

Profile response and dispersion of beach nourishment: Gold Coast, Australia

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ABSTRACT

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For over 30 years a primary coastal management concern in south-east Queensland, Australia has been the eroded beaches of the southern Gold Coast. The 380m extension of the Tweed River training walls from 1962-1964 interrupted the littoral supply of sand to the beaches of the southern Gold Coast which experienced sudden and severe erosion. A series of tropical cyclones and severe storms in 1967 initiated an investigation into the erosion problems by the Delft Hydraulics Laboratory. The report outlined the need for Gold Coast beaches to be able to withstand the impacts of a series of storms and erosion volumes similar to those of 1967. Several recommendations for structures and nourishment programs to address the issue have been implemented and the desire for a long-term solution resulted in the establishment of the Tweed River Bypassing Scheme in 2001. Since 2001, 4.6 M m³ of sand has been dredged from the Tweed River and 4.7 M m³ of sand has been bypassed and deposited within the active profile of southern Gold Coast beaches. Beach profiles surveyed between 1966 and 2006 were analysed to elicit the behaviour of the littoral system and the response to groyne construction, nourishment campaigns and finally the bypass operation. Recommendations for future capital works and management strategies derived from this work will be incorporated into the Gold Coast City Council Shoreline Management Plan.

ADDITIONAL INDEX WORDS: *Sand bar morphology, sediment transport, extreme storms, shoreline evolution.*

INTRODUCTION

The coastline of the City of Gold Coast, Queensland, Australia is a major attraction for national and international tourism. The Gold Coast population was estimated to be 507,439 as at June 30, 2006 and expected to increase to 683,568 by 2021 (HUNT *et al.*, 2008). As one of the fastest growing regions of Australia this area has had to cope with rapid and intense development. The 52km of sandy beaches are exposed to a highly variable wave climate which is dominated by moderate to high energy south to south east swells.

South to southeast swells originate from the eastward passage of low pressure systems in the Southern Ocean or from Tasman Sea lows between May and November. High energy northeast to east swells originating from cyclones in the Coral Sea are typically confined to the period from December to May. While tropical cyclones have the highest potential for extreme wave heights and destruction the intense storms known as East coast lows are responsible for more high wave events. East Coast Lows can develop rapidly in close proximity to the coast resulting in energetic swells and destructive winds. While they may occur

anytime, they are generally more prevalent between March and July (ALLEN and CALLAGHAN, 2000).

The tide is predominantly semi-diurnal and microtidal with tidal amplitude ranging from 0.2 to 2.1m and a mean range of 1m. The sediment is fine sand with $d_{50}=200 \mu\text{m}$. The northern end of the coast is more exposed to swells of southerly origin while Point Danger at the southern end induces an incomplete refraction of waves near shore. As a consequence there are often high rates of littoral drift in this area. The resulting net sediment transport rate has been estimated to be 500,000 m³/yr to the north. This is comprised of approximately 650,000 m³/yr of northward transport and 150,000 m³/yr of southward transport (TURNER, 2006).

There has been a long history of beach management on the Gold Coast in response to both inappropriate development and natural extreme events. Typical of this was the outcome of the extension to the Tweed River training walls to the south of Point Danger in 1962-64. The subsequent interruption to the natural littoral sand supply of the southern beaches was exacerbated by a series of extreme events in 1967 resulting in widespread erosion. An investigation into the littoral processes (DELFT HYDRAULICS LABORATORY, 1970) resulted in the implementation of a scheme of

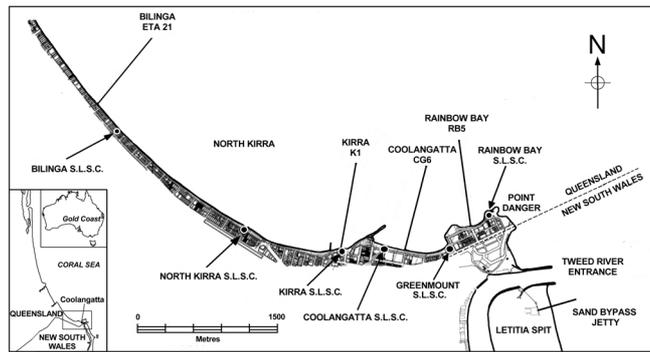


Figure 1. The southern Gold Coast with survey lines and beaches mentioned in the text and in Figures 3 to 6.

works and a review of the long term effects of these works on the littoral system is presented here. The response of the littoral system to these works is instructive for other locations where complex bathymetry and coastal alignment preclude the effective use of coastline evolution models. It has been identified historically, for example, that prior to the extension of the Tweed training walls, the net littoral drift bypasses the Point Danger headland in an episodic fashion, resulting in alternating periods of shoal formation on the down-drift (west) side of the point (TOMLINSON AND FOSTER, 1987).

BEACH MANAGEMENT HISTORY

The beaches of the southern Gold Coast were a popular destination for recreational beach users from the early twentieth century. Increasing levels of development occurred during the relatively calm conditions of the 1920's. During the 1930's the South Coast Road was opened and the beaches of Coolangatta and Kirra were popular weekend camping destinations even before Surfers Paradise gained popularity (LAZAROW, 2007).

Cyclone swells in 1936 and the early 1940's caused widespread erosion to the beaches of the southern Gold Coast and recent beachfront developments were protected with the construction of timber seawalls. A period of relative calm followed with the exception of a single significant erosive event due to a cyclone in 1954.

The problems re-emerged following the completion of the 380m extension of the Tweed River walls from 1962-1964. The walls were extended to aid navigability of the Tweed River entrance creating a sink for the naturally occurring northward sediment transport. In 1967 a series of seven cyclones caused severe and widespread erosion, particularly at the already depleted southern beaches. The Beach Protection Act of 1968 charged the Beach Protection Authority with the responsibility for investigating beach erosion problems and recommending solutions.

As part of investigations into the erosion issues commissioned by the Queensland Government, the Delft Hydraulics Laboratory recommended extensive nourishment for the immediate improvement of the affected beaches (DHL, 1970). The extension of the Tweed River training walls was considered to have resulted in an estimated deficit of the order of 1,530,000 m³ by 1973 (MCDONALD and PATTERSON, 1984; JACKSON, 1985). While it was acknowledged that the littoral transport would be re-established following the trapping and subsequent natural by-passing of the training walls, this process was estimated to take up to 20-25 years

to commence. Therefore it was recommended to supply this required sand in the nourishment scheme (LAZAROW *et al.*, 2008).

A cost/benefit analysis of implementing major nourishment works was conducted and revealed a projected loss in visitor spending of \$574 million (in 1972 values) between 1974 and 1982 if the beaches were not restored. This estimate was conservatively based on an 11% reduction in visitation (MAITRA and WALKER, 1972). With consideration to the economic effects, the report recommended a funding contribution for the works of 40% Federal, 40% State and 20% local government. As the funds were not forthcoming the Gold Coast City council began its nourishment campaign with a 20% State subsidy (HUNT *et al.*, 2008).

Several more severe cyclones occurred in 1972. An estimated 400,000 m³ of sand was lost from Coolangatta Beach between 1966 and 1972. A 175m groyne was constructed at Kirra point to retain the beach at Coolangatta. The groyne was successful in accreting the beach at Coolangatta and led to improved surfing at the popular Kirra point surf break (LAZAROW, 2007).

A boulder wall was constructed to protect the highway along the beachfront at Kirra in 1973 and in 1974/75 765,000m³ of sand dredged from the Tweed River was applied to Kirra Beach (ROELVINK and MURRAY, 1992). This nourishment rapidly eroded due to the longer term effect of the Tweed Wall extension (JACKSON, 1989). A short groyne was constructed adjacent to Miles Street to retain the beach in front of the Kirra Surf Life Saving Club and boulder walls were extended to North Kirra. From 1975 to 1976 the boulder walls were extended 1.7km further north from North Kirra to Bilonga Beach.

Following a significant storm event in 1983 which led to erosion and overtopping of the exposed boulder wall at Kirra and another event in 1984 it was evident that northwards migration of the erosion wave was continuing. In 1985, a 110m long, 5m high, sand-filled geotextile container groyne was constructed at North Kirra to stabilise the nourishment of the foreshore adjacent to the North Kirra Surf Life Saving Club. 215,000m³ was placed on shore and 100,000m³ placed nearshore (JACKSON, 1989).

Nourishment campaigns at the southern Gold Coast beaches continued in 1988 and 1989 despite the relatively mild conditions of the preceding two years. 1.5 Mm³ was deposited between Coolangatta and Bilonga at depths of 6 to 11 metres. 50,000m³ was pumped ashore at northern Bilonga in April 1989. Between November 1989 and May 1990 3.6 Mm³ of nourishment was applied to beaches from Kirra to Tugun during Stage 1 of the Southern Gold Coast Beach Nourishment Project. This project was deemed a success as two years after the nourishment in May 1992, 87% of the nourishment remained in the region

An analysis of the sediment budget of the southern Gold Coast by ROELVINK and MURRAY (1992) concluded that the net effect of the 1962-1964 Tweed wall extension was the accretion of 7.6 Mm³ of sand south of the Tweed River and the erosion of 7.2 Mm³ from the southern Gold Coast beaches. While natural by-passing was apparently increasing from 1983-1989, accretion was confined to the area of Durambah, Point Danger and Rainbow Bay. A growing erosion shadow had developed and extended northwards from Kirra to Bilonga. Combined beach nourishment to May 1990 provided 6.2 Mm³ to the affected area.

The Tweed River entrance responds to dredging by infilling and interrupts the littoral supply to the beaches further north. The need for a longer-term solution to ongoing dredging and beach nourishment resulted in the establishment of the Tweed River Entrance Sand Bypassing Project (TRESBP). From 1995 to 2006, 4.6 Mm³ of sand was dredged from the Tweed River and deposited on southern Gold Coast Beaches (TRESBP, 2008). 4.7 Mm³ of

sand has been pumped from Letitia Spit to outlets on the southern Gold Coast since its inception in 2001. An additional 200,000 m³ of sand was dredged from the Tweed River entrance between May 2008 and September 2008. This was deposited between Duranbah and Point Danger at a depth of up to 20m. In recent years the community has become increasingly concerned about the effects of variable sediment volumes on the recreational amenity and ecology of Coolangatta Bay and Kirra (LAZAROW *et al.*, 2008). This site was therefore chosen to slow the transport of the dredged material into Coolangatta Bay (TRESBP, 2008). Periodic dredging of the Tweed River entrance will continue to be required for safe navigation. The growth of the ebb-tidal delta is controlled primarily by the tidal flow rather than the littoral process (TOMLINSON, 1991).

BEACH PROFILES

Gold Coast beach profiles have been periodically surveyed since the early 1960's. A subset of these profiles was selected to represent distinct coastal compartments for this analysis. The number and time span of the selected southern Gold Coast beach survey lines available for this study are listed in Table 1 and the locations are depicted in Figure 1.

Table 1: Number and time span of available surveys for selected profiles (LAZAROW *et al.*, 2008)

Beach compartment	Survey line	Profiles	Time span
Bilinga	ETA 21	44	1966-2006
Kirra	K1	67	1974-2006
Coolangatta	CG6	64	1966-2007
Rainbow Bay	RB5	55	1984-2006

Volumes were calculated from a vertical reference level of 3m and a horizontal position relative to a design profile which covers the existing boulder wall (Figure 2). Volumes were calculated to the 3m depth contour at the seaward extreme. While the active profile of Gold Coast beaches can extend to a depth of at least 8m, the 3m depth limit was chosen to include a substantial number of surveys which do not extend beyond 3m. An additional consideration was that the recommendations for beach management arising from the Delft investigations (DELFT HYDRAULICS LABORATORY, 1970) were based primarily on analysis of beach profiles to this depth, and for these reasons the same limit has been imposed upon the analysis presented here.

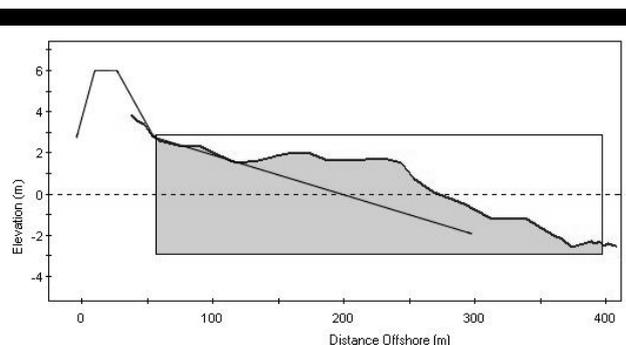


Figure 2. Profile volume calculation limits

ANALYSIS OF PROFILE VOLUMES

The evolution of profile volume, the cumulative volume, the cross-shore distance from the baseline of the shoreline and the 3m depth contour is displayed in Figures 3-6 for the selected compartments of the southern Gold Coast beaches.

Rainbow Bay

Rainbow Bay is a relatively short beach of approximately 0.5 km. The beach faces north-west with Point Danger to the east and Greenmount Headland to the west. The predominant south-east swell is strongly refracted around Point Danger and littoral transport of sediment is usually high. Profiles were available since 1984 and display small variations in volume of around 250 m³/m until 2000 (Figure 3). The minimum volume of 139 m³/m occurred in May 1993 and the maximum of 767 m³/m occurred in September 2002 shortly after permanent bypassing began. More than 500 m³/m of sand has remained in the vicinity of profile RB5 since 2001. The shoreline position has advanced from approximately 50m prior to permanent bypassing to around 150m by 2006.

Coolangatta

Not surprisingly, the CG6 profile of Coolangatta beach has been extensively surveyed since 1966. Profile volumes for CG6 are presented in Figure 4 and show a minimum of 76 m³/m in July 1972 following the severe erosion due to successive cyclones in 1967 and 1972. The beach profile volume has remained higher than 200 m³/m since the Kirra point groyne construction. Significant accretion and erosion cycles are evident and are coincident with the nourishments of the late 1980's and 1990's. The maximum profile volume of 1303 m³/m occurred following the extensive nourishment and establishment of permanent bypassing in March 2004.

Kirra

Kirra has been extensively surveyed since the construction of the Kirra groyne in 1974. A total of 67 profiles surveyed to July 2006 were available for the analysis and are presented in Figure 5. The depleted profile following the construction of the groyne to stabilise Coolangatta is clearly evident in the early 1980's. Nourishment applied in the late 1980's resulted in the profile accreting from 130 m³/m in February 1986 to 300 m³/m in July 1988. Further extensive nourishments to May 1990 resulted in a local profile volume maximum at that time of 786 m³/m. By February 1995, just prior to nourishment associated with TRESBP, the minimum profile volume of 117 m³/m was recorded at K1. The maximum profile volume of 1032 m³/m is also the most recently surveyed profile of July 2006.

Bilinga

There were 5 profiles available for analysis from survey line ETA 21 at Bilinga between June 1966 and June 1968 (Figure 6). The highest recorded profile volume was 413 m³/m in June 1968. After a gap of 20 years the record begins again following the last of the groyne constructions at Kirra. In November 1988 ETA 21 recorded a substantially lower volume of only 179 m³/m. The minimum profile volume of 81 m³/m occurred in July 1989.

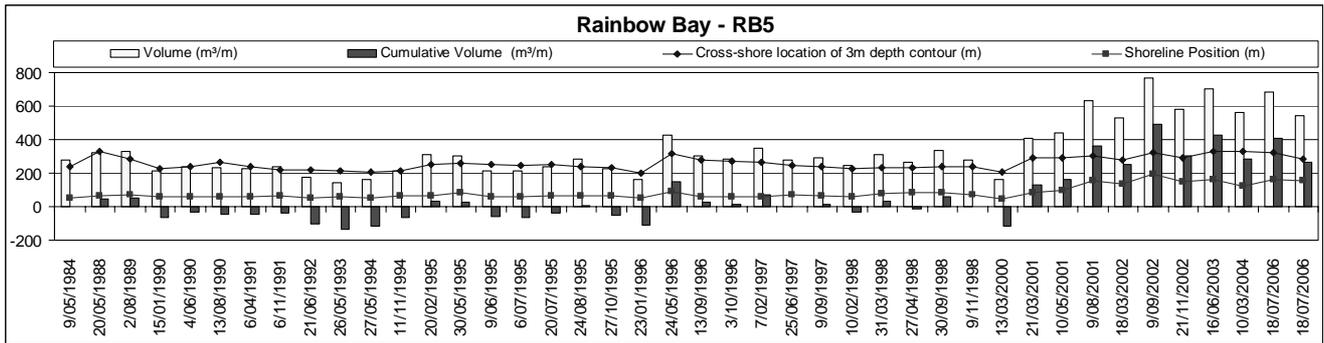


Figure 3. Rainbow Bay profile volume, cumulative profile volume and cross-shore distance to shoreline and to 3m depth contour.

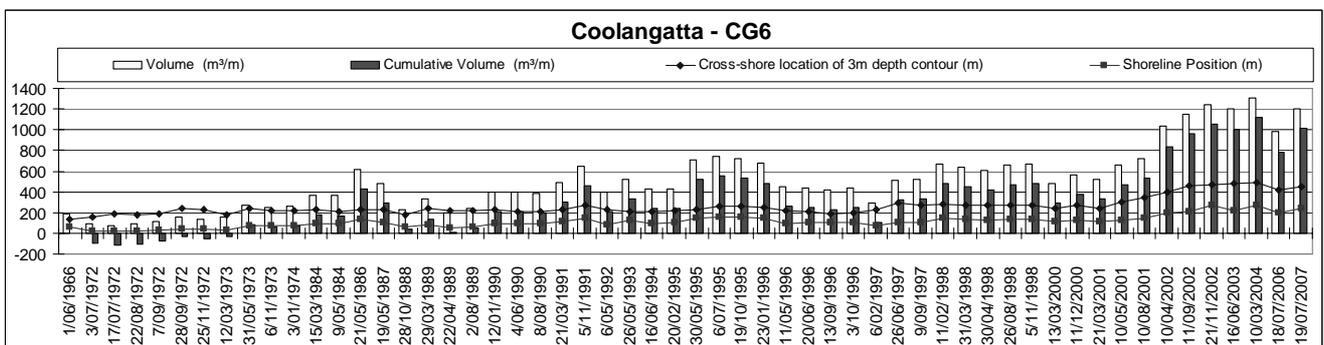


Figure 4. Coolangatta profile volume, cumulative profile volume and cross-shore distance to shoreline and to 3m depth contour.

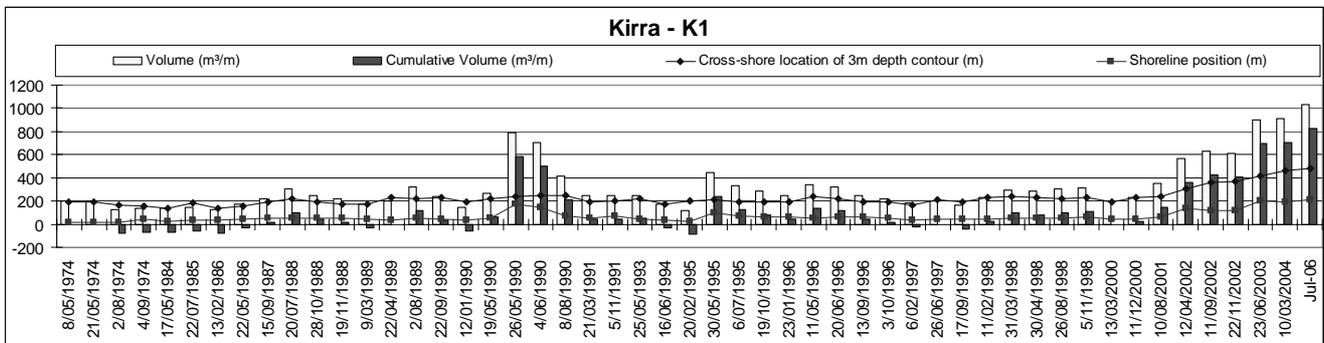


Figure 5. Kirra profile volume, cumulative profile volume and cross-shore distance to shoreline and to 3m depth contour.

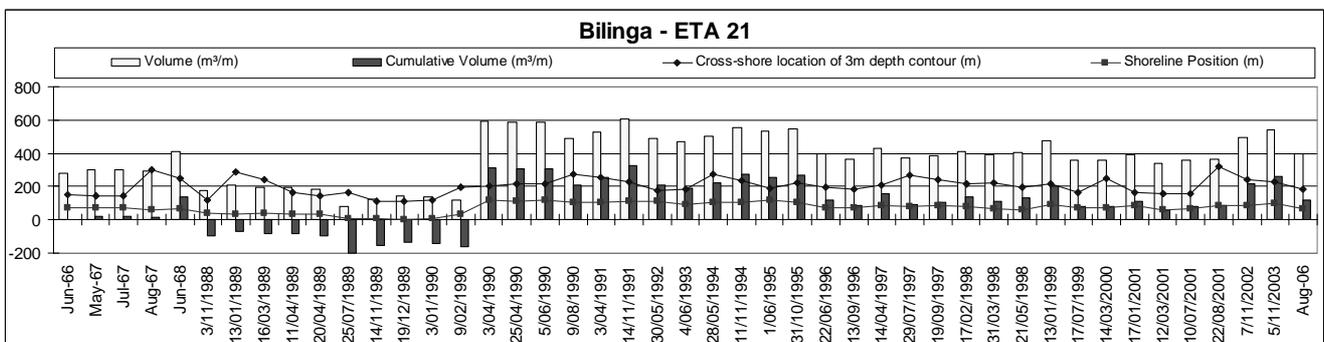


Figure 6. Bilinga profile volume, cumulative profile volume and cross-shore distance to shoreline and to 3m depth contour.

The beach rapidly accreted between February and April 1990 in response to extensive nourishment reaching a maximum volume of 604 m³/m by November 1991.

Volumes have remained above 300 m³/m since the establishment of the TRESBP nourishing campaign in 1995 and the permanent bypassing system in 2001. In contrast with the previous three profiles immediately up-drift, the Bilinga profile has not yet recorded a profile volume maximum as a response to TRESBP operations.

SUMMARY AND DISCUSSION

The challenges of managing the response of the natural system to extreme events and interventions caused by coastal structures are highlighted in the record. The variations in beach volumes demonstrate that to apply a coastal management solution for a specific location can be detrimental elsewhere.

Selected surveyed beach profiles collected over 30 years at the southern Gold Coast provide a useful time series of changes to beach volumes in a highly variable and energetic coastal region. The analysis of the profile data demonstrates the effectiveness of the bypassing and nourishments to widen the formerly eroded beaches from Point Danger to Kirra. The benefit to beaches further north has yet to become apparent. The analysis has shown that the impact of the extension to the Tweed training walls in 1962-1964 is still being felt on the Bilinga section of coastline. This is despite the extensive supply of sand to the Coolangatta and Kirra compartments via nourishment and the bypassing system.

A key factor in the current imbalance in beach sand volumes along the southern Gold Coast beaches is that the past 30 years have been a period of relatively mild conditions. Given the general episodic nature of the natural flow of sand past Point Danger, it was not unexpected that the sand deposited at Coolangatta and Kirra would remain there. When a period of heightened storm activity returns it is expected that the excess volume of sand will disperse to the north and infill the remnant deficit from the 1960s in the Bilinga area. The success of the sand bypassing works on the down drift coast will then become increasingly measurable.

The interim imbalance in beach sand volume along the coastline has highlighted the need for appropriate generalized modelling of coastal sediment budgets and wave-induced transport parameters in support of management decisions, to accompany major coastal interventions such as the TRESBP.

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