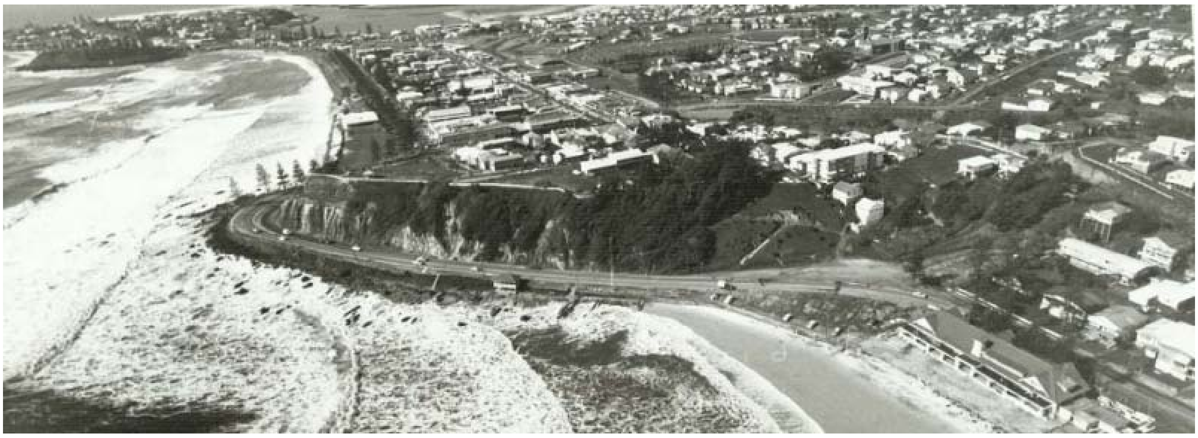
LAND AND PROPERTY MANAGEMENT AUTHORITY

TRESBP

Kirra Groyne Effects Study

301001-00826 – 001

9-Nov-09



Infrastructure & Environment
Level 6, 60 Albert Street
Brisbane QLD 4000
Australia
Telephone: +61 7 3221 7444
Facsimile: +61 7 3221 7791
www.worleyparsons.com
ABN 61 001 279 812

WorleyParsons

resources & energy

EcoNomics

LAND AND PROPERTY MANAGEMENT AUTHORITY
TRESBP
KIRRA GROYNE EFFECTS STUDY

SYNOPSIS

In this report a qualitative approach has been taken to describe sand movements and potential impacts of Kirra Point groyne under conditions of 'full' and 'average' sand supply to the study area that includes the southern Gold Coast beaches from Snapper Rocks to North Kirra between +5.0m and -10.00m AHD and Kirra Reef.

"Excess" sand supply is that typified by the volumes of sand delivered by the Sand Bypassing System between 2001 and 2006. These volumes were delivered deliberately in excess of the natural average supply between 2001 and 2006 to rebuild the sand depleted southern Gold Coast beaches. Less frequent swells and storms led to an accumulation of sand at Coolangatta and Kirra over the early years of TRESBP operations.

"TRESBP Natural" sand supply is the ongoing, naturally varying volume that the Sand Bypassing System emulates through pumping and periodic entrance dredging. The current estimated natural average is 500,000 cubic metres per annum.

Disclaimer

PROJECT 301001-00826 - TRESBP

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
A	Issued for internal review	S.Victory		N/A	1-Sep-09	N/A	
0	Issued for client review	S.Victory		N/A	1-Oct-09		
1	Issued for Govts Review	S.Victory	S.Messiter		9-Nov-09		

CONTENTS

Appendices

1. INTRODUCTION

The TRESBP (Tweed River Entrance Sand Bypassing Project) sand bypass system has been operating since March 2001, pumping over five million cubic metres of sand to the southern Gold Coast beaches without interruption so far (NSW Dept of Lands, 2009). The net movement of sand from Snapper Rocks through to North Kirra is meant to approximate the movement of sand that occurred prior to the Tweed River training walls construction in the mid 1960s. Artificial sand bypassing also keeps open a clear navigation channel at the Tweed River entrance in New South Wales at the same time as sand delivery to the southern Gold Coast beaches in Queensland, thus fulfilling objectives of both States.

Now that the sand bypass system is in place, a question has arisen as to the effects of a prominent structure on the Southern Gold Coast beaches viz, Kirra Point Groyne works. This structure was built at a time when the natural sand supply had been largely intercepted by the Tweed training walls and was built primarily to retain sand on Coolangatta beach. It is the effect of this structure on local beach alignment including beach bars that requires investigation under the Terms of Reference for this study. Specifically, the potential impact of Kirra Point Groyne on sand inundation of Kirra Reef is to be qualitatively assessed.

A qualitative approach has been taken to describe sand movements and potential effects of Kirra Point groyne under conditions of ‘excess’ and ‘average’ sand supply to the study area that includes the southern Gold Coast beaches from Snapper Rocks to North Kirra between +5.0m and -10.00m AHD and Kirra Reef.

1.1 TRESBP Objectives

As the Tweed River entrance is near the border between NSW and Queensland, the problems that arose from the extension of the Tweed River training walls in the 1960s became a matter for extensive negotiations between the two States (Dyson et al., 2001). These negotiations led to an agreement to undertake a joint project between New South Wales and Queensland to resolve both the problems with erosion of the sGCb and the poor condition of the navigation channel. The objectives of the Tweed River Entrance Sand Bypassing Project can be summarised as follows:

1) To improve and maintain improved navigation conditions at the Tweed River Entrance;
2) To rebuild the sand depleted Southern Gold Coast Beaches; and
3) To supply quantities of sand to the Southern Gold Coast Beaches consistent with the natural volumes moving along the coast.

1.2 Terms of Reference

The objective of this study is to assess and describe the likely impacts of Kirra Point Groyne on the shape and width of Kirra and Coolangatta/Greenmount Beaches, as well as the degree of exposure of

Kirra Reef, on the basis that the Tweed River Entrance Sand Bypassing Project is ensuring that the natural littoral drift quantities are delivered to Queensland.

Within the Study Area, and including reference to Kirra Reef, the requirement is to complete the following study action:

1. Assess and describe sand movements for the following timeframes:
    a) Pre 1960s (ie pre Kirra Point Groyne, pre training wall extensions);
    b) Post Kirra Point Groyne pre TRESBP; and
    c) Post Kirra Point Groyne with TRESBP and full sand supply.
2. Assess and describe other effects of Kirra Point Groyne on beaches in the Study Area in the context of the above timeframes and in terms of upper beach and nearshore profile (and alongshore alignment) behaviour.
3. For timeframes a), b), and c) above, assess and describe the impact of Kirra Point Groyne on the degree of exposure of Kirra Reef.
4. Assess and describe in general terms the potential changes to sand movements, and possible inundation effects on Kirra reef, if Kirra Point Groyne was lengthened or shortened.

1.3 Methodology

Sand movements from a qualitative perspective have mostly been recorded through photography that is either oblique stills (standing on the beach or on a hill) or aerial photography at various elevations (black and white before the 1970s and colour thereafter). Frequent digital images (Argus system), transferred via the internet and stored for analysis, can now provide information previously missed because of insufficient capture (Argus information has advantages with respect to statistical analysis). During the 1990s until present, regular hydro-surveys have also substantially contributed to the knowledge of quantitative sand movements.

Generalised observations have to be made in a brief qualitative report that cannot possibly hope to summarise the highly dynamic beach conditions and natural variability of these beach systems that can take place within any one season and for that matter within any month or week. Therefore the descriptions of sand movements and predicted effects of coastal structures are general appraisals and typical of the way coastal systems work based on the normal wave climate. The descriptions provided in this report cannot convey the morphological changes resulting from the occurrence of every type of wave event.

1.4 Available Data

Data assessed in this study came from the following sources:

- Vertical Aerial Photography;

- Historical Oblique Photography;
- Historical and recent Hydro-Survey;
- Argus Camera Imagery; and
- Limited quantitative analysis to illustrate comparison of sand movements.

1.5 Definitions

For the purposes of this report the following definitions apply:

"Excess" sand supply

Is that typified by the volumes of sand delivered by the Sand Bypassing System between 2001 and 2006. These volumes were delivered deliberately in excess of the natural average supply between 2001 and 2006 to rebuild the sand depleted southern Gold Coast beaches. Less frequent swells and storms led to an accumulation of sand at Coolangatta and Kirra over the early years of TRESBP operations.

"TRESBP Natural" sand supply

Is the ongoing, naturally varying volume that the sand bypassing system emulates through pumping and periodic entrance dredging. The natural net movement of sand from Letitia Spit to the southern Gold Coast beaches is estimated to be an average of 500,000 cubic metres per annum (currently being reviewed). Gross sand transport can very between 200,000 and 1,200,000 cubic metres per annum.

2. STUDY AREA BACKGROUND

The southern Gold Cost beaches are situated along a relatively high energy coastline subject to open ocean swells from the Pacific that show strong seasonal variability. Consequently, natural sand transport varies anywhere from 200,000 to 1,200,000 m^3 per annum (gross) and can include highly dynamic beach variability in the form of erosion events and subsequent beach recovery or accretion from the introduction of new sand into the coastal compartments. The average net sand transport is approximately 500,000 m^3 per annum towards the north (under review at the time of writing this report).

Sand transport is driven by both local seas and swells that propagate mostly from the south east sector and are predominantly of periods from 9 to 13 seconds and significant wave heights in the range of 0.5 to 2.0m (modal height) and generally less than 3.5m (Hyder Consulting, 1997). Extreme wave conditions sometimes result from tropical cyclones or East Coast Lows depending on storm track direction and the strength of the winds (maximum significant wave height recorded at Tweed Heads to date is 7.52m during May 1996).

Prior to the permanent sand bypassing system operations there have been numerous other dredging and sand nourishment campaigns within the study area during the periods being investigated that have affected the beach alignments and shapes. A short history of Kirra and Coolangatta beach and dredging campaigns of the area are presented in the TRESBP stage 2 EIS (taken from BPA newsletters). This description has been reproduced in Appendix 1 for convenient reference.

EPISODIC SAND MOVEMENTS

Sand movements pre 1960s were more episodic than the present system due to the inherent storage in the sediment pathways, and the dependence on the rate of sand transfer across the Tweed River entrance. The rate of sand transfer is a function of wave energy and the occurrence of wave directions capable of transporting sand around from Snapper Rocks.

Sand moving around the Point Danger headland was introduced to the beaches through nearshore shoals formed by refracted waves or large offshore sand bars moving into Rainbow Bay and Coolangatta under moderate wave conditions from easterly directions.

Sand supply in the pre 1960 era was largely uninterrupted, and even though storms would cause erosion of the beaches, they would recover in due course because the episodic nature of sand shoal movements provided an active source of sand for resupply. Minor sea defence works are evident around Coolangatta and Kirra from periods well before the 1960s and these can be exposed if beach erosion becomes severe.

Figure A.1 (a) in Appendix 3 is typical of the situation that existed at the entrance bar during energetic wave conditions resulting in sediment transport. Figure A.1 (b) taken during calmer conditions shows the structure of the entrance bar and the sediment pathway to Snapper Rocks. The entrance bar is highly variable in depth and shape as a result of river flow combined with tidal currents and wave action and this also influences the amount of natural bypassing and therefore intermittent movement of sand.

TWEED TRAINING WALLS AND COASTAL WORKS

The Tweed River training wall extensions were built between 1962 and 1965 and, once in place, started to have an impact on the sand movements of the southern Gold Coast beaches and within the Tweed River estuary. It was estimated the volume of sand that accumulated on Letitia Spit and within the lower estuary by 1994 was approximately seven million cubic metres (Hyder Consulting, 1997).

Following extension of the training walls (seaward by 380m), a series of severe storms in short succession in 1967 caused severe erosion of the southern Gold Coast beaches and they were not able to recover. Kirra was particularly affected and ‘hard’ coastal engineering structures in the form of rock walls were recommended in order to protect adjoining properties. Several cyclones in 1972 and again in 1974 (Boak and Jackson et.al., 2001) attested to a chronic erosion problem originating from the interrupted sand supply.

Consequently, the coastline in the Study Area was modified by coastal defensive works. These works were installed at a time when the littoral sand supply was severely depleted as a result of interception by the Tweed River entrance training walls. Kirra Point groyne was one such coastal structure, built in 1972 to protect Coolangatta and Greenmount beaches by retaining sand on them (Groynes are typically able to retain sand in calmer wave conditions but will not prevent the loss of the beach in severe storms).

While the other structures are mostly covered by sand now, Kirra groyne is still a prominent feature of the headland.

3. DESCRIPTION OF SAND MOVEMENTS

It was recognised in the TRESBP stage 2 EIS that unusually high and low wave energy years occur from time to time and this has an effect on sand transport patterns in the Study Area.

Qualitative descriptions of sand movements based on knowledge from general coastal engineering behaviour of headlands and beaches coupled with experience in regard to coastal systems are provided below.

3.1 Pre Tweed training walls (mid 1960s)

Prior to extension of the Tweed River training walls during 1962-65 there were no major coastal structures in the Study Area besides the original training walls that were built in the mid 1890s and they were not of sufficient length to interrupt the sand supply in a substantial way before natural bypassing resumed.

Sand transport throughout the Study Area in the pre 1960s era was characterised as follows:

- Normal sand transport patterns along Letitia Spit resulted in the natural bypassing of the river entrance via the ebb shoal (a net movement of sand towards Snapper Rocks occurs when wave directions are more southerly than approximately 70 degrees from north);
- The river entrance ebb shoal provided the source of sand for the eastern facing beaches along Point Danger and the accumulation of sand in the nearshore at Snapper Rocks. Under normal wave conditions, sand closer to shore would be carried around the headland by refracting waves. In the lee of the headland sand movements were observed as long oblate sand shoals ("fingers" of sand). Sand shoals exposed at low water can be identified in aerial photos, see Figure A.2. The transport of sand by the oblique wave direction (almost perpendicular to the beach) regularly formed shallow lagoons when sand moved across the embayments. Sand nourishment of the upper beach occurred under favourable combinations of water level and small waves;
- During south-easterly or southerly storms there was the potential for large volumes of sand to be carried by littoral and wind driven currents just to the west of Snapper Rocks. Subsequent waves from the east and north-east moved this sand into Rainbow Bay and the other beaches. Figure A.3(a) from a 1961 aerial photo is evidence of a type of large offshore sand shoal. Figure A.3(b), taken in 1965, shows the southern Gold Coast beaches and the recently completed Tweed River training walls. An outer beach bar is visible at Coolangatta and Kirra, and offshore bed forms are visible. Offshore profiles were still unaffected at this time;
- In the period before the early 1970s Kirra Point was an exposed rocky reef substrate and small headland (approximately 100m) that naturally retained sand on Coolangatta beach. A beach bar would form around the headland during higher energy wave events as depicted in Figure A.4. This beach bar connected Coolangatta to Kirra beach allowing the continual downdrift movement of sand from one side to the other during energetic wave events. (The Kirra beach bar is also

associated with the original renowned Kirra surf break, when one to three metre waves with an ideal right hand peel angle of about 35 degrees would break);

- Natural bypassing of Kirra headland, shown in Figure A.4, was achieved via the offshore beach bar in addition to the along shore beach break. A thin band of sand close to the base of the headland could feed sand from one side to the other and this sand supply rate increased when the beach width on the Coolangatta side grew seaward;
- The width of Kirra beach in the pre 1960s era was variable but normally would be about 100 m wide or more (estimated 'by eye' from pre 1965 aerial photos). Kirra beach width varied with the sand supply rate and the quantity of sand bypassing the headland.

If a long term commitment to emulating natural average sand supply rates could be achieved in future then it could be expected that the upper beach widths at Kirra would behave similarly to the pre 1960s era.

3.2 Post Kirra Groyne construction prior to TRESBP

Kirra Groyne was constructed in between May and June 1972. The decision to build the Kirra Point groyne was made at a time when no sand was present on Coolangatta beach and its depleted condition was due to the sequence of storms in 1967 and again in 1972 but without adequate sand supplies for the beach to recover naturally. Rock walls to protect property and roads had also been constructed after the storm events of 1967.

Sand transport at Kirra Point Groyne was characterised as follows:

- Construction sequence of Kirra Groyne is shown in Figure A.5. Photo (a) is without the groyne and by the end of June 1972, in photo (b), the groyne has been built. The description of Kirra Groyne is provided in Appendix 2;
- The groyne was reasonably successful in retaining sand on Coolangatta beach, but at the expense of beaches at Kirra and further downdrift. Dredging campaigns around the mid 1970s after storms also assisted to put sand back into Kirra and Coolangatta for a short time;
- In the period following construction of the Kirra Point Groyne a deep hole formed off its seaward end as a result of eddies scouring the seabed that were generated by interaction of long shore currents and return currents along the groyne;
- Figure A.6(a) is an aerial photo taken in 1972 that shows sand on the Coolangatta side of the groyne and very little beach on the Kirra side. Groyne structures usually have a detrimental effect on neighbouring beaches because they deprive them of a sand supply until natural bypassing occurs and they alter the alignment of the beaches on both sides of the structure. Consequently, the beach on the Coolangatta side became wider near the groyne but the beach in front of the Kirra Surf Club was seriously eroded;
- A groyne at Miles St was constructed in 1974 in order to retain sand in front of the Kirra Surf Club and can be seen in Figure A.6(b). Kirra beach conditions, in general, did not improve for

some decades except for short lived beach nourishment campaigns. As a consequence of the groyne construction at Kirra Point, the offshore beach bar moved further seaward there as it followed the contours from the wider beach on the Coolangatta side;

- The Kirra Point Groyne created a wider Coolangatta beach and a different sand transport pattern. Beach and offshore bar alignments were altered, and sand supply past Kirra Point was more variable with the groyne partially blocking the littoral zone. Construction of Kirra Groyne would have normally resulted in greater coverage of Kirra Reef with sand as the offshore bar moved seawards. However, the generally eroded state of the offshore areas were an overriding factor in exposure of the reef;
- Typically the beach width at Kirra was small in front of the surf club and a narrow sand strip along the Kirra side of the groyne fed the sand depleted beach. This narrow sand strip either came from around the end of the groyne, through the groyne, or over the lower parts of the groyne at the back beach end.

Figure A.7 shows the state of Kirra and Coolangatta/Greenmount beach in the twenty year period from 1977 to 1997 and although sand was retained on Coolangatta due to Kirra groyne and sand nourishment programs, the beach conditions to the west of the groyne were poor. Because of its alignment and the lack of sand supply, the rock wall in front of Musgrave St was always exposed and rarely had a beach during the 1970s, 80s and 90s unless nourishment programs occurred.

Note in Figure A.7(c) that approximately 30m had been removed from the end of Kirra Groyne (viz. 1996) and, with careful observation it can be seen that the sand has not yet covered the base (also refer to Appendix 2).

3.3 Post TRESBP

Appendix 5 presents aerial photos of Kirra and Coolangatta/Greenmount after the sand bypassing works were commenced through to the present year. Sand transport on either side of Kirra Point Groyne is characterised as follows:

- Sand movements in the year that the sand bypass station was being constructed (2000) and therefore not yet operational is shown in Figure A.8(a). There was no beach to the west of Miles St Groyne and substantial beach nourishment campaigns in the early and mid 1990s were only temporary solutions. Although a beach exists in front of Kirra Surf Club in this photo, due to the ability of the Miles Street groyne to retain sand, the property along this section of coastline was always vulnerable to big seas;
- Figure A.8(b) is the aerial view of the beaches from Greenmount to North Kirra taken in May 2001, around the time the sand bypass station commenced pumping sand (March 2001), although dredging had been ongoing since April 2000. The sand shoal moving around the headland into Greenmount is evidence that sand was being introduced to the beaches from the TRESBP works. Also note the sand moving around Kirra Point and beginning to fill the ‘hole’ on the downdrift side of Miles St groyne;

- As of, or before August 2002, the sand supply had filled the beaches at North Kirra and the Miles Street groyne was covered by sand, as can be seen in Figure A.9(a). This was the first time this area had achieved a permanent beach in front of the rock walls in nearly three decades. At this time Kirra groyne was still functioning and retaining sand on Coolangatta, so much so, the width of the beach was very full, even at the Greenmount end. The offshore beach bar is also evident in Figure A.9(a) and can be seen in front of the shoreline (approximately 200m). Alignment of the beach from one side of Kirra groyne to the other was still discontinuous at that stage, but as seen in the figure a new sand shoal was making its way around Greenmount headland;
- In May 2003, as shown in the aerial photo of Figure A.9(b) taken at low tide, the beach alignment was virtually a straight line from Greenmount headland to North Kirra. The offshore bar was also continuous and straight, and referred to as the 'super bank'. Breaking waves were providing experienced surfers with a ride from Snapper Rocks all the way to Kirra. However, this condition exhibits an oversupply of sand to these beaches and, as shown in Figure A.9, Kirra Point Groyne is close to, or no longer functioning to retain sand. It is clearly being bypassed by the volume of sand in the system. During this period the beach at Kirra grew so wide that the beach from Greenmount to North Kirra was continuous;
- Almost two years later in March 2005, Figure A.9(c), the beach at Kirra remained wide and no discontinuity was discernible in alignment between the beaches either side of the groyne. With no sand shoals making their way into Greenmount at that time, the shoreline there took up the horizontal plan alignment of the back beach and dune line;
- The aerial photo in Figure A.10(a) taken in June 2007 shows the shoreline once again starting to follow the headland shape but still wide beaches at Kirra and Coolangatta/Greenmount.
- Figure A.10(b) is an aerial photo (April 2009) taken before the severe storm in May 2009 that caused substantial and widespread erosion to much of the southern Queensland coastline including some of the Gold Coast beaches to the north of the Study Area. Wave events recorded at the Tweed River buoy were as follows:
    - 14-15 February 2009 (Hsig=3.12 m);
    - 11-12 March 2009 (Hsig=3.7 m);
    - 30-31 March 2009 (Hsig=4.1 m);
    - 1-6 April 2009 (Hsig=4.6 m); and
    - 19-22 April 2009 (Hsig=3.2 m);

  The May 2009 event was ranked third highest wave event recorded with a maximum significant wave height of Hsig = 5.6 metres.

  The southern Gold Coast beaches were well prepared and, although beach widths were reduced, they did not exhibit the high scarps and overtopping observed at other places because most of the wave energy was dissipated on offshore bars before reaching the shoreline. The nearshore and shoreline beach bars can be seen in Figure A.10(b) where waves are breaking and 'white water' is evident.

4. BEACH PROFILE AND OTHER EFFECTS

Other effects the Kirra Point groyne had on beaches in the Study Area are examined in this Section in terms of upper beach and nearshore profile behaviour.

The survey lines examined in this Section were confined to those in the vicinity of the Kirra Point groyne as shown in Figure A.11 in Appendix 6.

Hydrographic survey technology has improved over the decades and as a result surveys can be repeated on a more frequent and accurate basis than in earlier times. Hence, the survey database contains more frequent surveys at better resolution since the TRESBP started operating. However the survey line locations do not always overlap to provide a continuous record of beach profiles over the period from the early 1960s to the present day.

4.1 Pre 1960s

There are limited surveys in this era to form a basis for comparison. The earliest beach profile data the Beach Protection Authority (the BPA was disbanded in 2003) records contain, that is relevant to the Kirra groyne location, is circa 1963. This was around the time that the Tweed training walls were being extended.

Consequently, little comment can be made in relation to the shoreline and offshore bar location movements from the beach profile data for this period. What is evident from surveys undertaken before the construction of Kirra groyne is that the elevated profile covers most of the eastern reef and rather than an obvious beach bar, is a relatively uniform slope that joins the stable offshore profile approximately a kilometre from the shoreline (depth of closure).

4.2 Post Kirra Groyne construction and prior to TRESBP

After the Kirra groyne was constructed, the survey data of the beach shows the offshore profile lowering and the upper beach profile remaining higher and wider. The lowering of the offshore profile in front of Coolangatta beach in Figure A.12 and A.14 is attributable to the decrease in sand supply after the training walls interrupted the transfer of sand across the Tweed River entrance. However, Kirra groyne retained sand on Coolangatta beach and this is evident from the 1983 and 1994 beach survey profiles that indicate a raised upper beach and wider profile out to the shoreline.

The dates of the beach surveys do not coincide directly with aerial photography dates where the offshore beach bar is observed. Therefore it is not always possible to definitively locate the offshore beach bar on the survey profile figures, but in general it appears to be about the -2m contour within 100m of the shoreline according to the Beta 2.4 and 3.3 beach profiles corresponding to 1983 and 1994 surveys.

Also observed in the beach profiles in this era are the raised bed levels near the 1400 m chainage (Beta 3.3 profile) and 700 m chainage (K1 profile) that correspond to offshore sand placement during the southern Gold Coast beach nourishment works. Lowering of these profiles is again evident in the year following the nourishment works.

4.3 Post TRESBP

In the years following the TRESBP the beach at Coolangatta widens as indicated in profiles of CGM3 shown in Figure A.15 of Appendix 6. Slight lowering of the beach at around chainage 150m occurred following the survey in 2003.

Figure A.13, that shows the profile K1 and KM1, indicates the beach profile at Kirra post TRESBP has been raised substantially out to a chainage of approximately 700 m. The upper beach elevation is 3 m higher than the surveys between 1988 and 1994, but these were most likely around 2 m lower than upper beach elevations in the pre 1960s era as estimated from the Beta 3.3 profile.

The nearshore and offshore profile in KM1 is also substantially higher than in the post Kirra groyne era, and again, the beach bar is estimated to form at approximately the -2 m contour that is around 100 m from the shoreline.

From the Argus imaging data the beach at Coolangatta responds to newly introduced sand by building in width at the Greenmount end but remaining relatively constant at the Kirra Point end of Coolangatta beach. This is observed in Figure A.16 that shows the shoreline measured in the CGM3 profile is approximately 150m wide (note that Kirra groyne was approximately 180 m before 30 m was taken off the end of the groyne in 1996).

As the width of the upper beach at Kirra in the post TRESBP era steadily increased to find a new equilibrium with the excess sand volumes, the offshore beach bar at the western end of Kirra rotated seawards and its alignment in early 2009 was much straighter than in 2002. The highest proportion of sand transport occurs in the band between the shoreline and the offshore bar, resulting in coverage of the reef structure with sand from both longshore and cross-shore bed transport.

Figure A.17 shows recent survey information from the Kirra Point Section (courtesy of NSW Department of Lands) indicating how storms from February to April 2009 have cleared the offshore bar formations from Kirra that amount to approximately 218,000m^3 of sand (G. Elias, 2009, pers.comm., 8 October). This information serves as a reminder of the large sediment transport potential that is characteristic of this coastline and the relatively short timeframe that is needed to bring about substantial changes to beach morphology.

5. EFFECT OF KIRRA GROYNE ON KIRRA REEF

An overview of the impact Kirra groyne has had on the nearby reef and possible future effects are assessed in this Section based on aerial photos and surveys. Appendix 7 includes samples of suitable aerial photos used for undertaking this assessment. Not all aerial photography is suitable because of water discolouration, wave conditions, or the exposure of the photography including reflections and solar flaring on the images.

Kirra Reef is an area of rocky outcrop located several hundred meters offshore of Kirra beach in 5 to 10 meters of water. The reef exists in three outcrops as shown in Figure A.18. The outcrops are outer western reef, inner western reef, and the eastern reef.

Descriptions of Kirra Reef are provided that are consistent with the timeframes used throughout this report (see Terms of Reference).

5.1 Pre Tweed Training walls (mid 1960s)

There is limited suitable aerial photography available in this era for comparison and assessment of sand cover over Kirra Reef. The earliest of the aerial photography records, that is relevant to the Kirra groyne location, is circa 1930 shown in Figure A.19(a).

Consequently, limited assessment only can be made in relation to comparisons on the exposure of Kirra Reef throughout this period, notwithstanding the aerial photo of 1946 that shows similar exposure to the 1930 reef condition.

In Figure A.19(a) the eastern reef is visible but has a reasonable coverage of sand compared to more recent data. During this era the offshore profiles were higher than the post Kirra Groyne period and the reef was less exposed and smaller in plan area. When large sand shoals moved into Coolangatta at that time through natural sand flow variation, the eastern reef and the inner western reef would have been completely, or close to, completely covered. The inner western reef is barely visible in Figure A.19(a).

Survey profiles also indicate that offshore levels surrounding Kirra Reef were higher than the post Kirra Groyne era indicating that sand coverage of the reef was a normal occurrence when sand supply rates were natural.

5.2 Post Kirra Groyne construction and prior to TRESBP

After the construction of Kirra groyne and up to the commencement of the TRESBP operations the exposure of the reef generally became much more pronounced as shown in Figure A.18(b) and (c) . This was due to the lowering of the offshore profile caused by the lack of sand supply to the southern Gold Coast beaches.

Sand nourishment campaigns by dredge in the late 1980s and early and mid 1990s resulted in sand movement over the reef from placement zones to the west of Snapper Rocks. Similar to present TRESBP operations, the sand moved into the Kirra Reef placement exclusion zone from its original deposition location. Figure A.19 (b) and (c), shows greater exposure of the reef and (d) indicates that sand placed during nourishment campaigns has moved over the reef and covered parts of it. Figure A.19(c) particularly shows how exposed the reef had become at a time when the general condition of the beaches was very poor through depleted natural sand supply.

5.3 Post TRESBP

The exposure of Kirra Reef after the TRESBP operations began has reduced considerably. In the early stages of operations the inner western reef was completely covered similar to occasions in the pre 1960s era. This is due to the rebuilding of Kirra beach and a subsequent vertical shift in the profile from the rock wall to offshore similar to the pre 1960s era. Figure A.19(e), an aerial photo taken in 2002, shows the only reef visible at this stage was the outer western reef and both the inner western and the eastern reef had been covered by sand.

A photogrammetric analysis undertaken by the Dept Land and Water Conservation, on behalf of the TRESBP, determined the exposed plan area of Kirra Reef, as shown in Figure A.18, was for dates as of 1962 and 1965, 2001, and 2002 as shown in Table 1:

Table 1 Plan area of exposed reef outcrops

Zone	Range observed in 1962 & 1965 (sqm)	Prior to commencement of Stage 2 operations Feb 2001 (sqm)	August 2002 (sqm)
Inner Western Reef	0 – 4,900	2,000	0
Outer Western Reef	4,850 – 7,800	11,000	8,500
Eastern Reef	600 – 2,150	6,900	100
Total	7,000 – 13,300	19,900	8,600

By 2008, Figure A.19(f), sand moving out of Coolangatta had begun to accumulate in the lower wave energy area on the shoreward side of the reef. This resulted in the coast alignment at Kirra straightening and almost aligning with the Coolangatta side. Although more sand is moving through the nearshore system in the 2008 situation, it appears to be the closest comparison to the 1930 case out of all the other examples. A beach on the Kirra side of Kirra Point will typically result in more sand in the nearshore zone that will almost completely cover the inner reefs, and if very wide, the outer reef will also be subject to burial. However, the reef will become exposed again as the earlier placed excess sand volumes disperse and lower volumes are delivered by the system. Large wave and possibly several storms in succession will be needed to disperse sand away from Kirra as happened in the first half of 2009.

6. EFFECT OF KIRRA GROYNE LENGTH

This Section addresses the sensitivity of beach alignment and reef exposure to Kirra Point Groyne length.

NB: There is no consideration being given by relevant authorities to physically changing the existing length of Kirra Point Groyne. This analysis is undertaken purely to assess the level of dependence of local beach alignment and Kirra Reef coverage on groyne length.

Groynes are normally built for the purpose of retaining sand on beaches. However other side effects (beneficial as well as unfavourable) result from their construction. The most significant unfavourable impact of groynes is that they normally result in erosion downdrift of the net littoral sand supply direction as downdrift beaches are starved of sand if it is in limited supply. There are numerous examples of this effect and the fact that this is not the present case at Kirra Point Groyne is due to large amounts of sand in this coastal compartment. Emulation of the natural average sand supply by the TRESBP system will result in the beaches to the west of Kirra receding from their present shape to a beach width similar to pre 1960s conditions and sand will be held on a wider Coolangatta beach than pre 1960s condition due to the Kirra Point Groyne.

Figure 1 is derived from locating the offshore bar and shoreline from pre-1960s aerial photographs. Average locations of the offshore bar and shoreline are typical for Coolangatta and Kirra during the period when a natural sand supply prevailed. In Figure 2 the offshore bar and shoreline have retreated substantially due to the reduced sand supply rates resulting from the extension of the Tweed training walls. Also at this time, more of Kirra Reef was exposed because seabed levels were lower than they had previously been.

During the first 5-6 years of TRESBP operations sand volumes in excess of the natural average were supplied each year. Sand stored along Letitia Spit, in addition to the natural littoral drift, was moved by the sand bypass system to rebuild the depleted southern Gold Coast beaches. Figure 3 shows the effect of the excess sand supply on the offshore bar and shoreline positions. During the period from 2001 to early 2009 the shoreline and offshore bar continued to move seaward, eventually covering Kirra Reef. There was no interruption to the sand transport by Kirra Groyne as all of this excess material was bypassing the end of the structure (also see Figure A.9) and Coolangatta beach was full.

If an over-supply is delivered by the system on a continuing basis Letitia Spit should erode in a similar fashion to the southern Gold Coast beaches after the mid 1960s. So far, a case of chronic severe erosion does not appear to be the case, although it remains to be seen whether the same delivery rates can be sustained into the future. It is only when there is a deficit in the sand transport rate that the offshore profile begins to deepen, allowing larger waves to approach the shoreline. Larger waves promote the offshore movement of sand, filling the deficit there while producing a steeper beach. In subsequent storms more sand is required to build the offshore bar and some of this stays offshore to fill the deficit, initiating the erosion cycle of the beach.

Assuming the system delivery rates return to the long term natural average supply, beach profiles and widths will slowly reduce to pre1960s conditions. Kirra beach and Kirra Reef should then vary similar to how they did in the pre 1960s era but there would also now be a transition zone at Kirra Groyne that did not exist back then. Figure 4 shows the predicted locations of the offshore bar and shoreline assuming TRESBP delivers the natural average supply. This scenario will not revert back to the pre-1960s situation because Kirra Groyne is assumed in place. Consequently, Coolangatta beach is wider than in the pre-1960s and the bar is held further offshore, but it is assumed these will transition to beach widths at Kirra similar to those existing in the pre-1960s because natural sand transport rates operate.

The following Sections also consider the effect of Kirra Groyne for excess sand supply rates in addition to the emulation of the natural average by the TRESBP system.

6.1 Effect of extending Kirra Point Groyne

With an excess sand supply (as defined in Section 1.5) an increase in the length of Kirra Groyne would impact on both Coolangatta beach and the reef system. This conclusion is drawn from the fact that groynes retain sand on their updrift side and therefore Coolangatta sub-aerial beach will grow in width the same distance as the groyne extension. This will also result in the offshore beach bar moving seaward, but its distance from the new shoreline will depend on the depth of water the groyne extends to, and the limiting steepness of the nearshore profile.

With excess sand supply, the volume of sand moving through the system should move around the end of the Groyne to the downdrift side that will also fill. Kirra beach should increase in width with the increased sand supply (unless the groyne extension was substantial and then Kirra beach would be deprived of sand temporarily until bypassing recommenced). A substantial portion of Kirra Reef would be covered with an excess sand supply moving through the beach system.

There is also the possibility that a groyne extension would form a scour hole off its end, similar to when the groyne was originally constructed (refilled as soon as bypassing recommences).

Temporary erosion of the Kirra beach side of the groyne would occur when large wave conditions arise, as it does now, but with an excess sand supply the beach is reasonably well protected by the offshore profile and would accrete again relatively quickly.

A TRESBP natural sand supply (as defined in Section 1.5) and an increase in the length of Kirra Point Groyne would see more variability about an average shoreline alignment and less bypassing around its end resulting in a more pronounced difference in beach alignment on either side of the groyne.

Lengthening the groyne during a time of natural sand supply delivered by the TRESBP should result in the following sequence:

- Upon extension of the groyne Coolangatta beach width increases due to interruption of longshore transport in the zone between shoreline and offshore bar (this is elementary to how groynes trap sand and make wider beaches updrift);

- Coolangatta offshore bar moves further seaward. How far depends on the groyne extension, but more importantly the depth of water seaward of the shoreline, i.e. if the nearshore profile is mild this bar could be further offshore than in the case with a steeper profile;
- As this is occurring, the zone to the west of the groyne recedes, if only temporarily, until natural bypassing of the groyne recommences;
- Kirra beach width will recover and grow wider again to a distance dictated by the sand transport rate, i.e. the greater the sand transport rate passing the groyne, the wider Kirra beach (as witnessed in the early years of the project when excess sand transport rates were delivered);
- The inner reefs could be expected to be covered while Kirra beach widths remain similar to the pre1960s era. A strong correlation exists between Kirra beach width and sand coverage of Kirra Reef. Coolangatta's offshore bar would transition from beyond the end of the groyne on the Coolangatta side to join up with the Kirra beach offshore bar. The shape of this transition will depend on the difference in beach alignment on either side of the groyne, the instantaneous sand transport rate under the daily wave conditions, and the extension of the groyne; and
- The distance to the offshore bar when a natural sand supply is being delivered by the TRESBP is approximately half that observed during the years of excess sand delivery rates and should lead to less sand coverage of Kirra Reef (even with groyne extension). An 'average' width for Kirra beach requires time for excess sand to clear out of the Kirra beach area.

Figure 5 shows the predicted locations of the shoreline and offshore bar for an average natural sand supply delivered by the TRESBP assuming Kirra Groyne is extended approximately 60m. This has the effect of capturing more sand on Coolangatta beach, making it wider, and the offshore bar transition from the groyne to the Kirra side covering more of Kirra Reef. The bar transition should vary depending on the wave conditions. The offshore bar should cover more of Kirra Reef in storm conditions as sand transport rates increase and the bar migrates seaward under storm conditions. The shoreline and offshore bar should transition to the normal beach conditions at Kirra on the either side of the reef.

The assumptions are based on previous sand movements and compiling shoreline and offshore bar positions from historical aerial photography (1962, 1966, 1975, 1979, 1997, 2002, 2003, 2006, 2008, and 2009).

6.2 Effect of shortening (removal) Kirra Point Groyne

The shortening (or removal) of the Kirra Point groyne under the excess sand supply condition would have little impact on the offshore beach bar location because the volume of offshore material at any section of the coast is being replaced by an equal amount from updrift.

Realignment of the beaches must to some degree depend on their initial condition at the time Kirra Point Groyne is considered to be shortened or removed. If both sides of the groyne are reasonably full then very little realignment will take place. Similar to Miles St Groyne when an excess sand supply was delivered, Kirra Groyne would cease to function if its present length became shorter or was surrounded by sand.

Under an excess sand supply condition, the Kirra and Coolangatta beach alignment would be expected to be reasonably similar as surveys and imagery have shown that Kirra beach becomes very wide under such circumstances. Shortening or even removal of Kirra Point Groyne in this situation would most likely make only a slight difference to the initial beach alignment and to the exposure of Kirra Reef. The beach at the Greenmount end would be expected to be wider, tapering down to Kirra Point.

The removal of Kirra Point Groyne and a TRESBP natural average sand supply reflects the original beach system that prevailed in the pre1960s era. In this situation there is no groyne to hold back sand on Coolangatta beach and its width near Kirra Point headland should look similar to conditions prior to the mid 1960s. This is currently the only comparison available to determine typical beach widths at Coolangatta and Kirra under the TRESBP natural average sand supply rates (increased benefit to this system would be gained through episodic movements of sand).

TRESBP natural average sand supply rates should result in a regular beach width along Coolangatta until it tapers past the Kirra Point headland. Beach width at Kirra would be similar to pre 1960s conditions resulting in an observable difference in the alignment of the shoreline and offshore beach bar from the Coolangatta to the Kirra beach side. Regardless of the difference in alignment, the wider Kirra beach condition and accompanying offshore bar dictate the normal coverage of Kirra Reef that should also be similar to pre 1960 conditions, i.e. considerably greater than the period from the late 1960s to the late 1990s.

A larger difference in the plan-form alignment between Coolangatta and Kirra shorelines would provide better surfing conditions than in recent years due to an increased peel angle in the take-off zone. Although not as much as the post Kirra Groyne era when Kirra beach was receding back to the rock wall, this peel angle is sufficient to provide quality surfing conditions and should, on average, resemble the conditions in the pre 1960s era. This scenario depends on getting the right balance of sand delivery while still meeting the other objectives of the TRESBP.

Figure 6 shows the predicted locations of the shoreline and offshore bar for an average natural sand supply delivered by the TRESBP assuming Kirra Groyne is shortened (or removed). This has the effect of reducing Coolangatta beach width, and moving the offshore bar shoreward. The offshore bar transition should expose more of Kirra Reef and in the limit (with the removal of Kirra Groyne) the locations of the shoreline and the offshore bar should resemble the pre-1960s average conditions.

The assumptions are based on previous sand movements and compiling shoreline and offshore bar positions from historical aerial photography (1962, 1966, 1975, 1979, 1997, 2002, 2003, 2006, 2008, and 2009).

7. CONCLUSIONS

A qualitative assessment and description was undertaken of the likely effects of Kirra Point Groyne on the shape and width of Kirra and Coolangatta/Greenmount Beaches, as well as the degree of exposure of Kirra Reef, on the basis of the Tweed River Entrance Sand Bypassing Project delivering natural littoral drift quantities.

The following conclusions have been drawn from the assessment:

- Kirra Groyne has a localised effect on coverage of Kirra Reef. This is through the offshore bar transition from Coolangatta to its position on the Kirra beach side. There is also potential in short term events to cover more of the eastern part of the reef if excess sand transport (more than natural littoral drift quantities) is mobilised;
- Coverage of Kirra Reef is strongly linked to the beach width at Kirra and elevated bed levels offshore that are also interrelated;
- Sand transport rates greater than or equal to normal average quantities (as evident in post TRESBP operations) result in elevated offshore bed levels and a much wider offshore bar distance that covers a higher percentage of Kirra Reef. Sand movement through the reef system is mostly via bed load transport between the rocky outcrops;
- Alteration of Kirra Groyne length was assessed under both TRESBP natural average delivery rates and excess sand supply conditions. Under an excess sand supply, a substantial portion of Kirra Reef will be covered - more so for lengthening the groyne than removal. Similar to Miles St Groyne when an excess sand supply was delivered, Kirra Groyne would cease to function if its present length became shorter or was surrounded by sand. If the groyne was lengthened the transition zone would be a little wider and start further offshore. Conclusions are as follows for the TRESBP natural average supply condition:

    a. Lengthening the groyne would result in a wider beach at Coolangatta than at present and a more pronounced difference in beach alignment on either side of the groyne. The transition of the offshore bar from Coolangatta to its position on the Kirra beach side would be relatively local to the groyne area, based on historical aerial photos, and could cover most of the eastern inner reef. Short term storm events, depending on the strength of longshore currents, and the instantaneous sand transport along Coolangatta may also result in sand covering more of Kirra Reef.

    b. Shortening or removal of Kirra Groyne would result in a narrower Coolangatta beach at the Kirra headland and the transition zone of the offshore bar to its position on the Kirra beach side would be milder than when the groyne is present. It is assumed that Kirra beach width is similar for groyne extension or removal.

The width of Kirra beach with the groyne in place and TRESBP natural average sand supply rates being delivered has no precedent (the period around 2002 may come closest to emulating this scenario). Beach widths at Kirra are expected to be close to pre 1960s conditions for both situations of the groyne in place or removed, since sand supply rates should be similar for both cases.

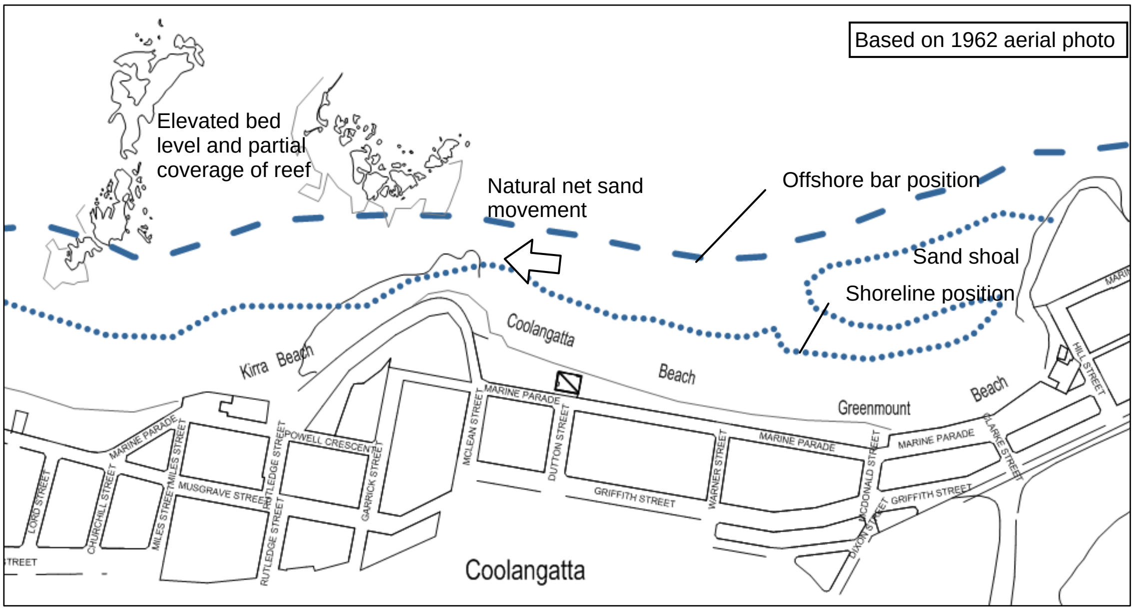


Figure 1 Pre-1960s natural average sand supply

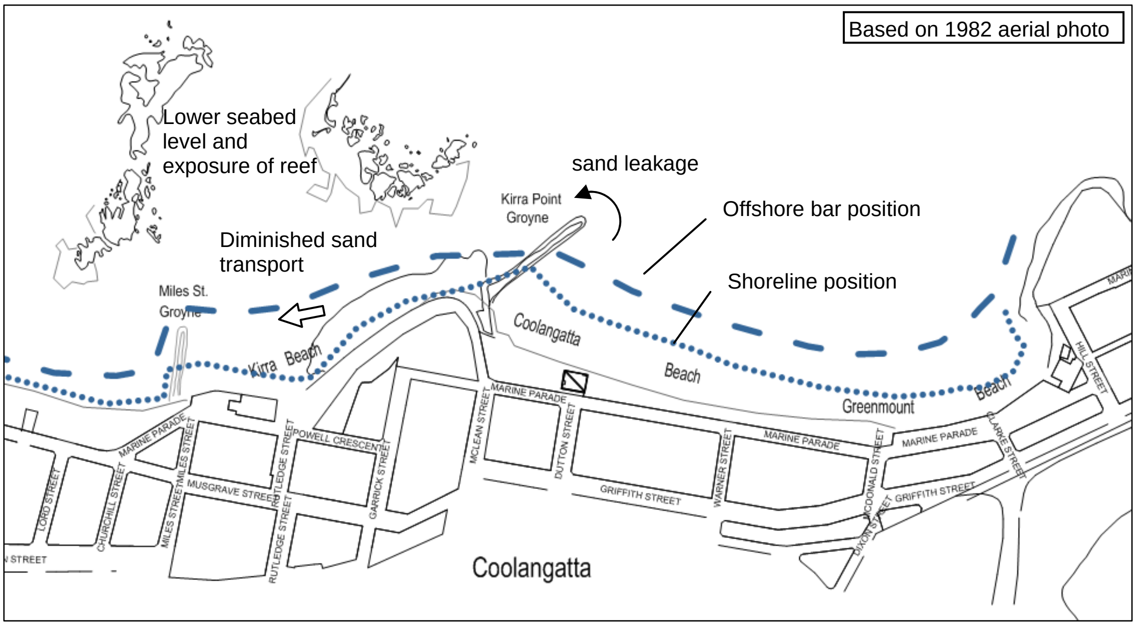


Figure 2 Pre-TRESBP including Kirra Groyne (diminished sand supply)

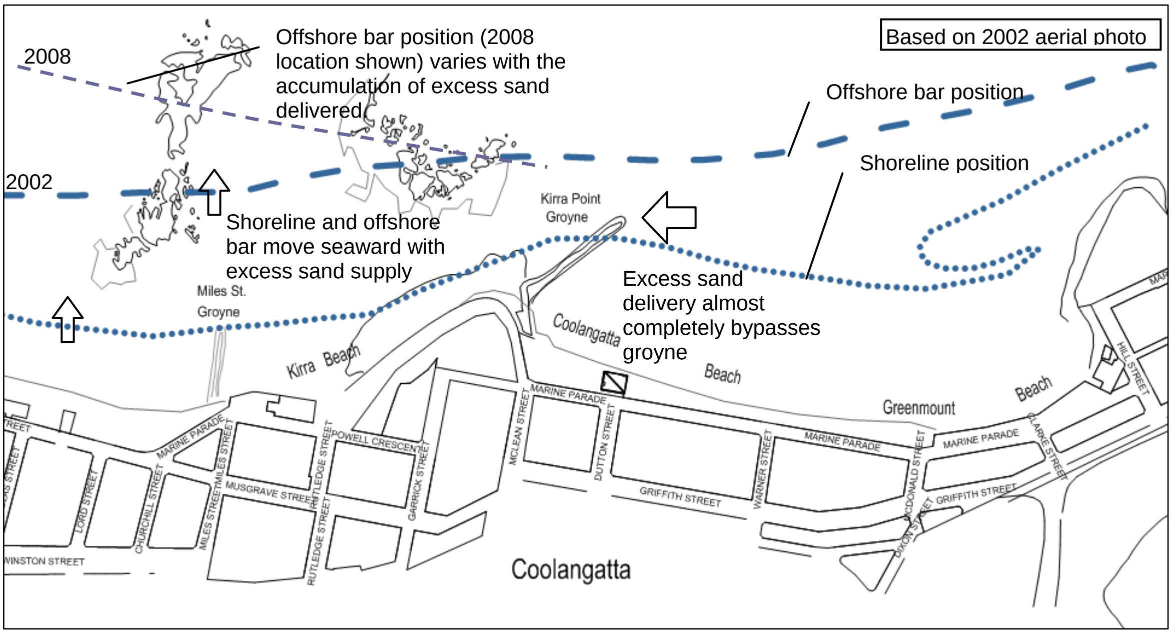


Figure 3 Post-TRESBP including Kirra Groyne (excess sand supply)

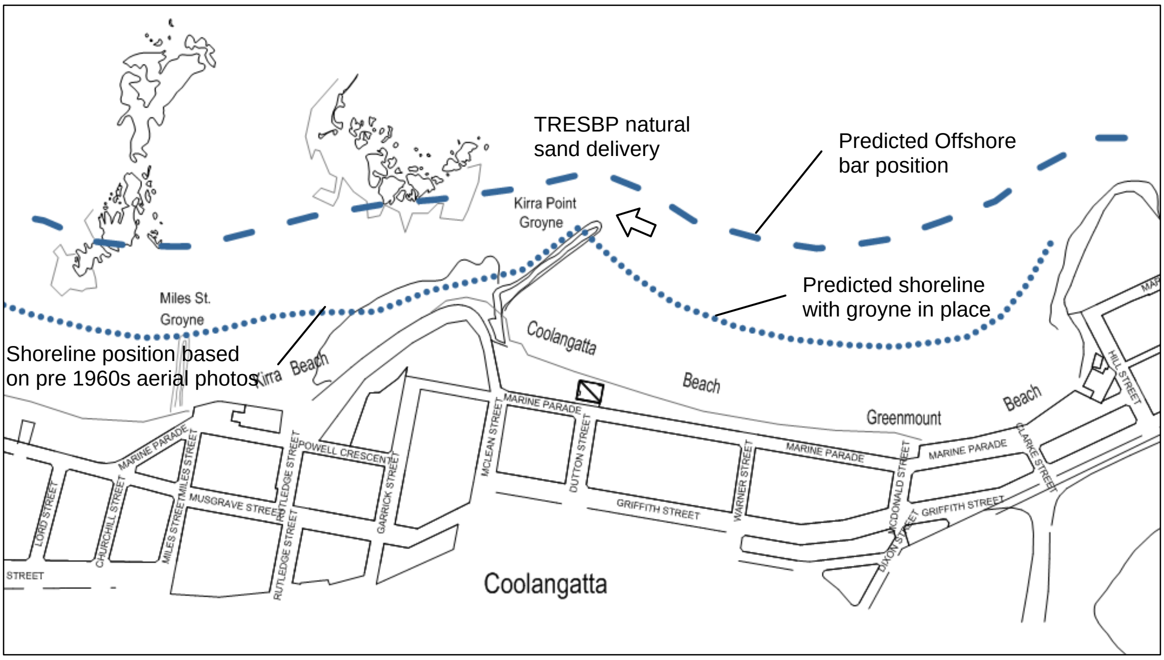


Figure 4 Post-TRESBP including Kirra Groyne (natural sand supply)

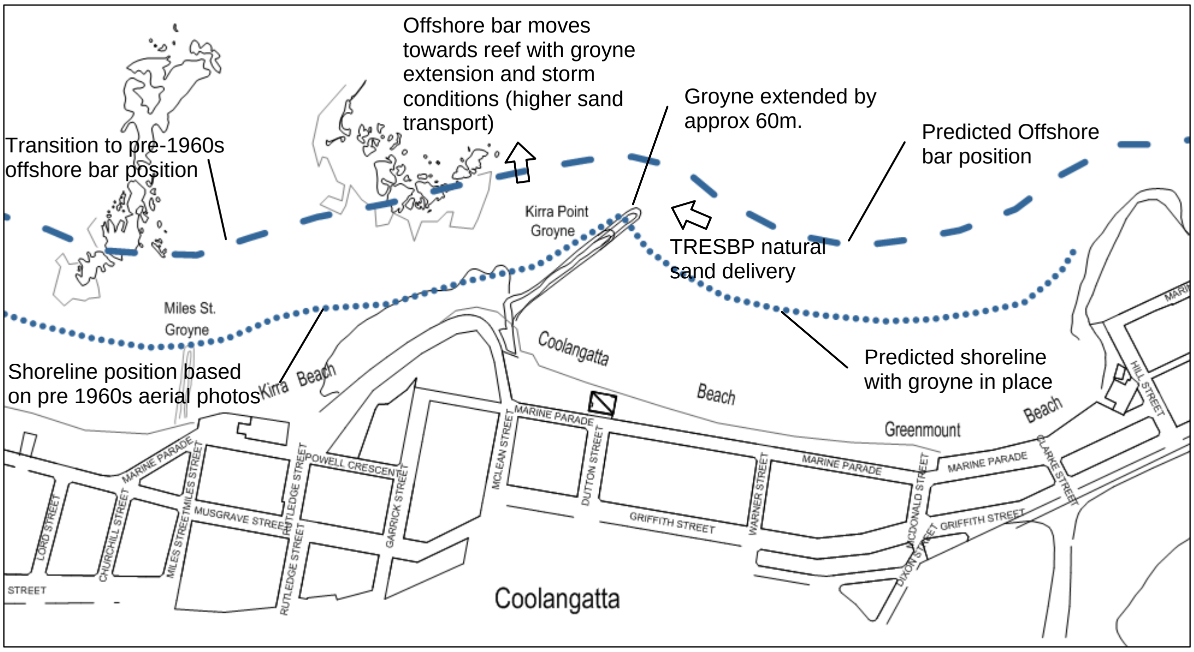


Figure 5 Post-TRESBP extended Kirra Groyne (natural sand supply)

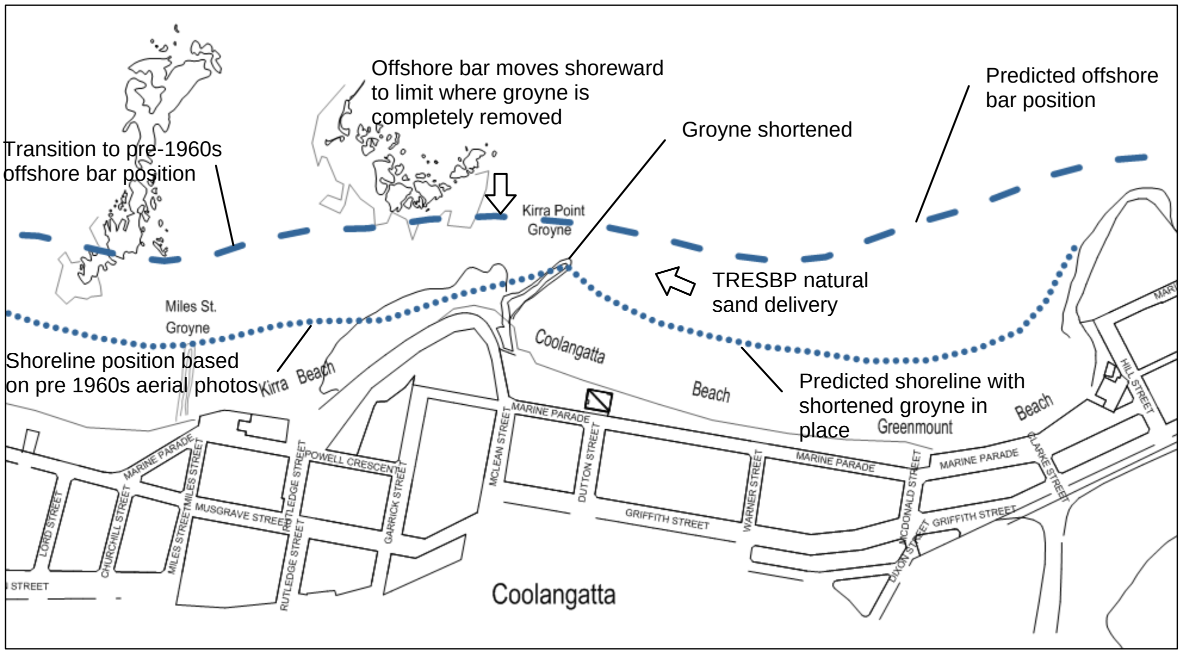


Figure 6 Post-TRESBP shortened Kirra Groyne (natural sand supply)

8. REFERENCES

NSW Dept of Lands, 2009, ‘Sand delivery’, viewed 1 September 2009, http://www.tweedsandbypass.nsw.gov.au/sand_delivery

Hyder Consulting, 1997, ‘*Tweed River Entrance Sand Bypassing Project Permanent Bypassing System Environmental Impact Statement / Impact Assessment Study’,* for New South Wales Department of Land and Water Conservation (now Department of Lands) and Queensland Department of Environment (now DERM), DLWC report No CFR 97/9.

L. Boak, L.A. Jackson, J. McGrath & M. Brosnan, 2001, ‘An overview of Gold Coast Coastal Management 1960 - 2001’, Australasian Coastal & Ocean Engineering Conference 2001 - Gold Coast, Australia.

Appendix 1 Early beach history

Reproduced from the TRESBP Stage 2 EIS, Ch.4.1.4, p.4-4:

The following extract 'Kirra' and 'Coolangatta' from Beach Conservation issues 11 and 12 (produced by the Queensland Beach Protection Authority) highlight the natural variability of those beaches.

Kirra

"Before 1920, the beach at Kirra consisted of a continuous line of undulating sand dunes extending from the base of Kirra Hill to the mouth of Coolangatta Creek, bounded generally by the route of the present Pacific Highway, but embracing the whole of Pease Park.

The road then followed the contour of Kirra Hill at the base of the present Winders Memorial Park. It is still there and useable…

A large part of the parking area now on the eat end of the surf pavilion, was then occupied by a deeper hollow…

The flow-off of rainwater from the Winders Memorial Park area and Rutledge Street ran into this hollow and gradually soaked away. Whatever overflow there was washed off evenly along the entire front of the hollow without damage to the natural sand dunes in front.

Up to this time, Kirra had experienced only that type of intermittent erosion which might be expected as the result of high tides and heavy seas on a completely natural area.

The reclamation of the area extending from the original road west to the Kirra Beach Hotel and its conversion into a car parking area necessitated the construction of a proper drainage system… One outlet… flowed directly on the beach… In time of heavy rains (which often coincide with heavy seas) the flow of storm water created a deep furrow from the outlet to the water's edge, providing ideal conditions for heavy seas, or even high tides, to erode the area…

While natural restoration cycles occurred, these became fewer and less effective because it became impossible by natural means to restore the abnormal quantities of sand eroded as a result of the two drainage systems. The first real erosion of the beach occurred in January 1924 and almost destroyed the Kirra Surf Club building (then situated next to the present public shelter shed)… In 1936 the sea washed into a corner store which was then on the existing Kirra Hotel site.

Coolangatta

"…around 1880, Coolangatta swamp - now known as Goodwin Park - drained into the sea across Greenmount Beach.

The area between The Grand and Queensland hotels then comprised natural sand dunes behind which extended a large hollow about 16 feet deep.

1920: *The hollow in front of the Town Hall war filed with sand from the ascent dunes to construct Marine Parade. Later reclamation of Coolangatta swamp was undertaken, first by an unsuccessful attempt to pump sand from the beach and later by tramway transport of sand from the dunes.*

1930: *During the depression years the area between The Grand and Queensland hotels was levelled and made available as building blocks. The vegetation stabilising the dunes disappeared in the process and the natural dunes lost their identity.*

1930-1960: *Many periods of erosion and natural restoration occurred, the beach width fluctuating greatly. Erosion came close to Marine Parade several times. Accretion always followed sometimes to such an extent that shallow offshore bars or spits effectively widened the beach to the seaward alignment of Greenmount Hill. At the same trine, accretion of Letitia Spit progressed to such an extent that the old Tweed River training walls ceased to be effective.*

1962-1964: *New training walls were constructed as extensions of the old ones. These walls acting as a groyne trapped a considerable amount of sand that would otherwise have passed to the Gold Coast beaches...*

1962: *The Gold Coast experienced a severe cyclone season. An estimated 500,000 cubic yards was removed from Greenmount-Coolangatta beaches and in the following year a boulder wall was constructed to protect Marine Parade. The combined detrimental effects of the boulder wall and the Tweed River training extensions prevented natural restoration of the beach.*

1970: *The Delft report recommended large-scale beach nourishment to restore the beaches. The logical source was the Tweed River or Letitia Spit.*

1972: *An experimental groyne was built at Kirra Point.*

1973: *The Beach Protection Authority advertised a scheme for Beach Erosion Control Districts Nos 2 and 11 which includes restoration by nourishment of over one million cubic metres of sand for Greenmount, Coolangatta and Kirra Beaches".*

The Kirra Point groyne was 180 metres long and was constructed with the intention of stabilising the beach at Coolangatta. In 2 years it was estimated that 306,000 m^3 had accreted on Coolangatta Beach and 503,000 m^3 eroded from Kirra beach.

*In **1974**, a short groyne 60m long was built at Miles Street, Kirra, just west of the Lifesaving building, to preserve a small beach at Kirra.*

Compiled from the TRESBP Stage 2 EIS, Ch.1.3.3.2, p.1-6 to 1-9:

A number of dredging campaigns have been undertaken following the extension of the Tweed training walls. The campaigns referred to in the TRESBP stage 2 EIS were compiled into Table xx and include channel maintenance, estuary reclamation, beach nourishment and landfill. More detailed accounts were provided for campaigns onwards from 1970.

Year	Dredge Campaign	Quantity(m^3)
1915-1920	*Entrance to Ukerebagh Island*	*380,000*
1974/75	*Kirra & Nth Kirra*	*765,000*
1985	*Nth Kirra*	*315,000*
1988	*Kirra Beach*	*1,500,000*
1989	*Bilinga (demonstration)*	*50,000*
1989/90	*sGCb nourishment project Kirra Point to Tugun*	*3,600,000*
1995/96	*TRESBP stage 1A*	*2,247,142*

Appendix 2 Kirra groyne

The Design of Kirra Groyne (taken from BPA memo, 1973)

Table 2 below provides the essential characteristics of Kirra groyne when it was originally constructed in 1972.

Table 2 Kirra Groyne design parameters

Design parameter	Original	Conversion
Alignment	north-east	
Length	600 feet	182.9 m
Height	R.L. 10.0 feet (State Datum)	3.05 m(1)
Armour (trunk)	5 to 8 tons	5.1 to 8.1 tonnes
Armour (head)	10 to 15 tons	10.2 to 15.2 tonnes
Design wave conditions	16 feet	4.9 m
Side slopes (natural)	1:1¼ to 1:1½	
Side Slopes (design wave condition)	1:2½	
Crest width	12 feet	3.6 m
Notes : *State Datum is roughly equivalent to AHD.*		

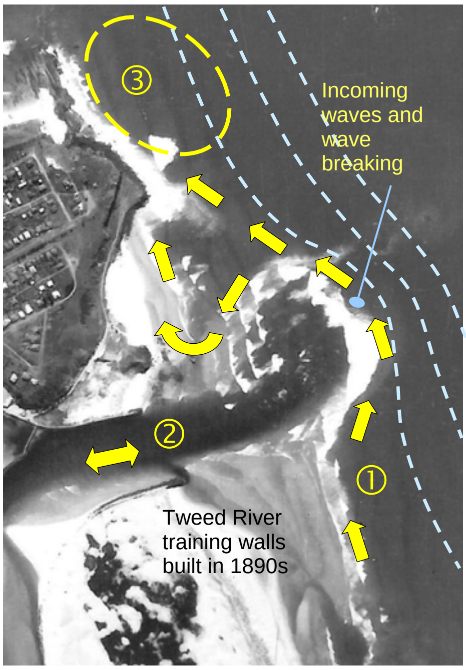
It was reported (BPA memo, 1973) that under the design wave conditions the groyne should retain the design crest width, making repairs easier. Furthermore, it was concluded that under the most extreme wave conditions foreseeable the structure could slump and the crest width may reduce to almost nothing. This could result in waves breaking over the end of the structure at times of high tides and under normal wave conditions.

The memo went on to point out that the structure would always be effective for beach protection purposes (retaining sand on the beach) but may not always be functional for other purposes, including beach walking, fishing, and direct maintenance of the structure.

After much discussion between the Gold Coast City Council and the Beach Protection Authority both the Kirra Point and Mile's Street groynes were shortened in May 1996 by 30 metres.

Appendix 3 Pre 1960s sand movements

(a)



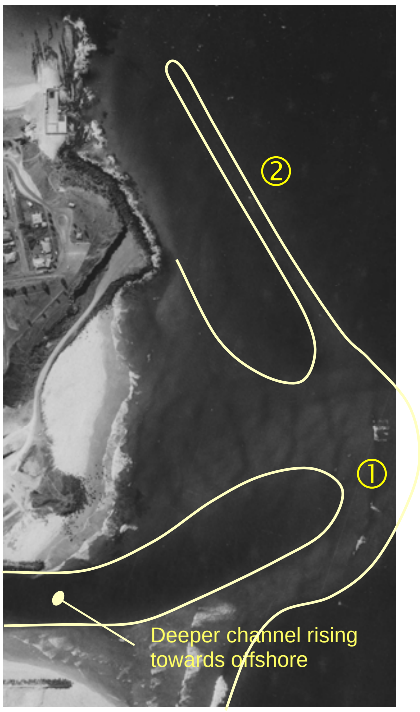
Sand movements pre 1960s (aerial photo 1944):

① River ebb tidal currents and incoming waves form the ebb shoal at the entrance. Sand transport along Letitia Spit is connected to Snapper Rocks via a 'sand bridge' along the shoal crest. Wave refraction in the shallow areas around the shoal causes the waves to bend and change direction forcing sediment transport along the crest of the shoal;

② Tidal currents and waves also promote exchange of sand inside estuary with the active coastal zone. Floods are also capable of moving large volumes of sand out of the lower estuary that have accumulated there;

③ Sand accumulates at Snapper Rocks if depleted or moves around the headland with wave refraction to form shoals in Rainbow Bay

(b)



Sand movements pre 1960s (aerial photo 1961):

① Ebb shoal is clearer in calmer conditions. The oblate shoal is outlined in this image by inner and outer solid lines. The highest part of the shoal (shallowest depth) is identified where waves are breaking (either side of the circled number). On the stronger ebb currents the deeper channel pushes sediment out of the estuary and as current speed falls off sediment settles out;

② Waves transport sediment from the ebb shoal to Snapper Rocks. The image in (b) contains the remnant bar that remains after energetic wave conditions have subsided;

Note: Tweed River training walls not yet built.

Figure A.1 Sand movements from Letitia Spit to Snapper Rocks (a) 1946 (b) 1961

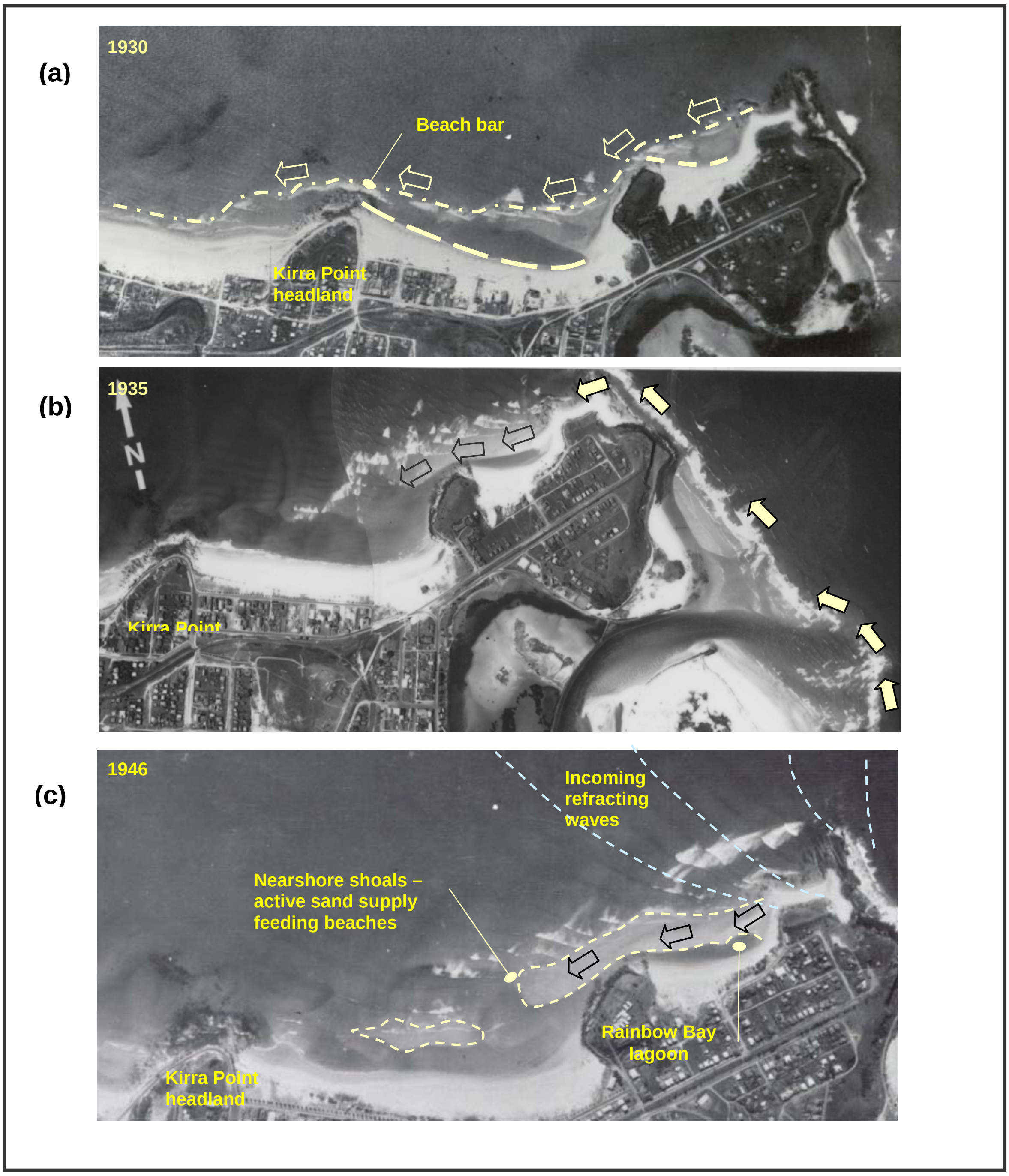
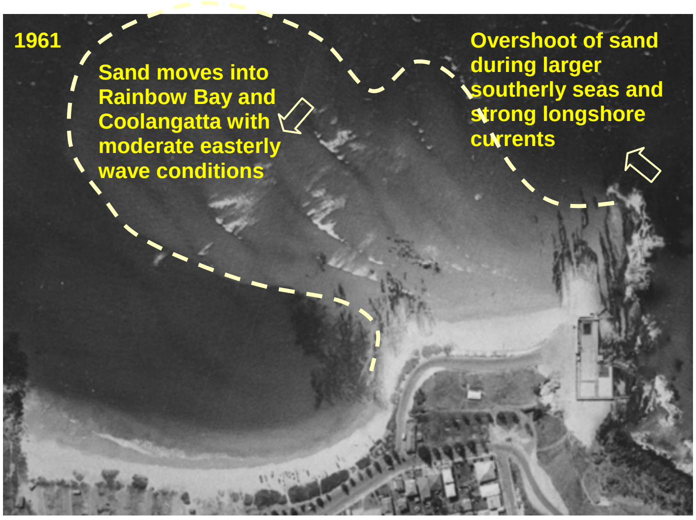


Figure A.2 Sand movements on southern Gold Coast beaches (a) 1930 (b) 1935 (c) 1946

(a)



(b)

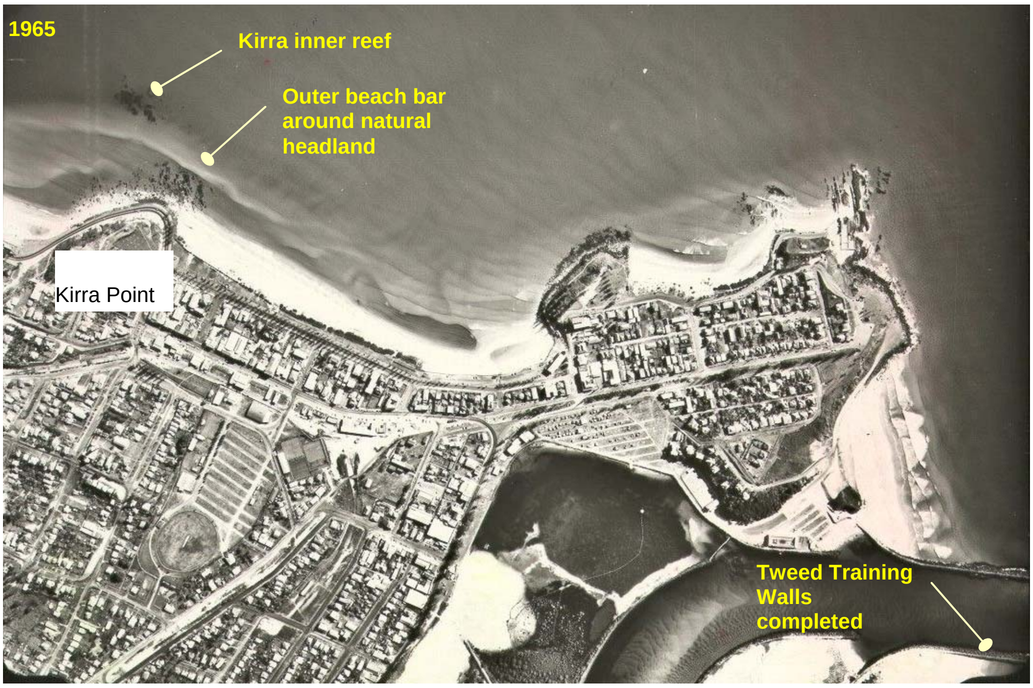


Figure A.3 Sand movements (a) 1961 (b) 1965

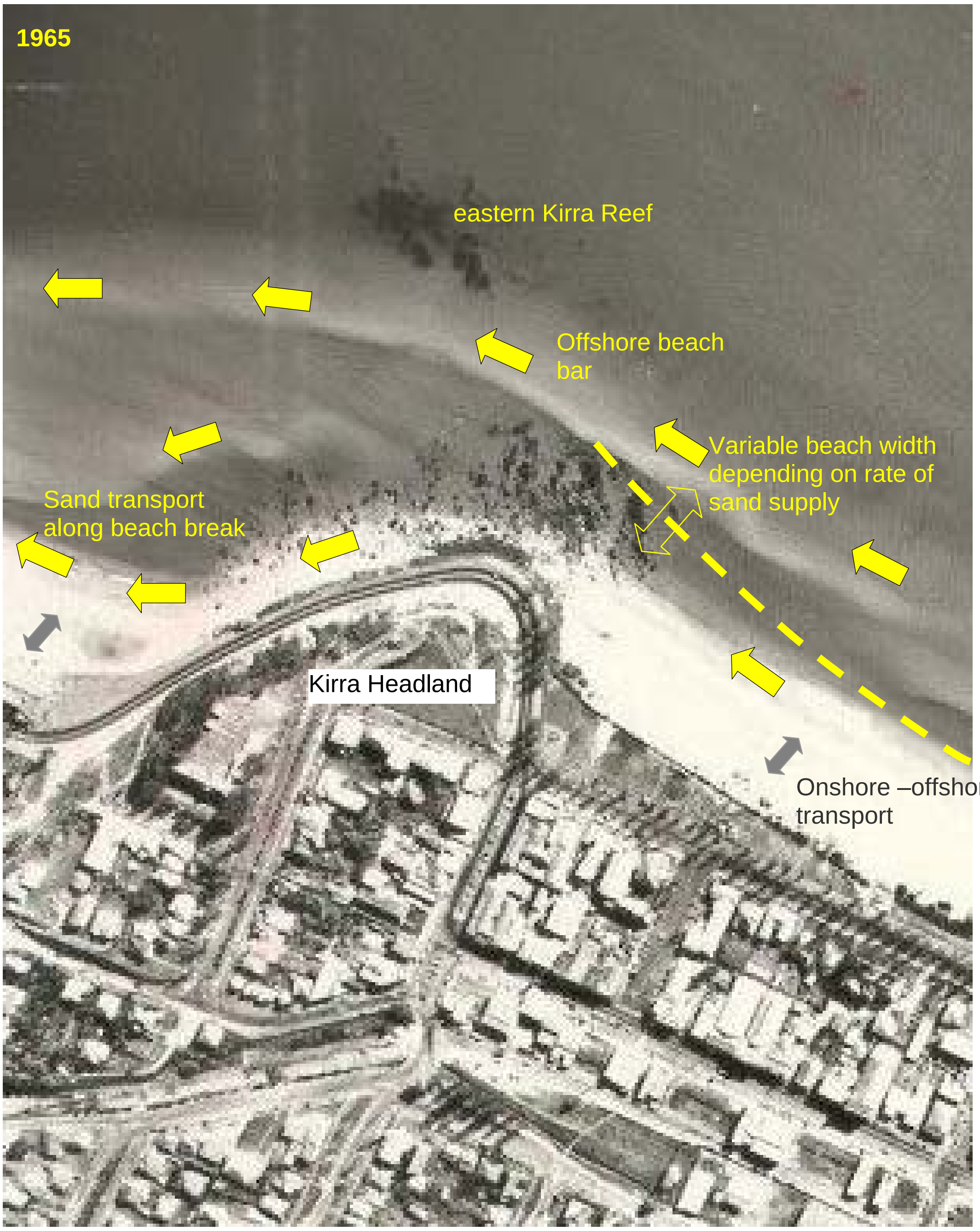


Figure A.4 Kirra headland sand movement mid-1960s

Appendix 4 Post Kirra Groyne sand movements

Figure A.5 Kirra Groyne (a) May 1972 (b) End of June 1972

Figure A.6 Sand movements post Kirra Groyne (a) 1972 (b) 1975

Figure A.7 Sand movements post Kirra Groyne (a) Apr 1977 (b) May 1992 (c) Mar 1997

Appendix 5 Post TRESBP sand movements

Figure A.8 Sand movements post TRESBP (a) May 2000 (b) May 2001

Figure A.9 Sand movements post TRESBP (a) Aug 2002 (b) May 2003 (c) Mar 2005

Figure A.10 Sand movements post TRESBP (a) Jun 2007 (b) Apr 2009

Appendix 6 Beach profiles

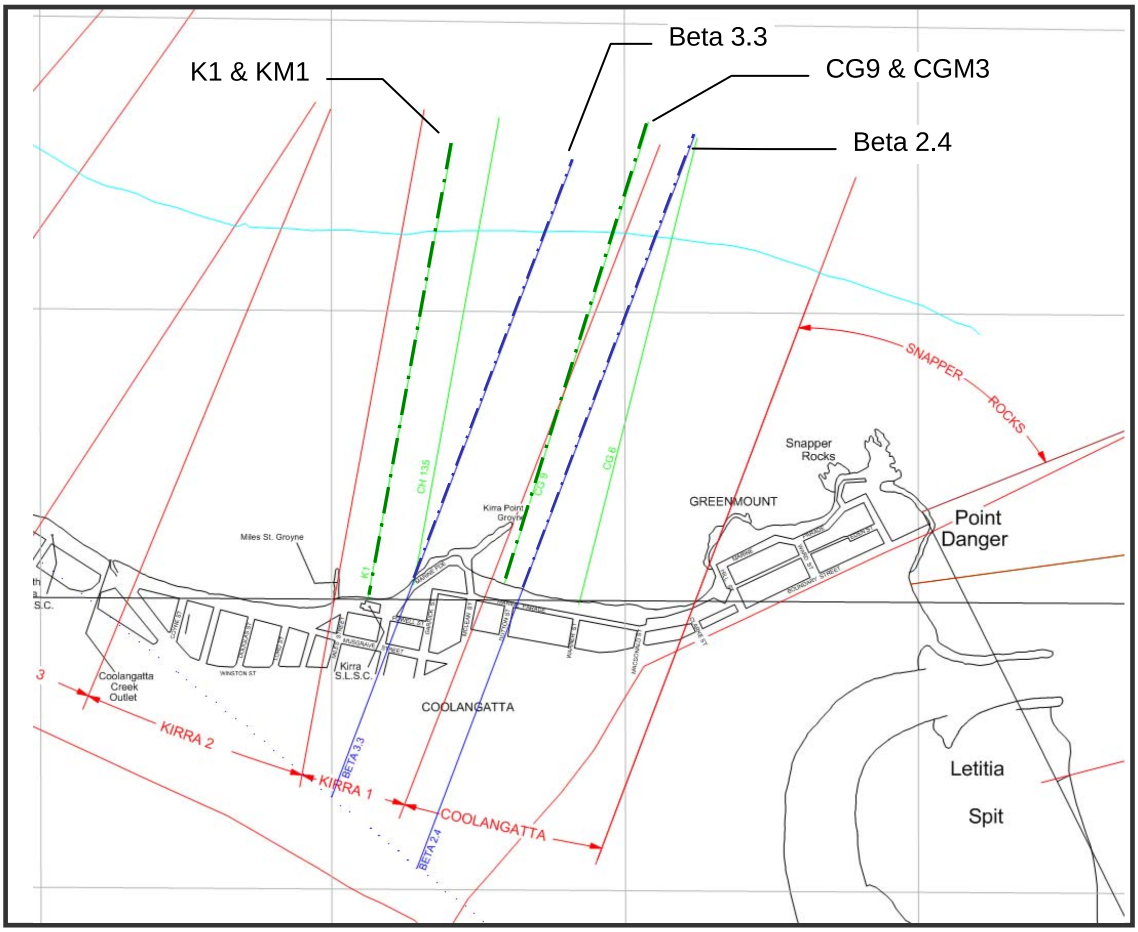


Figure A.11 southern Gold Coast beach survey line locations

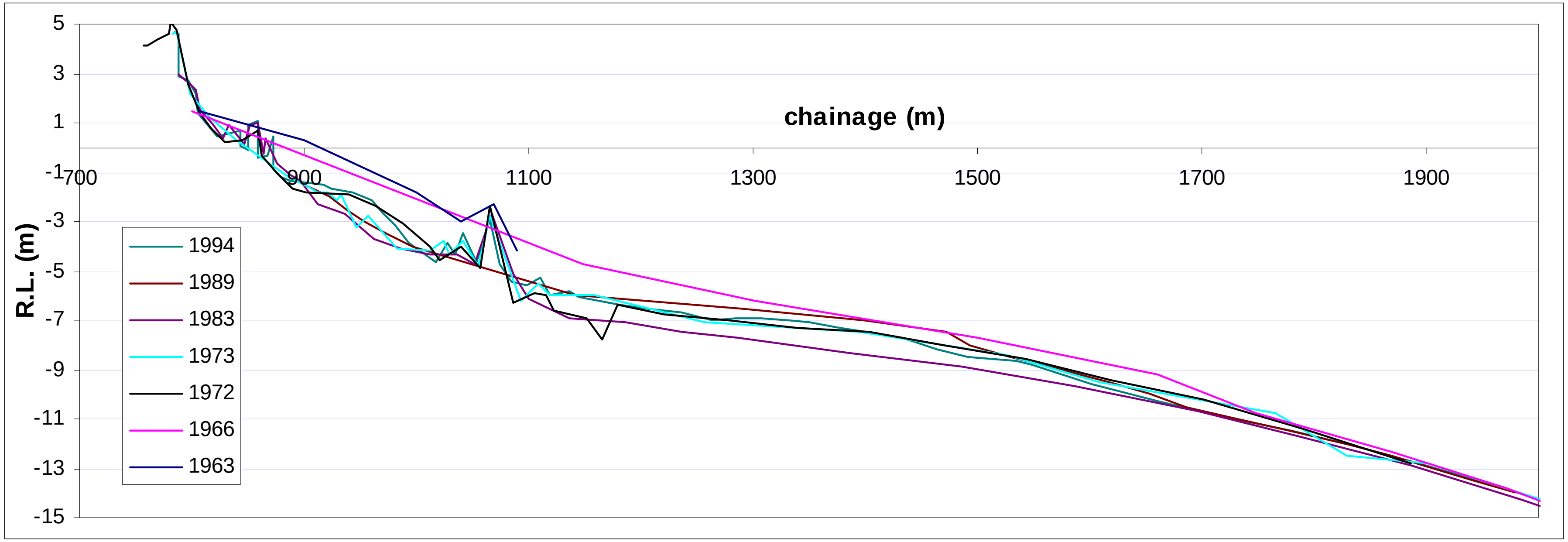


Figure A.12 Survey lines corresponding to Beta 3.3

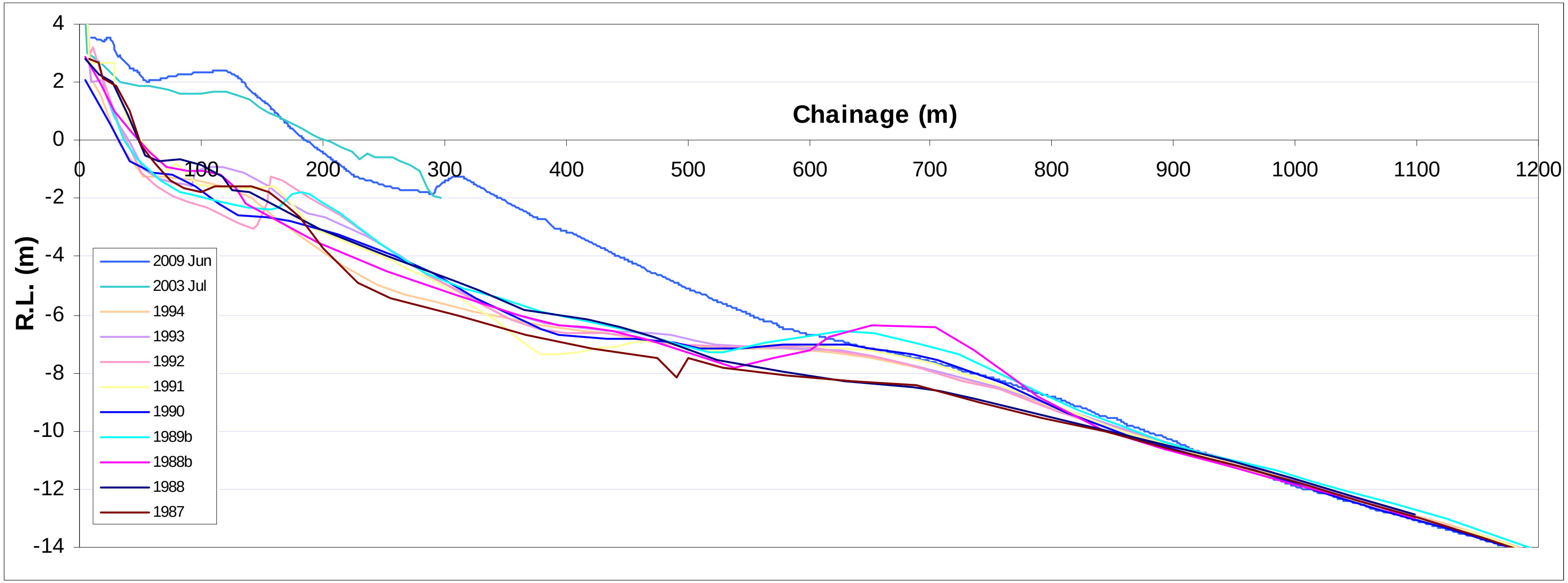


Figure A.13 Survey lines corresponding to K1 and KM1

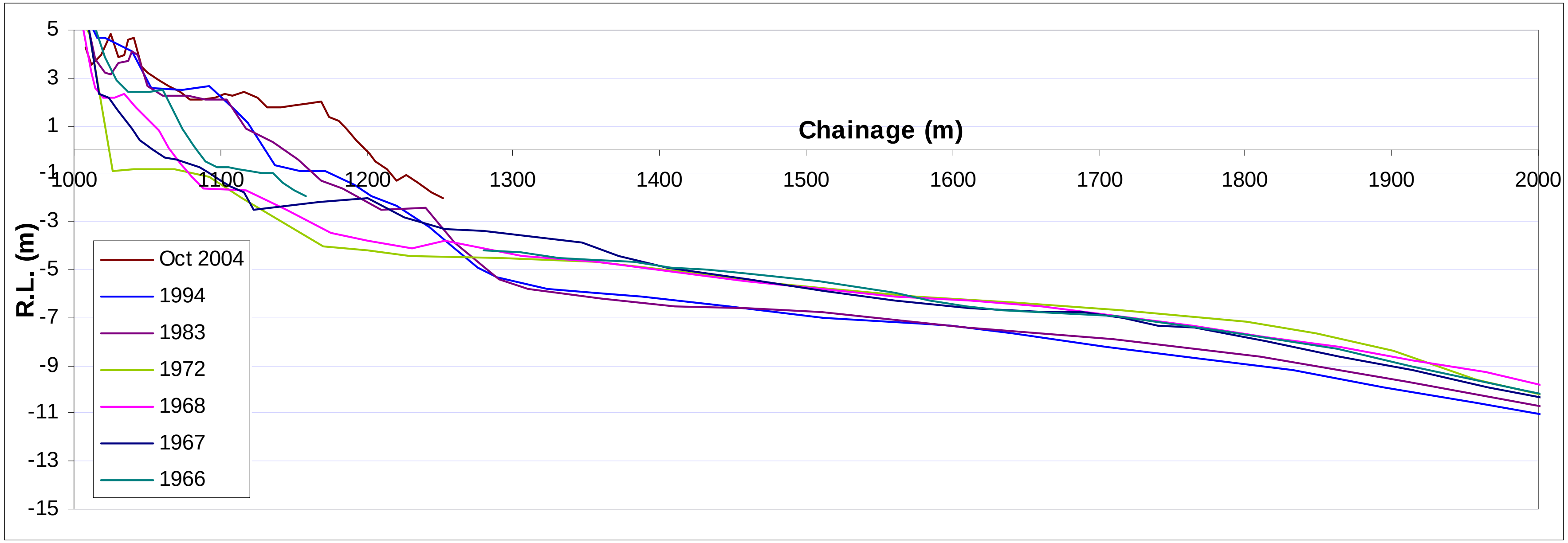


Figure A.14 Survey lines corresponding to Beta 2.4

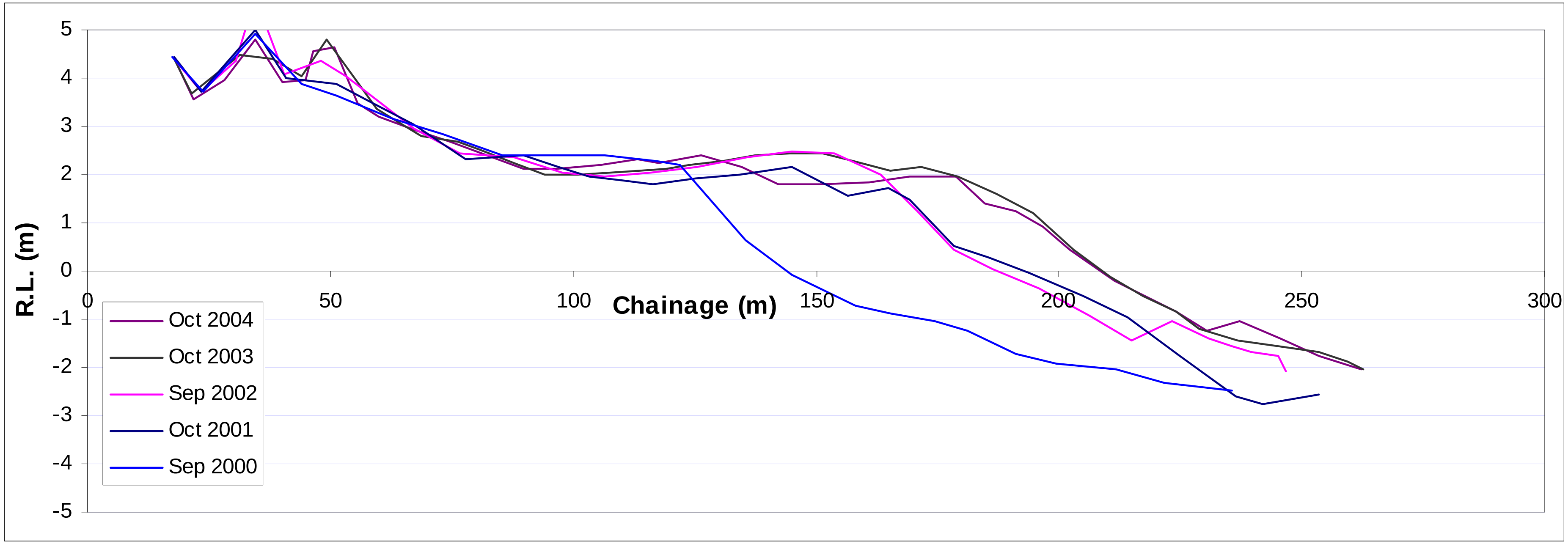


Figure A.15 Survey lines corresponding to CGM3 and CG9

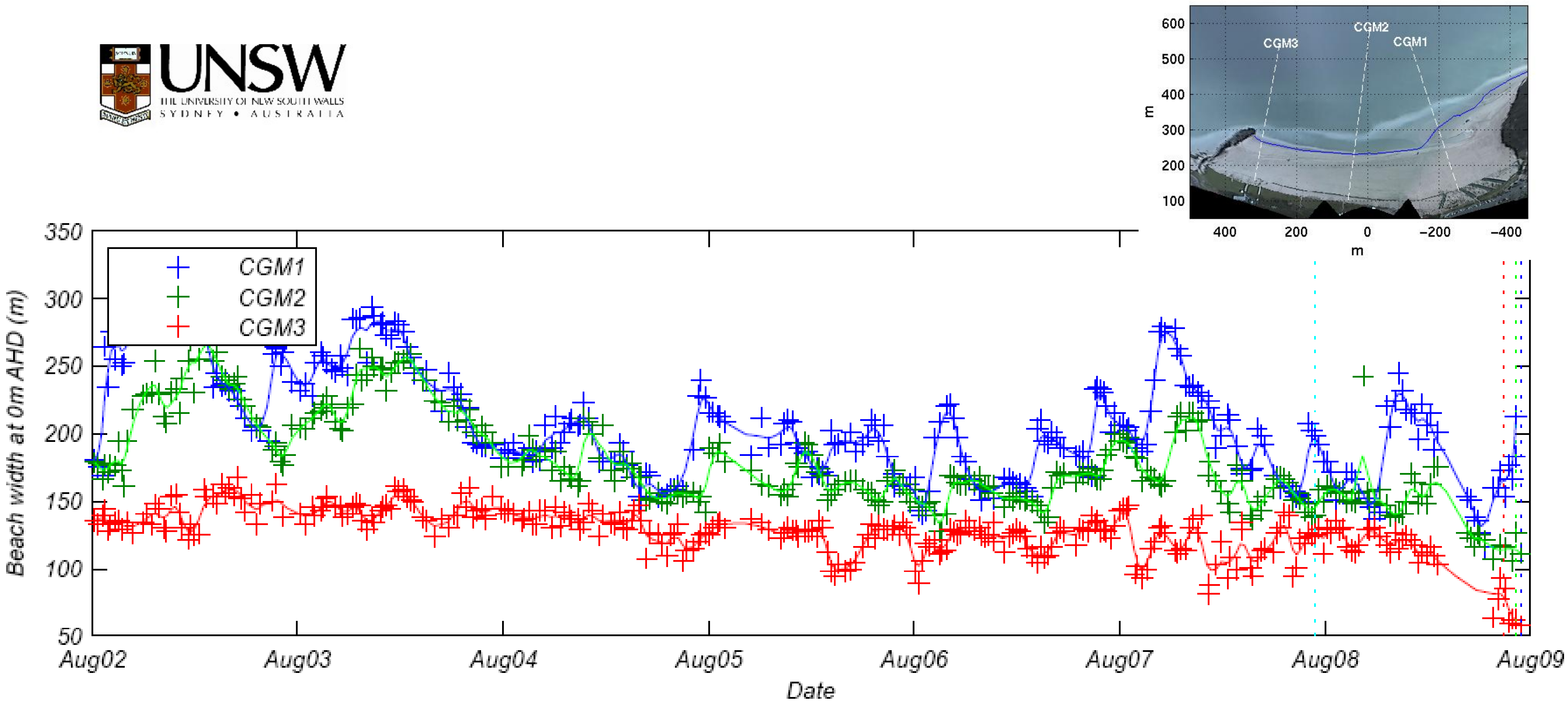


Figure A.16 Argus imaging data showing beach width derived from survey profiles along Coolangatta beach

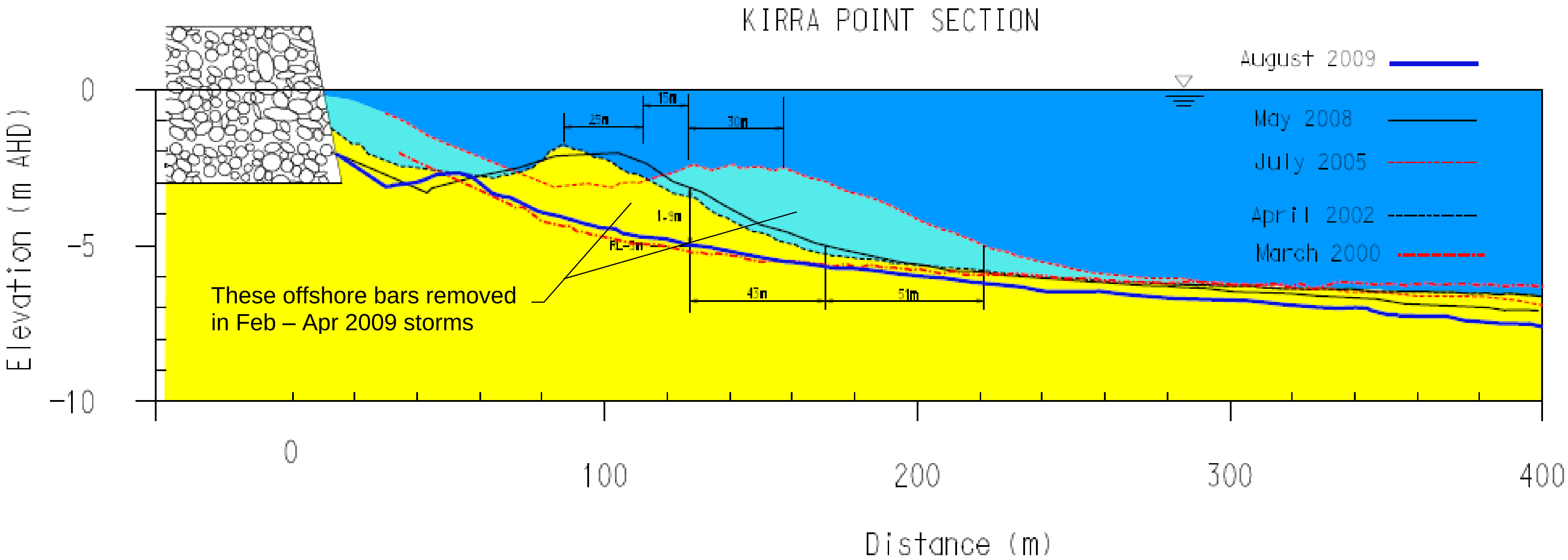


Figure A.17 Kirra Point Section profiles compared with August 2009

Source: NSW Dept of Lands

Appendix 7 Kirra Reef

Source: (NSW) Dept of Land & Water Conservation
Photogrammetric analysis (Feb 2000 & Aug 2001).

Figure A.18 Kirra Reef placement exclusion zone and reef outline

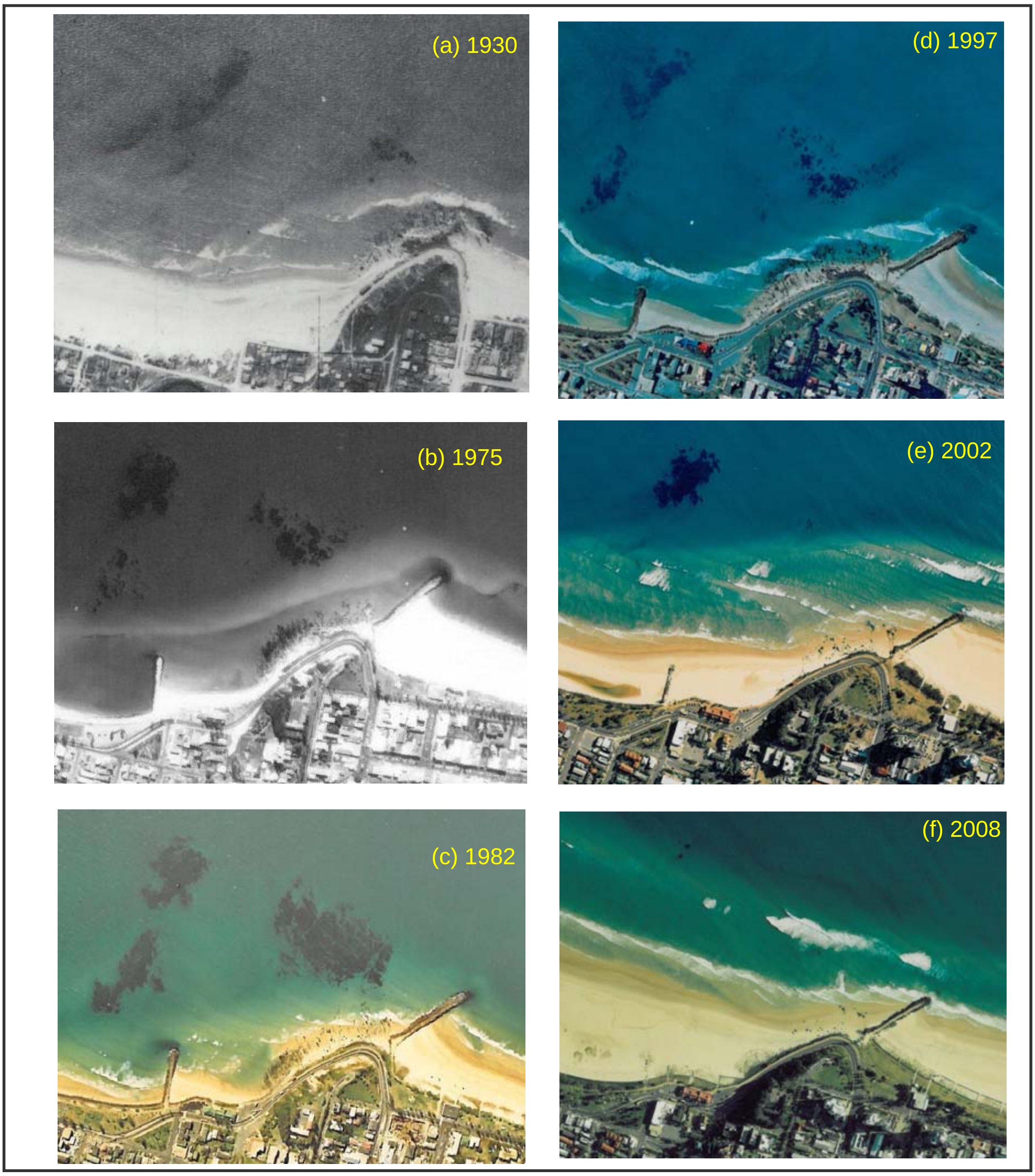


Figure A.19 Aerial photos of Kirra Reef (a) 1930 (b) 1975 (c) 1982 (d) 1997 (e) 2002 (f) 2008