Analysis of shoreline variability and erosion/accretion trends: December 2007- May 2008 report 8, Palm Beach coastal imaging system

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THE UNIVERSITY OF NEW SOUTH WALES

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ANALYSIS OF SHORELINE VARIABILITY AND EROSION/ACCRETION TRENDS: DECEMBER 2007 - MAY 2008

REPORT 8
PALM BEACH COASTAL IMAGING SYSTEM

by

M J Blacka, D J Anderson and L Mallen Lopez

Technical Report 2008/18
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SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
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1. INTRODUCTION

This report was prepared by the Water Research Laboratory (WRL), of the University of New South Wales for Gold Coast City Council (GCCC). It is the eighth in a series of six-monthly reports to describe, quantify and analyse the regional-scale coastline variability and erosion/accretion trends that occur at Palm Beach, Queensland, Australia. It is intended that this growing database of qualitative and quantitative coastal monitoring information will inform and enhance the current and future management of the Palm Beach embayment.

1.1 General

In June of 2004, an ARGUS coastal imaging system became operational at the Palm Beach site for an initial period of three years. This leading-edge technology was selected by Gold Coast City Council to provide regional-scale, continuous and long-term monitoring of this central Gold Coast coastal embayment. It is the ability to provide quantitative as well as qualitative information that distinguishes the ARGUS coastal imaging system from conventional 'webcam' or 'surfcam' technology.

The Gold Coast was the first of several coastal management sites in Australia that now utilise coastal imaging technology and associated digital image analysis techniques to monitor regional-scale coastal response to natural and engineered coastal impacts. A coastal imaging station has been operating at Surfers Paradise to the north of the Palm Beach site since 1999, and in 2002 four ARGUS coastal imaging stations were installed along the southern Gold Coast, to assist with the operation and monitoring of the Tweed River sand by-passing system.

The analysis of beach changes during the preceding six-month monitoring periods are detailed in:

- WRL Report 2004/38: June 2004 to November 2004 (Turner, 2004)
- WRL Report 2005/22: December 2004 to May 2005 (Turner, 2005)
- WRL Report 2005/36: June 2005 to November 2005 (Turner, 2006a)
- WRL Report 2006/14: December 2005 to May 2006 (Turner, 2006b)
- WRL Report 2006/37: June 2006 to November 2006 (Turner, 2006c)
- WRL Report 2007/21: December 2006 to May 2007 (Blacka *et al.*, 2007)
- WRL Report 2007/40: June2007 to November 2007 (Blacka *et al.*, 2008).

Electronic copies of all monitoring reports are made freely available for public viewing and download in PDF format at:

→ *www.wrl.unsw.edu.au/coastalimaging/public/palmqld* (link: monitoring reports).

The purpose of this eighth report is to present the results of shoreline change analysis and erosion/accretion trend analysis for the six-month monitoring period December 2007 to May 2008, and to assess the net changes that have occurred within the Palm Beach embayment since the commencement of the monitoring program 48 months ago in June 2004.

1.2 Maintenance, Upgrades and Operational Issues

In September 2005 the Body Corporate of the Royal Palm Building (atop which the Palm Beach ARGUS station is housed) requested that the cameras be temporarily removed while major roof restoration works were undertaken at the site. The ARGUS station was turned off on September 16th, and re-installed again on 12th December 2005. Unfortunately, unscheduled rectification works to correct several defects in the roof repairs necessitated the moving of the cameras again on the 19th December. Defect repairs continued through January 2006, with the ARGUS station finally re-installed and re-surveyed on 31st January 2006.

A major coastal storm struck the Gold Coast in early March 2006 and the electrical system within the host building suffered damage, causing a failure of the ARUGUS power supply. This was subsequently repaired and the system became operational again in the second half of March. From March 2006 the Palm Beach ARGUS station remained fully operational through until July 2007, with routine maintenance including cleaning of the camera housings being undertaken in mid March 2007.

In July 2007 the Palm Beach ARGUS station went offline for several weeks due to a faulty modem power cable, although routine scheduled image collection continued to occur, with the images stored locally at the site. This was rectified during a site visit in early August 2007, and all stored image data transferred to the remote server at WRL for the offline period. During a second visit to the station late in August, the remote power management device was reprogrammed, cameras were cleaned, and a spare computer was stored at the station.

The ARGUS server located at WRL suffered catastrophic failure on 18th October 2007, and was subsequently replaced by the 24th October. All data that had been stored on the failed server was restored using backup copies. Image data continued to be collected during this period, except for the day of the 18th October.

1.3 Report Outline

Following this introduction, Section 2 of this report provides a brief description of the Palm Beach embayment, and an overview of engineering works completed at Palm Beach since commencement of the monitoring program in mid 2004.

Section 3 contains a summary description of the ARGUS coastal imaging system, including the image types that are collected on a routine basis, and an overview of the digital image processing techniques used to analyse the images. The reader requiring more detailed information is referred to Report 1 Palm Beach Coastal Imaging System entitled *System Description, Analysis of Shoreline Variability and Erosion/Accretion Trends: June 2004 - November 2004* (Turner, 2004).

The web site which is used to promote and distribute the images collected by this monitoring program is introduced in Section 4. This description includes the web-based image archive that provides unrestricted public access to all images, weekly-updated quantitative analysis of current coastline conditions, and 'time-lapse' animation files that can be generated on-demand by GCCC staff.

Section 5 introduces the beach morphodynamic classification model of Wright and Short (1983), which is then used to describe in a qualitative manner the beach changes observed using the time-series of daily images for the six month period covered by this report.

The quantitative analysis of shoreline change for the current monitoring period is detailed in Section 6. This is followed in Section 7 by the corresponding analysis for the total 48 month period since monitoring commenced in mid 2004.

The application of an image analysis technique that enables patterns of beach erosion and accretion to be identified and quantified along the Palm Beach embayment on a regular (monthly) basis is presented in Section 8. Section 9 summarises the major findings of this eighth six-monthly monitoring period at Palm Beach.

2. BACKGROUND

2.1 Environmental Setting

Palm Beach is located along the central Gold Coast, south-east Queensland (Figure 2.1). The 5 km long embayment is located between Burleigh Headland to the north and Currumbin Headland to the south. As shown in Figure 2.2, the southern training wall of Tallebudgera Creek adjacent to Burleigh Headland marks the northern extent of the sandy beach. The trained entrance to Currumbin Creek and associated sand shoals, adjacent to Currumbin Headland, occur at the southern end of the Palm Beach embayment. Palm Beach is typical of the Gold Coast, with beachfront development running the length of the beach, and the beach patrolled by three surf life saving clubs along the oceanfront. In addition to the creek training walls at both the northern and southern ends of the embayment, two short rubble-mound groynes have been constructed, the northern groyne located at 21st Street, and the more southern groyne at 11th Street. A near-continuous and largely buried boulder wall runs the length of the beach from Tallebudgera Creek in the north, to the sand spit adjacent to Currumbin Creek in the south.

2.2 Nearshore Sand Nourishment

The monthly volumes of sand nourishment and the placement of this sand resource along the southern region of the Palm Beach embayment are summarised in Figure 2.3. The lower panel shows the location of the nearshore "dump boxes". The upper panel shows the volume of sand placed per month. There has been no nearshore beach nourishment undertaken during the current monitoring period, December 2007 to May 2008.

2.2.1 2004 Campaign

A campaign of nearshore sand nourishment commenced in April 2004 and was completed in December 2004. The first stage of sand nourishment was undertaken during April and May, and the second stage from October to December. This campaign of sand nourishment, sourced from offshore sand resources, comprised a total of **145,445 m^3**.

2.2.2 2005/2006 Campaign

From June to September 2005 a total of **22,870 m^3** of sand dredged from the entrance to the Tweed River was placed within the nearshore zone at Palm Beach. Commencing in October sand was sourced from the offshore region of the Palm Beach embayment, and during October 2005 – April 2006 a total of **240,217 m^3** of this sand was placed within the nearshore zone. Referring to Figure 2.3, since June 2004 approximately **385,668 m^3** of sand had been placed within the nearshore region of the Palm Beach embayment.

2.3 Placement of Currumbin Creek Dredge Material

Gold Coast City Council has maintained a program to dredge the lower estuaries of Currumbin and Tallebudgera Creeks every year, and uses the sand from Currumbin Creek to nourish the beachface at the southern end of Palm Beach. Sand from the Tallebudgera entrance is pumped north to Burleigh Beach.

2.3.1 July – September, 2004

From July to September 2004 sand from Currumbin Creek was placed along the beachfront at the southern end of the Palm Beach embayment. The location of this sand placement is shown in Figure 2.4 (upper panel), along the sand spit that separates the creek from the ocean. In total, **28,946 m^3** of sand was placed during the six week period 19/7/04 to 2/9/04. Sand was placed at the rate of approximately 110 m^3 per hour generally between 6 am and 6 pm, with the outlet pipe being moved 20 m southward, every two working days.

2.3.2 April - June, 2005

From April to June 2005 an additional **26,493 m^3** of sand was placed at a single discharge point, shown in Figure 2.4 (lower panel). Daily delivery rates varied between approximately 200 m^3 and 1100 m^3 per day, with the engineering works being completed between 6 am and 6 pm.

2.3.3 November – December, 2005

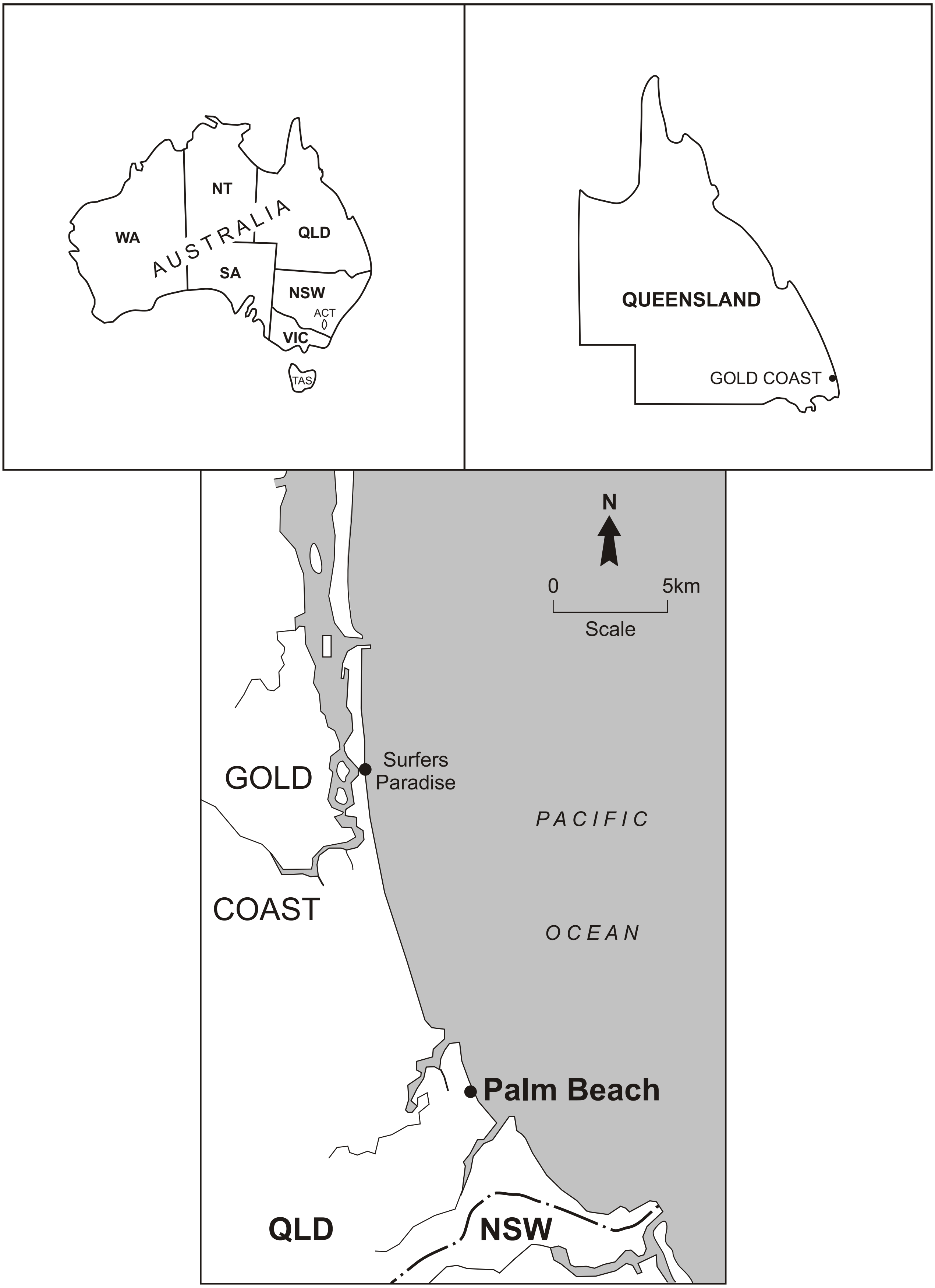
During the period 30th November to 14th December 2005 **11,593 m^3** of sand from Currumbin Creek was placed at the southern end of the Palm Beach embayment.

2.3.4 October – November, 2006

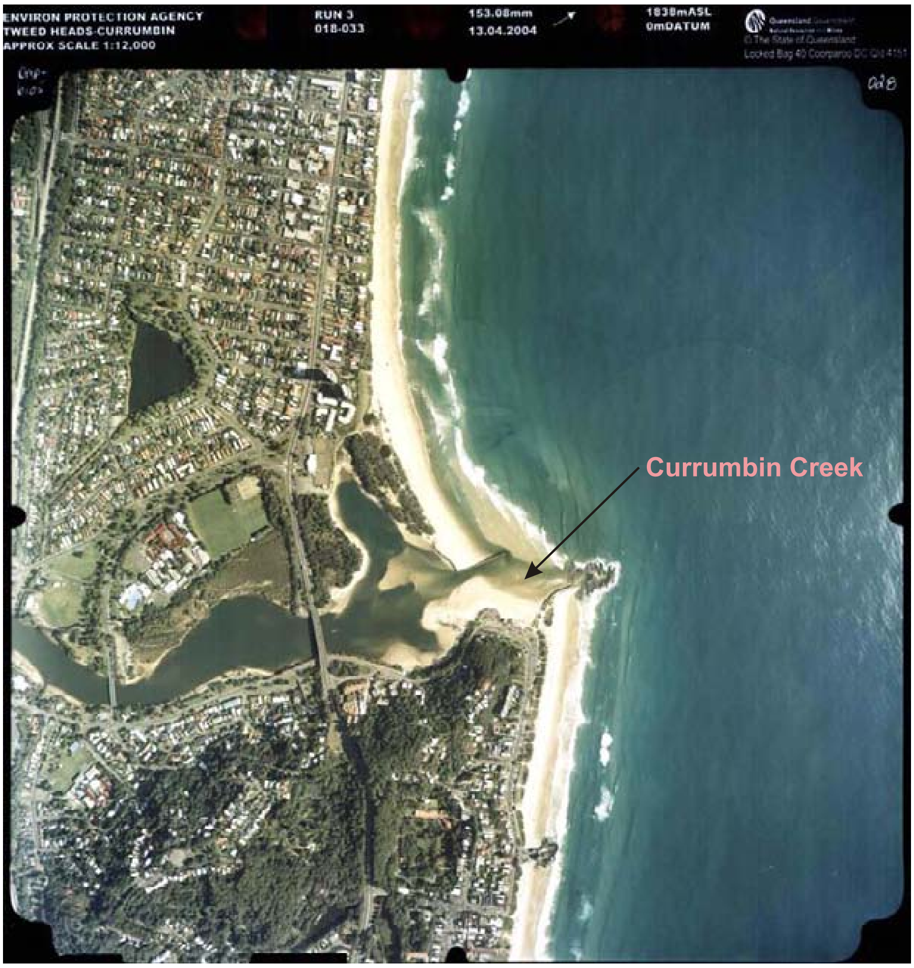
From 25th October to 15th November 2006 a further **37,724 m^3** of sand from Currumbin Creek (including 3,000 m^3 re-dredged infill) was placed at the southern end of the Palm Beach embayment.

2.3.5 October – November, 2007

From the 4th October to the 30th November 2007 **41,910 m^3** of sand was dredged from the Currumbin Creek entrance, and placed on the spit at the southern end of the Palm Beach embayment. This is the largest quantity of material dredged from the Currumbin Creek to be placed onto the spit in any year since the monitoring program commenced in mid 2004.



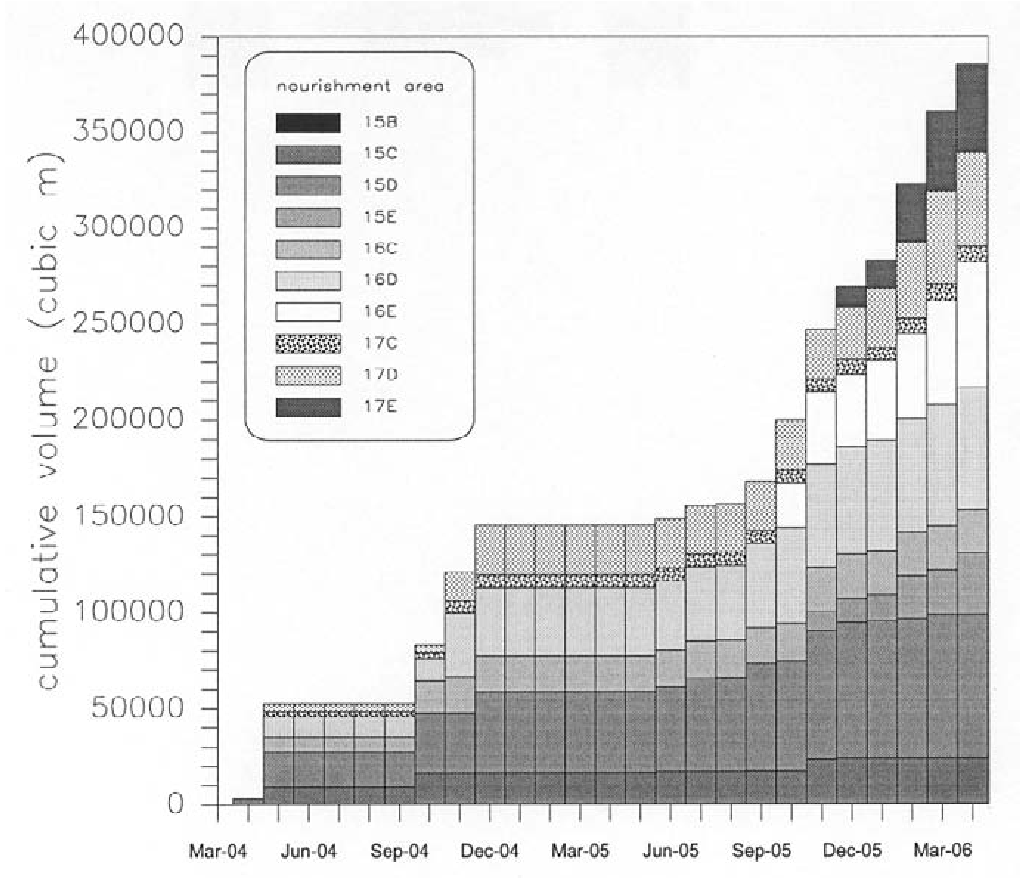
WRL Report No. 2008/18	LOCALITY	Figure 2.1 06037-2-1.cdr

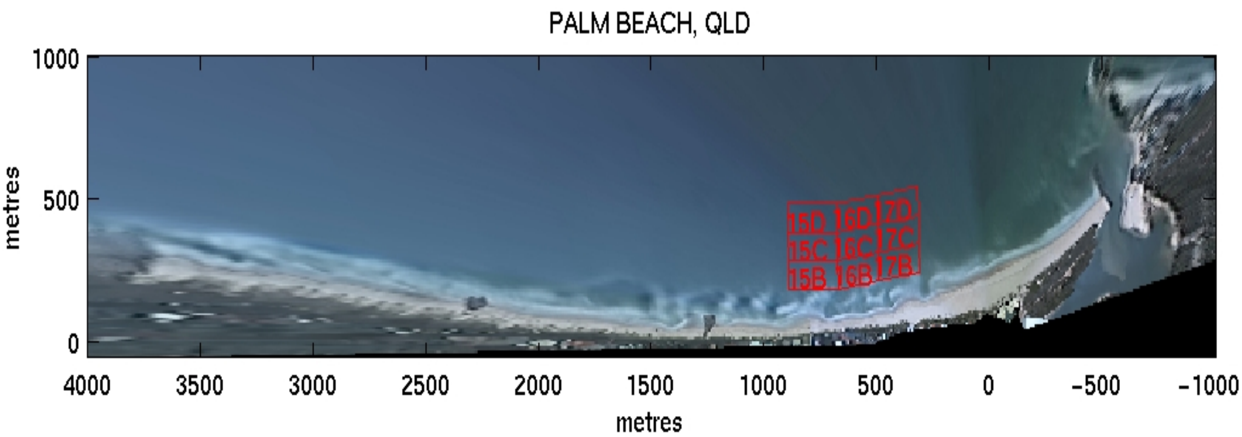


Palm Beach Embayment,
Southern Portion

Palm Beach Embayment
viewed from North

WRL Report No. 2008/18	PALM BEACH, GOLD COAST, QUEENSLAND	Figure 2.2 06037-2-2.cdr





WRL Report No. 2008/18	NEARSHORE NOURISHMENT DEPOSITION AREAS AND VOLUMES	Figure 2.3 06037-2-3.cdr

SAND PLACEMENT - 2004

SAND PLACEMENT - 2005

WRL Report No. 2008/18	PLACEMENT OF CURRUMBIN CREEK DREDGE MATERIAL	Figure 2.4 06037-2-4.cdr

3. OVERVIEW OF COASTAL IMAGING, IMAGE TYPES AND IMAGE PROCESSING METHODS

Comprehensive descriptions of the Palm Beach coastal imaging system, image types and image processing techniques were detailed in the first Palm Beach coastal imaging report *System Description, Analysis of Shoreline Variability and Erosion/Accretion Trends: June 2004 - November 2004* (Turner, 2004). For the sake of completeness, the following section provides a brief summary of the system and the image processing techniques being used to quantify beach changes.

3.1 What is Coastal Imaging?

'Coastal imaging' simply means the automated collection, analysis and storage of pictures that are then processed and analysed to observe and quantify coastline variability and change.

Aerial photography has been the tool most commonly used by coastal managers to monitor regional-scale coastal behaviour. This is expensive and as a result, coverage is often ‘patchy’ and incomplete. Pictures are only obtained when visibility from the airplane is satisfactory, often resulting in a limited number of suitable pictures per year (at most), with no information about the behaviour of the beach between flights.

In contrast, with the development of digital imaging and analysis techniques, one or more automated cameras can be installed at a remote site and, via a telephone or internet connection, be programmed to collect and transfer to the laboratory a time-series of images. These images, taken at regular intervals every hour of the day for periods of months and years, can cover several kilometres of a coastline. Not every image need be subjected to detailed analysis, but by this method the coastal manager can be confident that all 'events' will be recorded and available for more detailed analysis as required.

3.2 The Difference between Coastal Imaging and a 'Surfcam'

At the core of the coastal imaging technique is the ability to extract quantitative data from a time-series of high quality digital images. In contrast, conventional 'surfcams' are very useful to applications where a series of pictures of the coastline is sufficient, and these types of images can be used to develop a qualitative description of coastal evolution.

The extraction of quantitative information from the coastal imaging system is achieved by careful calibration of the cameras and the derivation of a set of mathematical equations that are used to convert between two-dimensional image coordinates and three-dimensional ground (or 'real world') coordinates (refer Turner, 2004). Sophisticated digital image processing techniques are then applied to extract and quantify information contained within the images.

3.3 The ARGUS Coastal Imaging System

The ARGUS coastal imaging system has developed out of years of ongoing research effort based at Oregon State University, Oregon USA (Holman *et al.*, 1993). A schematic of a typical ARGUS station is shown in Figure 3.1. The key component of an ARGUS station is one or more cameras pointed obliquely along the coastline. The camera(s) are connected to a small image processing computer (Silicon Graphics SGI workstation), which controls the capture of images, undertakes pre-processing of images, and automatically transfers the images via the internet from the remote site to the laboratory. The cameras installed at Palm Beach are fitted with high quality lenses. A switching interface between the cameras and computer maintains synchronisation of the captured images. The SGI workstation incorporates an internal analogue I/O card that enables all images to be captured, stored and distributed in standard JPEG digital image file format.

At WRL, a dedicated host computer (dual-processor Linux workstation) stores all images as they are received from the remote site within a structured archive. This workstation is also integrated to a world-wide-web server, with the images made available to all visitors to the web site to view and download within minutes of their capture and transfer from Palm Beach to WRL. Post-processing of the images is completed using a variety of Linux and PC computer hardware and custom image processing software within the MATLAB programming environment.

3.4 Installation at Palm Beach

The ARGUS coastal imaging system was installed at Palm Beach in late May 2004. The system is located at an elevation of approximately 80 m above mean sea level, within the roof services area of the Royal Palm building (Figure 3.2). The Royal Palm is located approximately 50 m - 100 m landward of the frontal dune, approximately 500 m to the north of the Currumbin Creek entrance.

The cameras are mounted externally on a single frame that stands on the roof of the building, and are protected within weatherproof housings (Figure 3.3). The SGI workstation is housed within a pump services room, where 240 V power and a dedicated phone line connection to the internet are provided. The system is designed to run autonomously, and is self-recovering should an interruption to the mains power supply occur. Routine maintenance of the system is achieved by connection to the remote system via the internet from WRL. Occasional cleaning of the camera lenses is required.

3.5 Image Types

The ARGUS coastal imaging system installed at Palm Beach is presently configured to collect three different types of images on a routine hourly basis. A fourth image type is created by automated post-processing at the completion of each day of image collection.

Images are collected every daylight hour. The image collection procedure is fully automated and controlled by the SGI workstation at the remote site. Prior to commencing the hourly image collection routines, a test is undertaken to determine if there is sufficient daylight to proceed with image collection. If the ambient light threshold is exceeded, image collection commences. The reason for first checking for daylight conditions is to avoid unnecessary image collection at night, without excluding image collection earlier in the morning and later in the evening during extended summer daylight hours.

3.5.1 Snap-Shot 'snap' Images

The simplest image type is the snap-shot image. This is the same image obtained if a picture of the beach were taken using a conventional digital camera. Snap-shot images provide simple documentation of the general characteristics of the beach, but they are not so useful for obtaining quantitative information. An example of a snap image obtained on May 31st 2008 is shown in Figure 3.4 (upper panel).

3.5.2 Time-Exposure 'timex' Images

A much more useful image type is the time-exposure or 'timex' image. Time-exposure images are created by the 'averaging' of 600 individual snap-shot images collected at the rate of one picture every second, for a period of 10 minutes.

A lot of quantitative information can be obtained from these images. Time exposures of the shore break and nearshore wave field have the effect of averaging out the natural variations of breaking waves, to reveal smooth areas of white, which has been shown to provide an excellent indicator of the shoreline and nearshore bars. In this manner, a quantitative 'map' of the underlying beach morphology can be obtained. An example of a timex image obtained on May 31st 2008 is shown in Figure 3.4 (middle panel).

3.5.3 Variance 'var' Images

At the same time that the timex images are being collected, an image type called a variance or 'var' image is also created. Whereas the time-exposure is an 'average' of many individual snap-shot images, the corresponding variance image displays the variance of light intensity during the same 10 minute time period.

Variance images can assist to identify regions which are changing in time, from those which may be bright, but unchanging. For example, a white sandy beach will appear bright on both snap-shot and time-exposure images, but dark in variance images. Because of this, other researchers have found that variance images are useful at some specific coastal sites for analysis techniques such as the identification of the shoreline, as the (bright) changing water surface is readily identifiable against the (dark) beach. An example of a var image obtained on May 31st 2008 is shown in Figure 3.4 (lower panel).

3.5.4 Day Time-Exposure 'daytimex' Images

The fourth image type routinely created from the coastal imaging system installed at Palm Beach is referred to as a daytimex image. It is created at the end of each day of image collection, by the averaging of all hourly timex images collected that day. This has the effect of 'smoothing' the influence of tides, and for some conditions may enhance the visibility of the shore break and bar features in the nearshore.

3.6 Basic Image Processing – Merge and Rectification

As noted earlier in Section 3.2, the key feature of coastal imaging technology that distinguishes it from conventional webcam systems is the ability to extract quantitative information from the images. As described previously, this is achieved through the solution of the camera model parameters to extract 3-D real-world position from 2-D image coordinates, and the application of image processing techniques to identify, enhance and manipulate the image features of interest.

Image merging is achieved by the solution of camera model parameters for individual cameras, then the boundaries of each image are matched to produce a single composite image. Image rectification is then undertaken, whereby the dimensions of the merged image are corrected so that each pixel represents the same area on the ground, irrespective of how close to, or how far from, the camera position it may be. (In contrast, for an unrectified image the area represented by each pixel increases with increasing distance from the camera.)

Image rectification is achieved by using the calculated camera model parameters to fit an image to a regular grid that defines longshore and cross-shore distance. The rectification of merged images produces a 'plan view' of the area covered by all four cameras. This is illustrated in Figure 3.5. Also shown in this figure is a ‘pan’ image, which provides an alternative wide-angle (but distorted) image of the coastline. The merged and rectified plan image created from five oblique images is analogous to a montage of distortion-corrected photographs taken from an airplane flying directly overhead Palm Beach. For convenience, the longshore and cross-shore dimensions of this image are referenced (in metres) to the location of the cameras. The pixel resolution of the merged/rectified images created at Palm Beach is 5 m; that is, a single pixel represents an area 5 m × 5 m on the ground.

3.7 Shoreline Detection and Analysis

To map the position of the shoreline and its changing location through time, a rigorous image analysis methodology is required to enable the extraction of this information from the database of hourly ARGUS images.

3.7.1 Pixel Intensity Clustering

The shoreline mapping methodology used at Palm Beach utilises the full colour information available from ARGUS images. Called ‘Pixel Intensity Clustering’ or ‘PIC’, the technique aims to delineate a shoreline feature from 10 minute time exposure images, on the basis of distinctive image intensity characteristics in pixels, sampled across the sub-aqueous and sub-aerial beach. Raw image intensities in Red-Green-Blue (RGB) colour-space, sampled from a region of interest across both the dry and wet beach, are converted to Hue-Saturation-Value (HSV) colour space, to separate colour (Hue, Saturation) and grey scale (Value) information. The HSV intensities are filtered to remove outliers and scaled between 0 and 1, to improve the contrast between two clusters of dry and wet pixels. Iterative low-passing filtering of the spiky histogram of scaled intensity data yields a smooth histogram with two well-pronounced peaks P_{dry} and P_{wet}, which mark the locations of the two distinct clusters of dry and wet pixels (Figure 3.6).

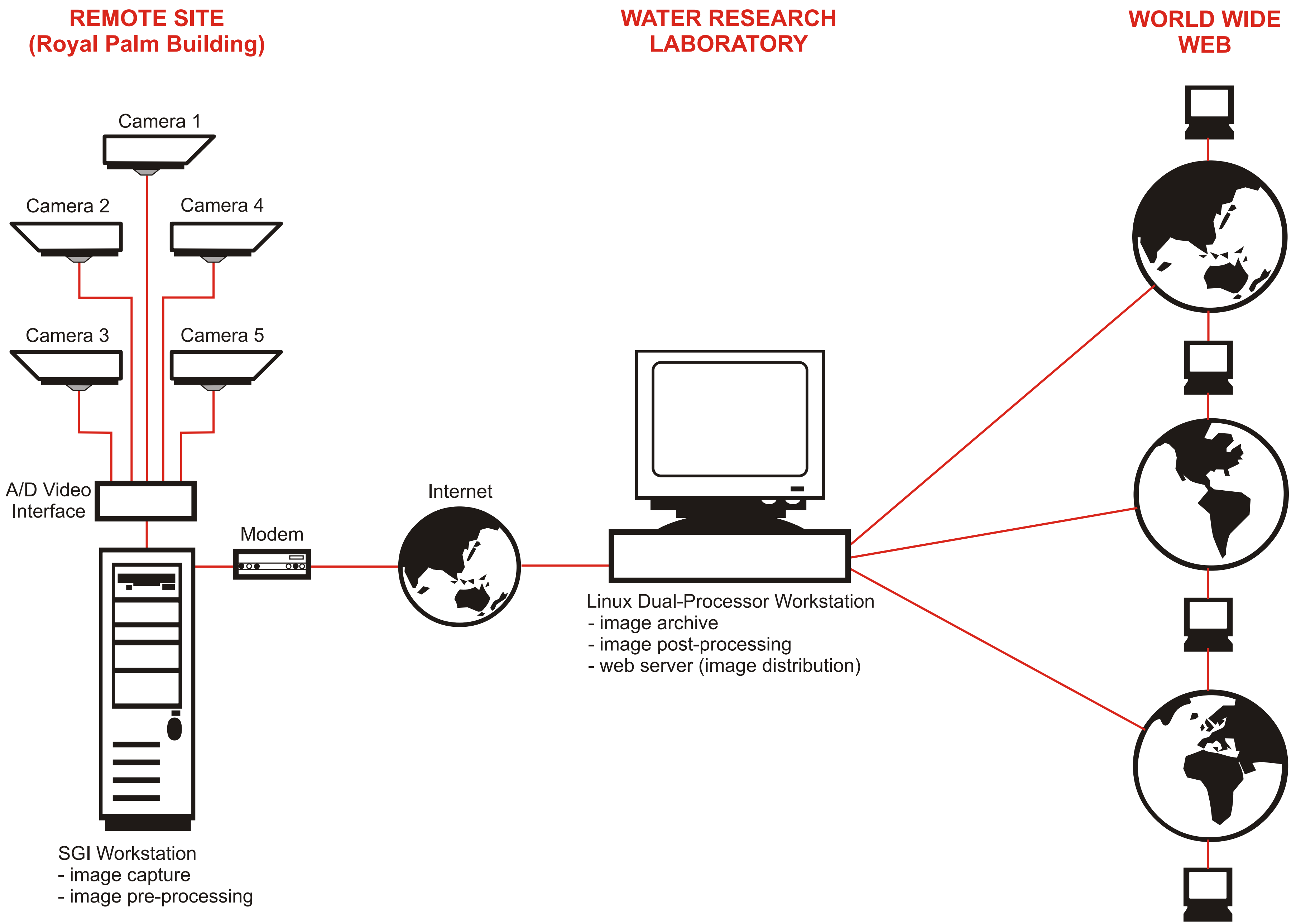
The filtered histogram is used to define a line to distinguish between Hue Saturation information used for colour discrimination (Figure 3.6a), or Value information in the case of luminance-based discrimination (Figure 3.6b). For both discriminators, the line defined in this manner crosses the saddle point of the filtered histogram, and thus provides the means to separate objectively the two clusters of dry and wet pixels within the region of interest. With the help of this line, a discriminator function Ψ is defined such that $\Psi = 0$ along this line (see Figure 3.6). The areas of dry and wet pixels are then mapped, and the boundary between the two regions defines the resulting shoreline feature of interest. Comprehensive description of the PIC shoreline identification technique is provided in Aarninkhof (2003), Aarninkhof and Roelvink (1999) and Aarninkhof *et al.* (2003).

3.7.2 Standardised Procedure for Shoreline Mapping

The procedure used to map the shoreline at Palm Beach is summarised in Figure 3.7. At weekly (nominal seven day) intervals, observed tide information is used to determine the hourly timex images that correspond to mid-tide (0 m AHD). The corresponding merged-rectified 5-camera image is then created. The database of wave information is also searched to determine the rms ('root mean square') wave height (H_{rms}) and spectral peak wave period (T_p) that correspond to these daily mid-tide images.

Based on a seven day cycle, the corresponding mid-tide image is checked to confirm that the wave height satisfies the low-pass criteria $H_{rms} \leq 1.0$ m ($H_s \leq \sim 1.4$ m). This wave height criteria is used for shoreline mapping as, above this wave height, wave run-up at the beachface increases and the width of the swash zone widens, introducing a corresponding uncertainty in the cross-shore position of the waterline. If the rms wave height is less than 1.0 m, then the shoreline is mapped. If the wave height exceeds the $H_{rms} = 1.0$ m threshold, then the mid-tide image for the preceding day is checked. If this image still does not satisfy the wave height criteria, then the following day's mid-tide image is checked. This process is repeated for up to ± 3 days from the original target weekly image, to locate a mid-tide image for which the rms wave height did not exceed 1.0 m. If no mid-tide images are available in any one seven day cycle that satisfy this criteria, then no shoreline is mapped for that week.

Once the mid-tide image to be processed has been identified, the PIC method is applied and the shoreline feature is mapped. Beach width is then calculated relative to the alignment of the existing boulder wall. By repeating this procedure every seven days, a growing database is developed that contains the time-series of weekly shoreline positions at all positions along the shore. These data are then subjected to a range of analyses as described in the following Sections 6, 7 and 8.



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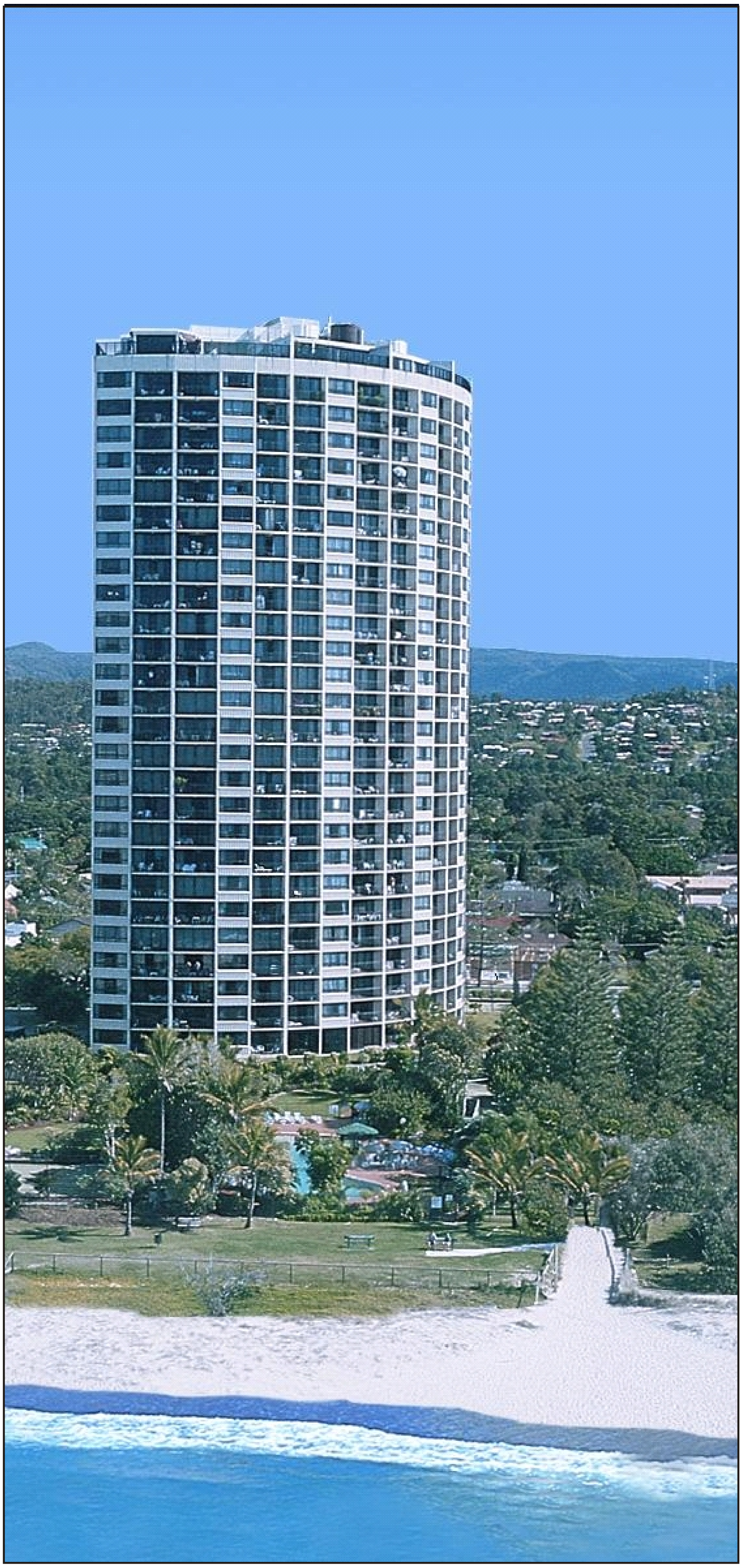
SCHEMATIC OF AN ARGUS COASTAL IMAGING SYSTEM

Figure
3.1

06037-3-1.cdr



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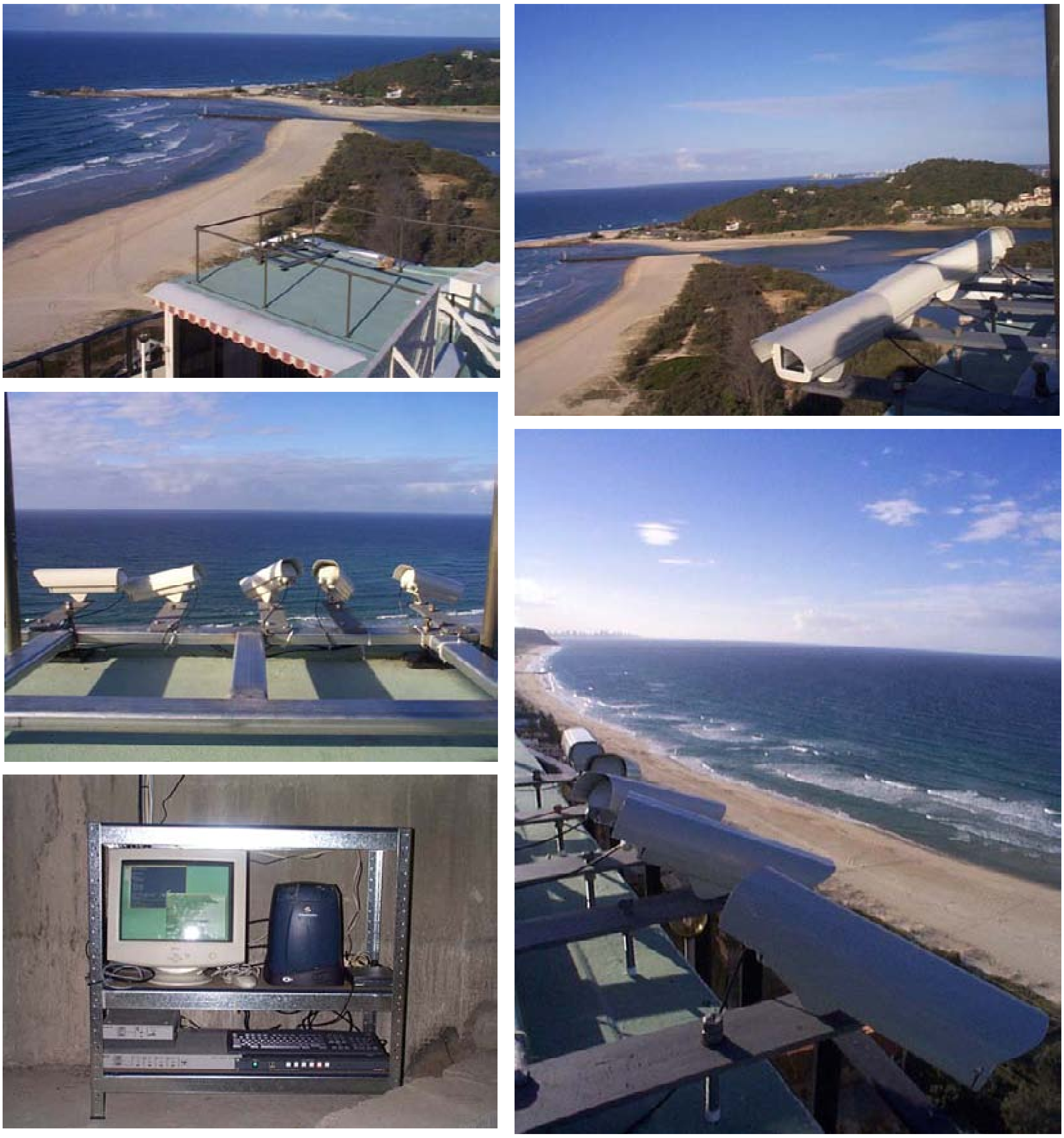
LOCATION OF COASTAL IMAGING SYSTEM
ROYAL PALM BUILDING

Figure
3.2

06037-3-2.cdr



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CAMERAS MOUNTED AT AN ELEVATION OF APPROXIMATELY 80m

Figure 3.3

06037-3-3.cdr

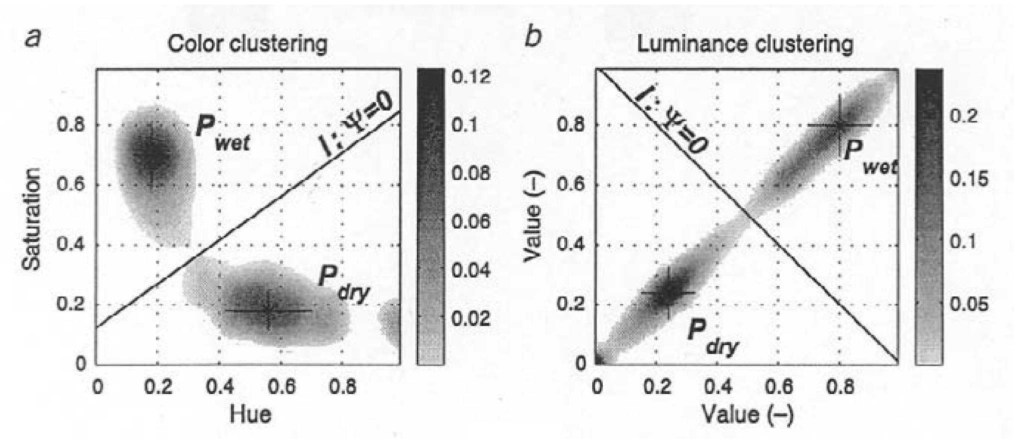
snap

timex

var

WRL Report No. 2008/18	SNAP-SHOT, TIME-EXPOSURE AND VARIANCE IMAGE TYPES (MAY 2008)	Figure 3.4

WRL Report No. 2008/18	PAN AND PLAN VIEW IMAGES: FIVE-CAMERA MERGE/RCTIFICATION (MAY 2008)	Figure 3.5



Source: Aarninkhof (2003)

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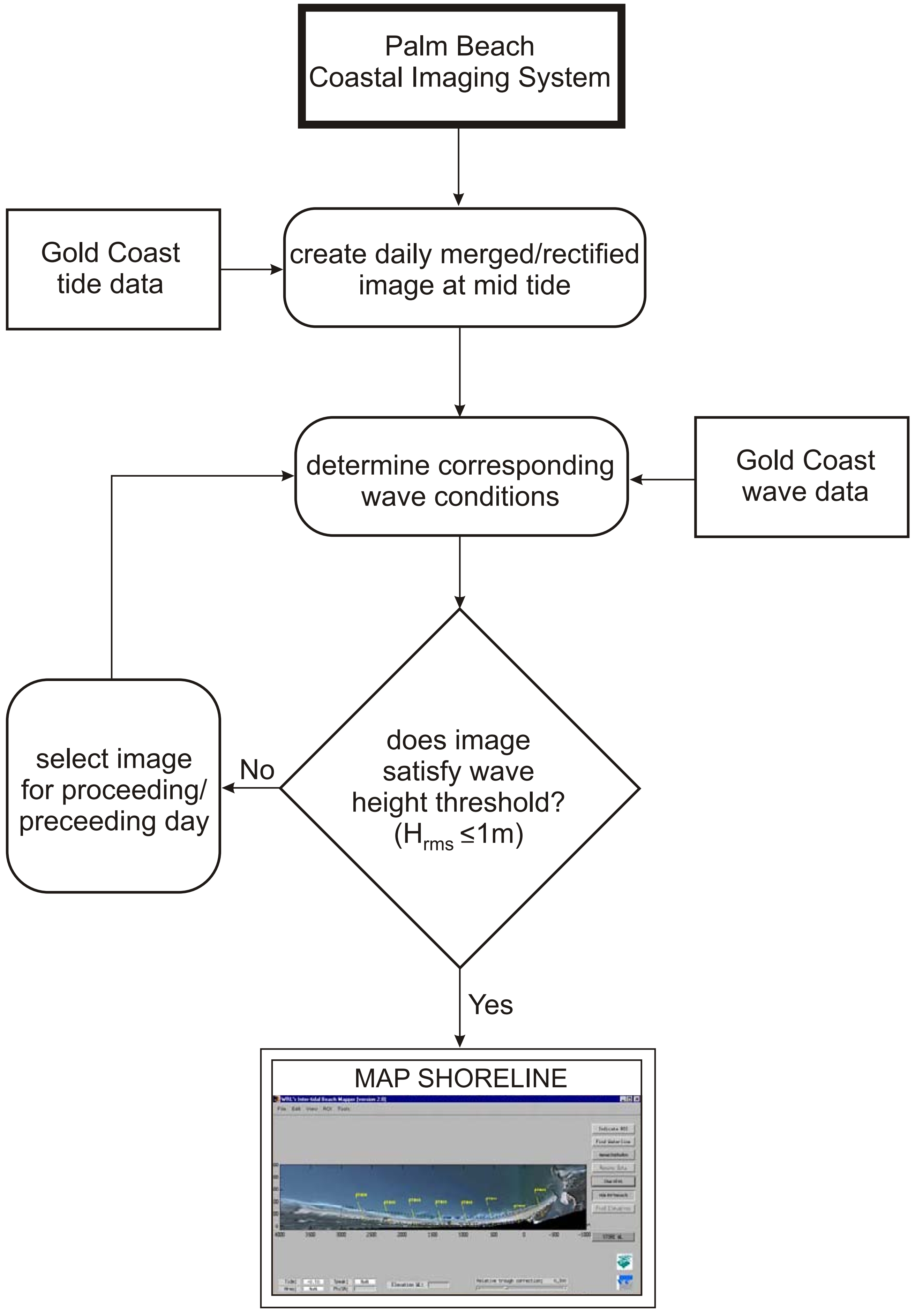
IDENTIFICATION OF 'SHORELINE' FEATURE FROM COLOUR IMAGES

Figure 3.6

06037-3-6.cdr



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STANDARDISED SHORELINE MAPPING PROCEDURE

Figure
3.7

06037-3-7.cdr

4. COASTAL IMAGING WEB SITE

4.1 Coastal Imaging Home Page

To promote the dissemination of information about the Palm Beach coastal monitoring project, to provide a convenient means to distribute images as they are collected, and to facilitate 'real-time' access to the regularly-updated results of shoreline monitoring and beach width analysis, a coastal imaging project site was established on the world-wide web at the following URL:

→ www.wrl.unsw.edu.au/coastalimaging/public/palmqld

The Palm Beach coastal imaging home page is shown in Figure 4.1. The most recent snap images are displayed here and updated every hour, enabling visitors to the site to observe the current beach conditions. This page also includes a number of links to a variety of background information including a description of the coastal imaging system, image types and image processing techniques. Links are also provided to the Gold Coast City Council web site, the waverider buoy site run by the Queensland Department of Environment, local weather information, and tidal predictions for the Gold Coast Seaway provided by the National Tidal Facility.

For general interest, a record is maintained of the number of visitors to the WRL coastal imaging web site and the countries they are from. At the time of writing, over **343,400 hits** to the WRL coastal imaging web pages have been recorded. Visitors from Australia account for approximately half the total visitors, with the remaining visitors coming from approximately 80 countries world-wide.

4.2 Image Archive

The current snap, timex images and var images are updated and available at the project web site every hour.

All present and past images can be accessed via the on-line image archive. This provides a convenient and readily navigable structure to quickly locate the image(s) of interest. Figure 4.2 shows an example of a daily page contained within the image archive. These images are provided freely to encourage their use by students, researchers, managers and other non-commercial organisations.

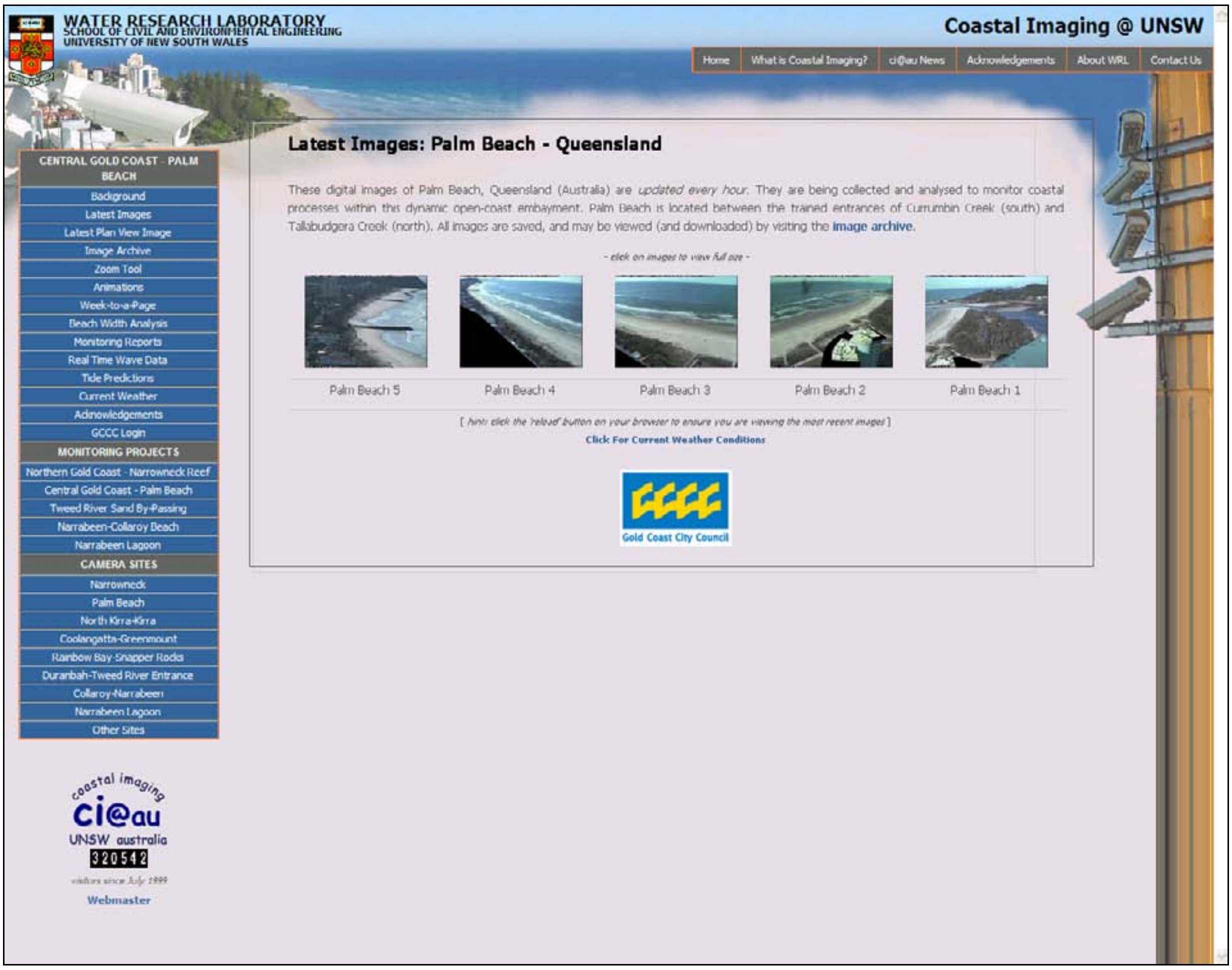
4.3 On-Line 'Beach Analysis System'

On-line access to 'real time' beach monitoring and analysis is made available at the Palm Beach coastal imaging web site. This capability results from the on-going research and development effort underway by the coastal imaging team at WRL. The purpose of this system is to provide regularly-updated results of the beach monitoring program to Gold Coast City Council and the general public on a routine basis, via the world wide web.

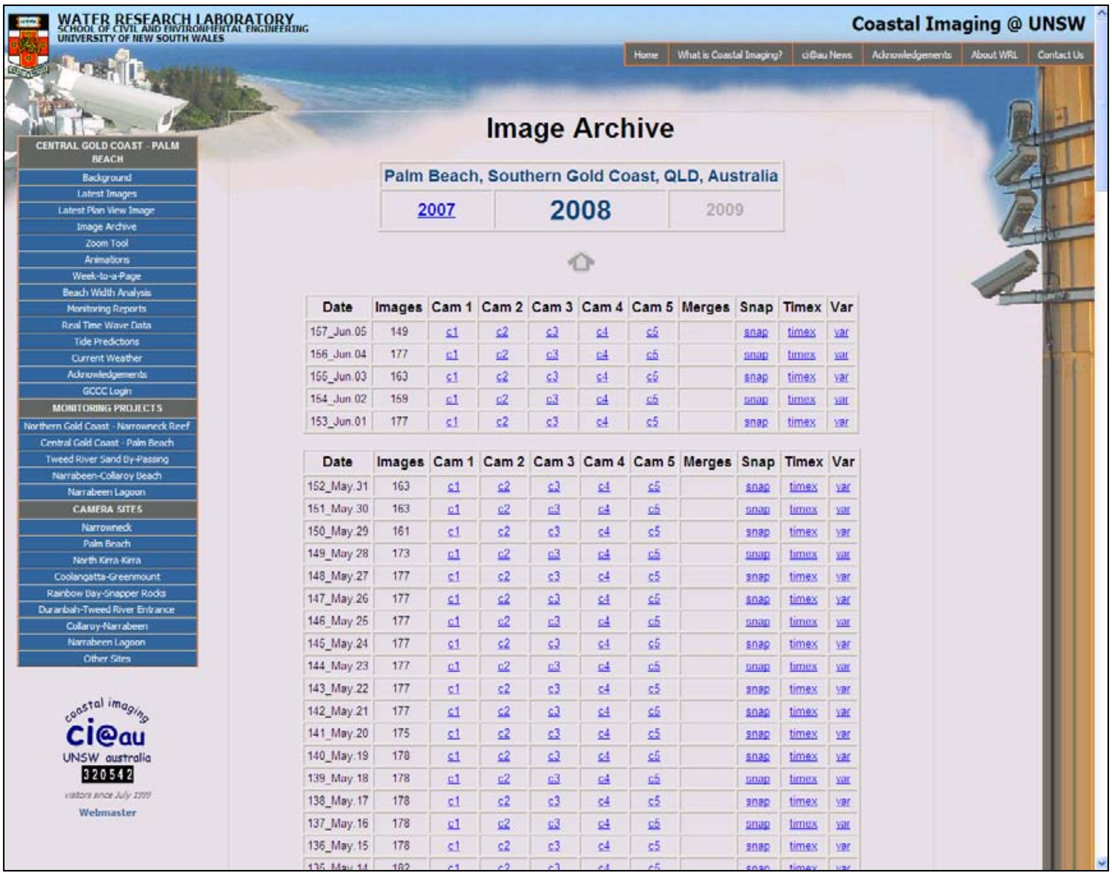
A description of the capabilities of this system was detailed in Anderson *et al.* (2003). To summarise, the features available at the project web site include the ability to view the latest mid-tide plan images; access to a zoom tool feature that enables zooming-in and panning through the current oblique and rectified images; full on-line access to all past and present monitoring reports; and two products specifically designed to assist both the qualitative and quantitative interpretation of images, shoreline data and the results of beach width analysis.

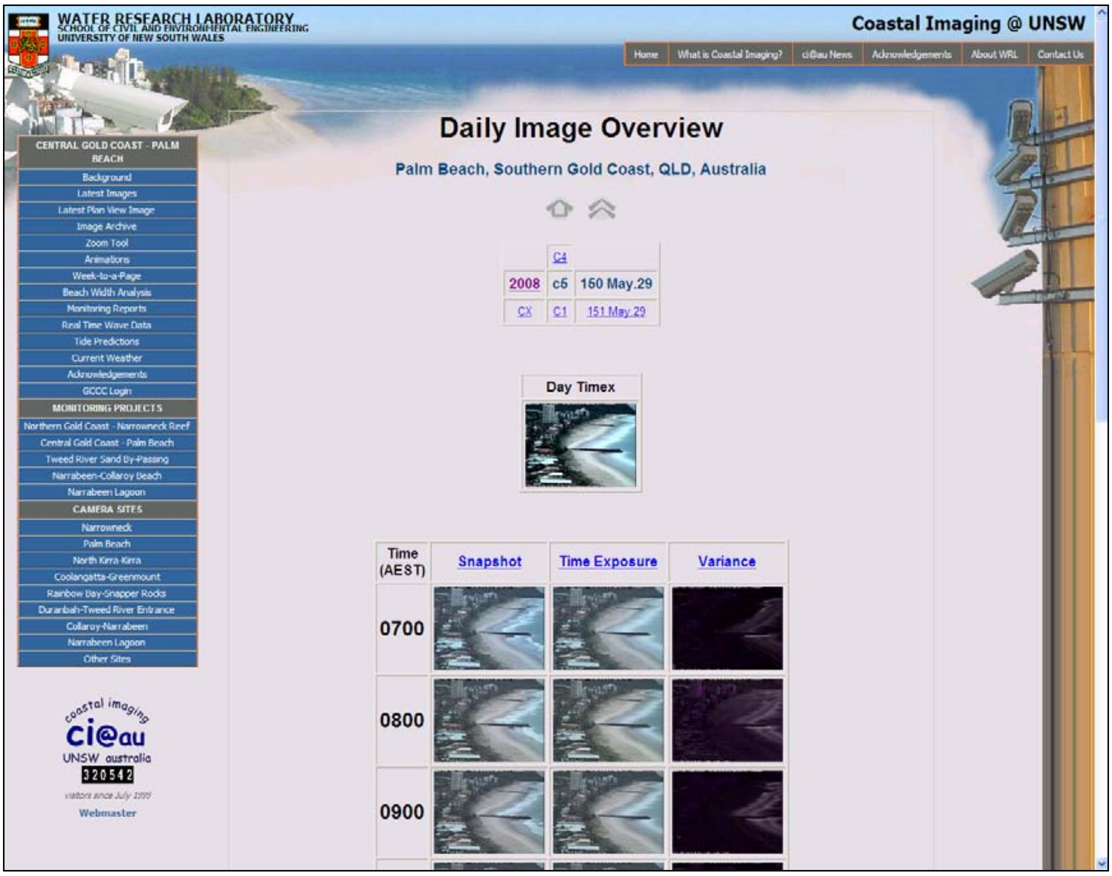
An example of the first of these products called 'week-to-a-page' is illustrated in Figure 4.3. Every Monday morning, this figure is generated and made available for viewing (and download, if required) via the project web site. The figure is pre-formatted to fit on a standard A4 page, to assist reporting. This figure compiles daily mean sea level plan view images of the entire Palm Beach study site for that week, into a compact one-page summary. A recent addition to the 'week-to-a-page' sheet is a plot showing wave and tide data for the week of interest. This product provides coastal managers a means of quickly and efficiently interpreting the daily changes in beach morphology and shoreline position, without continual recourse to the hourly images. An archive of these weekly figures is also maintained and available on-line.

The second product that is also updated each Monday morning and made available via the project web site is 'Beach-Width-Analysis' (Figure 4.4). This figure in graphical format summarises quantitative information of the mean shoreline position for that week; shoreline variability by comparing the current shoreline position with previous weeks and months; beach width along pre-defined monitoring transects; and beach width trends throughout the history of the monitoring project. A plot indicating the wave conditions during the week of interest has also now been added to this sheet, to increase the ease of data interpretation.

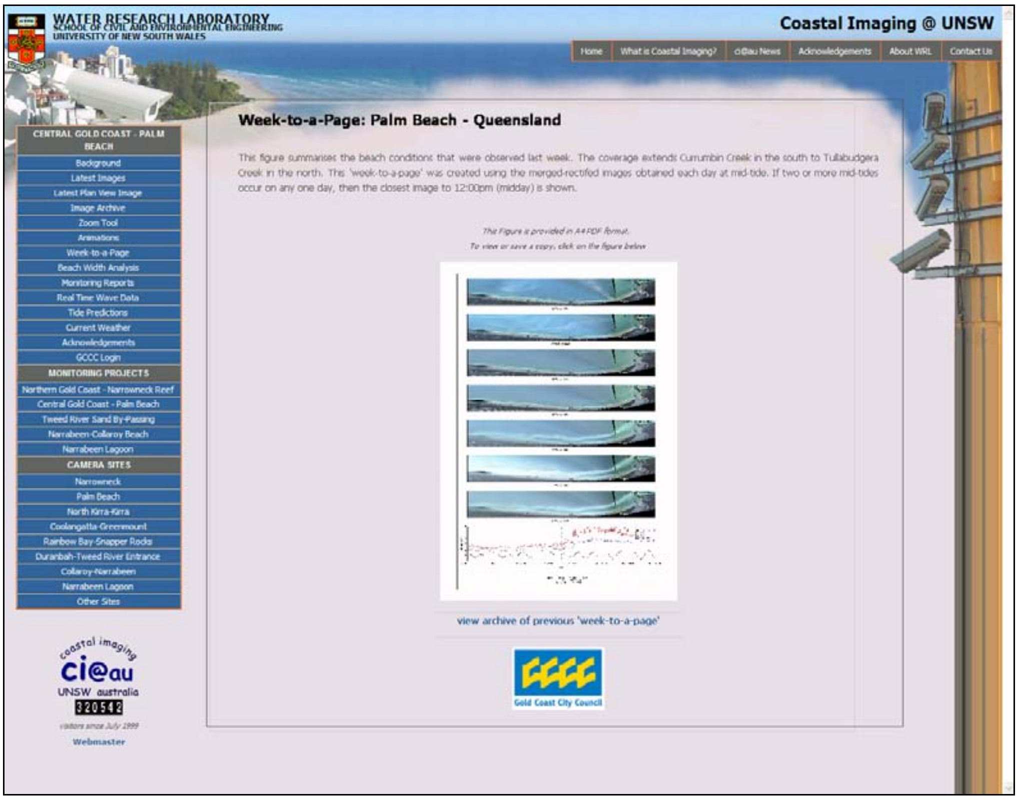


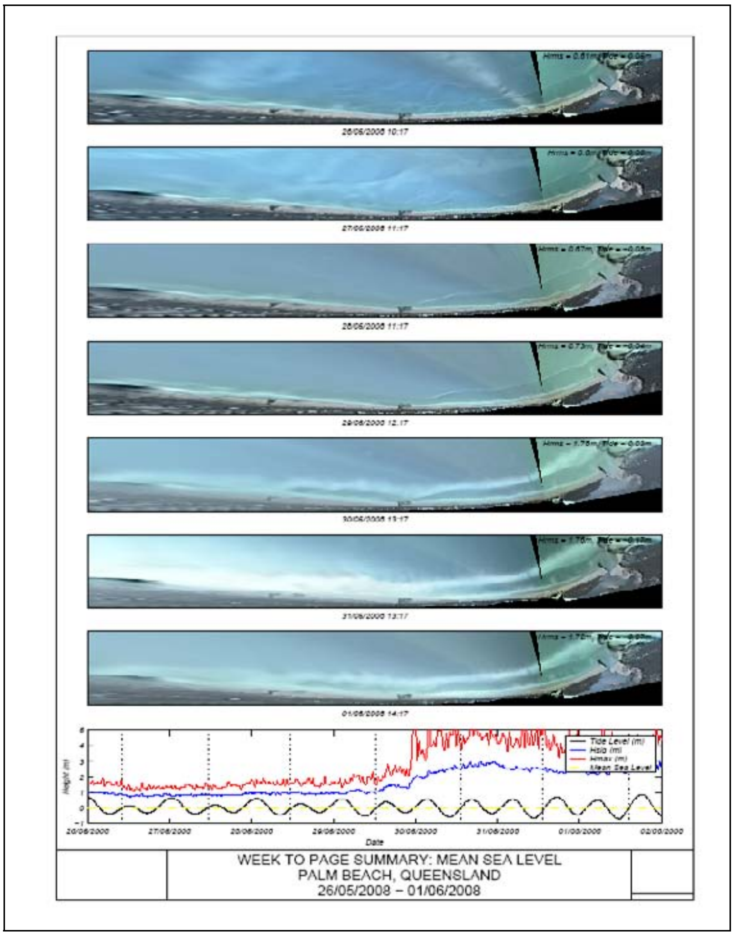
WRL Report No. 2008/18	COASTAL IMAGING WEB SITE - HOME PAGE	Figure 4.1



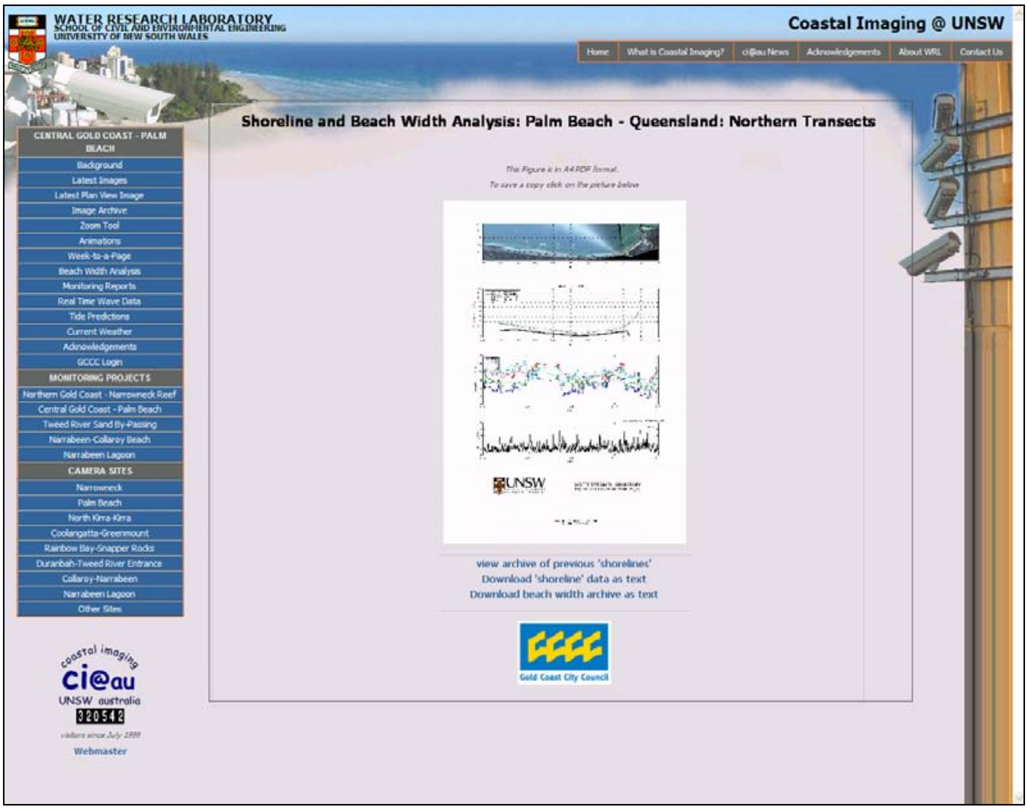


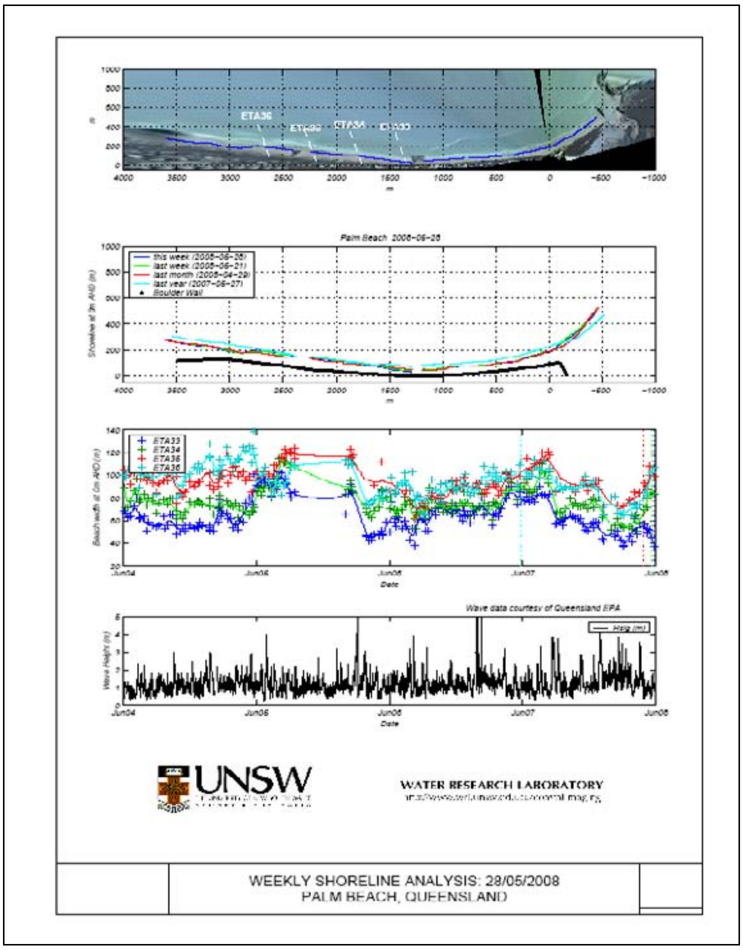
WRL Report No. 2008/18	COASTAL IMAGING SYSTEM WEB SITE – IMAGE ARCHIVE	Figure 4.2





WRL Report No. 2008/18	ON-LINE BEACH ANALYSIS SYSTEM 'WEEK-TO-A-PAGE'	Figure 4.3





WRL Report No. 2008/18	ON-LINE BEACH ANALYSIS SYSTEM 'BEACH WIDTH ANALYSIS'	Figure 4.4

5. MORPHODYNAMIC DESCRIPTION OF PALM BEACH: DECEMBER 2007 – MAY 2008

From the daily images obtained by the ARGUS coastal imaging station atop of the Royal Palm building, it is self-evident that Palm Beach is dynamic and continually changing. Bars move onshore and offshore and vary in shape from straight to crescentic, rips emerge and disappear, and the shoreline changes shape and translates landward and seaward in response to varying wave conditions. This section is included to provide a qualitative description of the observed beach changes during the present monitoring period December 2007 to May 2008. The 'week-to-a-page' summary figures that are updated every week and made publicly available for inspection and download via the project web site, are used in this section to illustrate the observed beach changes. The objective is not to describe every characteristic of Palm Beach during this period, but rather provide an overview of general trends and predominant features that were observed during this time.

To summarise beach changes in some structured manner, it is useful to first outline a systematic beach classification scheme with which to undertake this qualitative analysis. For consistency, this same classification scheme has been used in previous reports for both the Palm Beach and Northern Gold Coast (Surfers Paradise) sites.

5.1 A Morphodynamic Classification of Beaches

Despite the seemingly endless range of changes observed at any sandy coastline, in fact it has been shown that beaches tend to exhibit certain characteristics that vary in a systematic and predictable way. One such scheme for describing these changes is the 'Morphodynamic Beach State Model' first outlined by Wright and Short (1983). This beach classification scheme was developed in Australia, and is now the most widely-used descriptive beach model internationally. The term 'morphodynamics' derives from the combination of the words 'morphology' and 'hydrodynamics', emphasising the strong linkage between the shape of a beach and the associated wave and current conditions.

Beaches can be classified as being in one of six beach 'states' at any given point in time. The generalised cross-section and plan-form characteristics of these six beach states are summarised in Figure 5.1. A brief description of each of these states is provided below.

At one extreme is the *dissipative* beach state (Figure 5.1a), which is characterised by a very low profile slope and wide surfzone. Dissipative beaches are generally composed of fine sand and occur along coastlines exposed to high wave energy. Nearshore bathymetry is usually characterised by one or more straight and shore-parallel bars. The term 'dissipative' is used to describe beaches that exhibit these characteristics because wave energy is essentially dissipated by extensive wave breaking across the surf zone, before it can reach the shoreline.

At the other end of the beach state spectrum, *reflective* beaches (Figure 5.1f) are invariably steep, with no nearshore bars. Waves tend to break close to or right at the shoreline, and hence very little wave energy is dissipated; instead it is reflected by the beachface and propagates offshore. These beaches tend to be composed of coarse sediments and/or are generally located in protected or low wave energy coastal regions.

Between the dissipative and reflective extremes, four *intermediate* beach states can be identified. These incorporate elements of both the reflective and dissipative domains. The four intermediate beach types are referred to as *longshore bar-trough* LBT (Figure 5.1b), *rhythmic bar and beach* RBB (Figure 5.1c), *transverse bar and rip* TBR (Figure 5.1d) and *low tide terrace* LTT (Figure 5.1e). Together, these intermediate beach types form a sequence of characteristic beach states related to the movement of sand onshore (decreasing wave steepness) and offshore (increasing wave steepness). The onshore-offshore movement of sand is most easily recognised by the movement and changing shape of bars within the nearshore zone.

Following the characteristic offshore movement (*i.e.*, erosion) of sediment during a major storm, typical post-storm beach recovery includes the gradual onshore migration of nearshore bars and the development of weak and then stronger rips (LBT → RBB → TBR). If low wave conditions persist, bars ultimately disappear as the bar becomes welded to the beach to form a terrace (LTT). Beaches of the moderately high energy east Australian open coast are typically observed to transfer between these four intermediate morphodynamic beach states, in response to lower wave conditions interspersed by episodic storm events.

5.2 Morphodynamic Interpretation of Daily Images

All of the available week-to-a-page figures for the period December 2007 to May 2008 are presented in Appendix A. Each of these figures shows a week (seven days) of sequential mid-tide plan images, with the date of each indicated. All images are obtained at the same stage of the tide (mean sea level), to enable the direct comparison between different days and weeks. The region shown in these figures extends 5000 m alongshore, from the southern training wall at the Tallebudgera Creek entrance to the Currumbin Headland.

These images have been updated since previous reports, to now include tide and wave data plots recorded throughout each week.

To assist the interpretation of these images, Appendix B contains monthly summaries of wave height and period, obtained from the Gold Coast Waverider buoy and supplied to WRL by the Queensland Department of Environment. When data from the Gold Coast Waverider buoy has been unavailable, data from the Brisbane buoy has been substituted to fill the gap. The Gold Coast Waverider buoy is located at Latitude 27° 57.84' S Longitude 153° 26.55' E in a water depth of approximately 18 m, while the Brisbane Waverider buoy is located at Latitude 27° 29.75' S Longitude 153° 37.71' E in approximately 73 m water depth. Generally both buoys will measure similar wave conditions, however, the Gold Coast buoy measures wave heights after wave shoaling and refraction has occurred, as it is located in significantly shallower water.

5.2.1 December 2007

At the end of the previous monitoring period (June – November 2007), the Palm Beach embayment had an undulating detached offshore bar along the northern stretch, a series of complex transverse bars and rips in the mid section, before becoming two-dimensional and lower in energy at the southern end. Lower energy wave conditions continued throughout the first half of December 2007, before peaking to a significant wave height of 2.8 m on the 14th. Late in December a tropical low pressure system developed off the Queensland Whitsunday Coast. By the 2nd of January the low pressure system had intensified to a central pressure of 996 hPa and had migrated south, to be off the coast of Gladstone. The low pressure system was off the Sunshine Coast by the 4th of January, and continued to track south throughout the following days. The effect of the low pressure system was a rapid increase in wave height at the Gold Coast from the 28th to the 31st of December, with the significant wave height peaking at 5 m. The elevated wave heights continued in excess of 4 m before peaking again on the 4th of January at just over 5 m, then receding through until the 8th of January. The storm produced winds with gust speeds predicted to be 90 km/h as well as heavy rainfall.

The nearshore morphology of the beach changed very little throughout the first half of December, with relatively consistent lower energy wave conditions. With the peak in wave energy between the 12th and 17th, the beach responded accordingly, with the southern end of the beach having the most prominent morphological changes as sand was eroded from the beachface. Transverse bars and rips were evident throughout the surfzone for the ten days between the 17th and 27th, before the onset of the storm waves generated by the tropical low pressure system.

Leading up to the heavy storm conditions late in December, large tides impacted the Gold Coast beaches, resulting in minor scarping in localised areas. With the onset of the large storm waves on the 28th as a result of the developing low pressure system, the surfzone was seen to respond extremely rapidly with the formation of a wide detached offshore bar along the entire beach length.

5.2.2 January 2008

As discussed in Section 5.2.1, the deep tropical low pressure system which developed late in December and passed south down the coast during the first week of January produced large wave conditions with significant wave height ranging from 4 m to 5 m. These extreme wave heights dropped by the 8th of January, with the significant wave height fluctuating between 1 m and 2 m for the remainder of the month.

Throughout the first week of January the beach morphology remained very two-dimensional in a high energy state, with a detached offshore bar as well as a nearshore bar stretching the entire length of the beach. With ongoing moderate wave energy conditions (significant wave height ranging from 1.5 to 2.5 m) from the 7th of January until the end of the month, wave breaking across the detached offshore continued. The inner longshore bar migrated to an intermediate energy state, with closely spaced rips separating transverse bars along the southern half of the beach, becoming wider spaced further to the north. During this time sand was migrating from the outer detached bar back towards the inner surf zone, as the beach attempted to recover from the large storm event.

5.2.3 February 2008

Beach morphology was again dictated by a series of storm events during February 2008 with the significant wave height exceeding 2 m twice during the first half of the month, and reaching 4 m on the 20th. The wave conditions again lulled slightly during the remainder of the month. The ongoing higher wave energy throughout the first two thirds of the month saw the beach maintain a higher energy state, with two-dimensional morphology evident. A wide zone of wave breaking across an outer detached offshore bar as well as a narrower nearshore surfzone was evident most days. At the southern end of the embayment, a wider surfzone was evident, with both the outer and inner bars detached from the beach and separated by wide longshore troughs.

Throughout the last week of February the beach responded to a slight lull in wave energy, with no wave breaking evident over the outer detached bar, and only a very narrow nearshore surfzone present.

5.2.4 March 2008

Lower energy wave conditions occurred during the month of March, with the significant wave height varying around 1 m, peaking to over 2 m on occasions. The spectral peak wave period was also notably shorter during March than the previous months. The lower energy surfzone that was established late in February remained present during the first week of March, with wave breaking only apparent at the beachface.

A peak in wave energy during the middle of the month showed that the underlying two-dimensional morphology of the beach that developed from December to February was still present. The larger waves were observed to break initially over the outer detached bar, before passing through a narrow surfzone at the beachface. The detached offshore bar could be seen to increase in irregularity late in March during a period of lower wave energy, with rips and transverse bars present throughout the inner surfzone at the southern end of the beach. During the last three days of March, the surfzone of the beach was almost non-existent, as the lowest wave conditions in over three months (H_s of just over 0.5 m) were observed.

5.2.5 April 2008

The morphology of the beach continued in a low energy state during the first three days of April, with only a very narrow surfzone present at the immediate beachface. The slight increase in significant wave height to in excess of 2 m saw the surfzone again approach an intermediate state with a detached longshore bar intermittently present over the entire stretch of beach during the following fortnight.

From the 18th to the 21st of April the significant wave height was again observed to increase to approximately 3 m. During this time a clear detached offshore bar was present along the southern and northern sections of the beach, with this morphology typical of a LBT morphological state. The detached outer bar was less uniform along the mid section of the beach with undulations present, that were more typical of a RBB morphological state.

Lower energy wave conditions were experienced throughout the last week of April which resulted in little to no wave breaking over the outer bar and an increase in complexity of the nearshore surfzone. Transverse bars and rips could be seen to develop south of the 11th Street groyne, while further south the beach along the Currumbin Spit was more typical of a lower energy LTT state. North of the 11th Street groyne the beach showed very little morphological change.

5.2.6 May 2008

The first half of May 2008 saw ongoing low energy wave conditions, with the significant wave height typically less than 1 m. There was a slight increase in wave energy from the 19th to the 27th with the significant wave height reaching 2 m, and again at the end of the month when the significant wave height reached 3 m.

The ongoing low energy conditions throughout the first half of the month resulted in stable beach morphology. The low tide terrace on the Currumbin Spit was observed to increase in width, while further north the complex surfzone consisting of transverse bars and rips was maintained. The peak in wave energy during the last ten days of the month saw wave breaking across a detached longshore bar along the southern half of the beach, while north of the 11th Street groyne the outer surfzone was more irregular and again typical of a RBB morphological state.

5.3 Visual Assessment of Beach Width Changes (December 2007 – May 2008)

Beach and nearshore conditions during the first half of the current monitoring period December 2007 to February 2008 were dominated by the large storm waves at the end of December and start of January, as well as the storm event near the end of February. The later half of the monitoring period saw generally lower ongoing wave conditions, with sporadic short duration increases in wave height. The large tides and storm waves at the end of 2007 and start of 2008, resulted in significant erosion and scarping along most sections of the beach. Steady recovery of beach width was then experienced during the last half of the monitoring period. A qualitative visual assessment of the net trends in beach adjustment during this period can be seen by contrasting images of the beach obtained at the start and end of this six-month monitoring period.

Figure 5.2 shows the snap images obtained at mid-tide from Camera 2 (south) in December 2007 and May 2008 respectively. The corresponding snap images of the northern sections of beach obtained from Camera 5, are shown in Figure 5.3. Along the southern section of beach (Figure 5.2) in the region of the Currumbin Spit, the beach can be seen to be slightly narrower at the end of May 2008 compared to six months earlier. The effect of the higher energy waves experienced from December 2007 to February 2008 are still evident at the end of the current monitoring period, with the surfzone somewhat flatter and wider than six months previous.

Looking north along the Palm Beach embayment (Figure 5.3), from December 2007 to February 2008, it is apparent that the beach was eroded significantly in the vicinity of the 11^{th} Street groyne and also to the north of the 21^{st} Street groyne. The surfzone can also be seen to be wider and flatter across the northern section of the embayment, typical of a higher energy morphological state.

5.4 Visual Assessment of Total Beach Width Changes (June 2004 – May 2008)

The net beach changes to date since the commencement of monitoring at Palm Beach four years ago in early June 2004 are seen in Figures 5.4 and 5.5. In these figures, mid-tide timex images of the beach looking to the south and north along the Palm Beach embayment are shown at six-monthly intervals, for the entire monitoring period June 2004 – February 2008.

During the first six months June to November 2004, along the southern beach the surfeit of sand that was observed within the intertidal and nearshore zone in June, appeared to have moved onshore by November, resulting in modest beach widening and a general straightening of the beach alignment in this southern region. Towards the north, from June to November the southern end of this region appears to have generally widened. In contrast, towards the middle and northern end of the embayment, the shoreline appears much more irregular and scalloped, with a discernable trend of a generally narrower beach.

From December 2004 to May 2005 the southern beach receded again, and from visual assessment was clearly narrower than the initial beach conditions observed twelve months earlier in June 2004. In contrast, towards the north a general trend of beach widening was observed, with the beach reverting to a more uniform alignment than was observed to develop during the preceding six month period.

From June to December 2005 a general trend of beach widening was apparent at the far southern end of the Palm Beach embayment, while in the region in the immediate vicinity of the Royal Palm building little net change in beach width is discernable. The region immediately south of the 11^{th} Street groyne decreased in width, while the region between the 11^{th} and 21^{st} Street groynes increased in beach width. By December 2005 the southern beach was similar to the conditions that prevailed at the commencement of the monitoring program in June 2004, while along the central and northern regions of embayment the impacts of the nearshore nourishment campaign were clearly discernable, with the beach especially to the south and between the 11th and 21st Street groynes exhibiting a substantially wider beach and more uniform alignment alongshore.

During the period December 2005 to May 2006 a distinctive trend of beach narrowing was apparent at the far southern end of the Palm Beach embayment in the region of the Currumbin Spit. Immediately south of the 11th Street groyne the beach had increased in width, while the region between the 11th and 21st Street groynes and to the north exhibited a general trend of beach recession. The beach conditions that prevailed at the end of May 2006 along the southern Palm Beach embayment were similar to the eroded conditions observed 12 months earlier in May 2005. Along the northern beach the conditions in May 2006 were intermediate to the accreted beach that was observed in May 2005, and the eroded beach observed six months prior to that time in December 2004.

During the period between May and November 2006, a general trend of beach widening occurred across the far southern end of the Palm Beach embayment, while a more modest trend of increasing beach width was observed in the immediate vicinity of the Royal Palm building. Minor recession occurred across the region immediately south of the 11th Street groyne, while the region immediately to the north slightly widened. In the vicinity of the 21st Street groyne and further north along the Palm Beach embayment, little net change in the beach was observed.

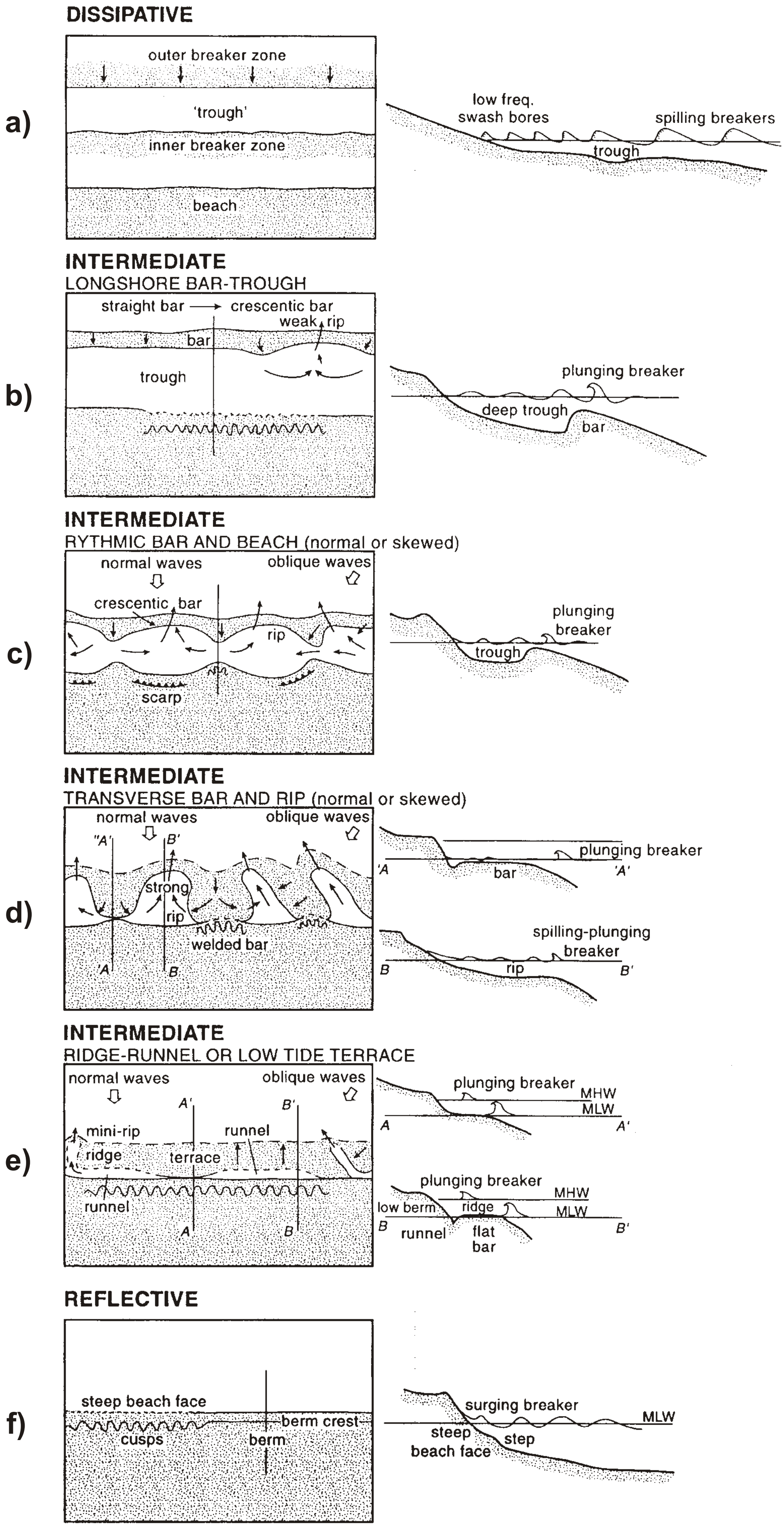
Between December 2006 and May 2007, notable beach recession occurred across the far southern end of the beach in the region of the Currumbin Spit, while minor narrowing of the beach in the immediate vicinity of the Royal Palm building was evident. Looking northward along the Palm Beach embayment, the beach generally widened, with significant accretion on the southern side of the 11th Street groyne, as well as in the vicinity of the 21st Street groyne and further to the north.

From June to November 2007, the southern section of beach in the region of the Currumbin Spit widened significantly, which was primarily the result of nourishment of this section of the beach during October and November. The effect of the nourishment on beach width decreased rapidly in a northward direction, with the beach actually decreasing in width in the vicinity of the Royal Palm building during the same period. Across the northern section of the Palm Beach embayment, the majority of the beach experienced a trend of erosion between June and November 2007, with the sections of beach adjacent the 11th Street groyne experiencing the most extensive narrowing, and erosion further north around the 21st Street groyne less pronounced.

During the current monitoring period between November 2007 and May 2008 the beach to the south of the Royal Palm building can be seen to have slightly narrowed. Further north, significant net erosion can be seen to have occurred in the vicinity of the 11th Street groyne and also to the north of the 21st Street groyne. The effect of the higher energy waves experienced from December 2007 to February 2008 are still evident at the end of the current monitoring period, with the surfzone somewhat flatter and wider than in November 2007.

From the images shown in Figures 5.4 and 5.5, a clear cyclic trend in beach erosion/accretion is evident. Generally at the start of winter (end of May), the section of beach extending south of the Royal Palm building along the Currumbin Spit is in an eroded state. Throughout the following winter and spring, this section of beach generally increases in width and is typically much wider at the end of November, with nourishment of dredge spoil from the Currumbin Creek entrance forming the major component of this process. The erosion/accretion cycle for the northern section of the embayment is typically the reverse of the southern section, with the beach typically appearing wider at the beginning of winter, and narrower at the beginning of summer. This trend was not evident during the current monitoring period, as the beach did not recover from the significant erosion which occurred in December 2007 and January 2008.

A more quantitative assessment of the response of Palm Beach for the period December 2007 to May 2008 is detailed in the following Section 6.



WRL Report No. 2008/18	MORPHODYNAMIC BEACH STATE MODEL (after WRIGHT and SHORT, 1983)	Figure 5.1 06037-5-1.cdr


ARGUS2.2-PAL snap palmqld Sat Dec 1 10:00:13 2007 AEST-10 F: 1196467213
C=2 S= 1 I= 0 O= 80


ARGUS2.2-PAL snap palmqld Sat May 31 14:00:13 2008 AEST-10 F: 1212206413
C=2 S= 1 I= 0 O= 80

WRL Report No. 2008/18	SNAP IMAGES FROM CAMERA 5 (NORTH): DECEMBER 2007 AND MAY 2008	Figure 5.3


June 2004


December 2004


May 2005


December 2005


May 2006


December 2006


May 2007


November 2007


May 2008

WRL Report No. 2008/18	SIX-MONTHLY BEACH CHANGES CAMERA 2 (SOUTH): JUNE 2004 – MAY 2008	Figure 5.4

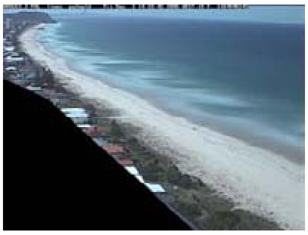
June 2004

December 2004

May 2005

December 2005

May 2006



December 2006

May 2007

November 2007

May 2008

6. QUANTITATIVE ANALYSIS OF SHORELINE CHANGES: DECEMBER 2007 – MAY 2008

The primary function of the coastal imaging system installed at Palm Beach is to quantify shoreline changes and beach variability along this partially engineered coastline, to document and better understand the behaviour of this coastal embayment. In addition, the impacts of past (and possible future) beach improvement works can be assessed. Quantitative analysis of shoreline position and beach width provide an objective measure to assess both beach amenity, and the extent of the storm buffer seawards of the existing boulder wall.

6.1 Weekly Shorelines

All available weekly shorelines for the period 01/12/07 to 31/05/08 are shown in Figure 6.1 (for shoreline mapping method and procedure refer Section 3.7). For reference, these measured shorelines are overlaid on to a representative merged/rectified timex image (image date: 31st May 2008). The image represents a 5000 m length of the Palm Beach embayment, extending from the southern training wall at Tallebudgera Creek in the north, to Currumbin Headland in the south. The ARGUS station is located at coordinate [0,0], just north of the sand spit that separates the lower Currumbin Estuary from the oceanfront. For reference, the alignment of the back-beach boulder wall (used to calculate beach width) is also indicated (landward red line).

To see more clearly the range of shoreline positions mapped during this six month period, Figure 6.2 shows a plot of the position of the weekly shorelines relative to the boulder wall alignment. The distance of these shorelines from the wall alignment is plotted in the upper panel, and for convenience the alongshore position in this figure is relative to the location of the ARGUS station (0 m). In the lower panel of this figure the same mid-tide timex image used in the previous figure is shown for reference.

During the monitoring period 01/12/07 – 31/05/08, it can be seen from Figure 6.2 that the beach along the Palm Beach oceanfront varied in width from a minimum of approximately 40 m (relative to the alignment of the back-beach boulder wall) adjacent to the 11th Street groyne, to around 180 m at the extreme northern end of the embayment adjacent to Tallebudgera Creek. The envelope of beach width changes along the entire embayment was in the range of 20 - 50 m during this period.

At the southern end of the boulder wall, adjacent to Currumbin Creek, the reference boulder wall alignment dips landward. In previous monitoring reports, the beach width along the Currumbin Spit has been shown to increase rapidly to the south along the spit, as a result of the width being documented relative to the end of the boulder wall. To allow for easier interpretation of the beach width further south than the boulder wall along Currumbin Spit, the reference line has been updated as an arbitrary line joining the end of the boulder wall with a fixed point on the southern training wall of the Currumbin creek. While this does result in a non-uniformity in plotted beach width relative to the boulder wall (Figure 6.2 top image), the data can now be interpreted more easily.

6.2 Shoreline Variability – Mean, Maximum, Minimum, Standard Deviation

The alongshore variability of the measured shoreline positions during the monitoring period 01/12/07 – 31/05/08 is further quantified in Figure 6.3. The upper panel of this figure shows a plot of the mean, maximum and minimum shoreline position at 5 m increments alongshore. For reference, in the lower panel the mean shoreline position during this period is overlaid on to a merged/rectified timex image of the northern Gold Coast (image date: 31st May, 2008).

Referring to Figure 6.3, the median beach width at mid-tide (relative to the alignment of the back-beach boulder wall) was of the order of 40 – 80 m along much of the Palm Beach embayment. With the alignment of the boulder wall changing orientation and dipping landward at the southern sand spit, the measured beach width is observed to increase accordingly, reaching 125 m in front of the site of the cameras (i.e., distance = 0 m alongshore in Figure 6.3).

The analysis of maximum and minimum beach width (upper panel, Figure 6.3) reveals a relatively uniform trend along the section of beach north of the 11th Street groyne, with the beach width varying by of the order of 10 m less and 20 m more than the mean shoreline position. The variation in beach width along the southern half of the embayment was typically less, with the beach width varying by ±10 - 15 m from the mean shoreline position.

The middle panel of Figure 6.3 shows the standard deviation (s.d.) of weekly shorelines from the mean shoreline position during the same period 01/12/07 - 31/05/08. Relatively uniform standard deviation of weekly shorelines of the order of 5 to10 m was experienced across the greater part of the embayment, which is indicative of a relatively stable beach throughout the present 6-month monitoring period. Over the southern sand spit, and along the far northern stretches of the beach, a higher standard deviation in beach width of 15 to 20 m was experienced.

6.3 Time-Series of Beach Widths at Transects ETA29 - ETA36

The variations in shoreline position measured at Gold Coast City Council's ETA transects 29 - 36 for the monitoring period December 2007 to May 2008 are shown in Figures 6.4 and 6.5. Figure 6.4 plots the weekly shoreline position at the southern transects ETA29 - ETA 32, and Figure 6.5 plots the weekly shoreline position at the more northern transects ETA33 - ETA36. The alongshore position of each of these beach transects is shown in the accompanying merged/rectified image (image date: 31/05/2008).

6.3.1 Southern Transects (ETA29 – ETA32)

At the southern-most transect ETA29 located across the southern Sand Spit, the beach was seen to erode at the end of December 2007 and throughout January 2008 due to the large storms experienced during these months. Almost 40 m in beach width was lost during these months at transect ETA29. Beach width was relatively stable from February to March 2008, and then increased significantly throughout the last half of April and into May 2008. At the completion of the current six month monitoring period, the beach had recovered to be similar in width to that observed some six months earlier.

The transects north of the Royal Palm building (ETA30, ETA31, and ETA32) all showed similar behaviour in terms of beach width throughout the current monitoring period. At these sections, the beach was observed to erode during the storm events of December 2007 and January 2008, before recovering slightly during February and March. During April and May 2008 the beach width remained consistent for the three transects between the Royal Palm building and the 11th Street groyne, ETA30, ETA31, and ETA32.

6.3.2 Central and Northern Transects (ETA33 – ETA36)

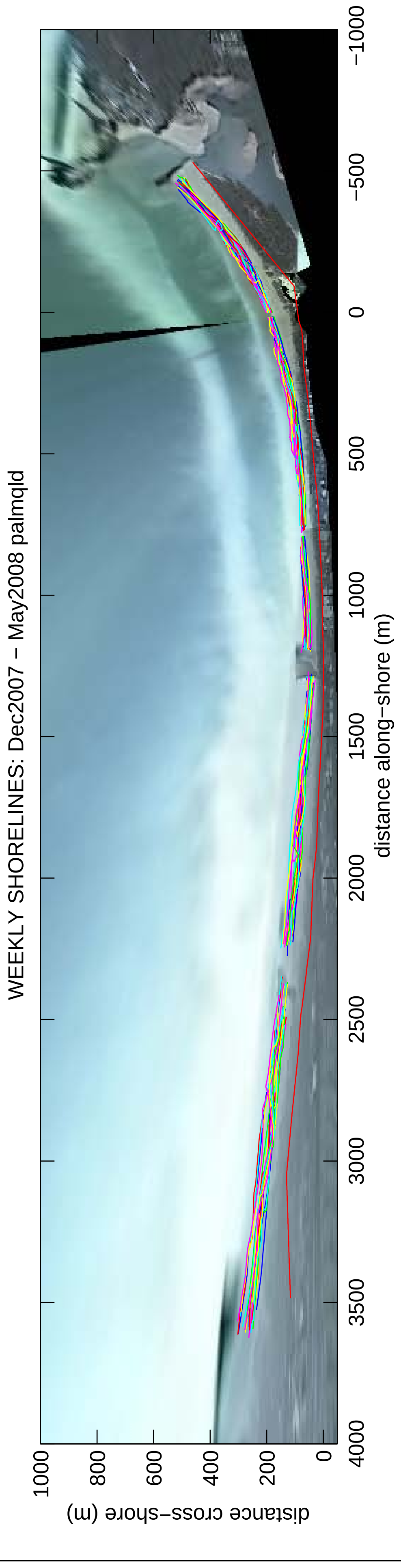
The weekly analysis of shoreline position at the central and northern transects ETA33 to ETA36 are shown in Figure 6.5. The beach width at these transects behaved similar to the transects immediately to the south, experiencing loss of beach widths during December 2007 and January 2008 as a result of several large storms. During these months, approximately 20 m in beach width was eroded. This was followed by steady beach width throughout February and March and then recovery of beach width during April and May. At the completion of the current monitoring period at the end of May 2008, beach widths across the northern half of the Palm Beach embayment were typically similar to those observed six months earlier.

6.4 Weekly Shorelines (December 2007 – May 2008) Relative to Mean Shoreline Position of Previous Monitoring Period (June - November 2007)

To summarise, Figure 6.6 presents the analysis of all available weekly beach widths for the period December 2007 to May 2008, relative to the mean shoreline alignment calculated for the prior six month period June to November 2007. In the upper panel the deviation of weekly shorelines from this prior mean shoreline alignment is plotted. In the lower panel this mean shoreline position for the previous monitoring period June to November 2007 is shown, along with the mean shoreline calculated for the present monitoring period.

This analysis shows that, relative to the mean shoreline position for the preceding six month period, the beach was generally narrower during the current monitoring period. North of the Royal Palm building, beach widths during the current monitoring period varied from typically 10 to 30 m narrower than the mean shoreline position from the previous monitoring period. The exception to the narrower beach widths was the section of beach south of the Royal Palm building along the Currumbin Spit, where beach widths were significantly greater during the current monitoring period. Along this section of the beach, beach widths ranged from being similar to 40 m wider than the mean beach width for the previous monitoring period. This is partially due to the eroded state of this section of beach during the previous monitoring period between June and November 2007, as well as accretion across this section of the beach during the later months of the current monitoring period.

It is important to point out that the shorelines shown in the bottom panel of Figure 6.6 are the mean shorelines for the current and previous monitoring periods, and as such, they do not show the full extent of the shoreline evolution throughout the monitoring period. Instead these shorelines represent the net trend of beach evolution, spanning multiple erosive/accretionary cycles, with short term (weekly – monthly) fluctuations not shown.



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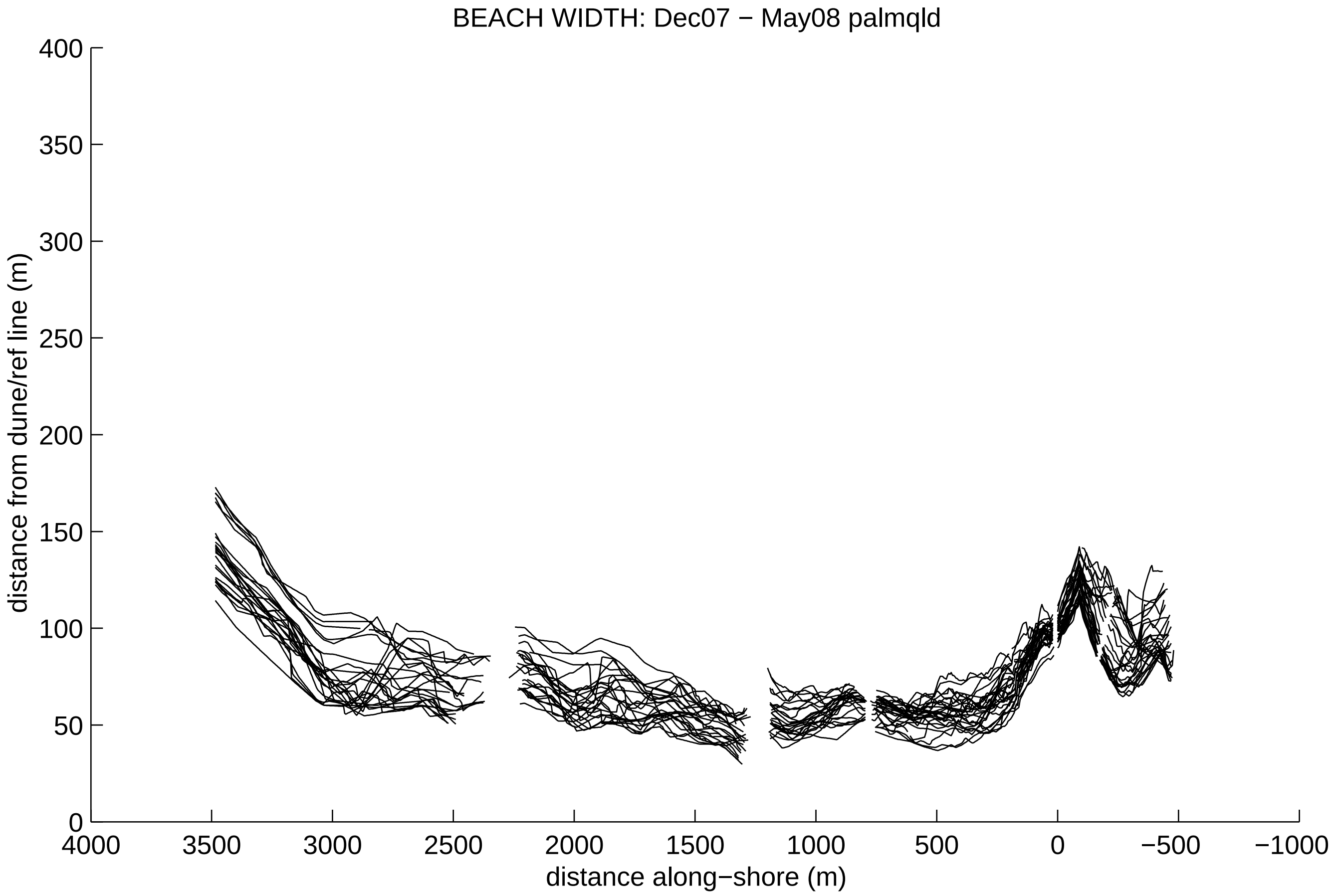
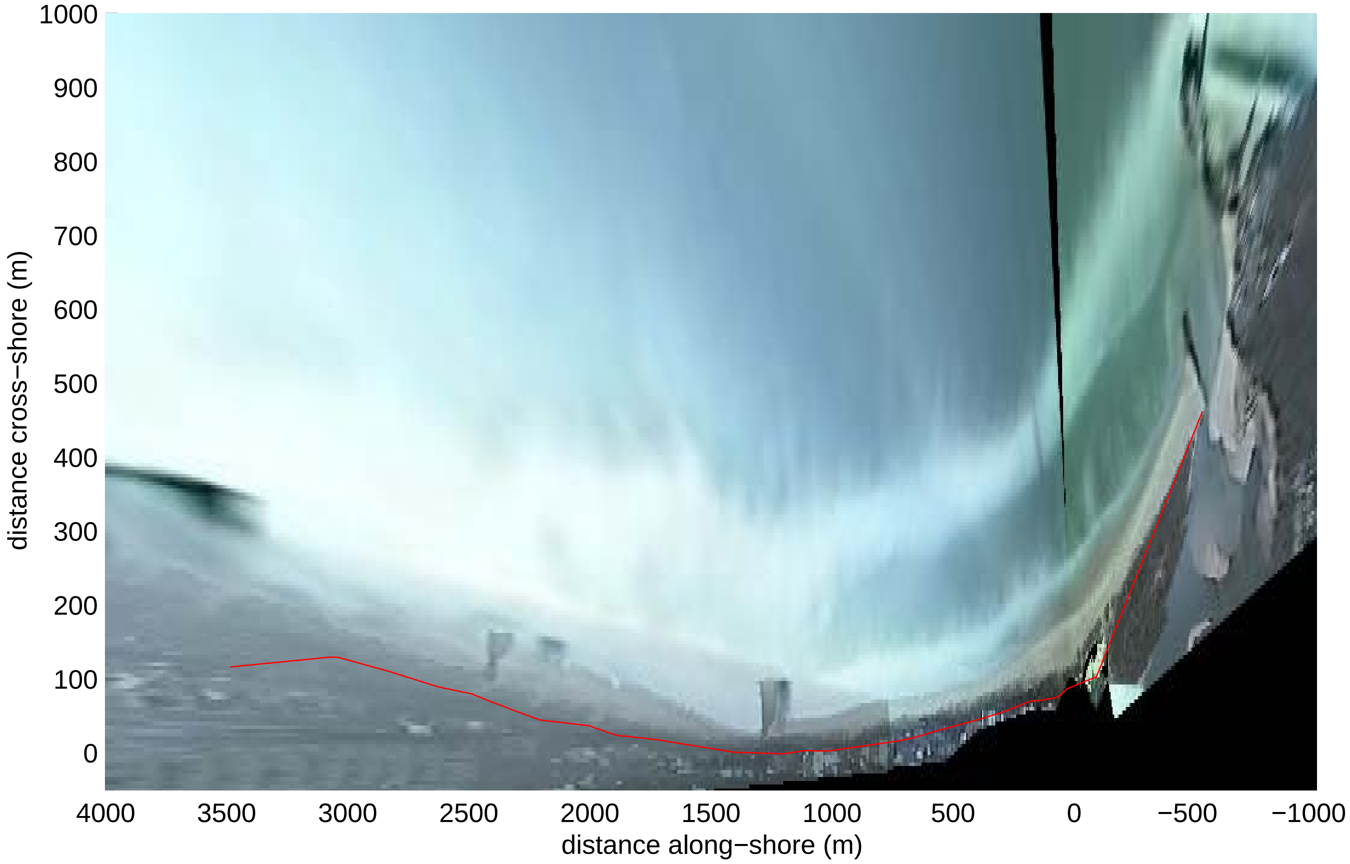
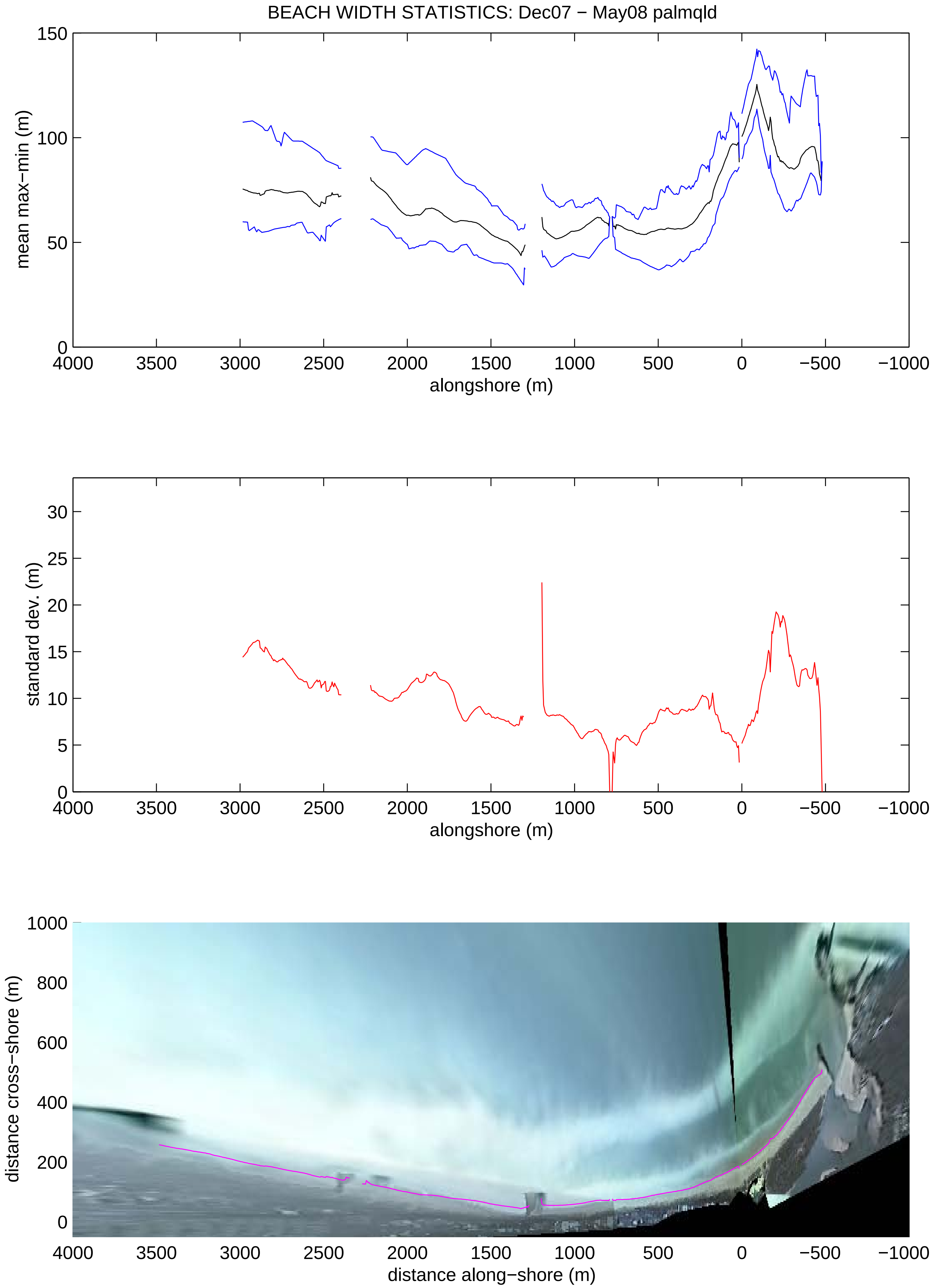
WEEKLY SHORELINES:
DECEMBER 2007 − MAY 2008

Figure 6.1

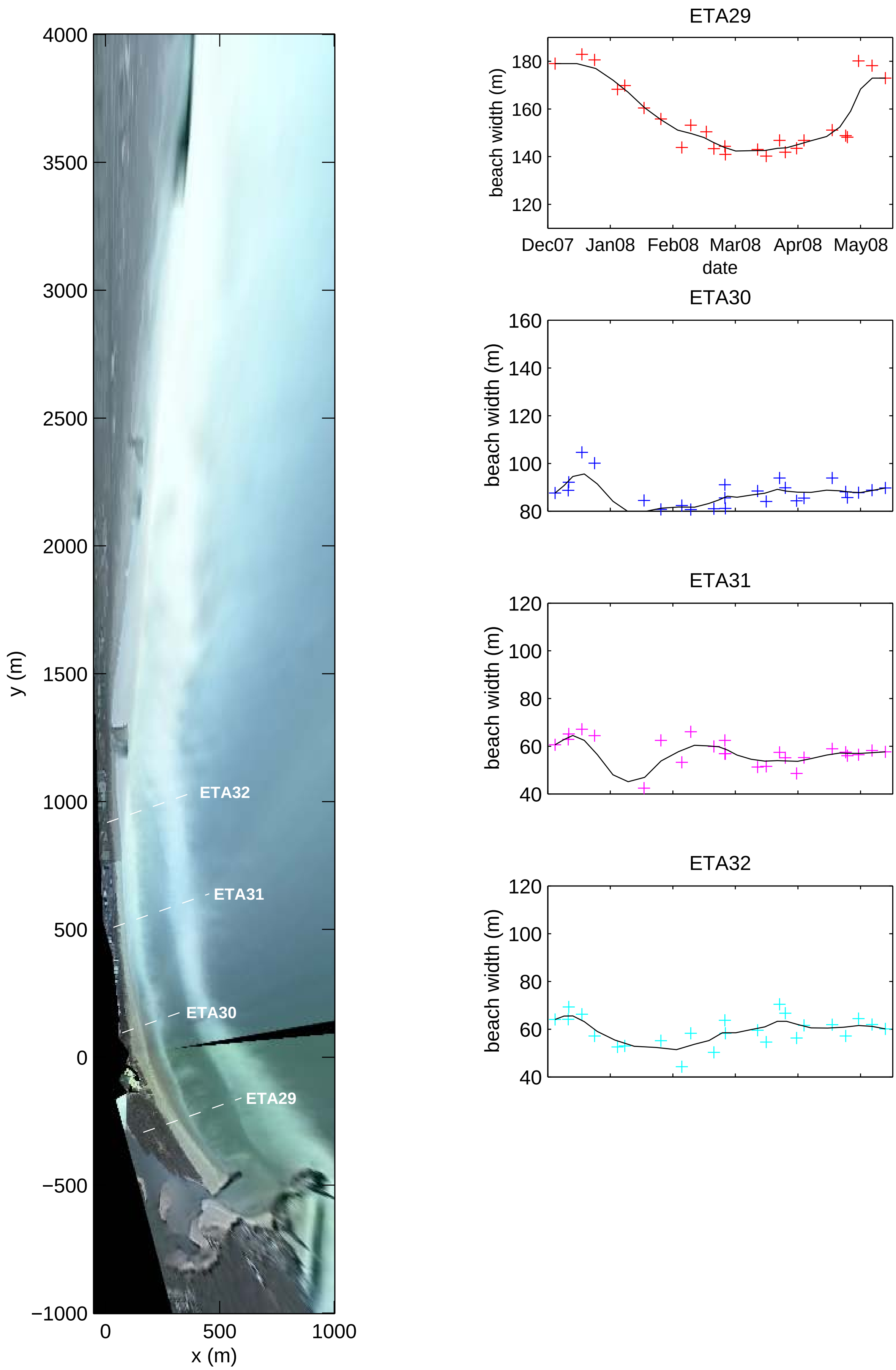




WRL Report No.2008/18	WEEKLY BEACH WIDTH: DECEMBER 2007 − MAY 2008	Figure 6.2



WRL Report No.2008/18	STATISTICAL SUMMARY OF BEACH WIDTH CHANGES: DECEMBER 2007 − MAY 2008	Figure 6.3



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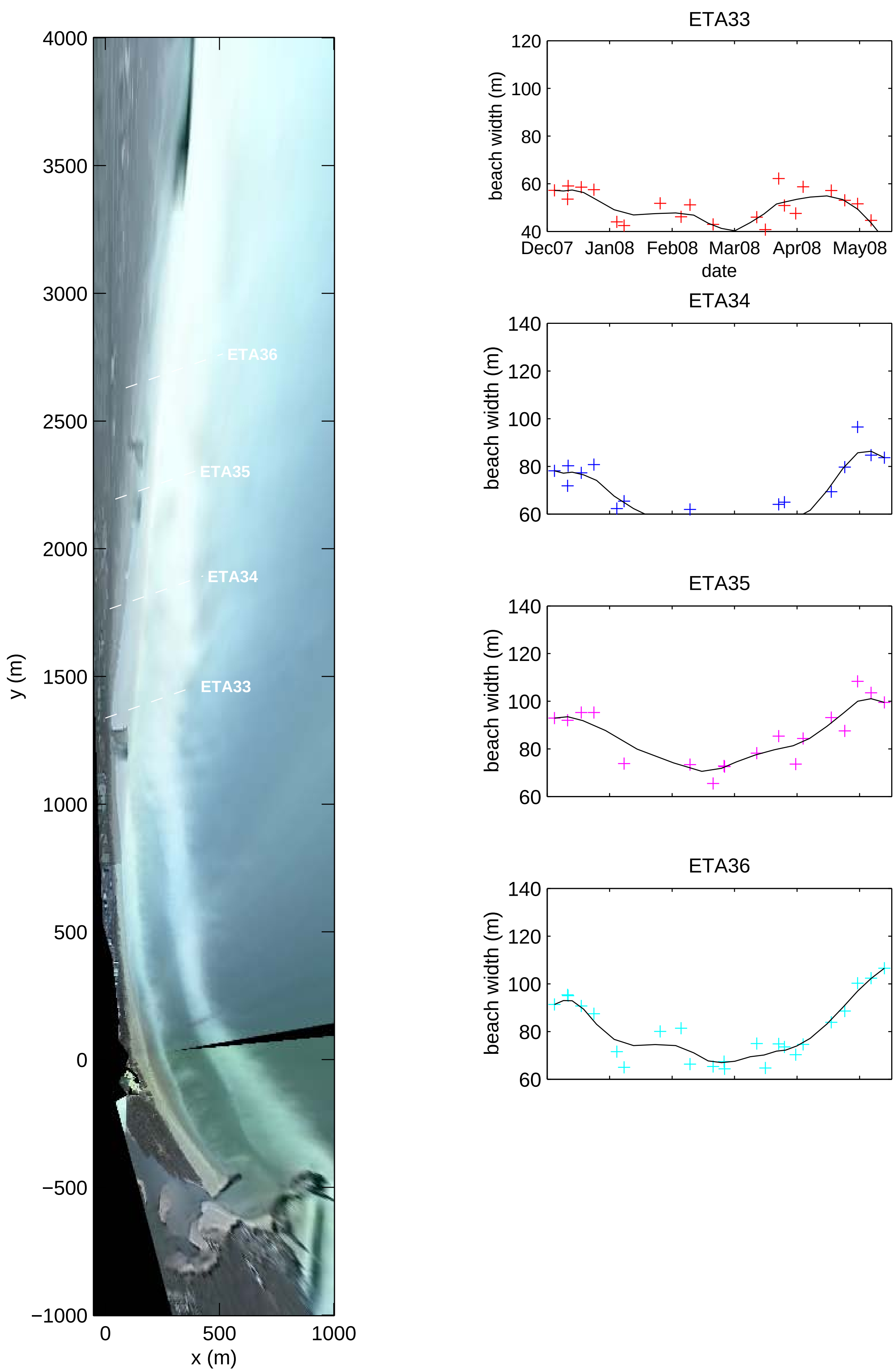
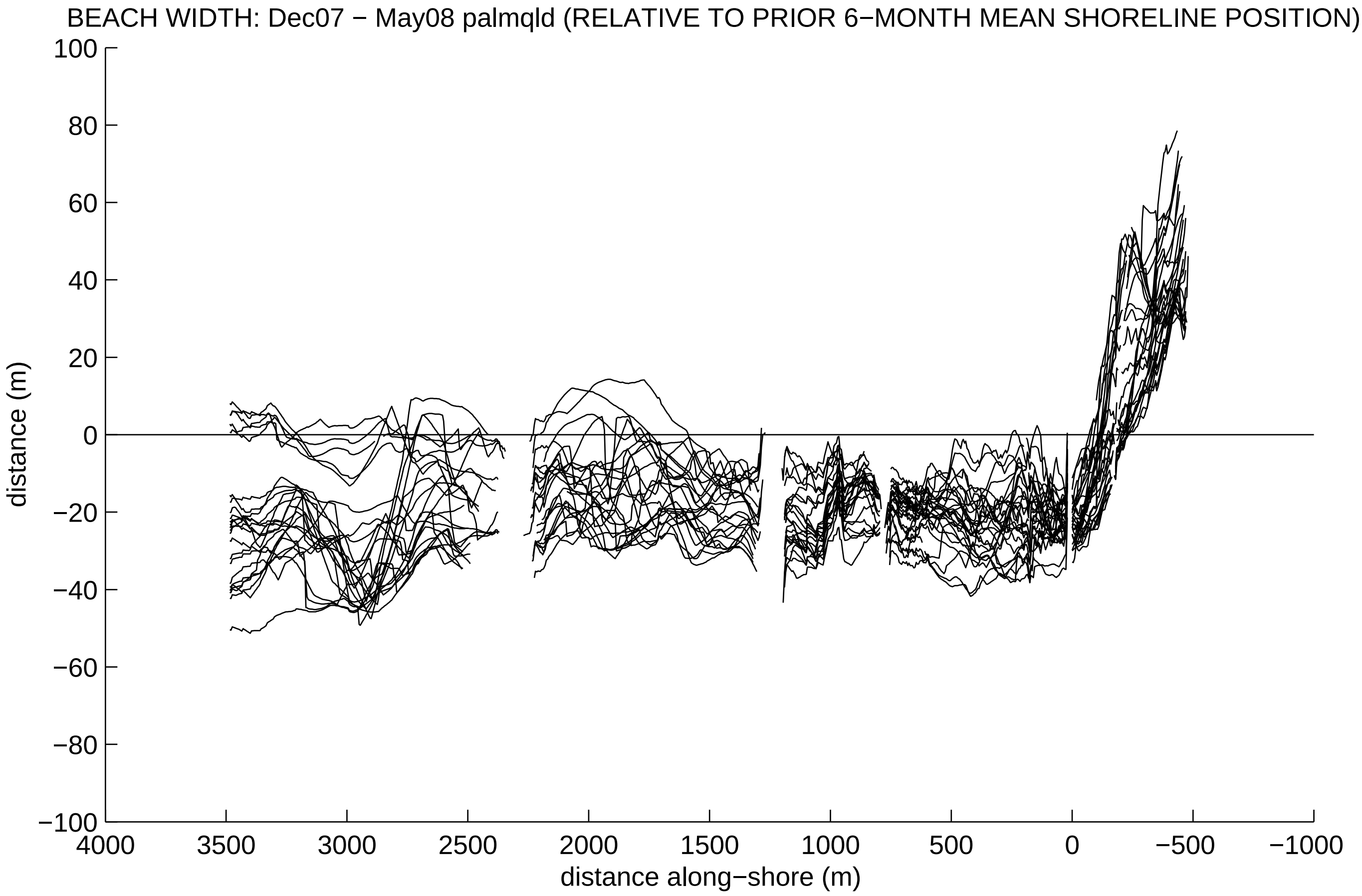
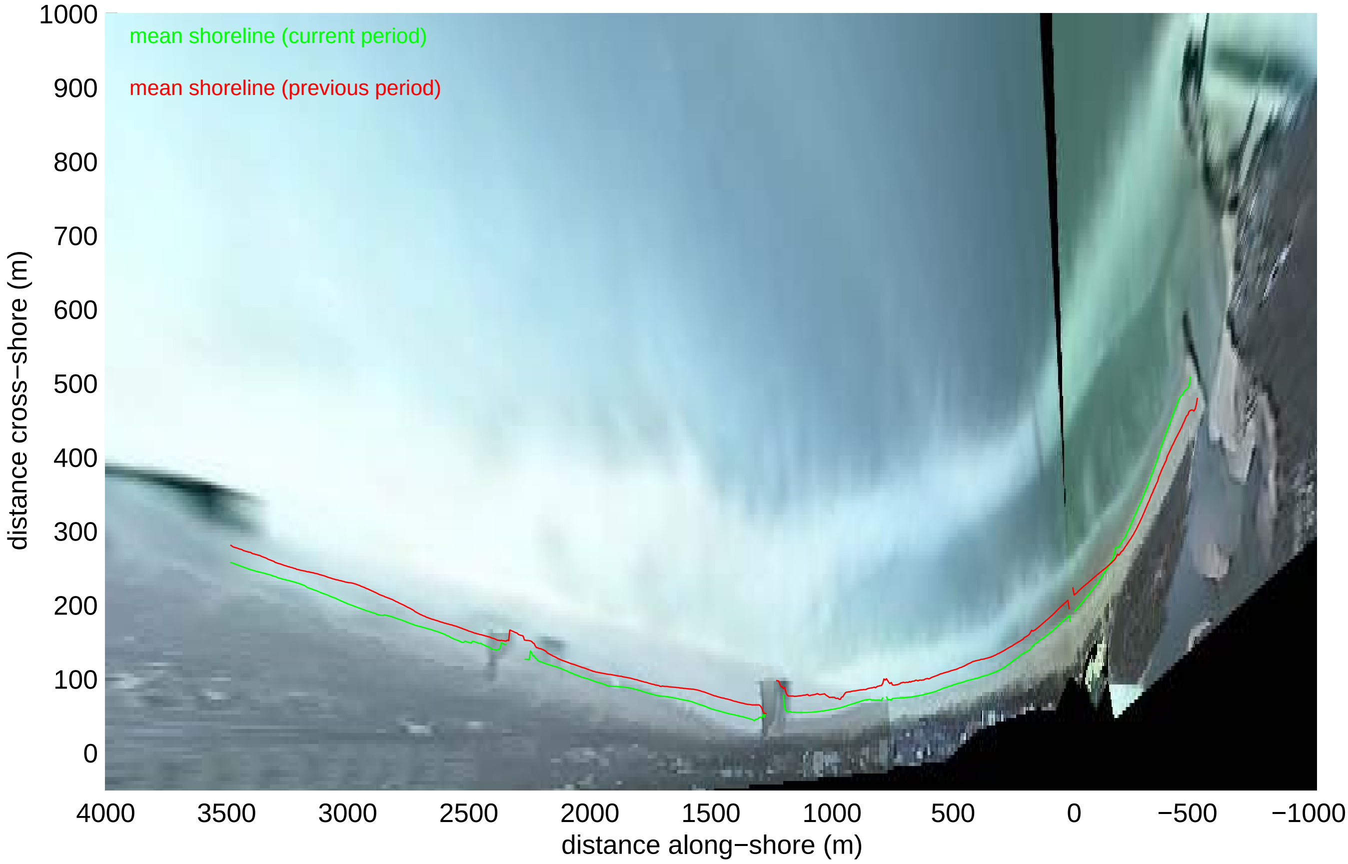
TIME−SERIES OF BEACH WIDTH (SOUTH):
DECEMBER 2007−MAY 2008

Figure 6.4



WRL Report No.2008/18	TIME−SERIES OF BEACH WIDTH (NORTH): DECEMBER 2007 − MAY 2008	Figure 6.5





WRL Report No.2008/18	WEEKLY BEACH WIDTH DECEMBER 2007 − MAY 2008 RELATIVE TO PRIOR SIX−MONTH MEAN SHORELINE POSITION	Figure 6.6

7. QUANTITATIVE ANALYSIS OF TOTAL SHORELINE CHANGES: JUNE 2004 – MAY 2008

The completion of a total of 4 years (48 months) of monitoring at Palm Beach provides the opportunity to summarise and analyse longer-term shoreline changes observed to date.

7.1 Weekly Shorelines and Shoreline Variability: June 2004 – May 2008

All weekly beach widths (relative to the alignment of the back-beach boulder wall) for the 182 week period June 2004 to May 2008 are shown in Figure 7.1. As per previous figures, a merged/rectified image is shown in the lower panel for reference (image date: 31st May 2008). Since June 2004 the mid-tide beach width along the entire Palm Beach embayment generally varied in the order of 50 - 60 m, with up to 80 m beach change recorded in the vicinity of the nearshore nourishment works (refer Section 2.2) located to the south of the 11th Street groyne and in the area of dredge spoil nourishment along the Currumbin Spit.

The variations in shoreline position measured at the eight ETA survey transects for the entire period June 2004 to May 2008 are shown in Figures 7.2 and 7.3. Figure 7.2 plots the weekly shoreline position for the southern transects ETA29 to ETA32, and Figure 7.3 shows the same for the central and northern transects ETA33 to ETA36. The alongshore position of each of these representative transects is shown in the accompanying merged/rectified image (image date: 31st May 2008).

7.1.1 Southern Sand Spit

At transect ETA29 (Figure 7.2) the beach changes during the initial 12 month period June 2004 to May 2005 were dominated by an initial accretionary response to the beachfront placement of sand, then subsequent readjustment as this sand redistributed alongshore and cross-shore. From mid July 2004 to early September 2004 the beach width grew rapidly from around 160 m to 190 m in width, then from September 2004 through to the end of the May 2005 a steady decline in beach was observed, with the final width of the beach in this region at that time around 130 m. From June to November 2005 the erosion trend reversed in response to the placement at the beachface of additional sand from Currumbin Creek, with the beach width regaining around 30 m to 160 m in December. This beach width was maintained through to the end of February 2006, at which time beach erosion by some 20 m was recorded, following the onset of the major storm in early March. Beach widths increased in the period from June to November 2006 due to beachface placement of sand, so that by the end of November 2006 the beach in this region had returned to similar conditions that prevailed 2.5 years earlier in June 2004. Throughout the period from December 2006 to May 2007, the beach width at the southern sand spit steadily decreased, with a net change in width during this period of approximately 20 m. It is interesting to note that although no significant storms occurred in the first half of 2007, the extent of erosion at transect ETA29 was similar in magnitude to that which occurred during the first half of 2006, when a significant storm event occurred. During the period June to November 2007, there was a significant 35 m increase in beach width at the southern most transect (ETA29) corresponding to sand being dredged from the Currumbin Creek entrance and placed on the beach at this location. It can be observed from the beach width plot for transect ETA29, that similar increases in beach width have been observed between June and November every year since the Palm Beach monitoring program began in June 2004.

Beach widths along the southern sand spit during the current monitoring period December 2007 to May 2008 were dominated by the large storm events which occurred in December and January. During these months, some 30 to 40 m of beach width was lost along the Currumbin spit. This was followed by the relatively rapid recovery of the beach in this area. At the end of the current monitoring period, the beach along the southern sand spit had recovered almost completely, to be similar in width to what it was at the start of the current monitoring period.

7.1.2 Central – Southern Embayment

Fluctuations of the beach width at ETA30 (Figure 7.2) were dominated by the beachface sand placement in 2004 and a second phase in April-May 2005. From June 2004 to September 2004 the beach width in this region increased by around 40 m to be 110 m - 150 m in response to the direct placement of sand in this area. A second increase then decline in beach width occurred during December 2004 to April 2005, as the ‘slug’ of sand placed in previous months along the central sand spit area moved northward through this region. In April – May 2005 the beach width again increased to 130 m, in response to the second phase of beachface placement, coinciding with the location of this transect.

From June to August 2005 the beach width then declined again by around 20 m, but in September accretion by approximately 10 m was observed. At this time the beach width had returned to within 5 – 10 m of the conditions that prevailed at the commencement of monitoring in June 2004. Similar conditions were observed in February 2006, with minor recovery commencing in June, erosion again in July - August, then the commencement of a more rapid recovery phase in October – November 2006. The beach continued to widen up until the end of 2006, and maintained a relatively constant beach width of just over 120 m from January – May 2007, with only minor fluctuations in beach width of the order of 5 - 10 m occurring.

During the current monitoring period June to November 2007, the beach at transect ETA 30 was observed to undergo minor fluctuations in width throughout June and July, before decreasing rapidly in width in response to the storms experienced during August and September. During this period, of the order of 35 m in width was lost from the beach. Throughout the last half of September, October, and November, beach width was again relatively stable, but in a more eroded state than six months earlier.

During the 12 month period June 2004 to May 2005 beach width changes at transects ETA31 and ETA32 (Figure 7.2) were dominated by the nearshore nourishment campaign completed in December 2004. Commencing November – December 2004 the beach at ETA31 and ETA32 began to increase in width, and by May 2005 this region of the Palm Beach beachfront increased in width by the order of 40 - 50 m. Commencing June 2005 and continuing through to mid September 2005, the beach at both ETA31 and ETA32 decreased by 20 – 30 m as a portion of the nourishment volume moved northward and the beach in this vicinity of the embayment adjusted towards a new equilibrium alignment.

By December 2005 the beach had recovered again, and at both ETA31 and ETA 32 was of the order of 40 m wider than at the commencement of monitoring in June 2004. Storm erosion in early March 2006 resulted in the temporary loss of this additional beach width, but by the end of May 2006 recovery in the range of 20 – 40 m was observed. From June to November 2006 the beach width oscillated by 20 m, with little net change in width occurring. From December 2006 to May 2007 the beach width continued to fluctuate throughout periods of two to four weeks, with an overall net increase in beach width of the order of 20 m observable.

During the period June to November 2007, the beach width at transects ETA31 and ETA32 experienced the most rapid period of erosion since the monitoring program began in June 2004. The erosion of the beach was the result of a series of four high energy storms in a period of three months, with the beach decreasing in width by approximately 35 m during this period. The transects north of the Royal Palm building (ETA30, ETA31, and ETA32) all showed further beach erosion during the present monitoring period December 2007 to May 2008, as a result of the large storm events experienced during December and January. Following these storms, this section of the beach was the narrowest it has been observed during the four year monitoring period, with beach widths of only 40 m to 80 m seaward of the boulder wall. The beach recovered slightly during February and March 2008, and then remained relatively stable throughout April and May 2008, with beach widths at the end of the current monitoring period similar to those observed four years earlier in June 2004 when monitoring began.

7.1.3 Central – Northern Embayment

From June 2004 to March 2005 the more northern transects ETA33, ETA34, ETA35 and ETA36 (Figure 7.3) located between and to the immediate north of the 11th and 21st Street groynes all exhibited fluctuations in beach width in response to the varying wave energy during this time, with no clearly identifiable trends emerging. At ETA33 and ETA34, located between the 11th and 21st Street groynes, a marginal trend of decreasing beach width was recorded, with the beach width decreasing to around 50 – 60 m. Commencing in March at the more southern ETA33 and ETA34 transects and a month later at the more northern ETA35, a distinct trend of beach widening was observed, with the beach width by mid September 2005 increased by 30 – 40 m. This widening was attributed to the continued northward movement of sand placed within the nearshore zone of more southern transects some six months previously. At the most northern transect ETA36 located to the north of the 21st street groyne, the beach width through the period June 2004 to September 2005 continued to respond to the varying incident wave energy, but with no net accretion or erosion trend in evidence.

A general trend of net erosion was observed from September 2005 to February 2006 at the more southern transects ETA33 and ETA34, and then distinctive and rapid storm erosion in early March 2006. Varying degrees of beach recovery were monitored through to the end of November 2006. At the more northern ETA36 and ETA35 transects, the beach was around 10 m narrower than the conditions that prevailed 2.5 years earlier in June 2004. At ETA34 located midway between the two groyne structures and ETA33 located immediately north of the 11th Street groyne, by the end of November 2006 the beach width conditions had returned to very similar conditions to those that were monitored 2.5 years earlier in June 2004.

From November 2006 to May 2007, all of the northern transects responded to fluctuations in wave energy, with a net overall beach widening of approximately 20 m occurring. The rate of accretion was the most significant during April and May 2007. During the following six month period, June to November 2007, steady increases in beach width were observed to continue through June and July, followed by 30 m to 35 m of storm erosion during August and September, with the intensity of the erosion decreasing along the far northern section of the embayment. During the final months of this period, the beach maintained a relatively stable width across the northern transects.

During the current monitoring period December 2007 to May 2008, the northern section of the beach at transects ETA33 to ETA36 suffered further erosion during the storm events of December and January, followed by recovery during the period March to May. Shortly following the December and January storm events, the beach width along the northern section of the Palm Beach embayment was the narrowest that has been recorded during the four year total monitoring campaign. The recovery of the beach during the later months of the current monitoring period saw the beach regain significant width, with beach width almost completely recovering from the storm events experienced during August/September 2007 and again in December 2007/January 2008.

7.2 On-Line Beach Width Analysis

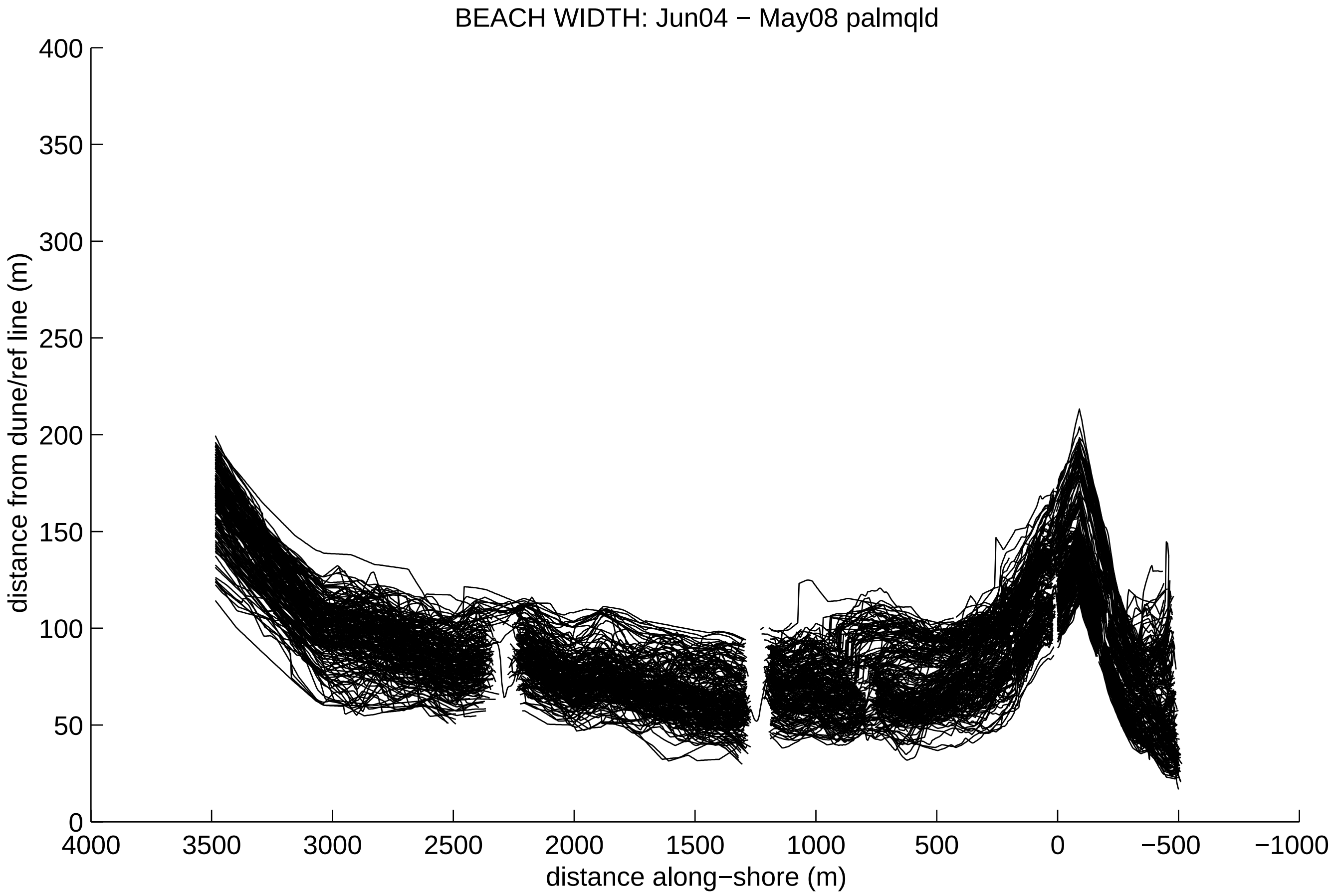
For the sake of completeness, Figures 7.4 and 7.5 are included here that show the same data presented in Figures 7.2 and 7.3, but in the on-line graphical format ('Beach Width Analysis') that are updated each week, and are available for public viewing (and download) via the monitoring project web site (refer Section 4). The top and bottom panels in these figures are equivalent to the two panels in Figures 7.2 and 7.3, with the additional feature that a selection of shorelines are also shown. As well as the same trends identified and discussed above, an interesting additional feature that is more clear in this alternative representation of the data, is the convergence towards a more uniform width alongshore for much of the Palm Beach embayment. Only at the far southern end of the embayment where ongoing nourishment of the beach is undertaken annually, does the beach width diverge from the remainder of the embayment. At the commencement of the monitoring program in June 2004 the width of the storm buffer seaward of the boulder wall varied by up to 150 m. As shown in Figures 7.4 and 7.5, by June 2005 the beach width at the ETA transect lines had converged towards a more uniform range of around 100 ± 20 m at all of the eight ETA transects. However, following the storm of March 2006 and a period of slightly higher wave conditions in late 2006 to early 2007, divergence of beach width alongshore was again apparent. From January 2007 until August 2007 the ETA transect lines again showed reasonably rapid convergence towards a uniform storm buffer, with a continuous beach width of 100 ± 20 m at all of the eight ETA transects. The series of storm events throughout August and September, and the nourishment of the southern end of the embayment during October and November again caused the beach width to vary significantly along its length.

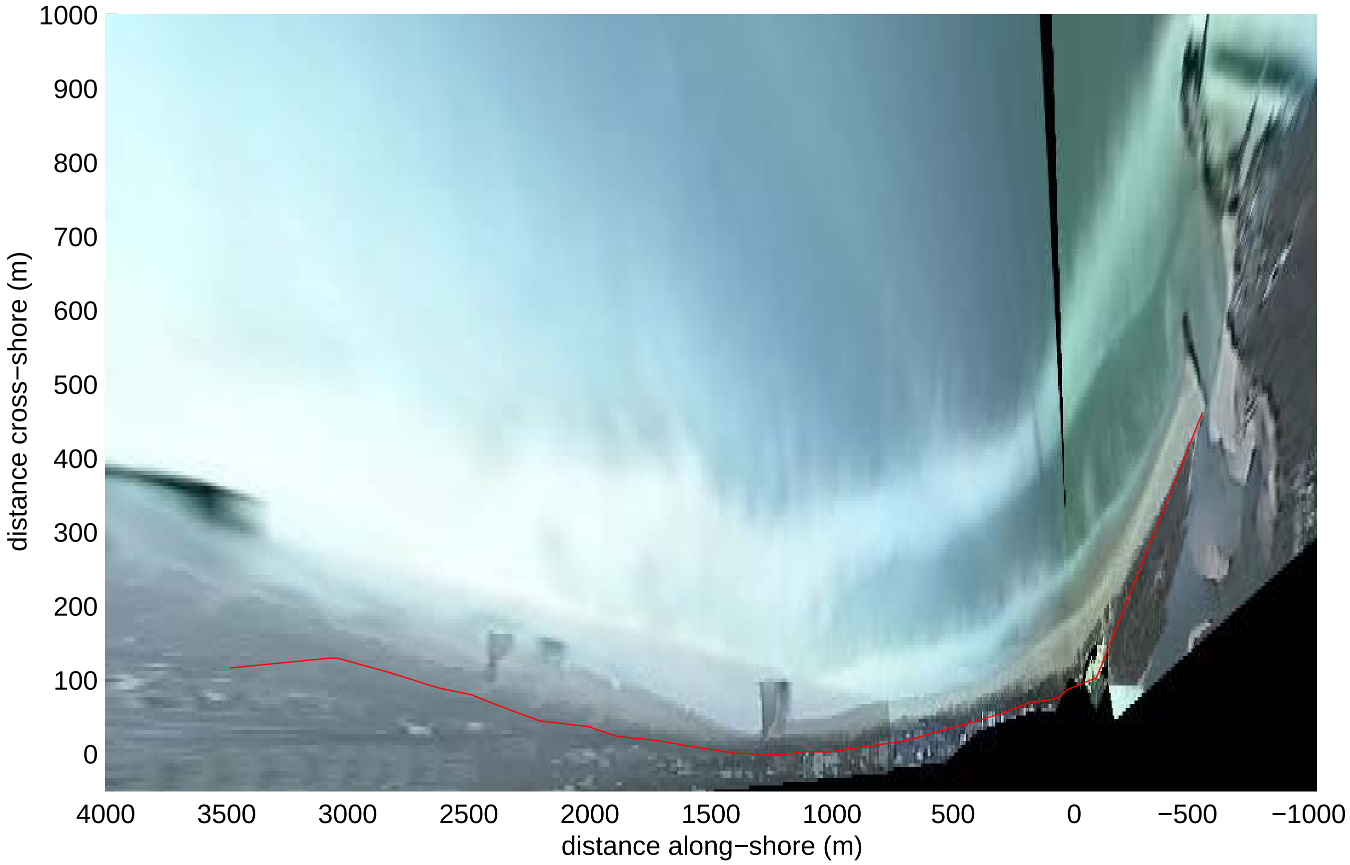
At the completion of the current monitoring period, there was a storm buffer seaward of the boulder wall of only 60 to 80 m beach width at the far southern end of the embayment, while at the north, the beach had a slightly larger buffer of 80 to 100 m.

7.3 Summary

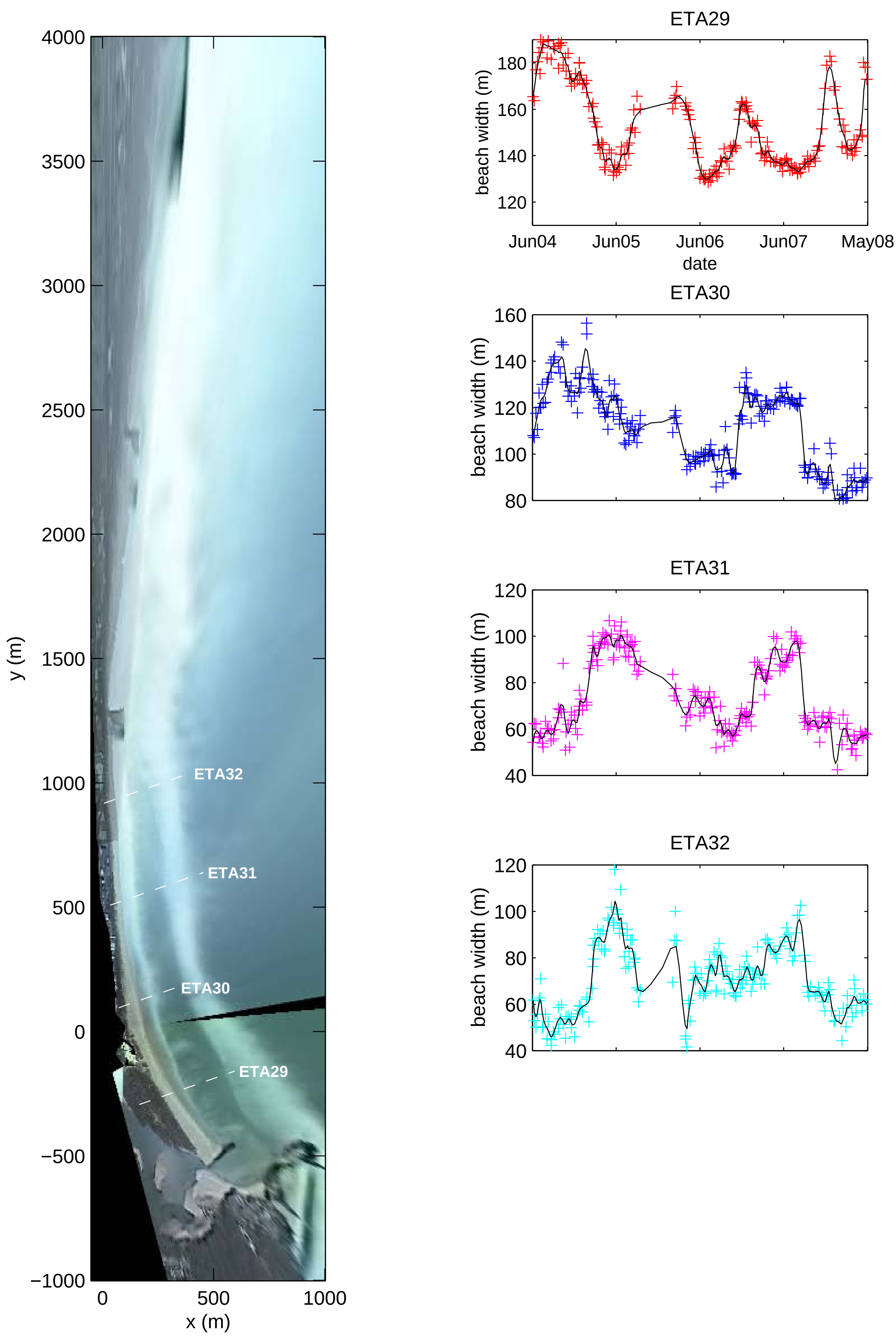
Prior to March 2006, the dominant beach changes observed within the Palm Beach embayment were directly attributable to the nearshore nourishment and beachface sand placement campaigns completed in 2004 and 2005. At the southern sand spit area (ETA29) the beach had receded due to the alongshore and cross-shore re-distribution of sand originally placed along the beachface. In contrast, in the southern-central region (ETA31 to ETA32) the landward movement of sand placed within the nearshore had resulted in a net widening and straightening of the beach. Between the 11th and 21st Street groynes (ETA33 to ETA35) the delayed widening of the beach has been observed, as a portion of the nearshore nourishment volume moved northward along the Palm Beach embayment. Only in the northern region of the Palm Beach embayment (ETA36) have significant impacts from the nourishment campaign not been observed.

The major storm event that occurred in March 2006 caused significant erosion of the beach along much of the Palm Beach embayment. A general trend of beach recovery was observed through to November 2006, with the addition of dredged material from the Currumbin Creek supporting beach recovery. Following completion of the 2006 nourishment campaign in November, the beach continued to accrete through until July 2007, with net widening observed at most transects. A series of storms in August and September 2007 resulted in erosion of the beach north of the ARGUS station, but resulted in little net change in beach width along the southern sand spit. The southern sand spit was again nourished during October and November 2007 with sand dredged from the Currumbin Creek entrance, resulting in a significant increase in beach width along this section of the embayment. Storm events experienced during December 2007 and January 2008 caused significant further erosion along the entire beach, which was followed by beach recovery during lower energy wave conditions experienced during February and March 2008.





WRL Report No.2008/18	WEEKLY BEACH WIDTH: JUNE 2004 − MAY 2008	Figure 7.1



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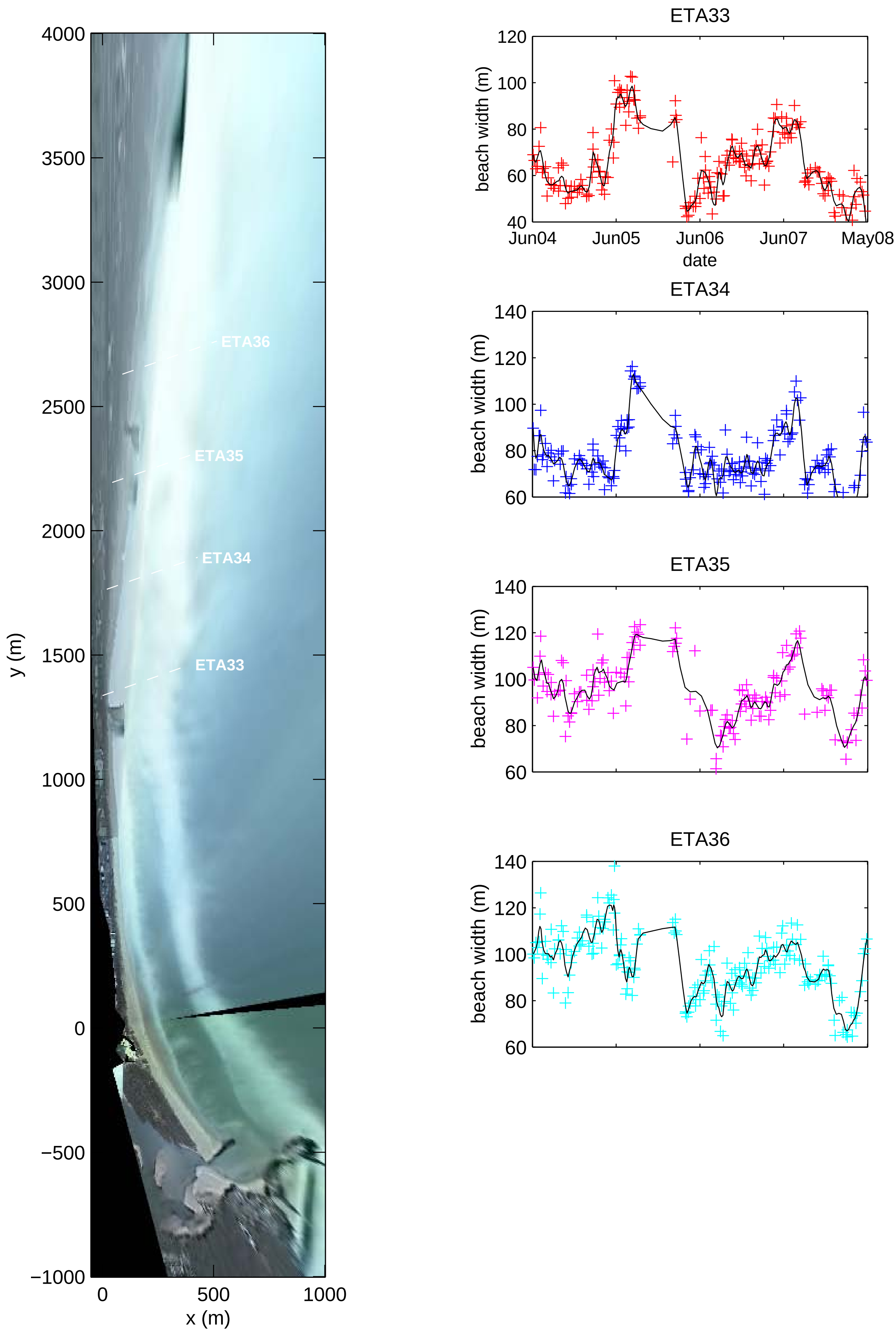
TIME−SERIES OF BEACH WIDTH (SOUTH):
JUNE 2004 − MAY 2008

Figure
7.2



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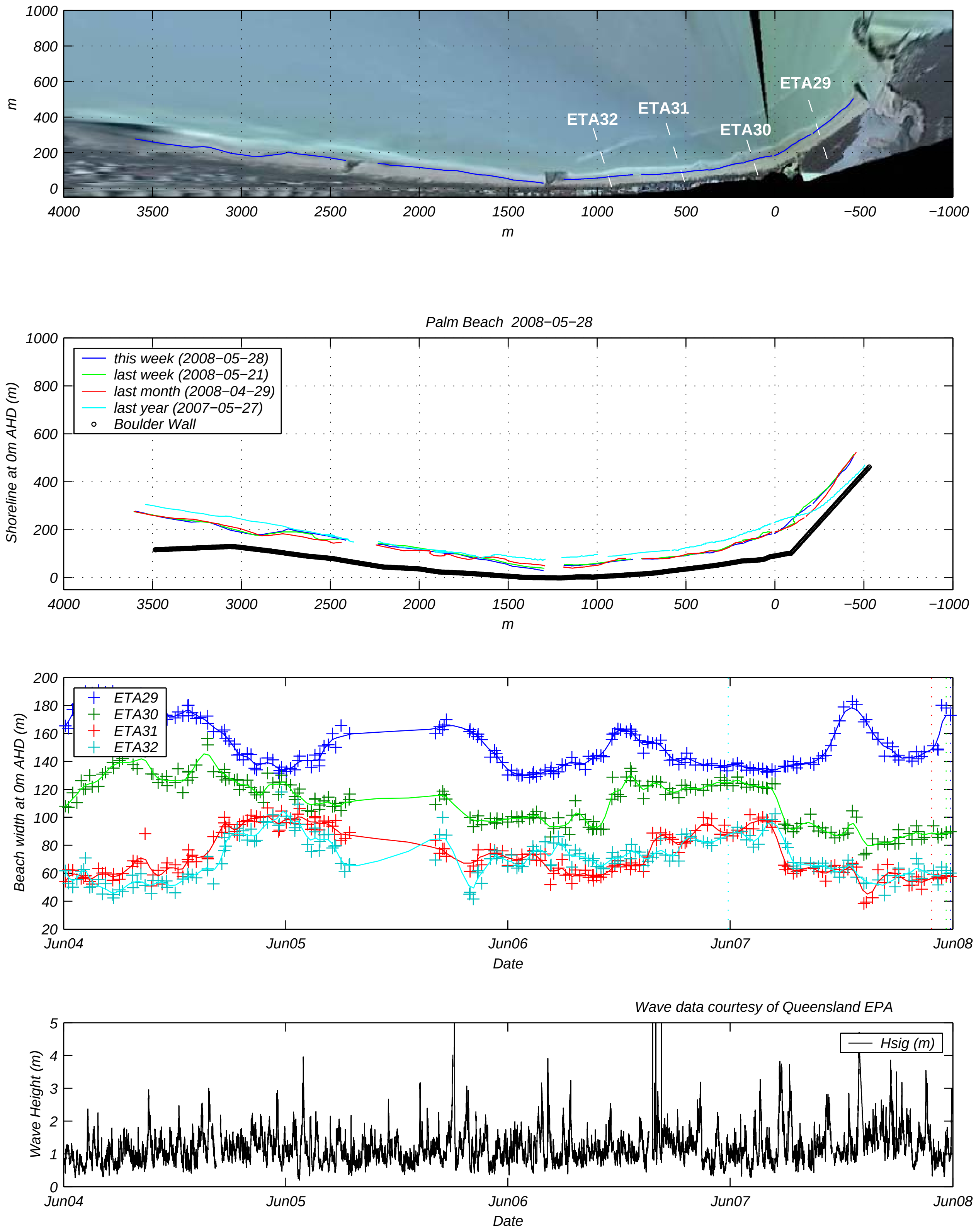
TIME−SERIES OF BEACH WIDTH (NORTH):
JUNE 2004 − MAY 2008

Figure 7.3



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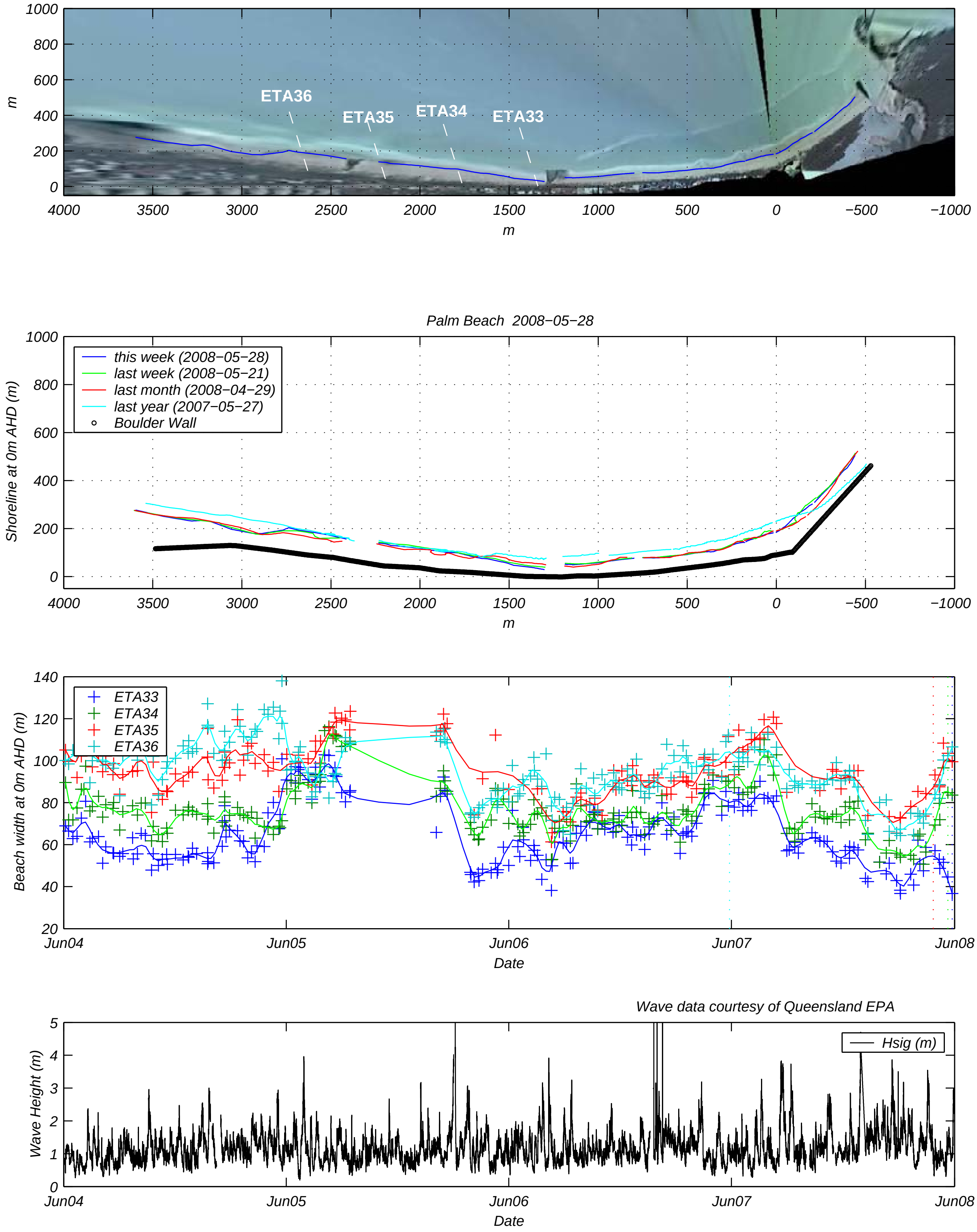
WRL Report No.2008/18	ON−LINE BEACH WIDTH ANALYSIS TO MAY 2008 (SOUTH)	Figure 7.4



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WRL Report No.2008/18	ON−LINE BEACH WIDTH ANALYSIS TO MAY 2008 (NORTH)	Figure 7.5

8. ANALYSIS OF EROSION-ACCRETION TRENDS

Coinciding with the implementation of the ARGUS-based beach monitoring program at Palm Beach in mid 2004, an image analysis technique was implemented enabling patterns of beachface slope erosion and accretion to be identified and quantified. On a monthly basis, hourly images throughout a single spring tide are analysed and a 3-D bathymetry of the beachface extending from the low tide waterline to the high tide waterline is derived. These data are further analysed to assess regions of beachface erosion and deposition within the Palm Beach embayment.

8.1 Methodology

A detailed description of the analysis techniques used to derive three-dimensional beachface bathymetry from two-dimensional image analysis was provided in Turner (2004). In summary, throughout a single spring tide cycle, the shoreline mapping technique is applied to locate the waterline in successive hourly images. The elevation corresponding to the detected waterlines is calculated on the basis of concurrent tide and wave information, which is incorporated in a model that combines the effects of wave setup and swash, at both incident and infragravity frequencies. As illustrated in Figure 8.1, if this process is repeated at all points alongshore throughout a complete spring-tide cycle, a three-dimensional bathymetry of the beachface - between the high tide and low tide waterlines - is derived. The beachface is the most dynamic region of sediment movement within the coastal system, and sand changes observed in this area are indicative of the total profile.

8.2 Monthly Beachface Bathymetric Mapping

Beachface bathymetries derived at approximately monthly intervals along the Palm Beach embayment are shown in Figure 8.2 (12th December 2007 and 7th January 2008), Figure 8.3 (10th February and 4th March 2008) and Figure 8.4 (5th April and 7th May 2008).

Analysis of intertidal beachface maps in previous monitoring reports has identified a persistent feature of the Palm Beach embayment that is not easily discernable from the raw images or shoreline analysis. This feature is a distinct flattening of the beach gradient northward along the beachfront. This observation is consistent with the increasing exposure of the beach to predominantly south-easterly waves. The flattening of the beach gradient with increasing distance north of Currumbin is attributed to the modal beach state transitioning from more reflective (steeper), lower-intermediate morphology in the south, to increasingly dissipative (flatter), higher energy intermediate beach states towards the north.

Early in the current monitoring period (December 2007) the beachface could be seen to be regular in alignment and steep to the south of the Royal Palm building, due to ongoing lower energy wave conditions. Between the ARGUS station and the 11th Street groyne, a series of undulations were present in the beachface, which are typical of lower/intermediate energy morphological conditions and nearshore rip currents. Along the northern section of the embayment, the intertidal beachface was relatively uniform, and notably flatter than the southern half of the beach.

During late December 2007 and early January 2008, a series of intense storm events caused high energy wave conditions to impact the Palm Beach embayment. This is evident when comparing the intertidal beachface maps for the months of December 2007 and January 2008 (Figure 8.2), where the beachface in January can be seen to have migrated significantly landward and become more uniform in alignment. The more uniform longshore beach alignment indicates that the beach shifted to a higher energy morphological state, with the cross shore sediment transport processes dominated more heavily by detached longshore bars, than nearshore rips.

Between January and February 2008, a series of undulations again developed on the intertidal beachface, in response to the relative lull in wave energy. This was particularly evident over the middle regions of the Palm Beach embayment. The lower wave energy continued to dominate morphological processes into March 2008, with the development of a LTT between the Royal Palm building and the 11th Street groyne. The entire beach continued to accrete very slightly between March and April 2008.

By the end of the current monitoring period in May 2008, the beachface was very irregular in alignment, after experiencing minor erosion and accretion over different sections of the beach. The section of beach on the south side of the 11th Street groyne eroded, with the intertidal beachface migrating by approximately 20 m landward. A pocket of erosion also occurred on the south side of the 21st Street groyne.

8.3 Monthly Erosion-Accretion Trends

By further processing of the monthly bathymetries shown in Figures 8.2 - 8.4, a quantitative measure of the net change in sand volumes across the beachface (between the elevations of -0.5 and +0.7 m AHD) throughout the Palm Beach embayment can be obtained. Figure 8.5a shows the results of these calculations to determine the net change in bed elevation between November – December 2007, December 2007 – January 2008, and January –

February 2008, and Figure 8.5b for February – March 2008, March – April 2008, and April – May 2008.

The top panel of Figure 8.5a shows that from November to December 2007, there was a general trend of modest accretion along the Palm Beach embayment. The extreme southern and northern stretches of the beach experienced the most significant accretion, with the beachface increasing by up to 1 m in vertical elevation over this area. Across the mid stretches of the embayment, patches of minor erosion and accretion were experienced. Averaged along the entire measured section of the Palm Beach embayment the net change in sand volume within the mapped beachface was **+21,120 m^3** of accretion, which equates to **+6.4 m^3 per m of shoreline** when averaged over the length of the beach (between -0.5 and +0.7 m AHD).

From December 2007 to January 2008 (Figure 8.5a, middle panel), the beach suffered a high level of erosion, as a result of a series of intense storm events striking the Queensland and northern New South Wales coastlines. Across much of the embayment, the intertidal beachface migrated some 40 m landward and lost in excess of 1 m of vertical elevation, resulting in significant scarping along the beach. It appears from the beachface map shown in Figure 8.5a (mid panel), that the 21st Street and 11th Street groynes provided some protection from the erosion, with the beach appearing to suffer lower levels of erosion on the southern side of these structures. In total, between 12th of December 2007 and 7th of January 2008 there was a predicted net erosion of some **-69,315 m^3** across the length of the embayment, equating to **-20.9 m^3 per m of shoreline** (between -0.5 and 0.7 m AHD). It is expected that over the entire beach profile, significantly larger quantities of beach would have been eroded during this period, however, analysis of this additional beachface area using the intertidal beachface mapping technique is not possible.

Between January and February 2008 there was little net change in intertidal beachface volumes experienced. Along the southern Currumbin Sand Spit, the beachface lost up to 1 m in vertical beachface elevation, while the area between the Royal Palm building and the 11th Street groyne experienced a gain in up to 1 m of vertical beachface elevation. North of the 11th Street groyne, localised pockets of both erosion and accretion were observed, with little net change in beachface volume experienced. From January to February there was a net beachface accretion over the entire embayment of **+6,116 m^3**, equating to **+1.8 m^3 per m of shoreline** (between -0.5 and +0.7 m AHD).

From February to March 2008, the northern half of the Palm Beach embayment had a net trend of erosion, increasing in intensity to the far north where up to 1 m in vertical beachface elevation was lost. South of the 11th Street groyne, pockets of localised erosion and accretion were somewhat irregular, with very little net change in the beachface along the southern sand spit. Overall there was a minor accretion of **+4,240 m^3**, equating to **+1.3 m^3 per m of shoreline** over the intertidal beachface (-0.5 m to +0.7 m AHD).

Between March and April 2008, a more continuous trend of low volume accretion was experienced over most parts of the embayment. The beachface was seen to accrete up to 0.5 m in vertical elevation during this period. The only notable exception to the overall trend of accretion was the southern sand spit, where very minor erosion of the intertidal beachface was experienced. In total the net beachface accretion over the entire embayment was **+12,671 m^3**, equating to +**3.8 m^3 per m of shoreline** (between -0.5 and +0.7 m AHD).

The most inactive one month period in terms of net sediment transport over the intertidal beachface occurred between April and May 2008. There was a general trend of slight erosion over the stretch of beach south of the Royal Palm building. Adjacent to and on the south side of the 11th Street groyne there was a patch of localised erosion, where the intertidal beachface lost over 0.5 m in vertical elevation over a length of beach of approximately 200 m. Between the 11th and 21st Street groynes the beach accreted slightly, while to the north of the 21st Street groyne patches of both erosion and accretion occurred. Between April and May 2008 the net beachface accretion over the entire embayment was **+1,563 m^3**, equating to **+0.5 m^3 per m of shoreline** (between -0.5 and +0.7 m AHD).

8.4 Net Erosion-Accretion Trends

The net change in beachface bathymetry calculated for the previous and present monitoring periods are summarised in Figure 8.6a-d. The upper panel of Figure 8.6a is for the six month period June –November 2004, while the lower panel of Figure 8.6a is for the six month period December 2004 – May 2005. Figure 8.6b shows the net change in beachface bathymetry for the period of June 2005 – September 2005 (at which time the cameras were temporarily removed for roof repairs), and February to May 2006. The net change in beachface bathymetry for the period June to November 2006 is shown in the upper panel of Figure 8.6c, while the lower panel of Figure 8.6c shows the net change during the period December 2006 to May 2007. The net change in beachface bathymetry observed during the period May to November 2007 is shown in the upper panel of Figure 8.6d, while the net change for the current monitoring period December 2007 to May 2008 is shown in the lower panel.

During June to November 2004 (Figure 8.5a, upper panel) the region of beach that extends southward from midway between 11th Street groyne and Currumbin Spit experienced a period of distinct beach accretion, centred around two areas: the first in the lee of the southern offshore sand dump boxes area, and the second where sand was placed from the dredging of the lower Currumbin Estuary during July – September 2004. Northward of this region a general trend of net beach erosion was observed. Lowering of the beachface profile by 0.2 m to 0.6 m was measured along the majority of the embayment.

In contrast, during December 2004 to May 2005 the southern sand spit eroded, whereas the region of beach extending from in front of the Royal Palm building (0 m alongshore) to around the 11th Street groyne exhibited a period of major beachface accretion. During this time the positive benefits of the 2004 nearshore nourishment campaign had emerged and were very clearly evident during this monitoring period.

The monitoring period June – September 2005 was dominated by the re-distribution along the Palm Beach embayment of the nearshore nourishment placed in the latter part of 2004. The northward movement of the surfeit of sand away from the region immediately inshore of the nourishment area (500 – 1000 m alongshore) resulted in the retreat of the southern half of the embayment, countered by accretion along the northern half as sand moved alongshore. At the extreme southern end along the sand spit adjacent to the Currumbin estuary, the beach accreted, in response to the beachface placement of sand dredged from the estuary entrance. During this four month period the Palm Beach embayment experienced an embayment-scale rotation, as a new equilibrium shoreline alignment developed to accommodate the approximately 250,000 cubic metres of sand had been placed within the nearshore at that time.

The monitoring period December 2005 – May 2006 (Figure 8.6b) was dominated by the storm erosion event that occurred in early March 2006, with substantial erosion of the beach resulting, and only modest recovery by May 2006. By May 2006 around 20% of the total sand volume that had been removed from the beachface during the storm three months earlier had returned to the beach. Net vertical erosion of the beachface by 1 m or more was characteristic of the entire embayment through to May 2006. Only in one very localised area immediately up-drift of the 11th Street groyne had this net erosion trend reversed by the end of May.

Modest accretion continued within the central and northern regions of the Palm Beach embayment during the monitoring period June – November 2006 (Figure 8.6c top panel). Towards the southern end the persistence of transverse bar-rip morphology resulted in a complex pattern of localised erosion-accretion 'cells' alongshore. At the extreme southern end of the embayment a distinctive trend of net beach accretion was observed, largely due to the beachface placement of sand in this region as a part of sand removal operations undertaken in October-November within the entrance to the adjacent Currumbin Creek (refer section 2.3).

During the period December 2006 to May 2007, the beachface across the northern sections of the embayment fluctuated between periods of erosion and accretion, with little net change in mapped beachface bathymetry. It can be seen from Figure 8.6c that the beachface along this section of the beach effectively steepened throughout the six month period, with minor erosion on the seaward edge of the beachface and minor accretion across the landward edge. South of the beach monitoring cameras, significant erosion occurred, with the beachface lowering by up to 1 m in vertical elevation along the Currumbin Spit. The trend averaged across the entire embayment throughout this period was minor accretion.

Significant net erosion occurred along the entire stretch of the embayment north of the ARGUS camera station during the period May to November 2007. During this time a series of four separate storm events with high energy wave conditions impacted the Gold Coast beaches. The most significant section of erosion was for the 1500 m stretch to the north of the Royal Palm building, where in excess of 1 m in vertical beachface elevation was lost as a result of the storm events. At the extreme southern end of the embayment a localised trend of net beach accretion was observed, again largely due to the placement of sand in this region as a part of sand removal operations undertaken in October-November within the entrance to the adjacent Currumbin Creek (refer section 2.3).

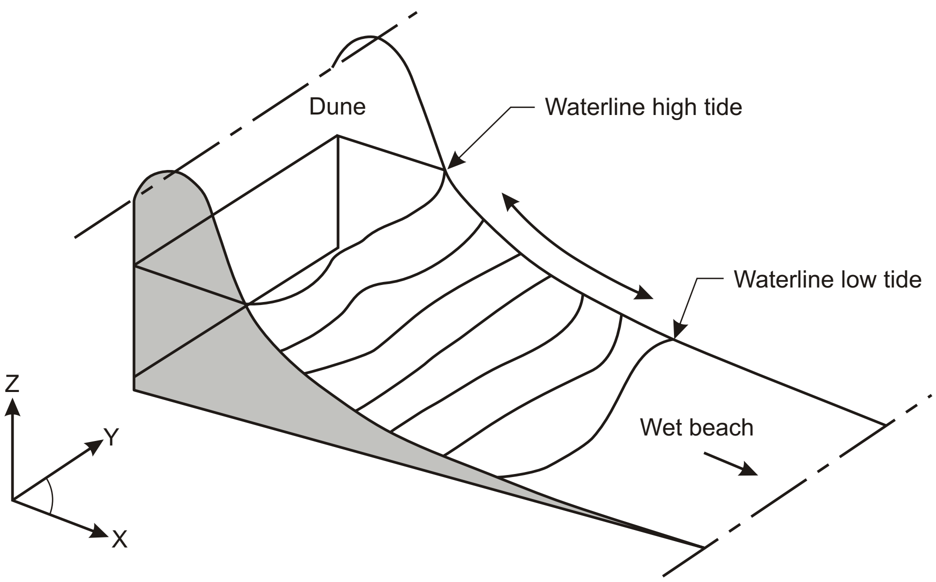
During the current six month monitoring period of December 2007 to May 2008, net erosion again occurred along the Palm Beach embayment. While most of this period was characterised by stable and slightly accretionary beach conditions, the storm events experienced during December 2007 and January 2008 dictated the net sediment transport determined for the intertidal beachface. Localised sections of the beach suffering the most notable net erosion were along the southern Currumbin Spit, on the south side of the 11th Street groyne, and to the north of the 21st Street groyne. In all of these locations, the intertidal beachface lost up to 1 m in vertical elevation, and the position of mean sea level migrated some 10 to 20 m landward.

8.5 Total Erosion-Accretion Trends: June 2004 – May 2008

Figure 8.7 shows the total net change in beachface bathymetry for the four year monitoring period June 2004 to May 2008. As has been observed during previous monitoring reports, it is apparent from this figure that the net erosion and accretion trends can be separated into four compartments along the length of the Palm Beach embayment. South of the monitoring cameras significant net erosion appears to have occurred, with the mapped beachface dropping in excess of 1 m in vertical elevation in this area. While the erosion/accretion analysis identifies this area as having undergone erosion, it is important to note that at the start of monitoring in June 2004, between 50,000 m^3 and 100,000 m^3 of nearshore nourishment had already been undertaken, and as a result, the beach was in an enhanced accreted state. With the longshore littoral drift moving sand along the coast, and only minor nourishment being undertaken since early 2006, there has been a trend of steady decline in the nearshore sand volume, which is being identified as overall erosion in the total erosion/accretion trend analysis, for the region to the south of the ARGUS station.

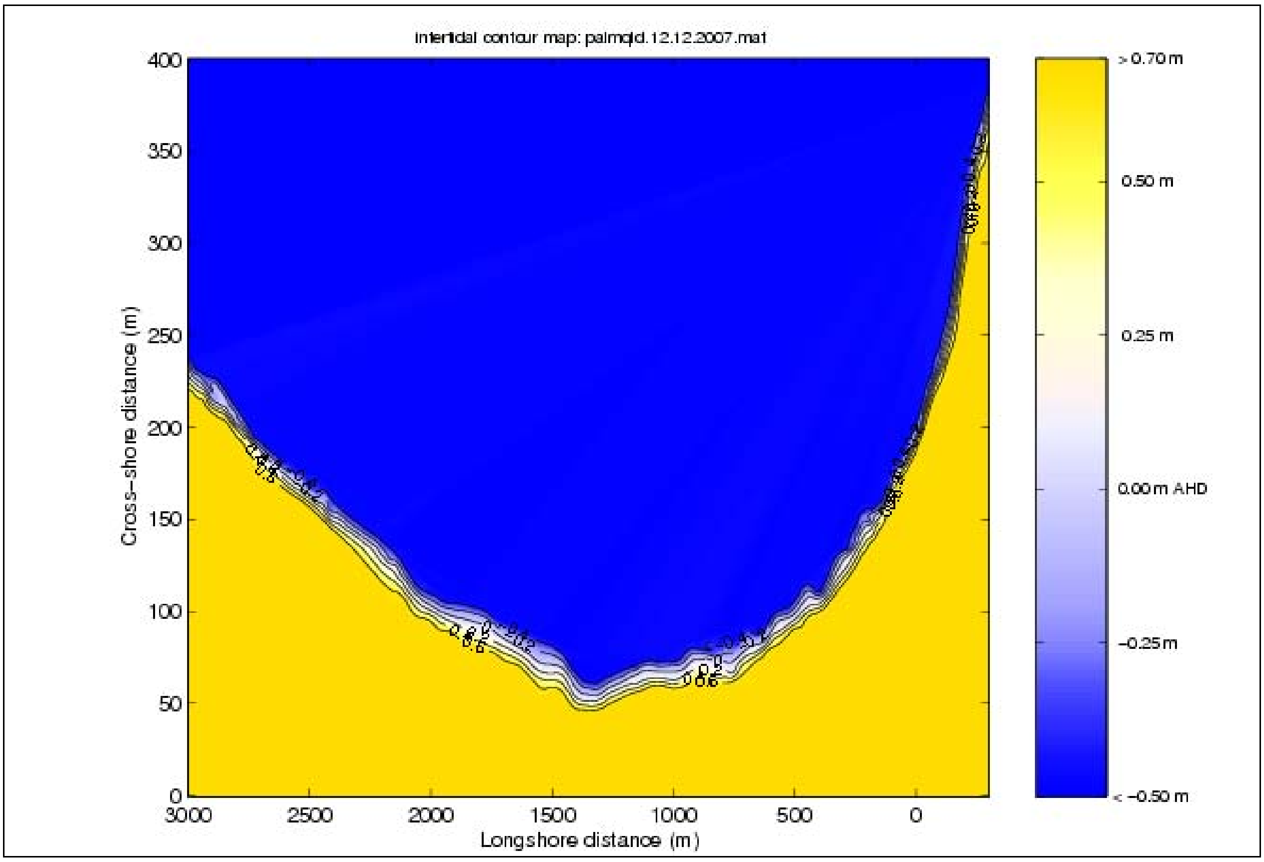
The section of beach between the Royal Palm building and the 11^{th} Street groyne has generally been a location of accretion, however, during the current six month monitoring period, the stretch of beach directly adjacent the 11^{th} Street groyne suffered uncharacteristically high localised erosion. Over the stretch of beach between the 11^{th} Street and 21^{st} Street groynes there has been minor net erosion, while north of the 21^{st} Street groyne there has been more modest net erosion observed, with the beachface approximately 1 m lower in vertical elevation at the end of the current monitoring period.

Within the intertidal beach (-0.5 and +0.7 m AHD) a total net volume of approximately **-51,076 m^3** of sand has been eroded along the ~3.5 km of beachfront included in this monitoring program, equating to an alongshore-average of around **-15.4 m^3** within the intertidal profile, for every 1 m alongshore.

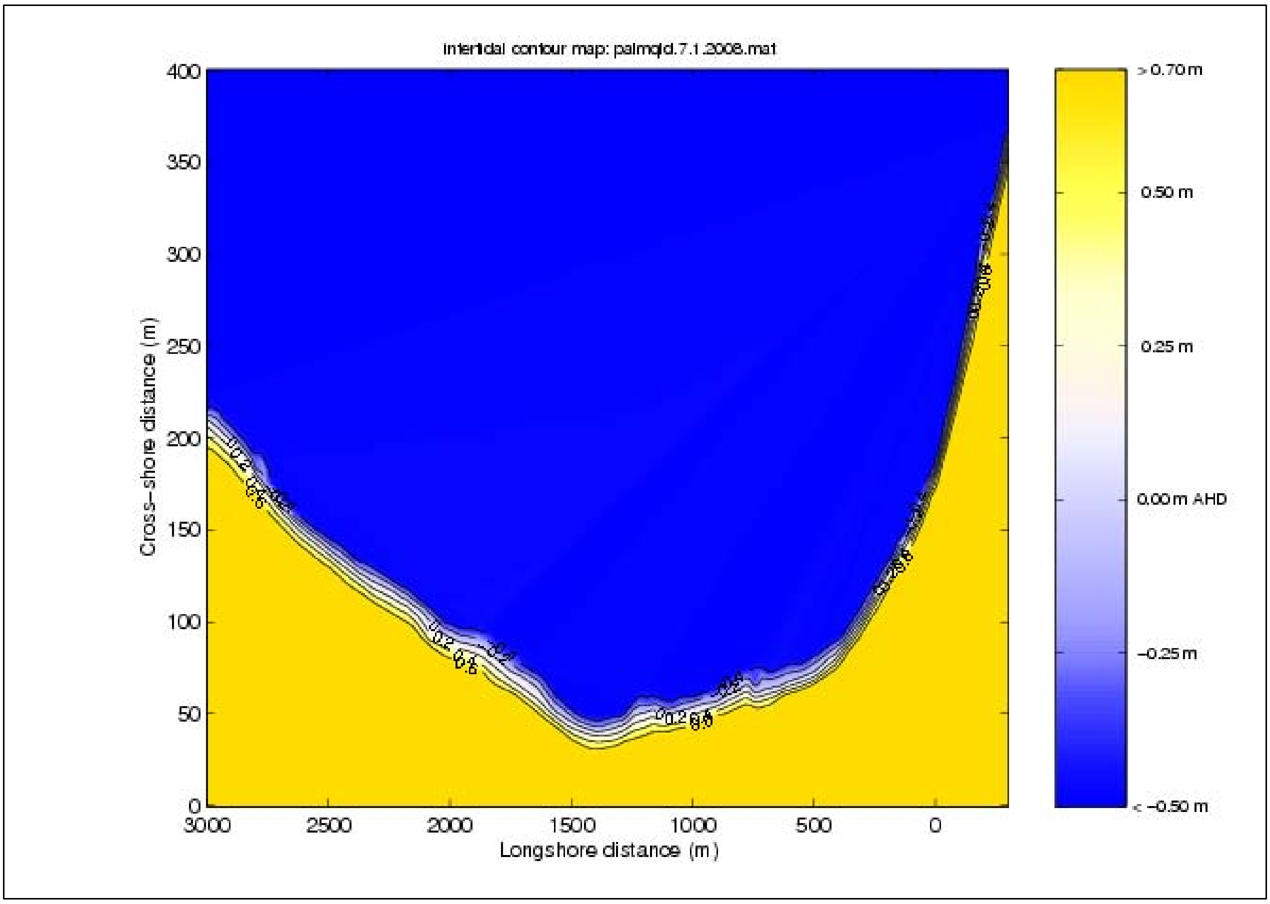


WRL Report No. 2008/18	DEFINITION SKETCH INTERTIDAL BATHYMETRY FROM HOURLY WATERLINES	Figure 8.1 06037-8-1.cdr

DECEMBER 2007

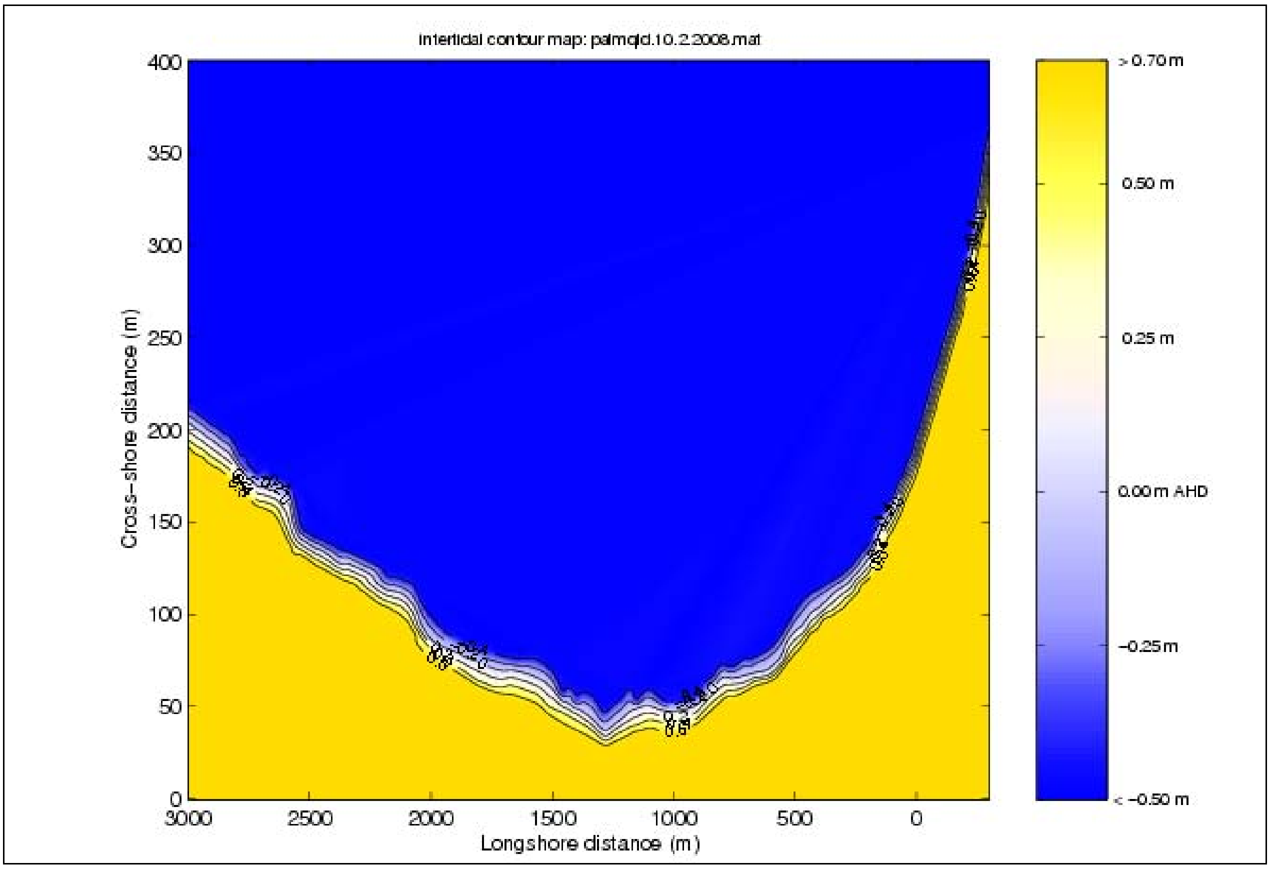


JANUARY 2008

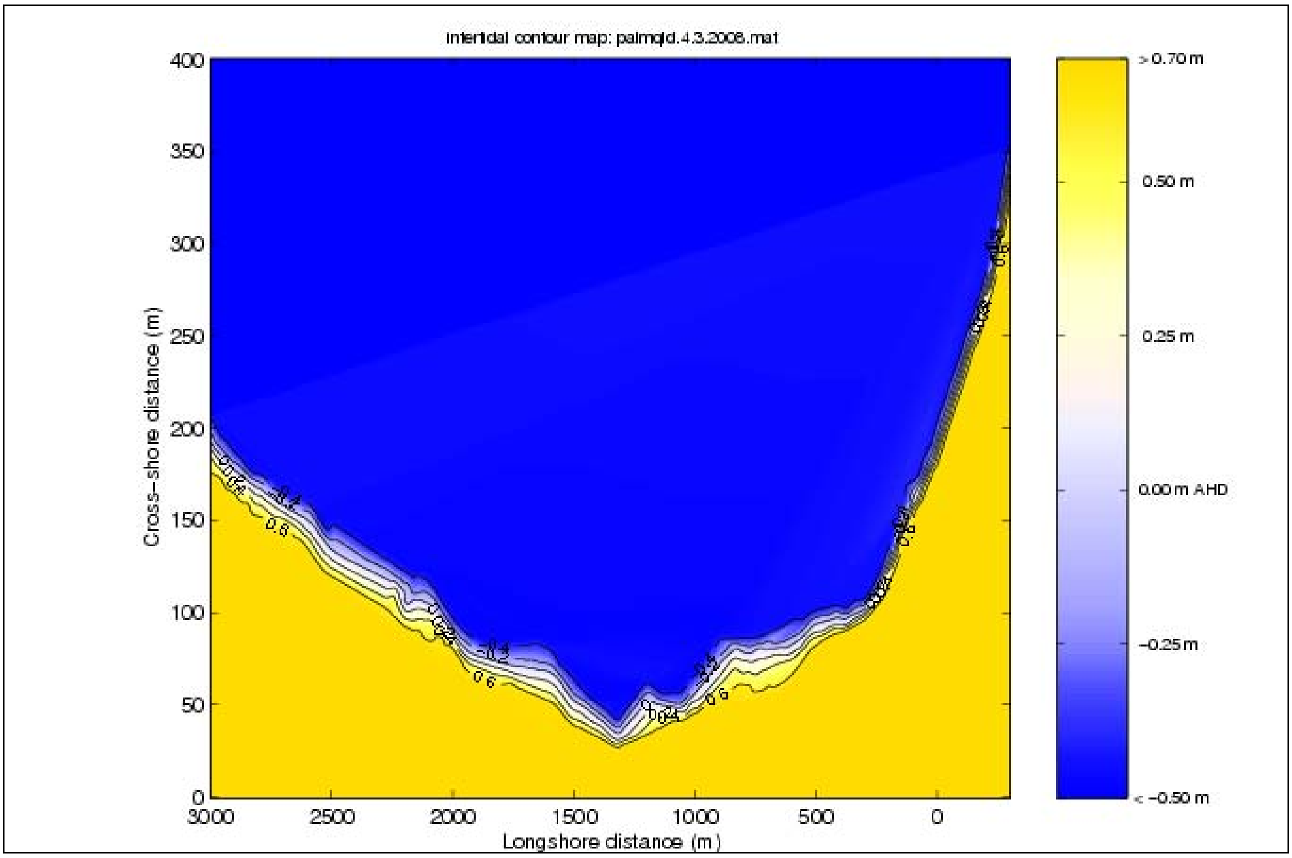


WRL Report No. 2008/18	BEACHFACE MAPPING – DECEMBER 2007, JANUARY 2008	Figure 8.2

FEBRUARY 2008

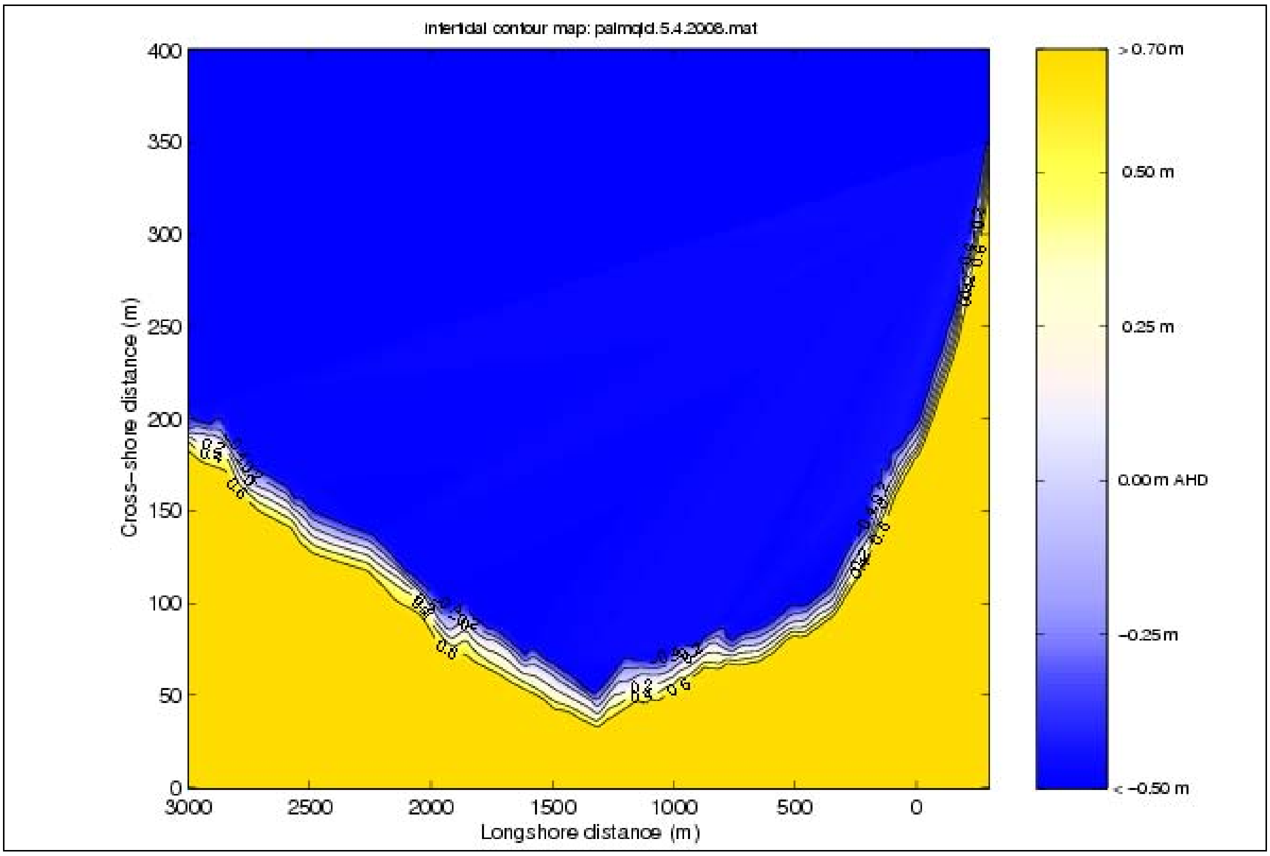


MARCH 2008

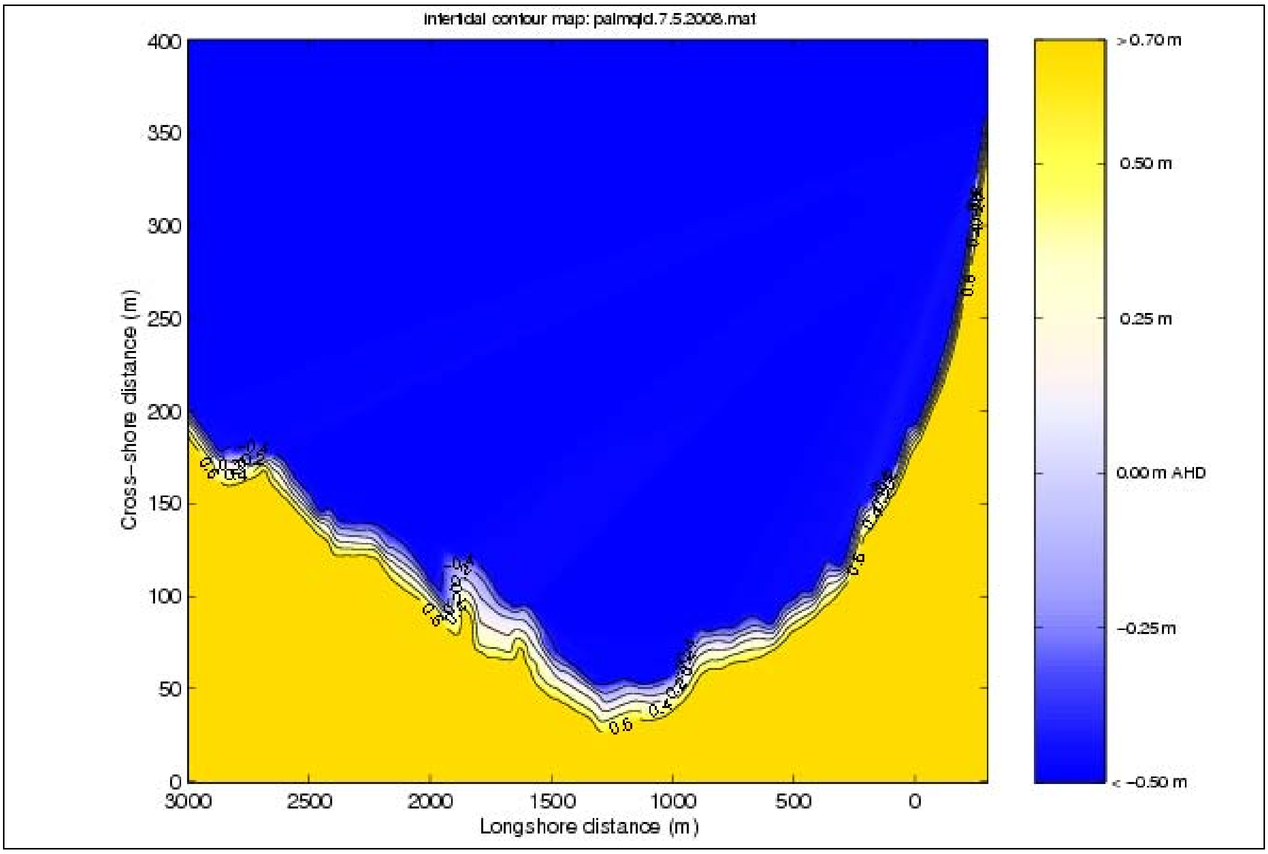


WRL Report No. 2008/18	BEACHFACE MAPPING – FEBRUARY, MARCH 2008	Figure 8.3

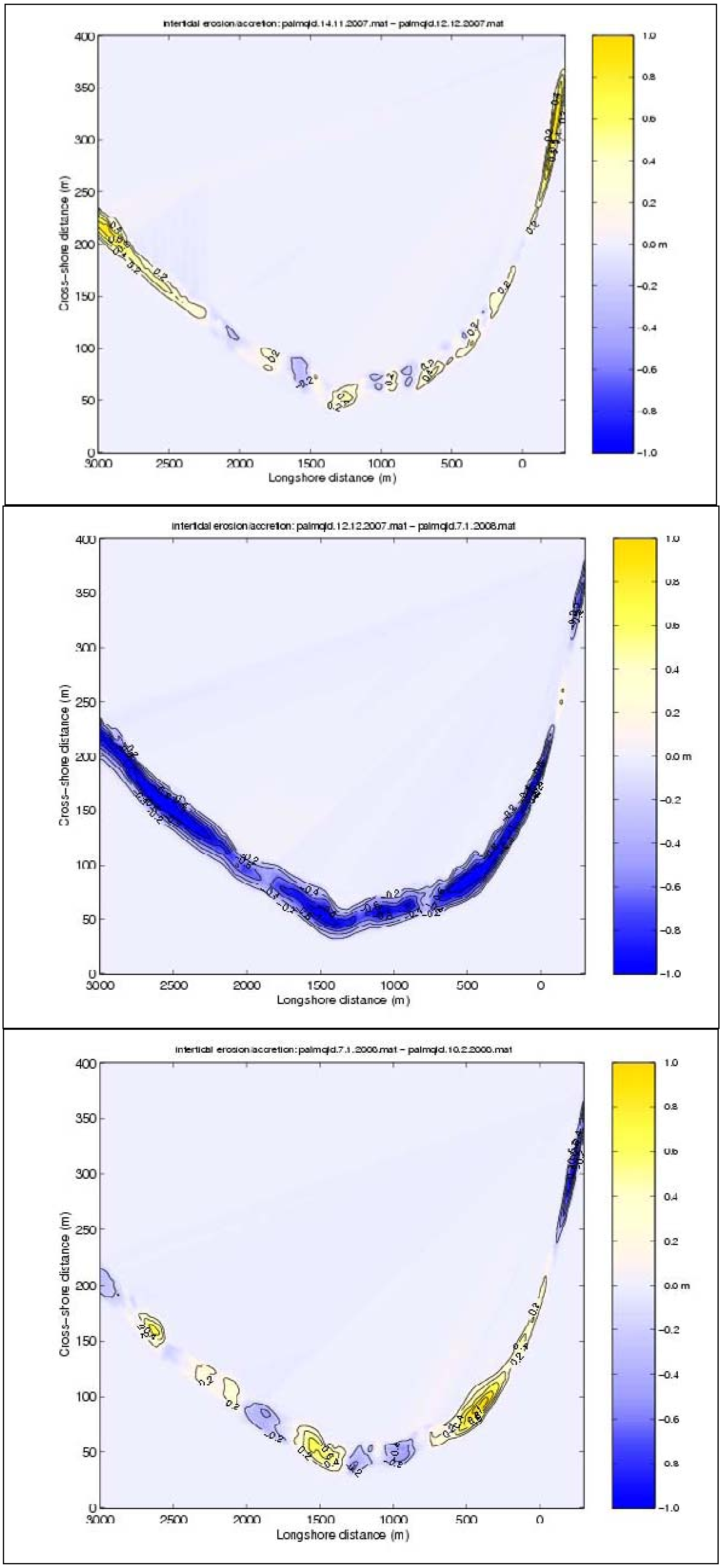
APRIL 2008



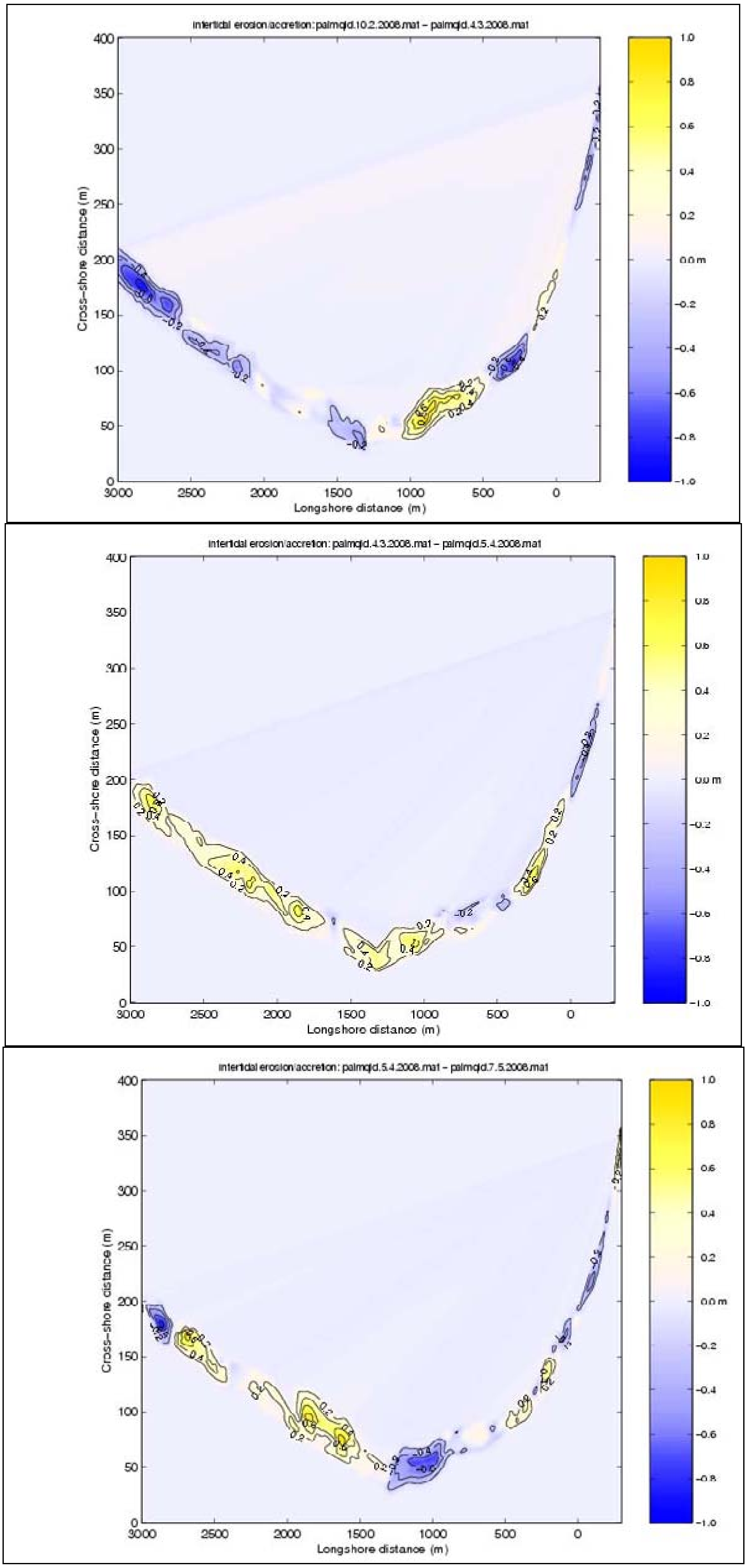
MAY 2008



WRL Report No. 2008/18	BEACHFACE MAPPING – APRIL, MAY 2008	Figure 8.4



WRL Report No. 2008/18	MONTHLY EROSION/ACCRETION: NOVEMBER 2007-FEBRUARY 2008	Figure 8.5a



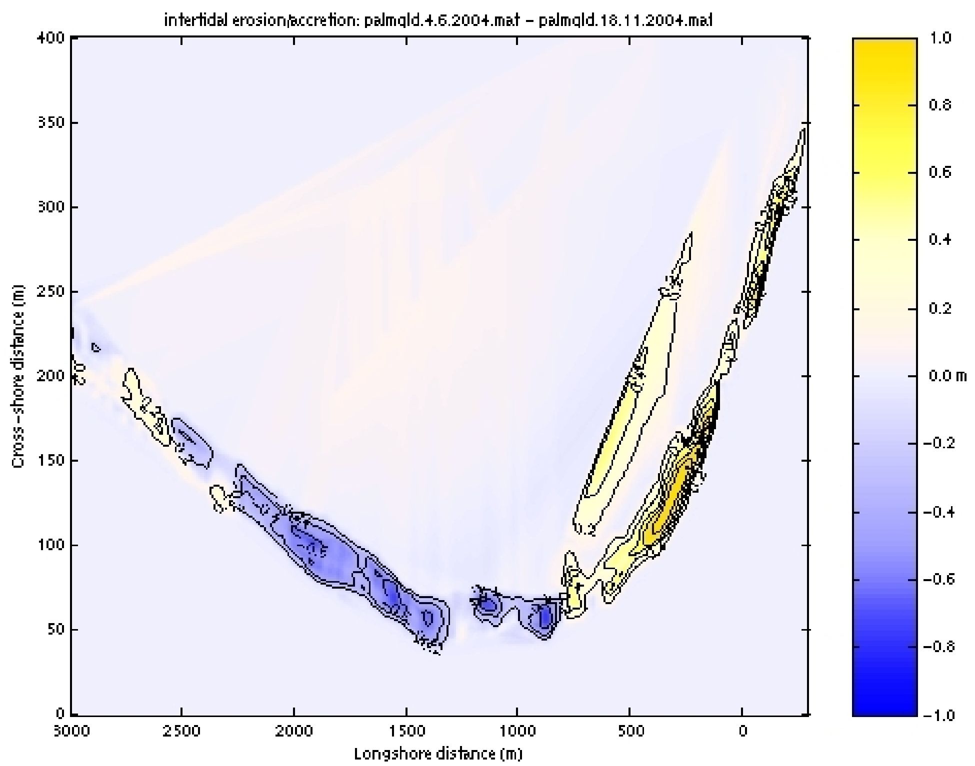
WRL

Report No. 2008/18

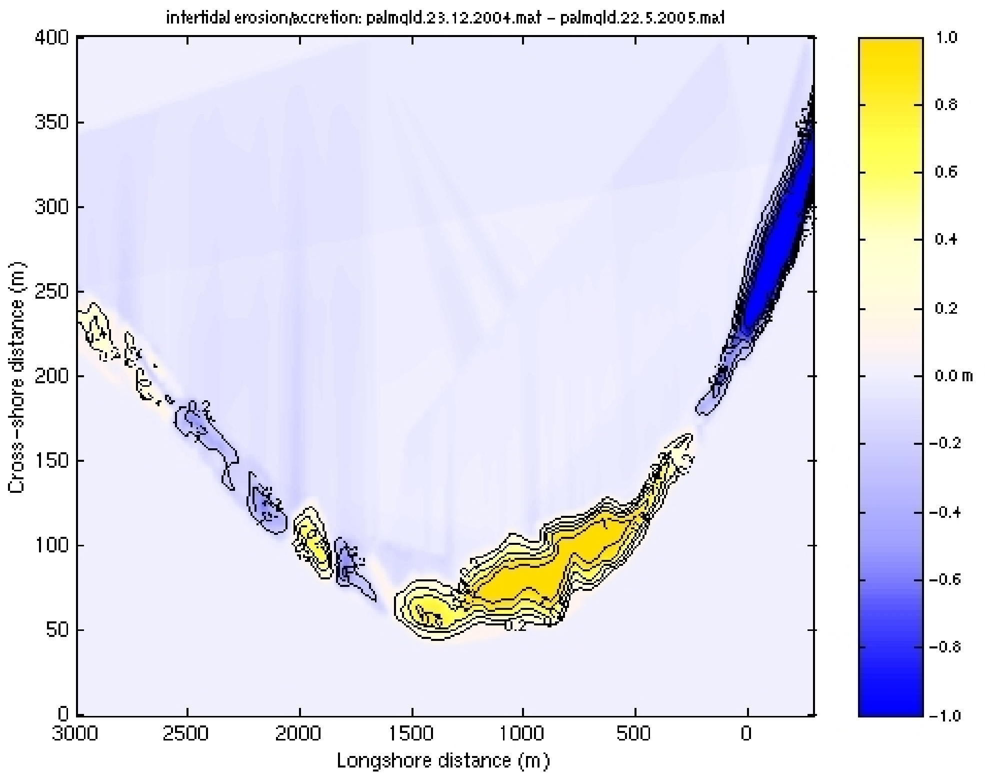
MONTHLY EROSION/ACCRETION:
FEBRUARY 2008 - MAY 2008

Figure
8.5b

NET CHANGE: JUNE - NOVEMBER 2004



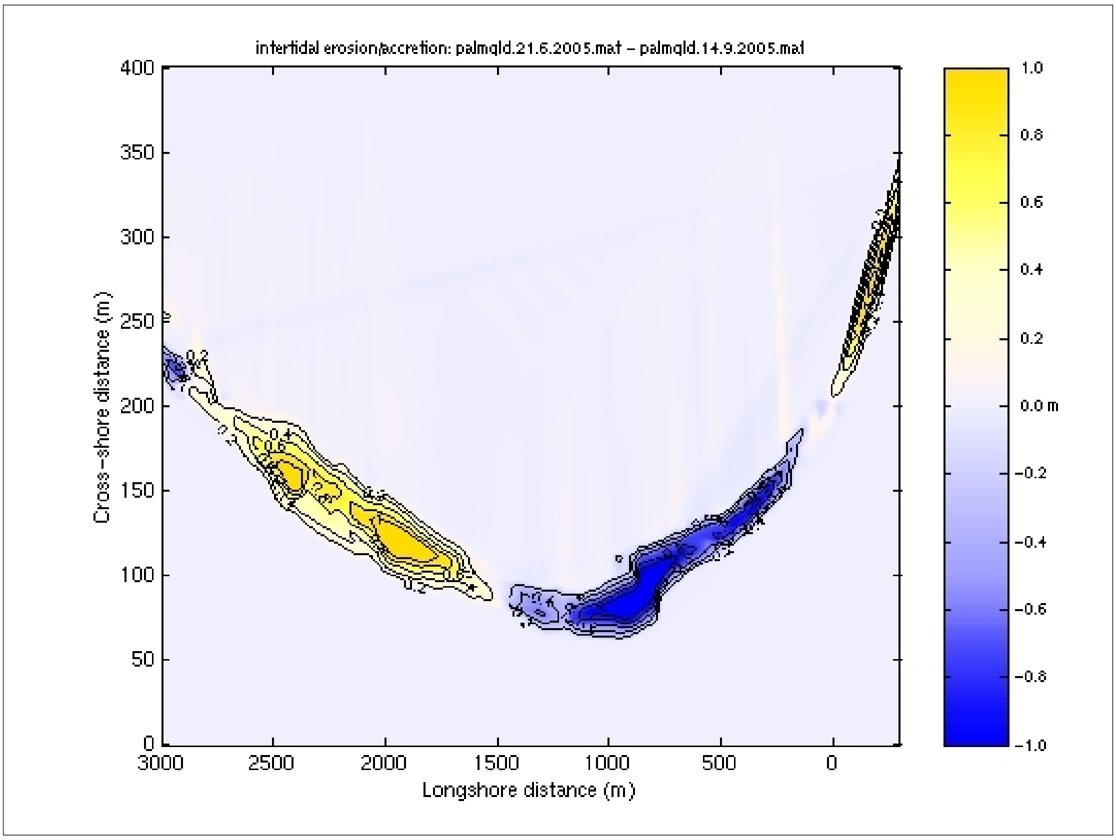
NET CHANGE: DECEMBER 2004 - MAY 2005



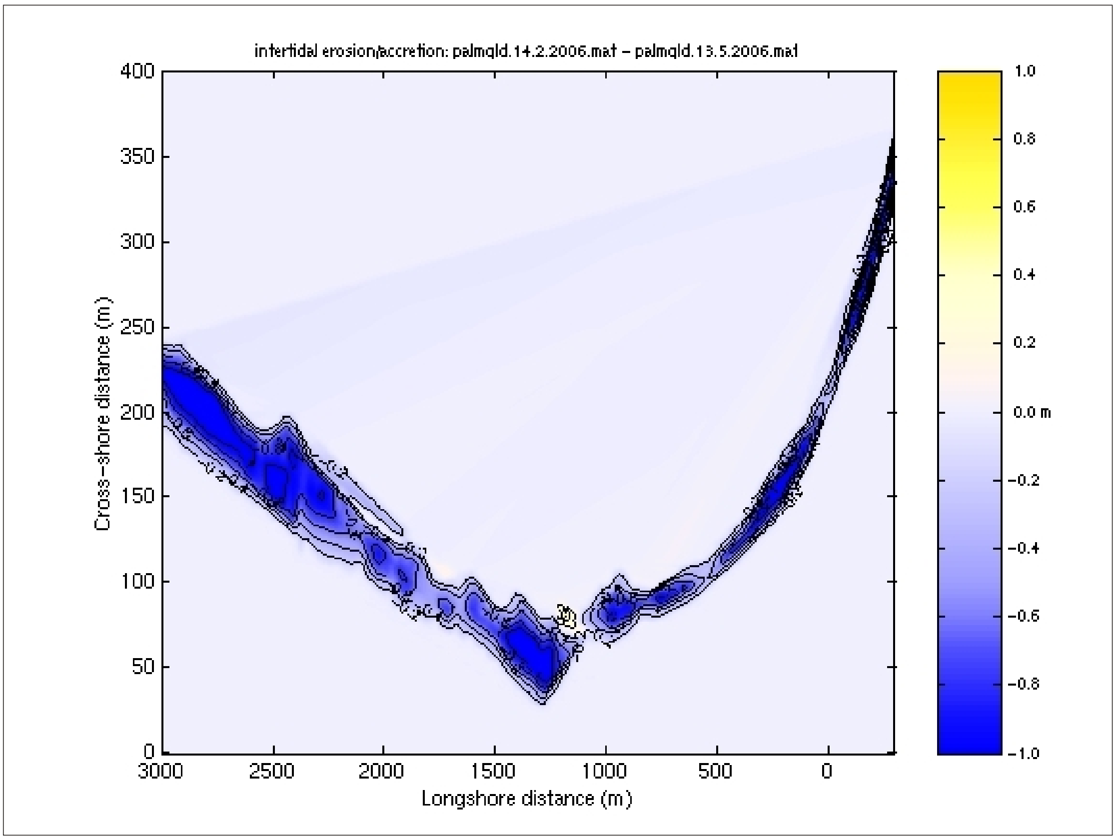
WRL Report No. 2008/18	EROSION/ACCRETION PER SIX-MONTH MONITORING PERIOD	Figure 8.6a

06037-8-6a.cdr

NET CHANGE: JUNE - SEPTEMBER 2005

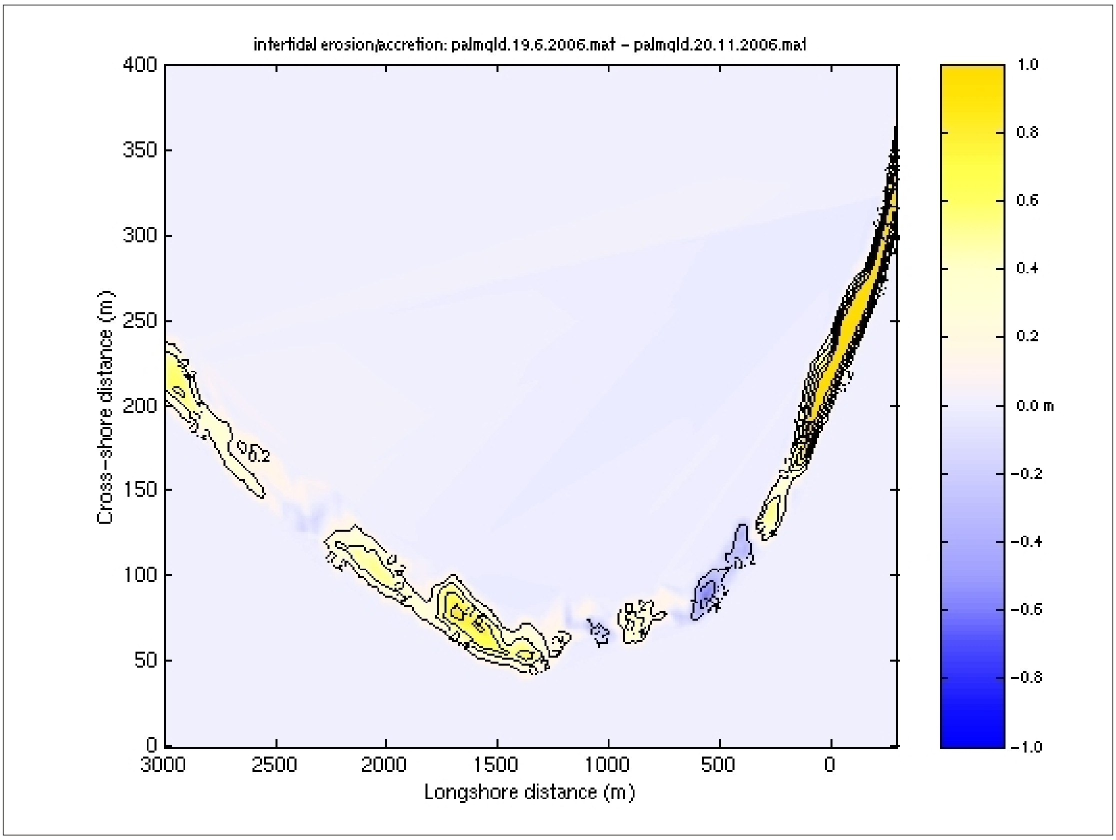


NET CHANGE: FEBRUARY - MAY 2006

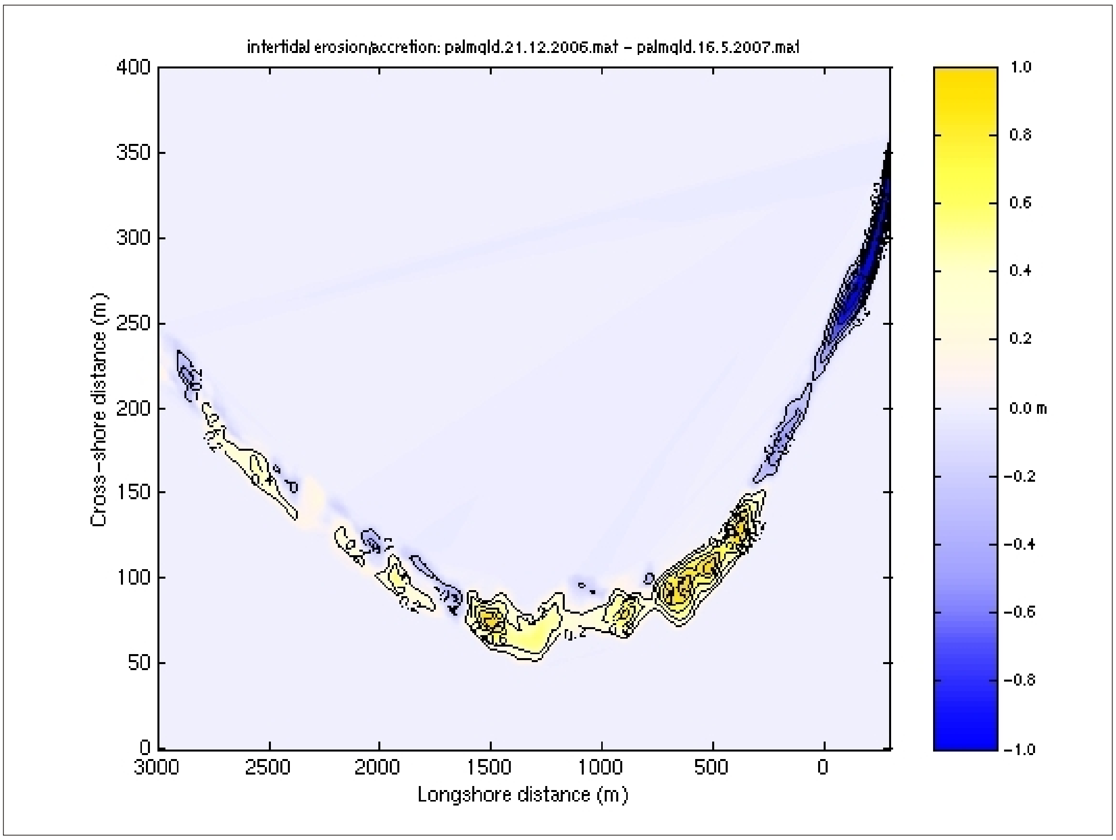


WRL Report No. 2008/18	EROSION/ACCRETION PER SIX-MONTH MONITORING PERIOD	Figure 8.6b 06037-8-6b.cdr

NET CHANGE: JUNE - NOVEMBER 2006



NET CHANGE: DECEMBER 2006 - MAY 2007



WRL Report No. 2008/18	EROSION/ACCRETION PER SIX-MONTH MONITORING PERIOD	Figure 8.6c

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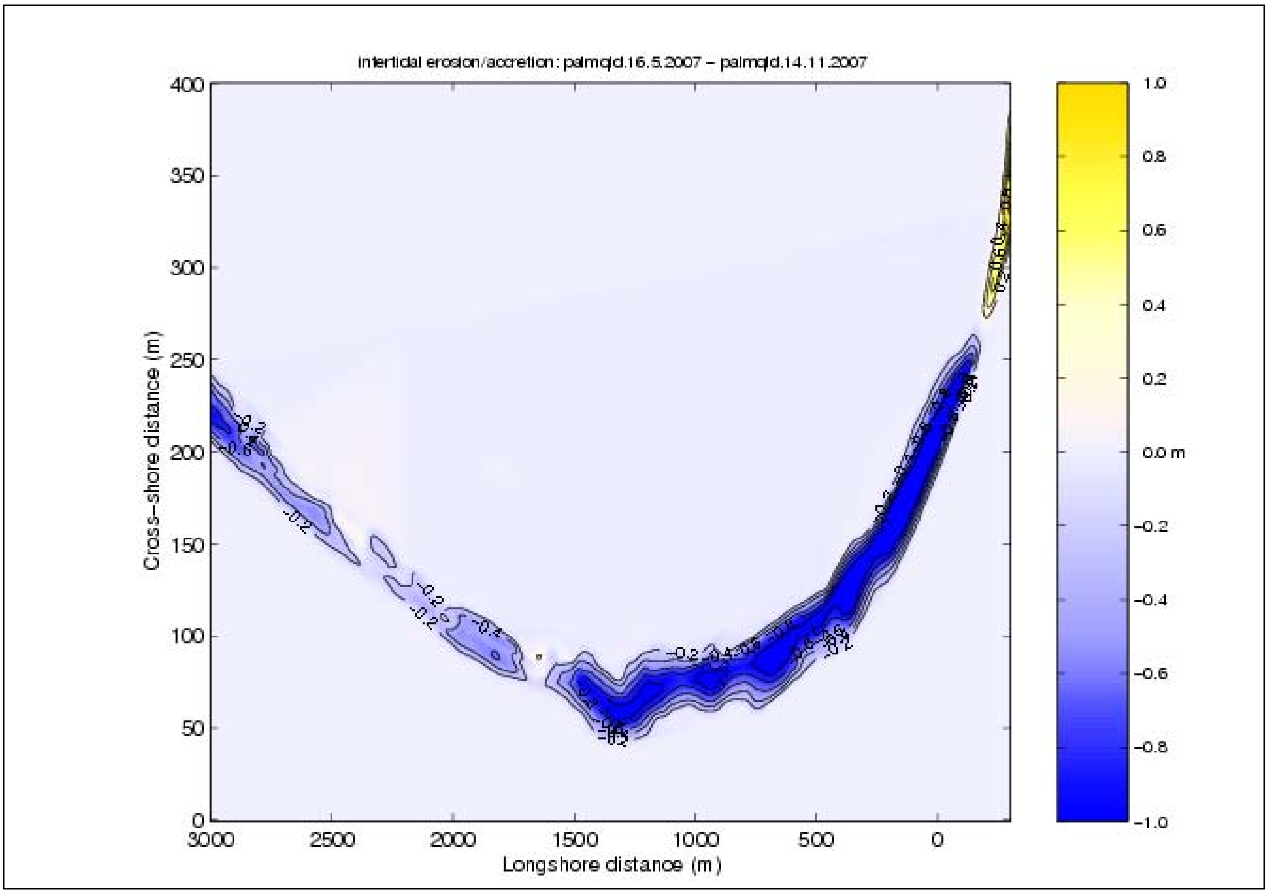
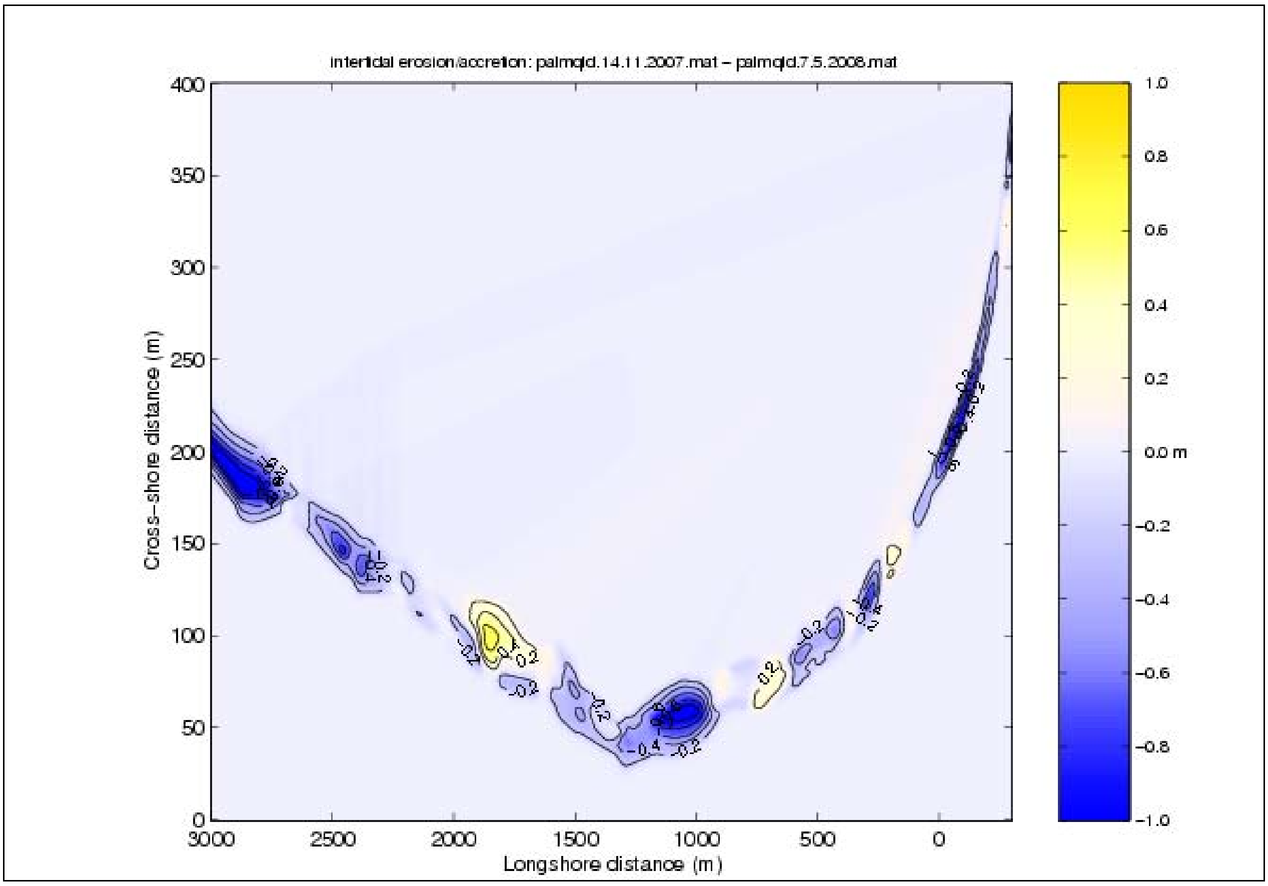
NET CHANGE: MAY- NOVEMBER 2007

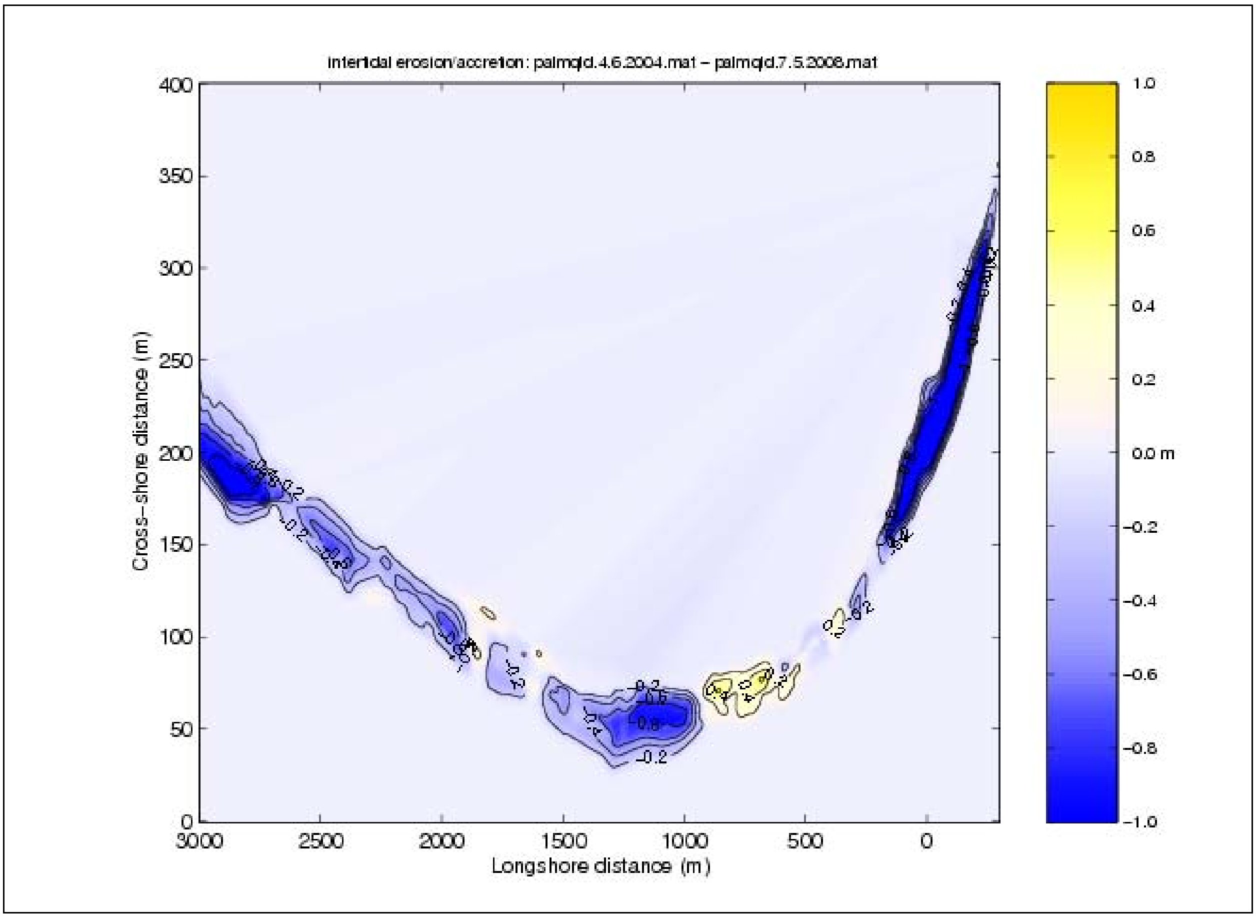


NET CHANGE: NOVEMBER 2007- MAY 2008



WRL Report No. 2008/18	EROSION/ACCRETION PER SIX-MONTH MONITORING PERIOD	Figure 8.6d

TOTAL NET CHANGE: JUNE 2004 – MAY 2008



WRL Report No. 2008/18	TOTAL NET EROSION/ACCRETION TO MAY 2008	Figure 8.7

9. SUMMARY AND CONCLUSIONS

The present monitoring period December 2007 to May 2008 is the eighth in the series of regular six-month monitoring reports to be produced for Palm Beach. The end of this monitoring period marks four years of continuous analysis of the Palm Beach embayment.

9.1 Qualitative Visual Assessment

An alongshore wave energy gradient generally exists at Palm Beach, due to the increased exposure at the northern end of the embayment to the predominately south-easterly swells. The effect of this gradient on the beach and nearshore zone is typically more noticeable following periods of high wave energy, with the beach appearing more uniform across its length after periods of low wave energy.

Beach and nearshore conditions during the first half of the current monitoring period between December 2007 to February 2008 were dominated by the large storm waves at the end of December and start of January, as well as the storm event near the end of February. The later half of the monitoring period saw generally lower ongoing wave conditions. The large tides and storm waves at the end of 2007 and start of 2008, resulted in significant erosion and scarping along most sections of the beach. Steady recovery of beach width was then experienced during the last half of the monitoring period.

A qualitative visual assessment of the net trends in beach adjustment during this period can be seen by contrasting images of the beach obtained at the start and end of this six-month monitoring period. A visual assessment of resulting beach changes from December 2007 to May 2008 (Figure 5.2 and Figure 5.3) shows that during the present six month monitoring period, along the southern section of beach in the region of the Currumbin Spit, the beach slightly narrowed. The effect of the higher energy waves experienced from December 2007 to February 2008 are still evident at the end of the current monitoring period, with the surfzone somewhat flatter and wider than six months previous. Looking north along the Palm Beach embayment, it is apparent that the beach was eroded significantly in the vicinity of the 11th Street groyne and also to the north of the 21st Street groyne. The surfzone can also be seen to be wider and flatter across the northern section of the embayment, typical of a higher energy morphological state.

Extending this qualitative visual assessment of images to include the entire four year monitoring period, (Figures 5.4 and 5.5) from June 2004 to November 2004, along the southern beach the surfeit of sand that was observed within the intertidal and nearshore zones in June 2004, appeared to have moved onshore by November, resulting in modest beach widening and a general straightening of the beach alignment in this southern region. Towards the north, from June to November 2004 the southern end of this region appeared to have generally widened. In contrast, towards the middle and northern end of the embayment, the shoreline appeared much more irregular and scalloped, with a discernable trend of a generally narrower beach.

From December 2004 to May 2005 the southern beach receded again, and from visual assessment was clearly narrower than the initial beach conditions observed 12 months earlier in June 2004. In contrast, towards the north a general trend of beach widening was observed, with the beach reverting to a more uniform alignment than was observed to develop during the preceding six month period.

During June to December 2005 a general trend of beach widening was apparent at the far southern end of the Palm Beach embayment, while in the region in the immediate vicinity of the Royal Palm building little net change in beach width is discernable. The region immediately south of the 11th Street groyne decreased in width, while the region between the 11th and 21st Street groynes increased in beach width. By December 2005 the southern beach was similar to the commencement of the monitoring program in June 2004, while along the central and northern regions of embayment the impacts of the nearshore nourishment campaign were clearly discernable, with the beach especially to the south and between the 11th and 21st Street groynes exhibiting a substantially wider beach and more uniform alignment alongshore.

During the period December 2005 to May 2006 a distinctive trend of beach narrowing was apparent at the far southern end of the Palm Beach embayment in the region of the Currumbin Spit. Immediately south of the 11th Street groyne the beach had increased in width, while the region between the 11th and 21st Street groynes and to the north exhibited a general trend of beach retreat. The beach conditions that prevailed at the end of May 2006 along the southern Palm Beach embayment were similar to the eroded conditions observed 12 months earlier in May 2005. Along the northern beach the conditions in May 2006 were intermediate to the accreted beach that was observed in May 2005, and the eroded beach observed six months prior to that time in December 2004.

During the period between May and November 2006, a general trend of beach widening occurred across the far southern end of the Palm Beach embayment, while a more modest trend of increasing beach width was observed in the immediate vicinity of the Royal Palm building. Minor recession occurred across the region immediately south of the 11th Street groyne, while the region immediately to the north slightly widened. In the vicinity of the 21st Street groyne and further north along the Palm Beach embayment, little net change in the beach was observed.

From November 2006 to May 2007 notable beach recession occurred across the far southern end of the beach in the region of the Currumbin Spit, reducing further to the north in the immediate vicinity of the Royal Palm building. Looking northward along the Palm Beach embayment, there was significant accretion on the southern side of the 11th Street groyne, as well as in the vicinity of the 21st Street groyne and further to the north. The similarity in appearance of the beach and nearshore zone looking both south and north, between the images taken at the end of May 2005 and May 2006, was worth noting.

From June to November 2007, the southern section of beach in the region of the Currumbin Spit widened significantly, which was primarily the result of nourishment of this section of the beach during October and November. The effect of the nourishment on beach width decreases rapidly in a northward direction, with the beach actually decreasing in width in the vicinity of the Royal Palm building during the same period. Across the northern section of the Palm Beach embayment, the majority of the beach experienced a trend of erosion between June and November 2007, with the sections of beach adjacent the 11th Street groyne experiencing the most extensive narrowing, and erosion further north around the 21st Street groyne less pronounced.

During the current monitoring period between November 2007 and May 2008 the beach to the south of the Royal Palm building can be seen to have slightly narrowed. Further north, significant net erosion can be seen to have occurred in the vicinity of the 11th Street groyne and also to the north of the 21st Street groyne. The effect of the higher energy waves experienced from December 2007 to February 2008 are still evident at the end of the current monitoring period, with the surfzone somewhat flatter and wider than in November 2007.

9.2 Shoreline Variability and Weekly Beach Width Analysis at GCCC Survey Lines ETA29 – ETA36

Based upon the quantitative analysis of the available weekly shoreline positions during the present monitoring period 01/12/07 – 31/05/08, the beach along the Palm Beach oceanfront varied in width from a minimum of approximately 40 m (relative to the alignment of the back-beach boulder wall) adjacent to the 11th Street groyne, to around 180 m at the extreme northern end of the embayment adjacent to Tallebudgera Creek. The envelope of beach width changes along the entire embayment was in the range of 20 - 50 m during this period.

At the southern end of the boulder wall, adjacent to Currumbin Creek, the reference boulder wall alignment dips landward. In previous monitoring reports, the beach width along the Currumbin Spit has been shown to increase rapidly to the south along the spit, as a result of the width being documented relative to the end of the boulder wall. To allow for easier interpretation of the beach width further south than the boulder wall along Currumbin Spit, the reference line has been updated as an arbitrary line joining the end of the boulder wall with a fixed point on the southern training wall of the Currumbin creek. While this does result in a non-uniformity in plotted beach width relative to the boulder wall, the data can be interpreted more easily.

The median beach width at mid-tide (relative to the alignment of the back-beach boulder wall) was of the order of 40 – 80 m along much of the Palm Beach embayment. With the alignment of the boulder wall changing orientation and dipping landward at the southern sand spit, the measured beach width was observed to increase accordingly, reaching 125 m in front of the site of the cameras. Analysis of maximum and minimum beach width reveals a relatively uniform trend along the section of beach north of the 11th Street groyne, with the beach width varying by of the order of 10 m narrower and 20 m wider than the mean shoreline position. The variation in beach width along the southern half of the embayment was typically less, with the beach width varying by ±10 - 15 m from the mean shoreline position. The standard deviation (s.d.) of weekly shorelines from the mean shoreline position was relatively uniform and of the order of 5 to10 m, which is indicative of a relatively stable beach throughout the present 6-month monitoring period. Over the southern sand spit, and along the far northern stretches of the beach, a higher standard deviation in beach width of 15 to 20 m was experienced.

The variation in shoreline position measured at Gold Coast City Council's ETA transects 29 to 36 for the monitoring period December 2007 to May 2008 shows that the beach generally eroded during the first two months of the period, and then steadily recovered throughout the remaining 4 months. At the southern-most transect ETA29 located across the southern Sand Spit, the beach was seen to erode at the end of December 2007 and throughout January 2008 due to the large storms experienced during these months. Almost 40 m in beach width was lost during these months at transect ETA29. Beach width was relatively stable from February to March 2008, and then increased significantly throughout the last half of April and into May 2008. At the completion of the current six month monitoring period, the beach had recovered to be similar in width to that observed some six months earlier. The transects north of the Royal Palm building (ETA30, ETA31, and ETA32) all showed similar behaviour in terms of beach width throughout the current monitoring period. At these sections, the beach was observed to erode during the storm events of December 2007 and January 2008, before recovering slightly during February and March. During April and May 2008 the beach width remained consistent for the three transects between the Royal Palm building and the 11th Street groyne, ETA30, ETA31, and ETA32.

The weekly analysis of shoreline position at the central and northern transects ETA33 to ETA36 are shown in Figure 6.5. The beach width at these transects behaved similarly to the transects immediately to the south, experiencing loss of beach widths during December 2007 and January 2008 as a result of several large storms. During these months, approximately 20 m in beach width was eroded. This was followed by steady beach widths throughout February and March and then recovery of beach width during April and May. At the completion of the current monitoring period at the end of May 2008, beach width across the northern half of the Palm Beach embayment were typically similar to those observed six months earlier.

When the weekly shoreline data for the period November 2007 to May 2008 were re-analysed to assess beach width changes relative to the mean shoreline position for the preceding six month period (Figure 6.6), the analysis shows that the beach was generally narrower during the current monitoring period. North of the Royal Palm building, beach widths during the current monitoring period varied from typically 10 to 30 m narrower than the mean shoreline position from the previous monitoring period. The exception to the narrower beach widths was the section of beach south of the Royal Palm building along the Currumbin Spit, where beach widths were significantly greater during the current monitoring period. Along this section of the beach, beach widths ranged from similar to up to 40 m wider than the mean beach width for the previous monitoring period. This is partially due to the eroded state of this section of beach during the previous monitoring period between June and November 2007, as well as accretion across this section of the beach during the current monitoring period.

In summary, storm events experienced during December 2007 and January 2008 caused significant erosion along the entire beach, which dominated the erosion/accretion for the entire monitoring period. Following these storm events, the beach recovered to varying degrees in response to ongoing lower energy wave conditions, with the beach only slightly narrower at each of the monitoring transects at the end of the current monitoring period.

9.3 Erosion/Accretion Trends

Beachface bathymetries derived at monthly intervals along the Palm Beach embayment (Figures 8.2 - 8.4) continue to show a persistent feature of the Palm Beach embayment that there is a distinct flattening of the beach gradient northward along the beachfront. This observation is consistent with the increasing exposure of the beach to predominantly south-easterly waves. The flattening of the beach gradient with increasing distance north of Currumbin is attributed to the modal beach state transitioning from more reflective (steeper), lower-energy intermediate morphology in the south, to increasingly dissipative (flatter), higher energy intermediate beach states towards the north.

Early in the current monitoring period (December 2007) the beachface could be seen to be regular in alignment and steep to the south of the Royal Palm building, due to ongoing lower energy wave conditions. Between the ARGUS station and the 11th Street groyne, a series of undulations were present in the beachface, which are typical of lower/intermediate energy morphological conditions and nearshore rip currents. Along the northern section of the embayment, the intertidal beachface was relatively uniform, and notably flatter than the southern half of the beach. During late December 2007 and early January 2008, a series of intense storm events caused high energy wave conditions to impact the Palm Beach embayment causing the beachface to migrate significantly landward and become more uniform in alignment.

Between January and February 2008, a series of undulations again developed on the intertidal beachface, in response to the lull in wave energy. This was particularly evident over the middle regions of the Palm Beach embayment. The lower wave energy continued to dominate morphological processes into March 2008, with the development of a LTT between the Royal Palm building and the 11th Street groyne. By the end of the current monitoring period, the beachface was very irregular in alignment after experiencing minor erosion and accretion over different sections of the beach. On the south side of both the 11th Street and 21st Street groynes the beach eroded, with the intertidal beachface migrating by approximately 20 m landward.

The top panel of Figure 8.5a shows that from November to December 2007, there was a general trend of modest accretion along the Palm Beach embayment. The extreme southern and northern stretches of the beach experienced the most significant accretion, with the beachface increasing by up to 1 m in vertical elevation, while across the mid stretches of the embayment patches of minor erosion and accretion were experienced. Averaged along the entire Palm Beach embayment the net change in sand volume within the mapped beachface was **+21,120 m^3** of accretion, which equates to **+6.4 m^3 per m of shoreline** (between -0.5 and +0.7 m AHD).

From December 2007 to January 2008 (Figure 8.5a, middle panel), the beach suffered a high level of erosion as a result of a series of intense storm events striking the Queensland and northern New South Wales coastlines. Across much of the embayment, the intertidal beachface migrated some 40 m landward and lost in excess of 1 m of vertical elevation, resulting in significant scarping along the beach. It appears from the beachface map shown in Figure 8.5a (mid panel), that the 21st Street and 11th Street groynes provided some protection from the erosion, with the beach appearing to suffer lower levels of erosion on the southern side of these structures. Between December 2007 and January 2008 there was a predicted net erosion of some **-69,315 m^3** across the length of the embayment, equating to **-20.9 m^3 per m of shoreline** (between -0.5 and 0.7 m AHD). It is expected that over the entire beach profile, significantly larger quantities of beach would have been eroded during this period, however, analysis of these sections of beach using the intertidal beachface mapping technique is not possible.

Between January and February 2008 there was little net change in intertidal beachface volumes. Along the southern Currumbin Sand Spit, the beachface lost up to 1 m in vertical beachface elevation, while the area between the Royal Palm building and the 11th Street groyne experienced a gain in up to 1 m of vertical beachface elevation. North of the 11th Street groyne, localised pockets of both erosion and accretion were observed, with little net change in beachface volume experienced. From January to February there was a net beachface accretion over the entire embayment of **+6,116 m^3**, equating to **+1.8 m^3 per m of shoreline** (between -0.5 and +0.7 m AHD). Between February and March 2008, the northern half of the Palm Beach embayment had a net trend of erosion, increasing in intensity to the far north where up to 1 m in vertical beachface elevation was lost. South of the 11th Street groyne, pockets of localised erosion and accretion were somewhat irregular, with very little net change in the beachface along the southern sand spit. Overall there was minor accretion of **+4,240 m^3**, equating to **+1.3 m^3 per m of shoreline** over the intertidal beachface (-0.5 m to +0.7 m AHD).

Between March and April 2008, a more continuous trend of low volume accretion was experienced over most parts of the embayment. The beachface was typically seen to accrete up to 0.5 m in vertical elevation during this period. In total the net beachface accretion over the entire embayment was **+12,671 m^3**, equating to +**3.8 m^3 per m of shoreline** (between -0.5 and +0.7 m AHD). The most inactive one month period in terms of net sediment transport over the intertidal beachface occurred between April and May

2008. There was a general trend of slight erosion over the stretch of beach south of the Royal Palm building, while adjacent to and on the south side of the 11th Street groyne there was a patch of localised erosion, where the intertidal beachface lost over 0.5 m in vertical elevation. Between the 11th and 21st Street groynes the beach accreted slightly, while to the north of the 21st Street groyne patches of both erosion and accretion occurred. Between April and May 2008 the net beachface accretion over the entire embayment was **+1,563 m^3**, equating to **+0.5 m^3 per m of shoreline** (between -0.5 and +0.7 m AHD).

The final analysis of total net change in beachface bathymetry for the entire four year monitoring period June 2004 to May 2008 (Figure 8.7) shows that to date, the net erosion and accretion trends can be separated into four compartments along the length of the embayment. South of the monitoring cameras significant net erosion appears to have occurred, with the mapped beachface dropping in excess of 1 m in vertical elevation in this area. While the erosion/accretion analysis identifies this area as having undergone erosion, it is important to note that at the start of monitoring in June 2004, between 50,000 m^3 and 100,000 m^3 of nearshore nourishment had already been undertaken, and as a result, the beach was in an un-naturally accreted state. With the longshore littoral drift moving sand along the coast, and only minor nourishment being undertaken since early 2006, there has been a trend of steady decline in the nearshore sand volume, which is being identified as overall erosion in the total erosion/accretion trend analysis, for the region to the south of the ARGUS station.

The section of beach between the Royal Palm building and the 11th Street groyne has generally been a location of accretion, however, during the current six month monitoring period, this area suffered uncharacteristically high localised erosion. Over the stretch of beach between the 11th Street and 21st Street groynes there has been minor net erosion, while north of the 21st Street groyne there has been more modest net erosion observed, with the beachface approximately 1 m lower in vertical elevation at the end of the current monitoring period.

Within the intertidal beach (-0.5 and +0.7 m AHD) a total net volume of approximately **-51,076 m^3** of sand has eroded along the ~3.5 km of beachfront included in this monitoring program over the past four years, equating to an alongshore-average of around **-15.4 m^3** within the intertidal profile, for every 1 m alongshore.

10. ACKNOWLEDGEMENTS

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The Body Corporate of Royal Palm are thanked for permitting the ARGUS system to reside on the roof of the building. Also, we thank the building managers for their support during installation and routine maintenance visits to the site.

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Doug Anderson of WRL continues to manage the wave and tide data processing, computer operations for remote communications, image storage, off-line image archiving and web serving at WRL. Luis Mallen Lopez of WRL completed the weekly analysis and updating of monitoring program information via the project web site.

Finally, Professor Rob Holman of Oregon State University and the growing world-wide team of ARGUS users are acknowledged for continuing system development. These research efforts are providing practical tools for coastal monitoring and management.

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APPENDIX A

WEEK-TO-A-PAGE: DECEMBER 2007 – MAY 2008

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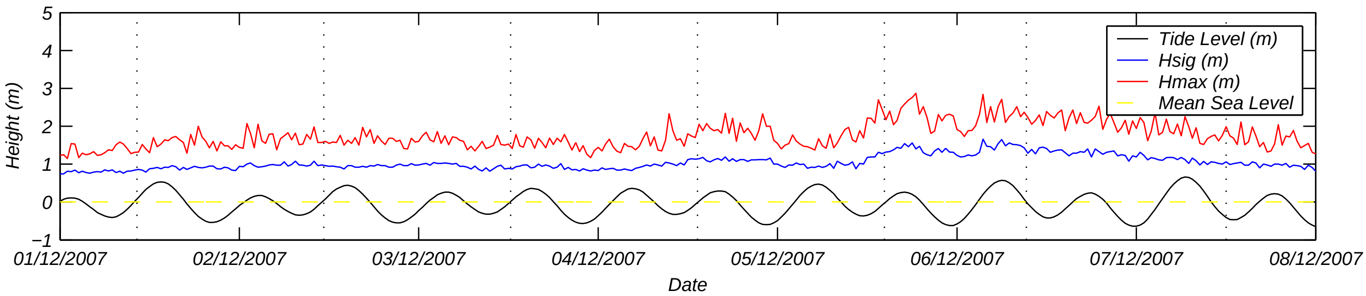

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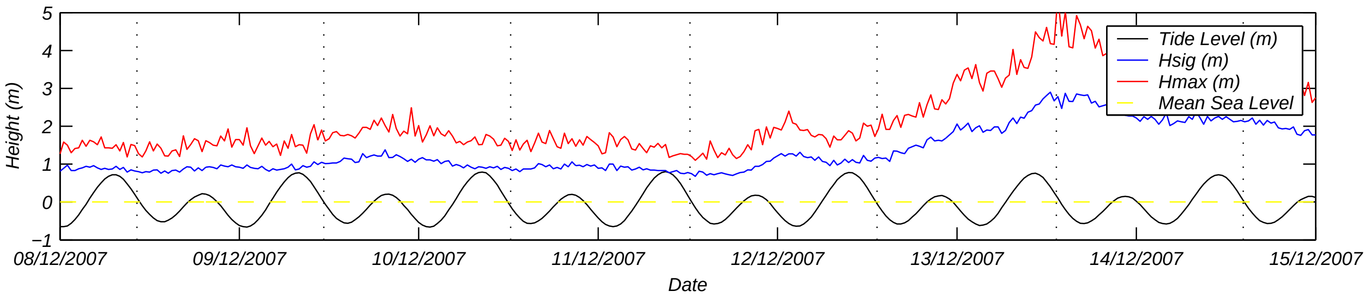

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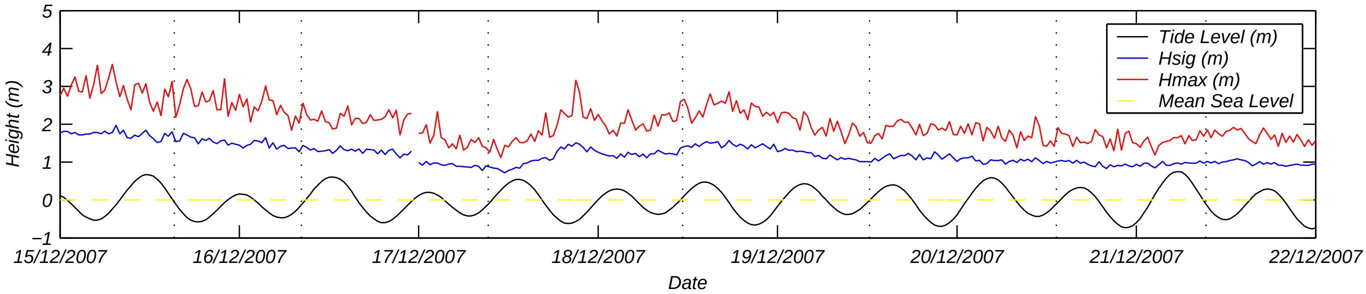

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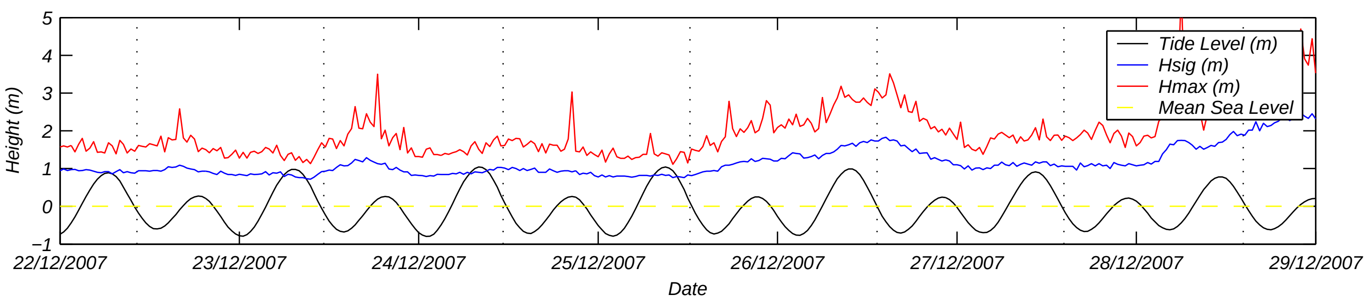

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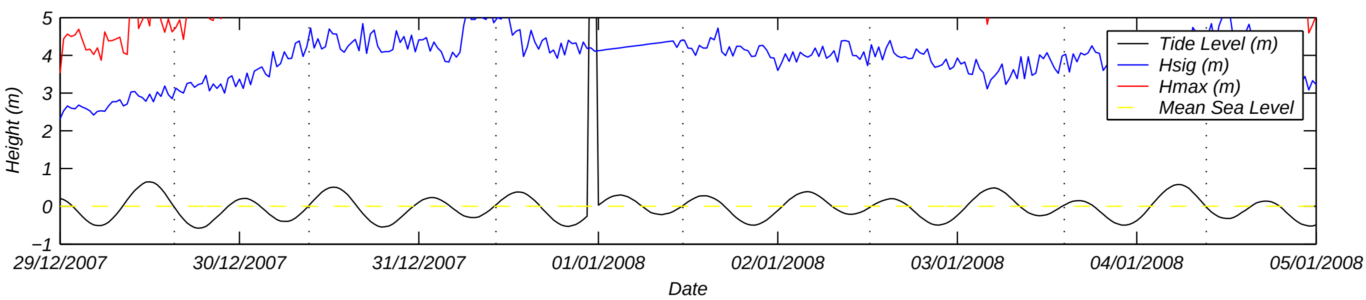

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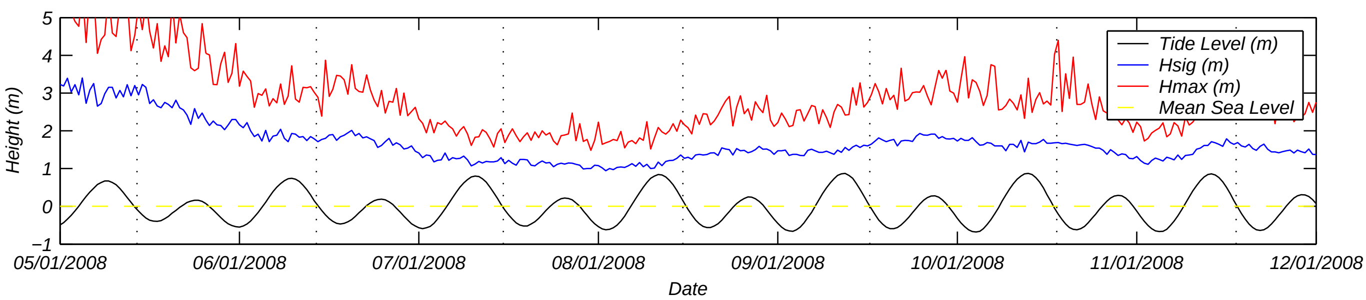

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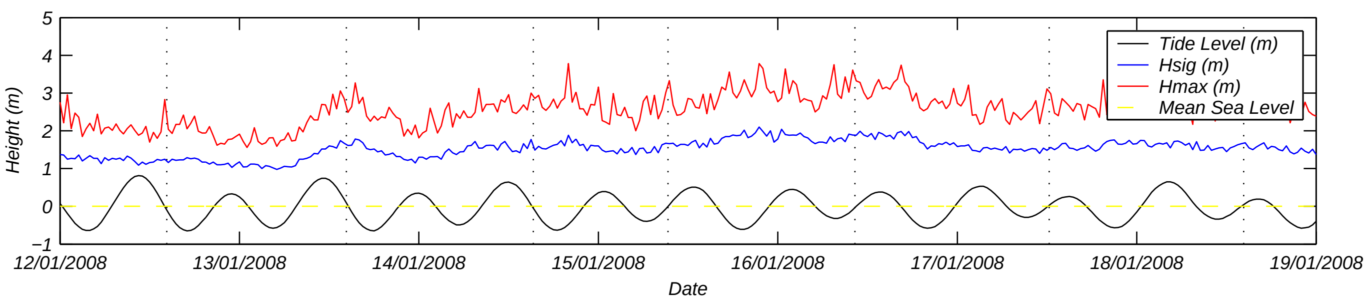

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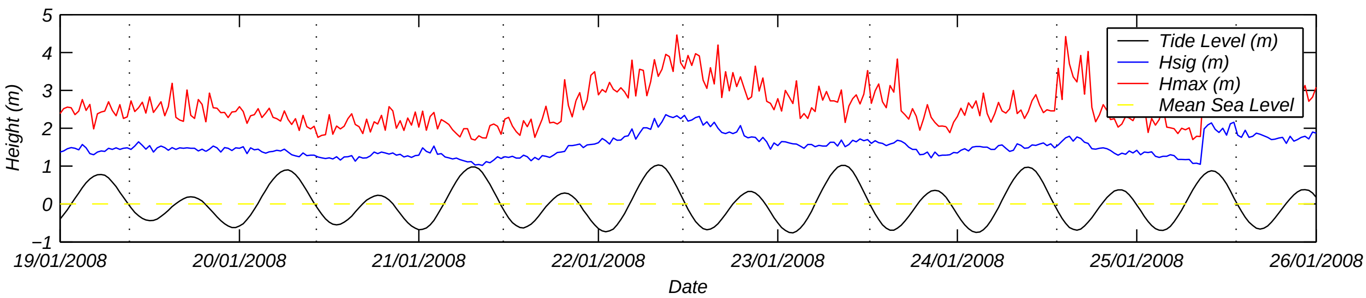

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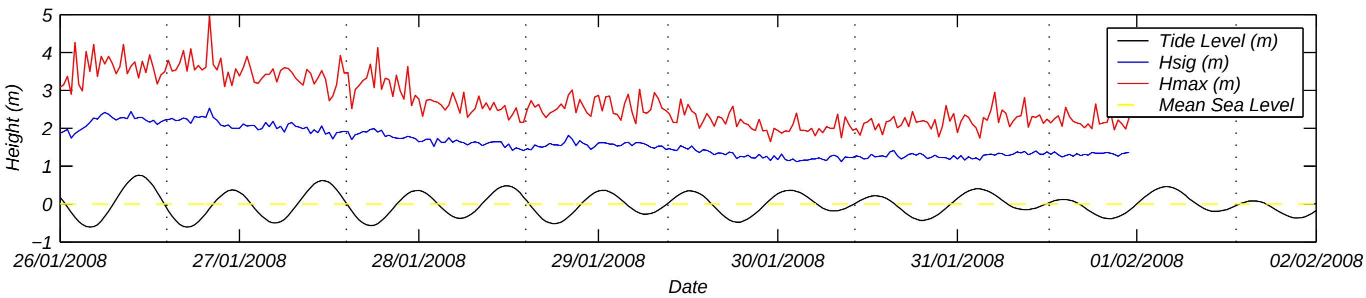

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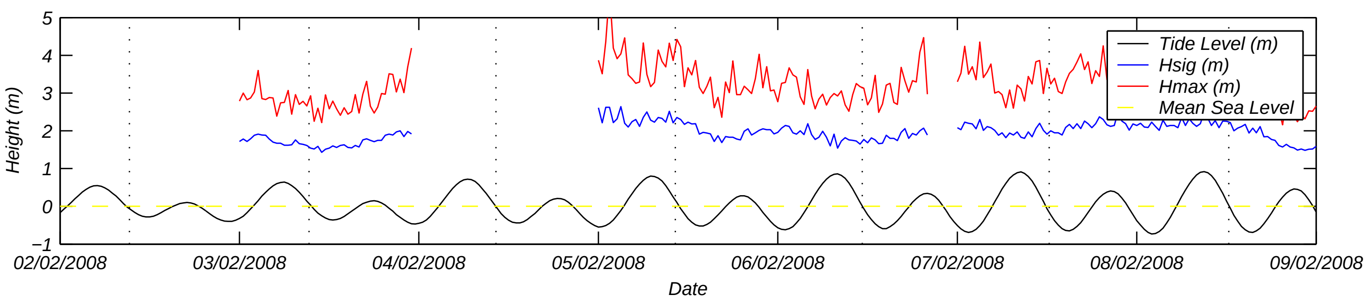

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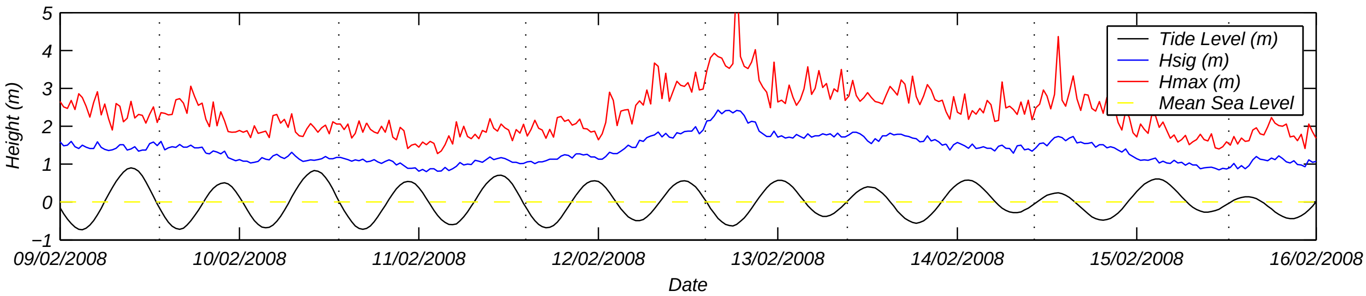

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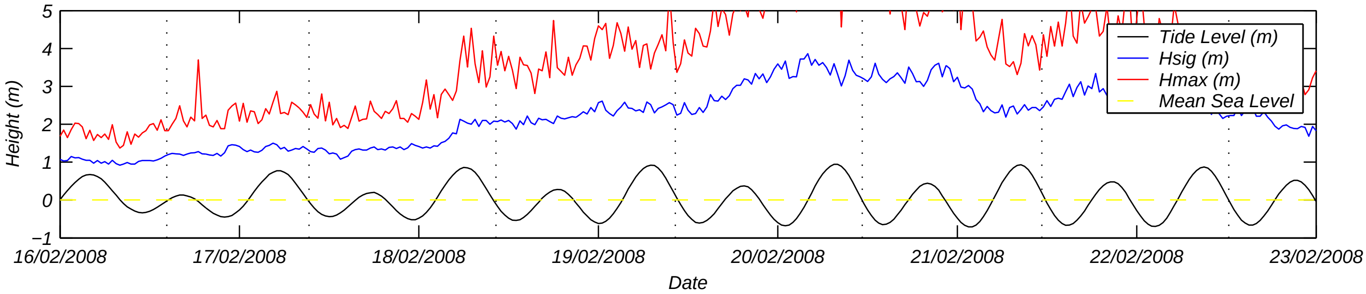

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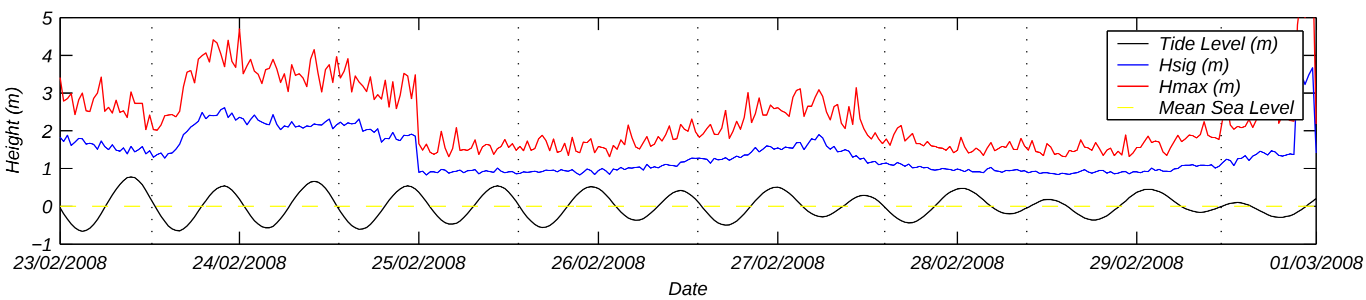

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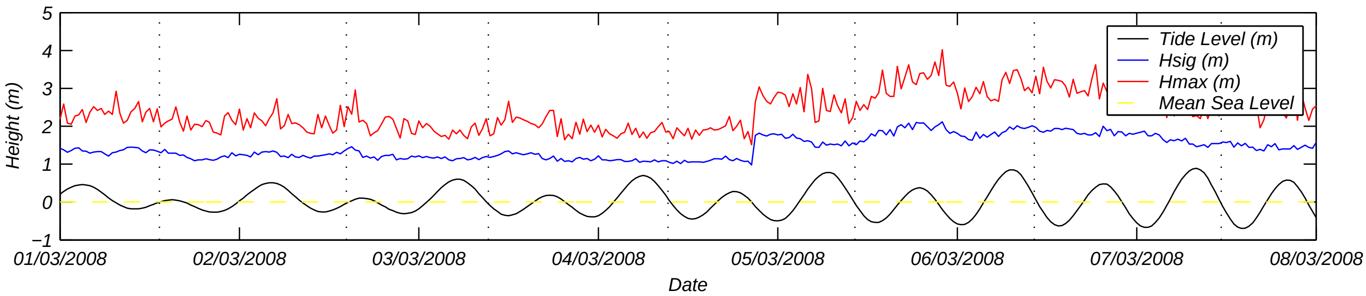

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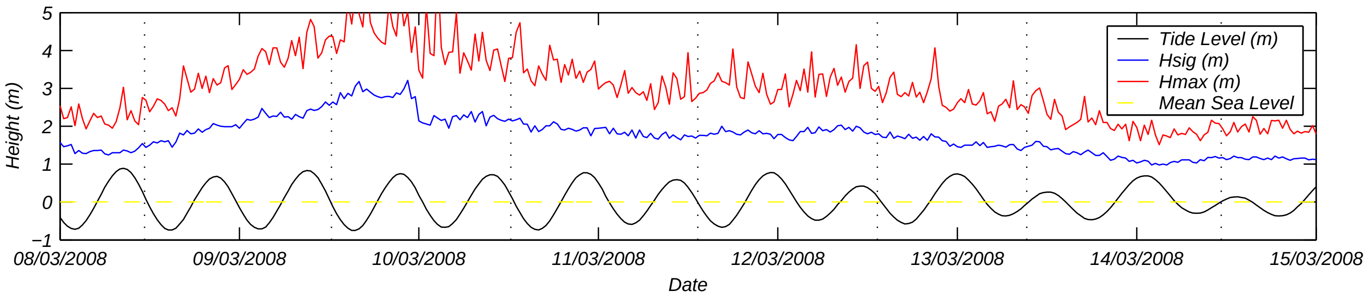

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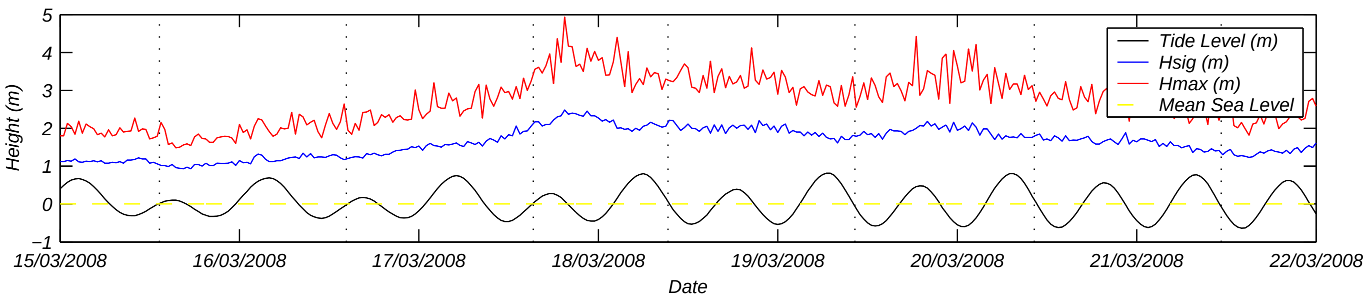

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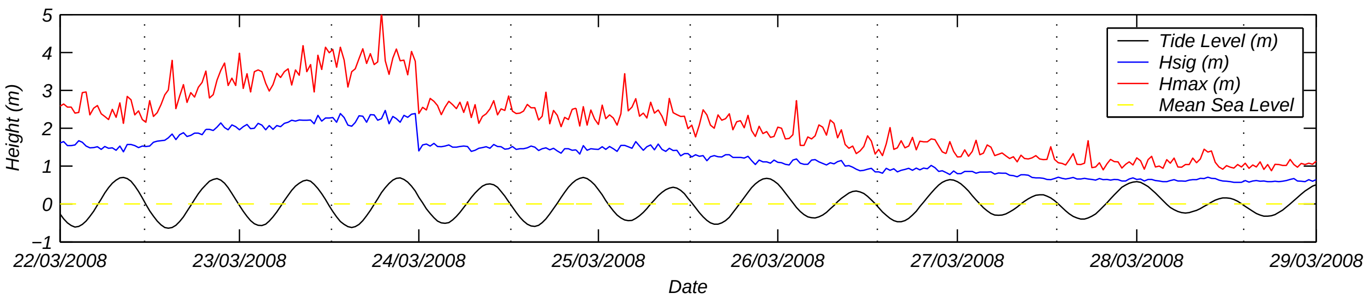

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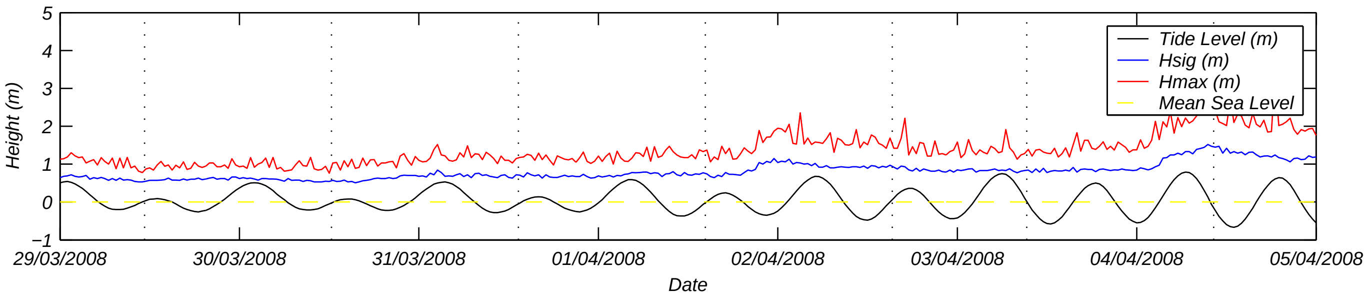

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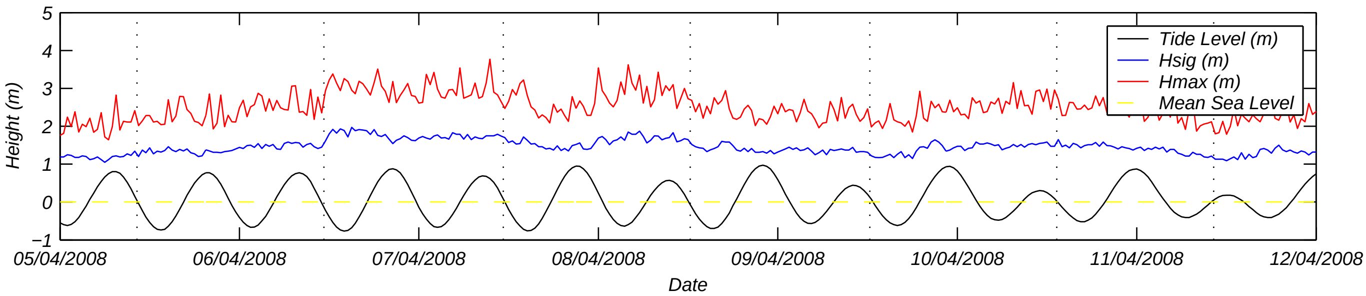

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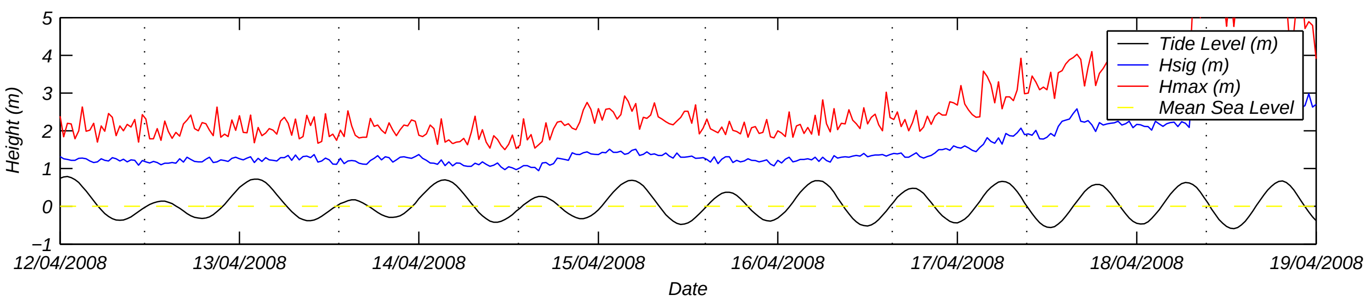

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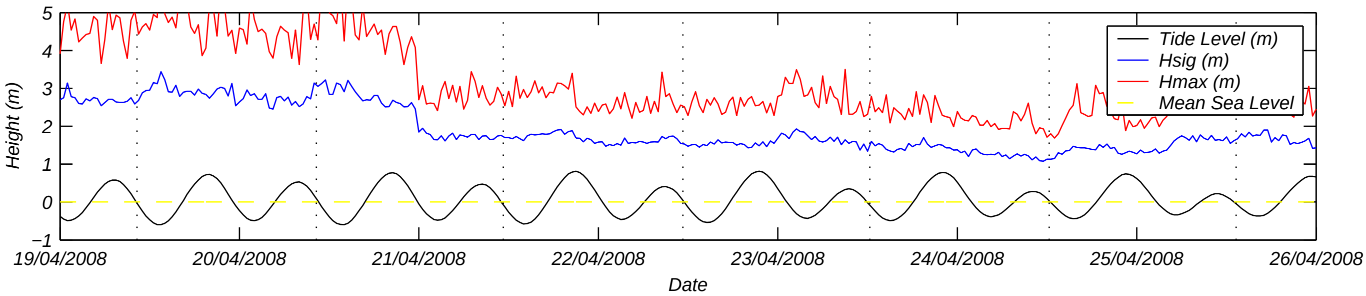

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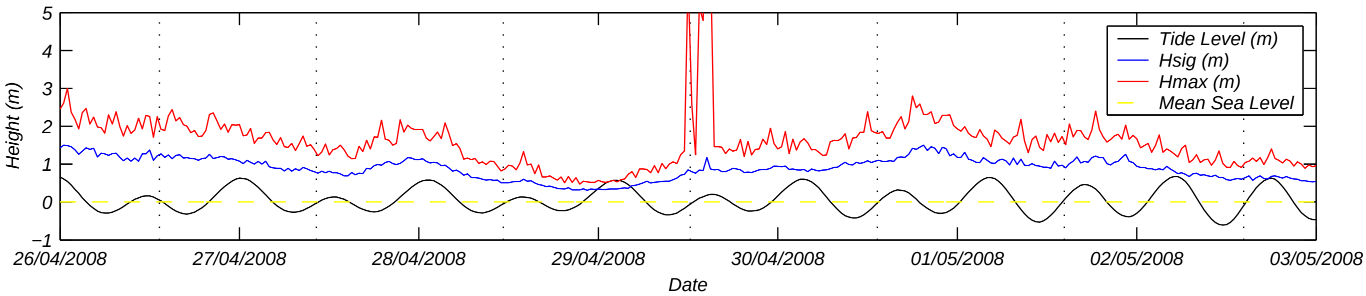

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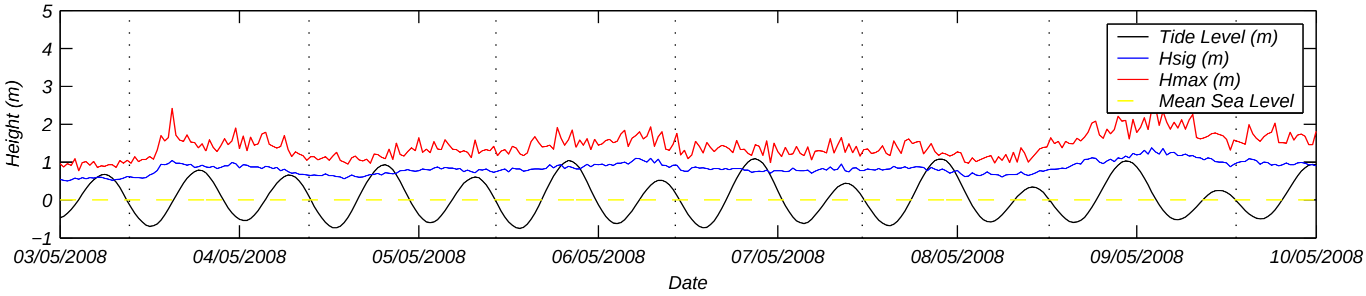

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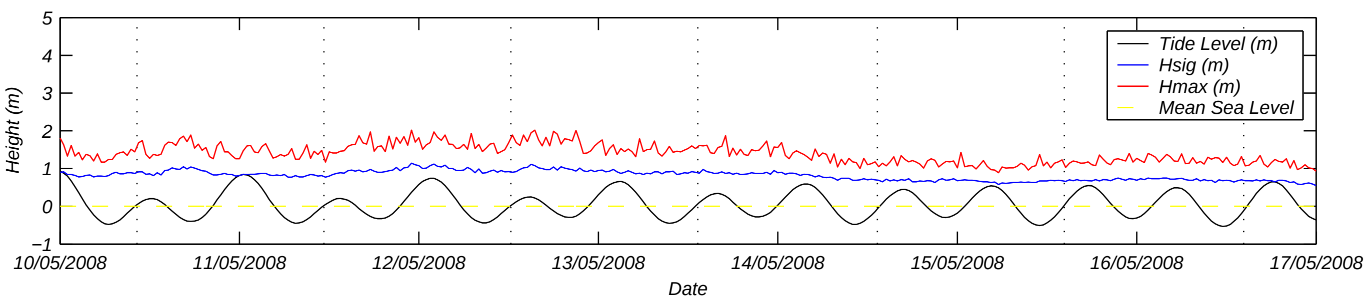

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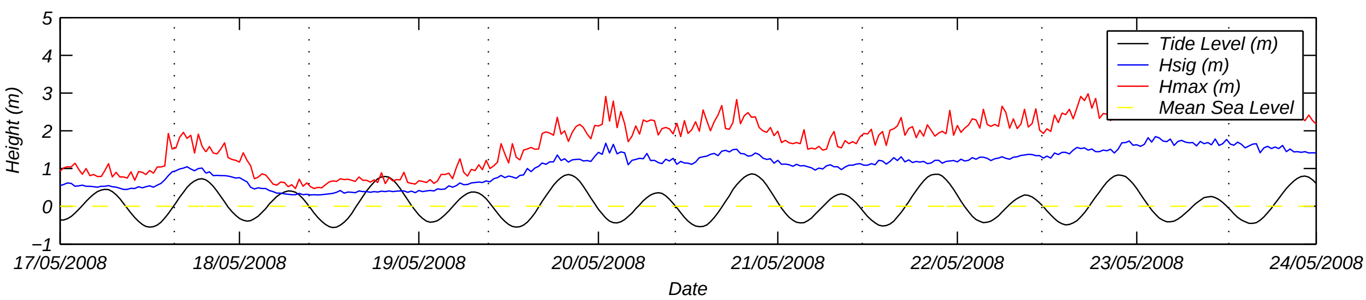

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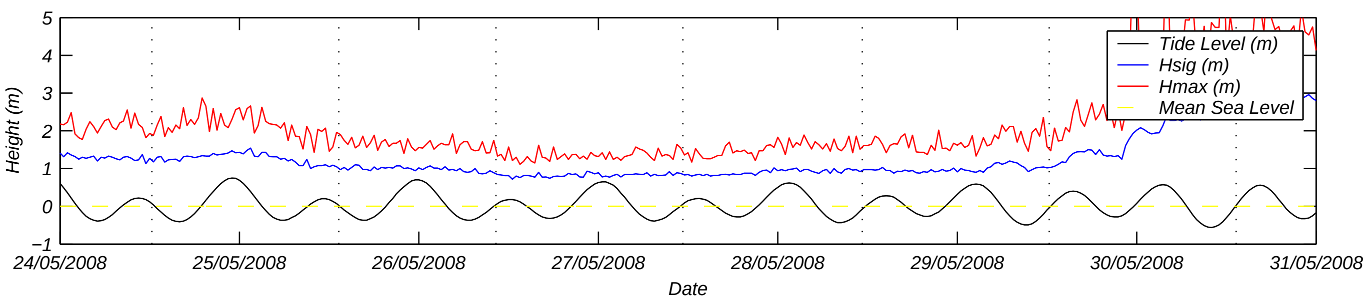
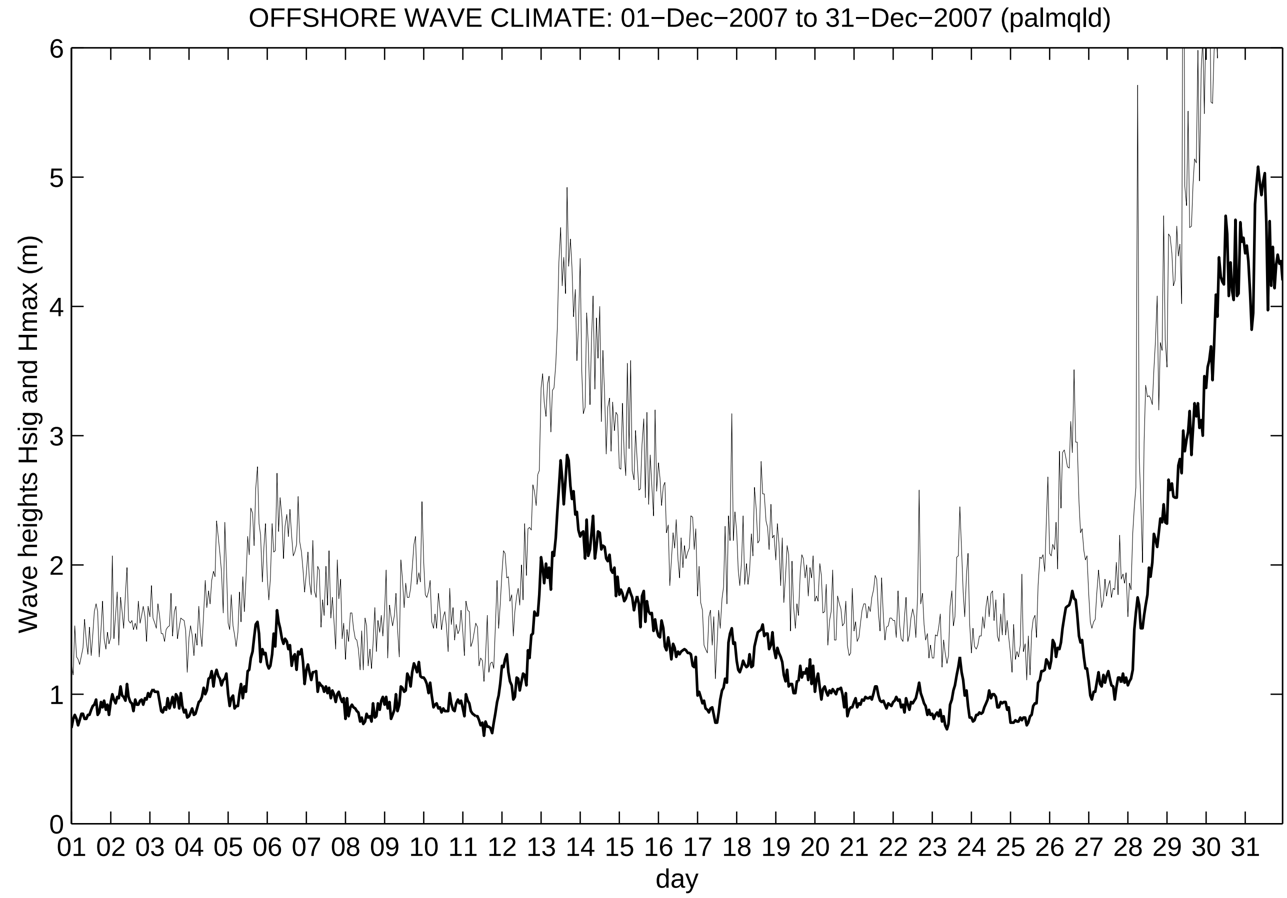
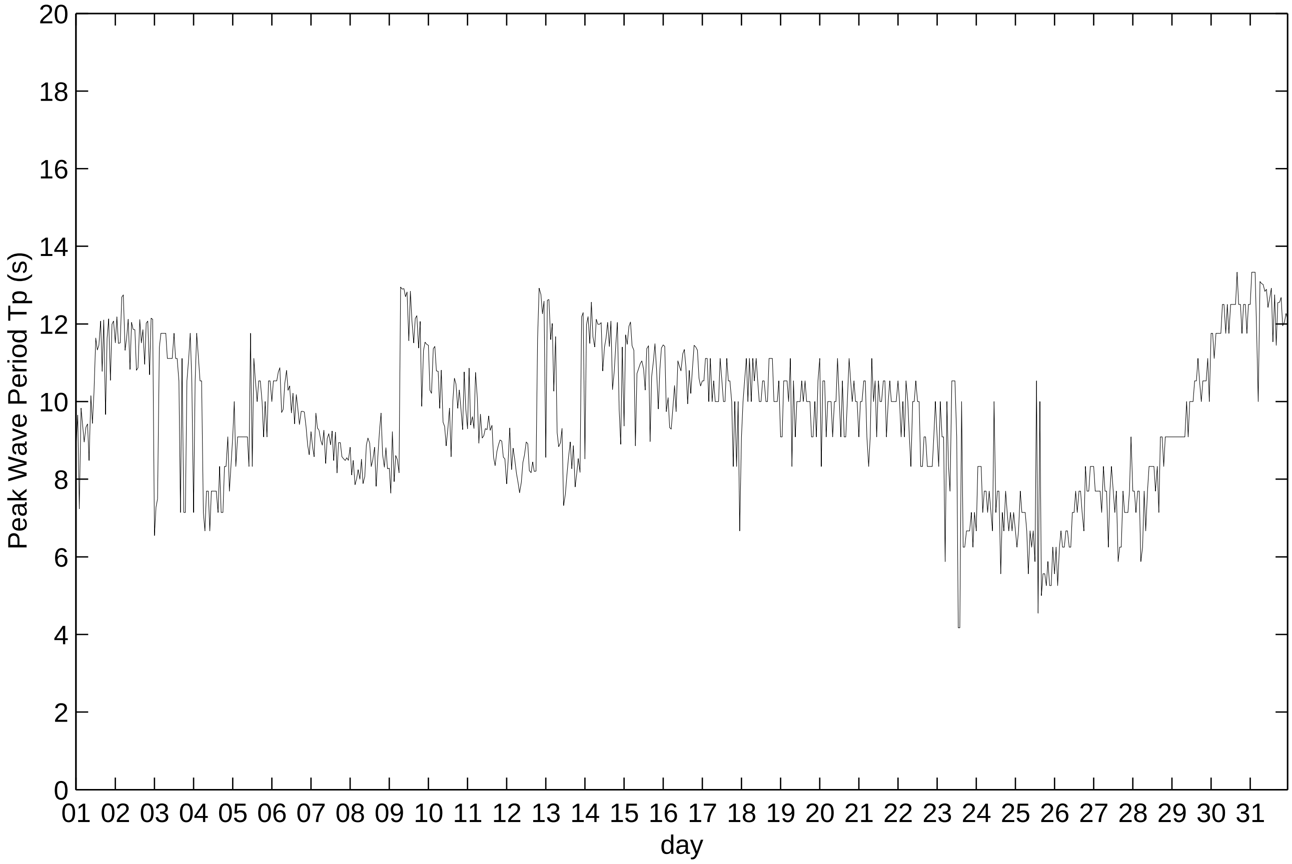


WRL	WEEK TO PAGE SUMMARY: MEAN SEA LEVEL PALM BEACH, QUEENSLAND 24/05/2008 − 30/05/2008	Figure A26
Report No.2008/18		

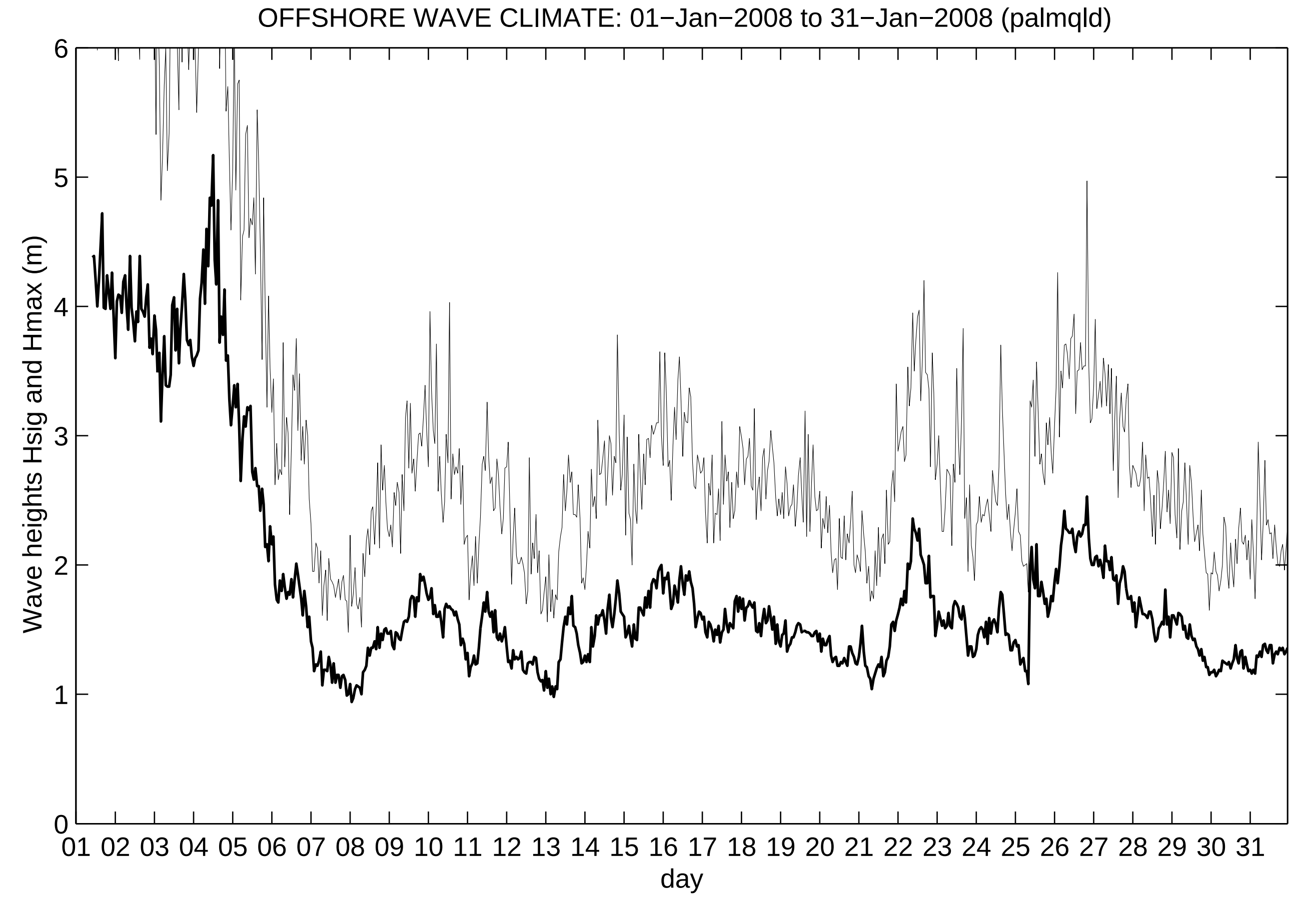
APPENDIX B

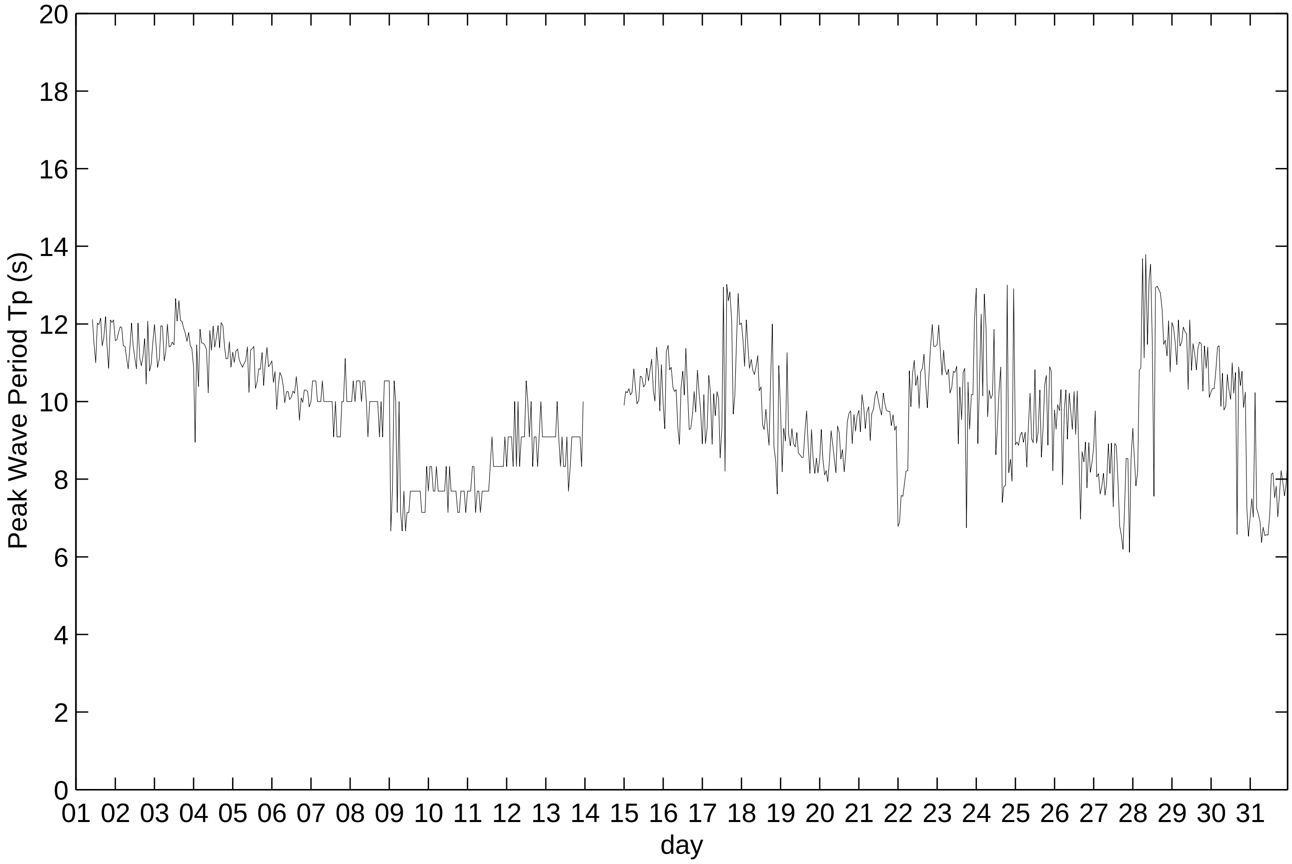
MONTHLY WAVE CLIMATE SUMMARIES: DECEMBER 2007 – MAY 2008



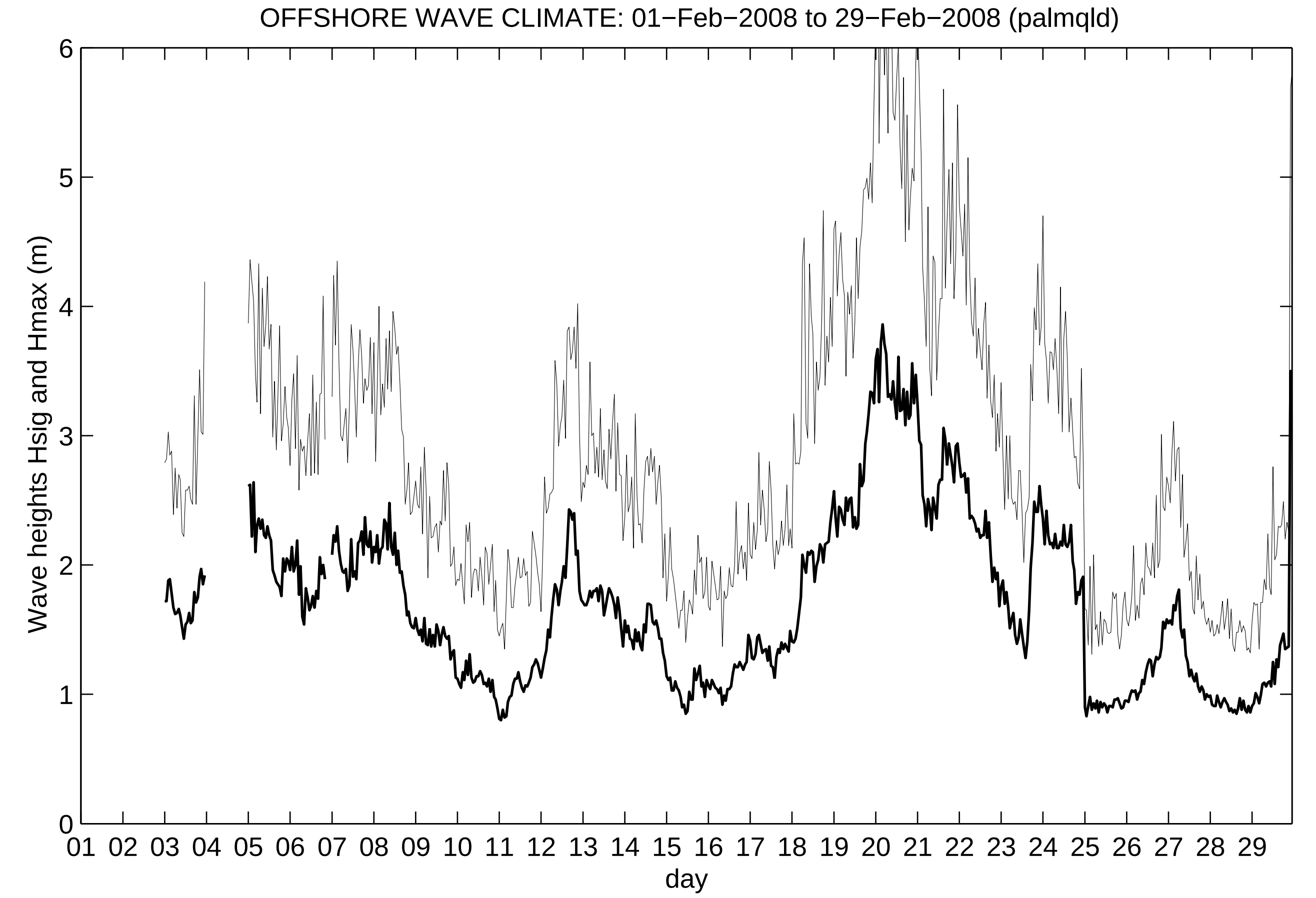


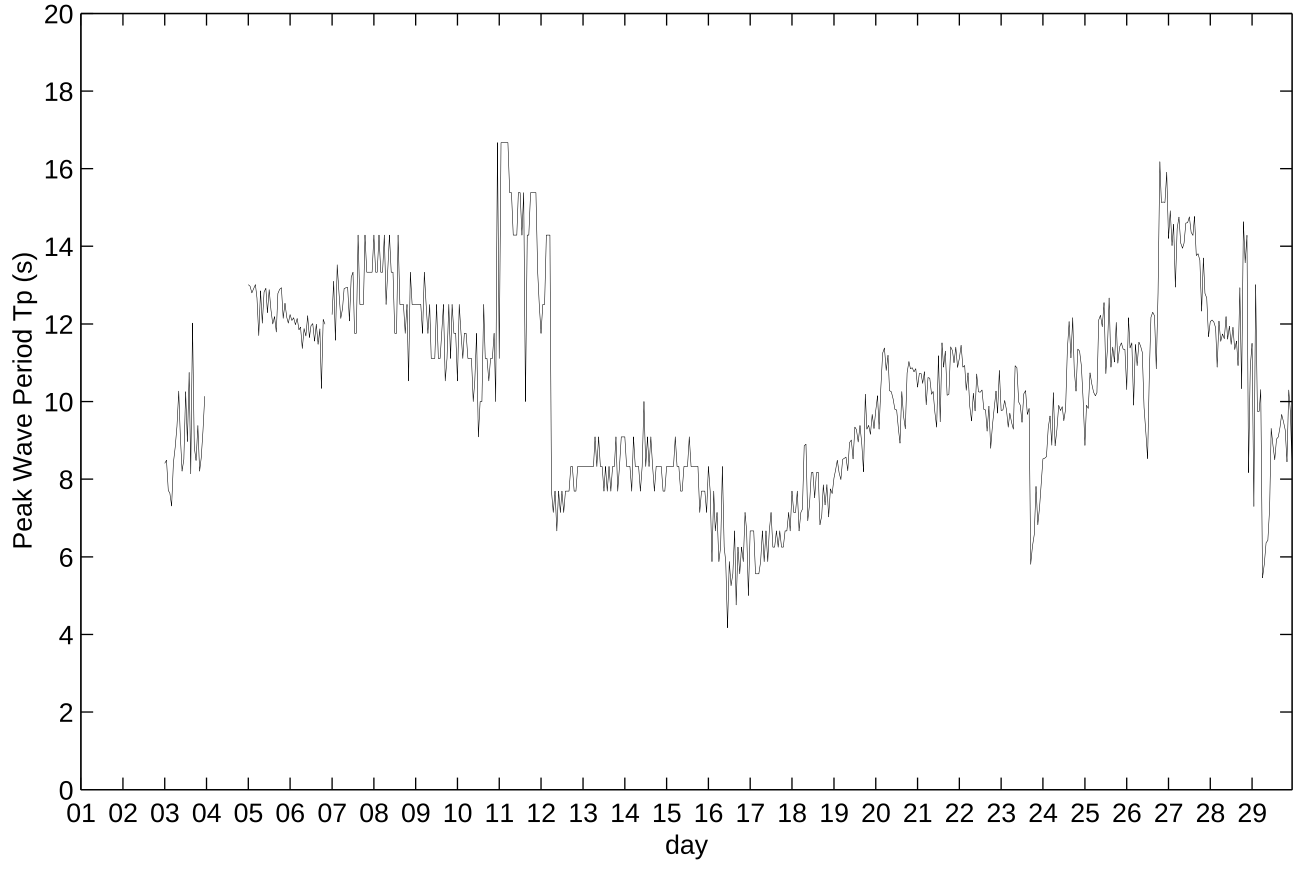
WRL Report No.2008/18	MONTHLY WAVE SUMMARY DECEMBER 2007	Figure B1



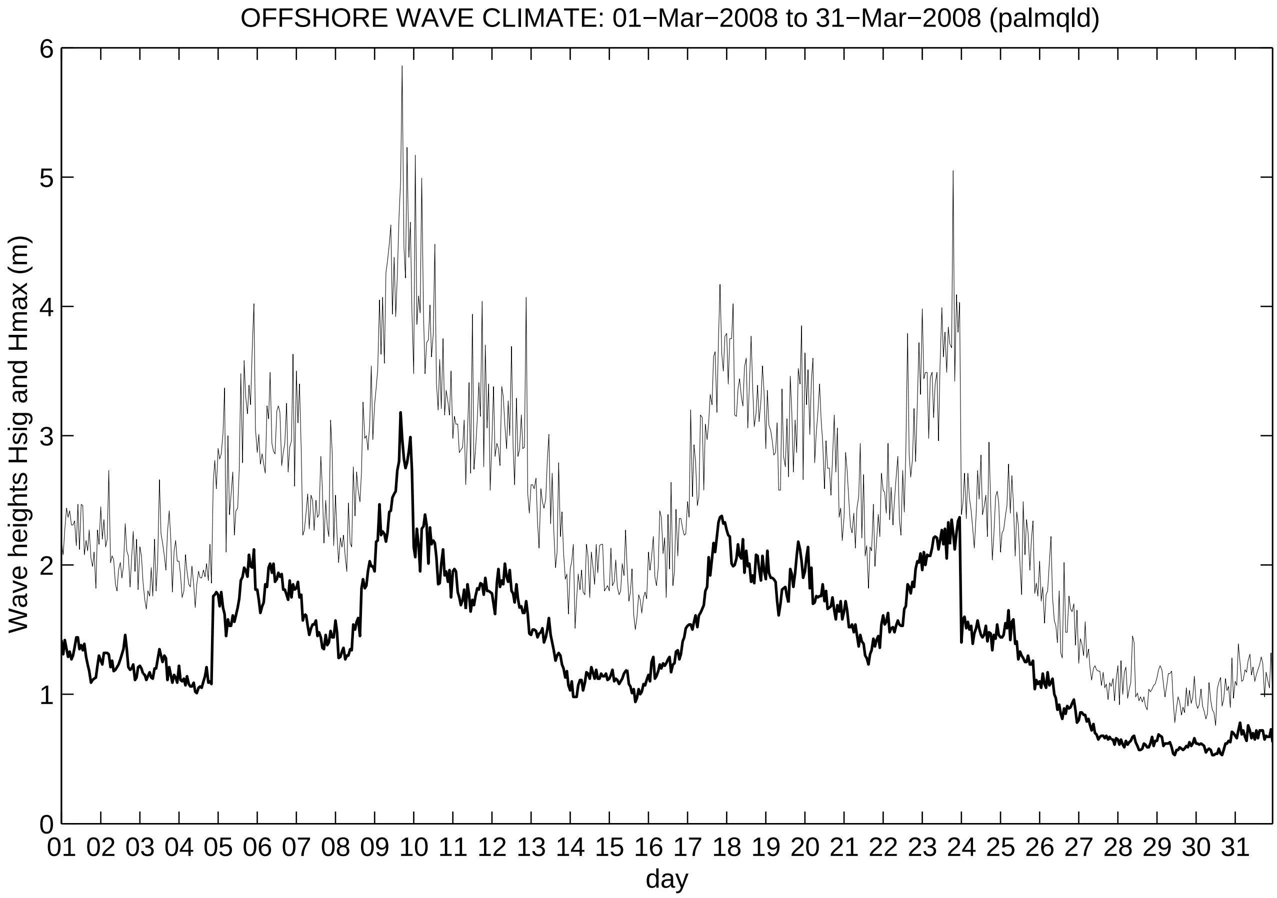


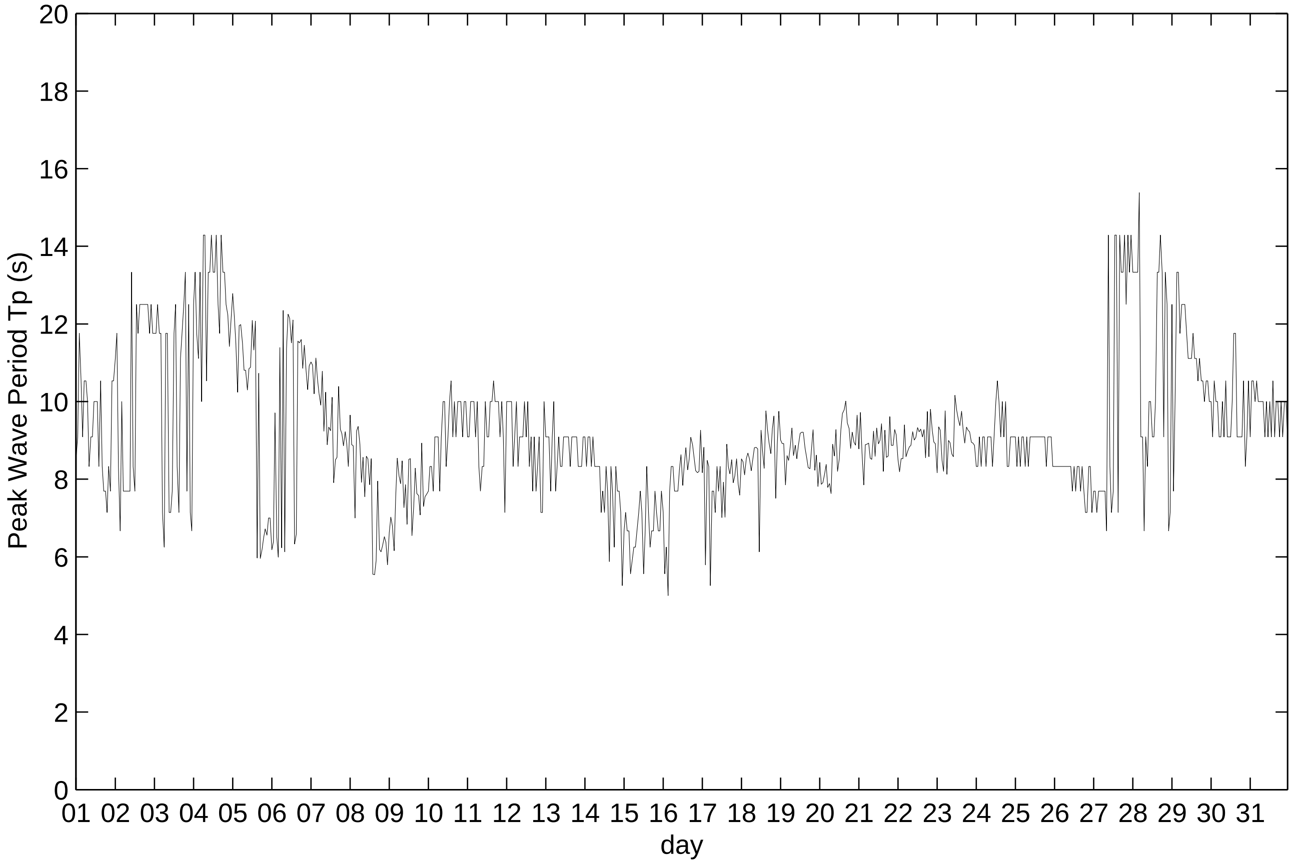
WRL Report No.2008/18	MONTHLY WAVE SUMMARY JANUARY 2008	Figure B2



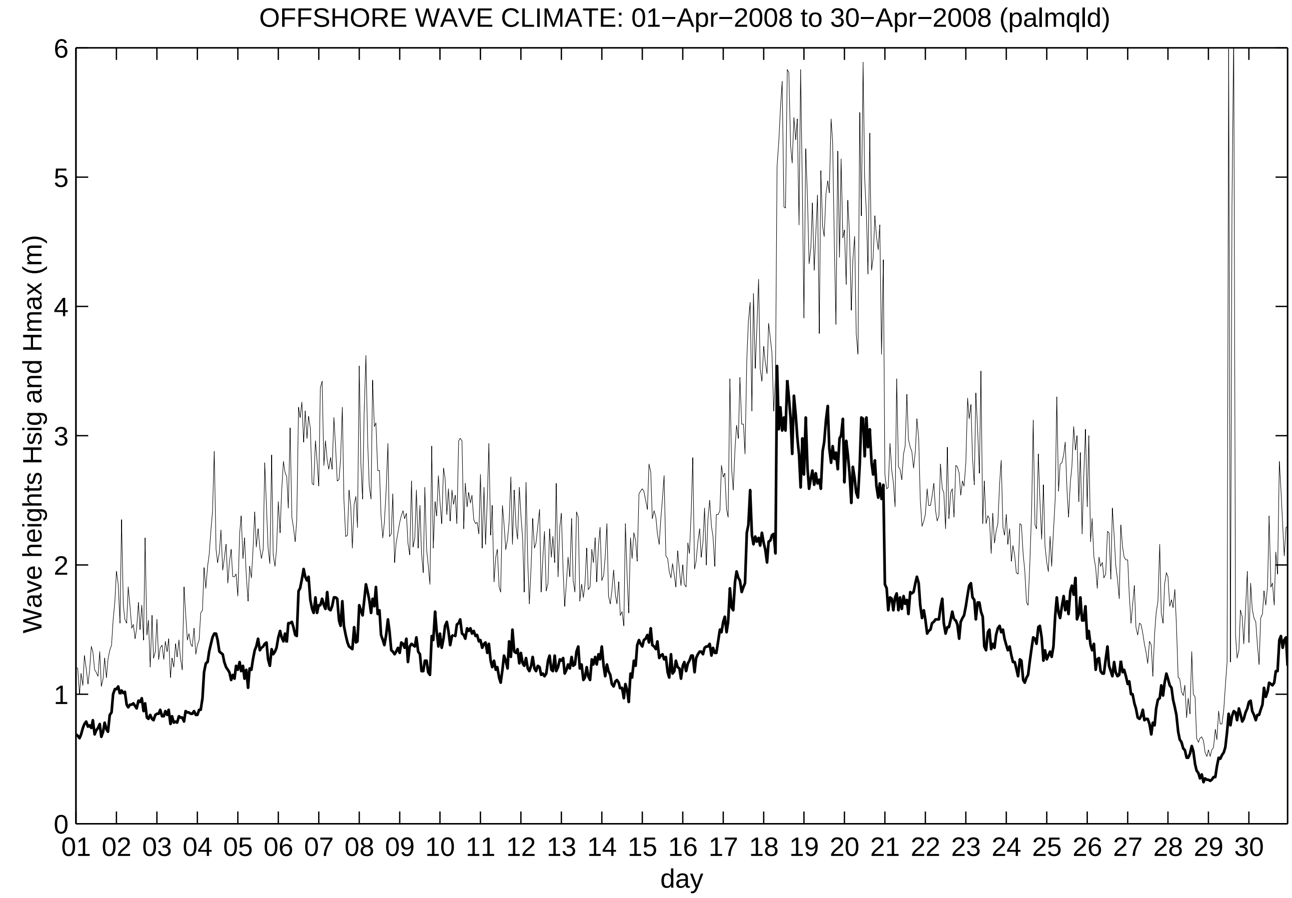


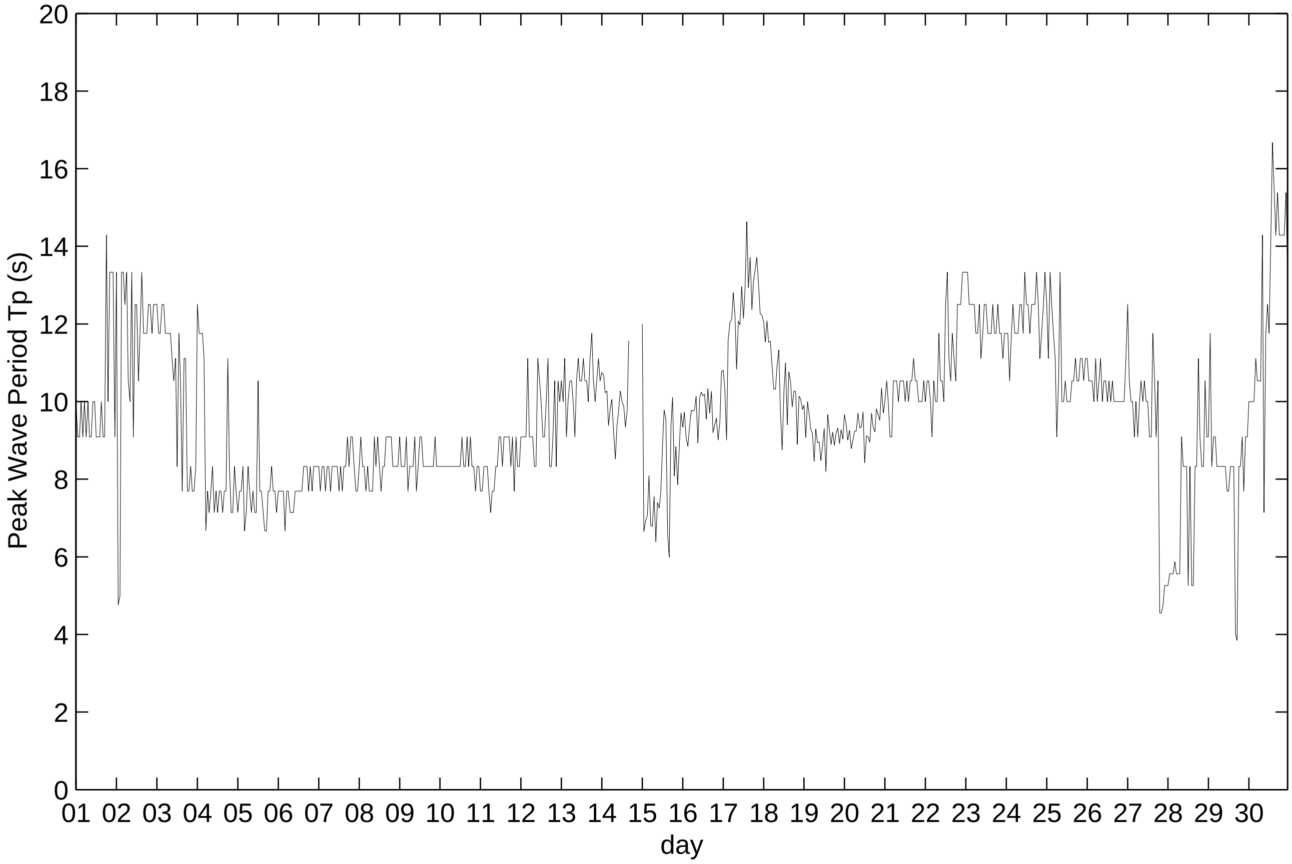
WRL Report No.2008/18	MONTHLY WAVE SUMMARY FEBRUARY 2008	Figure B3



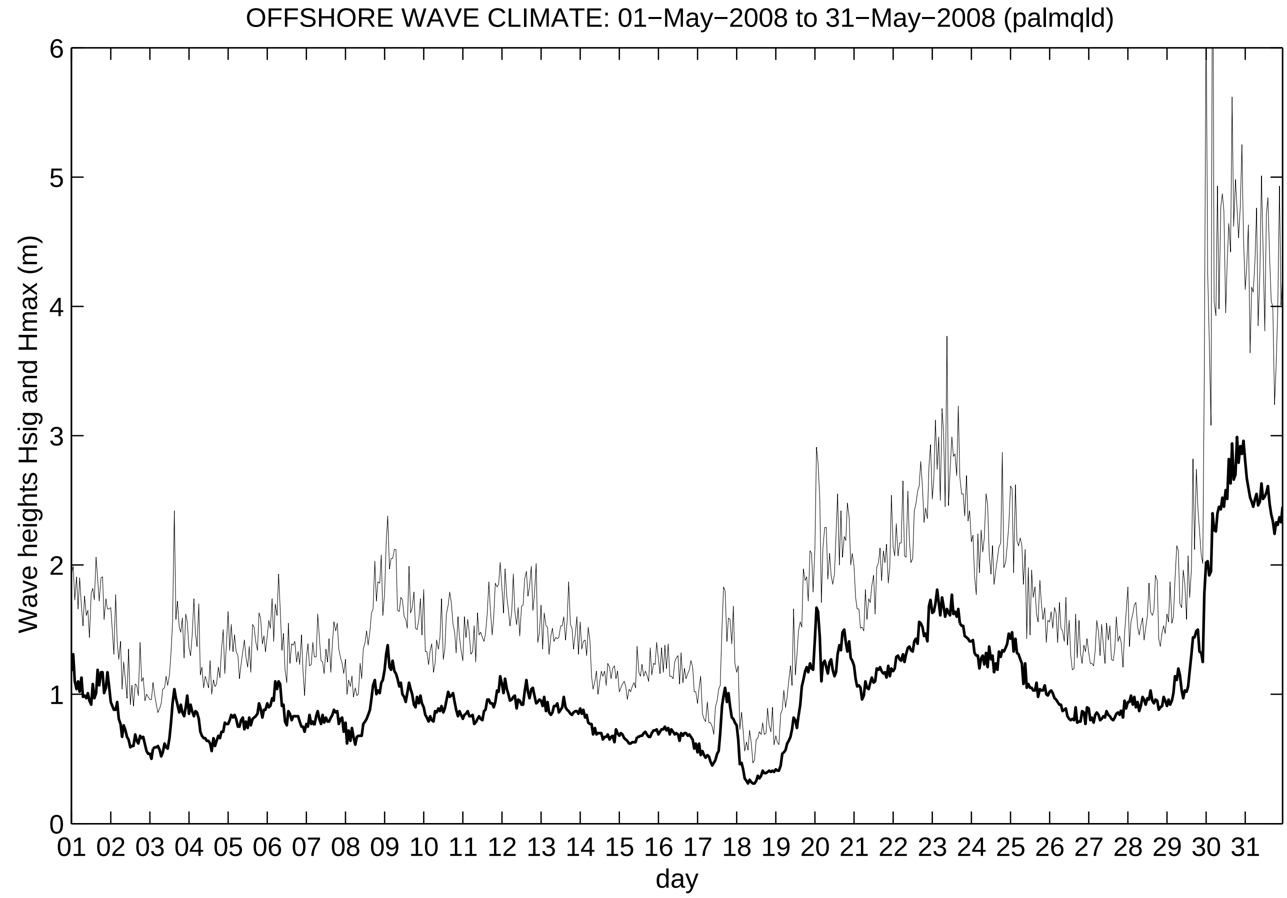


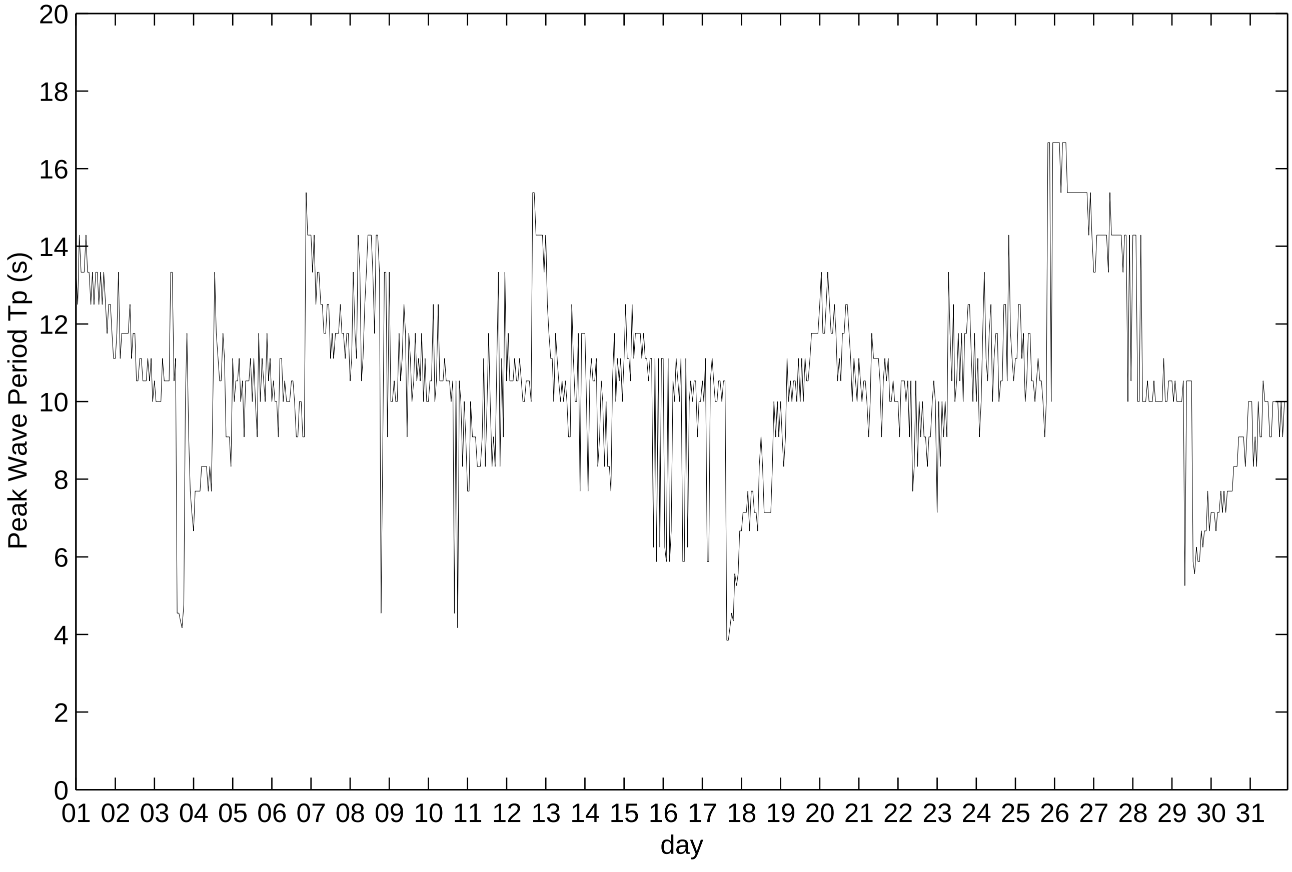
WRL Report No.2008/18	MONTHLY WAVE SUMMARY MARCH 2008	Figure B4





WRL Report No.2008/18	MONTHLY WAVE SUMMARY APRIL 2008	Figure B5





WRL Report No.2008/18	MONTHLY WAVE SUMMARY MAY 2008	Figure B6