Coastal Management Implications of Groyne Removal

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SUMMARY: This paper describes a study performed to investigate coastal management implications of groyne removal, for the southern Gold Coast beaches in Queensland, Australia. The GENESIS shoreline evolution model was chosen to examine the impact of groyne removal on the stabilised beaches of Coolangatta and Kirra, under a range of different model wave climates. Predicted shoreline changes generated by computer modelling were compared to actual shoreline changes obtained from the preliminary results of beach profile monitoring. It was found that model simulation was improved with the inclusion of a long diffracting groyne to represent a natural headland. Simulation of a realistic wave energy climate which included large storm events, produced rapid recession of the beach profile following groyne shortening. The study demonstrated limitations of applying shoreline evolution models in complex coastal environments. These limitations and the preliminary results of the beach profile monitoring programme associated with the groyne shortening are also described.

1. INTRODUCTION

Gold Coast City located in Southeast Queensland, and extends from Coolangatta to South Stradbroke Island and includes some 47 kilometres of clean, sandy, surfing beaches. Owing to the beautiful beaches, climate and lifestyle, the Gold Coast is a popular tourist destination experiencing high population growth. The existence of adequate beaches for recreational activities is vital to the city's economy and the lifestyle of its residents. This highlights the importance of combating beach erosion in the maintenance and management of the Gold Coast beaches. Beach erosion initially became a problem because residential and tourist developments were located on the active dunal systems. Protection of foreshore properties from the damage caused by cyclones, prevalent during summer months, prompted the construction of sea walls along most of the Gold Coast.

The problem of beach erosion was exacerbated by the extension of the Tweed River training walls in the early 1960's. The net northerly longshore transport of sand, created by the high average wave energy from the southeast, was interupted starving the Gold Coast beaches of an estimated 7 million cubic metres of sand by 1990 (Jackson,1992). The initial responce to the Gold Coast erosion problems was the construction of rock groynes first at Kirra Point to protect Coolangatta Beach (1972) and next a smaller groyne at Miles Street to hold the beach in front of the Kirra Surf Life Saving Club (1974). Erosion problems continued to develop to the north of these structures. In the mid 1970's the Gold Coast City Council adopted soft projects (eg beach nourishment) as its preferred method of coastal protection and 8.6 million cubic meters of sand has been pumped into the Southern Gold Coast Beach system between 1974 and 1996. The area most affected by the compartmentalisation of beaches was the southern end of the Gold Coast (Figure 1).

Figure 1: Locality map

The headland of Point Danger shelters this area from the predominate south east wave climate. Sediment transport mechanisms of these protected beaches are unlike a continuous beach system, as the deepwater littoral drift off Point Danger is only activated during high energy wave states (Smith,1990). Sand is therefore transported spasmodically in a “slug” formation.

In March 1994, thirty two years after the 1960's extension of the Tweed Training walls the Queensland and New South Wales State Governments signed an agreement to jointly solve the problems at the Southern Gold Coast. The Tweed River Entrance Sand Bypassing Project (TRESBP) has the joint objectives of improving and maintaing the southern Gold Coast beaches and establishing and maintaining an improved navigable entrance to the Tweed River. The project will involve artificially bypassing sand across the Tweed River from NSW into QLD.

Following the initial stage of the TRESBP, the Gold Coast City Council requested approval from the Queensland Beach Protection Authority to remove 30m from the ends of Kirra Point and Miles Street groynes. The Queensland Beach Protection Authority issued a permit in October 1995 to the Gold Coast City Council to shorten the Kirra Point and Miles Street groynes by 30m. One of the conditions of this permit was to undertake monitoring of the effect of the works on the beach system.

It has been suggested that Kirra's rock groynes deflect the longshore stream of sediment away from the North Kirra area (Jackson and McGrath, 1993). With the commencement of the TRESBP the Gold Coast Council resolved to commence removal of the groynes in line with its commitment to soft coastal managment solutions to coastal problems.

To examine coastal management implications of this decision a public opinion survey, computer modelling to predict shoreline change and a monitoring program were undertaken. This paper presents findings of the above mentioned investigations.

2. PREDICTED SHORELINE CHANGE

2.1 Data Preparation

The one dimensional shoreline evolution model GENESIS, was chosen to examine the impact of groyne removal on the stabilised beaches of Coolangatta and Kirra. The numerical computer model required information on wave climate, shoreline position, beach profile, offshore bathymetry and location of structures to be specified. Parameters requiring model specification were accurately determined from the large database of information concerning the coastal environment of the Gold Coast.

Statistical analysis of wave rider buoy information for the six year period from 1988 to 1993, provided a full year standard wave data set. Wave rider buoy information contains measurements of wave height and wave period on an hourly basis. This data was manipulated to achieve four records of wave data per day. To obtain information on wave directions a separate study was undertaken in which derived average wave directions off Coolangatta for the four year period from 1989 to 1992 were refracted to the 10m offshore contour (Jackson & McGrath,1993). Refracted wave directions randomly assigned to the wave data set and the corresponding wave height reduction due to refraction, provided a realistic representation of the actual wave climate experience by the upper beaches. Statistics of the wave data set include average wave height of 0.8 metres and an average wave period of 7.3 seconds.

2.2 Model Verification

Calibration of the numerical computer model entailed altering empirical coefficients until the predicted shoreline closely resembled the measured shoreline. The empirical coefficients represent measures of longshore transport produced by obliquely incident breaking waves, and the longshore gradient in breaking wave height (Hanson & Kraus,1989). The model was initially calibrated utilising a real time series of wave data for the calibration period, after which the program was rerun using the standard wave set. Calibration coefficients were adjusted if required to provide an annual net sediment transport rate equivalent to 223,000 m^3 for the upper Coolangatta beach and 150,000 m^3 for the upper Kirra beach, which corresponds to measured sediment transport rates of this region (Jackson & McGrath,1993).

2.3 Modelling Methodology

A beach profile in equilibrium with the standard wave climate was established to form the initial state for the shoreline change model. The modelling strategy adopted incorporated simulating shoreline changes updrift of Miles Street groyne at Kirra beach and updrift of Kirra Point groyne at Coolangatta beach. The flexibility of the GENESIS model allowed the effect of removing either 30m or all of the groyne to be examined. The variability of shoreline recession after groyne modification was also examined by increasing wave heights to simulate the impact of a storm or cyclone being included in the standard wave data set.

2.4 Coolangatta Beach

To model shoreline response at Coolangatta Beach two different boundary conditions were imposed;

?? a gated boundary condition at Kirra Point groyne and
?? a pinned beach condition to represent a stable section of beach.

A gated condition is where sand flow is controlled and a pinned condition where sand is not restricted and free to flow across the boundary (Hanson & Kraus, 1989). Simulating beach recession with the standard wave set revealed the beach would take a period of over 10 years to reach a new equilibrium position after the removal of 30m from Kirra Point Groyne (Figure 2). Given the low average wave height of the standard wave set, this result would be representative of a best case scenario incorporating mild wave conditions.

The impact of more intense wave climates was also undertaken to estimate the worse case scenario. This demonstrated that the time period of beach recession could be significantly reduced to around 1 to 3 years should cyclones afect the area.

It is estimated from the modelling that a sand volume change of the magnitude of 48,500 m^3 could be expected for the upper part of Coolangatta Beach after groyne shortening. The actual volume change is expected to be greater than the estimated value, as the modelled beach did not include the far southern and northern ends of Coolangatta beach, due to the difficulty in representing the boundary conditions in the GENESIS model.

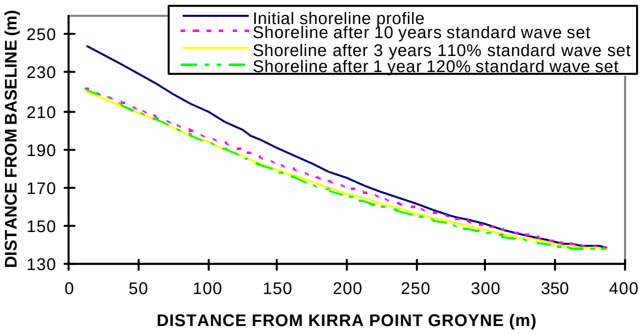

Figure 2: Shoreline recession at Coolangatta Beach after 30m groyne shortening.

To simulate complete removal of Kirra Point groyne, it's length was reduced to the position of the existing natural rocky headland and permeability increased to allow it to behave like a partial littoral drift barrier (WAS THIS TWO SEPARATE MODELS? IF SO THIS NEEDS TO BE CLEARLY STATED!!!). The beach profile obtained with the various wave sets, established equilibrium shapes shoreward of the natural Kirra Point headland (Figure 3). The modelled shoreline did not recede past these established profiles because the pinned beach condition acted to restrain beach recession. This type of boundary condition assumes a constant supply of sediment to Coolangatta beach. Previous information on sediment transport mechanisms suggest this type of sediment movement is not typical of this region, as sand is supplied spasmodically in slugs only during high energy wave events. (SMITH)

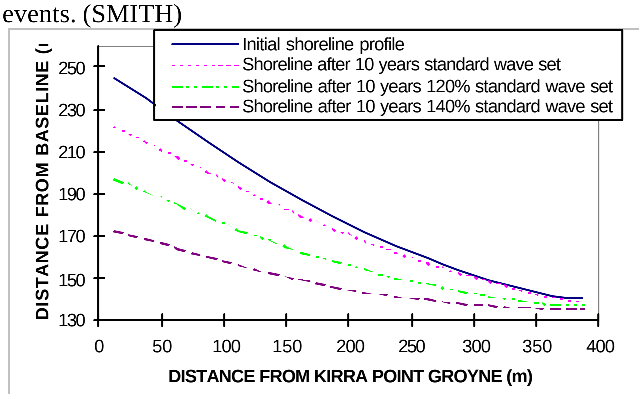

Figure 3: Shoreline Recession at Coolangatta Beach after complete groyne removal.

2.5 Kirra Beach

A variety of model configuations were employed and trialed to simulate beach changes after modification to Miles Street groyne. Initial model set ups tried to model beaches updrift and downdrift of the groyne, incorporating pinned beach boundary conditions at either ends. Inclusion of these boundary conditions did not allow accurate representation of beach change. Even with a single pinned beach condition, model simulation was similarly not improved. The problem was rectified by incorporating a long diffracting groyne to represent the natural headland of Kirra Point. This allowed for an improved modelling result to be obtained, as the groyne acted as a barrier to littoral drift until enough sediment accreted to allow sand bypassing around the groyne head. Beach recession was therefore greatest in the first modelled year. Removal of 30m of the groyne revealed the beach receded with the standard wave set after 3 years and only 2 years with a more intense wave climate (Figure 4).

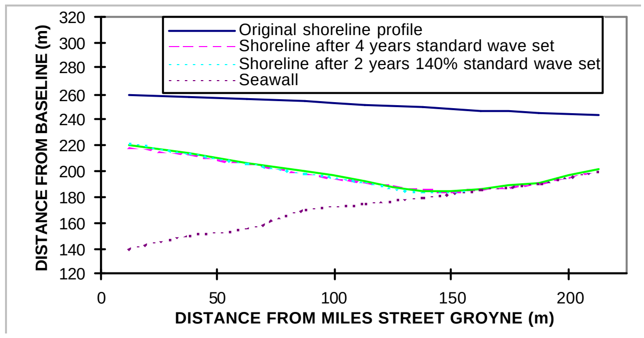

Figure 4: Shoreline Recession at Kirra Beach after groyne shortening.

The predicted beach profile attained may not necessarily be representative of the actual beach profile. This is because the diffracting groyne implemented to represent Kirra Point headland produces a downdrift erosion profile on Kirra beach, resulting in the section of beach near the groyne base receding to the seawall. It was estimated that the sand volume change at upper Kirra beach would be of the magnitude of 159,000 m^3, which is greater than the estimated volume change at Coolangatta beach. This was unexpected as Kirra beach is a lot shorter than Coolangatta beach. The discrepancy between values is due to the influence of the seawall on beach change calculations. Therefore the estimated value for beach change at Kirra beach is questionable.

Complete removal of Miles Street groyne showed the beach receded to the position of the seawall. The time period for beach recession decreased with more intense wave climates. Such results would be representative of the impact of a large storm or cyclone, or if the groyne is removed and no sediment supplied.

3.0 GROYNE REMOVAL

3.1 Process and Equipment

Kirra Point groyne was originally about 175m long in a north easterly direction off Kirra Point. Miles St was about 120m in a northly direction off the Esplanade. Each of the groynes were shortened by 30m during the autumn and winter months of May to August 1996. Weather conditions during this period are characterised by westerly winds and a small wave climate. Large swells are sometimes encountered during the winter months but these originate from low pressure systems in the southern Pacific Ocean and so the Southern Gold Coast beaches are protected. Autumn and Winter were therefore deemed to be the most appropriate time to undertake groyne shortening.

Groyne shortening involved the use of land based equipment, making preparation of a road surface on top of the groyne necessary. A standard 17 tonne excavator utlising both a rock grab and bucket removed the boulders off the end of the groynes in layers. Boulders removed ranged from between 3 and 9 tonnes and were loaded onto 10 tonne trucks and stockpiled at the Council Depot for emergency coastal protection works. With this type of equipment it was difficult to remove all the boulders, especially below the water surface. Boulders therefore remain immersed in sand for the end 30m section, causing it to behave somewhat like a submerged groyne. Other limitations encountered by this process of groyne shortening resulted from natural forces such as tide height and wave conditions, however, the benefit of using such simple technology meant the cost of groyne shortening was only $117,000. The process of groyne shortening took approximately 3 months to complete. The initial stage of the TRESBP was underway during the period of groyne shortening which involved the placement of 2,225,000 m^3 into the Southern Gold Coast beach system.

3.2 Public Opinion

Whilst the groyne was being shortened, a public opinion survey was undertaken to identify social implications associated with the removal of these groynes. The survey aimed to determine the public's attitude towards shortening of the rock groynes at Kirra and gain the level of public understanding of beach processes operating. Key findings include - a high level of public awareness about the decision to modify the groynes; the public perceive the most recent storm/erosion events as the most harmful; majority of people surveyed believed Kirra Point groyne was an important part of the history of the area; concern was expressed from the surfing community about possible degradation of the quality surfing wave at Kirra Point.

4. ACTUAL SHORELINE CHANGE

4.1 Monitoring Program

A comprehensive monitoring program was implemented by the Gold Coast City Council to examine the impact of groyne shortening. Components of this program included regular surveys of areas updrift and downdrift of Kirra's rock groynes, periodic photographing of Kirra, Coolangatta and Rainbow Bay beaches and monitoring of the wave climate. In an attempt to understand beach changes after groyne shortening, the preliminary data available from the monitoring program required further analysis. Visual data was analysed by considering the tide level and tide height of each photograph and noting changes in the beach shape and wave conditions. Beach survey data available for before (11/05/96), during (20/06/96) and after (3/10/96, 6/02/97) groyne shortening, was converted into offshore contour maps of the region. Information from these maps placed into the KEAYS program allowed isopachs to be generated, which highlight areas of accretion and recession. The initial beach survey, completed before groyne shortening (11/05/96), was the base map used to generate isopachs and compare to the other beach surveys. Volumes of beach change were also determined by using the KEAYS program. To obtain values which could be accurately compared to predicted values, survey areas for calculating beach change were identical to the model set up used in GENESIS.

Analysis of the preliminary monitoring data has been complicated by beach nourishment works undertaken as part of the Tweed River Entrance Sand Bypassing Project. Beach nourishment works at the southern Gold Coast in 1995, involved onshore and offshore sand dumping totaling 2,000,000 m^3. A further 271,000 m^3 of sand was dumped offshore in 1996 from the period January to March. Identification of the specific areas in which beach nourishment occurred proved difficult. Therefore during analysis consideration has been given to possible movements of beach nourishment sand, wave conditions and sediment transport mechanisms of this area.

4.2 Monitoring Results

The visual account of beach change dates back to January 1996, five months prior to groyne shortening. During this period the spasmodic movement of sand slugs is evident as well as the effect of beach nourishment. Early in 1996 the beaches at Coolangatta and Kirra were wide and well established, mainly because of beach nourishment works undertaken in 1995 and sediment movement off Rainbow Bay beach. A useable beach had been established downdrift of Miles Street groyne at North Kirra. However, as the summer months progressed, the increased wave climate and northerly longshore drift, caused a large sediment movement off Coolangatta and Kirra beach. The previously straight alignment of North Kirra beach, became curvilinear in shape as the section of beach immediately downdrift of Miles Street groyne receded. Photographic records of beach change display the high tide erosion escarpments. The recession of beach profiles at Coolangatta and Kirra was compensated by accretion at Rainbow Bay. The effect of beach nourishment works undertaken in early 1996 and movement of sediment around Point Danger, contributed to this accretion. The accretion of sand around Rainbow Bay assisted in development of a large sand shoal off Coolangatta and Rainbow Bay beaches. Inspection of the offshore contour map prior to groyne shortening, revealed the exact location this sand shoal, the presence of a small slug of sand situated off Kirra beach and deep holes at the tip of Kirra's groynes caused by scouring around the groyne head.

Shortening Miles Street groyne permitted sand from Kirra beach to easily bypass around the groyne head. This movement of sand combined with the northerly dispersion of the sand slug located off Kirra, assisted to establish a large sand shoal at North Kirra, which extends past the length of Miles Street groyne. The visible beaches at both Kirra and North Kirra receded as sediment moved offshore, while the visible beach at Coolangatta remained relatively unchanged (Figure 5). The deep hole at the tip of Kirra Point accreted as sand began to bypass around the groyne head, due to the slow shoreward progression of the large sand shoal located off Coolangatta beach.

Figure 5: Changes in the visible beach profile.

Immediately after Kirra Point groyne was shortened sand continued to bypass the groyne and consequently the visible beach accreted and the depth of water at the groyne tip became shallower. The movement of sand off Coolangatta and Kirra beach due to groyne shortening, continued to increase the size of sand shoals off North Kirra and Kirra beaches. The location of these sand shoals were visible at low tide and were separated from the shoreline by a small gutter. The visible beach immediately downdrift of Miles street groyne accreted slightly as some of this sand moved onshore.

The latest survey of beach profiles taken after completion of all groyne shortening works, showed the large offshore sand shoal off Coolangatta beach progressed further onshore, dispersing in a northerly direction (Figure 6). This has created a large sand bank which runs from Rainbow Bay to Kirra Point. The location of this sand bank offshore has caused a rip current to develop along Coolangatta beach. The rip current, created by waves refracting off the large sand bank, runs in a southerly direction from Coolangatta to Greenmount. The effect of this current has caused the visible beach in the middle of Coolangatta to recede, however, the section of beach near Kirra Point groyne accreted because sand continued to bypass around the groyne head. The visible beach at Coolangatta therefore became increasingly curved in shape as the beach began to re-establish itself with the wave climate and new groyne length. Sand bypassing around Kirra Point groyne caused the offshore contours at Kirra beach to accrete, but the visible beach receded because of realignment with the new groyne length. The northward movement of the sand shoal located at North Kirra and scouring around Miles Street groyne, caused the section of beach immediately downdrift of Miles Street groyne to recede to the seawall.

Figure 6: Offshore contours 6/02/97.

4.3 Comparison with Predicted Results

To verify the accuracy of shoreline changes predicted by GENESIS they were compared to the most recent offshore contour map available (6/02/97). In the seven month period since groyne shortening, the southern Gold Coast beaches have suffered from the effect of numerous large swells, created by passing cyclones and storms. The predicted shorelines obtained for comparison with the actual shorelines, were achieved with the higher wave climates. Figure 7 shows the actual and predicted beach profiles at Coolangatta are significantly different. Beach changes have not been accurately represented in the GENESIS model because beach recession after groyne shortening was restricted by inclusion of the pinned beach boundary condition. Accurate representation of sediment transport mechanisms was therefore difficult to achieve.

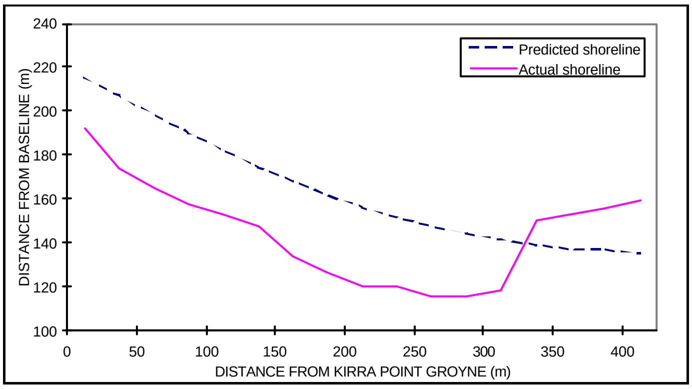

Figure 7: Coolangatta beach

Inclusion of a long diffracting groyne at Kirra beach, to represent the natural headland of Kirra Point, provided an improved modelling result (Figure 8). The modelled shoreline was predicted to retreat to the position shown after 2 years with a higher wave climate. Although the time period involved for beach recession is different the predicted shoreline closely resembles the actual shoreline. The long diffracting groyne implemented resulted in the section of beach at the groyne base receding to the seawall.

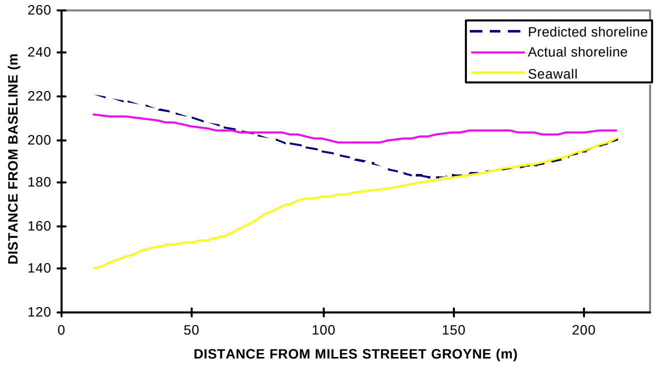

Figure 8: Kirra beach

Beach volume changes which occurred after groyne shortening are displayed in Figure 9. The beach at Kirra progressively receded after shortening Miles Street groyne. The influence of the large sand shoal located off Coolangatta, caused the Kirra groyne survey area to be divided into 2 separate regions. The Kirra groyne outer region shows the advancement of this sand shoal into the survey area, with most movement occurring in the period 3/10/96 to 6/02/97. The Kirra groyne inner region highlights the variability of beach change, however, an overall sand loss of 29,501 m^3 occurred at Coolangatta beach after groyne shortening. The predicted value of beach change with the GENESIS model was a 48,500 m^3 sand loss with the higher wave climate. The comparison of such values is somewhat arbitrary as the shorelines were significantly different and the effect of beach nourishment was not considered.

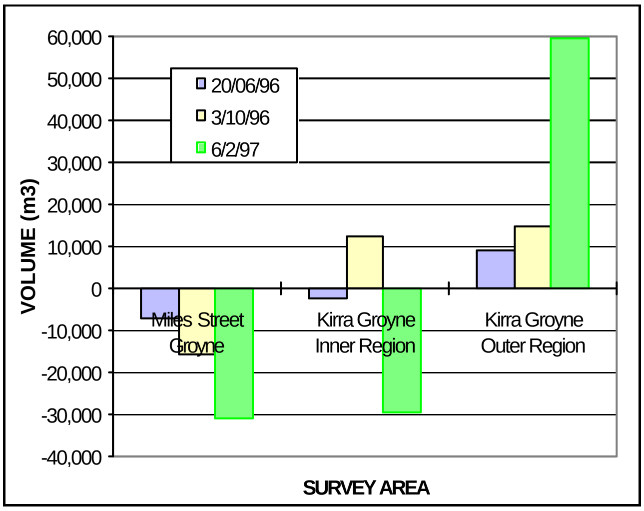

Figure 9: Cumulative Beach volumes changes dating from 11/05/96

4.4 Future Predictions

Evaluation of actual shoreline changes since groyne shortening, show a reduction in the visible beaches at Coolangatta and Kirra. The reduced beach profiles may become suspectible to increased beach erosion problems because this region is now less resistant to storm attack. Preliminary results of beach profile monitoring show that groyne shortening has not fixed the problem of beach erosion at North Kirra. It seems that the effect of Miles Street groyne on the adjacent beach is the dominate factor influencing the visible beach width. To overcome the beach erosion problem at North Kirra, Miles Street groyne would have to be lengthened, to eliminate the effect of the downdrift erosion profile created by this groyne. It may however, be possible to remove both Kirra's groynes completely when artificial sand bypassing of the Tweed River commences. Sand could be pumped onto Kirra beach to maintain a constant visible beach width. Sand could also be pumped into Rainbow Bay to replenish the offshore sand shoals to their pre-training state. If a constant supply of sediment can be provided to the southern Gold Coast beaches and the spasmodic movement of beach sediment eliminated, the problems associated with beach erosion may be overcome. The removal of both Kirra's groynes will however change the rip currents operating in this region. Observations prior to construction of Kirra's groynes, suggest a strong rip current from Coolangatta to Kirra will develop (Stolz,1996).

5. CONCLUSION

The impact of shortening the rock groynes at Kirra has been assessed by computer modelling, a public survey and analysis of preliminary monitoring results. Numerical modelling of shoreline changes due to groyne shortening, demonstrated the difficulties is simulating shoreline response in complex coastal environments. Accurate representation of wave refraction, sediment transport mechanisms and beach nourishment requires experimentation with the GENESIS model set up. Comparison of predicted shoreline changes with actual changes, demonstrated that inclusion a long diffracting groyne, to represent a natural headland, improved the modelling result obtained. Simulation of a more realistic wave energy climate which included large storms and cyclones produced rapid recession of the shoreline after groyne shortening. Reducing the groyne length subsequently reduced the amount of beach material available to act as a buffer against such high energy wave events. Preliminary results from the monitoring program have indicated that shortening the groynes at Kirra has not solved the problem of beach erosion at North Kirra.

6. ACKNOWLEDGMENTS

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