Wooli Coast-Cams Image Analysis

March 2013 – July 2014

Prepared for:

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Cover page: Large beach cusps captured by the centre coast-cam at Wooli.

Executive Summary

Introduction

The attached document from Dr. Shaw Mead of eCoast is the second annual report on results produced by the automated camera system monitoring Wooli beach, which considers daily and monthly beach changes for the southern part of Wooli Village beach.

CCPA set up the system as an initial step in addressing a lack of detailed data about Wooli beach and the processes that shape it. The photographs and analysis from this and future years will provide information that can contribute to an evidence-based long term beach management and protection strategy for Wooli (see Note 1 below).

Objectives

The primary objective in this second year was to measure changes in "beach position", as well as consider the changes to the quarterly beach profiles measured along the stretch of beach covered by the camera monitoring.

The beach position was considered by monitoring the high tide mark on a daily and monthly basis for the area of the beach being photographed. The quarterly beach profiles provide a record of the changes to the beach height and volume.

Examples of other valuable objectives for which the system can be used (subject to available funding) are:

- Measuring the impact of particular storms and recovery time from them.
- Identifying trends from La Nina and El Nino weather cycles.
- Contributing to an overall model of Wooli bay in conjunction with information from beach surveys, offshore data gathering, and other available data.
- Gaining an understanding of nearshore bar/trough formations.

- Calibration of wave and morphological (Note 2) models.
- Increasing our understanding of processes within the whole embayment

Results

The camera system's headline results from this first year are:

- The average and maximum (accretion and erosion) daily beach position changes are significantly higher over the recent 16 months in comparison to prior 12 months, and again shown that the beach has the ability to recover just as fast as it can erode (refer eCoast report p23, para3). This is shown by the large fluctuations in daily beach position (Note 3 below)
- The overall high tide beach position accreted over the 16 month period from March 2013 to July 2014, and the overall trend of the beach over the 28 month period is one of accretion (P24, para1).
- There is good agreement in beach position between the data from the camera system and that from the beach surveys, and the accretion observed in the daily high tide beach position data is shown in the beach profile data to represent substantial beach height and volume increases; i.e. up to 2 m vertical height increase, and ~30 m^3/linear metre of beach along the monitored stretch (p24, para3). The increases in the height of the back beach are attributed to the beach plantings and sand fences.
- In its second year the camera system was operational for approximately 95% of the time (compared to 85% in the first year)S. Daily monitoring of the camera system has greatly increased response time and improved the operational percentage, however, automatic shutdowns due to Microsoft Windows have still resulted in lost days of coverage. Remote start-up can be achieved by a constant power source through a LAN connection (rather than a USB), which is currently being investigated.

Notes

1. The camera system is a part of the monitoring process aimed at supporting a beach management and protection strategy. It provides hourly high resolution data for a defined part of the beach (see Figure 1.1). This data can then be put into the context of the whole beach by combining it with results from the 3-monthly beach surveys of the whole beach. This monitoring plan includes developing an understanding of how the beach 'works' (e.g. what are the extents of retreat and advance, and what conditions drive these processes?) and the tools to apply to future projections of beach evolution, to consider the design and impact of particular beach management and protection strategies (e.g. dune planting, renourishment, sand retention structures, etc.; what has been the impact of the training walls on Wooli Beach?), and other factors that together will underpin a long-term beach management and protection strategy.

2. Coastal (geo)morphology is the scientific study of coastlines and the processes that shape them. It aims to understand why beaches currently look the way they do and to predict future changes through a combination of field observations, physical experiments, and computer modelling.

3. The beach position (high tide location) varied on average 4.5 m each day during the March 2013 to July 2014 period (either seawards – advance or shore-wards – retreat) (Table 3.1, page 7). Maximum daily retreat is similar to maximum daily advance, 33.9 m and 35.4 m, respectively (Table 3.1, page 7), which are significantly higher values than during the March 2012 to March 2013 period. While there are a number of variables that affect the location of the high tide mark it is a useful proxy for the width of the beach. These variations are seen as 'noise' in the data without significant impact on the overall trends.

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1 Introduction

This report describes the findings of the analysis of 16 months of coast-cam image data collection between March 2013 and July 2014, and follows on from the previous analysis (March 2012 to March 2013 (Mead and Atkin, 2013)). The coast-cam system is comprised of 3 high-resolution cameras atop the Wooli water tower and is detailed in Mead (2012). The primary purpose of this data capture and analysis is the development of a long-term continuous dataset of Wooli beach position. Prior to the initiation of the coast-cams, only very sparse data on beach position was available in the form of historical aerial photographs that represent only snapshots of the beach position and provides little if any information with respect to the patterns of beach change and how the beach responds to particular events. Wooli Beach is over 7 km long. This dataset provides hourly images each day along a stretch of Wooli Village Beach some 420 m long (Figure 1.1).

While these data can be applied to a range of uses (e.g. determining the extent of beach erosion during a particular wave event, or multi-annual return period events, the duration of beach recovery after a particular erosion event, validation of sediment transport modelling, etc.), here we are considering the fluctuation of the high tide position along the length of the beach monitored on a daily basis. Although there are a number of variables that effect the location of the high tide mark (neap versus spring tidal phase, barometric pressure, wave set-up, wind set-up, wave height and period, etc.), the high tide mark is a useful proxy for the width of the beach at any one time. Much of these variations are seen as ‘noise’ in the data versus the overall trends. In addition, the approximately quarterly beach profile data for the area has been compared to the camera data to consider the trends and variability of the 2 datasets.

Figure 1.1. The useable[1] field of view from the coast-cam system is represented by the green line, with the Wooli water tower denoted with the star, which is 33.5 m above Australian Height Datum (AHD), which is approximately mean sea level (MSL).

[1] The camera system captures images that cover more than 2 km of beach, however, the confidence in the rectification and determination of the high tide mark decreases markedly with increasing distance from the water tower.

2 Methods

2.1 Image Calibration and Rectification

The initial stage in the image analysis was the re-calibration of the image rectification to ensure that accurate positions of rectified images are compared – subtle changes in camera position (and so, field of view) since the last image analysis need to be accounted for. The system's 3 cameras take a photograph of the beach on the hour during daylight; to the north, east and south. Since the primary aim of the remote monitoring system is to record the beach position (i.e. trends of erosion and accretion), the images need to be rectified; that is transformed so that they represent an ortho-corrected image, a 'bird's eye' view from straight above. The methodology followed to achieve this is detailed in Mead 2012 (Wooli Coastal Camera – Rectification) and was repeated prior to image analysis.

Briefly, RTK GPS positions[2] were recorded for the locations shown in Figure 2.1. The pixels corresponding to each of the GPS locations (northing, easting and height to Australian Height Datum (AHD), which is approximately mean sea level (MSL)), were incorporated into the rectification software (detailed in Mead, 2012). Figure 2.2 presents the changes to rectification control points following the new calibration to account for subtle changes in camera positions – the differences in control positions due to changes in camera field of view ranged from 0.55 m to 7.2 m. Images from late March 2013 (i.e. the end of the initial period of image analysis) through to the end of July 2014 were rectified and used in the following image analysis.

[2] RTK GPS survey was undertaken by Brian Saye on 16 July 2014, while coincident image capture for each position was recorded for control point data collection.

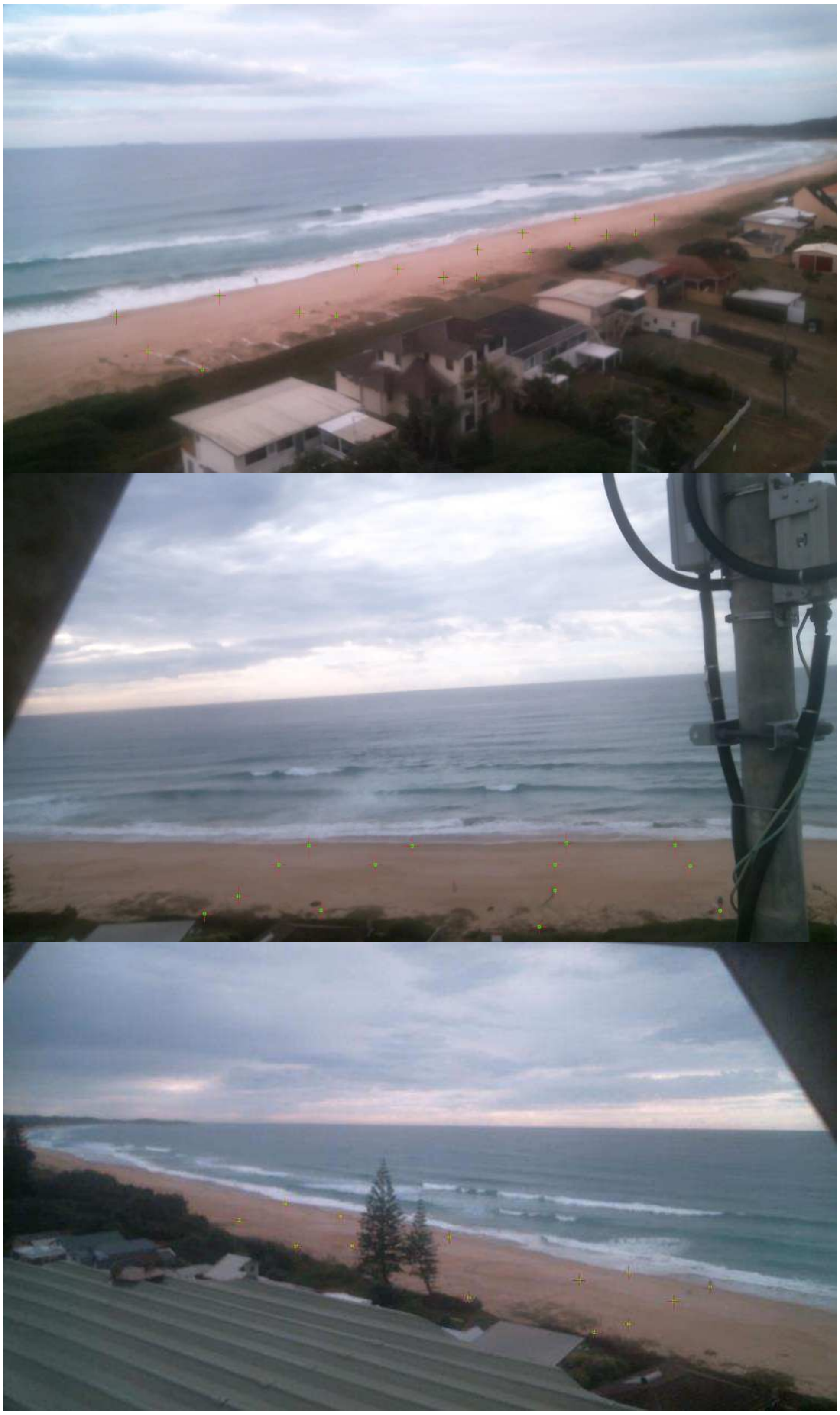


Figure 2.1. The red-circles indicate the pixel/point where RTK GPS locations were recorded.

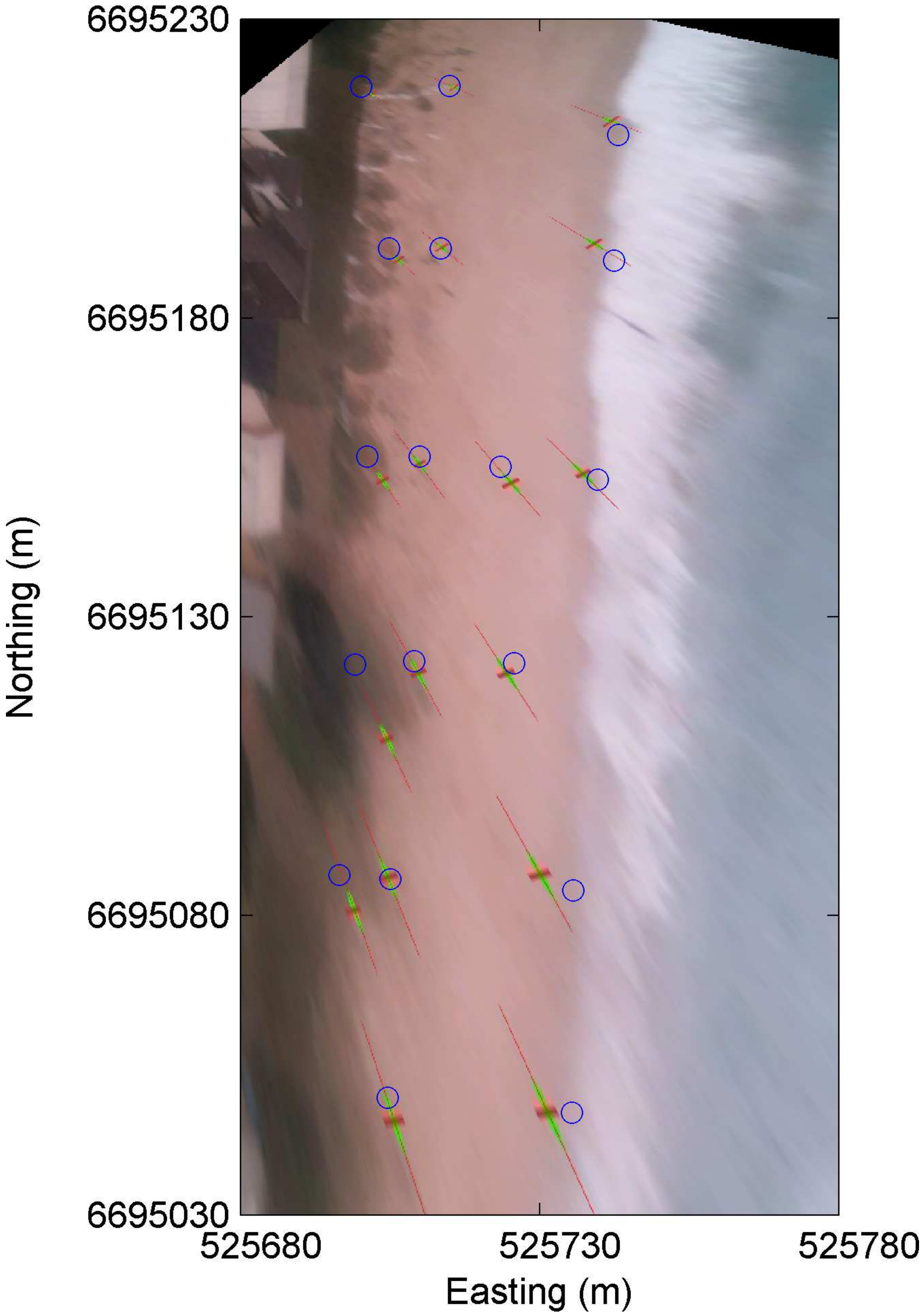


Figure 2.2. The blue-circles indicate the control points from the 2012-2013 rectification, in comparison to the new control points (green/red crosses).

2.2 Image Selection

The automated image capture software (see Mead, 2012) effectively filters poor quality images based on available light (day/night). To consider beach changes, daily beach position was focussed on, and so the clearest images for each of the 3 cameras each day were required. The images required further filtering as met-ocean conditions often created poor images for processing – sun-strike, rain/salt-spray on the camera housing, sea mist, etc. This was achieved by removing all images with specific RGB values (too bright due to glare, or too dark due to cloud cover or shadowing, and so on). Early morning images were selected as a priority, because the low angle of the sun light creates a shadow zone landward of the high-tide beach berm, thus identifying the apex/berm crest. The images in the proceeding and subsequent hours were used to ensure that the berm was accurately identified.

Evaluation of the high-tide/storm berm in many images could not be completed for a number of reasons, but primarily because of metrological conditions. At some points, even in a clear image a berm was indistinguishable as it was not prominent due most likely to a gently sloping/planar beach. However, this may be in the wake of a significant storm event where the berm has been driven to the landward extent of the beach. At other times, interference from beach traffic prevents clear identification (walkers, quad bikes, logs, etc.). In general, wherever there was ambiguity with the location of the berm crest the data point (daily in this case) was disregarded. In total, 360 rectified images from the southern (right) camera were used in the analysis, 370 from the centre, and 387 from northern (left).

2.2 Evaluation of the High-Tide Berm

Following industry standards for image analysis, the high-tide mark is used to determine the beach position, rather than the vegetation line which is often used for longer term beach position analysis. This method does have limitations with respect to the changing wave run-up elevations due to the wave heights, direction, period and high water level on any given day, which are similar to the limitations of using MSL to consider beach position due to the changing width of the swash zone. However, in terms of weekly, monthly and yearly trends, this variability is smoothed and overall trends become apparent – i.e. the variations are seen as ‘noise’ in the data versus the overall trends.

For the daily analysis, transect were overlaid on the images. Where the transect and berm line intersect a point was marked and the pixel location recorded. For the northern images three transect locations where used; for the central five, and for the southern images four berm locations were marked (Figure 2.3). Transects are number from north to south (top of rectified image to bottom of rectified image) To convert the pixel location values of berm position to metric values, the pair of rectifying coordinates (see Mead, 2012) closest to the study area was used.

For the monthly analysis the best images for berm identification closest to the 10th of each month was annotated along the length of the berm. Localised overtopping of the berm was ignored and simple interpolation of the berm line was used. For each monthly image the entire length of the beach position was recorded (rather than 3-5 points along transects as in the daily datasets).

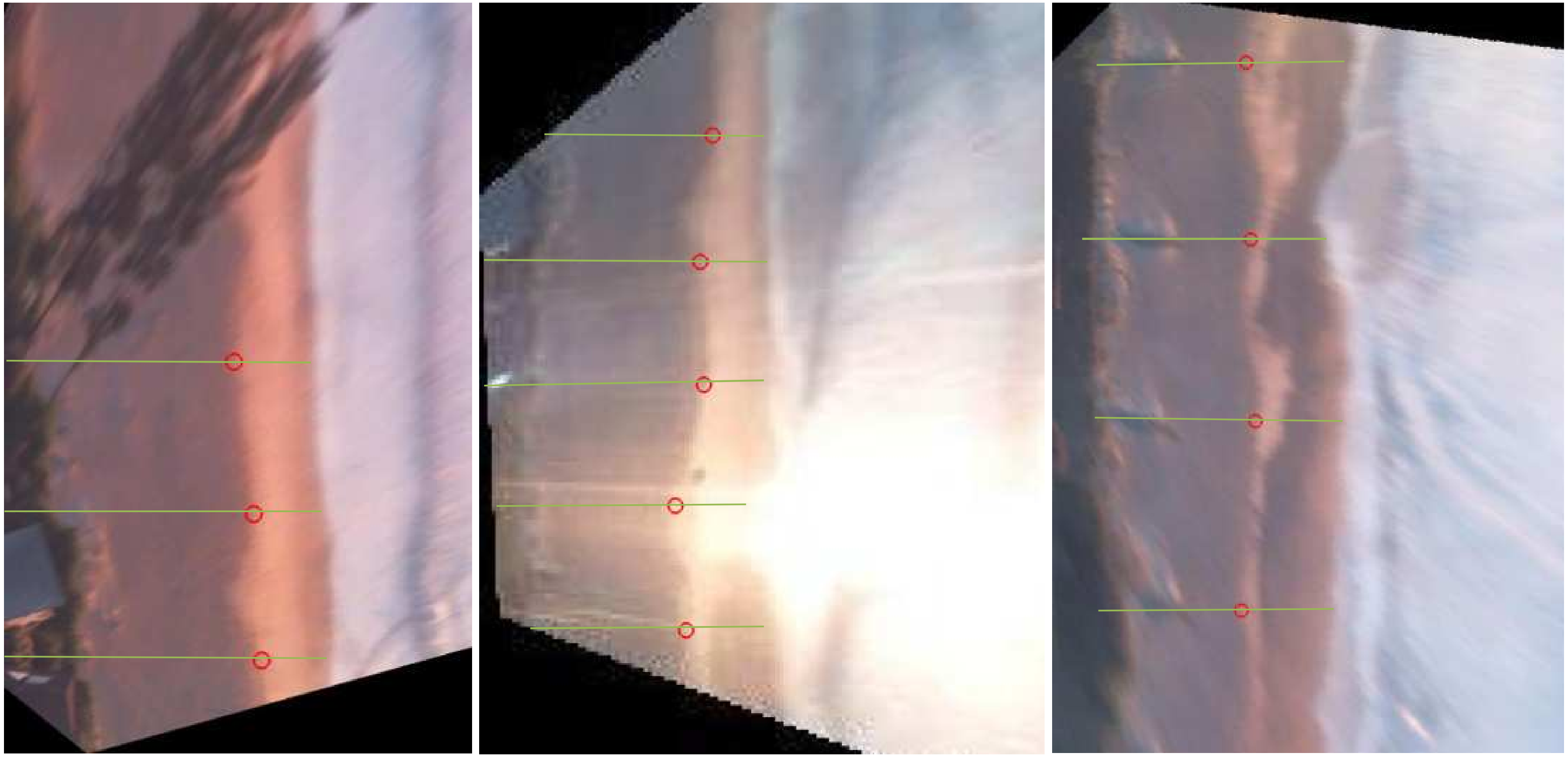


Figure 2.3. The red-circles indicate the pixel/point where the beach normal transects intersect with the high-tide berm.

3 Results

3.1 Daily Images

Figure 3.1 to Figure 3.3 present the results of the daily image analysis for the beach normal transects from the north to the south of the field of view (Figure 2.3). An obvious feature is the daily variability between beach locations, with Table 3.1 providing the mean and maximum retreat/advance daily change in beach position. In comparison to the positional changes that were determined in the 2012-2013 dataset, the average daily movement in the 2013-2014 dataset is some 1.4 m greater, while the daily maximum retreat and advance are also significantly greater (12.4 m and 17 m, respectively). When these results are considered in detail (Figure 3.1 to Figure 3.3), it is seen that the beach has the capacity to repair itself (i.e. accrete) just as quickly as it can be damaged (i.e. eroded) by storm action.

Table 3.1. Daily high-tide beach positional changes calculated from all transects.

Daily Beach Change	2013 (m)	2014 (m)
Average	±3.2	±4.6
Max Retreat	-21.5	-33.9
Max Advance	18.4	35.4

The northern camera captures the large erosion/accretion events through into the winter of 2013, as well as events of similar magnitude in spring and early summer of 2013/2014 (Figure 3.1). However, the seasonal variation of the beach position, with the beach most eroded in the late winter months and most accreted in late summer is not as evident as the previous year, and by August 2013 the beach has recovered to higher volumes than the summer of 2013 and continues to fluctuate around an overall accretionary trend (Figure 3.1). Following a relatively active period of erosion and accretion through March and April 2014, the beach was relatively stable, but for an erosion event that recovered relatively quickly in early July (Figure 3.1).

Similar trends can be seen in the central and southern transects (Figure 3.2 and Figure 3.3). However, the magnitude of the erosion/accretion events is less in centre transects (Figure 3.2) and less again in the southern transects (Figure 3.3); i.e. there is a similar trend of erosion/accretion along the whole monitored area, rather the variation between the 3 parts observed in the previous year (Mead and Atkin, 2013).

When the whole dataset back to March 2012 is considered (i.e. 28 months), there has been an overall trend of accretion, which has been greatest in the northern area (16-22 m), lowest in the southern area (2-6 m), and inbetween in the central area (11-18 m); i.e. the monitored area has a trend for increasing accretion rates moving from south to north (for example, Figure 3.4). The general accretion trend is summarised in Table 3.2. In comparison, the daily data for beach position for the previous year (i.e. March 2012 to March 2013) indicated that the beach had undergone erosion over the period.

Table 3.2. High-tide beach positional changes (accretion) calculated from all transects for each area for the full 28-month dataset and the associated annual rate of accretion.

	Range (m)	Average (m)	Annual rate (m/yr)
North Camera	16-22	18.67	8
Central Camera	11-18	13.2	5.7
Southern Camera	2-6	4.5	1.9

The daily beach position data for the past 28 months has highlighted two particular issues that relate to the need for long-term daily beach monitoring in order to determine long-term trends. The first is that sporadic measurements of beach position (e.g. historical aerial photograph analysis) can easily mis-represent the actual erosion/accretion trends. For example, in the space of one day the beach can erode or accrete over 30 m (note, accretion does not always immediately follow erosion, and vice versa, as can be seen on close inspection of Figure 3.1 to Figure 3.3). In addition, there are seasonal trends and longer term climatic variations (e.g. ENSO and IPO) that can bias observations with sporadic and long (decadal) spacings. Secondly, that a short data set is not a good indicator of long-term erosion/accretion trends, as shown by considering the March 2012-2013 12 month dataset to the full 28 month data set.

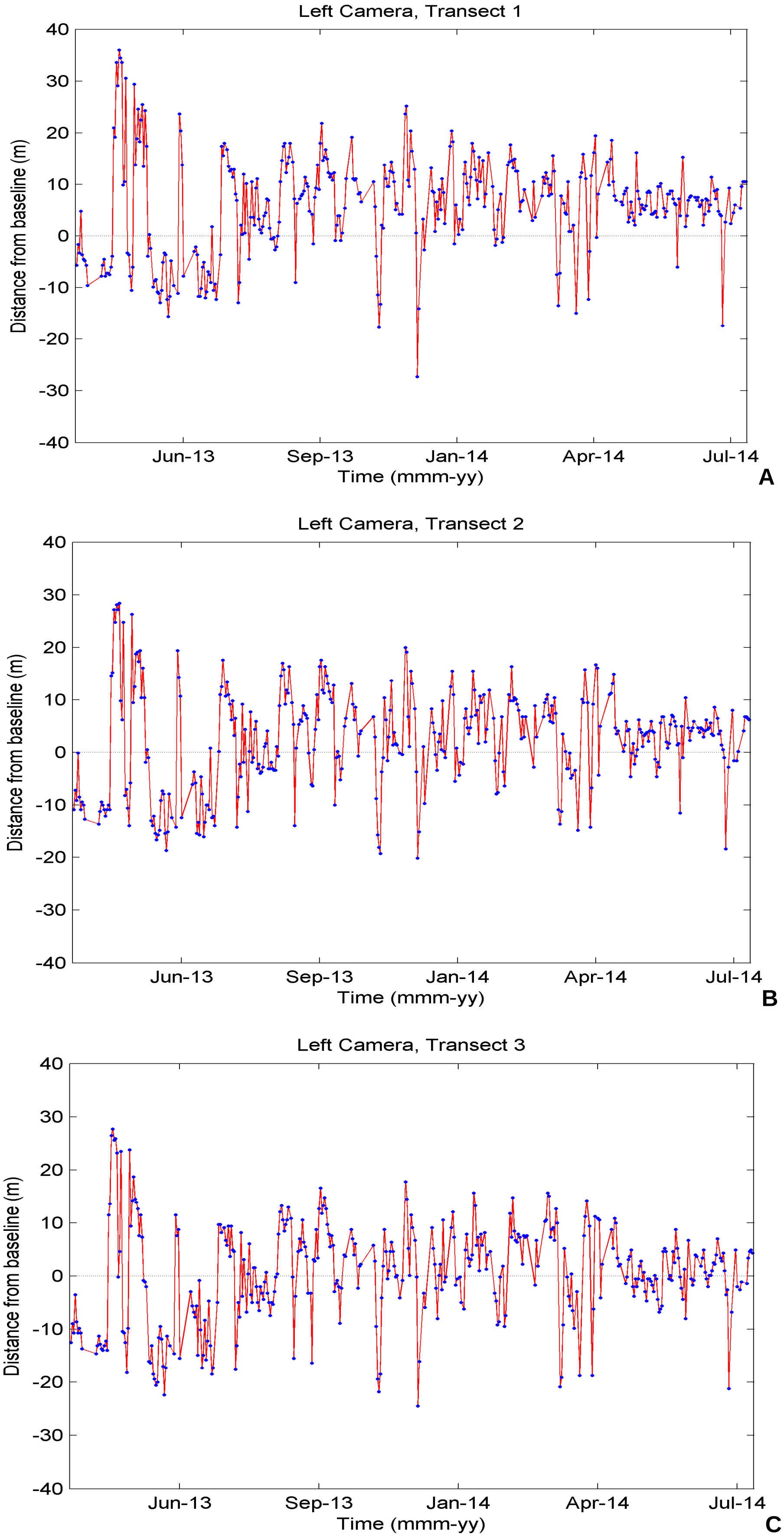
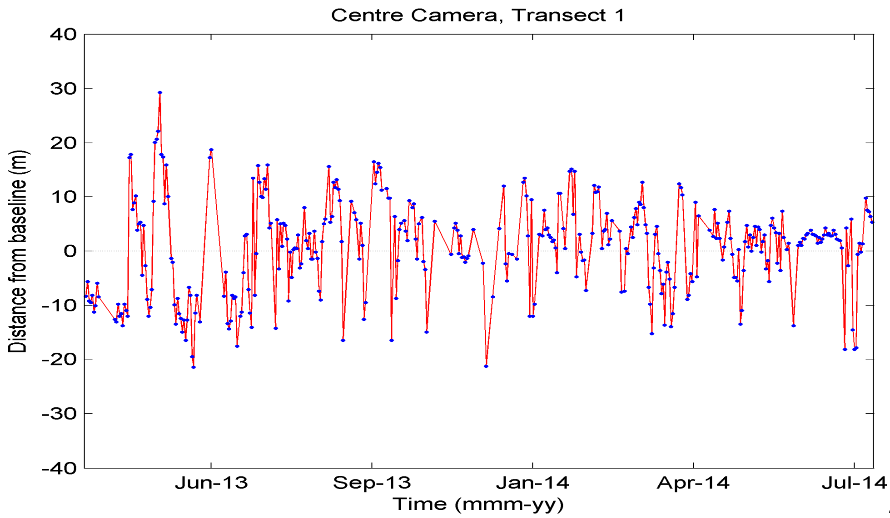
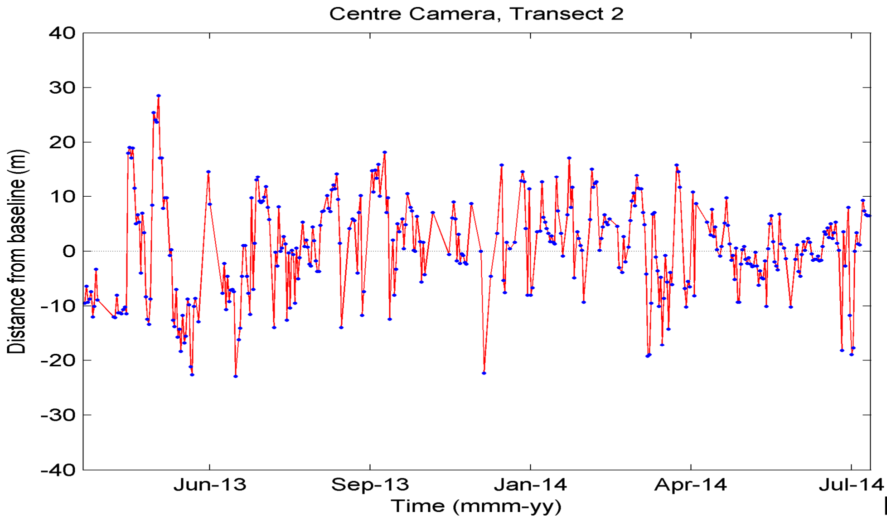


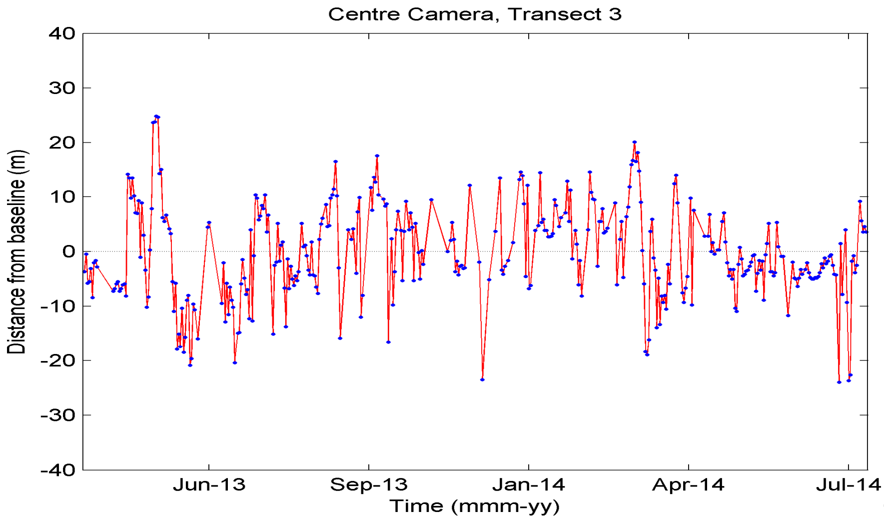
Figure 3.1. High-tide beach location for the 3 transects on the northern camera (Figure 2.3).


Centre Camera, Transect 1
Distance from baseline (m)
40
30
20
10
0
-10
-20
-30
-40
Jun-13
Sep-13
Jan-14
Apr-14
Jul-14
Time (mmm-yy)

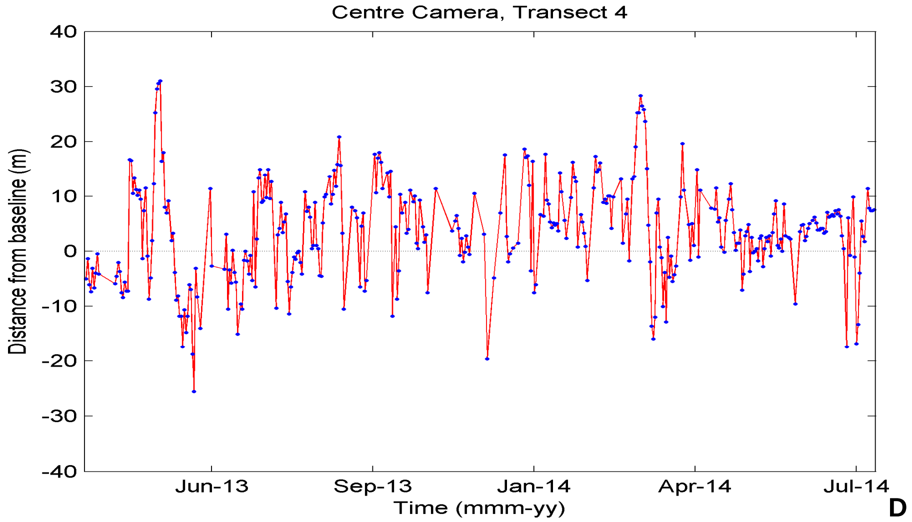
A


Centre Camera, Transect 2
Distance from baseline (m)
40
30
20
10
0
-10
-20
-30
-40
Jun-13
Sep-13
Jan-14
Apr-14
Jul-14
Time (mmm-yy)

B


Centre Camera, Transect 3
Distance from baseline (m)
40
30
20
10
0
-10
-20
-30
-40
Jun-13
Sep-13
Jan-14
Apr-14
Jul-14
Time (mmm-yy)

C



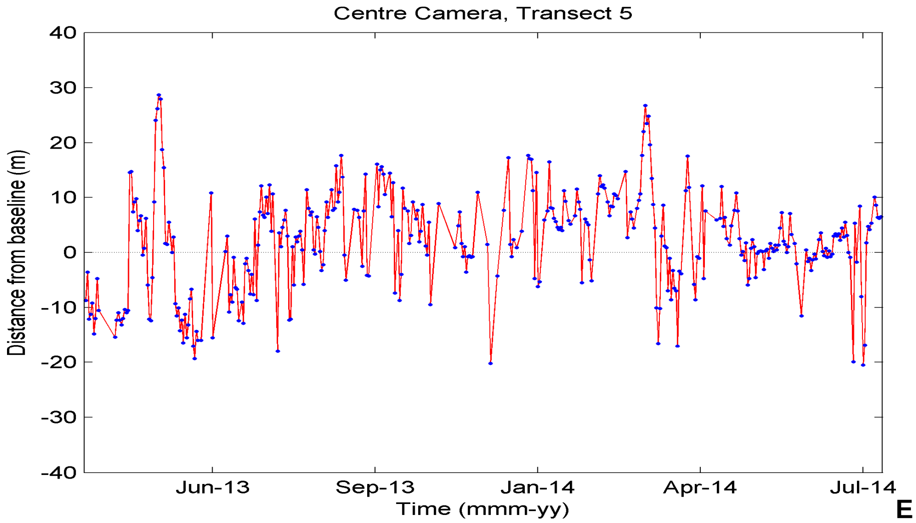
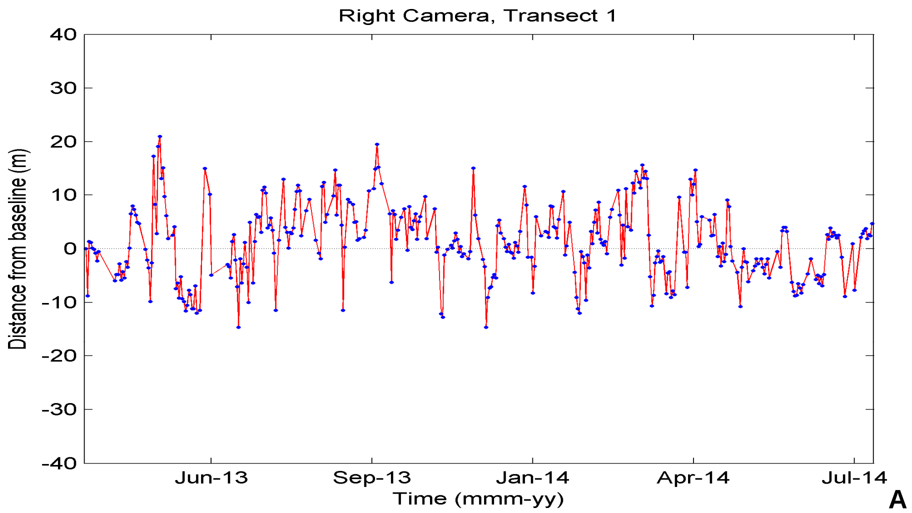
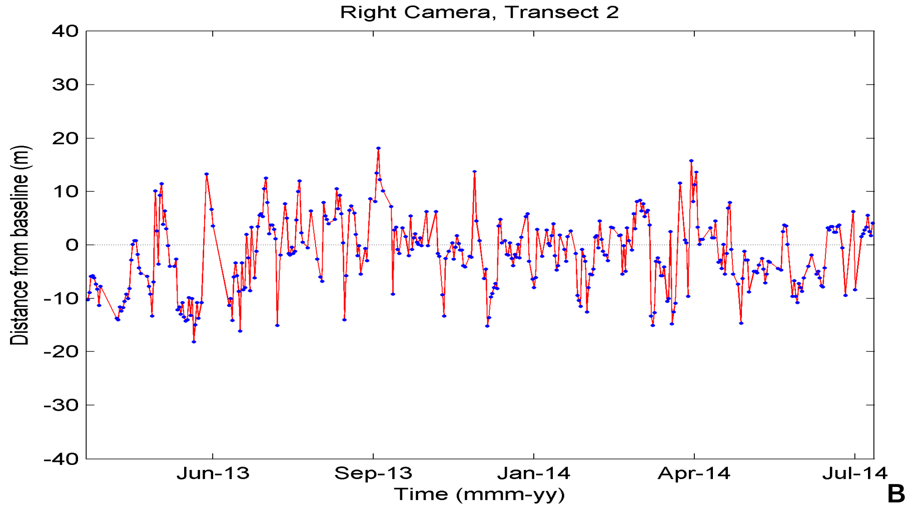
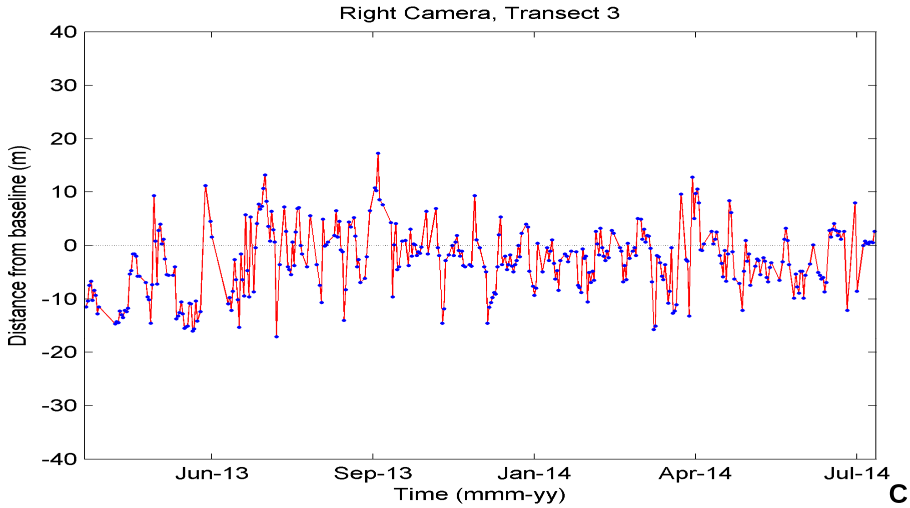


Figure 3.2. High-tide beach location for the 5 transects on the central camera (Figure 2.3).

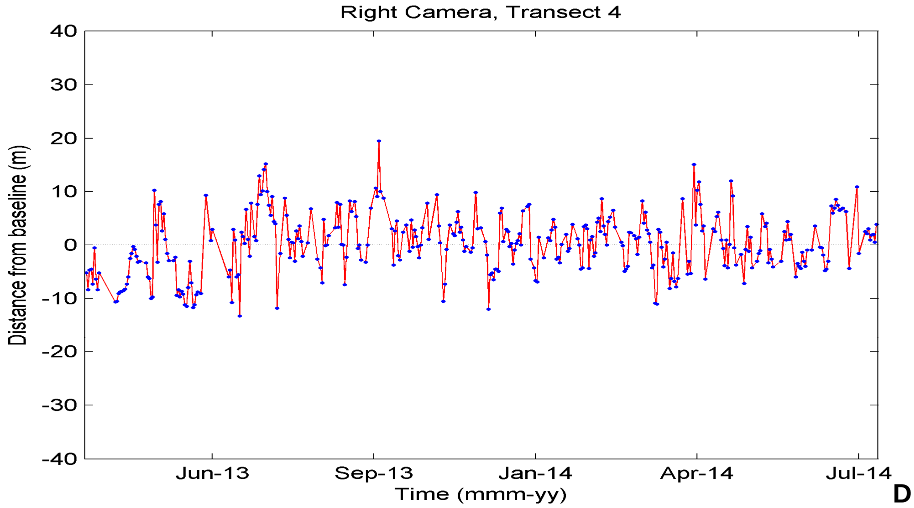




B



C



D

Figure 3.3. High-tide beach location for the 4 transects on the southern camera (Figure 2.3).

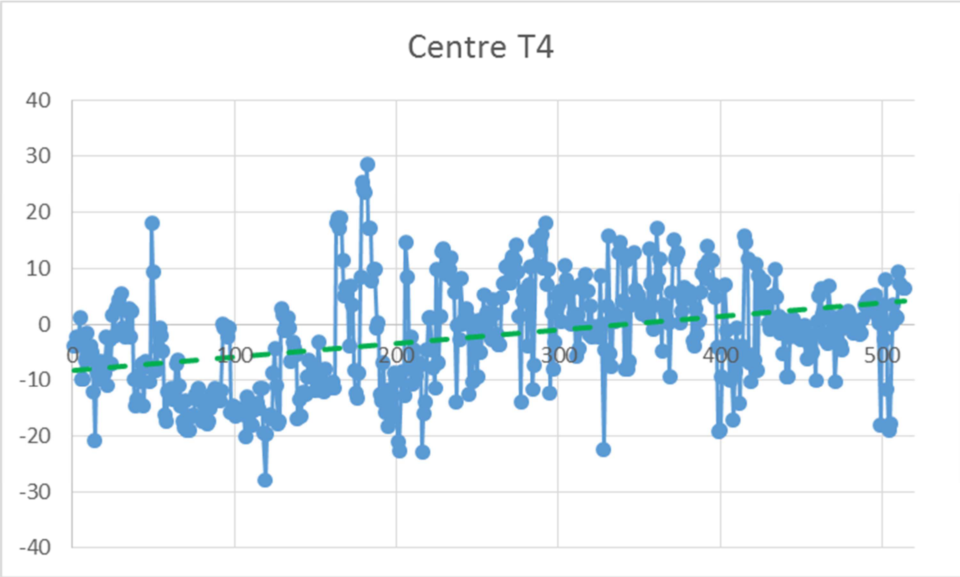


Figure 3.4. High-tide beach location for transects 4 on the central camera (Figure 2.3) as an example of the accretion trend at Wooli Beach.

3.2 Monthly Beach Position

The monthly locations of the high-tide beach mark close to the 10th of each month are presented in Figure 3.5 to Figure 3.7. While these results follow those presented for the daily transects analysed for the 3 camera areas, they also show that the beach fluctuations are not constant changes both on-offshore and alongshore, i.e., there is variability along the length of each area. Such variability is usually driven by the morphology of the nearshore bars and the consequent feedback that can lead to temporary stability and relatively large perturbation in comparison to the offshore features (e.g. Coco and Murray, 2007). Of note are the very large beach cusps in May 2013 and April/May 2014.

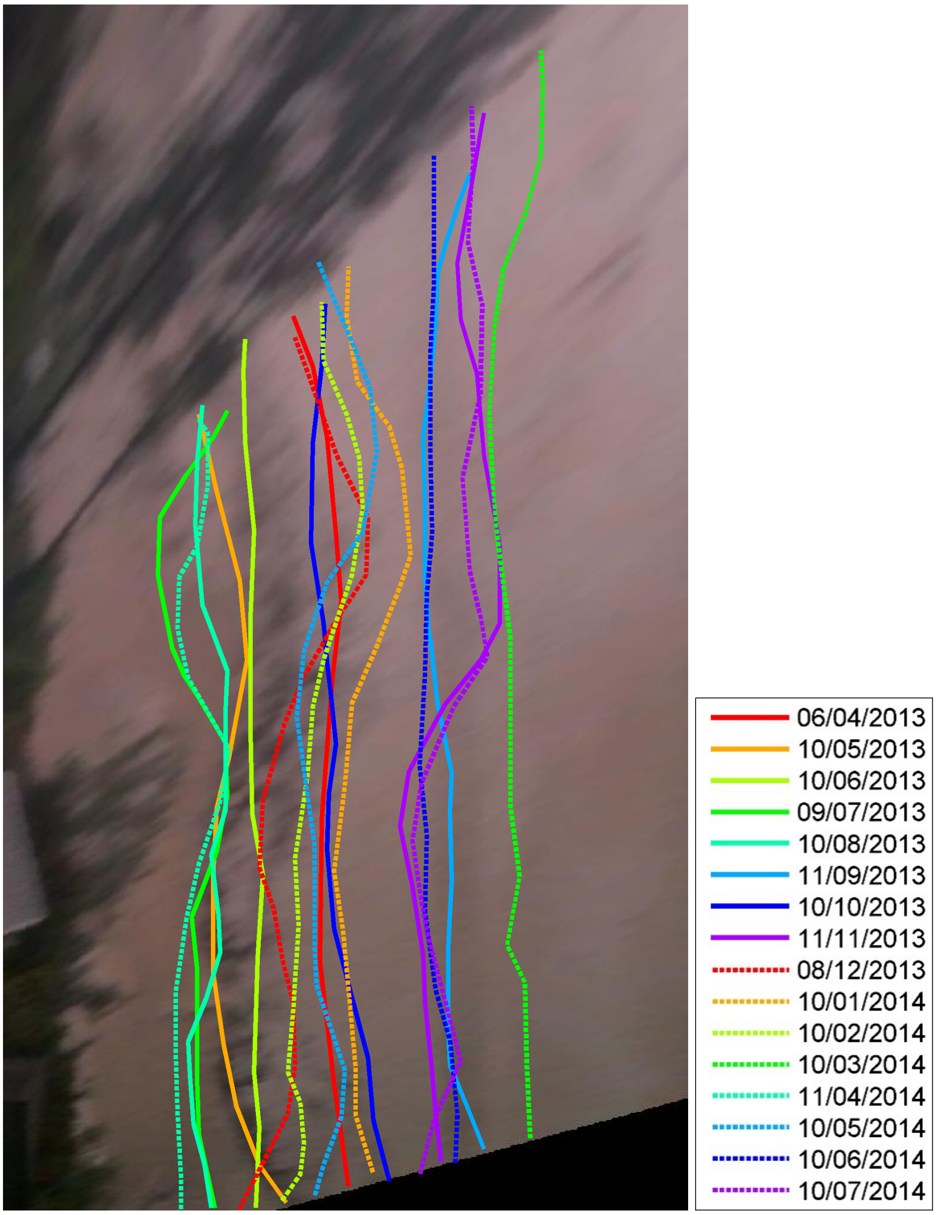


Figure 3.5. Monthly beach position for the northern camera.

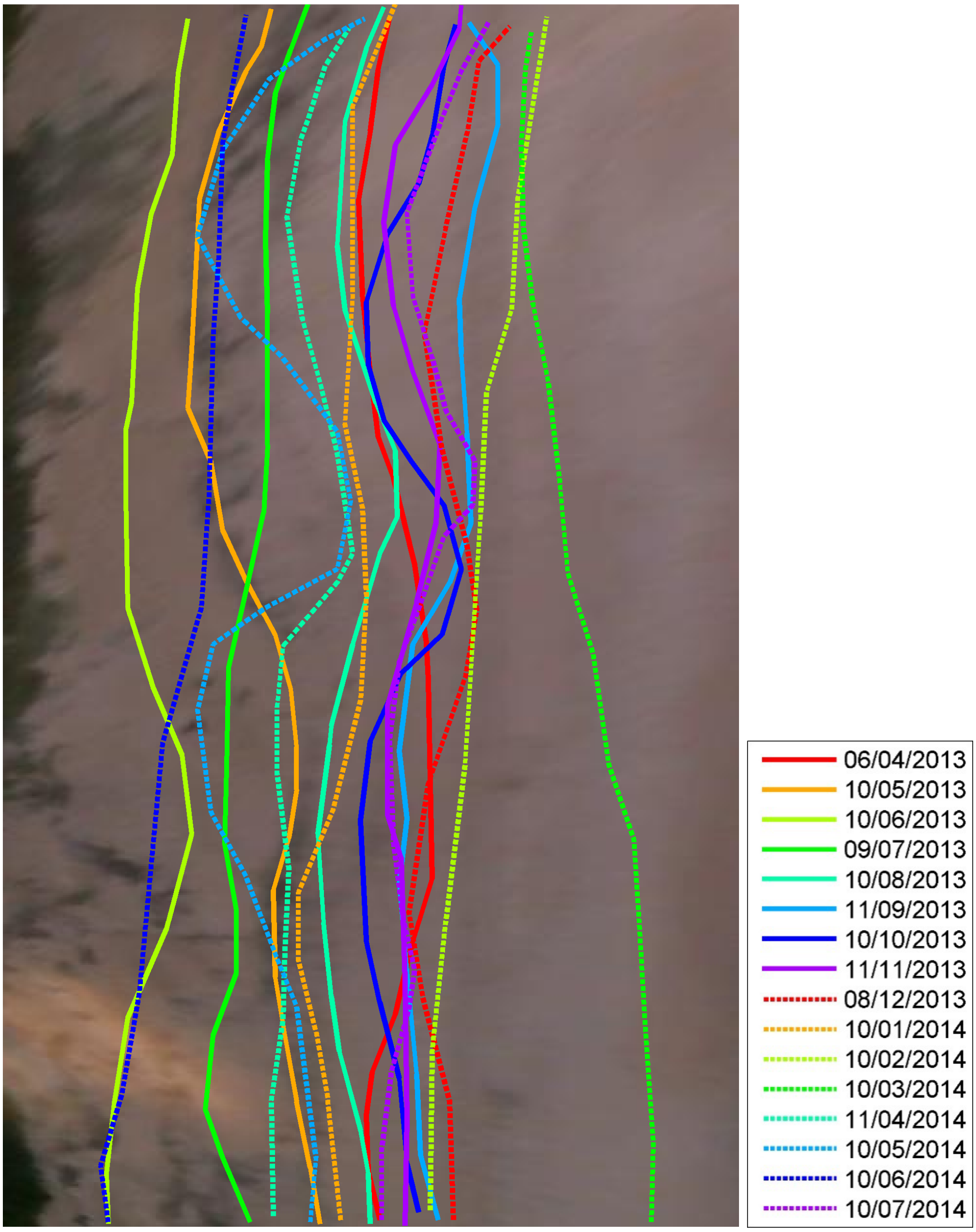


Figure 3.6. Monthly beach position for the central camera.

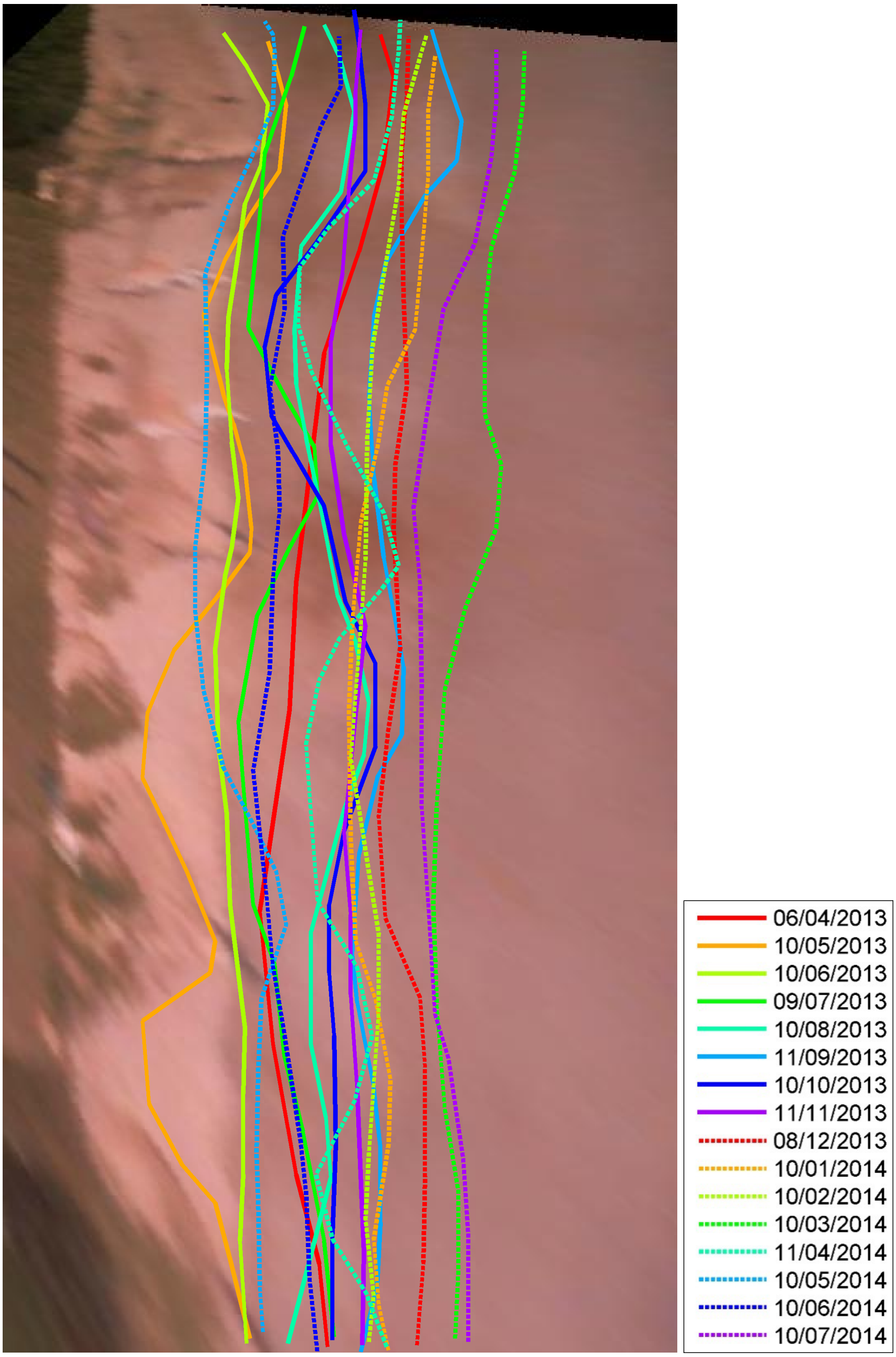
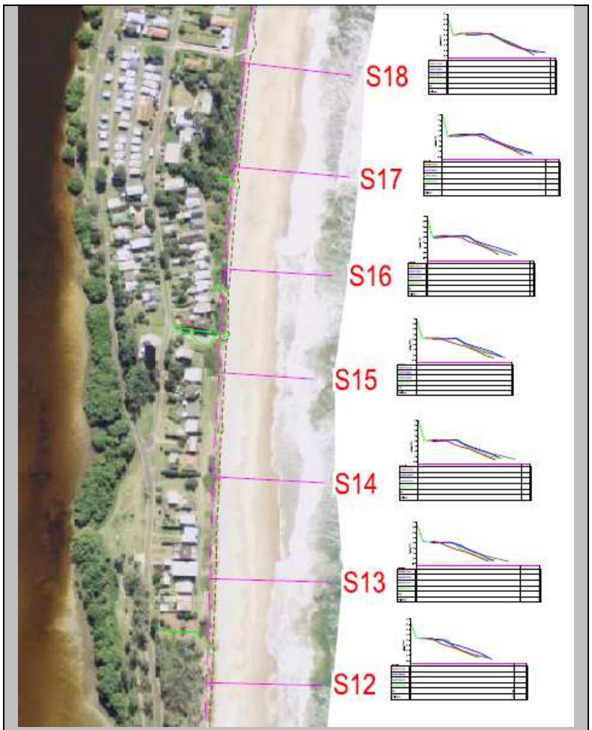


Figure 3.7. Monthly beach position for the southern camera.

4 Comparison to Quarterly Beach Profile Data.

The quarterly beach profile data (measured by surveyor Brian Saye) for profiles S12-S18 cover the field of view and area of transects from the water tower cameras (Figure 4.1). Although the beach profile data do not provide the kind of information on beach position changes on a daily basis and in response to particular combinations of wave, tide and wind events, they provide valuable information with respect to the volumetric distribution of sand on the beach (rather than only a 2-dimensional/horizontal beach position), and also long-term trends with continued monitoring and the development of a long-term dataset.



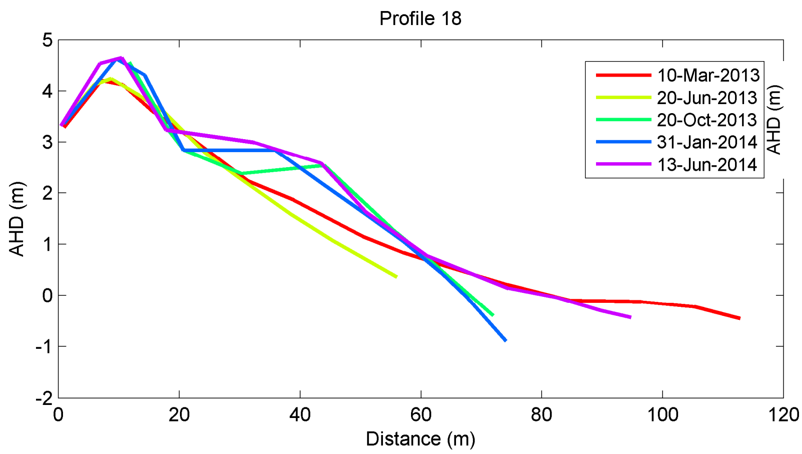
Survey Dates
10/03/2013
20/06/2013
20/10/2013
31/01/2014
13/06/2014

Figure 4.1. Locations of the quarterly beach profiles within the field of view of the water tower cameras.

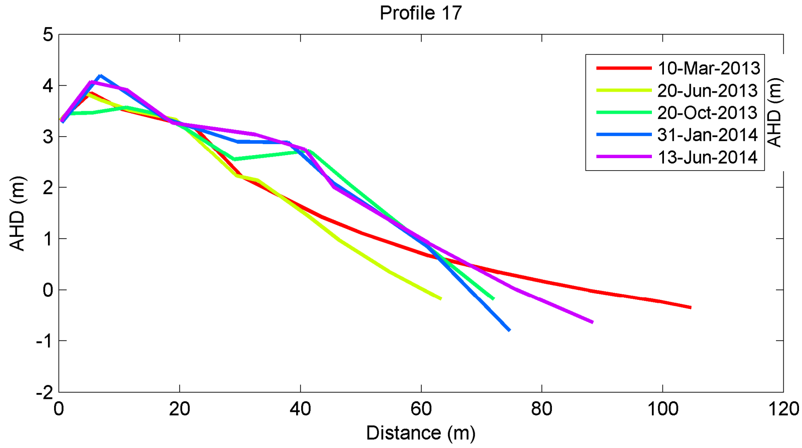
By comparing the date of the beach profile surveys with the high-tide beach location for the camera image of the same date, a general trend of accretion and seaward transgression of the beach berm is found in the camera image data. This trend is broadly replicated in the beach profile data, along with several additional features.

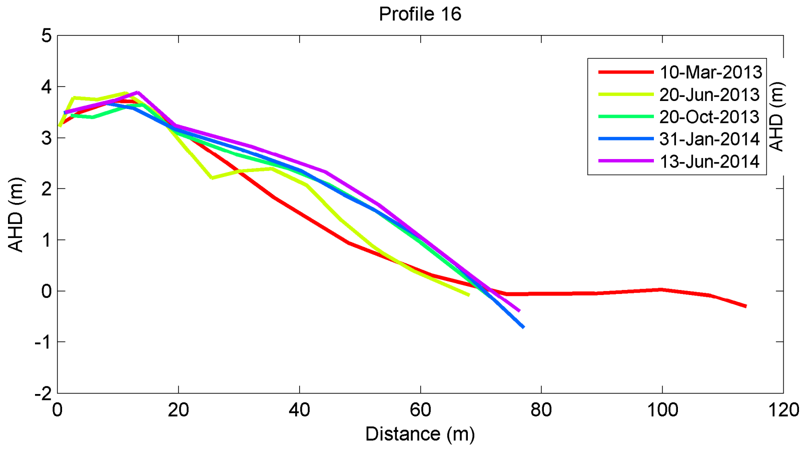
One of the most obvious features is the increasing height of the foredune/back beach along this stretch of the beach monitored by the cameras, and is attributed to the continued accumulation of sand in the foredune due to the planting of sand-stabilizing spinifex and the sand fences.

Another feature of beach evolution present in the beach profile data is the large increase in the volume of sand above means sea level (MSL), which is similar to the Australian Height Datum (AHD), or zero on the graphs in Figure 4.2. In the northern area of the video-monitored stretch of beach, the beach height has increased by up to 2.0 m over the 15 month period (Figure 4.2 A, B and C). The increase in beach height above MSL decreases (i.e. 1-1.5 m) moving southward along the monitored stretch ((Figure 4.2 D-F). However, in the southern area, the beach height increase extends to the low tide mark, and so represents a similar to greater volume of beach accretion (i.e. ~30 m^3/linear metre of beach). In the northern area (Figure 4.2 A, B and C), the beach below MSL is steeper in une 2014 than it was in March 2013, the latter of which was a period of aggressive erosion due to a series of late summer storms.



A


Profile 17
AHD (m)
Distance (m)
10-Mar-2013
20-Jun-2013
20-Oct-2013
31-Jan-2014
13-Jun-2014
B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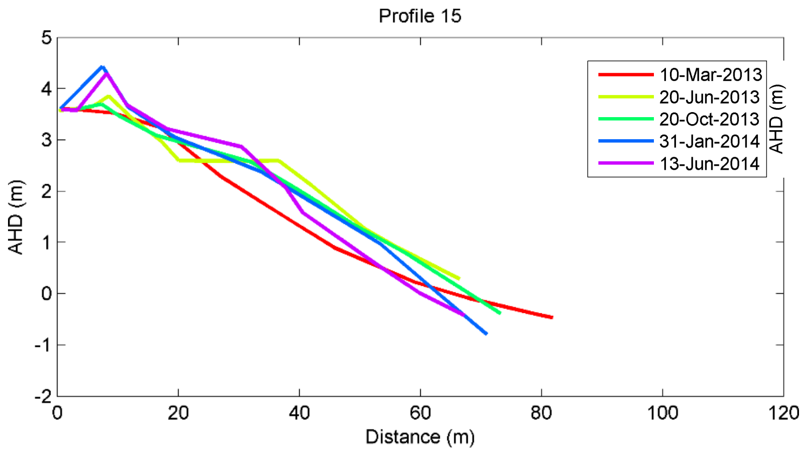
AHD (m)
Distance (m)
10-Mar-2013
20-Jun-2013
20-Oct-2013
31-Jan-2014
13-Jun-2014
C


Profile 15
AHD (m)
Distance (m)
10-Mar-2013
20-Jun-2013
20-Oct-2013
31-Jan-2014
13-Jun-2014
D

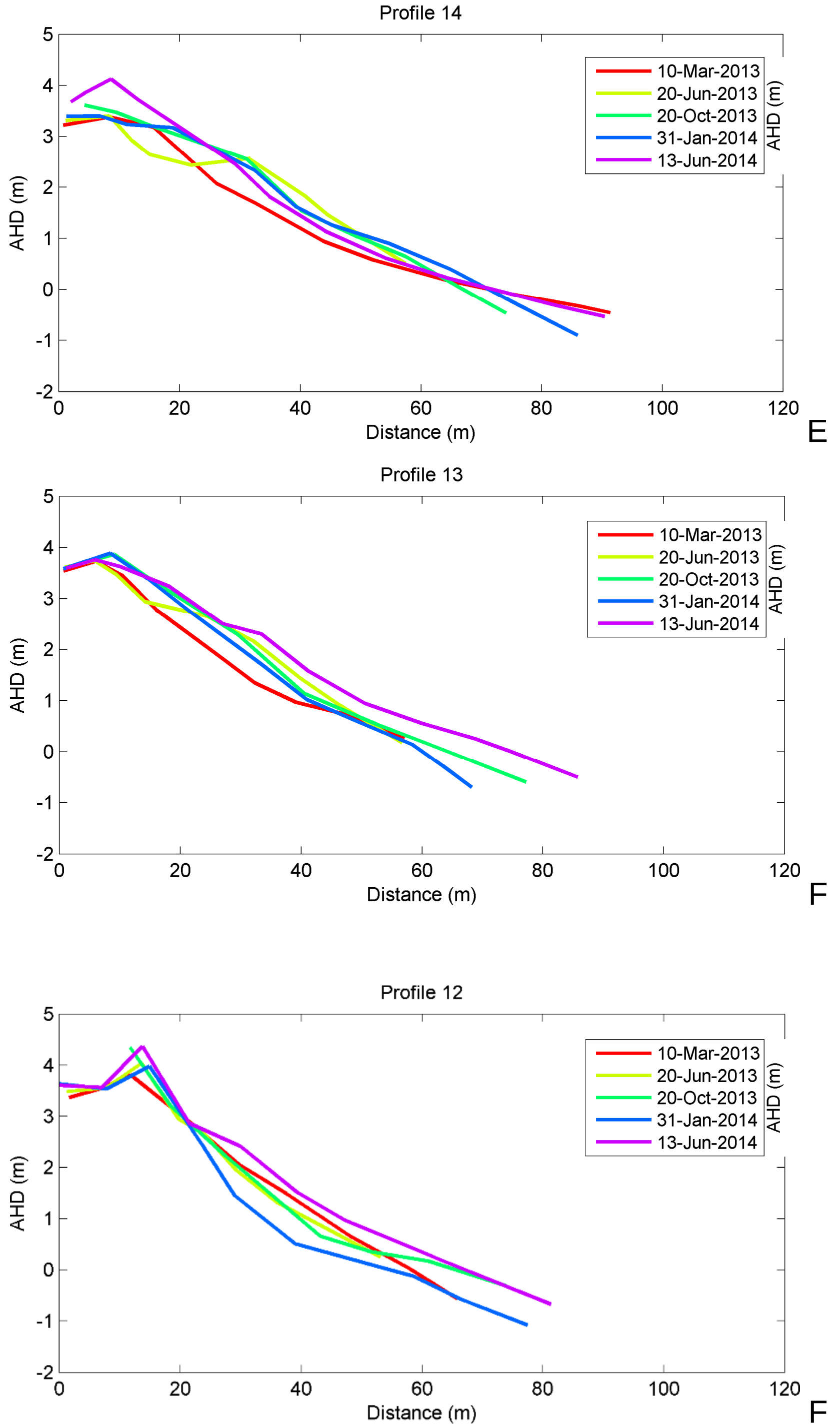


Figure 4.2. Quarterly beach profiles S12 to S18 from 10 March 2013 to 13 June 2014.

5 Discussion

The analysis of the dataset of rectified daily beach images has provided a comprehensive picture of the beach changes between March 2012 and July 2014 along the southern part of Wooli Village – with this report focussing on the March 2013 to June 2014 period; March 2012 to March 2013 was reported previously (Mead and Atkin 2013). Here we have considered the fluctuations of the beach position along the length of the beach monitored on a daily basis, and also considered the changes in beach height/volume measured by the quarterly beach profiles. As previously stated (Mead and Atkin, 2013), it is important to note that these data can be applied to a range of uses (e.g. determining the extent and rate of beach erosion during a particular wave event/series of events, or multi-annual return period events, the duration of beach recovery after a particular erosion event, validation of sediment transport modelling, etc.), and so will be very useful with respect to the development of a Beach Management and Protection Strategy for Wooli Beach.

In comparison to the March 2012 to March 2013 analysis of the daily and monthly high-tide beach locations, the usual trend of summer-winter-summer beach position (which refers to accreted-eroded-accreted), is not so obvious. In basic terms, the long period summer swells build the beach, while the short period winter storms take sand offshore to form more distinct shore-parallel bars (e.g. Dean, 1988; Short and Wright, 1984). However, following the recovery of the beach after the series storms during the late summer of 2013, the high tide beach position has fluctuated around an almost linear norm with an accretionary trend.

The average and maximum (accretion and erosion) daily beach position changes (Table 3.1), are significantly higher over the recent 16 months in comparison to prior 12 months, and again shown that the beach has the ability to recover just as fast as it can erode, which has been recorded on New Zealand's north eastern coast (Mead *et al*., 1998) and on the Gold Coast (Turner, 2004). Indeed, the maximum daily advance of the high tide beach position is greater than the maximum daily retreat.

The overall high tide beach position accreted over the 16 month period from March 2013 to July 2014. Following the results of the prior 12 months (i.e. March 2012 to March 2013), which indicated an overall erosive trend that was considered either due to the late summer storms of 2013 and possibly part of the rotation mechanism described by Ranasinghe *et al*. (2004) where we would expect the beach width in the area of Wooli Village to be reduced as sediment is redistributed to the north due to swing to El Nino conditions, the overall trend of the beach over the 28 month period is one of accretion.

The daily beach position data for the past 28 months has highlighted two particular issues that relate to the need for long-term daily beach monitoring in order to determine long-term trends. The first is that sporadic measurements of beach position (e.g. historical aerial photograph analysis) can easily mis-represent the actual erosion/accretion trends. For example, in the space of one day the beach can erode or accrete over 30 m. In addition, there are seasonal trends and longer term climatic variations (e.g. ENSO and IPO) that can bias observations with sporadic and long (decadal) spacings. Secondly, that a short dataset is not a good indicator of long-term erosion/accretion trends, as shown by comparing the trends of the March 2012-2013 12 month dataset to the full 28 month dataset – the former indicates an erosional trend, while the latter indicates accretion.

As with the 2012-2013 daily dataset, there is agreement in beach position with the beach profile data, which validates the analysis presented here. However, although the beach profile data do not provide the kind of information on beach position changes on a daily basis and in response to particular combinations of wave, tide and wind events, they provide valuable information with respect to the volumetric distribution of sand on the beach (rather than only a 2-dimensional/horizontal beach position), and also long-term trends with continued monitoring and the development of a long-term dataset. The accretion observed in the daily high tide beach position data is shown in the beach profile data to represent substantial beach height and volume increases; i.e. up to 2 m vertical height increase, and ~30 m^3/linear metre of beach along the monitored stretch.

The beach profile monitoring clearly shows the increasing height of the foredune/back beach along the stretch of the beach monitored by the cameras, and is attributed to the continued accumulation of sand in the foredune due to the planting of sand-stabilizing spinifex and the sand fences. Accretion has been mostly above MSL in the northern part of the daily monitored stretch of beach, and over the whole beach to low tide in the southern area, with similar volumes of accretion over the whole stretch.

Continued beach monitoring will aid the development of an effective management strategy for the long-term protection of Wooli Beach. As previously stated, no single source of data capture and analysis is yet available which provides the dataset needed to adequately support this task in terms of long-term data for the complete beach at a detailed level on a frequent basis.

The daily coast-cam system and quarterly 'whole-beach' surveys will substantially assist to fill in the detailed dataset that has been unavailable to previous studies. As the duration of data collection increases, future studies will no longer need to rely so heavily on the 12 'points in time' of photogrammetry data spread across over 70 years.

No changes to the monitoring are recommended. However, continued coastcare through the planting of spinifex is recommended for the whole of Wooli Beach to increase resilience to erosion events. This represents a significant task for the full ~7 km of beach, however, perseverance can lead to creation of a healthy and robust beach, as has been demonstrated in many parts of north eastern New Zealand (Figure 5.1), which has many similarities with the NSW east coast.

At present, the El Nino Southern Oscillation (ENSO) index is tending towards El Nino (i.e. more events from the southeastern quarter), after several years of La Nina conditions (i.e. events from the northeastern quarter dominate). Should El Nino conditions develop over the coming year, the effects of this change on the beach could be considered in the next analysis.

Figure 5.1. Aggressive erosion of Omaha Beach (north eastern New Zealand) following the bulldozing and clay-capping of the foredune for development in the 1970's resulted in retreat of >30 m of beach front and the loss of properties. Today, following 10 years of dune restoration, the ~4 km beach continues to accrete – this photograph, taken during an equinox high tide during a north-easterly storm, shows the latest foredune that has evolved since dune restoration began.

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