Report 5: Coastal Monitoring

Gippsland Lakes Coastal Assessment

August 2013

DOCUMENT STATUS

Version	Doc type	Reviewed by	Approved by	Date issued
v02	Draft Report	Tim Womersley	Warwick Bishop	09/04/2013
v03	Draft Report	Warwick Bishop	Warwick Bishop	30/08/2013

PROJECT DETAILS

Project Name	Gippsland Lakes Coastal Assessment
Client	Department of Environment and Primary Industries
Client Project Manager	Tania Brooker
Water Technology Project Manager	Warwick Bishop
Report Authors	Warwick Bishop, Tim Womersley
Job Number	2363-01
Report Number	R05
Document Name	2363-01R05v03a_Monitoring.docx

Cover Photo: Ninety Mile Beach at Steamer Landing (16 July 2012)

15 Business Park Drive
Notting Hill VIC 3168

Telephone (03) 8526 0800
Fax (03) 9558 9365

ACN No. 093 377 283
ABN No. 60 093 377 283

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1. INTRODUCTION

1.1 Overview

The Department of Sustainability and Environment commissioned Water Technology to undertake the Gippsland Lakes Coastal Hazard Assessment Project. The assessment has broadly identified key coastal processes and hazards within the study area through the application of various tools including detailed hydrodynamic modelling. The potential physical impact of these hazards has been further investigated in detail at a number of critical locations for a range of future sea level scenarios.

This report describes a scope of limited coastal monitoring undertaken for this study. In addition, recommendations are made for ongoing and future monitoring that will support the refinement of coastal hazard predictions and also track changes in observed coastal hazard over the medium to longer term. This monitoring should facilitate the building of technical understanding to underpin awareness and facilitate adaptation to future climate change. Future monitoring may also support benchmarking of mitigation or adaptation works / strategies.

The report incorporates the following components:

- Description of Ninety Mile Beach profile monitoring
- Description of the lake shoreline profiles monitoring
- Description of sediment sampling
- Recommendations for future monitoring to support ongoing coastal hazard assessments by tracking any changes.

Provide recommendations for future coastal monitoring to enable tracking and assessment of ongoing coastal change (or stability) and of the effects and success or otherwise of coastal protection structures or strategies. Undertake, document and archive a first round of monitoring records.

1.2 Reporting

This document is part 5 of a series of reports produced as part of the Gippsland Lakes Coastal Assessment Project. It should be read in conjunction with the other reports. The complete set of reports is as follows:

- Report 1: Summary Report
- Report 2: Inundation Hazards
- Report 3: Outer Barrier Coastal Erosion Hazards
- Report 4: Lake Shoreline Erosion Susceptibility
- **Report 5: Coastal Monitoring**

2. NINETY MILE BEACH PROFILES

2.1 Survey Locations

Coastal profiles have been surveyed along the [1]Ninety Mile Beach as to enable monitoring and assessment of ongoing coastal profile change to be undertaken. A total of 5 coastal profiles have been surveyed. The locations for undertaking the coastal profiles were identified through analysis of the outer barrier dune profiles from the LiDAR dataset to identify sections of the barrier with the lowest volumes and therefore increased potential vulnerability to erosion. The coastal profile locations were also cross-checked against other geomorphic and historical evidence of significant coastal change along the Ninety Mile Beach. The five locations selected for coastal profile surveying are displayed in Figure 2-1 and detailed below:

Seaspray

The outer barrier at Seaspray is low and narrow with a volume above MHHW of less than approximately 200 m^3/m. Historical accounts from early visitors and campers to this area contain a number of references to washover events in this area. Significant erosion of the dune occurred in this area during the June 2007 East Coast Low events. Two coastal profiles (western & eastern) within the vicinity of Seaspray have been surveyed.

Blowholes

In this section of the Ninety Mile Beach, the outer barrier separates the ocean from Bunga Arm, a narrow lagoon that runs parallel to the coast for approximately 15 km, directly behind Ninety Mile Beach. The Bunga Arm lagoon is a paleo entrance channel to the Gippsland Lakes that was deflected eastward by longshore sediment drift and finally sealed within the last 3,000-4,000 years. The outer barrier is very narrow in sections along Bunga Arm. At two locations known as the ‘1st’ and ‘2nd’ Blowholes the dune volume and crest elevations are relatively low. Anecdotal accounts report that the barrier was breached at the 2nd Blowhole in the early 1950’s following a severe storm event. Coastal profiles have been surveyed at both the 1st and 2nd Blowholes.

Eastern Beach

To the east of Lakes Entrance, the outer barrier separates the ocean from Cunninghame Arm. Cunninghame Arm is another narrow coastal lagoon that intermittently formed the entrance channel to the Gippsland Lakes prior to the permanent artificial entrance being constructed in 1889. Following the opening of the artificial entrance, the reduction in tidal flows and eastward longshore sediment drift, rapidly sealed the ocean entrance to Cunninghame Arm. Over the last 120 years, the outer barrier has built significantly in volume and crest height across what was once a semi-permanent tidal entrance to the Gippsland Lakes.

[1] Within *Report 3: Outer Barrier Coastal Erosion Hazards*, the Ninety Mile Beach is defined as the most seaward terrestrial expression of the ‘Outer Barrier’. The ‘Outer Barrier’ is an elongate accumulation of sand initiated by waves, aeolian transport and vegetation growth that extends continuously (except for the artificial entrance at Lakes Entrance) along the entire length of the study area.

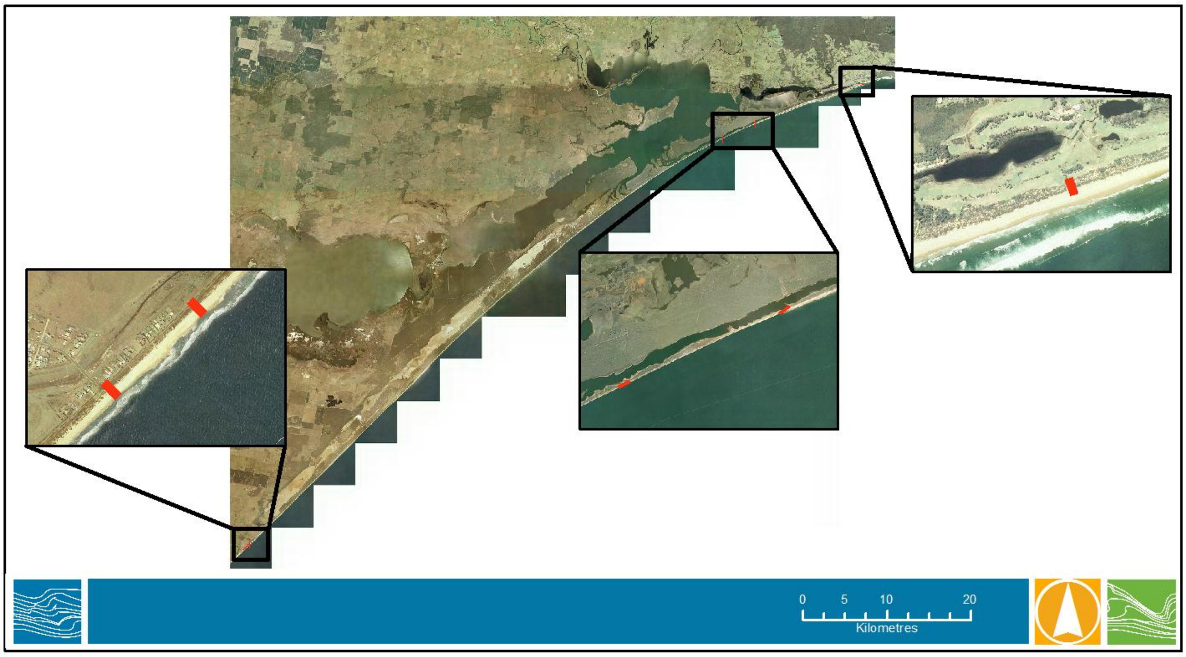

Figure 2-1 Ninety Mile Beach Coastal Profile Survey Locations

2.2 Profile Survey Method

The coastal profiles were surveyed using a Trimble GeoExplorer® 6000 series GeoXR differential GPS (dGPS). The dGPS receiver provides horizontal and vertical accuracies of ±0.1 m. Coastal profile surveys have been provided in GDA zone 55 coordinates. Vertical elevations are relative to AHD. The coastal profile surveying was undertaken on the 15-16th October 2012.

The coastal profile surveys have been compared to coastal profiles extracted at precisely the same location from the coastal LiDAR survey which was captured by DSE in September 2007.

The change in barrier volume between the September 2007 LiDAR survey and October 2012 survey has been calculated for each coastal profile for elevations above 0.8 m AHD (MHHW).

Whilst no temporary benchmarks were established for these sites, the locations were accurately recorded using GPS. Hence the profiles can be readily re-established in the future using similar high-accuracy GPS equipment. If desired it would be possible to construct temporary or permanent benchmarks for these sites, however given the affordability, portability and cost of high-accuracy GPS loggers it may not be justified. This is something that can be decided in the future.

2.3 Profile Survey Results

2.3.1 Overview

The coastal profiles surveys and comparison to 2007 LiDAR profiles are displayed in the following sections. Electronic copies of the data, including location are provided in the accompanying Study Data DVD.

2.3.2 Western Seaspray

The survey profile results are for Western Seaspray are plotted in Figure 2-2, with the survey start-end coordinates provided in Table 2-1. Figure 2-3 shows a photo looking landward at the profile location. The results show there has been erosion of the dune crest and volume between 2007 and 2012.

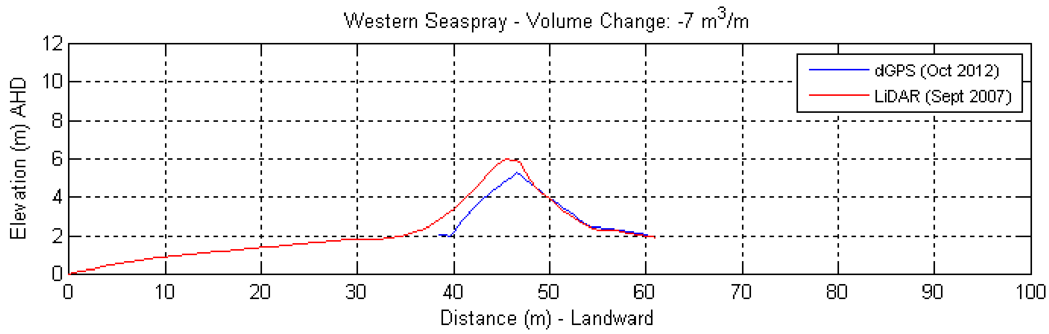

Figure 2-2 Western Seaspray Coastal Profile

Table 2-1 Location of the Western Seaspray Coastal Profile (Coordinates given in GDA 1994 - MGA Zone 55)

	X	Y
Start (Landward)	517074.32	5752736.14
End (Seaward)	517125.03	5752689.35

Figure 2-3 Western Seaspray Coastal Profile Location (15th October 2012)

2.3.3 Eastern Seaspray

The survey profile results are for Eastern Seaspray are plotted in Figure 2-4, with the survey start-end coordinates provided in Table 2-2. Figure 2-5 shows a photo looking landward at the profile location. The results are very similar to Western Seaspray and show there has been erosion of the dune crest and volume between 2007 and 2012. Both the Seaspray profiles show good agreement with the LiDAR survey on the back-dune side, providing confidence in the accuracy of the measurements.

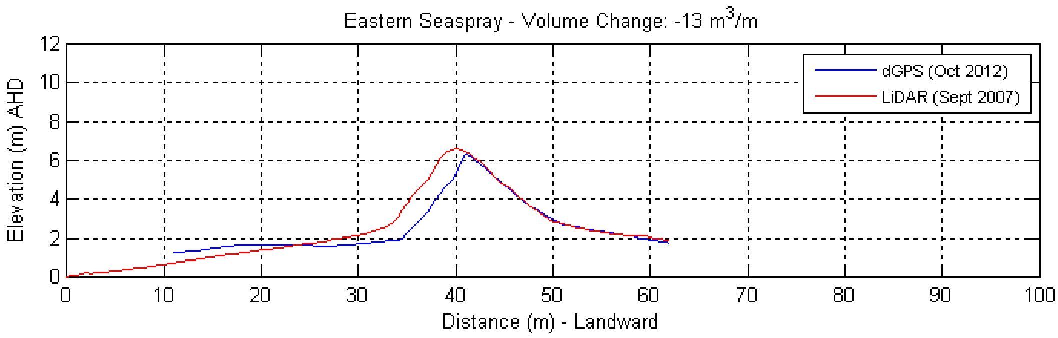

Figure 2-4 Eastern Seaspray Coastal Profile

Table 2-2 Location of the Eastern Seaspray Coastal Profile (Coordinates given in GDA 1994 - MGA Zone 55)

	X	Y
Start (Landward)	517429.71	5753086.13
End (Seaward)	517480.91	5753035.51

Figure 2-5 Eastern Seaspray Coastal Profile Location (15th October 2012)

2.3.4 Bunga Arm - 1st Blowhole

The survey profile results are for the First Blowhole are plotted in Figure 2-6, with the survey start-end coordinates provided in Table 2-3. Figure 2-7 shows a photo looking landward at the profile location. The results show there has been significant erosion of the foredune and some erosion on the backface (lakeside) of the dune between 2007 and 2012. This is consistent with the photo image that shows clear dune cut and vegetation falling down the face of the dune.

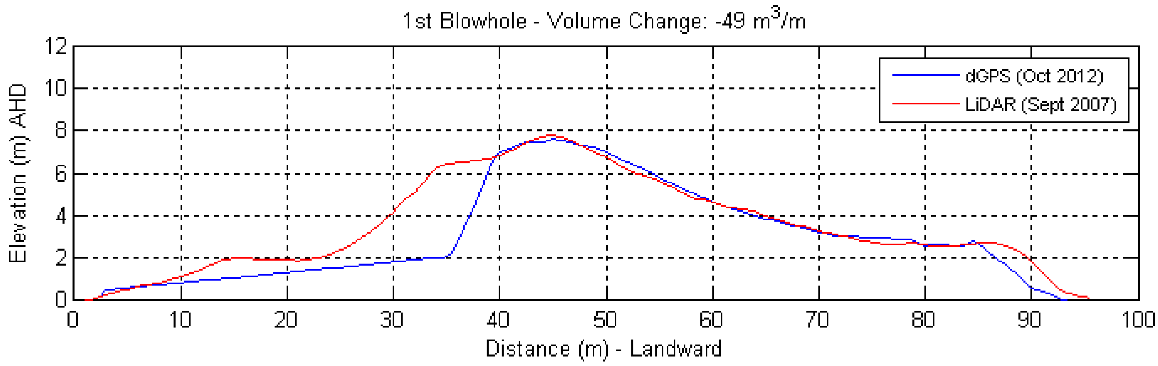

Figure 2-6 1st (western) Blowhole Coastal Profile

Table 2-3 Location of the 1st (western) Blowhole Coastal Profile (Coordinates given in GDA 1994 - MGA Zone 55)

	X	Y
Start (Landward)	573532.05	5801144.85
End (Seaward)	573579.52	5801058.55

Figure 2-7 1st Blowhole Coastal Profile Location (15th October 2012)

2.3.5 Bunga Arm - 2nd Blowhole

The survey profile results are for the Second Blowhole are plotted in Figure 2-8, with the survey start-end coordinates provided in Table 2-4. Figure 2-9 shows a photo looking landward at the profile location. The results show there has been significant erosion of the foredune between 2007 and 2012. This is consistent with the photo image that shows clear dune cut and vegetation falling down the face of the dune.

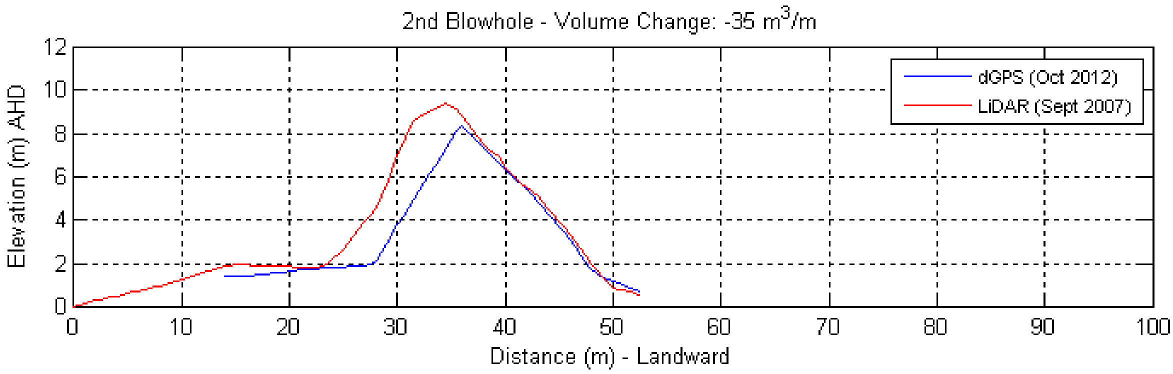

Figure 2-8 2nd (eastern) Blowhole Coastal Profile

Table 2-4 Location of the 2nd (eastern) Blowhole Coastal Profile (Coordinates given in GDA 1994 - MGA Zone 55)

	X	Y
Start (Landward)	577382.68	5802892.79
End (Seaward)	577407.69	5802838.80

Figure 2-9 2nd Blowhole Coastal Profile Location (15th October 2012)

2.3.6 Eastern Beach

The survey profile results are for Eastern Beach are plotted in Figure 2-10, with the survey start-end coordinates provided in Table 2-5. Figure 2-11 shows a photo looking landward at the profile location. The results show there has been minimal change to the dune between 2007 and 2012, with only minor redistribution of sand on the foredune and some deposition on the back face.

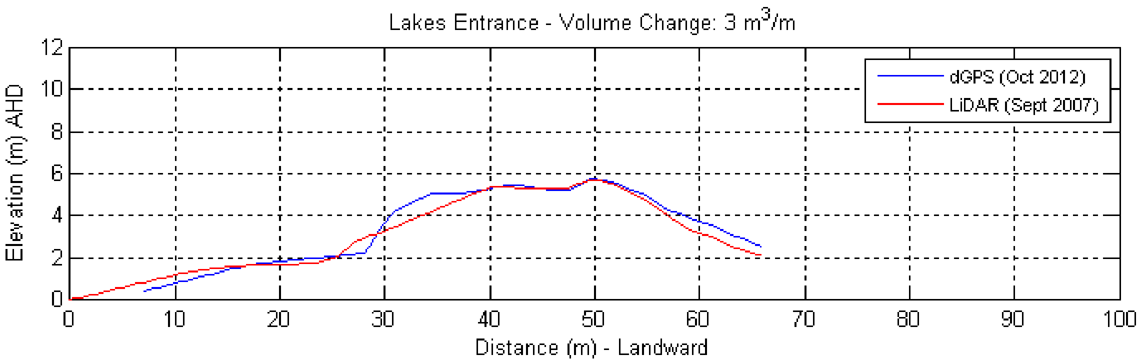

Figure 2-10 Lakes Entrance Coastal Profile

Table 2-5 Location of the Lakes Entrance Coastal Profile (Coordinates given in GDA 1994 - MGA Zone 55)

	X	Y
Start (Landward)	589976.68	5807603.95
End (Seaward)	590000.25	5807534.86

Figure 2-11 Lakes Entrance Blowhole Coastal Profile Location (16th October 2012)

3. LAKE SHORELINE PROFILES

3.1 Survey Locations

Lake-side shoreline profiles were surveyed at various locations around the Gippsland Lakes to enable monitoring and assessment of ongoing shoreline position and profile change to be undertaken. A total of six profiles were surveyed, on the 3rd and 4th of February 2013, at the locations shown in Figure 3-1**Error! Reference source not found.**. Some additional profiles were captured the previous week, however the data for these was unfortunately lost due to a rare equipment failure.

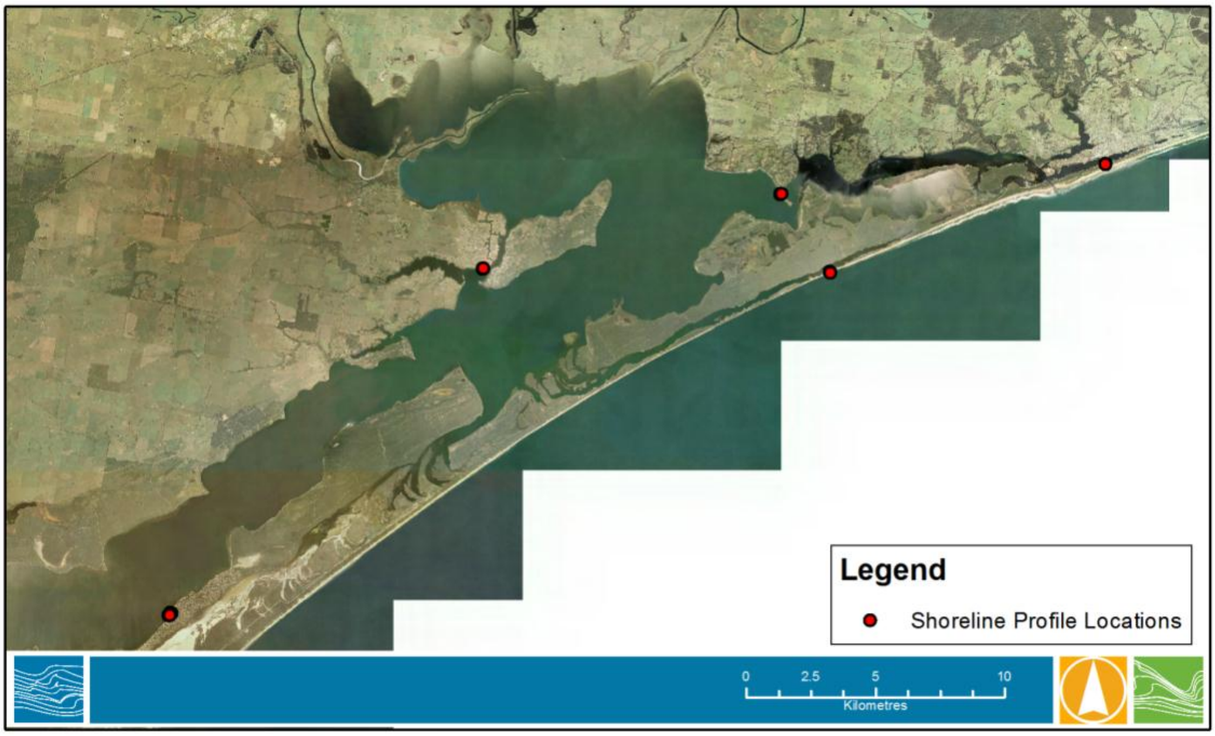

Figure 3-1 Lakes Shoreline Profile Locations

3.2 Profile Survey Method

The lakes shoreline profiles were surveyed using a Trimble GeoXH 6000 Series 3.5G CM Edition with NMEA, enabling decimetre (0.1 m) accuracy. Vertical elevations of the profiles are given relative to AHD, and coordinates in GDA 1994 - MGA Zone 55. As for the Ninety Mile Beach profiles, there were no benchmarks established for these sites as the start and end coordinates were recorded and can be readily re-established in the future.

3.3 Profile Survey Results

3.3.1 Overview

The lake shoreline profile surveys and comparison to 2007 LiDAR profiles are displayed in the following sections. Electronic copies of the data, including location are provided in the accompanying Study Data DVD.

3.3.2 Bunga Arm

The survey profile results are for Bunga Arm are plotted in Figure 3-3, with the survey start-end coordinates provided in Table 3-1. Figure 3-3 shows a photo looking landward at the profile location. The results show there has been minimal change to the lakeside part of the profile, whereas the main dune has eroded significantly and begun to translate to a more inland location between 2007 and 2013. The photo shows that dune vegetation has gone and subsequently a blowout formed.

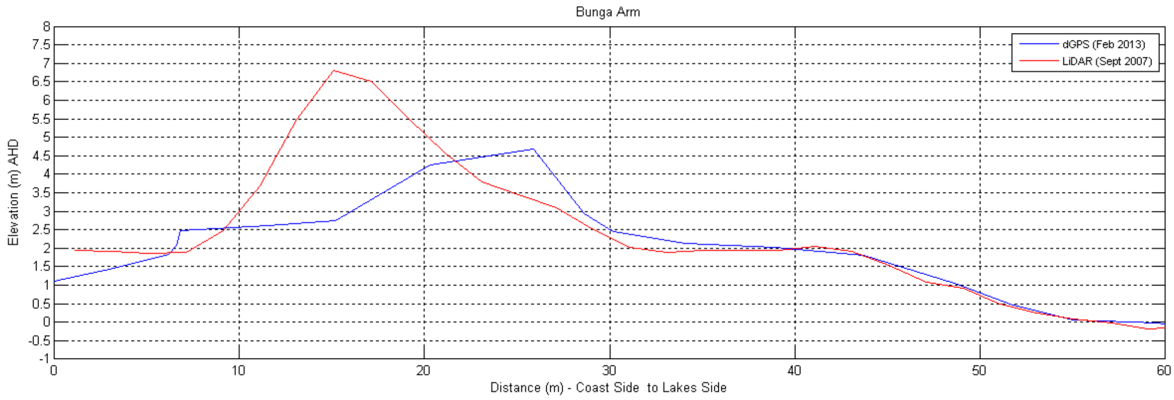

Figure 3-2 Bunga Arm Coastal Profile

Table 3-1 Location of the Bunga Arm Coastal Profile (Coordinates given in GDA 1994 - MGA Zone 55)

	X	Y
Start (coast-side)	576879.44	5802635.28
End (Lake-side)	576852.39	5802691.17

Figure 3-3 Bunga Arm Coastal Profile Location (3rd February 2013)

3.3.3 Paynesville

The survey profile results are for Paynesville are plotted in Figure 3-4, with the survey start-end coordinates provided in Table 3-2. Figure 3-5 shows a photo looking seaward at the profile location. The results suggest there has been some loss of sand from near the lake shore between 2007 and 2013. However, this is inconclusive as the 2007 data may incorporate disturbance from the water surface.

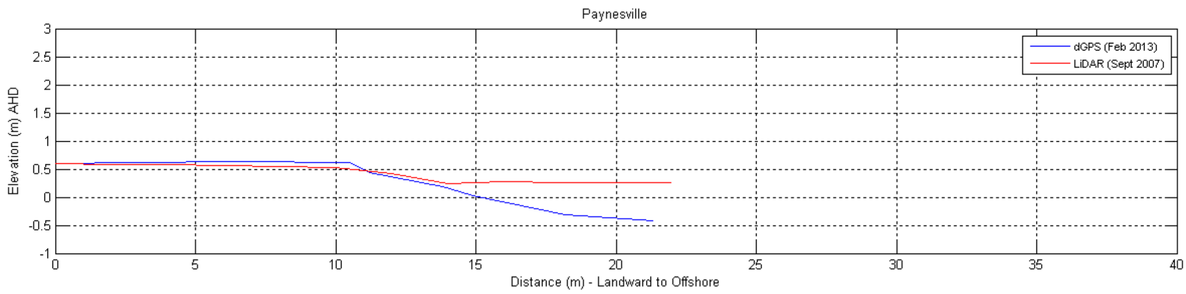

Figure 3-4 Paynesville Coastal Profile

Table 3-2 Location of the Paynesville Coastal Profile (Coordinates given in GDA 1994 - MGA Zone 55)

	X	Y
Start (Landward)	563463.64	5802809.73
End (Lakeward)	563450.66	5802791.97

Figure 3-5 Paynesville Coastal Profile Location (4th February 2013)

3.3.4 Metung

The survey profile results are for Metung are plotted in Figure 3-6, with the survey start-end coordinates provided in Table 3-3. Figure 3-7 shows a photo looking north at the profile location. The results suggest there has been some cut into the rise behind the beach between 2007 and 2013. However, the shoreline appears to be stable, or to have recovered.

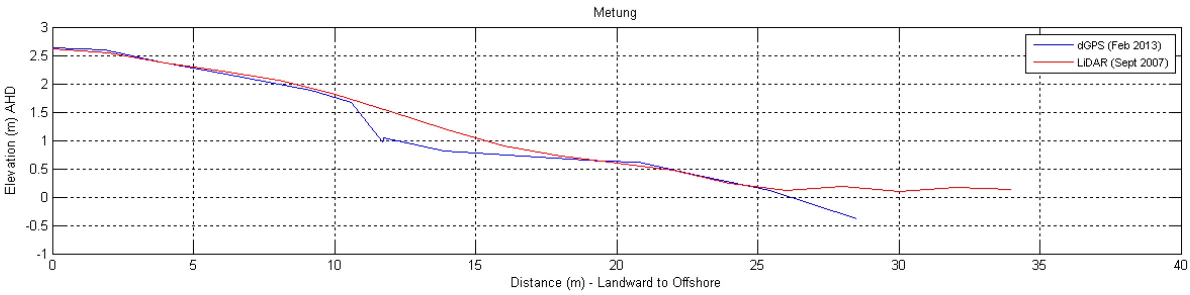

Figure 3-6 Metung Coastal Profile

Table 3-3 Location of the Metung Coastal Profile (Coordinates given in GDA 1994 - MGA Zone 55)

	X	Y
Start (Landward)	574993.23	5805683.69
End (Lakeward)	574960.67	5805673.59

Figure 3-7 Metung Coastal Profile Location (4th February 2013)

3.3.5 Lakes Entrance – Cunninghame Arm

The survey profile results are for Lakes Entrance are plotted in Figure 3-8, with the survey start-end coordinates provided in Table 3-4. Figure 3-9 shows a photo looking west at the profile location. The results suggest there has been minimal change to the beach, with perhaps some accretion between 2007 and 2013.

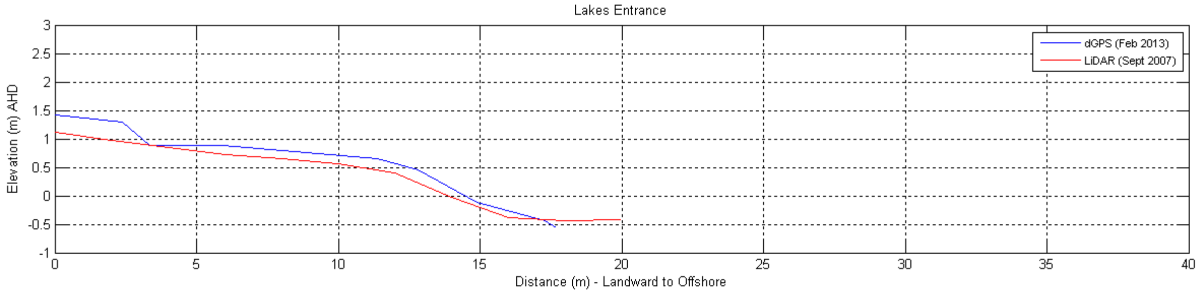

Figure 3-8 Lakes Entrance - Cunninghame Arm Coastal Profile

Table 3-4 Location of the Lakes Entrance - Cunninghame Arm Coastal Profile (Coordinates given in GDA 1994 - MGA Zone 55)

	X	Y
Start (Landward)	587517.65	5806829.04
End (Lakeward)	587518.70	5806849.01

Figure 3-9 Lakes Entrance – Cunninghame Arm Coastal Profile Location (4th February 2013)

3.3.6 Loch Sport A

The survey profile results are for Loch Sport A are plotted in Figure 3-10, with the survey start-end coordinates provided in Table 3-5. Figure 3-11 shows a photo looking east at the profile location. The results suggest there has been erosion from the upper sections of the profile and accretion in the lower sections between 2007 and 2013. Whilst not verified, it appears that the beach profile may have been recently altered due to artificial nourishment.

Figure 3-10 Loch Sport A Coastal Profile

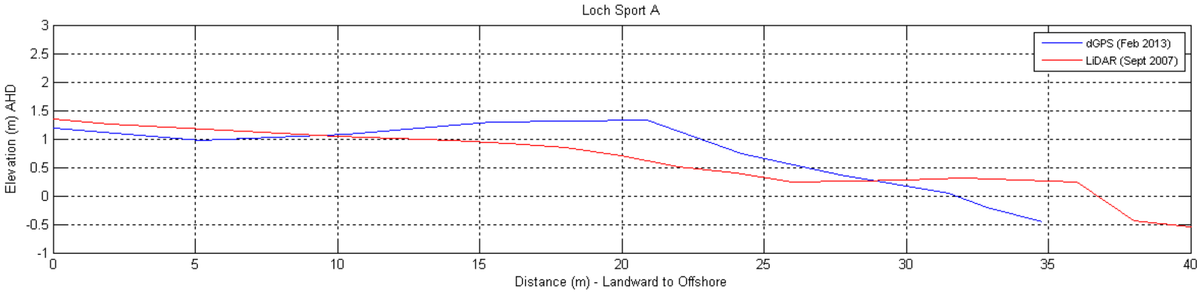

Table 3-5 Location of the Loch Sport A Coastal Profile (Coordinates given in GDA 1994 - MGA Zone 55)

	X	Y
Start (Landward)	551342.26	5789406.81
End (Lakeward)	551299.17	5789427.95

Figure 3-11 Loch Sport A Coastal Profile Location (4th February 2013)

3.3.7 Loch Sport B

The survey profile results are for Loch Sport B are plotted in Figure 3-12, with the survey start-end coordinates provided in Table 3-6. Figure 3-13 shows a photo looking east at the profile location. The results suggest there has been significant build-up of the profile between 2007 and 2013. Whilst not verified, it appears that the beach profile may have been altered due to artificial nourishment.

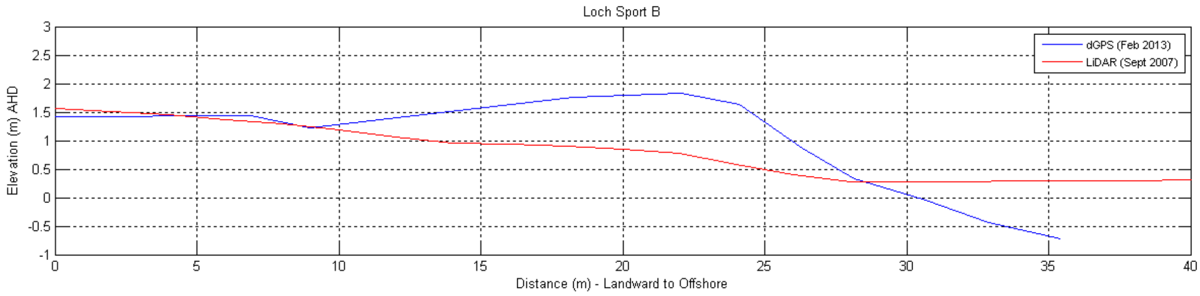

Figure 3-12 Loch Sport B Coastal Profile

Table 3-6 Location of the Loch Sport B Coastal Profile (Coordinates given in GDA 1994 - MGA Zone 55)

	X	Y
Start (Landward)	574993.23	5805683.69
End (Lakeward)	574960.67	5805673.59

Figure 3-13 Loch Sport B Coastal Profile Location (4th February 2013)

4. SEDIMENT SAMPLING

4.1 Overview and Method

Sediment samples were collected from Seaspray and Paradise Beach. Samples were collected from the mid face of the dune and the swash zone at both locations. The particle size distributions of the samples were assessed via sieving analysis by ALS Environmental, at a NATA accredited laboratory. The particle size distributions are presented in Table 4-1 to Table 4-4 below.

4.2 Sediment Sampling Results

The sediment samples of the dune face and swash and swash zone along the Outer Barrier yielded median sediment grain sizes representative of medium coarse sand. Median grains sizes were larger and the distributions skewed to larger fractions in the swash zone compared to the dune.

4.2.1 Seaspray

Table 4-1 Particle Size Distribution for a Sediment Sample Taken from the Dune Face at Seaspray

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	97%
0.60	85%
0.425	78%
0.300	58%
0.150	1%
0.075	1%
Median	0.225 mm

Table 4-2 Particle Size Distribution for a Sediment Sample Taken from the Swash Zone at Seaspray

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	99%
2.36	99%
1.18	90%
0.60	66%
0.425	49%
0.300	25%
0.150	1%
0.075	1%
Median	0.425 mm

4.2.2 Paradise Beach

Table 4-3 Particle Size Distribution for a Sediment Sample Taken from the Dune Face at Paradise Beach

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	86%
0.60	76%
0.425	69%
0.300	41%
0.150	0%
0.075	0%
Median	0.300 mm

Table 4-4 Particle Size Distribution for a Sediment Sample Taken from the Swash Zone at Paradise Beach

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	99%
1.18	83%
0.60	64%
0.425	52%
0.300	24%
0.150	1%
0.075	1%
Median	0.363 mm

5. FUTURE MONITORING OPTIONS

5.1 Overview

As discussed in the Victorian Coastal Hazard Guide (DSE, 2012), Victoria has a paucity of reliable historical data on shoreline movement and coastal processes. The Gippsland Lakes and Ninety Mile Beach are no exception. This highlights the need for a well-targeted monitoring program that can help to refine the assessment and understanding of coastal hazards, track trends and benchmark mitigation or adaptation strategies in the future.

In order for an adaptive management approach to be successful there has to be a basis on which to evaluate system behaviour over time. This allows decision-makers to determine what if any changes are required to actions or policies to meet the changing circumstances over the medium to long term.

The following sections outline the type of monitoring that may be considered to support the ongoing management of the lakes and surrounding coastal areas.

5.2 Outer Barrier

5.2.1 Overview

Data collection to track the spatial and temporal variation in the barrier dune and near-shore zone over time is highly desirable. This could include the following:

- Repeat condition surveys at specific locations
- Comparative profile surveys at specific locations
- Aerial survey of dune system
- Bathymetric profiles/survey
- Wave monitoring
- Other methods of data capture

5.2.2 Condition Surveys

Different sites have specific characteristics that may be recorded and compared over time, both through a standard log sheet with appropriate descriptions and by photography. This may include aspects such as:

- Prevailing wind/wave conditions at the time
- Any observed geomorphologic features (erosion cut for example, changes in stratigraphy/sediment)
- Vegetation cover/composition change
- Photos of the site from repeatable positions/perspectives

There are standard proforma's for this type of monitoring that may be readily applied to the Gippsland Coast.

5.2.3 Profile Surveys

Repeat surveys of shore/dune profiles have typically been captured using a survey benchmark at each location, with a level and tape used to record point locations. More recently, high-accuracy portable GPS equipment has become available that eliminates the need for benchmark establishment, enabling more flexibility in data capture. Manual surveys have the disadvantage of being labour intensive and hence can be relatively costly for the amount of data captured. On the other hand, they enable close observation of sites and hence more detailed site analysis and context to be gathered, compared to a remote capture technique.

5.2.4 Aerial Dune Survey

There are two main sources of aerial topography survey and image capture available at present. These are:

- ***LiDAR and high resolution aerial imagery captured from an aircraft*** - With this method a high-accuracy terrain model of the entire Ninety Mile Beach could be captured fairly rapidly. However whilst the price of LiDAR has come down in recent years, this would still be a relatively expensive exercise.
- ***Unmanned aerial vehicle (UAV) image capture*** - UAV technology is fairly new to civil survey applications but is gaining popularity quite rapidly. With this method, high resolution images can be captured and a DEM derived via photogrammetry techniques.

The UAV method is applicable for smaller areas as each sortie has limited range, although the deployment costs are low. The terrain information from UAV is not as robust as LiDAR as it cannot produce reliable terrain in vegetated areas in the way LiDAR can. Taking these limiting factors into account, UAV may be suitable for rapid deployment and capture of local areas of dune for post-storm survey for example. Due to the much lower costs it may also be possible to conduct regular surveys of key sites over the longer term. This has the potential to provide highly useful information for tracking of barrier dune response over time-frames ranging from seasonal to yearly.

5.2.5 Bathymetric Profiles/Survey

Regular bathymetric profiles of the near-shore zone would assist in the understanding of cross and longshore sediment transport. However, the Ninety Mile Beach is an isolated and treacherous coastline. Practicality and safety concerns would need to be considered before attempting to implement a regular profile survey program.

Bathymetric LiDAR would provide a more spatially comprehensive process to capture variations in the sea bed, although not as accurate at the local scale. Such a program would, however, be a significant undertaking and not likely be repeated frequently.

5.2.6 Wave Monitoring

Waves are presently monitored off Lakes Entrance by Gippsland Ports. This provides a good record of wave energy at the eastern end of the study area. Whilst better wave information at the western end of the Ninety Mile Beach would be desirable, it is not a high priority in terms of data that could contribute to better understanding of coastal hazards into the future.

5.2.7 Other Types of Data Capture

There are other forms of data capture such as community-based information gathering and fixed beach cameras. These typically consist of one or more cameras permanently mounted on poles that take regular images of a section of beach. Analysis of these images can provide useful information on beach changes as well as waves at the shore.

5.3 Gippsland Lakes Shoreline

5.3.1 Overview

The Lakes shoreline varies dramatically from Lakes Entrance to Sale, with significant changes often occurring over small distances. Detailed monitoring of the entire shoreline is a daunting task. Hence, it is considered that remote techniques are likely to be required to perform system-wide gathering of data. More detailed local data capture should be targeted to critical and generally representative locations.

Further monitoring of the lake shoreline could include the following:

- Mapping of shoreline vegetation response to salinity change
- Repeat erosion/condition surveys at specific locations
- Profile/bathymetric surveys at specific locations
- Aerial survey of the shoreline
- Wave monitoring

5.3.2 Mapping of shoreline vegetation response to salinity change

As recommended in Report 4: Lake Shoreline Erosion Susceptibility, mapping of shoreline EVCs that differentiate between reed beds and the scrubland, would enable the impact of changes to reed bed extent to be quantified. If coupled with more detailed salinity measurements, this could enhance the understanding of vegetation response to sea level rise and salinity change.

5.3.3 Repeat erosion/condition surveys at specific locations

As described in Section 5.2.2, site condition monitoring is able to capture many details around the context of short-term changes to shoreline conditions. Site condition monitoring could readily be undertaken at many sites within the Lakes as access is generally good.

5.3.4 Profile/bathymetric surveys at specific locations

Compared to the open coast, bathymetric profiles or survey within the Lakes would be more readily achieved, due to the sheltered nature of the shoreline.

5.3.5 Aerial survey of the shoreline

The Gippsland Lakes has an extensive shoreline of approximately 350 km in length. Not only is the shoreline very long, but there is significant variation in the composition, land-use and vegetation type along its length. Therefore remote sensing techniques are likely to be the only way to monitor the entire shoreline at regular intervals. Aerial imagery and LiDAR are would both be useful to gain an understanding of changes to shoreline position and vegetation. This data could be coupled with more localised monitoring of representative sites to gain an overall understanding and tracking of coastal hazard around the Lakes.

5.3.6 Wave and Wind Monitoring

Wave data within the Lakes would assist in the understanding of coastal processes and help to verify existing wave models. In conjunction with these measurements, better local wind data for the Lakes would also be beneficial. Whilst currently available regional stations capture the general pattern of wind, experience suggests that local variations can be quite significant, particularly at the lower wind speed range and for sea breezes.

5.3.7 Other Types of Data Capture

Monitoring of man-made, physical structures and their impact/performance over time may provide useful insights into the change in coastal hazards and what measures are effective in different situations.

5.4 Recommendations

Drawing on the above options and based on our understanding of the system we recommend the list of monitoring options proposed below in Table 5-1. These measures should be considered to assist ongoing hazard assessment and management of the Lakes system.

Any monitoring program should have very clear objectives and a means of closely relating the monitoring objective to the monitoring plan. Who undertakes these measurements and what funding may be available to facilitate them is unclear at present. Co-ordination by the various interested stakeholders is likely to be required and would lead to the most engaged and effective overall monitoring program.

Table 5-1 Preliminary Recommended Priority Monitoring

Monitoring Objective	Monitoring Target	Method	Range	Frequency
Assess coastal shoreline response to short and long-term coastal processes and sea level rise.	Outer Barrier Profile	GPS, possibly UAV	4 sites	Seasonally and after major storms
	Outer Barrier Survey	LiDAR	Whole coast	Once every 5-10 years
Assess lake shoreline response to short and long-term coastal processes and sea level rise.	Lakes Shoreline profiles and mapping	GPS, UAV, aerial imagery	Whole shore including indicator sites	Yearly, at key sites after major storms
	Shoreline vegetation mapping	UAV, aerial imagery, ground truthing	Lakes shoreline plus indicator sites	Once every 2-5 years
	Wave spectra	Bottom mounted, pressure sensing device	Temporary sensors at key locations	One-time deployment
	Wind speed and direction	Standard anemometer	At least one additional location in the central-lakes area	Continuous

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