Government of **Western Australia**
Department of **Transport**

Coastal Management

Technical Note

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Formation of Mandurah sand bars outside the Mandurah entrance channel – Coastal Engineering assessment and recommendations

1. Background

A build-up of sand (sand bar) across the flood tide channel immediately west of the Mandurah Ocean Entrance has required the Department of Transport (DoT) in November 2014 to install additional navigation aids to help vessels safely transit the entrance. On behalf of the City of Mandurah, DoT undertakes an annual sand bypassing program to ensure down-drift beach stability and to maintain the Mandurah Ocean Entrance at near to its charted depth of 2 metres. The 2014 sand bypassing program was recently completed

Figure 1. Mandurah entrance channel in Oct 1981 (PWD 1983)

and dealt with a larger than usual influx of sand with a total bypass volume of approximately 150,000 m^3 compared with the usual volume of 100,000 m^3. Despite this extra work, the flood tide channel is below that depth and vessels have been diverted to the ebb tide channel.

The extent of sand build-up near the entrance channel is determined by the rate of ocean littoral drift and strength of channel flow. Under its original natural behaviour, this Ocean Entrance was partially blocked each year, and in the 1940’s was totally blocked to flow for several years, so the training walls were built to ensure an hydraulic connection each year. Their spacing was designed to ensure that riverine floods could be carried without back-flooding the agricultural drainage area adjoining Peel and Harvey Inlets, as shown in Figure 1. Permanent navigation was not anticipated when they were built. Subsequently, sand bypassing was found to be needed to avoid a sea erosion threat to down-drift urban development.

Bypassing was also intermittently carried out to allow the commercial fishing fleet to access the ocean during the rock lobster season. More recently, with the development of canal estates and the Mandurah ocean marina (which is built on accreted littoral drift sand in previous sand bar areas) bypassing volumes have been increased to allow for recreational navigation. Monitoring of depths, and occasional navigational diversions, have been a part of the ongoing bar management methodology.

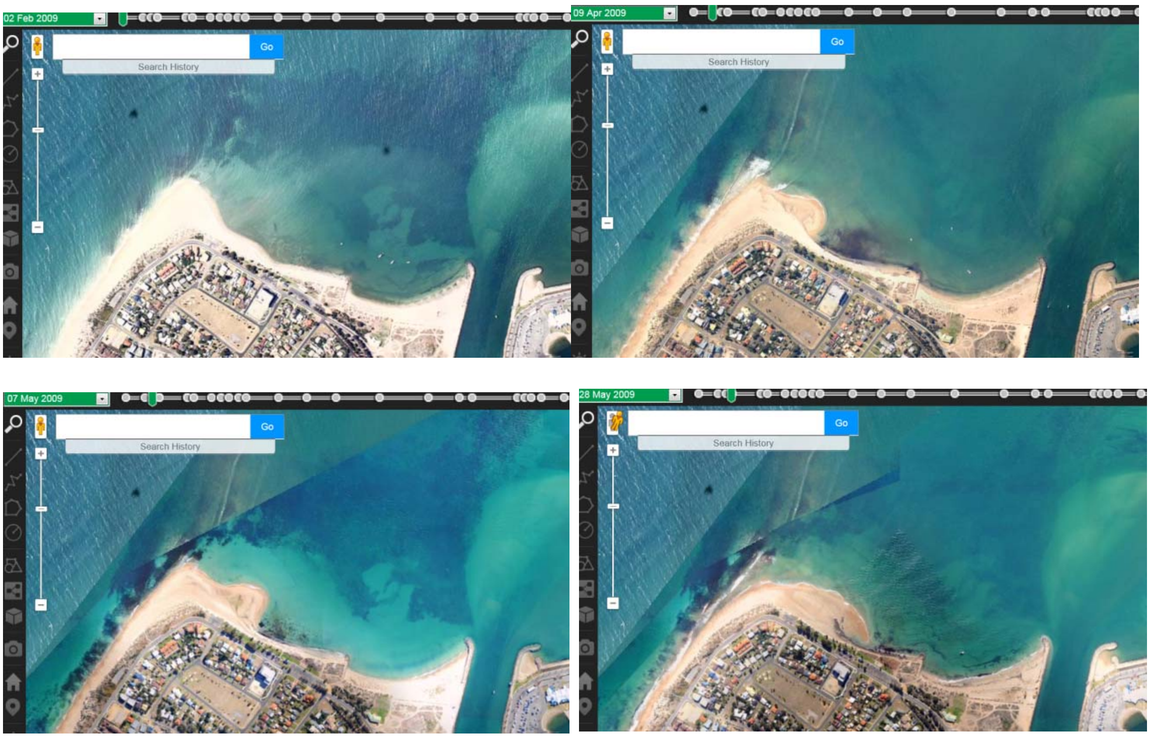

Figure 2. Sand movement occurs in “slugs” near Mandurah channel, photo taken on 2 Feb, 9 April 7 May, and 28 May 2009.

Typically, the majority of sand movement occurs from south to north over winter under the influence of south-westerly swell waves. During this period, it has been found that most sand movement occurs in ‘slugs’, estimated at between 10,000-30,000m3, following storm events

(DoT 2006) as shown in Figure 2. The amount of water passing through the channels is based on changes in water level, driven largely by tides, and also by the amount of freshwater entering the estuary through adjoining rivers. Where channel flow is low relative to littoral drift a bar may form in the channel entrance while a relatively high flow will move the bar further offshore. The local wave climate, water level, tidal and freshwater outflow at Mandurah varies from year to year and together are used to give a rating of the annual 'storminess'.

2. Location of the sand bar in Nov 2014

The latest Nearmap aerial photo and DoT hydro-survey (Figure 3 and 4) show the current location of the sand bar.

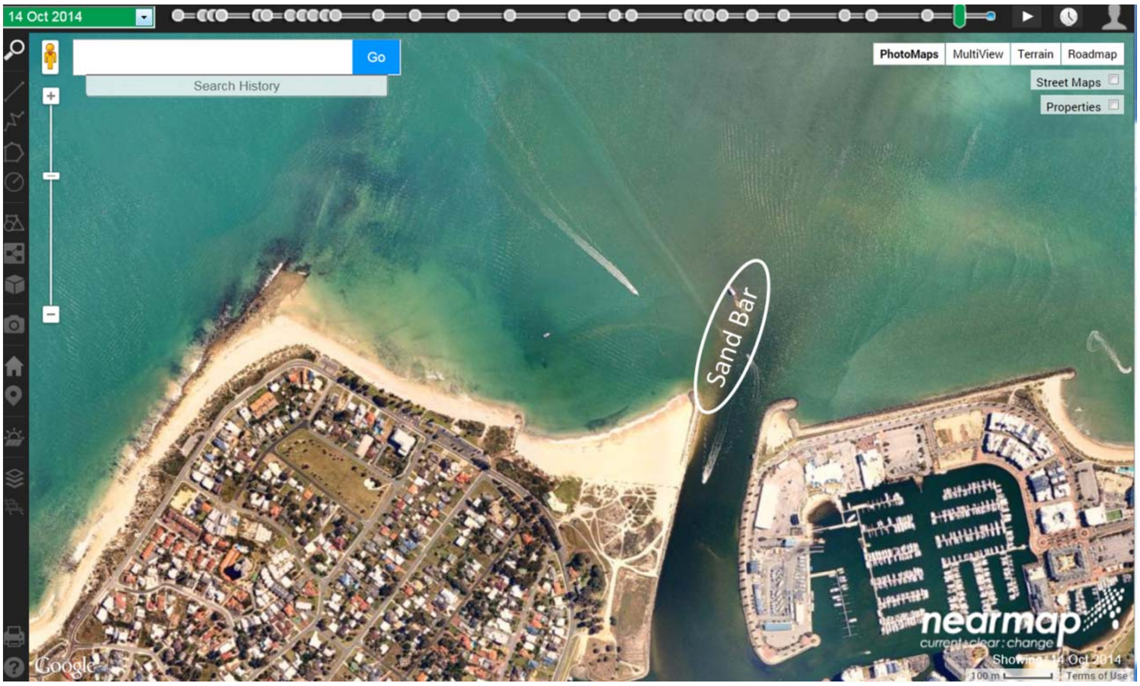

Figure 3. A full sand trap one month after the completion of 2014 Sand bypassing (Nearmap photo taken on 14 Oct 2014).

3. Present bar management methodology

The Mandurah navigational channel sand bypassing operations uses a Slurrytrak machine which takes sand from the water's edge and pumps it through a discharge pipe. The contract involves concurrent operations with the Dawesville Channel bypass, and has been successful in operation for the past 20 years. However, significant sand can escape from the sediment trap and interaction with the channel tidal flow to create a large sand build-up at the west of the Mandurah entrance channel, as happened in Nov 2014.

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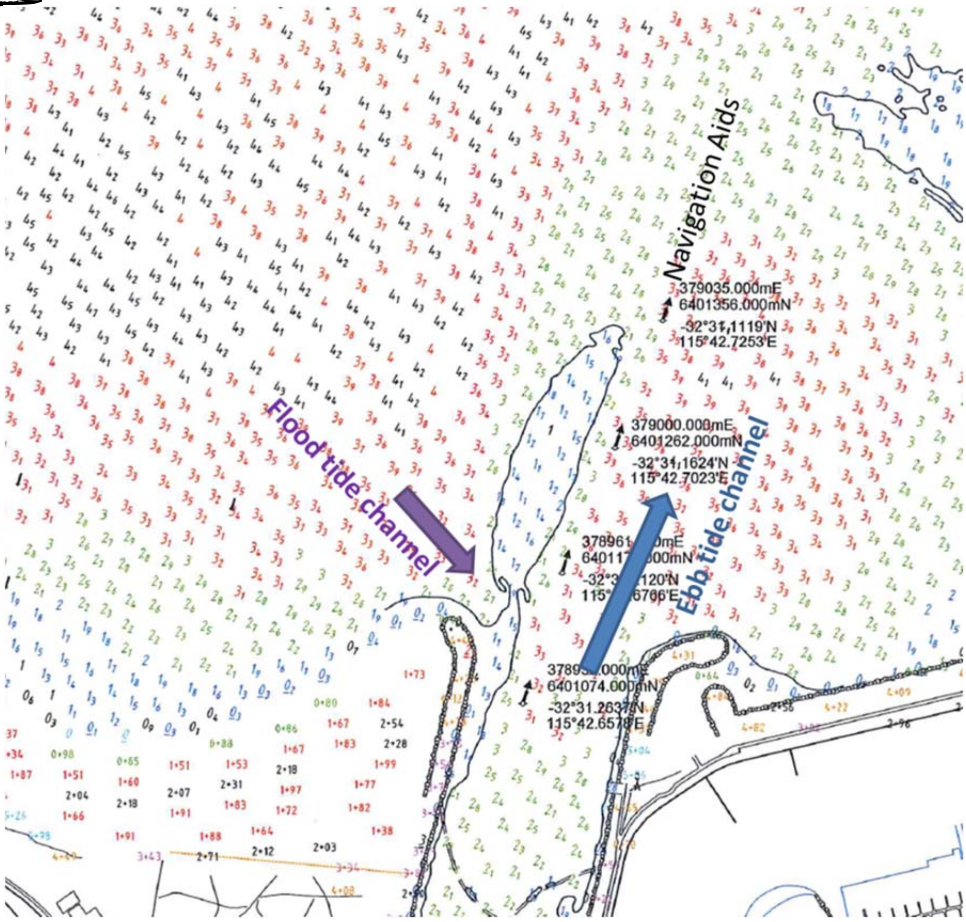

Figure 4. DoT Hydro-survey 12 Nov 2014 shows the location of a sand bar and the new navigation aids

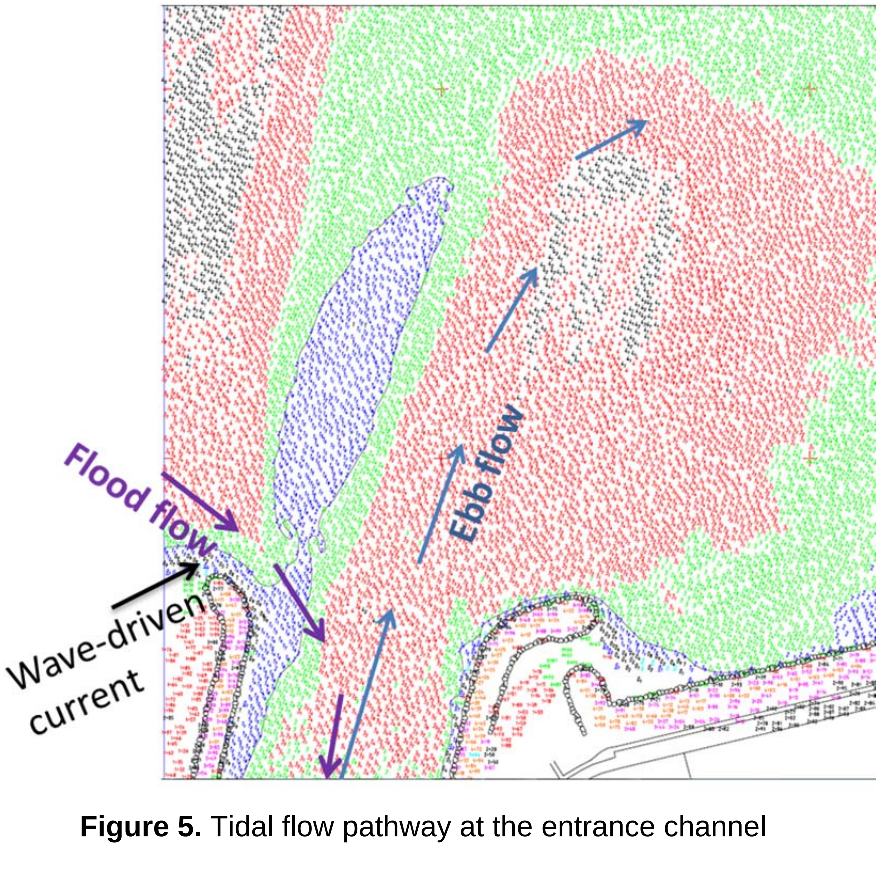

Figure 5. Tidal flow pathway at the entrance channel

Typically Mandurah Bypassing is undertaken over winter and complete around September to November. By November each year the on-shore sand trap should have plenty of room to capture the east flowing sand driven by the summer SW waves as shown in Figure 6.

However, as shown in Figure 3, the sand trap was saturated only one month after the completion of bypassing operation in 2014. There were four powerful storm events which occurred in Sep and Oct 2014 (as shown in Figure 7) which pushed large volumes of sand into the sand trap after the completion of the 2014 sand bypassing on 17 Sep 2014.

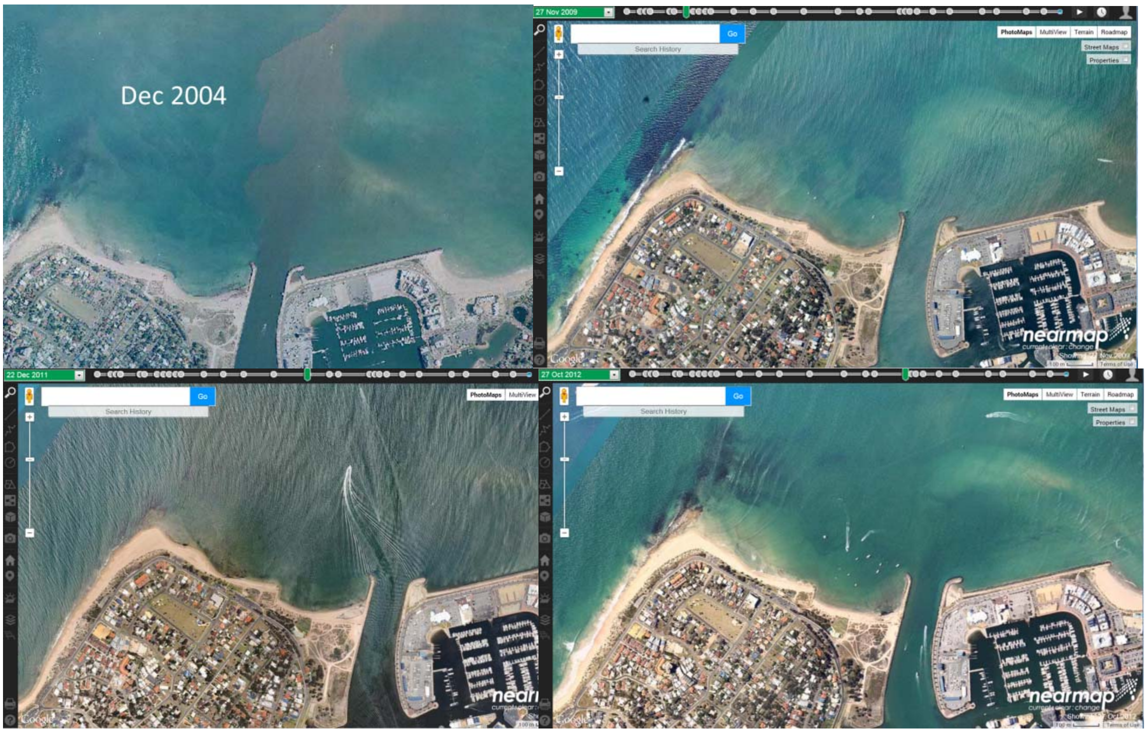

Figure 6. Typical condition of the Mandurah sand trap in October to December (aerial photo taken Dec 2004, Nov 2009, Oct 2011 and Oct 2012).

4. Likely movement and stability of the sand bar in next 3 to 6 months (Nov 2014 ~May 2015)

- The sand bar will persist for an extended period due to the saturation of the sand trap.
- The sand bar will probably grow bigger and become shallower over the next three to six months if no additional sand bypassing occurs to clear the trap.
- A sand bar presence at this location during this time of year is not unusual. Historically it has formed at least in Nov 2003, 2004 and 2007. However, a sand trap which is totally full, immediately after a large volume of sand bypassing from May to mid-Sep 2014, is very rare.

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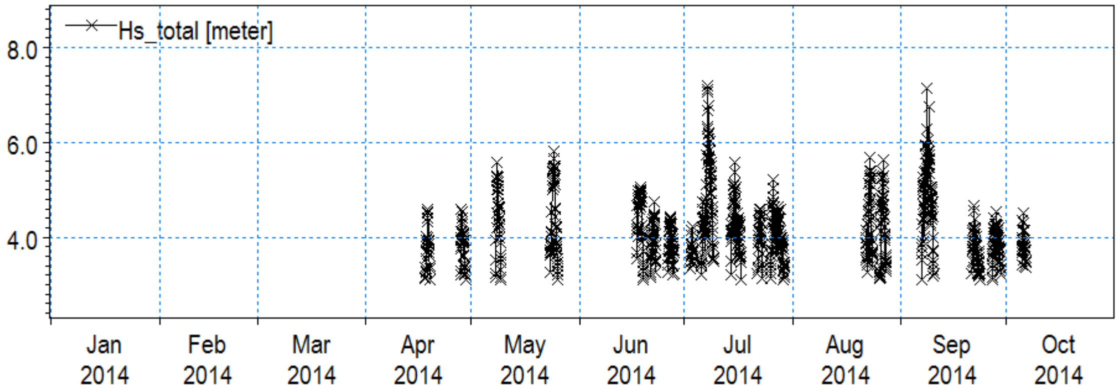

Figure 7. Storm wave height in 2014 (based on Jan to Oct Rottnest wave buoy recording)

5. Historical sand bypassing volume and timing

The volume and timing of the historical sand bypassing campaigns and sand volume are summarised in Table 1 and Figure 8. Over the 20 years of sand bypassing operation at Mandurah entrance channel the annual bypassed volume varies significantly from 74,000 m^3 in 2006 to 164,278 m^3 in 2008.

Table 1 Historical sand bypassing campaigns and volume

Year	Volume (m3)	Start date	Finish date
2014	149,930	16/05/2014	17/09/2014
2013	120,000	5/06/2013	4/10/2013
2012	150,043	11/06/2012	8/11/2012
2011	130,409	6/07/2011	4/11/2011
2010	101,886	30/06/2010	15/10/2010
2009	112,129	3/06/2009	29/10/2009
2008	164,278	4/08/2008	13/11/2008
		8/02/2008	20/03/2008
2007	120,000	25/06/2007	20/09/2007
2006	74,000	10/07/2006	28/11/2006
2005	100,000	Jun-05	Oct-05
2004	99,000	Jun-04	Nov-04
2003	100,000	Jun-03	Nov-03
2002	100,000	May-02	Oct-02
2001	100,000	Jun-01	Sep-01
2000	108,000	Jun-00	Sep-00
1999	112,000	Jun-99	Oct-99
1998	105,000	Jun-98	Oct-98
1997	58,000	Sep-97	Nov-97
1997	39,000	May-97	Jul-97
1996	142,000	Jun-96	Nov-96
1995-96	26,000	Dec-95	Feb-96
1995	44,000	May-95	Jul-95

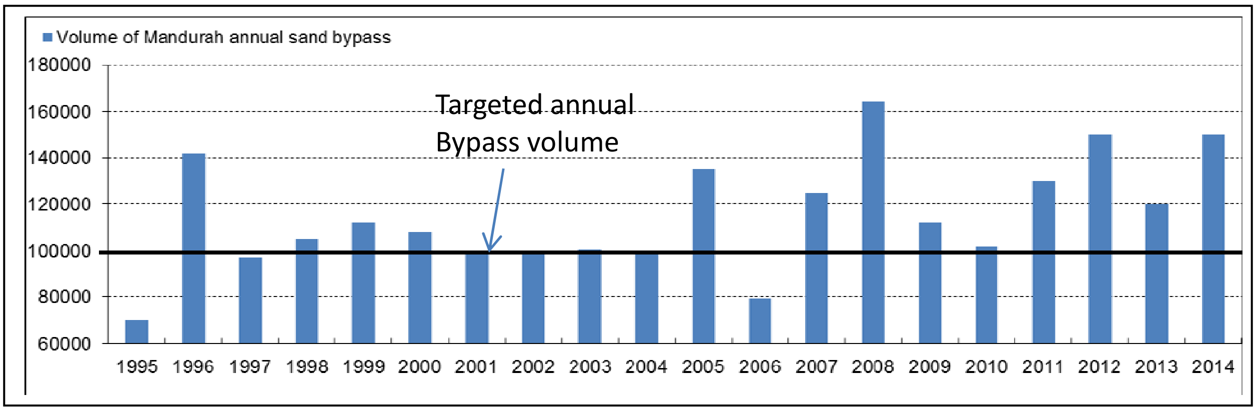

Figure 8. Mandurah sand bypass volume (m3) from 1995 to 2014

It was speculated that annual wave climate and water level have a significant impact on the level of sand movement along this stretch of coastline. To reveal this relationship between wave climate, mean sea level and sand volume, a wave climate and water level analysis was conducted based on the Rottnest wave buoy record (started 1994) and Fremantle water levels for the same period.

The Annual storm wave power index, as shown in Figure 9, is defined as the sum of total storm wave energy in a year divided by its 20 year mean. 1996 and 2007 were clearly very stormy, as a result large sand bypass volumes occurred in 1996 (142,000m^3) and in 2007-2008 (120,000 m^3, 164,000 m^3). 2013 was a stormy year with 120,000 m^3 bypassed. The 2014 could be stormier as in this analysis only the wave record from Jan to Oct 2014 is accounted for.

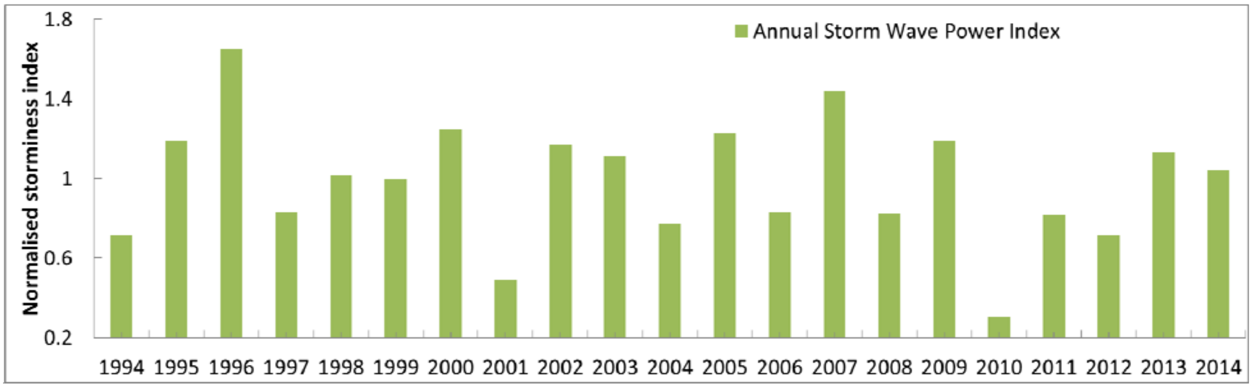

Figure 9. Rottnest annual storm wave power index *(note that for this analysis only the Jan to Oct 2014 wave record is available. Therefore, the 2014 index could be significantly higher than that indicated in this graph).*

A Fremantle water level has also been analysed and shown in Figure 10. The data shows elevated water levels both in duration and magnitude in recent 4 years (2011 to 2014). Those elevated water levels are usually associated with storms.

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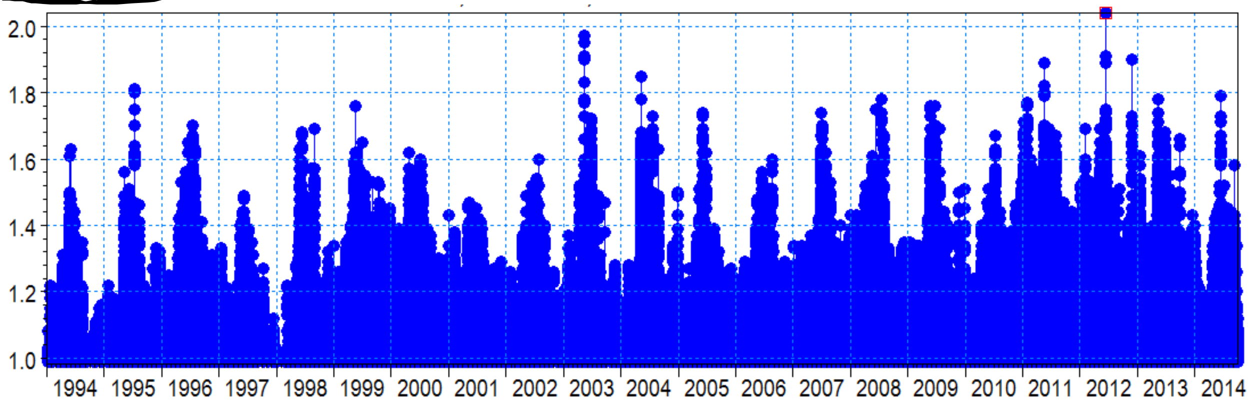

Figure10. Fremantle observed water level from 1994 to 2014 (half-hourly records, m CD)

6. High energy swell and sea wave climate in 2014

Fishermen in Mandurah noticed a bigger than usual swell year in 2014. To put the 2014 swell climate into a historical context WA's longest wave buoy record at Rottnest was analysed. The available ten months for the 2014 swell wave and sea wave climate (Jan to Oct) have been compared with their counterparts when directional wave records were available (2005 ~2014). In term of large swell wave (Hs>1.0 m) hours in 10 months (Jan to Oct), 2014 tops the rank, followed by 2007 as shown in Figure 11 and Table 2.

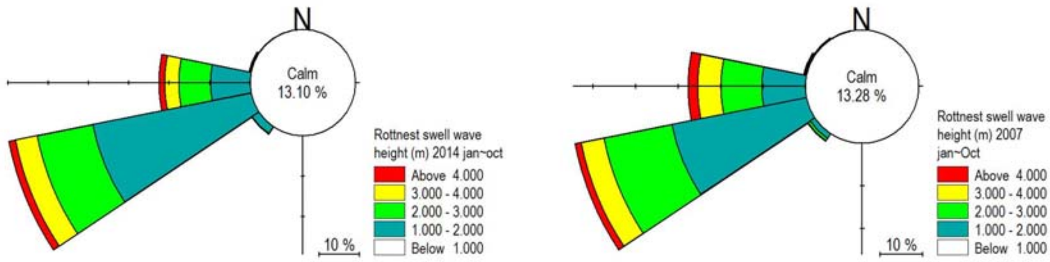

Figure 11. Swell Roses in the top two stormiest years (2014 and 2007) in last 10 years ranked by large Rottnest swell wave hours.

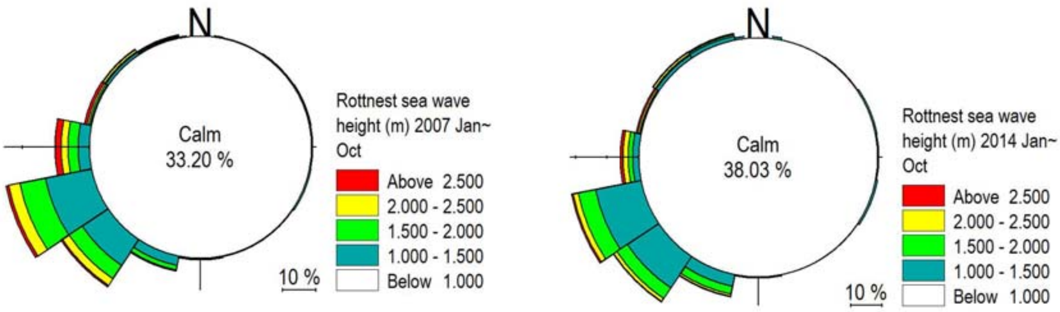

Figure 12. Sea wave roses in the top and the fourth stormiest year (2007 and 2014) in last 10 years ranked by large Rottnest sea wave hours.

The sea waves in 2014 and 2007 are relatively strong as well (ranked the fourth and the first). Figure 12 plot the sea wave roses in 2007 add 2014.

Table 2 Wave storminess ranking by Rottnest wave record 2005~2014

Storminess ranking	By the total hours when swell wave height larger than one metre from 1 Jan to 31 Oct	By the total hours when sea wave height larger than one metre from 1 Jan to 31 Oct
1	2014	2007
2	2007	2005
3	2009	2009
4	2005	2014

Figure13. Aerial photo taken in Jan 2008 shows a full sand trap, 4 months after 2007 bypassing completed on 20 Sep 2007 (a few weeks later the extra sand bypassing campaign started on 8 Feb 2008).

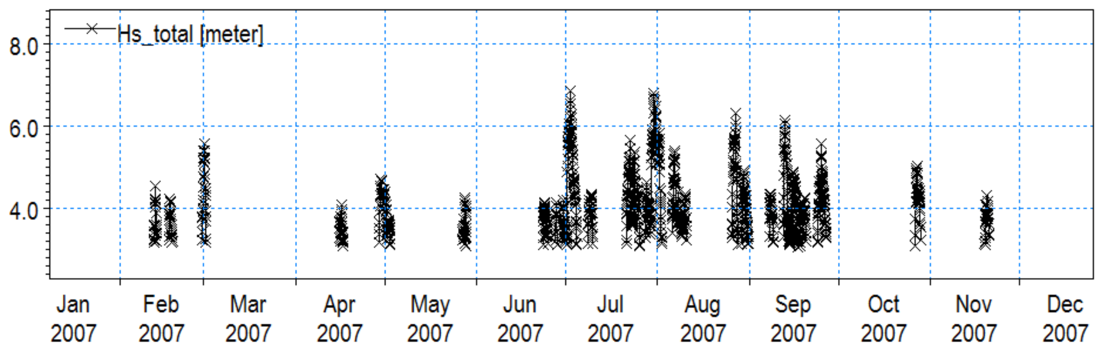

Figure 14. Storm events in 2007 based on Rottnest total wave height.

7. Conclusions

- Current situation is equivalent to, if not worse than, the sand trap condition in November 2007, Figure 13. From February to March 2008, an additional bypassing campaign had to be conducted before the usual winter bypassing with a total of bypassing volume of 164,000 m^3 in 2008. It is noted that the 1983 investigation (PWD 1983) identified the annual bypass volume as between 100,000 and 200,000 cubic metres of in-situ sand. (The current campaign measures pumped volume).

- The entrance channel is currently managed by the urgent installation of additional navaids. However, the sand bar is highly dynamic under storm conditions. Figure 14 shows the major storm distribution in 2007. The first storm in 2015 could come as early as mid-February if the history repeats itself.

- The major wave storms in Mandurah usually come in April (Figure 6). As a minimum, the next bypass campaign should commence no later than April 2015. However, the annual Mandurah Channel campaign will continue to need the occasional extension in some stormy years.

- Since the Government now has a perpetual obligation to bypass sand at the Mandurah Entrance for both beach stabilisation and recreational boat navigation, but no longer needs to allow for major flooding of Peel Inlet (because of Dawesville Channel being available), consideration should be given to (a) installing a fixed bypass (as discussed in the 1983 PWD Report) which can pick up sand to a deeper level and at any needed time, and (b) modifying the shape of the training walls such that both flood and ebb tide flows are co-directional. Funding should be mainly obtained from the beneficiaries of the bypass works.

8. Recommendations:

- Urgently install additional navigation aids to help skippers safety transit the area.
- The local DoT staff must continue to observe the marked channel, and act to manage navigation as required, including closing the channel if deemed necessary.
- Continue monitoring survey the channel depth after each major storm and shift the navigation aids if necessary.
- Investigate feasibility of an additional sand bypass campaign to clear some room in the sand trap.
- City of Mandurah and DoT coordinate a review of the targeted annual sand bypass volume and methodology for next 5 years as the current 100,000 m^3 bypassing volume has been exceeded significantly and consecutively since 2007.

Reference

DoT, 2006, Review of Sand Bypassing at Dawesville and Mandurah

PWD, 1983 Mandurah – Peel Inlet: Navigable Ocean Entrance Investigations

Coastal Zone Management, 2009, Mandurah Coastal Zone Climate Change Risk Assessment and Adaptation Plan