Dampier Palms and Hampton Oval Redevelopment

Sand Renourishment Feasibility Study

Seashore Engineering
June 2018

Report 062-01-Rev1

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Cover Photograph

View north of beach in front of Hampton Oval (Photograph supplied by City of Karratha).

Document Control

Index	Author	Date	Review	Date	Comment
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1. Introduction

The City of Karratha (the City) has commissioned Seashore Engineering to investigate the feasibility of sand renourishment at Dampier Palms Beach, located at the southern end of Mermaid Sound (Figure 1-1). Sand renourishment is intended to increase the amenity of the beach, as part of the proposed Dampier Palms and Hampton Oval Redevelopment (Appendix A). Objectives of renourishment are to construct a wider beach and increase sand coverage over rock presently exposed along the shoreline.

Key factors likely to influence the feasibility of sand renourishment are the physical setting of Dampier Palms Beach and availability of suitable material. The physical setting influences the volume and extent of sand renourishment and affects the rate of future renourishment to offset ongoing losses. Investigations undertaken in this study have identified:

- Local geomorphology of the site, including extent of presently exposed rock;
- Potential drivers for coastal change, including tropical cyclones; and
- Historic beach changes;

Investigations have largely used existing information, including reports, metocean records, historic aerial photography, surveys and site photography.

Investigations to assess the potential stability of renourished material have included analysis of sediment sizes from the beach and possible sources, SBEACH cross-shore modelling, and evaluation of the directional wind wave climate assessment.

Two concepts for beach renourishment have been developed which consider the physical setting at Dampier Palms Beach, and potential cost for sand supply and placement from the Karratha Earthmoving. The concepts provide sand coverage over exposed rock along the shoreline, resulting in a sandy beach, following placement, approximately 80% of the time. The presence of a relatively continuous near-level rock platform around −1m AHD, limits the capacity to improve beach amenity at low tide. The rock platform at the toe of the beach will remain exposed approximately 20% of the time.

This study does not consider environmental or social impacts of beach renourishment at Dampier Palms Beach.

Figure 1-1: Site Figure

2. Local Geomorphology

The wider Dampier coast is described in detail in Damara WA (2011), including:

- *"The Dampier coast is characterised by rock features close to the beach which are evident along almost the entire coast. For the majority of the shore, there is a distinct rocky coastal scarp, fronted by a narrow, low-lying beach formation, which is in turn perched on a shallow low-tide rock platform."*
- *"The limited extent of beaches is determined by the low sediment supply to Mermaid Sound and the dominant role played by tidal currents in sediment transport. Under these conditions, there is a hysteresis[1] between erosion and recovery mechanisms, which limits the potential for vertical growth at deposition lobes. Instead, sedimentary features are strongly influenced by alongshore controls, including rocky headlands and coastal structures."*

Dampier Palms Beach is an west facing beach at the southern extent of Mermaid Sound (Figure 1-1). The beach forms the central portion of a 1200m long arcuate beach which is flanked by rocky headland to the north and south, which have been artificial extended by the installation of breakwaters for recreational and commercial harbours. These harbour effectively block sediment exchange to or from adjacent beaches.

The beach is highly sheltered, with available fetch for wind wave generation limited across to East Intercourse Island (2000m to northwest) and causeway (1500m to west). Installation of East Intercourse Island causeway has sheltered the beach by substantially reducing available westerly fetch for wave generation and blocking tidal flow through the southern portion of Mermaid Sound. The resulting changing in hydrodynamic forcing is likely to have contributed to progressive beach reorientation, with erosion near Dampier Palms and corresponding accretion in the south, evident in historic aerial imagery (refer Section 3.2).

The beach is perched on an almost continuous rock platform, which is exposed during low tides (Figure 2-1). Alongshore sediment transport at the beach is likely to be driven predominantly by wind waves, particularly during tropical cyclones, when higher water levels are also possible. Sections of slightly elevated rock are evident as rock outcrops along the shore, providing local modification to alongshore sediment transport.

A creek outlet located on the south side of the Hampton Oval is subject to occasional flows during high rainfall events. Flows can supply sediments from upstream, and may scour the adjacent beach and dune, forming an ephemeral ‘sand splay’ on the lower beach.

[1] *Hysteresis – the lag in response exhibited by a body in reacting to changes in the forces.*

Figure 2-1: Site Photograph – Looking North along Dampier Palms Beach on 30/08/2017

3. Assessment of Available Datasets

This section identifies previous beach changes and infers potential drivers of coastal change at Dampier Palms Beach through assessment of available key datasets. Datasets assessed have included metocean records, site photographs, historic aerial photographs, and survey information.

3.1. METOCEAN RECORDS

Metocean datasets assessed in the following subsections are summarised in Table 3-1, with locations shown in Figure 3-1.

Table 3-1: Metocean Records Assessed

Description	Location	Data Period	Latitude (°S)	Longitude (°E)
Tropical Cyclones	King Bay tide gauge	1970-2017 (post satellite)	−20.6236	116.7491
Water levels	King Bay tide gauge	1982-2015	−20.6236	116.7491
Wind	Dampier Salt (BOM Station 5061, elevation 6.0m)	1969-1993	-20.7278	116.7483
	Karratha Aero (BOM Station 4083, elevation 5.3m)	1993-2017	-20.7097	116.7742
	Legendre Island (BOM Station 4095, elevation 5.2m)	1992-2017	-20.3583	116.8431
Rainfall	Dampier Salt (BOM Station 5061)	1972-2017	-20.7278	116.7483

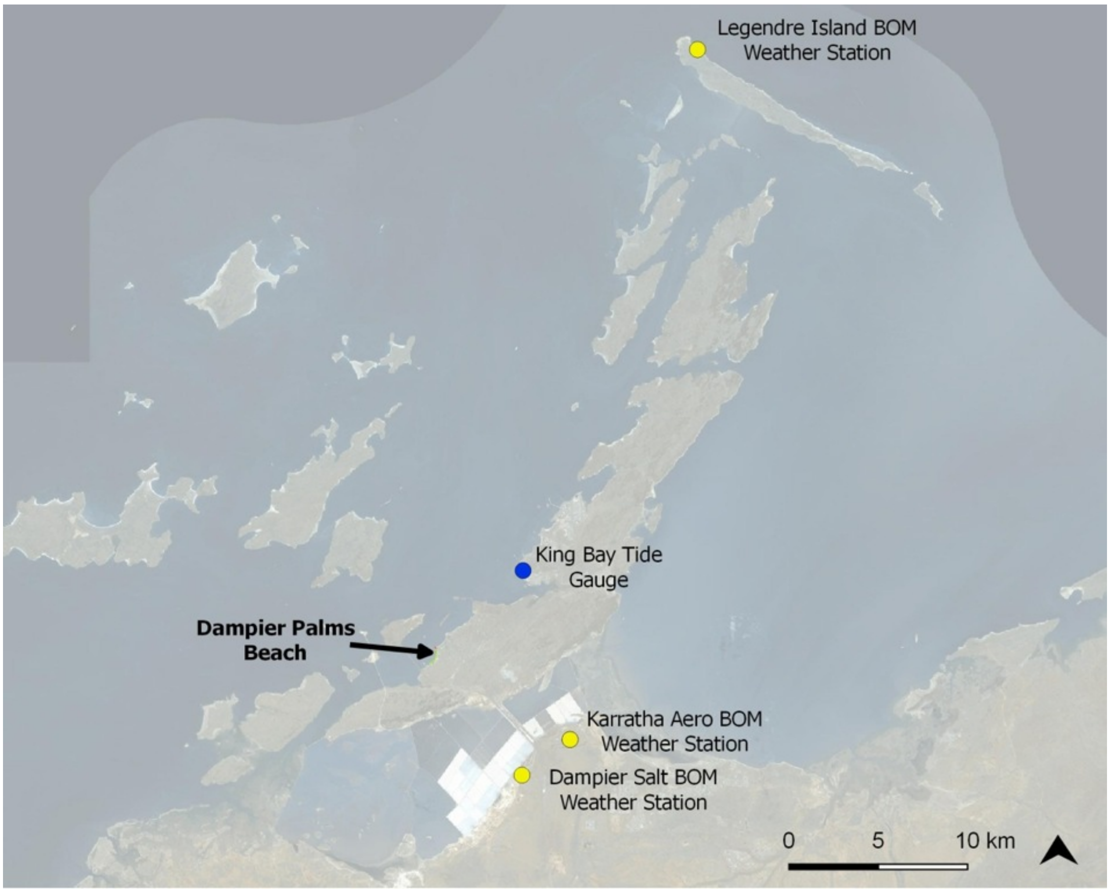

Figure 3-1: Locations of Metocean Data Collection

3.1.1. Tropical Cyclones

The potential for high waves and surge at Dampier Palms Beach during tropical cyclones is dependent on cyclone track and intensity, with onshore winds for wave and surge generation typically generated by cyclones which track to the west, and offshore winds generated which track to the east.

Interrogation of the Bureau of Meteorology tropical cyclone record in the post-satellite era (since 1970) has identified 24 cyclones which tracked to within 150km of Dampier, and had a central pressure of less than 980hPa (Table 3-2). These cyclones are considered most likely to have produced elevated wave, wind or water levels along the Dampier coast. Of these events, there were five events which tracked to the west as severe tropical cyclones (i.e. central pressure less than 940hPa).

Table 3-2: Significant Tropical Cyclones Likely Producing Strong Winds at Dampier
Cyclones listed tracked within 150km of Dampier and with a central pressure of <980hPa

Year	Cyclone Name	Cyc ID	Date	Nearest Point (km)	Bearing (°N)	Min CP (hPa)	Nearest CP (hPa)
1971	SHEILA	AU197071_10U	3/02/1971	58	98	925	925
1973	KERRY	AU197273_03U	21/01/1973	72	70	960	960
1975	TRIXIE	AU197475_10U	18/02/1975	26	276	925	931
	JOAN	AU197576_02U	8/12/1975	140	112	915	947
1977	KAREN	AU197677_10U	6/03/1977	36	8	970	971
1982	IAN	AU198182_13U	5/03/1982	130	343	964	964
1983	LENA	AU198283_05U	7/04/1983	121	55	980	980
1984	CHLOE	AU198384_16U	29/02/1984	55	139	955	958
1985	GERTIE	AU198485_06U	31/01/1985	30	62	973	974
1987	CONNIE	AU198687_01U	19/01/1987	101	129	950	965
1988	ILONA	AU198889_01U	17/12/1988	84	248	960	960
1989	ORSON	AU198889_10U	22/04/1989	63	228	905	923
1991	DAPHNE	AU199091_04U	23/02/1991	102	357	976	978
1992	IAN	AU199192_06U	2/03/1992	126	239	930	965
1995	BOBBY	AU199495_02U	24/02/1995	90	279	925	940
1996	OLIVIA	AU199596_14U	10/04/1996	116	222	925	930
1999	JOHN	AU199900_02U	14/12/1999	79	80	915	940
2000	STEVE	AU199900_06U	6/03/2000	21	311	975	975
2004	MONTY	AU200304_05U	1/03/2004	101	230	935	965
2006	CLARE	AU200506_05U	9/01/2006	29	328	960	960
	DARYL	AU200506_06U	21/01/2006	123	337	976	1902
	GLENDA	AU200506_14U	30/03/2006	81	315	910	924
2011	CARLOS	AU201011_17U	22/02/2011	18	118	970	980
2013	CHRISTINE	AU201314_04U	30/12/2013	56	123	948	950

(1) Cyclones which tracked west of Dampier with central pressure <940hPa shown in red highlight.

(2) Cyclones which tracked west of Dampier with central pressure >940hPa shown in orange highlight.

3.1.2. Wind

The Bureau of Meteorology has recorded coastal wind near Dampier at Dampier Salt (1969-1993), Karratha Aero (since 1993) and Legendre Island (since 1992). Data assessed is generally 3 hourly, with Dampier Salt recordings limited to daylight hours.

Winter and summer wind roses showing speed and direction frequency from the Karratha Aero record demonstrates the seasonal variation in wind climate (Figure 3-2). Directional bands for onshore winds at Dampier Palms Beach for wind wave generation are shown in red shading. The following is noted:

- During summer months, winds are dominated by moderate to strong WSW to WNW winds, which correspond to prevailing sea breezes. Winds are predominantly onshore at Hampton Oval Beach, generating wind waves across from East Intercourse Island and the causeway; and
- During winter, the sea breeze system weakens and winds become more mild and variable. There is limited occurrence of onshore winds at Hampton Oval Beach.

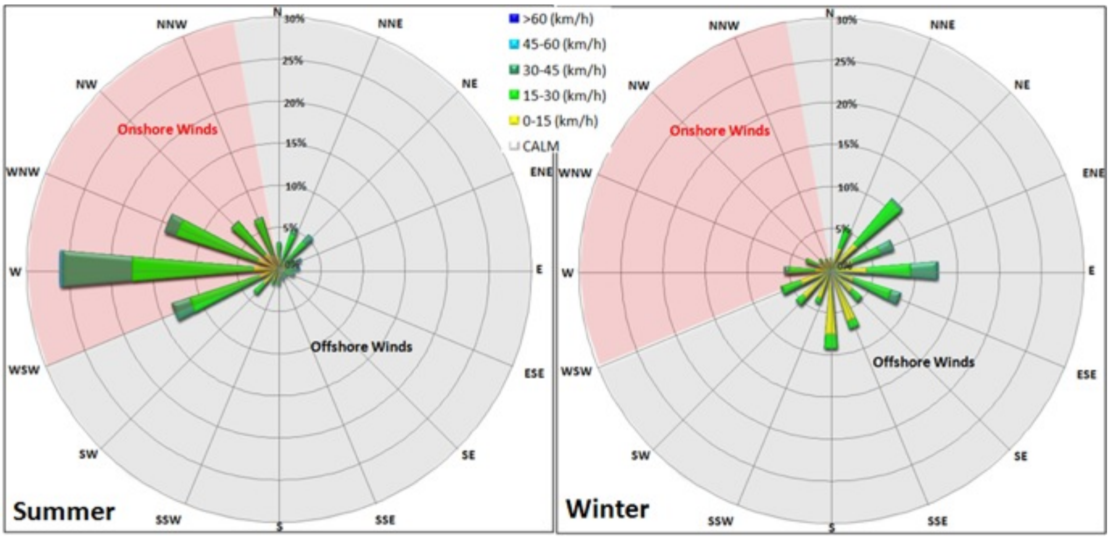

Figure 3-2: Summer and Winter Wind Roses at Karratha Aero 1993-2017

A wind rose plot showing the directional frequency of all winds above 45km/hr, demonstrates strong onshore winds almost exclusively occur from the west. However, the potential for extreme winds during the passage of tropical cyclones in all directions, depending on cyclone track, is recognised.

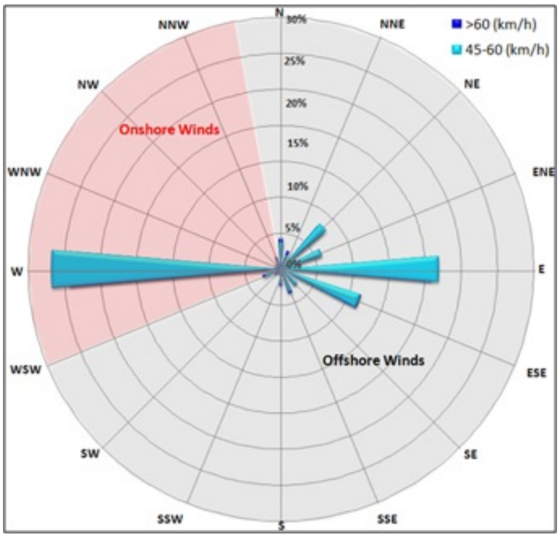

Figure 3-3: Wind Rose for Winds above 45km/hr at Karratha Aero 1993-2017

Wind speed observations from the combined Dampier Salt, Karratha Aero and Legendre records are shown in Figure 3-4. Comparison of the strong wind record against the Bureau of Meteorology tropical cyclone database suggests that all wind events above 70km/hr may be attributed to tropical cyclones (Figure 3-2). It is recognised that peak wind speed during a number of tropical cyclones were missed, with causes including instrument failure during peak winds or the timing of recordings (i.e. daylight hours only).

Wind directions during tropical cyclones suggest the strongest winds generally occur from the northeast quadrant for cyclones tracking to the west. As the cyclones make landfall, winds then weaken and shift round to the northwest. The highest wind speeds in both records were recorded from the northeast, with 111km/hr during TC Ilona at Dampier Salt and 131km/hr during TC Clare at Legendre Island.

The wind and tropical cyclone records have been assessed to identify tropical cyclones considered likely to have produced strong onshore winds at Dampier Palms Beach (Table 3-1). The dominant direction of alongshore transport for each event has been inferred based on recorded winds or cyclone track. These events are considered in the context of historic shoreline changes detailed in Section 3.2.

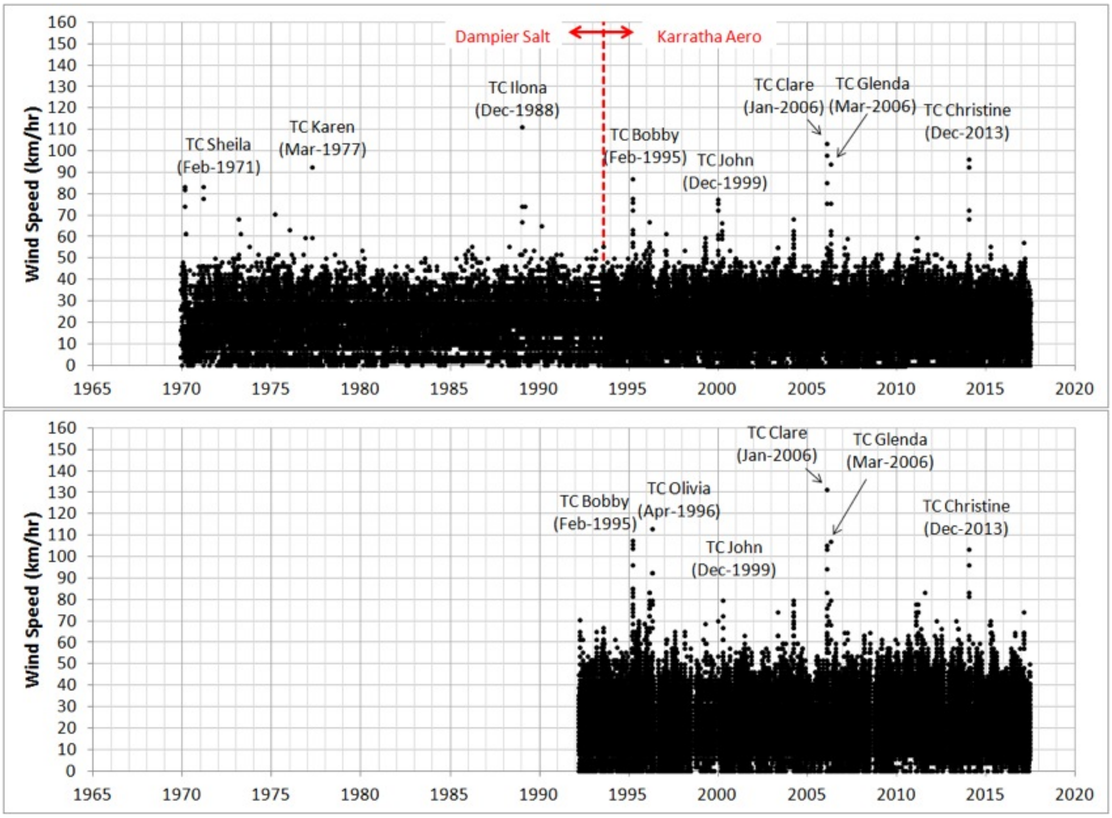

Figure 3-4: Wind Speed Observations (Source BoM)
(Top) Dampier Salt and Karratha Aero (Bottom) Legendre Island

Table 3-3: Potential Alongshore Transport Events

Tropical Cyclone	Date	Max Onshore Wind		Dominant Sediment Transport Direction
		Dampier Salt/ Karratha Aero	Legendre Island	
Sheila	3/02/1971	83km/hr W	No record	Northward
Trixie	18/02/1975	Missed peak (daylight record only)	No record	Possibly southward
Orson	22/04/1989	Instrument failed before peak	No record	Possibly southward
Bobby	24/02/1995	57km/hr NNW	83km/hr NNW	Southward
Olivia	10/04/1996	Instrument failed before peak	92km/hr NNW	Southward
Clare	10/01/2006	103km/hr W	76k/hr NW	Possibly northward
Glenda	30/03/2006	30km/hr NNW	Instrument failed after peak	Limited

(1) *Cyclones listed either recorded strong onshore winds (i.e. from 245°N to 345°N) or tracked to the west with central pressure below 940hPa.*

3.1.3. Water Levels

Water levels influence the portion of the beach subject to hydrodynamic forcing (e.g. waves and currents). At Dampier Palms Beach, water level also affects beach amenity, with an extensive flat rock platform exposed at the toe of the beach during low tide.

Water level observations at Dampier are available since 1983 from the King Bay tide gauge which is managed by the Department of Transport on behalf of Pilbara Ports Authority (Figure 3-5). No observations were available between 2010 and 2013, or after 2015. Water level processes evident in the record include tides, surge event (e.g. tropical cyclones), seasonal and inter-annual mean sea level variations. Water levels are shown to Chart Datum (CD), which is 2.77m below AHD (Australian height Datum, which approximately corresponds to mean sea level).

Tides in the region are semi diurnal, with a highest astronomic tide of 5.10m CD. The tidal sequence is strongly affected by monthly spring-neap cycle and a bi-annual cycle, with peaks near the March and September equinoxes.

There has been a relatively low occurrence of high water level events associated with storm surge in the record, with only two events exceeding the highest astronomical tide of +5.10m CD (2.43m AHD). These occurred during severe cyclones which tracked to the west of Onslow and coincided with high tides, with +5.81m CD (3.04m AHD) recorded on 21/03/1999 in TC Vance and on 30/03/2006 in TC Glenda. Low or neap tides restricted water levels to below HAT during the passage of TC Orson (1989), TC Bobby (1995) and TC Olivia (1996), which tracked within 150km west of Dampier with central pressure less than 940hPa.

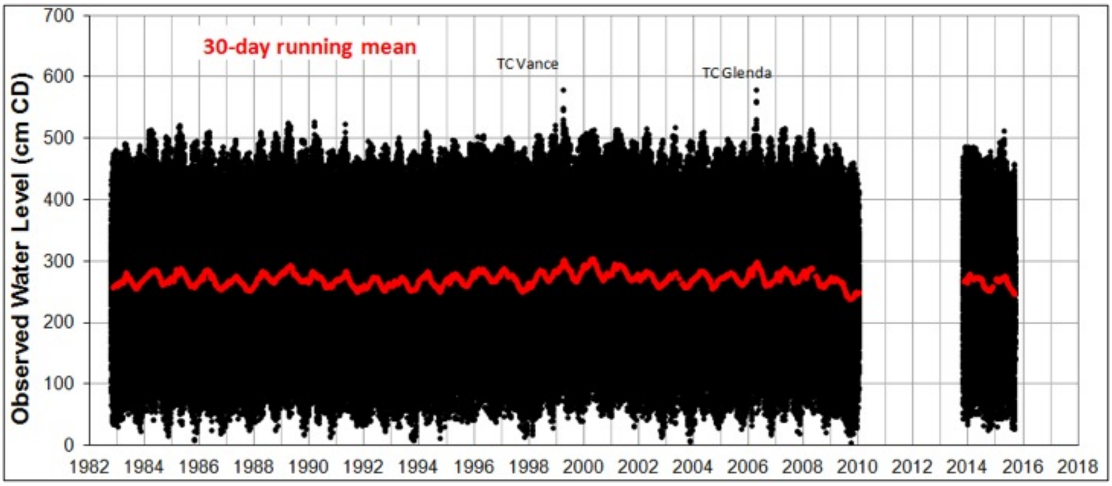

Figure 3-5: Hourly Water Level Observations at King Bay Tide Gauge (Source: Department of Transport)

Present day extreme still water levels at Dampier are estimated in Damara WA (2014), based on Bureau of Meteorology modelling (BOM 1996), and summarised in Table 3-4. Water levels at the shoreline are enhanced by wave run-up, with up to an additional 1.5-2.5m run-up possible along the Dampier coast, depending on wave exposure (MRA 2014; Damara WA 2014).

Table 3-4: Present Day Extreme Still Water Level Intervals at Dampier

ARI	10yr	20yr	50yr	100yr
WL	6.0m CD (3.2m AHD)	6.5m CD (3.7m AHD)	7.1m CD (4.3m AHD)	7.6m AHD (4.8m AHD)

3.1.4. Waves

Dampier Palms Beach is highly sheltered, with available fetch for wind wave generation limited across to East Intercourse Island (2000m to northwest) and the causeway (1500m to west). Potential wave heights generated by extreme winds acting over these fetches are considered in Section 4.2, with a 100year ARI wave height of 1.5m previously estimated by MRA (2014).

Mermaid Sound is also exposed to a narrow directional window, within roughly ±15^{o} of north, which may provide an extended fetch for wave generation during tropical cyclones passing to the west of Dampier. Dampier Palms Beach is heavily sheltered from these wave conditions due to its westerly aspect and location at the southern end of Mermaid Sound, in the lee of Hampton Harbour. To provide an indication of extreme wave heights at Dampier Palms Beach associated with these events, diffraction co-efficients have been applied to extreme wave heights derived at the Dampier Bulk Liquids Berth (refer Figure 1-1), a site with sounding -9.6m AHD, by cyclonic wave modelling undertaken by Metocean Engineers (2004). The diffraction co-efficients were derived based on diffraction diagrams presented in the USACE (1984) and a diffraction angle of 30°, measured from the tip of the Hampton Harbour Breakwater to the beach. It is noted that the 100 year wave height of 1.1m is lower than the 100year wave height of 1.5m derived by MRA (2014) from East Intercourse Island. However, no direct wave measurements have been available for this assessment.

This simple analysis identifies the potential for larger northerly waves to be generated during a cyclone, which could erode placed material at the north end of the beach and transport this material to the south.

Table 5: Average Recurrence Intervals for Northerly Cyclonic Waves

ARI	10 yr	20 yr	50 yr	100 yr	200 yr	500 yr
Hs At Dampier Bulk Liquids Berth (Metocean Engineers 2004)	3.4m	4.8m	6m	6.6m	7.1m	7.8m
Diffraction Co-efficient	0.15	0.15	0.16	0.16	0.17	0.17
Hs At Dampier Palms Beach	0.5m	0.7m	0.9m	1.1m	1.2m	1.3m

3.1.5. Currents

No information on currents has been reviewed or obtained to support this assessment, although Seashore Engineering notes that installation of the causeways is likely to have substantially reduced tidal flows near Dampier Palms beach.

3.1.6. Rainfall

A creek outlet located to the south of Hampton Oval is subject to occasional flow during high rainfall. The 24 hour (to 9am) rainfall observations at Dampier Salt since 1972 are shown in Figure 3-6. There have been four extreme rainfall events which have exceeded 150mm since 2006, with the highest of 208mm on 9 February 2017. Flows during these rainfall events may have contributed to scour of sediments at the creek entrance, south of Hampton Oval which is evident in aerial photography (refer Section 3.2).

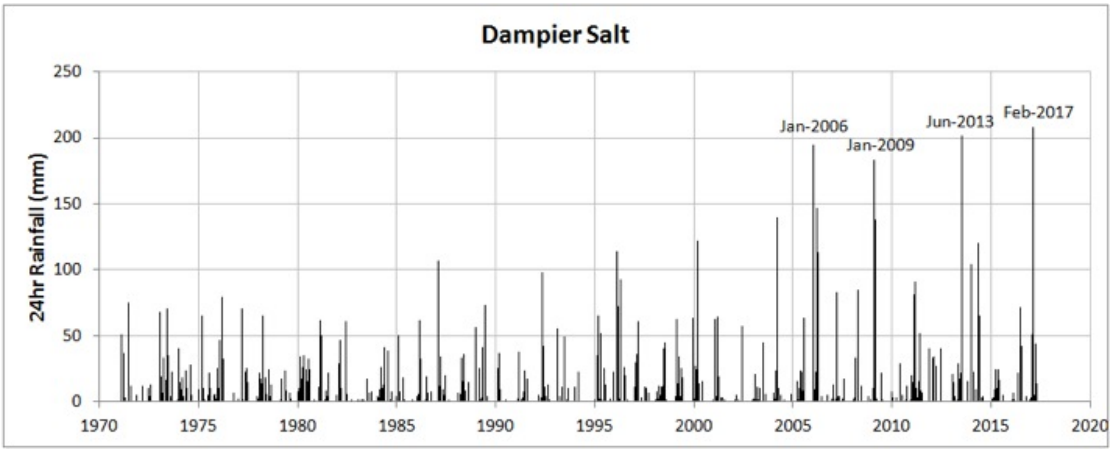

Figure 3-6: Dampier Salt Rainfall Record 1972-2017
Source: Bureau of Meteorology

3.2. AERIAL PHOTOGRAPHY

A series of historic aerial photographs since 1943, shown in Appendix D, have been assessed to identify beach changes in the vicinity of Dampier Palms. This understanding is important to infer potential behaviour of sand renourishment placed at Dampier Palms Beach.

There was no significant net loss or gain from the 1200m section of beach extending between the harbours to the north and south since 1943. This implies the beach is largely a 'closed' system, with limited external sediment supply (e.g. from the creek). Alongshore loss is restricted by the harbours and cross-shore loss is restricted by the extensive flat rock platform.

Key changes shown in Figure 3-7 demonstrate alongshore sediment transport within the 1200m section of beach and include:

- Southward sediment migration between 1968 and 2001, with 25m of beach erosion at Dampier Palms Beach and corresponding accretion south towards the causeway.
- Minor beach erosion on the southern side of Hampton Harbour since 2001; and
- Scour of the beach adjacent to the creek outlet on the southern side of the over the last 5-10 years, likely associated with runoff during high rainfall events.

A first pass estimate of volume of southward sediment migration between 1968 and 2001 is 35,000m^3, based on measured changes in beach width in aerial photograph and surveyed profiles. The migration is likely to have occurred mainly during episodic tropical cyclones, as these provide the main (albeit irregular) source of southward energy required to cause southward alongshore transport (refer to Section 3.1.2). There is a relative absence of strong or sustained winds from the north in the Karratha Aero wind record. Tropical cyclones which may have caused southward alongshore sediment transport and contributed to erosion of Dampier Palms Beach include TC Trixie (1975), TC Orson (1989), TC Bobby (1995) and TC Olivia (1996).

Dampier Palms Beach has experienced a period of relative stability since 2001. This has been influenced by a reduction in southward sediment migration potential associated with:

- Increased sediment size (i.e. finer fraction was transported south);
- Increased exposure of rock along the shoreline and at low tide; and
- Reduced volumes of sediment able to be mobilised, due to beach narrowing and reorientation.

There is limited capacity for sediments accumulated to the south to redistribute north after installation of the causeway to East Intercourse Island. The causeway provides significantly reduced the available fetch for wind wave generation during prevailing westerly winds and reduced tidal flows through the southern part of Mermaid Sound.

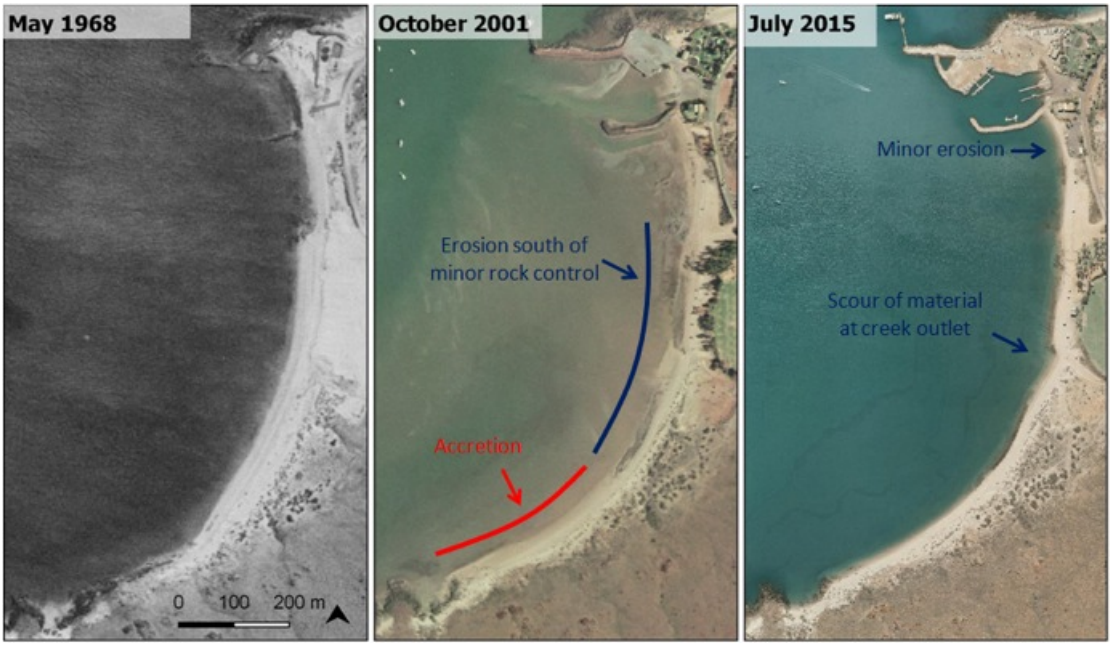

Figure 3-7: Key Beach Changes Observed in Historic Aerial Photographs

3.3. SURVEY INFORMATION

Survey information at the beach is available from a LIDAR survey captured in 2011 and a feature survey in January 2017. Profile changes between the two surveys confirm there has been limited beach change along Damper Palms Beach for the period, with changes at two beach transects shown in Figure 3-8. The location of transects are shown in Figure 3-9.

Key characteristics of the beach profiles include:

- A rock platform at the toe of the beach, generally below −1m AHD;
- A minor berm at +2.2m AHD along parts of the beach, including the northern profile (i.e. a high tide berm);
- Beach grade is generally 1V:11H, measured between the berm and rock platform; and
- Exposed rock outcrops along the reach up to +3m AHD. These provide local interruption to alongshore sediment transport.

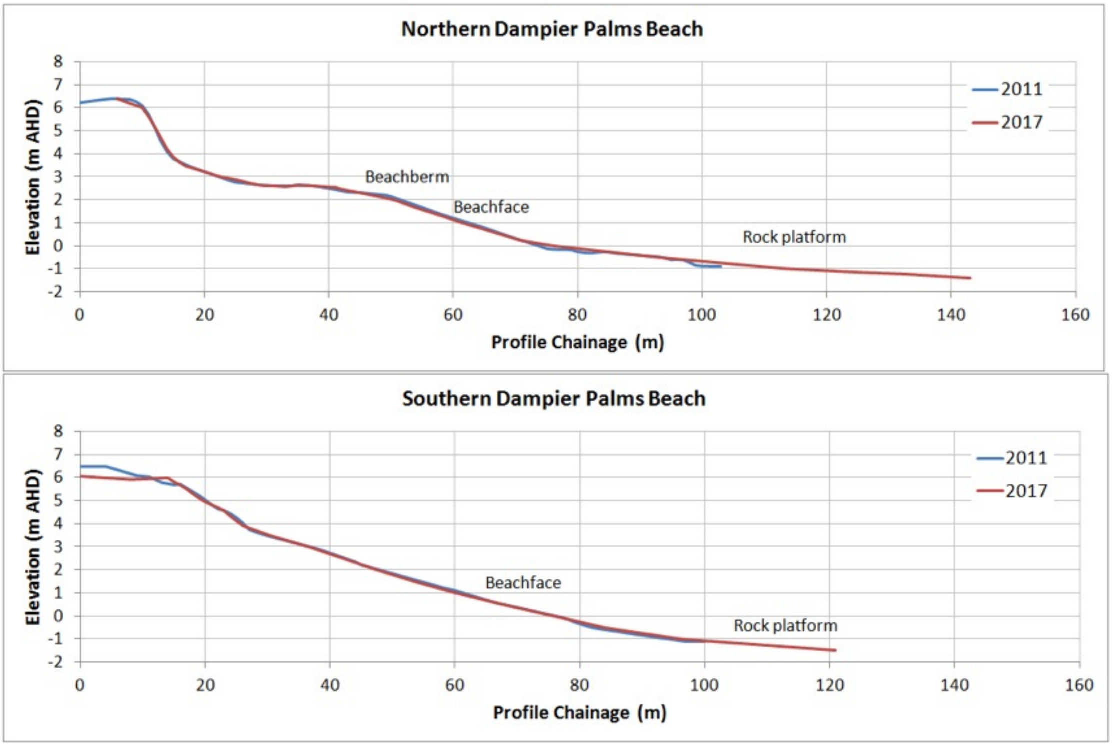

Figure 3-8: Surveyed Beach Profiles

Figure 3-9: Beach Transect Locations

3.4. SITE PHOTOGRAPHY

Site photographs from three dates have been compared, with sets of photographs at similar locations and field of views provided in Figure 3-10, Figure 3-11 and in Appendix A. The photographs were captured on 11 January 2011 by Damara WA, 15 October 2014 by MP Rogers and Associates and on 30 August 2017 by the City for this project.

Limited beach change is evident in the photographs. Photographs captured at low tide show the extent of the rock platform at the toe of the beach and exposed rock along the shoreline.

Figure 3-10: Hampton Oval Pavilion – Looking South

Figure 3-11: Hampton Oval Carpark – Looking North

4. Sand Renourishment Stability

The section investigates the stability of sand renourishment at Dampier Palms Beach, through assessment of sediment sizes and SBEACH cross-shore modelling.

4.1. SEDIMENT SIZE

Sediment size is a critical design parameter for sand renourishment projects, as described in USACE (2006):

> *"The grain-size distribution of the borrow material [2] will affect the cross-shore shape of the nourished beach profile, the rate at which fill material is eroded from the project, and how the beach will respond to storms."*

Sediment size is generally limited by sand availability and the cost to transport it to the project site, however sizes for renourishment are generally sought that either match or are coarser than native [3] beach material.

The City collected surface sediment samples from three sites along the Dampier Palms Beach (Appendix B) and possible sand sources at Wickham and Karratha (Karratha Earthmoving) identified by the City. Samples were analysed for particle size distribution (PSD), with results shown in plot form in Figure 4-1 and summarised in Table 4-1.

The samples from Dampier Palms Beach show significant variability, with:

- Coarser sediments at the southern and northern sites at Dampier Palms Beach, including approximately 40% gravel (>2mm) at the northern site. This is likely to represent a coarser faction of sediments along the wider beach, with finer material (more mobile) expected to have been lost between 1968 and 2001 and transported southward. Coarser sediments have likely contributed to greater relative beach stability observed since 2001; and
- The central site is significantly finer, and likely represents a local accumulation of fine material adjacent to the rock control, possibly supplied from the adjacent dune area by pedestrian and vehicle activity.

Sediment from Karratha Earthmoving sand source is well matched to native beach sediment at the central site, but is significantly finer than sediments at the northern and southern sites. The implication of this using this sand for renourishment at Dampier Palms Beach is that it will erode at a significantly higher rate than the native material, which is significantly coarser overall. Erosion is anticipated to occur mainly episodically during tropical cyclones, with some progressive loss due to moderate summer seabreezes. Sediment from the Wickham sand source is significantly finer than all three samples at Dampier Palms and the Karratha Earthmoving sand source.

[2] Borrow material – material has been extracted for use at another location.
[3] Native material – existing material at Dampier Palms Beach.

Table 4-1: Summary of Grain Sizes

Location		D16 (mm)	D50 (mm)	D84 (mm)	Description
Dampier Palms Beach	North	0.49	0.96	1.98	Coarse sand/poorly sorted
	Central	0.20	0.34	0.89	Medium sand/poorly sorted
	South	1.00	1.90	3.83	Very coarse sand/poorly sorted
Possible Sand Sources	Wickham	0.15	0.21	0.27	Fine sand/well sorted
	Karratha Unscreened	0.21	0.39	1.01	Medium sand/poorly sorted
	Karratha Screened	0.19	0.29	1.01	Medium sand/poorly sorted

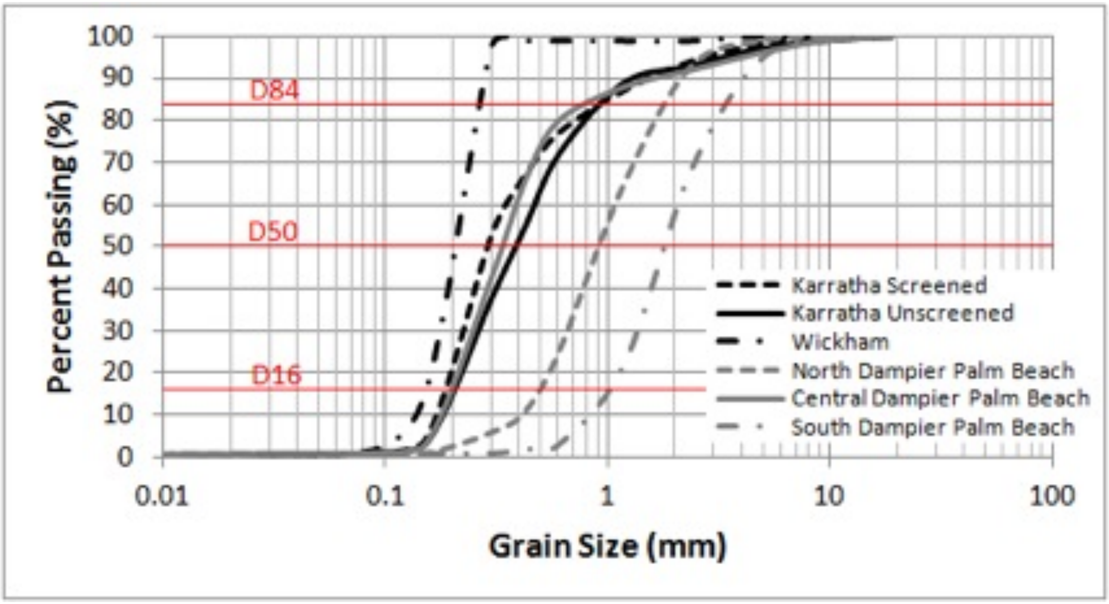

Figure 4-1: Particle Size Distribution Curves

Various comparative analysis techniques are available to compare sand-size distributions of the natural beach to be nourished and borrow material, reported as an overfill ratio. Analyses typically assume that borrow material placed on the beach will undergo sorting as a result of coastal processes; and given enough time, will approach the native grain-size distribution. The portion of borrow material that does not match the native sediment grain-size distribution is assumed to be lost (USACE 2006). In simple terms, an overfill ratio of 1 is considered stable, while a ratio of 2 suggests the imported sand will erode at a significantly higher rate than the native beach material, requiring twice the volume to achieve the design.

The USACE (2006) method of assessing an overfill factor have been applied to provide a conceptual assessment of the suitability of the three sand sources to provide sand for nourishment of the Dampier Palms Beach. This method developed by Krumbein & James (1965) assumes that the fraction of sediments that is coarser than the native sediments will be winnowed out of the beach fill as well as the finer sediments. It requires assessment of the median grain size (D50) and sorting, in particular d_{16} (fine fraction) and d_{84} (coarse fraction), as detailed in Table 4-1.

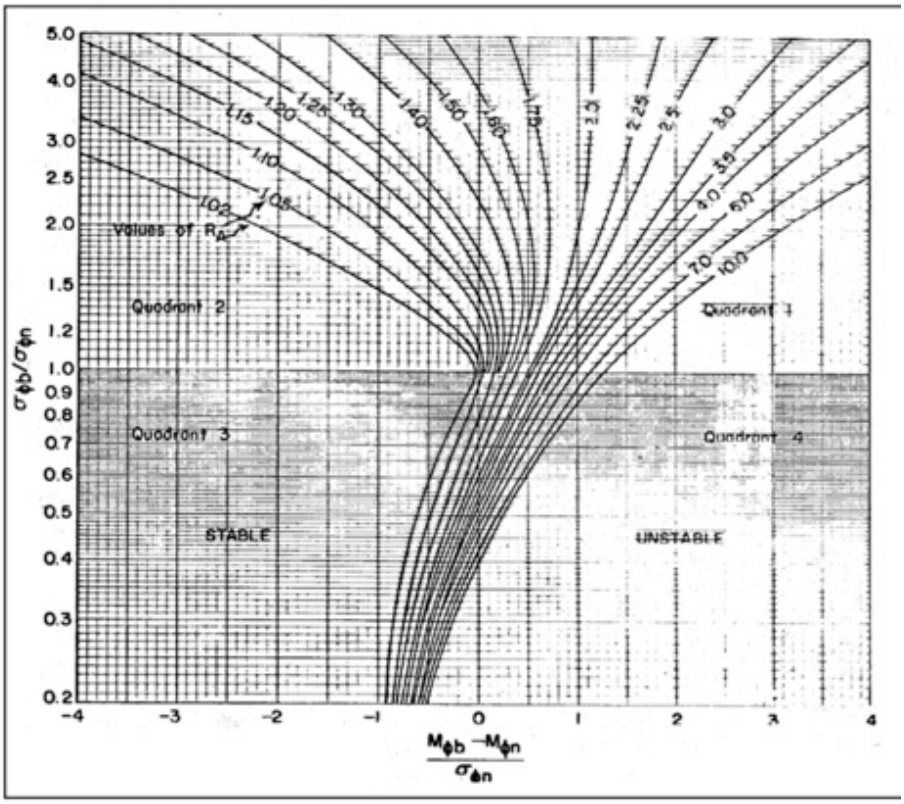

Figure 4-2: Overfill Factors from USACE (2006), based on Krumbein and James (1965);

The overfill ratios for the three potential sources, based on comparison to the three beach samples and a synthesized 'average' sample using the methods outlined above, are provided in Table 4-2. The outcomes of this assessment include:

- Wickham sand source is classified as unstable, and is unsuitable for the beach renourishment of Dampier Palms Beach;
- Due to a slightly higher coarse fraction, the unscreened sand at Karratha Earthmoving is preferred over the screened sand; and
- Up to 70% of the unscreened sand from the Karratha Earthmoving is likely to be mobile, based on the average overfill ratio of 3.25, and will likely be transported to south. Further consideration of the conditions which will contribute to loss is given in Section 4.2.

Table 4-2: Calculated Overfill Ratios

Location	Wickham	Karratha Unscreened	Karratha Screened
North Dampier Palms Beach	Unstable	2.75	3.25
Central Dampier Palms Beach	Unstable	1	1.05
South Dampier Palms Beach	Unstable	6	8
Average	Unstable	3.25	3.75

4.2. SBEACH MODELLING

The SBEACH model has been used to simulate cross-shore erosion response of two renourished profiles at Dampier Palms Beach (Figure 3-9). Each profile was subjected to a constant wave height and water level over a duration of 6 hours, with key model inputs summarised in Table 4-3. The sensitivity of the response was tested for three sediment sizes and wave heights, which resulted in nine model runs for each profile.

The model outputs are representative of what processes are included in the model. In particular, the model does not represent alongshore sediment transport which is a key erosion process when storm waves occur at an angle to the beach. The modelling and interpretation is undertaken with recognition of the limitations of SBEACH in a low-energy environment and cognisant of difficulties encountered by the model to represent nearshore friction (Komar *et al.* 1995).

Table 4-3: Key SBEACH Model Inputs

Input	Values	Description
Renourished beach profiles	-	Two profiles were constructed by increasing beach width by 15m from existing profiles extracted from the surveys.
Hard bottom	-	Extended rock platform to landward.
Wave height	0.9m (~100km/hr wind) 1.2m (~120km/hr wind) 1.5m (~160km/hr wind)	A range was selected to test the sensitivity of cross-shore beach response to wave height. Wave heights are based on a simple fetch-limited wave hindcast (USACE 1984), which considers possible winds during the passage of a tropical cyclone acting over the maximum 2000m fetch (WNW) to East Intercourse Island. The 1.5m is considered to represents a 100 year ARI wave height (MRA 2014).
Wave height duration	6 hours	Potential duration of wind from exposed northwest fetch during the passage of a tropical cyclone.
Water level	1.76m AHD	Selected to ensure breaking waves occur on the renourished beach profile, as SBEACH calculates an equilibrium profile from the point of wave breaking upwards.
Sediment Size (D50)	0.2mm 0.3mm 0.5mm	A range was selected due to the difficulty in sourcing sediment equivalent to the existing coarse sand on the beach.

Profile outputs from each model run are shown in Appendix E, with runs for a sediment size of 0.3mm (D50) at the northern profile shown in Figure 4-3. The profiles demonstrate erosion of the beach berm and transport offshore to lower beachface. Erosion distances at +2m AHD in Table 4-4 provide a measure of the offshore sediment transfer. The following is noted:

- Greater profile response for D50 of 0.2mm and 0.3mm;
- Profile response for D50 of 0.5mm only occurred for wave heights of above 0.9m; and
- Profile responses for each run were similar at the two profiles.

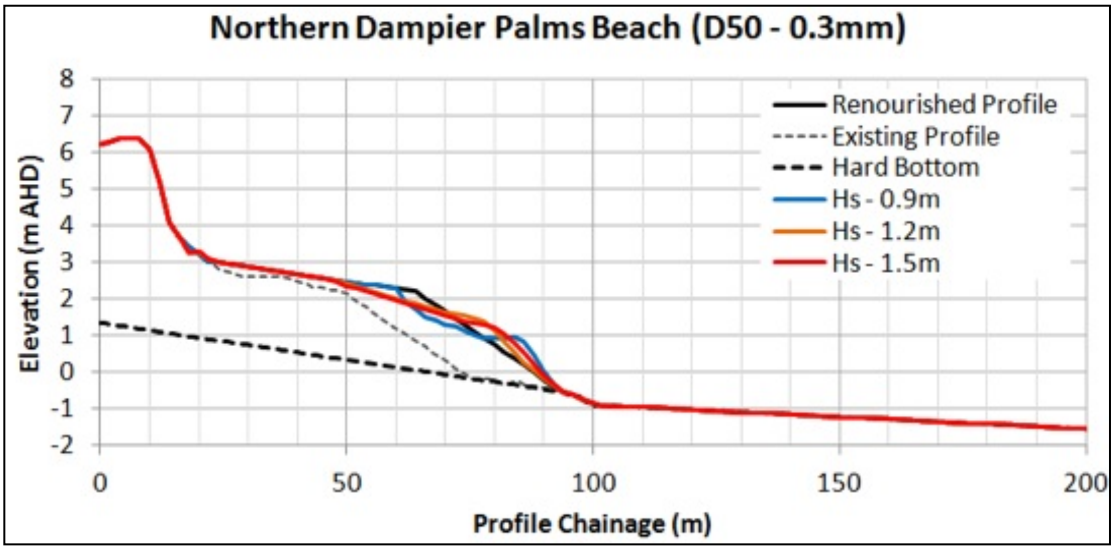

Figure 4-3: SBEACH Model Outputs - Northern Profile and Sediment Size 0.3mm

Table 4-4: SBEACH Modelling Results – Erosion Distances at +2.0m AHD

	Southern Profile			Northern Profile		
	D50 - 0.2mm	D50 - 0.3mm	D50 - 0.5mm	D50 - 0.2mm	D50 - 0.3mm	D50 - 0.5mm
Hs - 0.9m	6.8	4.7	None	6.4	3.9	None
Hs - 1.2m	6.0	5.7	3.7	5.1	5.3	3.7
Hs - 1.5m	7.8	7.3	5.4	6.3	6.5	5.3

Additional SBEACH model runs were performed to identify wave heights which induce initial profile changes for various sediment sizes (Table 4-5). Wind speeds along the maximum fetch length of 2km required to generate the wave heights have been inferred based on a simple fetch-limited wave hindcast (USACE 1984).

It is noted that the characterisation of response to wave height based upon grain size does not produce firm thresholds for beach mobility. Some transport is possible for coarser material under relatively low wave energy under the certain coincidences of wave direction, beach shape and water level. However, the analysis has highlighted that use of coarse material may substantially reduce the range of conditions under which mobility occurs, thereby reducing the rate of material loss. Specifically, the analysis suggests:

- Transport of sediment sizes above 0.4mm is likely to predominantly occur during rare tropical cyclones (i.e. wind speed >63km/hr) tracking to the west, producing strong onshore winds; and
- Sediment sizes of below 0.4mm may be mobile during westerly sea breezes, which can reach 50km/hr in summer (refer Section 3.1.2), and are far more common than tropical cyclones.

Table 4-5: Estimated Thresholds for Sediment Mobilisation

Sediment size (D50)	0.2mm	0.3mm	0.4mm	0.5mm
Wave height threshold	0.2m	0.4m	0.6m	0.9m
Wind Speed	30km/hr	50km/hr	70km/hr	100km/hr

5. Potential Behaviour of Sand Renourishment

Cross-shore sediment loss is restricted by the extensive flat rock platform which extends approximately 400m offshore. Any material transferred offshore during elevated wave conditions is expected to gradually transfer back to shore during milder wave conditions.

Alongshore transport potential at Dampier Palms Beach has been demonstrated by the southward sediment migration of approximately 35,000m³ between 1978 and 2001. This likely occurred mainly during tropical cyclones. The potential for redistribution of sediments back to the north, to Dampier Palms Beach, was significantly reduced by the installation of the causeway to East Intercourse Island and harbour to the south. This has significantly reduced the available fetch for generation of waves by westerly winds.

Factors likely to influence rates of southward sediment migration of renourished material are summarised in Table 5-1. They have been considered in the development of a design layout and profile in Section 6. Lower rates of loss may be achieved if renourishment only occurs to the north of the minor rock feature on the beach.

Assessment of sediment sizes suggests 70% of the unscreened sand from the Karratha Earthmoving is likely to be mobile at Dampier Palms Beach (Section 4.1), with 50% likely to be mobile during prevailing summer seabreezes based on derived wave height thresholds (Section 4.2). These sediments could be progressively lost to the south during WNW seabreezes or in a short burst during passage of a tropical cyclones tracking to the west. A tropical cyclone to the west occurs on average every 5 years, but can occur in any given year.

Table 5-1: Key Factors Influencing Southward Sediment Migration

Factor	Impact on Southward Sediment Migration Rates
Tropical cyclones	Strong onshore winds at Dampier Palms Beach during tropical cyclones tracking to the west have the potential to cause significant sediment loss to the south. Interrogation of the BOM cyclone record suggests tropical cyclones track within 150km west of Dampier once every five years, and once in ten years with central pressure <940hPa.
Sediment size	Transport of sediment sizes above 0.4mm will likely be generally limited to tropical cyclone events, while sizes below 0.4m may also be mobile during moderate to strong summer seabreezes from the WSW to WNW.
Rock outcrops	A minor rock outcrop extending offshore from the Dampier Palms Beach shoreline interrupts alongshore sediment transport. Rates of loss are likely to be lower on the northern side of the rock.
Proximity to creek outlet	The beach adjacent to the creek outlet is subject to greater variability, with sediment scour occurring during flows after rainfall events.
Sediment availability	Rates of loss are expected to be higher with increased sand volumes placed on the beach.

6. Sand Renourishment Design Profile and Layout

A concept design profile and layout has been developed for two sand renourishment options to determine possible sand volume requirements (Figure 6-1, Figure 6-2). Layouts consider renourishment of the beach to the north and south of a minor rock control. As the rock control will retain sediments to the north, loss of renourishment due to southward sediment migration is expected to be greater from the southern section. The layouts and associated volumes assume beach nourishment material can be sourced that matches native beach material (i.e. overfill ratio = 1.0)

The layout considers the proposed Dampier Palms and Hampton Oval Redevelopment (Appendix A), including location of carparks and pedestrian access. No renourishment of the beach adjacent to the creek outlet during flows has been considered due to the likelihood of sediment loss during creek flows.

Design cross-section profiles are based on the natural beach berm height of 2.2m AHD and a beachface grade of 1V:11H (refer Section 3.3), and consider heights and extents of exposed rock. It is recognised that the use of sand finer than the native material may produce a beach with flatter beach grade. This would increase sand coverage of the rock platform which extends from the toe of the beach, but would also increased potential exposure of rock outcrops along the shoreline.

The two options considered are a 10m (Option 1) and 15m (Option 2) increase in beach width at the beach berm height of 2.2m AHD, with estimated sand volumes initially required to achieve the design profile provided in Table 6-1. For both options, sand will cover existing exposed rock above mean sea level along the shoreline, with the wider beach in Option 2 having increased tolerance to:

- Changes in beach grade and offshore sediment transfer during storms; and
- Redistribution of sand renourishment, including southward sediment migration;

Due to the wide and flat structure of the rock platform, the depth of rock exposed at the toe of the beach is expected to remain around −1m AHD. This rock will still be exposed during low tides, and will continue to limit amenity for beach users. Based on water level observations, renourishment will result in a sandy beach for approximately 80% of the time (i.e. rock platform exposed 20% of the time).

Table 6-1: Sand Renourishment Volumes

	Length (m)	Option 1 Volume (m^3)	Option 2 Volume (m^3)
Northern	120	4500	7000
Southern	135	3500	6500
Total	255	8000	13500

Volumes allow for 20% bulking of sand and assume overfill ratio = 1.0. Significantly larger volumes may be required if renourishment material is finer than native beach material.

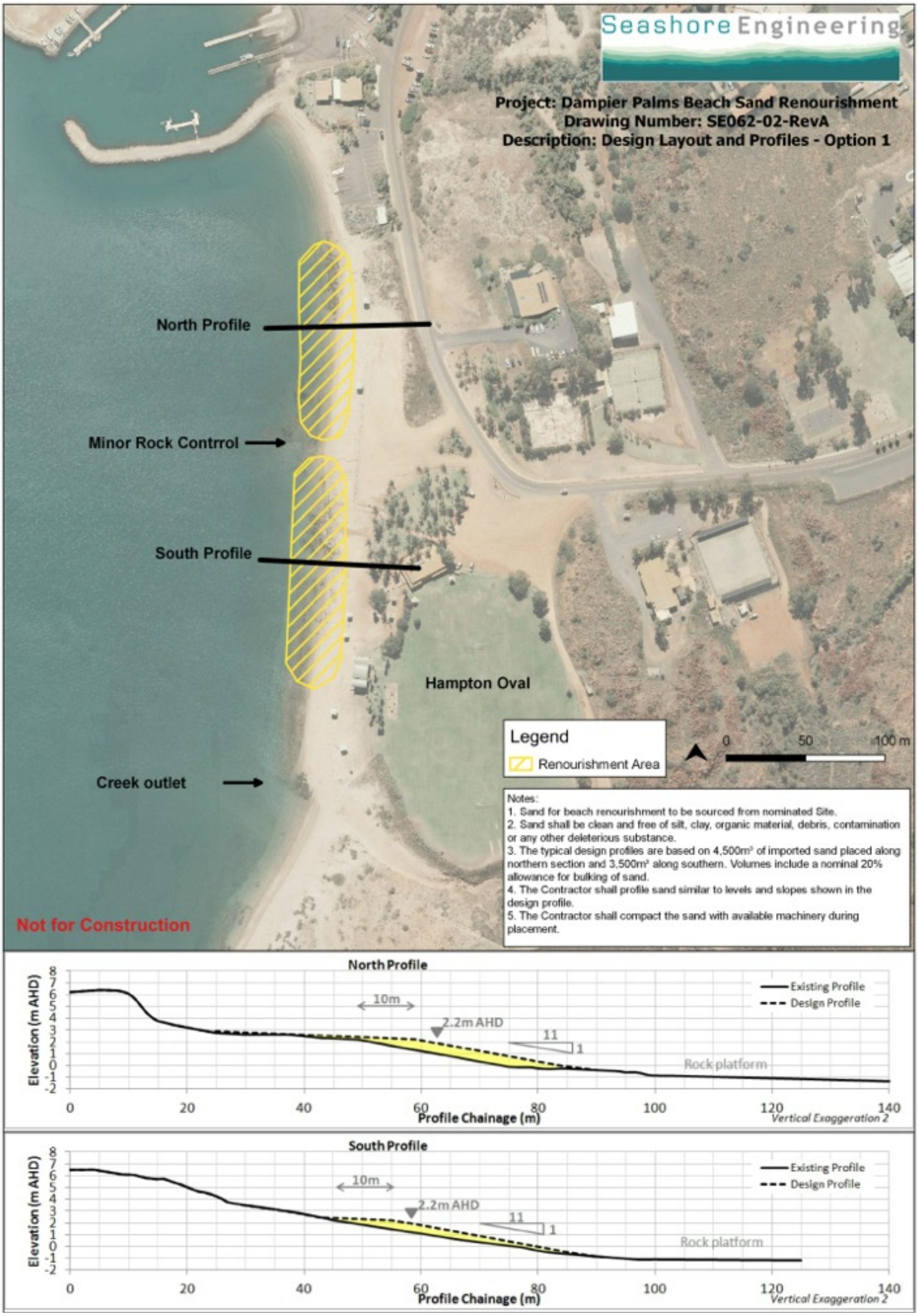

Figure 6-1: Option 1 Design Profile and Layout

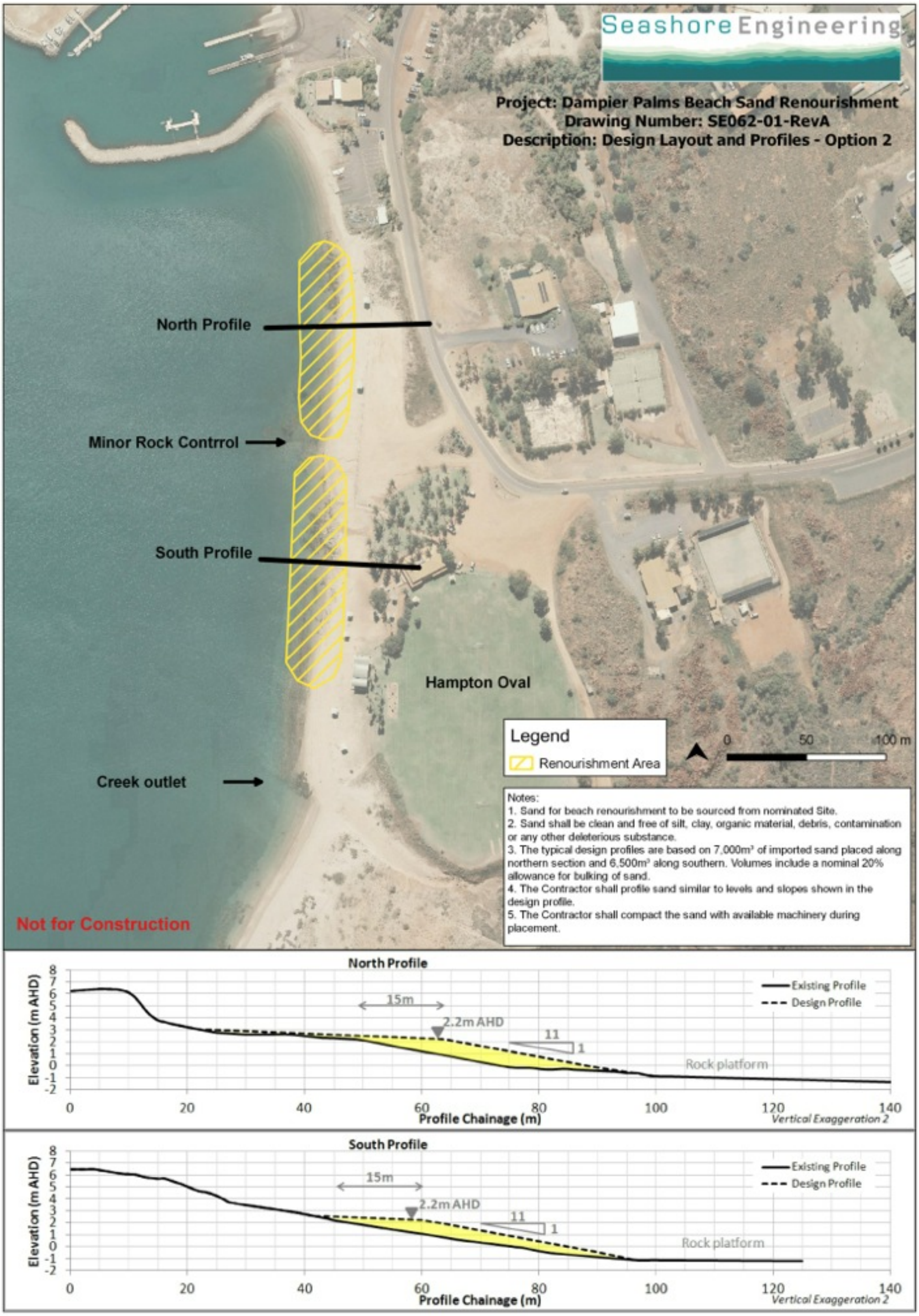

Figure 6-2: Option 2 Design Profile and Layout

7. Cost Estimate

Indicative costs for the supply and placement of sand for the two options are provided in Table 7-1. Costs are based on a nominal cubic metre rate for sand supply and placement from a potential source in Karratha, identified by the City (Table 7-1), and assume alternate sand can be sourced that matches the particle size distribution of the native beach sand (i.e. overfill ration = 1.0). Sediment from the two sources identified by the City are finer than native beach material and would require significantly larger volumes than identified in Table 7-1. The requirements for future renourishment will also be strongly dependent on the sediment sizes used and weather, particularly tropical cyclones (refer Section 5).

Initial costs and future renourishment requirements may be reduced by only placing sand along the northern section. Rates of southward sediment migration for this section are expected to be lower than the southern section, due to the partial control provided by the minor rock feature on the beach.

Table 7-1: Indicative Initial Renourishment Costs (Overfill Ratio = 1.0)

			Option 1		Option 2	
Description	Unit	Rate ($ Ex GST)	Initial Quantity	Amount ($ Ex GST)	Initial Quantity	Amount ($ Ex GST)
Supply and place sand along northern beach	m^3	$35.00	4500	$157,500.00	7000	$245,000.00
Supply and place sand along southern beach	m^3	$35.00	3500	$122,500.00	6500	$227,500.00
			Totals	**$280,000.00**		**$455,000.00**

Note: These costs assuming alternate sand can be sourced that matches the particle size distribution of the native beach sand at Dampier Palms Beach. Finer material may have significantly higher cost.

8. Conclusions

Key findings at Dampier Palms Beach include:

- The 1200m section of beach extending between harbours to the north and south is largely a 'closed' system, with limited external sediment supply (e.g. from creek) or potential sediment loss. However, sand moves within the beach system.
- Cross-shore sediment loss is restricted by the extensive flat rock platform which extends approximately 400m offshore.
- The alongshore transport potential at Dampier Palms Beach has been demonstrated by the southward sediment migration which occurred between 1978 and 2001. This is likely to have occurred sporadically due to tropical cyclones tracking west of Dampier.
- The potential for the redistribution of sediments back to the north, to Dampier Palms Beach, has been significantly reduced by the installation of the causeway to East Intercourse Island and harbour to the south.
- Reduced sediment availability, coarser sediments (i.e. finer fraction previously transport to south) and increased shoreline control provided by exposed rock has likely contributed to the relative stability of the Dampier Palms shoreline since 2001.
- The creek outlet on the southern side of Hampton Oval is subject to occasional flows, which can scour sediments from the adjacent beach.
- A section of slightly elevated rock provides shoreline control to Dampier Palms Beach.

Two options for renourishment have been developed based existing beach configuration, including heights and extents of exposed rock. For both options, sand covers the majority of existing exposed rock along the shoreline above mean sea level, resulting in a sandy beach for 80% of the time. However due to the flat and wide structure of the rock platform, the depth of rock exposed at the toe of the beach is expected to remain around −1m AHD. This rock will likely still be exposed 20% of the time during low tides, and will continue to affect amenity for beach users. The renourishment is considered to be susceptible to alongshore loss to the south:

- During a tropical cyclone events tracking to the west. This has occurred on average once every five years since 1970s; or
- If sediment sizes used for renourishment are inadequate, with sediment size (D50) below 0.4mm likely to be mobile during prevailing summer seabreezes.

Lower rates of loss may be achieved if renourishment only occurs to the north of the minor rock control.

Sediment from sand sources identified by the City from Wickham and Karratha Earthmoving are significantly finer than native sediments at Dampier Palms Beach. This implies the sand will transport to the south at a higher rate, potential requiring high initial sand volumes and ongoing renourishment. Assessment of sediment sizes suggests 70% of the unscreened sand from the Karratha Earthmoving is likely to be mobile at Dampier Palms Beach, with 50% potentially mobile during prevailing summer seabreezes.

9. Recommendations

The following recommendations have been identified for the potential nourishment of Dampier Palms Beach.

- The City should consider coarser alternatives to the Wickham and Karratha Earthmoving sand sources to reduce the required volume and associated cost. This would also increase the potential design life of the initial nourishment. Sediment sizes used for renourishment at Dampier Palms Beach should generally match the native beach sediment.
- Investigate the potential use of sediment which has accumulated along a 300m stretch of beach to the south of Dampier Palms Beach between 1968 and 2001 for renourishment. Should this material be suitable and the environmental and social impacts of removing this material be acceptable, this could provide a lower cost and sustainable alternative sand source. Investigations to assess the suitability of this sand should include:
    - Collection of three surface sediment samples from the beachface (i.e. subject to daily tide range) at evenly spaced sites along the 300m section of beach;
    - PSD testing of the sediment samples and analysis to determine the suitability of grain sizes;
    - Laboratory testing of sediment samples for comparison against human health triggers (i.e. ANZECC/NHMRC guidelines);
    - Beach survey and further assessment of 2010 LiDAR survey information to determine available volumes for extraction. A first pass estimate of volume of accretion in this area is in the order of 35,000m3;
    - Consideration of methods for harvesting, carting and placement. This should include access, plant requirements, trucking routes, public safety, dust management and environmental monitoring;
    - Liaison with Rio Tinto, as we understand this site may be adjacent to or within their lease areas;
    - Consideration of potential environmental and social impacts, including requirements for assessment under the Environmental Protection Act (1986), and notification to Department of Aboriginal Affairs.
- If sources matching native beach sediments are not identified, nourishment material should at least have the majority of sediments above 0.5mm (D50). This will require additional volumes and cost, and will erode at a higher rate, however, erosion during non-cyclonic conditions is expected to be limited.
- Any alternative sand sources identified should be evaluated for their suitability for renourishment at Dampier Palms Beach.
- Unscreened sand from Karratha Earthmoving is preferred over the screened sand, or sand from Wickham. However, the use of this sand is likely to require additional sand volume due to potential ongoing loss southward.

- Consider the use of structure(s) to reduce restrict the loss of renourishment, particularly if coarser sands are not available. This may include a minor extension offshore of existing rock feature towards the centre of Dampier Palms Beach (e.g. a groyne).
- Should nourishment occur, survey of a number of fixed transects should be undertaken and evaluated to monitor the redistribution of sand after renourishment. Surveys should generally occur before and after renourishment, then before and after cyclone season.

This study suggests the nourishment of Dampier Palms beach may be feasible provided sand that matches native material can be sourced within a reasonable distance from site. Should suitable material be available, we would recommend the concept design profiles in this report are further refined to allow the initial volumes and costs of the sand nourishment to be better defined, and the potential ongoing costs to the City to maintain this improvement to beach amenity to be understood and budgeted for going forward. We would also recommend this design process includes a coastal engineering inspection of the beach and the potential sources, and further consideration of social and environmental factors.

10. References

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Appendix A Dampier Palms and Hampton Oval Redevelopment Concept

Appendix B Sediment Sample Locations

Appendix C Site Photography Comparison

South of Creek Outlet – Looking North

At Creek Outlet – Looking North

Hampton Oval – Looking Southwest

Hampton Oval Pavilion– Looking North

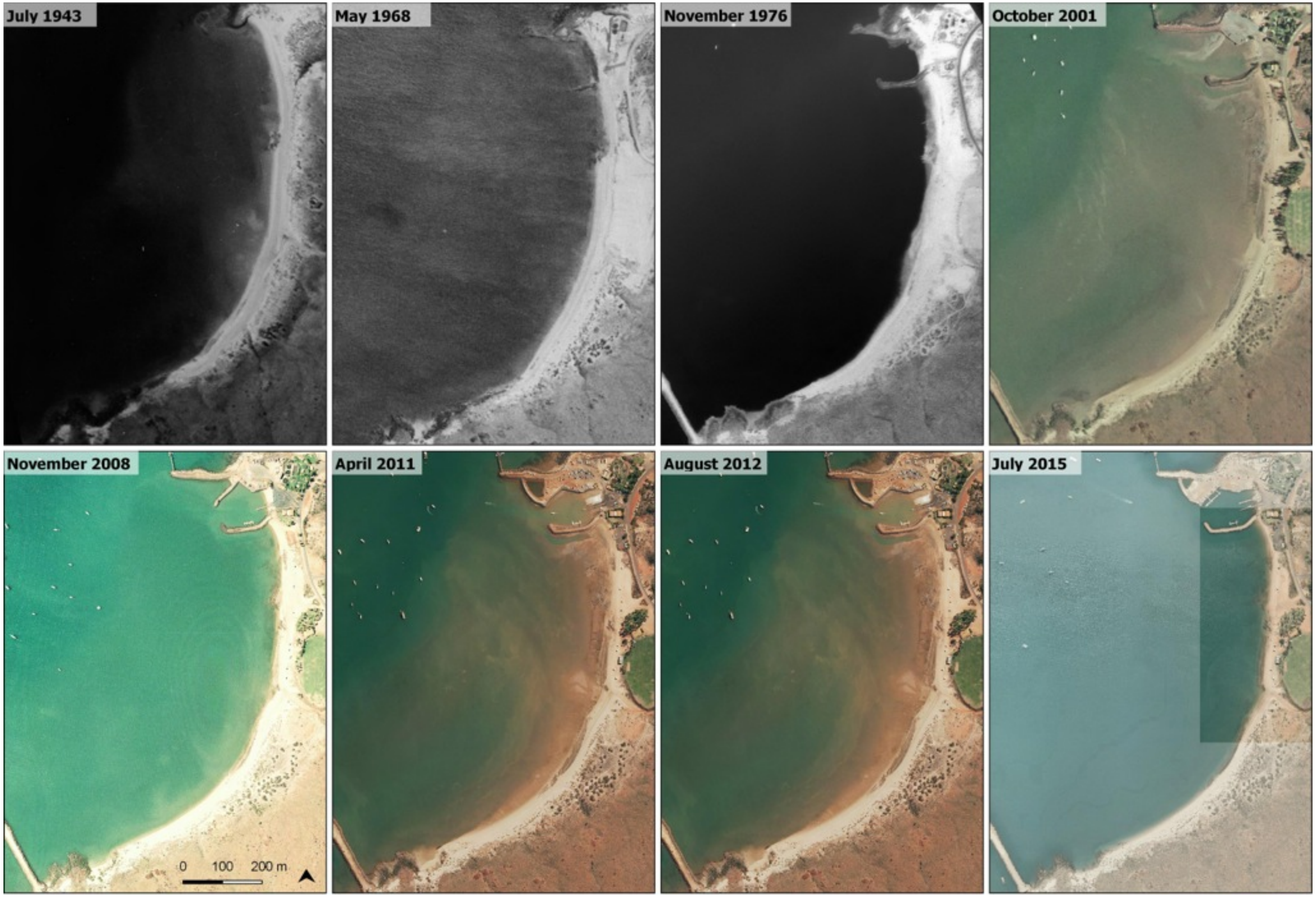
Hampton Oval Pavilion– Looking South

Hampton Oval Carpark – Looking North

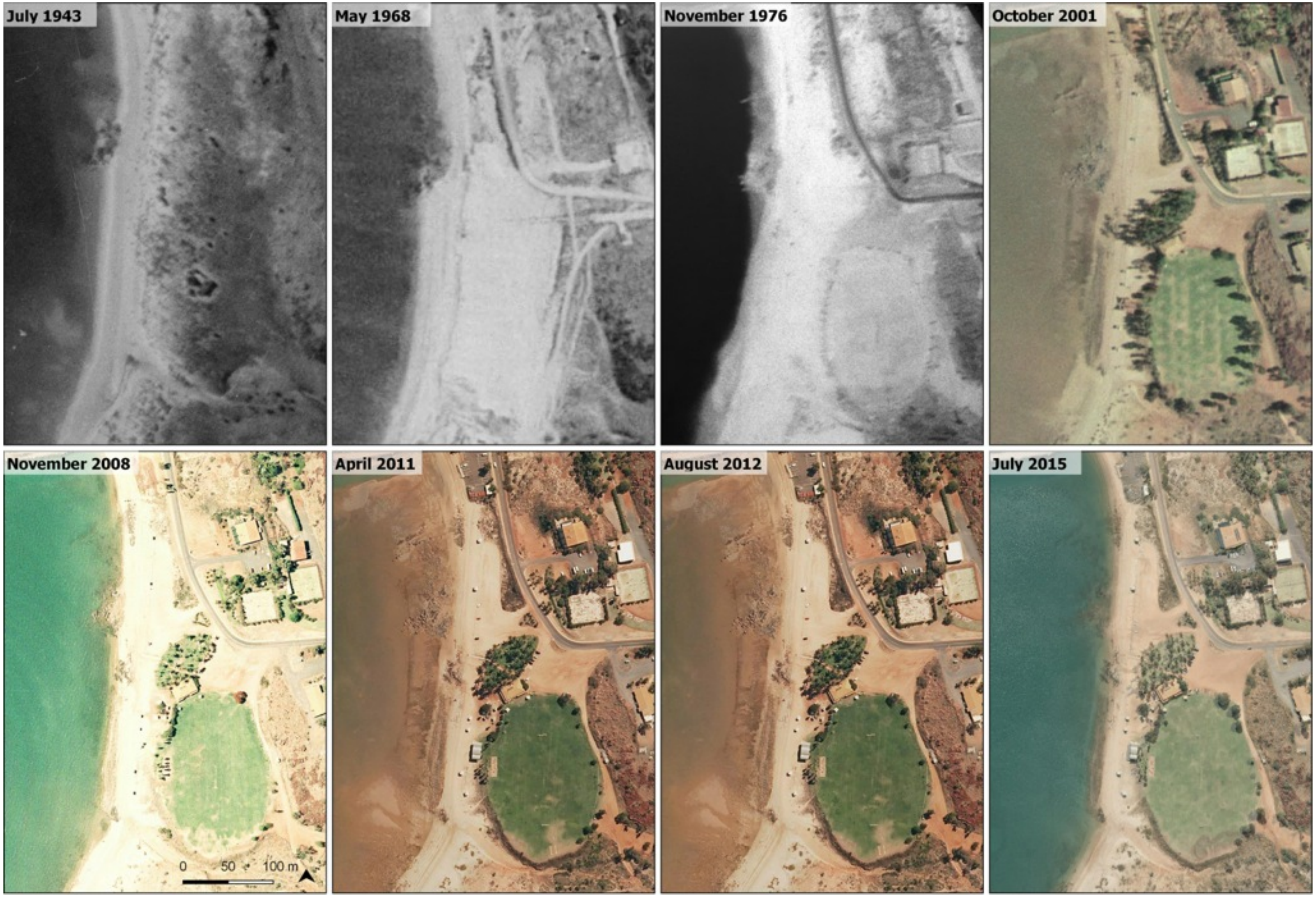
Looking Southwest from the Esplanade

Hampton Harbour Boat and Sailing Club Carpark– Looking North

Appendix D Historic Aerial Photography Comparison

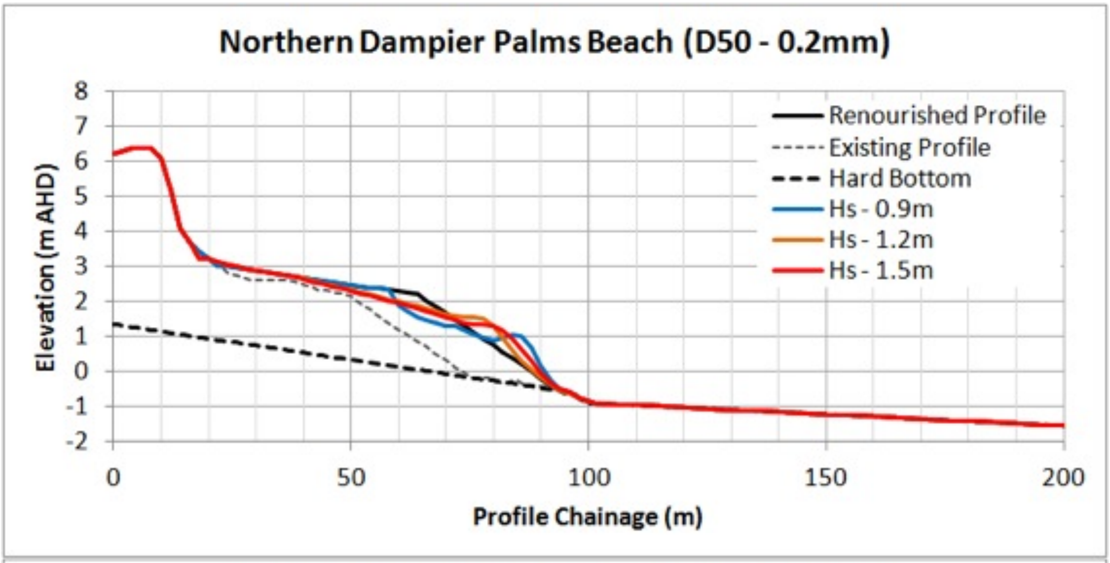


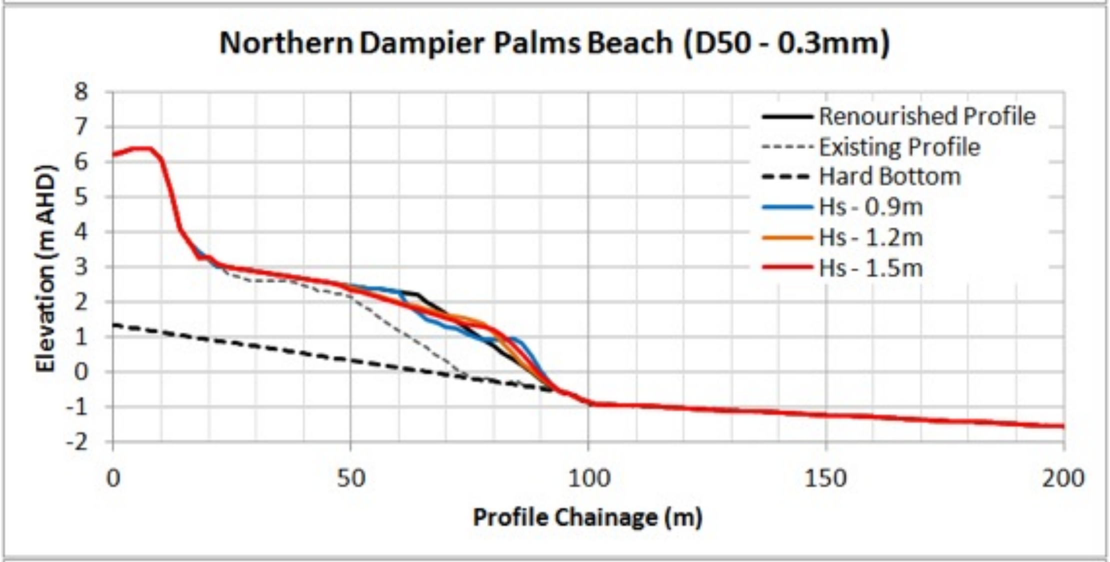
Hampton Oval Beach – Wide Scale

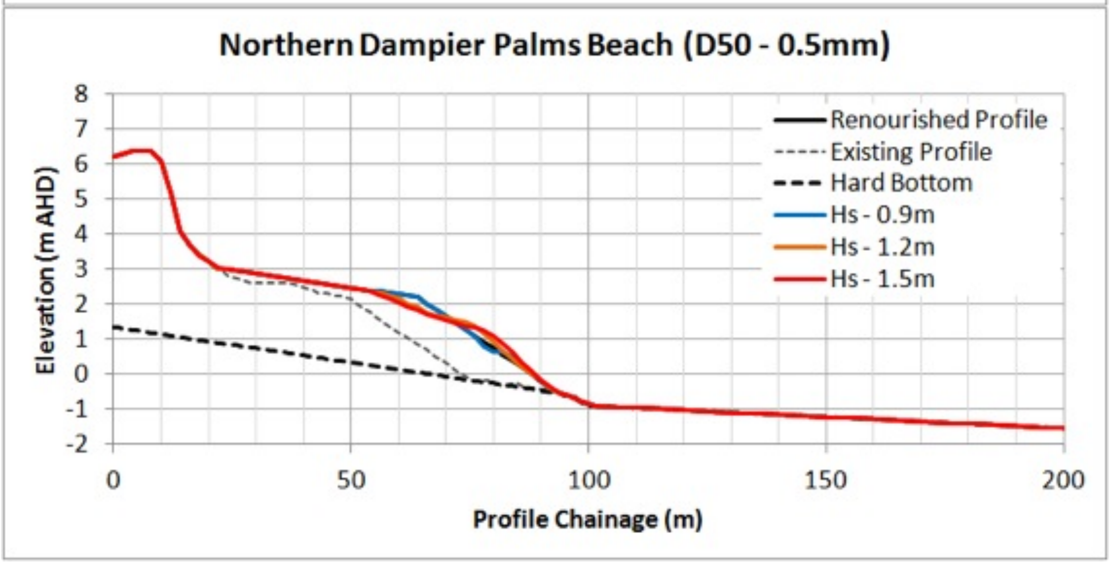


Hampton Oval Beach – Fine Scale

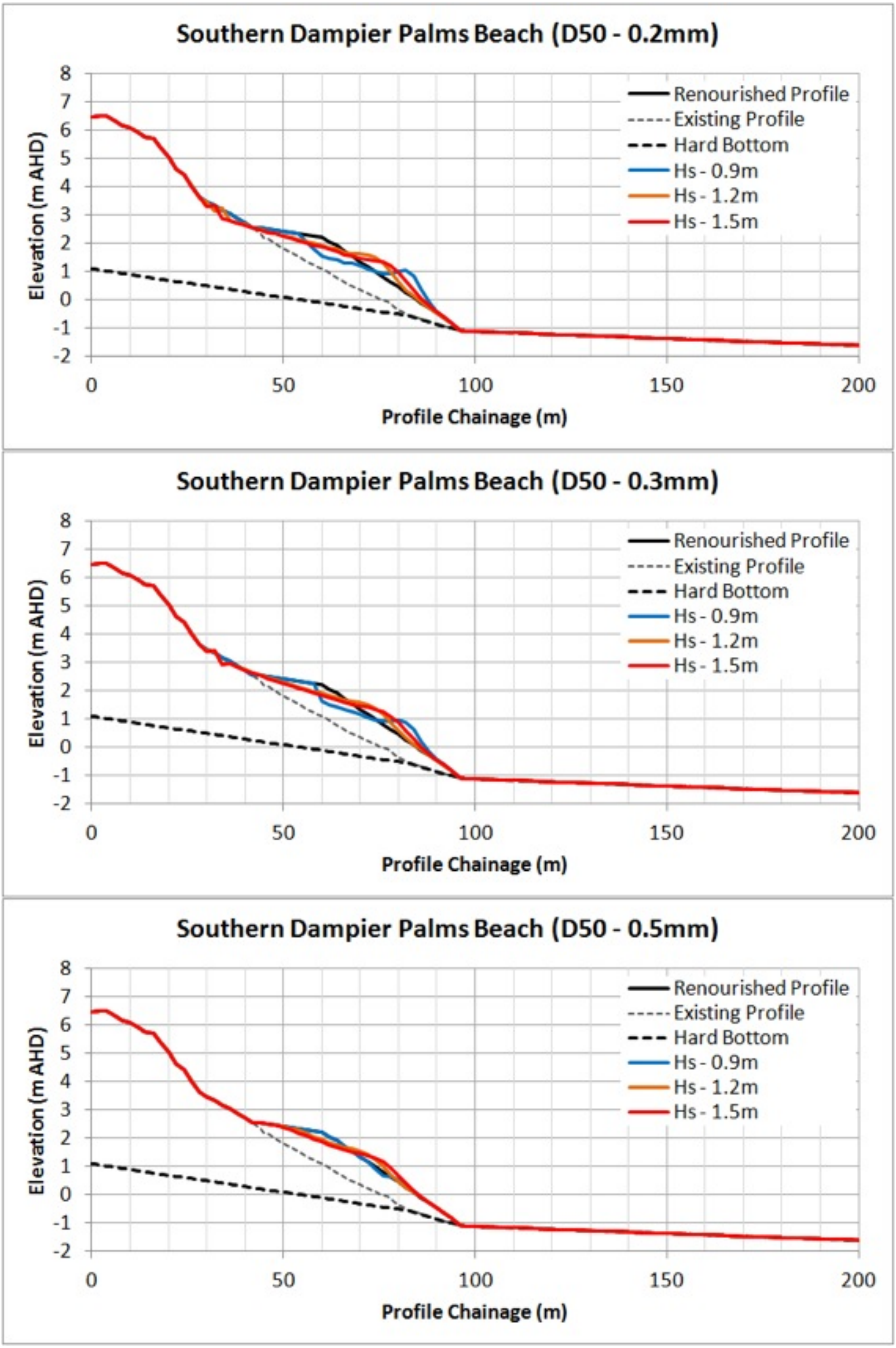
Appendix E SBEACH Modelling Profile Outputs







SBEACH Modelling Results - Northern Profile



SBEACH Modelling Results - Southern Profile