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R733 Rev 1

May 2016

City of Joondalup

Joondalup Coastal Monitoring Baseline Monitoring Report

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Table of Contents

1. Introduction 4
2. Monitoring Activities 6
3. Beach Monitoring Profiles 7
3.1 Baseline Data 8
4. Changes in Sediment Volume 11
4.1 Calculation of Volumes 11
4.2 Volume Analysis 11
5. Shoreline Movement 12
5.1 Mapping 12
6. Photographic Monitoring 13
6.1 Periodic Photographic Monitoring 13
6.2 Fixed Camera Monitoring 14
7. Discussion of Changes 16
7.1 Beach Profile Surveys 16
7.2 Shoreline Mapping 17
8. Conclusions 18
9. References 19
10. Appendices 20
Appendix A Shoreline Movement Plans 21
Appendix B Beach Profiles 22
Appendix C Photo Monitoring Locations 23
Appendix D 2015 Photo Monitoring 24

Table of Figures

Figure 1.1 Joondalup Monitoring Study Area 4

Figure 3.1 Location of Beach Monitoring Surveys 7

Figure 6.1 Photo Monitoring Locations 13

Figure 6.2 Spatially Calibrated Photo (21 April 2016) 15

Figure 6.3 Spatially Calibrated Photo (2 February 2016) 15

Figure 7.1 Nearmap Photos of Stockpile at Profile 8 16

Figure 7.2 Eroded Dune & Damaged Fencing at Whitfords Nodes (May 2016) 17

Table of Tables

Table 2.1 Proposed Monitoring Frequency 6

Table 3.1 Position of the MSL 9

Table 3.2 Position of the Vegetation Line 10

1. Introduction

The City of Joondalup (City) has established a coastal monitoring program for the shoreline within its boundaries. The City's shoreline extends from Marmion in the south, to Burns Beach in the north (Figure 1.1).

Figure 1.1 Joondalup Monitoring Study Area

The Joondalup coastal monitoring program has been set up to monitor changes to the shoreline within the study area, and to assist the City in managing their coastal assets. The monitoring program has been established under a Coastal Adaptation and Protection grant from the Department of Transport (DoT) and includes the following elements.

- Beach and hydrographic surveys conducted every 2 years, from behind the primary dune to several hundred metres offshore. 21 profiles are completed over approximately 15 km.
- Inspections and photographic monitoring of the beaches within the study area.
- Mapping of the shoreline from aerial photographs.
- Analysis of the monitoring surveys by experienced and professional coastal engineers, identifying areas of accretion or erosion.
- Establishment of a fixed monitoring camera to monitor the shoreline in Marmion.
- A report on the monitoring results and analysis each year, highlighting notable variations in shoreline movements and estimating the sediment movement within the study area.

The City engaged M P Rogers & Associates Pty Ltd (MRA) to complete the Joondalup coastal monitoring and undertake photographic monitoring of the beaches within the study area. This is the first year of the coastal monitoring program and presents the initial data. It provides a baseline to assess future shoreline change.

2. Monitoring Activities

The Joondalup coastal monitoring program includes the following monitoring activities:

- Beach profiles (survey).
- Shoreline mapping (coastal vegetation line mapped from aerial photographs).
- Photographic monitoring (seasonal).
- Fixed camera monitoring (Marmion).

The results of the monitoring will be presented in Coastal Monitoring Data reports. This report forms the baseline data report for comparison with future monitoring activities. Table 2.1 presents the planned frequency of the monitoring activities.

Table 2.1 Proposed Monitoring Frequency

Activity	Frequency	2015	2016		2017	
		October	March	October	March	October
Beach profiles	Biennial	✓				✓
Shoreline mapping	Annual	✓		✓		✓
Photo monitoring	6 monthly	✓	✓	✓	✓	✓
Fixed camera monitoring	Continuous		✓	✓	✓	✓

The surveyed beach profiles will notionally be completed in October every 2 years, following winter. It is important that they are completed at the same time each period (following winter) to minimise the impact of seasonal changes on the shoreline.

The shoreline mapping will be completed by mapping the position of the coastal vegetation line from ortho-rectified aerial photography. The shoreline mapping will be used to assess shoreline movement and monitor large scale trends in movement. The mapping should be completed annually and use aerial photographs from consistent times of the year to remove any seasonal variations from the record.

Photographic monitoring will be completed at fixed sites notionally in March (end of summer) and October (end of winter) each year. The photo monitoring will assist in highlighting seasonal movements on the shoreline and visually show any changes to beaches.

The data collected in the October 2015 and March 2016 monitoring periods will be discussed in the coming sections.

3. Beach Monitoring Profiles

A beach monitoring program has been established to monitor the shoreline within the City's boundaries. Beach and hydrographic surveys will be collected and analysed to allow long-term changes in shoreline position and coastal processes to be monitored.

The beach monitoring program consists of 21 profiles across the full extent of the City's coastline, approximately 15 km. The location of the beach monitoring profiles are shown in Figure 3.1.

Figure 3.1 Location of Beach Monitoring Surveys

The locations of the profiles are shown along with the beach profiles on the survey plans in Appendix B.

Profiles 1 to 10 have previously been surveyed for works on the proposed Ocean Reef Marina development. These profiles were therefore retained in the same locations to allow comparison with the existing surveys from 2010 and 2013.

The 11 new beach surveys were located to represent the relevant shoreline sectors around them. They were generally located some distance from coastal structures to minimise the seasonal influences of structures on the results.

All of the surveyed profiles extend from behind the coastal dune to approximately 1 km offshore. This is important to capture the extent of sediment movement and accurately assess the shoreline changes and coastal processes.

Due to the dynamic nature of the coast, it is useful to have specific triggers for the investigation of shoreline recession in order to focus on key trends. These triggers should be sufficiently large that short term fluctuations and variations in shoreline position are unlikely to exceed the triggers, while still identifying changing shoreline movement trends in time to take remedial action.

It is proposed to use the recession of 5 m or more of the Mean Sea Level (MSL) contour or vegetation line to identify areas requiring investigation. This generally indicates movements that are greater than the natural fluctuations.

The 0 mAHD contour is generally taken as an approximation of the MSL contour. The MSL can be used as a measure of shoreline position but is susceptible to short term fluctuations as a result of the influences of astronomical tides and changes in meteorological conditions.

The vegetation line is often used as a more consistent indicator of the shoreline position as it is not as readily influenced by short term fluctuations like the water line. Based on the surveys provided, the approximate location of the vegetation line was obtained at each profile. The approximation of a vegetation line on the surveyed profiles will be used to provide a direct comparison point with the shoreline mapping, which maps the coastal vegetation line.

The elevation of the vegetation line varied across the study area, but at the majority of profiles was between +3.0 and 4.5 mAHD. For analysis, a notional vegetation line indicator of +3.5 mAHD will be used across the surveys. The use of a contour line from the surveys to represent the vegetation line allows consistent analysis across all profiles and accounts for areas where the vegetation line may be artificially altered (eg Sorrento SLSC, access tracks), or the vegetation line at the profile location may not represent the vegetation line for the adjacent sections of shoreline.

3.1 Baseline Data

In each monitoring report, the relative position of the MSL (0 mAHD) and the vegetation line (+3.5 mAHD) contours will be recorded for each profile. The movement of these contours will then be identified and any significant changes investigated.

The baseline data from the end of winter 2015 surveys is presented in Tables 3.1 and 3.2. The same table format will be used to compare the results of future surveys. The values presented for 2015 show shoreline positions in metres relative to a reference baseline. The last column will highlight any profiles exceeding the triggers for further investigation.

Table 3.1 Position of the MSL

Survey Profile	Nov 2015	Oct 2017	Oct 2019	Oct 2021	Change in Past Year (m)	Change from Baseline (m)
1	142.2					
2	108.8					
3	170.3					
4	187.4					
5	141.3					
6	201.8					
7	207.2					
8	OCEAN REEF BOAT HARBOUR					
9	146.9					
10	183.7					
11	55.1					
12	75.2					
13	34.2					
14	56.5					
15	46.9					
16	66.9					
17	38.0					
18	33.2					
19	44.8					
20	93.6					
21	80.6					

Notes: 1. Values in table are position in metres, relative to a nominal baseline.
2. Positive values indicate accretion, negative values indicate recession
3. The MSL is approximated by the 0 mAHD contour.

Table 3.2 Position of the Vegetation Line

Survey Profile	Nov 2015	Oct 2017	Oct 2019	Oct 2021	Change in Past Year (m)	Change from Baseline (m)
1	121.0					
2	71.5					
3	135.8					
4	159.5					
5	90.8					
6	194.0					
7	140.3					
8	OCEAN REEF BOAT HARBOUR					
9	122.8					
10	165.0					
11	35.2					
12	49.3					
13	7.4					
14	22.0					
15	15.0					
16	28.6					
17	16.5					
18	7.6					
19	16.0					
20	35.5					
21	6.7					

Notes: 1. Values in table are position in metres, relative to a nominal baseline.
2. Positive values indicate accretion, negative values indicate recession
3. The vegetation line is approximated by the +3.5 mAHD contour.

4. Changes in Sediment Volume

4.1 Calculation of Volumes

By calculating the volumes of change in sediment across the profiles and shoreline, a sediment budget can be developed. A sediment budget highlights sinks, sources and pathways of sediment movement in the area and is useful in assessing coastal processes.

The volume of change on each of the beach profiles will be estimated from future surveys. To estimate the volumes, it will be assumed that each profile represents an area of shoreline to either side, equal to half the distance to the adjacent profile. This is an approximation of the actual shoreline but useful to determine volumes of change and therefore movement.

The change in area between the current year and previous year profiles will be calculated over the active zone for each profile, from the back of the dune to the estimated depth of closure. The estimated active zone and the depth of closure will be reviewed with each new survey. The depth of closure is generally defined as the seaward limit of significant cross-shore sediment movement on sandy beaches (Nicholls et al 1998). It will be assessed from the surveyed profiles in future monitoring activities as the depth of no significant change between surveys.

On profiles with rock cliffs or seawalls, only the change in area seaward of the cliff or seawall will be estimated. Total volumes accreted or eroded for each shoreline sector will be estimated by summing the individual changes.

4.2 Volume Analysis

As 2015 is the baseline data set, a volume of change is not able to be estimated from previous monitoring years for the entire program.

Future monitoring reports will calculate volumes of change for each profile and shoreline sector and use these volumes to produce a sediment budget, including estimated sediment pathways, sources and sinks for the study area.

5. Shoreline Movement

5.1 Mapping

The movement of a shoreline can also be estimated through mapping the position of the coastal vegetation line from aerial photography. As noted previously, the vegetation line is a good indicator of the shoreline position, as it generally represents the limit of coastal processes and is less susceptible to short term fluctuations than other markers such as the waterline. By mapping the historical position of the vegetation line, changes to the shoreline can therefore be estimated.

For the Joondalup coastal monitoring program, mapping of the coastal vegetation line provides a continuous estimate of the shoreline position for the study area. This expands upon the surveyed beach profiles used to represent the various shoreline sectors.

Shoreline movement plans covering the study area have been prepared and are included in Appendix A. The shoreline movement plans use historical vegetation lines captured from the following sources:

- Department of Transport (1942, 1965, 1980, 1987, 1996 and 2004).
- MRA database (2000, 2002, 2003, 2005, 2006, 2008, 2010 and 2013).

For this monitoring study MRA captured the position of the 2015 vegetation line from aerial photography provided by the City. The estimated accuracy of the position of these vegetation lines is believed to be in the order of ±5 m, depending on the resolution of the aerial photographs and the rectification process.

The shoreline movement plan shows the position of historical vegetation lines back to 1942. It should be borne in mind that since this time, there have been a number of changes to the shoreline in the City, including the following:

- Construction of Ocean Reef Boat Harbour.
- Construction of Hillarys Boat Harbour.
- Construction of Sorrento groyne field.

These coastal works as well as others outside the boundaries of the City will affect the local coastal processes and the position of the coastal vegetation lines. This should be considered when assessing the movements and estimating future trends in movement of the shoreline.

It is recommended that the shoreline movement plans are updated as part of the monitoring program with new vegetation lines every 1-2 years.

6. Photographic Monitoring

6.1 Periodic Photographic Monitoring

The coastal monitoring program includes seasonal photo monitoring of specific locations within the study area. Through the use of a specific field of view (FOV), photo monitoring programs can be used to obtain visual estimates of the changes occurring on the coast. Erosion and accretion trends can be observed, while photos taken at more frequent intervals can capture seasonal movements or the changes due to storm events.

MRA selected a number of locations within the study area to represent the shoreline and monitor changes to the City coast. The locations were selected with consideration of the photo monitoring guidelines prepared by the DoT (2012). Most of the locations selected were at the end of beach compartments. Figure 6.1 presents the location and orientation for all the points used in the photo monitoring program.

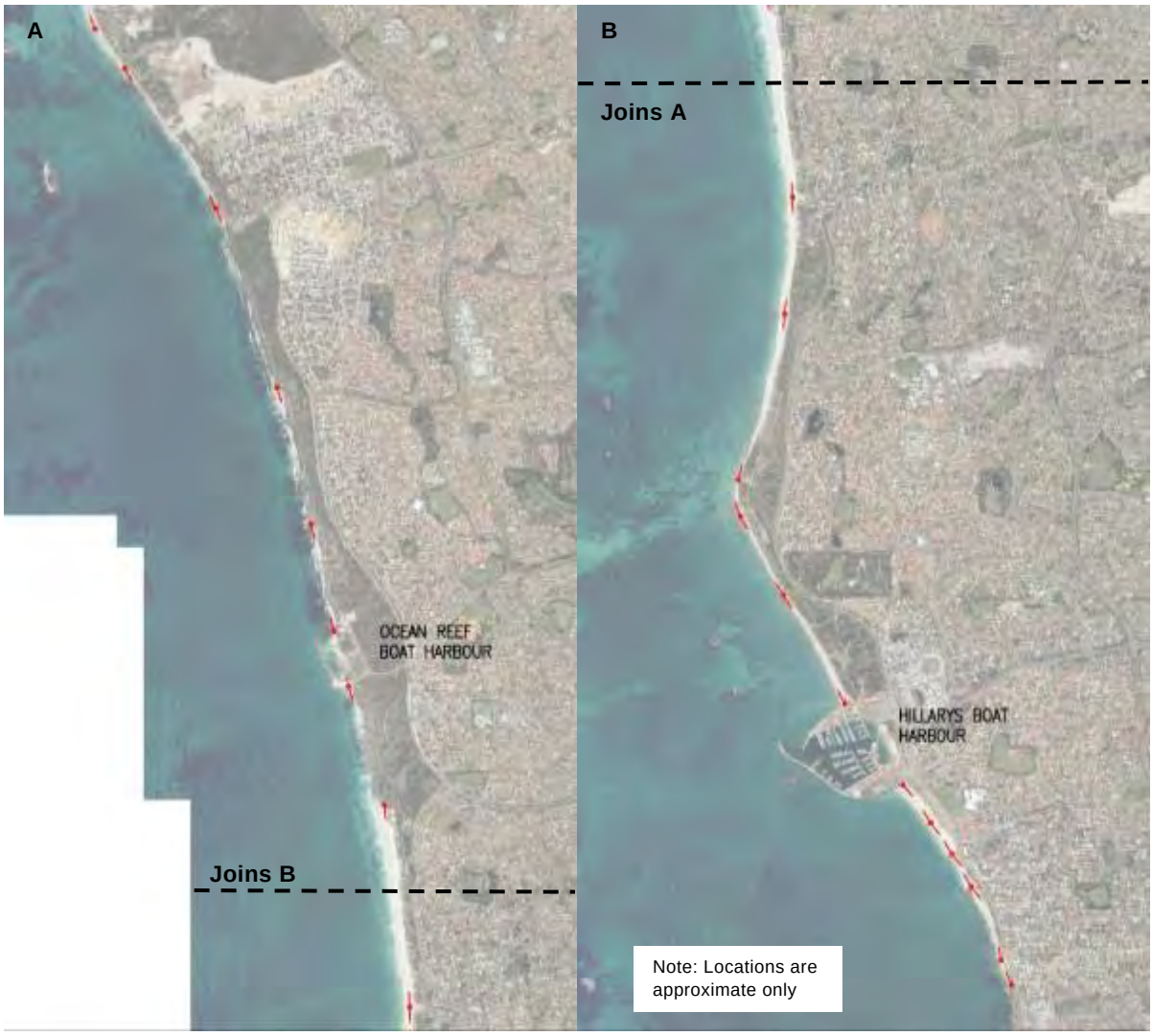

Figure 6.1 Photo Monitoring Locations

A drawing presenting the photo monitoring location is included in Appendix C.

A data sheet was completed along with the photos at each location, recording information such as date, time, GPS coordinates, camera, height, FOV, and descriptions of any landmarks which frame the FOV. This information allows replication of photographs in future years.

The data sheets and accompanying monitoring photos are included as Appendix D.

6.2 Fixed Camera Monitoring

In addition to periodic photo monitoring at fixed points, the coastal monitoring program also includes monitoring using a time lapsed camera. Following discussion with the City, it was agreed that the camera be installed at the new carpark north of the Mullaloo Angling and Aquatic Club (MAAC). The fixed camera was installed in February 2016 to assist with the following.

- Monitor the bank in front of the new carpark and protection offered to the carpark.
- Assess and manage public use of the beach.
- Provide qualitative and quantitative information on seasonal/storm changes in shoreline position.

Photographs are taken daily at 9am and 3pm and wirelessly transmitted to MRA and the City.

Through the use of spatial calibration, the time lapsed photos can be used to estimate the seasonal movement and storm erosion in this section of shoreline. To spatially calibrate a photo, ImageJ (a Java based image processing programme) was used to scale the image pixel against a known distance (a 1,700 mm survey staff placed on the beach) on the image. The location of the known distance on the image is referred to as the reference location. As the field of view is consistent over time, once the calibration is completed, photography taken at different times can be imported into ImageJ for direct comparison. Spatially calibrated photos are presented below in Figures 6.2 and 6.3.

From Figures 6.2 and 6.3, it is noted that there is negligible change to the width of the beach berm since the installation of the camera in February 2016. The beach berm width at the reference location as measured by Image J is in the order of about 4.5 m. Using this methodology, future monitoring analysis and reports will be able to estimate the beach movement at the reference location. It is noted that distance estimated is most accurate near the reference location, where it is calibrated. Distances estimated at other locations will be affected by distortion as a result of the depth of field.

Figure 6.2 Spatially Calibrated Photo (21 April 2016)

Figure 6.3 Spatially Calibrated Photo (2 February 2016)

7. Discussion of Changes

As this is the first year of the Joondalup coastal monitoring programme, the survey data obtained in 2015 has been used to create a baseline dataset for analysis in future years. A full analysis of shoreline changes is therefore not possible. However, where historic data exists, general observations on movements have been made.

7.1 Beach Profile Surveys

Existing beach profile surveys completed for the proposed Ocean Reef Marina development provide some data from 2010 and 2013 for comparison. Comparison of the existing and new surveys for the existing Profiles 1 to 10 shows the following:

- Profile 2 at Pinnaroo Point experienced significant shoreline recession from 2010 to 2013, with minor accretion after 2013.
- Profile 3, north of Pinnaroo Point, experienced minor accretion.
- A change in profile is shown in the surveys for Profile 6, but this is believed to be an area of rock and a likely survey error. MRA has queried the surveyors on this issue and are awaiting a response.
- Profile 8 showed recession between 2010 and 2015. It is noted that this area is a sand stockpile within the Ocean Reef Boat Harbour.
- Other Profiles show very minor change between 2010 and 2015.

As stated above, Profile 8, is located over a sand stockpile within the Ocean Reef Boat Harbour. This area is regularly worked during periods of harbour dredging and sand nourishment works. Nearmap photographs from late 2015 show works being completed in this area, with a dredge in the water and machinery working in the stockpile area (Figure 7.1). The change seen in the surveys has therefore been assessed to be due to work in this stockpile area rather than natural movement of the profile.

Figure 7.1 Nearmap Photos of Stockpile at Profile 8

7.2 Shoreline Mapping

The shoreline movements in recent years have also been generally assessed from the shoreline movement plans, between 2010 or 2013 to 2015. The main trends in movement are summarised below:

- The shoreline south of Hillarys Boat Harbour is continuing to accrete.
- The shoreline north of Hillarys Boat Harbour experienced general recession.
- The shoreline at Pinnaroo Point has eroded up to 20 m between 2010 and 2015.
- The shoreline between Pinnaroo Point and Oean Reef has generally accreted up to 10 m between 2010 and 2015.

There is some noticeable erosion at Pinnaroo Point, where the vegetation line has receded up to 20 m. This erosion is seen in both the beach profiles and the shoreline mapping. While there is currently a wide foreshore at Pinnaroo Point and limited infrastructure at risk, the buffer will be quickly reduced if this rate of erosion continues. The erosion in this area should continue to be monitored.

It is also noted that there is a considerable accretion trend south of Hillarys Boat Harbour and erosion trend to the north. While the accretion on Sorrento Beach to the south has been occurring since construction, the erosion of the shoreline to the north of the harbour has not previously been a concern. However the beach widths in the area are now decreasing, the dune is eroding and the shoreline retreating. Figure 7.2 shows a recent photograph of storm damage, narrow beach and loss of dune fencing in the area.

Figure 7.2 Eroded Dune & Damaged Fencing at Whitfords Nodes (May 2016)

The construction of Hillarys Boat Harbour has obviously interrupted the longshore sediment transport in the area and altered the coastal dynamics. Should this erosion trend continue north of the Harbour, the City may wish to consider movement of sediment from south to north of the Harbour.

In future reports, this section will analyse changes and trends in the shoreline position of the monitoring profiles and will recommend coastal management options as required.

8. Conclusions

This report presents the initial Joondalup coastal monitoring data collected in 2015. This data includes:

- Beach profiles (survey).
- Shoreline movement plans.
- Photographic monitoring (seasonal).
- Fixed camera monitoring (Marmion).

This will form the baseline data set which will be used to determine future changes in shoreline position within the study area and assist in the management of the Joondalup coastline.

There has been some recent erosion at Pinnaroo Point, reflected in both the shoreline mapping and beach profile surveys. This area should be closely monitored in coming years to assess whether the recent erosion continues.

The next coastal monitoring report will present a summary of the movement between the 2015 baseline data set and the 2017 survey results. Photo monitoring will be conducted annually, and will therefore be carried out in conjunction with the 2017 beach monitoring surveys. Fixed camera monitoring is being undertaken continuously, and will be used to determine any change in shoreline position.

9. References

Department of Transport, 2012. *How to photo monitor beaches*. Coastal Infrastructure Department, Government of Western Australia, Perth.

10. Appendices

Appendix A **Shoreline Movement Plans**

Appendix B **Beach Profiles**

Appendix C **Photo Monitoring Locations**

Appendix D **2015 Photo Monitoring**