact wave focussing throughout the Port, making it difficult to predict future wave conditions along the foreshores. The patterns of change are commensurate with erosion across the leading faces of the flood tide delta and deposition further inside the entrance. Nevertheless, bed elevations within Shoal Bay appear to have remained relatively stable between 1994 and 2007.
6	During coastal storms in NSW (typically during winter) waves are focussed by the curved entrance shoal at (5) onto the western end of Shoal Bay. During periods of positive SOI (La Nina), preliminary modelling indicates that changes to typical storm waves would result in this effect being enhanced. Erosion of the western end of the Shoal Bay shoreline results. Modelling indicates that complex wave transformation processes lead to waves obliquely approaching the Halifax Park shoreline, which is ideal for driving sediment transport from east to west.
7	Measurements by Austin *et al*. (2009) show that tidal currents along this length of foreshore are overwhelmingly dominated by currents from east to west. When combined with the sand stirring action of waves hitting the shoreline of western Shoal Bay, a net transport towards Nelson Head results
	<u>Figure 2.9</u>
8	Sand transport processes along Shoal Bay encourage the formation of a lobe of sand. The lobe is likely to vary in size and extent depending on prevailing conditions.
9	Sand bypasses the headland within the upper shoreface. The rate of sand bypassing is variable, as indicated by the residual sand on the northern shoreline of Nelson Head, which ranges from effectively nothing (late 1990s / early 2000s) to a broad sandy beach (re-established since about 2008). As sand is transported along the upper shoreface, some is likely to slump down the steep edge, through the Halifax Park sponge gardens and into the deeper tidal channel. This sand is likely to be carried away quickly by the swift tidal currents in this area.
10	As sand is pushed into the tidal channel, either off the sand lobe or down the steep slope from the upper shoreface, it is transported by swift tidal currents to form ebb tide and flood tide sand splays, with deposition occurring where current speeds decrease. The flood-tide splay could extend some distance westward, and may be contributing to increases in the size of sand dunes offshore of Fly Point, although this process requires further investigation.
11	Refracted swell waves strike the shoreline of Halifax Park obliquely, helping to transport sand from east to west. A proportion of the sand moving along the upper shoreface will slump into deeper waters due to over-steepening of the bed profile.
12	A second lobe of sand has accumulated at this location, resulting from continued supply of sand along the northern Nelson Head shoreline. Port Stephens Council removed sand from this area in late 2010.
13	Wind waves originating from the north-east to north-west and refracted swell waves coming around Nelson Head impact on the shoreline at Little Beach obliquely, causing on-going transport of sand southwards towards the boat ramp where it can interfere with boat launching activities.



Title:
Conceptual Model of Sand Movement

Figure: 2-8

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Approx. Scale

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Filepath : K:\N2128_FlyPointDredgingStudy\Docs\Figures\Figure2_8_20110727_ConceptualMorphologyModel.WOR

Title:
Likely Sand Transport Around Nelson Head

Figure: 2-9

Rev: A

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3 ASSESSMENT OF POTENTIAL MANAGEMENT ACTIONS

3.1 Shoal Bay Management Plan

The Shoal Bay Management Plan was prepared by MHL (2001) following a series of technical assessments by MHL into the coastal processes of Shoal Bay. Recognising the long history of nourishment of Shoal Bay beach, along with the construction of shore normal structures such as the boatramp and jetty, the Shoal Bay Management Plan aims to maintain maintenance and enhance the natural character of Shoal Bay, whilst accommodating the natural dynamic beach variability and ensuring the continuation of the beach and foreshores as a superior recreational locality.

The Plan indicates that the preferred approach to management of the identified beach recession at Shoal Bay is through regular beach renourishment of the eastern end of the beach using sand sourced (mainly) from the western end of the beach on a twice-yearly basis. The behaviour of the beach should be closely monitored over time and the frequency and method of sand placement reviewed regularly. The volume of material to be moved (twice yearly, outside of major tourist seasons) would be approximately 2,000 to 3,000m^3. The Plan identifies that sand is to be taken from the western end of the beach between Anzac Park and Nelson Head, by skimming approximately 200 – 350mm of sand from the beach over an area of 600m long by 15m wide.

The Management Plan also includes ancillary works to provide improved beach access and to enhance the beach amenity. An emergency plan for the management and restoration of the beach is also recommended by the Plan, such that the efficient protection of the beach and restoration of the beach amenity can be undertaken within acceptable timeframes.

Although the Shoal Bay Management Plan was developed in 2001, it appears that there has been no implementation of actions or strategies documented in the Plan since that time.

3.2 Areas Requiring Sand Removal

The areas requiring sand removal have been prioritised giving consideration to the following aims:

- Protecting undamaged areas within dive sites from further degradation;
- Limiting the on-going movement of sand from Shoal Bay around Nelson Head along the upper shoreface;
- Removing existing sand from within the dive sites, where possible; and
- Enabling tidal processes to scour sand from middle and low levels of the underwater profiles.

On the basis of the above aims, locations requiring sand removal are prioritised as follows (higher priority areas shown on Figure 3-1):

Higher Priority Areas

1. Offshore of Fly Point: to reduce the risk of Fly Point being affected from further sand inundation;
2. Sub-aerial beach and sand lobe immediately east of Nelson Head: to reduce the main source of sand to Halifax Park;

3. Sub-aerial beach, western Shoal Bay: To narrow the beach width and provide for some capture of longshore transport, and delay reformation of the sandy lobe that has formed offshore;
4. Foreshore, Halifax Park: To remove any excess sand from the upper profile at Halifax Park, preventing the further slumping of sand into the lower profile;

Lower Priority Areas

5. Sub-aerial Little Beach: This area is a lower priority in terms of protecting dive sites. The area was cleared during November 2010 and the main reason for dredging in this area is to protect operation of the boat ramp.
6. Sub aqueous slope, Halifax Park: Evidence suggests the natural clearing of sand in this area by tides, providing any new sand supply is limited. Given the likely expense of delicate sand removal operations that would need to be employed, monitoring this area to assess its response to removal from other initiatives is recommended in the first instance.
7. Deep Channel North of Nelson Head: Again, it is considered likely that tidal currents will assist in clearing this area, if sand accumulation is problematic, and recommend monitoring as a suitable initial option.

3.3 Options for Placement of Sand

There are several options that can be considered for placement of the sand removed to be from the priority areas. These options include:

- Nourishment of the eastern foreshore of Shoal Bay. There is limited capacity to accommodate sand within the existing beach profile, although the periodic placement of sand onto this foreshore does form the basis for the previous Shoal Bay Management Plan;
- Local stockpiles at the eastern end or western end of Shoal Bay. Given the limitations of immediate demand for nourishment onto the eastern end of Shoal Bay, there would be merit in stockpiling sand that can be accessed and placed on an as-needs basis. Depending on space restraints and other amenity / aesthetic constraints, there may be opportunity to stockpile sand within areas close to the foreshores at the eastern end or the western end of Shoal Bay. It would be important that these stockpiles are outside the active beach profile and outside the storm bite zone, so that the material is not introduced to the beach system inadvertently;
- Nourishment of Jimmy's Beach or other locally receding foreshores. There is an on-going demand for nourishment at Jimmys Beach on the northern side of Port Stephens. There are also receding foreshores along other part of the Port, which are compromising amenity. There may be some scope for using the sand extracted from the priority areas for localised nourishment works, depending on the cost penalties associated with transportation. To this end, sand could also be used for on-going nourishment works of Stockton Beach (it is understood that this sand reserve is currently being investigated as part of a Sand Scoping Study for Stockton Beach by Newcastle City Council);

Title:

Priority Areas for Removal

Figure:

3.1

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BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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- Disposal within the deeper sections of Port Stephens. The FTD is slowly migrating into Port Stephens, and as it does so, it gradually infills the deeper paleo valley that forms the underwater bathymetric profile. For small volumes of sand, it may be possible to dispose of dredged material on the distal (landward) face of the FTD. This approach has been employed for dredging within Swansea Channel at Lake Macquarie, where the FTD is migrating into the deeper lake at a rate of about 1m/year.

- Offshore disposal. If no onshore or nearshore disposal sites can be found, then disposal of the sand offshore could be an alternative. Although the material is unlikely to be contaminated, it would need to be carefully assessed for environmental impacts. Disposal would typically be in an area considered beyond the active sand transport zone, and may be in waters of 30+ metres. Offshore disposal usually comes at a high cost, as the material needs to be barged and dumped in open water.

  As an alternative to offshore disposal, dredged material could be barged 30km down the coast and sidecast into the surf zone of Stockton Beach, to help meet the nourishment needs of this erosion coastline. Previous nourishment works at Stockton have involved placement of approximately 100,000m^3 of sand into the surf zone from dredging of the nearby Newcastle Harbour navigation channel.

  Costs associated with offshore disposal or Stockton Beach nourishment would be high, and would involve specialised equipment and contractors. Mobilisation costs of the equipment alone (up to $1M) would generally make this option cost prohibitive unless the equipment can be used for other works, thus offsetting some of the set-up and mobilization.

For any of the disposal options, careful consideration would need to be given to a wide range of potential environmental, social and economic impacts. Indeed, disposal of the material can be a major component of the total costs of a dredging campaign, and therefore a clear indication of feasible disposal options is needed in order to determine expected total costs of dredging works.

It is anticipated that disposal options would be more carefully considered at the next stage of investigations, which would then consider environmental impacts and social constraints.

3.4 Estimates of Sand Volumes for Removal from Priority Areas

Estimations of sand volumes to be removed are difficult due to the lack of data. The general approach has been to:

- Compare the 1994 hydrosurvey with the 2007 hydrosurvey and LiDAR data along the foreshore to estimate changes during this time. Due to the availability of data, 1994 has been adopted as a baseline for volume calculations;
- Compare 2006 aerial photography to more recent aerial photography in GIS to estimate more recent changes; and
- Combine these findings with other measurements and anecdotal evidence to estimate volumes requiring removal.

The volume estimates are described in Table 3-1 for the priority areas only. The estimates are preliminary because of the uncertainty in calculations, which would ideally be based on direct measurements that are generally not available. It is understood from discussions with the Office for Environment and Heritage that the availability of bathymetric LiDAR information is imminent, however, it could not be provided for the present study.

Table 3-1 Preliminary Sand Removal Volume Estimates (priority areas only)

Location	Volume	Discussion
1-Offshore Fly Point	20,000 m^3	Data within this area is limited. Anecdotally, it is understood that a pre-existing 'dune' offshore of Fly Point has grown in recent years. Plots of bathymetry from swath mapping undertaken by the PSGLMPA in 2005 and 2011 were provided, although the coverage is limited offshore from Fly Point. The raw data could not be provided in time for completion of this report, so only inaccurate methods could be employed. An estimated ~0.5 m increase in height in this area has occurred from 2005 to 2011 over an area of about 40,000 m^2. The assumptions here are crude, and additional comprehensive survey of the area should be obtained, analysed and compared to previously available data before proceeding with any works in this area.
2-Subaerial beach and sand lobe, east of Nelson Head	60,000 m^3 in sand lobe and 25,000m^3 in sub aerial beach (85,000m^3 in total)	The amount of sand that had deposited on the sand lobe since 1994 was calculated from the comparison of 1994 and 2007 surveys. An area of around 55,000 m^2 with average deposition of some 0.6 m was calculated giving a volume of around 35,000 m^3. Recent reports from PSGLMPA and data presented by Harris (2009) suggest a typical storm may move around 5,000 m^3 from the western end of the beach onto the sand lobe. Assuming 5 such events occurred between the survey of 2007 and the onset of positive SOI conditions in Autumn 2010, and a further 5 have occurred since then, an additional 50,000 m^3 may have been added to the shoal. However, it has also been assumed that around 50% of that sand would have been lost under tidal and wave action. This results in an estimated 75,000 m^3 of sand to be removed from the sand lobe. From Aerial Photography, it appears the shoreline position and beach width at the western end of Shoal Bay has not changed markedly. However, sand appears to have accumulated on the sub-aerial beach. Figures from Harris (2009) show net erosion of around 5 m at the shoreline over a 12 month period, however this profile may be in an area prone to wave focussing and erosion. In estimating this volume, it has been assumed that sand can be removed over the full profile height (between 0.0 m AHD and ~ 5 m AHD) along a beach length of 150 m south from Nelson Head (avoiding the removal of sand from in front of permanent assets). This gives a total volume of 25,000m^3. ,
3-Subaerial Beach, Shoal Bay	25,000 m^3	Similar to the sub-aerial beach removal adjacent to Nelson Head, additional sand extraction along a beach length of 150m. When combined with the removal of sand adjacent to Nelson Head, this will form a "trap" for longshore transport at the western end of the beach. Sub-aerial beach removal can be done relatively effectively using earthmoving equipment, such as dozers. Working with 'dry' material, as opposed to a 'slurry' when extracting subaqueous material (especially if dredged) means that dewatering is not required prior to transportation or stockpiling.

Location	Volume	Discussion
4-Foreshore, Halifax Park	7,000 m^3	Removal of sand from this area is expected to replicate work undertaken in December of 2010. Since that time, sand has continued to move along the foreshore of Halifax Park, and accumulate along the shoreline. Prior to November, 2010, De Luzuriaga (2011) indicates that 1.0 m of sand typically covered the previously rocky foreshore in this area. It has been assumed that a similar level of sand accumulation may have occurred since completion of Port Stephens Council's clearance operation in late 2010, by the time works begin. Over an area of some 7,000 m^2, this results in 7,000 m^3 of sand requiring removal.

3.5 Estimates of Longshore Transport Rate

Having reviewed the available information, it is considered that a single calculated average value for longshore transport needs to be interpreted with caution for the following reasons:

- The methods available for calculating longshore transport (CERC Equation, Kamphuis) are known to have a low level of accuracy;
- The curved entrance shoal apparently has a significant impact on wave refraction patterns, and is presently moving into the Port, meaning that areas subject to wave focussing will change over time; and
- The focussing effect of the entrance shoal on storm waves may cause significant changes to shoreline exposure between average and positive SOI conditions, such as has been experienced during the past 12 months (Figure 2-7). The annual transport rate onto the sand lobe and/or around Nelson Head within the upper shoreface may be several times more than during an 'average' year given these conditions.

Ideally, estimates should be based on measurements. Interpretations based on information gathered during the study are:

- Harris (2011) notes that between May 2008 and May 2009, around 10,000 m^3/yr was lost from Shoal Bay. Most of this sand was lost from the western areas of the beach during storms between March and May 2009. Harris' estimate only accounts for volumes above 0.0 m AHD. If sand below 0 m AHD were included, a transport rate of between 8,000 and 15,000 m^3/yr could be expected;
- Following the 1994 nourishment exercise, Watson (1997) monitored beach volumes along Shoal Bay for 28 months. Considering the two westernmost sectors (Sectors 4 & 5) used by Watson, it is clear that there were immediate gains in sand volume within Sector 4 following nourishment and that this rate diminished with time. Overall, around 28,000 m^3 accumulated in Sector 4 over a period of some 28 months, although it also seems that at least 10,000 m^3 (and probably more) may have initially passed from Sector 4 to Sector 5 very soon after the nourishment exercise. Sector 5 was apparently eroding from mid - 1994, and continued at a similar rate (around 5,000 m^3/yr net loss) following an initial gain of around 5,000 m^3 immediately after the nourishment exercise. Combining this information, a transport rate of around 16,500 m^3/yr over the period of monitoring is apparent, although this was probably enhanced as the beach adjusted to nourishment at the eastern end;

- The Shoal Bay Management Plan (MHL, 2001) estimates natural recession of Shoal Bay beach of some 5,000m^3/yr. Although largely mobilised by storm events, the sand would remain within the active beach profile (down to approximately -3m AHD), and would be transported alongshore towards the western end of the beach.

Although there is some variability in these estimates, it is considered that the average annual longshore transport rates into the western section of Shoal Bay would be in the order of about 10,000 m^3/yr. It is expected that most of this sand then moves offshore from the western end of the beach onto the sand lobe, where it is deposited, or is moved off the lobe and into the deeper tidal channel (then directed eastward with ebb tides or westward with flood tides), or moved back onto the upper shoreface of Nelson Head and onto the Halifax Park shoreline. It is important to appreciate that rates can vary significantly from year to year, ranging from virtually zero, to several times the average rate.

3.6 Community Values and Suggested Options

The community meeting on 19 July 2011 highlighted the significant value of the affected dive sites to many stakeholders. The issue of sand accumulation at the sites has economic ramifications for a number of businesses around Port Stephens and further afield. It may be important for further studies to quantify these values.

Ultimately, the stakeholders desire:

- Protection of those areas presently threatened (i.e. Fly Point for the purpose of this study); and
- Rehabilitation of those areas that have been damaged (i.e. Halifax Park).

This study primarily assesses the movement of sand. Minimising further smothering by sand and removing sand from already smothered areas are therefore the key objectives of the management strategies discussed below. Ecological recovery of damaged sites is beyond the scope of this study.

Community stakeholders suggested the following actions:

- Dredging;
- Pushing sand away from the shoreline and stabilising with vegetation;
- Constructing a groyne at the western end of Shoal Bay; and
- Removing sand from the shoreline and shallower parts of Halifax Park as a priority.

In addition to these options, government stakeholders raised the following points:

- Sand won from the site could potentially be sold commercially to offset the capital outlay, however, during recent sand removal activities at Halifax Park (2010), no commercial operators were willing to undertake the exercise, even if royalties were waived, due to the complexities of dewatering and washing the dredged material. Sand stockpiled at the northern end of Little Beach is freely available at present, and is not being taken;
- Construction of a sand trap at the western end of Shoal Bay is considered a positive option; and
- Work is needed to remove sand that may soon migrate along Little Beach under the influence of wind and swell waves, which refract around Nelson Head.

The issues of high expense and potential funding arrangements, and the potential for integrating with other projects (e.g. a shared dredger between Port Stephens, Lake Macquarie & Tuggerah Lakes) were raised, however, detailed consideration of these issues is beyond the scope of this study and would involve broad political involvement. An assessment of potential options is limited to evaluation of qualitative benefits and indicative capital and ongoing costs, as detailed below.

3.7 Short Term Management

A number of activities that could be utilised in a short term strategy for dealing with accumulated sand are summarised and assessed in Table 3-2 overleaf.

Table 3-2 Available Actions for Short Term Management

Options	Constraints, Benefits, Environmental Impacts & Discussion	Capital Cost	Assessment
Do nothing	Sand will continue to bypass Nelson Head, at least in the short term. More sand may accumulate at Fly Point. By next summer, Halifax Park may be completely covered with sand. This would have flow on effects to the local economy and small businesses in the area. With the onset of summer, sand accumulation at Little Beach, including adjacent to the boat ramp may again become an issue, depending on the rates of transport over the next few months.	*$0*	STATUS QUO ⟷
Dredging	The most likely and cost effective method of dredging the subaqueous clean marine sands is by cutter suction dredger. Areas such as western Shoal Bay are subject to high energy wave events and strong tidal currents. Dredging from a more sheltered location inside Tomaree Headland in 1994 was only possible for 50% of the available time, meaning the per cubic metre rate is likely to be relatively high. Sand pumped ashore as a slurry can be handled in a number of ways such as (i) dewatering locally on the beach face, and subsequent removal by truck or to nourish upper parts of the beach profile (ii) dewatering in purpose built onshore settlement ponds and subsequent trucking to final destination (this requires a lot of space) (iii) pumping to a final destination for direct nourishment (e.g. Eastern Shoal Bay ~ 2.5 km; Jimmys Beach ~ 4 km). All operational options involve some loss of beach access while the works proceed and, depending on the location, some interference with navigation. Dredging can also involve sub-aqueous disposal at nominated disposal locations. As discussed in Section 3.3, these could include areas within Port Stephens, beyond the active FTD, or they could be offshore locations, beyond the active beach coastal zone.	*$500,000 site establishment & $20-$30/m^3. Higher costs if process involves significant transport of material (eg offshore disposal)*	✓ HAS MERIT
Land Based Excavation	Land based excavation has already been employed at the site in Little Beach. It is relatively cost effective but limited to the immediate beach face and shallow, protected nearshore areas. Access needs to be arranged and an area set aside for stockpiling, either permanently or temporarily prior to transport elsewhere by truck.	*$10,000 site establishment & $5/m^3 (sand stockpiled locally), up to $8/m^3 if trucked and spread up to 3km away*	✓ HAS MERIT
Diver Dredging	Diver Dredging comprises the underwater, hand held operation of a suction hose connected to a slurry pump, eventually discharging the sand/water mixture ashore. Specialised personnel are required to operate the equipment, which can remove up to 15m^3/hr. This method could be employed in areas where sand has inundated within the rocky substrate (e.g. Halifax Park) and a cutter suction dredger is	*$125/m^3 removal + pump ashore.*	✖ NOT SUITED

Options	Constraints, Benefits, Environmental Impacts & Discussion	Capital Cost	Assessment
	likely to cause significant damage. Aside from the low rates of sand removal, within the areas where such methods might be employed there are only short windows of opportunity to undertake the work at slack tide due to the otherwise strong tidal currents. These two factors make the method very expensive. The suction hose also stirs sediment, and it would be difficult to control the dispersion of sand with even low tidal currents. The availability of suitable contractors is uncertain in Eastern Australia. This option should only be considered as an emergency measure only.		
Temporary Structures	If dredging were to be employed, part of the sand could be used to construct temporary "groyne" structures, comprising shore normal, filled geotextile tubes. There are a number of potential locations where these tubes could be placed, with the primary aim of widening the beach and increasing the storage capacity at the western end of the Beach, thus limiting bypassing onto the Halifax Park shoreline. Any additional accumulated sand could then be moved from the beach by conventional land-based equipment at relatively economic rates. While relatively inexpensive if dredging is being undertaken in adjacent areas, further investigation would be required to determine the impact that these structures would have on local sediment processes and pathways, and the subsequent impacts on wave and tidal hydrodynamics. This option introduces a risk that additional sand is being stored in relatively close proximity to the sensitive habitats being protected. Should the structure fail, this stored sand could suddenly be re-introduced to the sediment pathway, which would smother downdrift localities. The temporary nature of these structures would need to carefully consider how and when they would be removed, and the ramifications of such actions. This option should be considered further but with extreme caution.	*$60,000 (assuming around 60 m of tubing)* *Plus all dredging costs*	✓ HAS MERIT
Re-profiling of the beach	This action was undertaken at the end of 2010, where sand was moved from lower parts of the profile onto areas higher on the beach. Subsequent stormy weather eroded some of this sand, returning it to the lower profile and swash zone, where it would return to the longshore sediment pathway. If the sand was stockpiled beyond the immediate storm bite and active beach zone, there would be some merit in re-profiling. It is considered, however, that there would be limited scope for stockpiling sand behind the existing beach. Therefore, while this may be a suitable short-term action, it does not address the on-going need for removing sand from the western end of the beach. This option should only be considered if it is in combination with a mechanism for transferring the sand to an alternative location (eg the eastern beach foreshore – see below).	*$10,000 site establishment & $5/m^3*	✓ HAS MERIT

Options	Constraints, Benefits, Environmental Impacts & Discussion	Capital Cost	Assessment
Transport and Placement of Sand onto Beach at Eastern Shoal Bay	Eastern Shoal Bay has a history of erosion, requiring nourishment regularly over the past three decades. If the dive sites are to be protected, it makes sense to transport the sand back to the eastern end of Shoal Bay. This does not introduce additional sand to the beach compartment, and potentially deals with two problems (ie win-win). This formed the basis of the Shoal Bay Management Plan (MHL, 2001), which has not been implemented to date. While erosion at eastern Shoal Bay may not be a problem immediately, having a ready supply of sand stockpiled or otherwise stored at this end of the beach to deal with erosion problems when they arise in future seems sensible (assuming suitable and adequate storage facilities). Transporting the sand is not without issues. Numerous truck movements would be required to take material by road. Other means for transporting the sand along the beach may interfere with access, and create noise. Furthermore, appropriate locations for placing the sand in Eastern Shoal Bay would need to be identified.	*$10,000 site establishment & $5/m^3*	✓ HAS MERIT
Commercial Sale of Sand	A preliminary investigation into the commercial sale of dredged sand was undertaken prior to sand clearing operations in late 2010. Unfortunately, no contractor could be found who was willing to remove the sand. Larger volumes of sand involved in priority removal areas may prove more commercially viable. More detailed study needs to be undertaken to investigate this issue. It has been assumed that the cost for transporting sand (stockpiled adjacent to the removal area) may be offset by the commercial value of the material. This would result in a net loss of sand from Shoal Bay, and won't address future erosion issues at its eastern end.	*$10,000 site establishment & $5/m^{3,} balanced by commercial sale at about $20/tonne = Approx. Break Even*	✓ HAS MERIT

3.8 Long Term Management

Sand will continue to be transported from east to west along Shoal Bay. From time to time, sand will build up on the western end of Shoal Bay and will bypass around Nelson Head. At times (such as presently being experienced), the rate of bypassing may be high, which may have repercussions for wider environments and habitats within the estuary.

In the absence of sand being added to the system, the movement of sand will continue to manifest as long term erosion of Shoal Bay, with the most severe impacts being felt at the eastern end. The Shoal Bay Management Plan (MHL, 2001) recommends the regular (twice yearly) transfer of sand from the western end of the beach back to the eastern end, in order to maintain beach amenity and limit further shoreline recession. This Plan has not been implemented to date.

If allowed to continue with no form of abatement, the beach at Shoal Bay will eventually adjust to an equilibrium shape where the alignment of the embayment limits longshore transport and loss out of the beach compartment. Also, before reaching this equilibrium alignment, it is likely that many existing assets located behind the present-day beach would be impacted.

Long term management will be required of this system, with a particular emphasis on addressing risks of erosion of Shoal Bay as well as bypassing of Nelson Head and smothering of dive sites by sand. Furthermore, it is expected that projected sea level rise will also have an impact on the equilibrium profile and alignment of Shoal Bay, potentially exacerbating the current natural tendency for recession.

Long term management of Shoal Bay is not covered in the scope of this preliminary investigation, as it will involve substantial consideration and input by broader stakeholders likely to be affected in the future. Notwithstanding, brief discussion is provided on two likely long term solutions that would aim to maintain the existing shoreline, namely:

- Groyne at western Shoal Bay; and
- On-going sand removal.

3.8.1 Groyne at Western Shoal Bay

A groyne (or series of groynes) along the western end of Shoal Bay may provide additional storage of sand prior to bypassing around Nelson Head. Building a structure(s) such as this in a relatively exposed coastal location would be expensive and would also have significant impacts on local coastal processes and community amenity (including aesthetics). A preliminary cost for the construction of a groyne would be in the order of $2M.

The structure would need to be designed to minimise the possibility of adverse impacts on tides within Shoal Bay and throughout broader Port Stephens. Further, the main function of the groyne, to prevent sand from bypassing Nelson Head, would also remove any positive aspects relating to the sand movement. For example, if sand bypassing were completely removed, then this may eliminate supply to Little Beach, resulting in a narrowing, or loss of the sandy beach in this location. Further, the balance of sand moving through Halifax Park prior to its recent inundation may have been a feature that had some ecological benefit.

All environmental and social impacts would need to be carefully considered before advancing this as an option.

3.8.2 Ongoing Sand Removal (as per the existing Shoal Bay Management Plan)

Following the initial removal of sand, an ongoing process of active sand removal and relocation may be required. The need for this may vary from year to year, but initial estimates suggest a rate of 10,000 m^3/yr may require relocation. This is essentially the same as the recommendation in the existing Shoal Bay Management Plan, wherein 2,000 – 3,000m^3 should be transferred from the western end of the beach to the eastern end of the beach, twice yearly.

The major risk of this management strategy is the need for long term commitment and monitoring, even during times where there is no visible benefit from the work.

The strategy would need to consider many factors, such as how much bypassing is acceptable, and/or should it be encouraged in some circumstances. Also, the removal of sand from western Shoal Bay would need to consider the loss of beach amenity and removal of the store of sand protecting back beach assets from coastal erosion, particularly with the onset of climate change.

The most obvious location for placement of the removed sand is the eastern end of Shoal Bay, where erosion has been most common in the past.

While the Shoal Bay Management Plan was developed primarily to manage on-going shoreline erosion and recession, the recommendations made here also target the excess accumulation of sand at the downdrift end of the beach. Significant nourishment works of Shoal Bay over the past 20 years or so has introduced a large quantity of 'external' sand to the system. As such, the beach has reached capacity within the accumulation area without a commensurate depletion within the recession area. In order to return the beach to a manageable "closed" loop system, there may need to be removal of sand from the Shoal Bay beach system in entirety.

Options available for on-going sand management are discussed below:

- Fixed in place sand interception and pumping infrastructure can be installed to take the sand from the beach and nearshore area and pump it back along the beach to eastern Shoal Bay. The need for permanent pipelines and power are draw backs of this solution. Some of the proprietary units presently available are relatively easy to remove, and unobtrusive when installed. A review of available products would be required. Further, some sand could be piped around Nelson Head, if desired, to provide sand to Little Beach without disturbing Halifax Park in between. Preliminary purchase and installation costs for a "sand shifter" unit, one of the proprietary devices available, are estimated at $0.5M with an ongoing cost of around $10 / m^3;
- Repeated one-off campaigns of dredging and sand removal, whenever the need arises. This provides a greater deal of flexibility, with the work being done as required. Establishment costs for dredging campaigns are relatively expensive, with per cubic metre rates very dependent on the location of disposal. Dredging would likely be considered if there is an on-going need to reduce the total volume of sand from the entire beach system (with disposal elsewhere, eg within the Port or offshore). Costs are expected to be prohibitive from an on-going management perspective.

- Sand removal from the beach face to establish, and then periodically re-establish, a ‘sand trap’ at the western end of the beach. This more pro-active approach would be considered as an alternative to reactive as-required dredging. Longshore transport would fill this trap until it reaches capacity, at which time it could be maintained (ie re-dredged). Monitoring would be required to measure the progress of infilling of the sand trap, which would inform the need for upcoming maintenance dredging works. The cost for each campaign would vary with the amount of sand needing removal. It is expected that the larger the amount of sand removed from the trap, the longer it would take to refill (although there would be a trade-off as a deeper trap would actually increase the rate of infilling, as the natural system tries to ‘smooth out’ bathymetric variances). Sand removal of some 50,000m^3 every 5 to 10 years would cost in the order of $400,000, providing there is a suitable location for placement (at least some of this is expected to be placed back on the eastern end of the Shoal Bay foreshore).

4 RECOMMENDED STRATEGY

4.1 Overview of Short Term Strategy

A short term strategy has been devised and approximately costed, based on information in Table 3-1 and Table 3-2. More detailed costs cannot be provided until such time that volumes to be removed can be better quantified, which required additional bathymetric survey of Shoal Bay. Additional information and assessments are required in order to progress these works, as outlined below and in Section 4.2.

The recommended short term strategy (Figure 4-1) is based on a reasonably sound understanding of overall sediment transport processes, however, the overall estimates of sand volumes (and hence costs) are indicative only and require further clarification. The strategy assumes that funds can be sourced, and there is a willingness to undertake the necessary work.

The recommended short term strategy comprises:

1. Obtain detailed bathymetric and beach survey to validate the findings of this study and the quantify the volumes of material to be removed from the high priority sites. This is essential to obtain better cost estimates than the preliminary figures provided below.
Cost = $30,000 approx.;

2. Undertake detailed design and environmental assessment for subaerial sand removal from the western end of Shoal Bay beach and from Little Bay beach (total volume approximately 57,000m^3). Disposal options would need to be fully explored as part of the environmental assessment, but could include local back-beach areas adjacent to the western end of the beach as well as locations near the eastern end of the beach, where it can then be used easily in the future for sand nourishment. It is expected that some of the material could be placed immediately on the eastern end of the foreshore, while some material could also to taken to nourish other eroding foreshores around Port Stephens (subject to liaison with PSC to confirm locations, suitability, etc). Consultation with the local sand supply industry should also be undertaken to explore opportunities for commercial use and sale of the material (with any royalties to potentially offset some of the costs).
Cost = $150,000 approx.;

3. Following approval of works, seek an appropriate contractor and undertake subaerial removal from the western end of Shoal Bay beach and from Little Bay beach. It is considered that the removal of subaerial sand would follow an easier assessment path than subaqueous dredging, and therefore these works have been recommended to be fast-tracked, with assessment costs commensurately lower that the dredging alternative (see below).
Cost = $400,000 approx. (assuming $5/m^3 for 32,000m^3 stockpiled locally, and $7.50/m^3 for 25,000m^3 carted up to 3km and spread, plus $50,000 allowance for set-up and site works);

4. Detailed design and environmental impact assessment for subaqueous dredging at Fly Point and the lobe adjacent to Nelson Head (total volume approximately 80,000m^3). Once again, disposal options will be thoroughly investigated as part of the environmental assessment, and should consider on-shore locations as well as sites within the Port and further offshore. Again, consultation with the local sand supply industry should be undertaken to explore opportunities for commercial use and sale of the material (with any royalties to potentially offset some of the

costs).
Cost = $300,000 approx.;

5. Following approval of works, seek appropriate contractor and undertake the subaqueous dredging at Fly Point and the lobe adjacent to Nelson Head.
Cost = $2.5M approx. (assuming 80,000m^3 at $10/m^3 for extraction and additional $15/m^3 for pumping and disposal, plus $500,000 for set-up, mobilization and environmental protection works);

6. Ongoing monitoring for a period of two years, which would assist with the formulation of a longer term sand management study for Shoal Bay.
Cost = $120,000 approx.[7];

7. Prepare long term strategy (refer Section 4.3)
Cost = $50,000 approx.

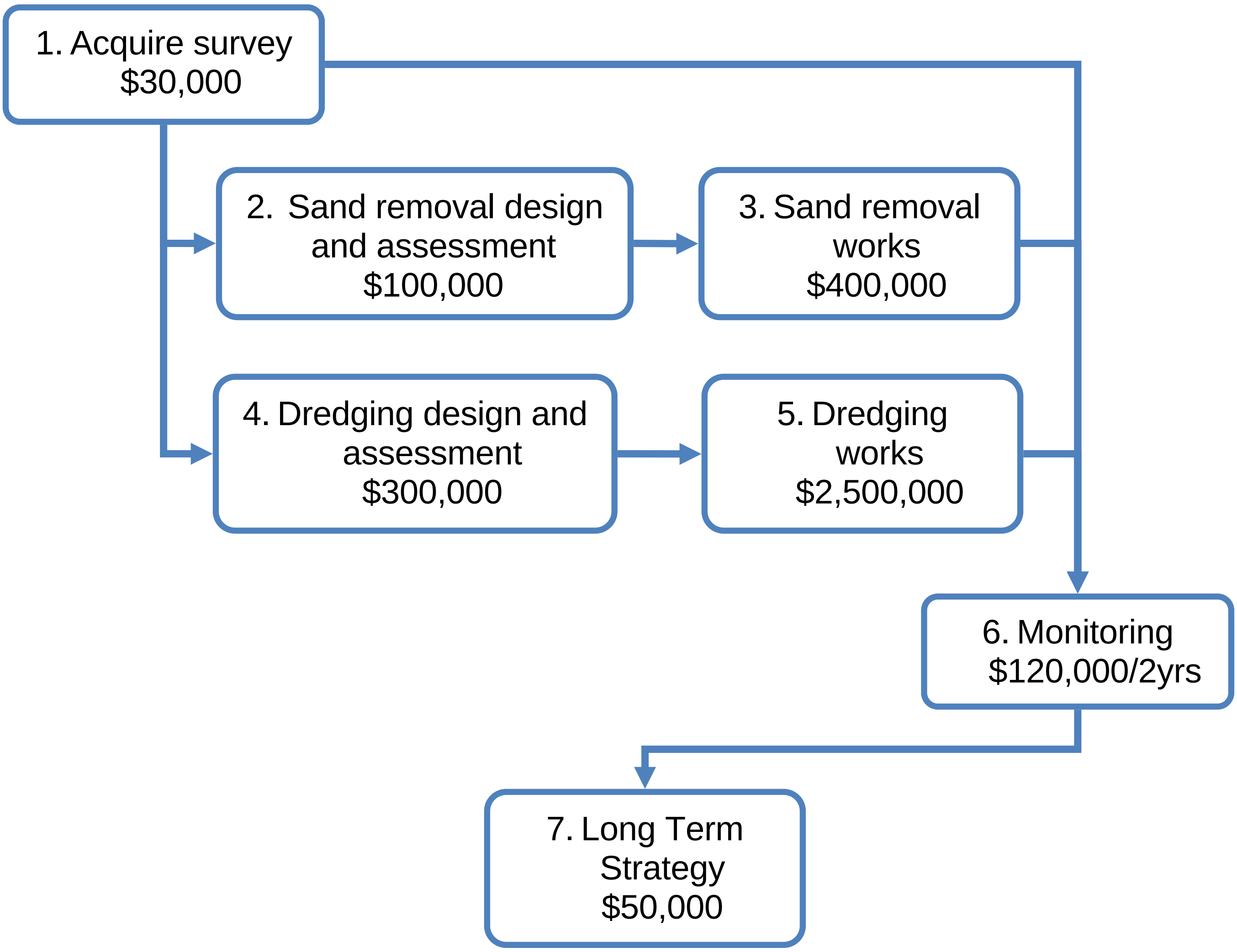

Figure 4-1 Short Term Strategy

[7] This monitoring only includes repeated surveys to measure and validate sand transport rates. More detailed monitoring studies may be required as part of a studies to support a long term strategy (e.g. ecological studies)

4.2 Required Data Collection and Additional Study

4.2.1 Survey

A comprehensive survey of the site is required. It should include all of the southern shoreline from Shoal Bay, Halifax Park, Little Beach, Fly Point and further west for some 300 m. The survey should capture the full extent of the deep channel running north of this area. The survey should extend for 500 m west and south of Nelson Head. The survey should also extend onshore to cover the active beach profile and dunes.

The purpose of this survey is to validate the findings of this study and provide the confidence required to complete the design of the short term works. In particular, data to validate the volume estimates is required.

The LiDAR data that is presently being sourced by OEH will provide most of this coverage, but additional hydrographic survey may be required.

4.2.2 Detailed Environmental Assessment and Approvals

Following acquisition of the survey, a more detailed environmental assessment should be undertaken, incorporating the following activities:

- Refined calculation of the volumes accumulated in various areas, based on more recent survey, and that acquired in 2007;
- Further consideration of the processes leading to sand accumulation at Fly Point;
- Consideration of existing coastal hazard lines and the appropriateness of sand removal from western Shoal Bay;
- Consideration of incoming monitoring data, as it becomes available;
- Additional wave and hydrodynamic modelling to assess the efficacy of placing temporary structures, and the impact of sand removal across a range of wave and tide conditions;
- Determination of whether a temporary structure can be used to offset some of the need (and expense) associated with the removal and transport of sand,
- Detailed examination of logistical constraints for the onshore treatment and handling of dredged sand;
- Detailed examination of transport options, and areas for emplacement;
- Detailed examination of commercial opportunities for the sale of dredged sand;
- Development of a detailed cost estimate;
- Refinement of the short term strategy;
- Development of detailed design drawings for the removal works;
- Preparation of environmental assessment and development approval documentation;
- Preparation of a technical specification for the works; and
- Liaison with approving authorities.

As outlined in Section 4.1, it is recommended that the environmental assessment be separate for sand removal from the subaerial beach, and subaqueous dredging. Sand removal from the beach is in accordance with the Shoal Bay Management Plan. It is expected to have fewer environmental constraints, but maybe more community issues.

Early consultation with the relevant regulatory authorities is recommended to identify an appropriate approvals process for both the sand removal and the subaqueous dredging. It may be possible that the works (at least the sand removal from the subaerial beach) could comply with provisions set out under SEPP (*Infrastructure*) 2007, and as such, a Part 5 (or the *Environmental Planning and Assessment Act, 1979*) approvals process may a possibility.

4.2.3 Ongoing Monitoring

The most useful data that can be collected in order to inform a long term management strategy for Shoal Bay comprises the following:

- Survey of the areas of key interest at no greater than quarterly intervals. This includes those priority areas outlined in Table 3-1. To be useful, monitoring surveys must link both the sub-aerial beach profile and the underwater nearshore profile to the depth of active sand movement. More frequent surveys should be undertaken immediately after any removal works, and additional surveys should be undertaken following major storms;
- Yearly surveys that replicate the extent described in Section 4.2.1 but extend to cover the whole beach along Shoal Bay. Again, profiling should extend both offshore and onshore to cover the entire active beach profile; and
- Collation of georectified Aerial Photography as it becomes available. These data can now be obtained digitally from a number of sources.

A number of survey methods may be employed, including boat mounted hydrosurvey, standard topographic survey, RTK GPS or remote sensing. Importantly, data should be accurately geo-referenced to AHD and a standard co-ordinate system. The involvement of a registered surveyor is recommended, with a representative vertical accuracy of less than 0.1 m being desirable.

4.3 Long Term Strategy

The Shoal Bay Management Plan (MHL, 2001) aims to address on-going concerns regarding recession, accumulation and maintenance of amenity along Shoal Bay beach. Coastal management within the site considered in this report, incorporating Shoal Bay through to Fly Point, will continue to be a challenge, and even more so while ever the Shoal Bay Management Plan remains unimplemented..

A key longer term sustainable outcome for Port Stephens would consider the integrated management of the coastal system and associated sand resources extending from the eastern end of Shoal Bay through to Fly Point. This should involve all principal players including (as a minimum) Marine Parks, Lands and Port Stephens Council.

Some actions that may be considered as part of a longer term strategy are discussed in Section 3.8. These are expensive options, however, with potentially significant environmental impacts that require ongoing commitment.

As a precursor to undertaking any of these long term actions, a broad ranging study should first be considered that investigates the following:

- The ongoing viability of preventing sand bypassing of Nelson Head, particularly considering the expected impacts of climate change;
- The ongoing viability of protecting existing commercial and residential development along Shoal Bay and determination of areas that are viable for future development;
- The recreational activities and likely response of Little Beach;
- Broader consultation with the community in and around Shoal Bay;
- Utilisation of state of the art numerical modelling methodologies, including morphological change over a variety of time scales, to assess the impact of implementing any long-term strategies being considered. The available models are continuously improving and should be validated to available data in and around the area in question;
- Ecological values, including a review of monitoring data, which may arise from attempts to rehabilitate the dive site at Halifax Park.

Much research has already been undertaken in and around the study site, some of which has been able to be reviewed as part of the present study. That information should be collated, assessed and integrated into the broader longer-term study described above. For example, a comprehensive survey of Port Stephens exists from 1969, and this could be digitised to enable comparison with more recent survey from 2007, to determine whether the theories raised by Frolich (2007) and Harris (2009) regarding behaviour of the FTD are sound. The study should also incorporate a thorough analysis into the findings of monitoring data proposed as part of the short term strategy.

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