



# Currumbin Coastal Processes Assessment

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<p><b>Synopsis:</b> This study has assessed the evolution of the southern Gold Coast system over the period from 1962 to 2015, during which time the natural system has been impacted by the Tweed River entrance training wall construction and other coastal works. A key objective of the study was to develop an improved understanding of the coastal system changes in the vicinity of Currumbin.</p>		

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## Executive Summary

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The Tweed River Entrance Sand Bypassing Project (TRESBP) commissioned a study to assess the historical and potential future coastal system changes in the vicinity of Currumbin that can be attributed to:

- (1) extension of the Tweed River entrance training walls in 1962;
- (2) the re-instatement of sand supply by TRESBP Stage 1 (from 1995) and Stage 2 (from 2000).

In order to meet the study objective a conceptual model of coastline evolution of the southern Gold Coast between the Tweed River entrance and Palm Beach has been developed covering the period from prior to the Tweed River entrance training wall extension, commencing in 1962 through to the present day. This period includes a number of substantial anthropogenic interventions in the southern Gold Coast littoral system, including:

- Construction of the Tweed River training wall extensions;
- Construction of the coastal protection structures, including groynes and seawalls;
- Sand nourishment within the Coolangatta to Kirra embayment;
- TRESBP Stage 1 dredge bypassing; and
- TRESBP Stage 2 bypassing by a combination of sand pumping jetty and dredging.

The study has been informed by analysis of coastal sand profile surveys undertaken by state government agencies and the City of Gold Coast (CGC). These surveys have been undertaken at varying intervals and levels of detail since the 1960's and document the beach profile response to natural wave climate variability as well as anthropogenic perturbations, most notably the Tweed training wall extension. Analysis of key survey profiles throughout the study area from Letitia Spit to Palm Beach have been undertaken to assist with derivation and verification of conceptual model inputs.

The conceptual model developed for this study is at the highest level a sediment budget for the littoral system from Fingal Head to Currumbin. The conceptual model principally documents sand volume changes over time, within sub-compartments of the overall littoral system and has been derived for six sub-periods between 1962 and 2015. The 1962 starting date immediately precedes the commencement of construction of the Tweed River training wall extensions.

Prior to TRESBP Stage 1 (by 1993) the sand budget assessment has shown that 8.9M m<sup>3</sup> had accumulated across the survey compartments within NSW (relative to 1962). Letitia Spit accretion accounted for +4.1M m<sup>3</sup>, the Entrance and Duranbah +3.4M m<sup>3</sup> and the lower Tweed River +1.4M m<sup>3</sup>. At the same time the Queensland volume deficit had already been substantially offset by the southern Gold Coast nourishment project/s, which had imported 6.2M m<sup>3</sup> from offshore sand supplies into the active littoral system. In 1993 the total volume within the littoral system from Point Danger to Currumbin was -1.3M m<sup>3</sup> relative to the 1962 baseline.

The period from 1993 to 2009, which included the Stage 1 dredging and the first 9 years of Stage 2 operations, also saw the Queensland volume deficit become +3.4M m<sup>3</sup> increase (relative to 1962). A majority of the additional sand volume added to Queensland during this period had accumulated in the Kirra / Bilinga embayment. The rate of sand delivery during the initial period of TRESBP Stage 2 operations as

## Executive Summary

required by the legislated “supplementary increment” was in hindsight excessive in the context of the longshore sand transport capacity of the natural system.

By 2015 there was a total increase of 9.2M m<sup>3</sup> over the entire system from Fingal to Currumbin relative to 1962. Within NSW, Letitia Spit accounts for +0.9M m<sup>3</sup>, the lower Tweed River estuary for +1.2M m<sup>3</sup> and the Tweed River Entrance for +2.9M m<sup>3</sup> for a total of +5.0M m<sup>3</sup>. In Queensland, there has been an overall increase in sand between Point Danger and Currumbin of +4.2M m<sup>3</sup>. Considering the sources of the 9.2M m<sup>3</sup> increase in the system, 6.2M m<sup>3</sup> can be attributed to nourishment from offshore sand supply sources while the remaining 3.0M m<sup>3</sup> can be attributed to an inferred transport differential between Fingal and Currumbin.

During the most recent 2009 to 2015 period, sand bypassing was entirely by jetty pumping at an average rate of 432,000 m<sup>3</sup>/year. During this same period, the Tweed River entrance compartment accumulated sand at an average rate of 61,000 m<sup>3</sup>/year and by late 2015 had reached a total volume similar to 1993 (i.e. prior to TRESBP Stage 1). Aside from the increased risk of compromised entrance navigability, the accreted entrance also allowed for natural bypassing to increase to 170,000 m<sup>3</sup>/year. Hence, during this period where the rate of bypassing was intentionally reduced, the total rate of delivery to Queensland (including natural bypassing) still exceeded the transport into Letitia Spit. This finding suggests the requirement for entrance dredging and bypassing as part of the ongoing sustainable operation of the TRESBP.

Shoreline evolution modelling of the period from 1900 to 2100 has been undertaken to analyse and help understand the observed historical trends and to help derive a future shoreline evolution prognosis (based on certain assumptions). The model predictions indicate that the substantial volume (4.2M m<sup>3</sup>), which predominantly accumulated in the Kirra / Bilinga embayment since 2001, will continue to be dispersed gradually northwards. This will have the effect that Currumbin and Palm Beach will experience a re-instated (increased) sand supply.

At Currumbin, the magnitude of changes related to the re-instated supply are expected to be quite subtle and certainly much smaller than the change that was imposed by the Currumbin Rock groyne construction in 1973. Currumbin entrance will continue to experience natural infilling, with a substantial year to year variability in volumes and spatial distributions. The re-instatement of supply to Palm Beach is also expected to contribute a subtle but positive additional profile volume. However, without additional intervention, Palm Beach will likely continue to remain vulnerable to short-term storm erosion events due to the insufficient sand supply buffer in front of the A-line seawall defences.



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# 1 Introduction

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## 1.1 Overview

The Tweed River Entrance Sand Bypassing Project (TRESBP) commissioned a study to assess the historical and potential future coastal system changes in the vicinity of Currumbin that can be attributed to:

- (1) extension of the Tweed River entrance training walls in 1962;
- (2) the re-instatement of sand supply by TRESBP Stage 1 (from 1995) and Stage 2 (from 2000).

In order to meet the study objective a conceptual model of coastline evolution of the southern Gold Coast between the Tweed River entrance and Palm Beach has been developed covering the period from prior to the Tweed River entrance training wall extension, commencing in 1962 through to the present day. This period includes a number of substantial anthropogenic interventions in the southern Gold Coast littoral system, including:

- Construction of the Tweed River training wall extensions;
- Construction of the coastal protection structures, including groynes and seawalls;
- Sand nourishment within the Coolangatta to Kirra embayment;
- TRESBP Stage 1 dredge bypassing; and
- TRESBP Stage 2 bypassing by a combination of sand pumping jetty and dredging.

The timeline of key events that are most relevant to the coastal process evolution of the southern Gold Coast have been tabulated in Section 2.1, with commentary provided about their significance.

The study has been informed by analysis of coastal sand profile surveys undertaken by state government agencies and the City of Gold Coast (CGC). These surveys have been undertaken at varying intervals and levels of detail since the 1960's and document the beach profile response to natural wave climate variability as well as anthropogenic perturbations, most notably the Tweed training wall extension. Analysis of key survey profiles throughout the study area from Letitia Spit to Palm Beach have been undertaken to assist with derivation and verification of conceptual model inputs, and are described in Section 3.

A number of major studies have been previously undertaken investigating coastal processes on the southern Gold Coast. Where possible the current study has made use of previously published analysis, including the "Delft" reports (Delft Hydraulics Laboratory, 1970; and Roelvink and Murray, 1992), and the more recent TRESBP Reassessment of Long Term Average Annual Net Sand Transport Rate (BMT WBM, 2015).

The conceptual model developed for this study is at the highest level a sediment budget for the littoral system from Fingal Head to Currumbin. The conceptual model principally documents sand volume changes over time, within sub-compartments of the overall littoral system. With additional knowledge (or assumptions) about the transport in (or out) and any sources the sediment mass balance can be solved for the transport out (or in).

## Introduction

The conceptual model has been derived for six sub-periods between 1962 and 2015. The 1962 starting date immediately precedes the commencement of construction of the Tweed River training wall extensions. For the period from 1962 to 1989 the conceptual model inputs have in the main been derived from the Roelvink and Murray (1993) analysis. From the period from 1993 to 2015 the conceptual model inputs have been derived from the recently updated “LTA” analysis (BMT WBM, 2015). The conceptual model methodology, inputs and outputs are further detailed in Section 4 of this report.

The conceptual model sand budget analysis has been supported by numerical shoreline evolution modelling analysis, which is described in Section 5. The shoreline evolution modelling helps with interpretation and understanding of the observed coastal evolution, plus provides a means for forecasting future evolution trends. Process-based numerical models also facilitate the exploration of hypothetical “what if” scenarios that can further aid system understanding and inform the selection of future management options.

The future prognosis for southern Gold Coast shoreline evolution and the consequences for north of Currumbin are discussed in Section 6.

## 1.2 Currumbin Context

Currumbin beach is located approximately 8km north of Point Danger and the New South Wales – Queensland border. The coastline here faces roughly ENE, in contrast to the more northerly facing Gold Coast beaches located further south in the Coolangatta / Kirra embayment. Currumbin beach may be considered as the most northern extent of the southern Gold Coast beach system. Both Flat Rock and Elephant Rock to the south of Currumbin beach form minor shoreline alignment control points, while the Currumbin Rock (and groyne) acts as a more substantial headland control with a substantial change in shoreline alignment between Currumbin and southern Palm Beach. The Palm Beach alignment is controlled by Burleigh Headland and the Tallebudgera Creek training wall in the north.

Currumbin Creek is located immediately to the north of Currumbin Rock and has been substantially modified by entrance training works. The coastal processes related to Currumbin Creek have been assessed in a number of studies, including WBM Oceanics (1999), Castelle et al (2007) and Shaeri et al. (2013).

Historical development of the esplanade road along Currumbin Beach occurred within the active beach/dune system (Delft 1970) and consequently this section of coastline was particularly vulnerable to storm erosion events, such as those that occurred in 1936 and 1954. The natural state of the Currumbin Creek entrance was also very dynamic (i.e. unstable) with substantial migration of the entrance occurring in cycles. Due to these factors, a key recommendation of the 1970 Delft report was the construction of a rock groyne connecting Currumbin headland to Currumbin Rock. This coastal structure was constructed in 1973 and a northern training wall was added to the creek entrance in 1981. The resulting change in sand transport pathways led to substantial accretion of Currumbin beach as well as re-alignment (and accretion) of southern Palm Beach.

Immediately to the north of Currumbin, Palm Beach has long been understood to be vulnerable to coastal erosion, again due to the historic development within the active dune system. This section

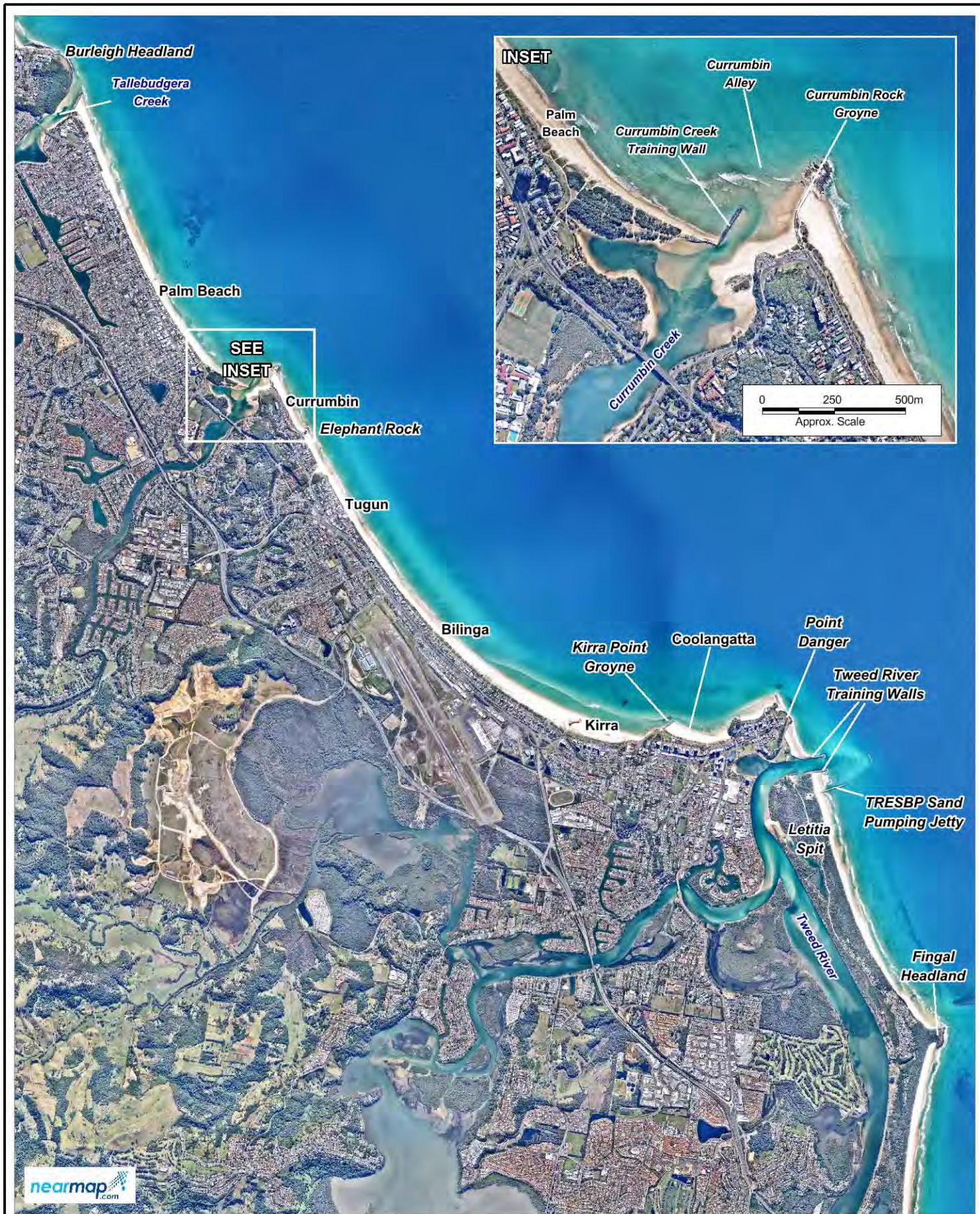
## Introduction

of coastline was also clearly impacted by the construction of the Currumbin Rock groyne, which during the 1970s and 1980s resulted in a reduced northward supply of sand. In response to the ongoing erosion vulnerability the Palm Beach shoreline project is currently being progressed by the City of Gold Coast.

Management of Currumbin Creek has required regular dredging to remove sand which has been transported into the entrance by wave and tidal action. The dredged sand is pumped north to Palm Beach. The dredging is undertaken annually in order to maintain water quality, amenity and to alleviate the potential for upstream flooding.

The southern Gold Coast system has been heavily modified by coastal works and to understand the historic evolution and future prognosis for Currumbin it is necessary to assess the combined effects of these coastal process interventions, which are discussed in further detail in the following sections.





Title:  
**Locality Plan**

Figure:  
**1-1**

Rev:  
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## 2 History (of Southern Gold Coast)

Anthropogenic impacts have been imposed on the natural evolution of the Gold Coast since the late 19<sup>th</sup> century, associated with training wall, groyne and seawall structures, sand removal for reclamation, sand supply as beach nourishment and river/creek entrance sand bypassing.

### 2.1 Timeline

A timeline of substantial events of relevance to contemporary evolution of the southern Gold Coast is provided in Table 2-1 and discussed further below.

**Table 2-1 Timeline of Significant Coastal Process Events**

Year	Event	Commentary
Circa 1880	Tweed River training walls constructed.	Training walls constructed to stabilise and improve safety of navigating the entrance.
Circa 1920	Coolangatta Swamp reclamation.	Sand sourced from active dune system.
Circa 1950	Greenbank Island reclamation.	Sand presumably sourced from lower Tweed River, i.e. removed from active littoral system.
1880-1960	Letitia Spit accretion.	By 1960 Tweed River entrance had become hazardous to navigate.
1962 (to 1964)	Tweed River entrance training wall extension.	New training walls extended 380 m further seaward.
1966	First comprehensive coastal survey.	Undertaken as part of the Delft report investigations. Comprehensive 1966 survey provided important pre-event baseline for the severe storm erosion events of 1967.
1967	Severe storm erosion.	A series of five Tropical Cyclone or East Coast Low events occurred between January and August 1967, culminating in major erosion at Coolangatta / Kirra, Palm Beach and Surfers Paradise / Main Beach. <a href="http://www.goldcoast.qld.gov.au/documents/bf/fs-history-coastal-storms.pdf">http://www.goldcoast.qld.gov.au/documents/bf/fs-history-coastal-storms.pdf</a>
1968	Beach Protection Act	Constitution of the Queensland Beach Protection Authority (BPA) for regulating and advising in respect of coastal development activities.
1970	Delft report.	Technical report considering coastal erosion and related problems affecting the Gold Coast. The study conclusions underestimated the impacts of the Tweed River training walls on Gold Coast beaches and were subsequently updated (refer Pattearson & Patterson 1983, Roelvink & Murray 1992). Recommendations of the 1970 Delft Report included: <ul style="list-style-type: none"> <li>• Currumbin Creek entrance training works;</li> <li>• Nerang River entrance training works;</li> <li>• Southern Gold Coast sand nourishment;</li> <li>• Continuation of regular coastal profile surveys.</li> </ul>
1972	Sand volume	By 1972 the sand gain along Letitia Spit and loss to Gold Coast beaches as a

## History (of Southern Gold Coast)

Year	Event	Commentary
	summary (relative to 1962)	result of the Tweed Entrance training wall extension in 1962 was <b>NSW +3.3M m<sup>3</sup>; QLD -2.6M m<sup>3</sup></b> . <sup>1</sup>
1972	Kirra Point groyne construction	Constructed to assist in restoring Coolangatta beach, however this led to additional downdrift erosion at Kirra where further major dune recession occurred during cyclones in 1972.
1973	Currumbin Rock groyne construction	Recommendation from the Delft Report to manage the vulnerability of the Currumbin esplanade to storm erosion and to stabilise the Currumbin Creek entrance. The modified sand transport pathways caused significant accretion both updrift (Currumbin Beach) and downdrift (South Palm Beach), which resulting erosion caused further north along Palm Beach and at Burleigh.
1975	Little Kirra (Miles Street) groyne	The Miles Street groyne aimed at maintaining some sand in front of the Kirra surf club.
1974-1975	Tweed River dredging and Kirra placement.	About 0.76 million cubic metres of sand were pumped to Kirra from the lower reaches of the Tweed River in an attempt to offset the erosion there. This quantity was too small and the nourishment ultimately represented no net gain to the eroded beaches.
1981	Currumbin Creek northern training wall constructed.	This training wall further stabilised the location of Currumbin Creek entrance.
1974-1997	Currumbin Creek entrance dredging.	The trained Currumbin Creek entrance has a tendency to infill with sand, with potential to cause water quality and amenity issues. Over the period from 1974 to 1997 this process was managed by intermittent dredging campaigns and subsequently by annual dredging.
1983	Sand volume summary (relative to 1962)	By 1983 the net gain to Letitia Spit and loss to the Gold Coast was <b>NSW +6.4M m<sup>3</sup>; QLD -4.2M m<sup>3</sup></b> . <sup>1</sup>
1984	Palm Beach groynes construction	Relatively short groynes were constructed on Palm Beach in the mid-1980s in an attempt to address severe erosion following the Currumbin Creek entrance works.
1985	Burleigh nourishment (300k m <sup>3</sup> )	The requirement for this nourishment is also likely to be linked to the updrift Currumbin Creek and Palm Beach coastal works.
1985	Kirra nourishment (315k m <sup>3</sup> )	The first of a major program of beach nourishment along the southern Gold Coast, importing sand from offshore in order to offset the losses from the Tweed River training wall construction. Sand was both pumped onshore and placed nearshore by bottom-dumping.
1988	Coolangatta to Bilinga nourishment (1.87M m <sup>3</sup> )	Nourishment with sand imported from offshore using the dredge "W.H. Resolution". Sand was placed by bottom-dumping in the active littoral zone at Kirra beach. Refer, Meisner (1991)
1989	Kirra to Tugun nourishment (3.6M m <sup>3</sup> )	A massive sand nourishment program was undertaken over several months in 1989/90. Sand was dredged from inactive offshore locations and placed in the upper beach and nearshore profile from Kirra to Tugun Refer, Murray et al. (1993)

## History (of Southern Gold Coast)

Year	Event	Commentary
1992	Southern Gold Coast littoral sand supply report.	The Roelvink and Murray (1992) report, also known as the second Delft Report, analysed the southern Gold Coast littoral sand supply for the period following the 1962 extension of the Tweed River entrance training walls.
1993	Sand volume summary	By 1993 Letitia Spit was continuing to accrete albeit at a lesser rate due to natural bypassing of the Tweed River entrance, which had increased to around 60% of the natural supply rate. The net gain to Letitia Spit and loss to the Gold Coast was <b>NSW +8.9M m<sup>3</sup>; QLD -1.3M m<sup>3</sup></b> . <sup>1</sup> The Queensland losses were by this time being substantially offset by the late 1980's mass nourishment program.
1995-1996	TRESBP Stage 1A Dredging (2.25M m <sup>3</sup> )	Dredging of sand from the Tweed River entrance and placement in both the upper beach and nearshore profile between Point Danger and Kirra. Dredging was undertaken by the "Pearl River", "Ngamotu" and "Krankeloon". This dredging differed from the earlier nourishment campaigns in that sand is being bypassed rather than imported into the littoral system. Refer Boswood et al. (2001), Colleter et al. (2001).
1996	Kirra Point groyne shortening.	The Kirra Point groyne length was reduced by 30 m to assist with the movement of increased volumes of sand resulting from the bypass project. Refer Kirra Groyne Study (Worley Parsons, 2009).
1997-1998	TRESBP Stage 1B Dredging (0.8M m <sup>3</sup> )	Bypass dredging of the Tweed River entrance continued with the much smaller "Port Frederick". Sand was placed by dumping in the nearshore zone between Point Danger and Kirra.
1997	TRESBP EIS completed	An Environmental Impact Statement was completed for a permanent Tweed River entrance sand bypassing system. The bypassing system mechanism/s were not yet decided at the stage of the EIS.
1997-ongoing	Annual Currumbin Creek entrance dredging.	Since 1997 City of Gold Coast has undertaken annual dredging of Currumbin Creek entrance. Between 30,000 m <sup>3</sup> and 70,000 m <sup>3</sup> of sand is dredged from the Creek entrance and pumped northward to Palm Beach.
2000	Commencement of TRESBP Stage 2	TRESBP Stage 2 was awarded as a Design and Construct contract to McConnell Dowell. A sand pumping jetty similar to the system already implemented at the Gold Coast seaway was chosen as a key component of the Stage 2 bypassing system. It was also anticipated that ongoing periodic entrance dredging would be required in conjunction with the sand pumping. Prior to commissioning of the sand pumping jetty approximately 530,000 m <sup>3</sup> was dredged from and bypassed to Queensland.
2001	Sand volume summary (relative to 1962)	With the commencement of TRESBP bypassing the Letitia Spit sand accumulation was now being reduced and Queensland was in a position of net gain for the first time since the mid-1960s. <b>NSW +7.4M m<sup>3</sup>; QLD +0.5M m<sup>3</sup></b> . <sup>1</sup>
2001	Commissioning of TRESBP sand pumping jetty	The TRESBP Stage 2 sand pumping jetty was commissioned in March 2001. The jetty pumping became the major contributor to sand bypassing, with supplementary dredging occurring periodically.
2005	Palm Beach nourishment (400k m <sup>3</sup> )	In response to ongoing erosion problems along Palm Beach Sand was sourced from an offshore borrow area south of Currumbin entrance.
2007	Completion of	For the first 6-years of operations sand was bypassed at a rate that exceeded

## History (of Southern Gold Coast)

Year	Event	Commentary
	“supplementary increment”	the rate of natural longshore sand transport. This “supplementary increment” was part of the Deed of Agreement between Queensland and New South Wales. It is now understood that the “supplementary increment” was larger than required to re-instate the southern Gold Coast sand volumes.
2009	LTA re-assessment	The “Long Term Average” (LTA) was a quantity defined in the TRESBP Deed of Agreement, which was essentially the amount of sand to be bypassed by the system. This quantity was defined as the long term average of the sand transport into Letitia Spit minus the natural bypassing to Queensland. This determination is dependent on the assessment of natural bypassing of sand to southern Queensland beaches (among other factors), which in turn is dependent on how the TRESBP sand bypassing system is operated. Refer (BMT WBM, 2011).
2009	Sand volume summary (relative to 1962)	Following the first 8 years of TRESBP jetty bypassing (and supplementary dredge bypassing), the accretion along Letitia Spit had been substantially pulled back and there was a substantial net increase in sand volumes north of Point Danger. <b>NSW +5.2M m<sup>3</sup>; QLD +3.4M m<sup>3</sup>.<sup>1</sup></b>
2013	Kirra Point groyne re-instatement.	The Kirra Point groyne was in 2013 re-instated to its original length (+30m) in order to improve recreational surfing amenity.
2015	LTA reassessment update	The LTA re-assessment was recently updated based on a further 6 years of data (BMT WBM, 2015)
2015	Sand volume summary (relative to 1962)	At the completion of the assessment period there was a net 9.3M m <sup>3</sup> sand in the active littoral system between Fingal Headland and Currumbin. <b>NSW +5.0M m<sup>3</sup>; QLD +4.3M m<sup>3</sup>.<sup>1</sup></b>

<sup>1</sup> Refer Section 4 for further detail.

## 2.2 Geological History

The modern Gold Coast beaches are the product of their geological evolution under the influence of the prevailing wave climate and major sea level change, primarily over the last 120,000 years of the late Pleistocene and most particularly during the Holocene period of the last 10,000 years. Sea level fell by about 120 metres to the peak of the last ice age and then rose back to around the present level over the 12,000 years from 18,000BP to 6,000BP. Sand was brought from the continental shelf to the coast in the latter part of that sea level rise, forming Holocene dunes seaward of the former residual Pleistocene barrier. The Holocene barrier has subsequently evolved under the influence of waves, with the shoreline responding to gradients in the relatively strong northward alongshore sand transport of about 500,000m<sup>3</sup>/yr.

Thom *et al* (1978) suggest that 7,000 years BP sea level was somewhere between 10m and 15m below present and, at this sea level, Cook Island and Fingal Head were acting as littoral barriers along the coastline. The Tweed River would have exited to the sea via Wommin Lake. A sand barrier may have extended up from Cudgen Headland. In the same respect, Letitia Spit, because of the Fingal Head littoral barrier, would probably not be completely developed at that time.

## History (of Southern Gold Coast)

The attainment of present day sea levels, approximately 6,000 years ago, would have drowned the postulated land bridges between existing outcrops of bedrock. Furthermore, this was the period of maximum onshore sand flux and under the influence of the northward alongshore sand transport, the outlet of the Tweed River would have migrated northwards past Fingal Point, leaving a complete sand barrier from Cudgen Headland to Fingal Point.

The behaviour of the lower Gold Coast shoreline during those processes was extremely complex, affected substantially by the groyne effect of the Fingal reef barrier to alongshore supply at somewhat lower sea levels, with subsequent high resupply as that barrier was submerged by the rising sea (Patterson, 2013). The result was substantial initial shoreline recession into the former Pleistocene barrier as sea levels fell and redevelopment of the wide Holocene barrier evident today along Bilinga-Tugun, Palm Beach, Burleigh and north from Mermaid Beach around 8,000BP to 5,000BP. Whether or not that barrier has experienced subsequent natural recession due to diminishing sand supply from the south is subject to speculation.

There have been many significant investigations of alongshore sand transport and shoreline change at the Gold Coast. It is generally understood that the natural average annual alongshore transport rate, unaffected by anthropogenic interference, is approximately uniform along the Gold Coast at a rate of about 500,000 m<sup>3</sup>/year with little or no natural long term erosion. Aside from the substantial impacts of the Tweed River entrance training works on sand supply post-1962, the known Gold Coast erosion hot spots are locations where historically development has occurred within the active dune system, resulting in vulnerability to storm event driven erosion/accretion cycles.

Patterson (2013) also concluded from modelling of the Holocene coastline evolution that there remains a slight ongoing shoreward sand supply of about 1.0-1.2 m<sup>3</sup>/m/year at 20m depth along much of the Coast, but less (~0.6m<sup>3</sup>/m/yr) north of around Surfers Paradise. While only minor, this represents a net supply to the beaches of about 10,000 m<sup>3</sup>/year along each 10km section of coastline.

However, anthropogenic impacts have been imposed on the natural evolution since the late 19<sup>th</sup> century, associated with training wall, groyne and seawall structures, sand removal for reclamation and sand supply as beach nourishment. Most recently, sand bypassing has been implemented across the Tweed River mouth. All of these works have impacted on the beach system to varying degrees. They are summarised in the timeline in Table 2-1 and are described briefly below.

### 2.3 Prior to 1960

The earliest works having significant impact on the lower Gold Coast beaches were undertaken around 1900 at the Tweed River mouth where the natural bar was shallow, inconsistent in location and dangerous for navigation. It was affected by both the coastal sand transport and fluctuations in the downstream river channel which most probably broke through Letitia Spit to the sea from time to time. Letitia Spit then was relatively stable and vegetated only as far north as 'South Head', about 1000m south of Point Danger, north of which it was an unstable bare sand spit (Figure 2-1). Figure 2-1 shows the design of river training works proposed in 1896 and constructed shortly after, although the mouth training walls did not extend as far seaward as the design indicates. These works stabilised the river within defined banks and the mouth location against 'North Head'. A



considerable quantity of sand accumulated on Letitia Spit south of the training walls. By 1956, the shoreline of northern Letitia Spit had prograded seaward and the Spit and river entrance became stable at its present location against North Head (Figure 2-2).

Figure 2-1 also highlights in yellow the large area of South Tweed Heads that was reclaimed for residential development during the late 1950s, not yet evident in 1956 (Figure 2-2). It is estimated that about 1.2 million cubic metres of sand were taken from the lower river for those works, sand that was part of the active coastal system and represents a direct loss from the beaches.

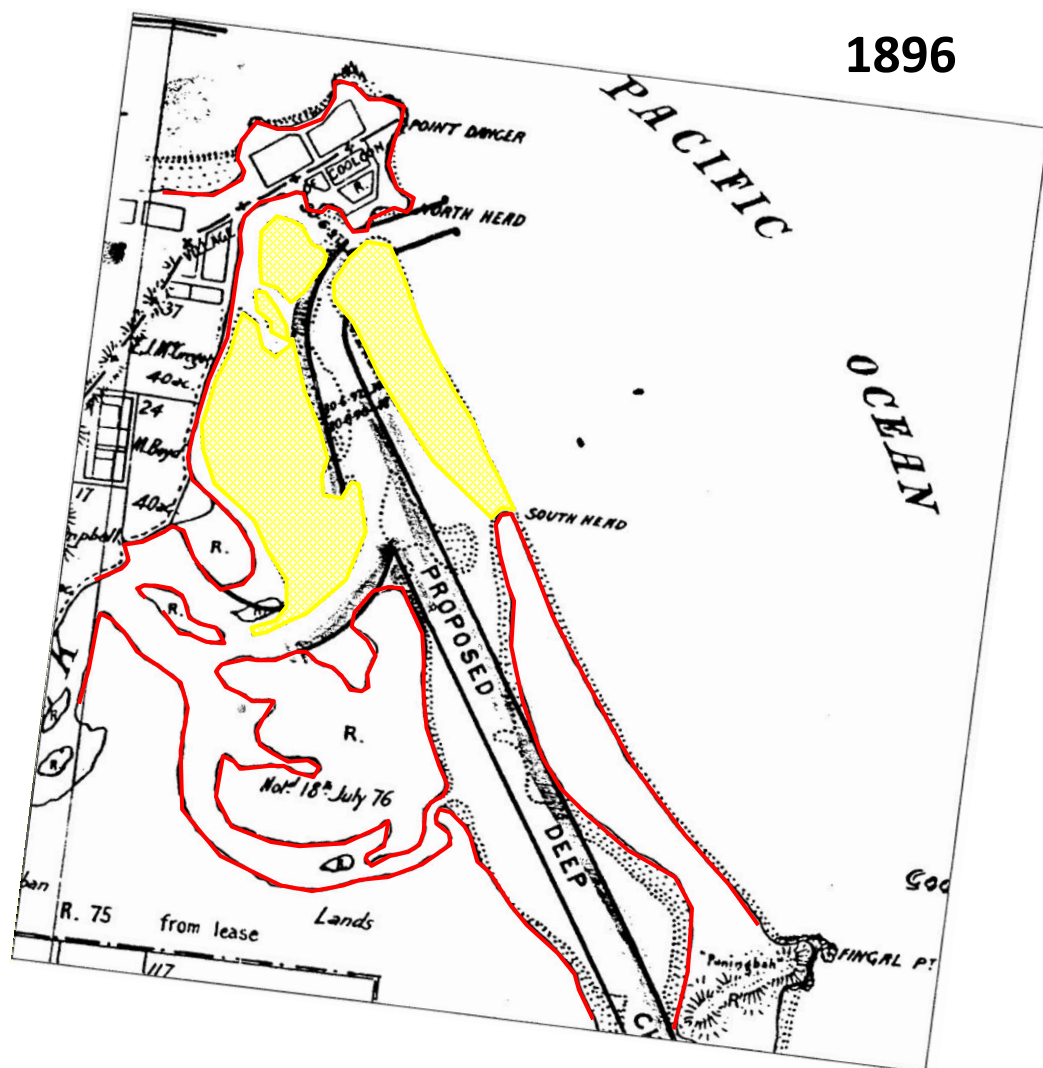
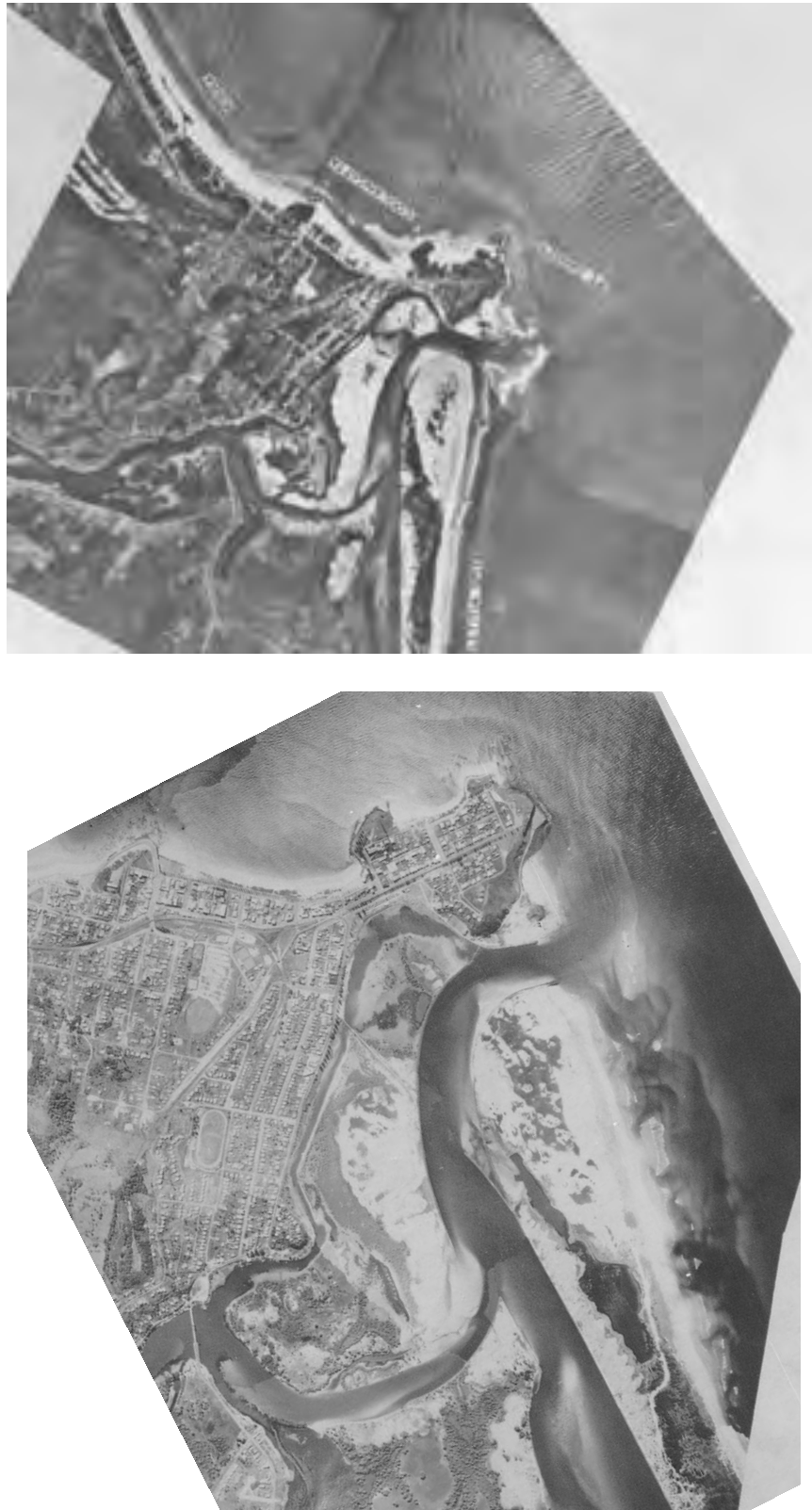


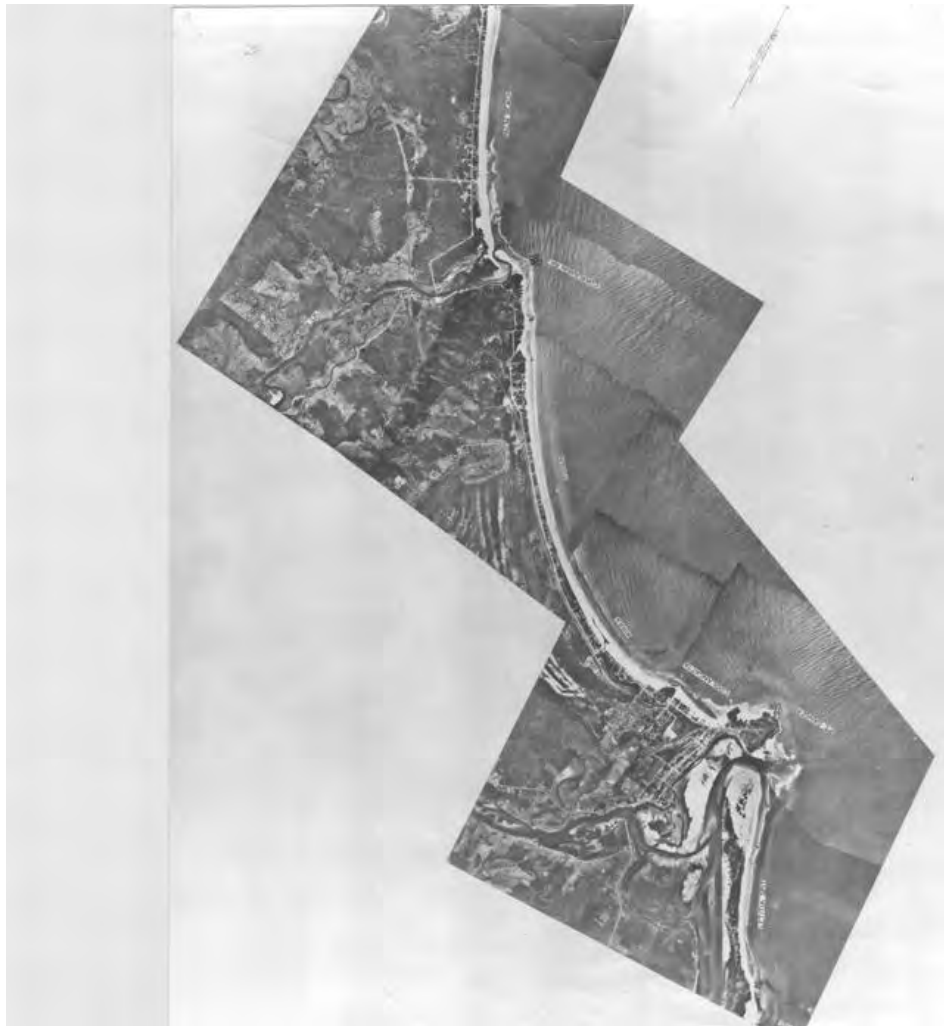
Figure 2-1 Tweed River and Letitia Spit 1896 with proposed training wall design



**Figure 2-2 Tweed River and Letitia Spit 1930 (top) and 1956 (bottom) with accumulation against training walls**



From knowledge of the effects of the subsequent extension of those walls, it is can be assumed with certainty that the effect of these initial river training walls in trapping sand along Letitia Spit caused an associated loss of sand from the southern Gold Coast beaches, potentially of several million cubic metres, over the following decades. An aerial photo mosaic of the area dated 1930 is shown in Figure 2-3.



**Figure 2-3 1930 aerial photo mosaic of southern Gold Coast**

A photographic history of the beaches at Coolangatta and Kirra can be found at the web site [www.tweedsandbypass.nsw.gov.au/historical-images](http://www.tweedsandbypass.nsw.gov.au/historical-images) dating back to the 1930s. Some selected images are included here, sourced as applicable from the Gold Coast City Council Local Studies Library.

Photographs taken of Coolangatta and Kirra around the 1930s, including after storm erosion in 1936 (Figure 2-3), most probably reflect a condition that was depleted relative to the previous natural situation. The loss of sand from the southern Gold Coast beaches was made more acute by direct removal of dune sand at Kirra during the 1930s depression years to fill swamp land behind for development (Figure 2-4).



Figure 2-4 Coolangatta – Greenmount 1935



Figure 2-5 Coolangatta 1937



Figure 2-6 Kirra 1935



Figure 2-7 Kirra erosion 1936





**Figure 2-8 Wagons on tracks to remove sand from dunes during 1930s**

Despite those losses of sand, the beach further north at Bilinga was in good condition with a wide and well vegetated dune in 1951 (Figure 2-9). This suggests that natural bypassing of the Tweed River mouth and transport through the lower Gold Coast beaches had resumed 50 years after the initial training wall works.



**Figure 2-9 Bilinga-Tugun 1951**

At Currumbin, attempts had been made early in the 20<sup>th</sup> century to construct a beachside road, including dune levelling and widening to provide sufficient width in front of the emerging development (Figure 2-10). This was severely eroded in 1936 (Figure 2-11). Whether or not this erosion was exacerbated by the northward progression of the erosion from the Tweed training walls at that time is not known. There is evidence of early protection works to prevent erosion into the reclaimed foreshore land following the 1936 storms (Figure 2-12).



Figure 2-10 Currumbin circa 1930 showing esplanade road construction



Figure 2-11 Currumbin erosion in 1936





Figure 2-12 Currumbin with timber and rock seawalls in 1937



1939



1940



1950



1950

Figure 2-13 Currumbin over the period 1939 to 1950

North of Currumbin at Palm Beach, the 1936 erosion event impacted directly on several houses located on the frontal dune (Figure 2-12). While it is evident that this development was located too close to the sea with insufficient dune buffer for erosion, it is plausible that the erosion effects of the original Tweed River training walls and sand removal from dunes at Coolangatta and Kirra may have propagated this far north and exacerbated this erosion.



**Figure 2-14 Palm Beach erosion in 1936**

There were several major cyclone events during the early 20<sup>th</sup> century that no doubt caused erosion and led to attempts to protect the increasing development, however, few details are available. The largest and most severe was probably the cyclone of February 1954 (Figure 2-15 and Figure 2-16).

This cyclone crossed the coast at Coolangatta where the barometer fell to 971.9 hPa, while some reports from the Coolangatta/Tweed Heads area had pressure readings to 962 hPa. The worst damage in that area was around the Cudgen in NSW where some houses were blown apart and trees more than 1 metre in diameter were twisted out of the ground. There was widespread structural damage at Gold and Sunshine Coasts and around Brisbane. A storm surge of 0.64m was recorded on the Moreton Bay gauge. Waves at Kirra brought water onto the highway picking up cars. The skating rink adjacent to the swimming pool at Burleigh was destroyed and waves there reportedly overtopped the foreshore and washed into the nearby picture theatre foyer. Damage at Palm Beach is shown in Figure 2-17.



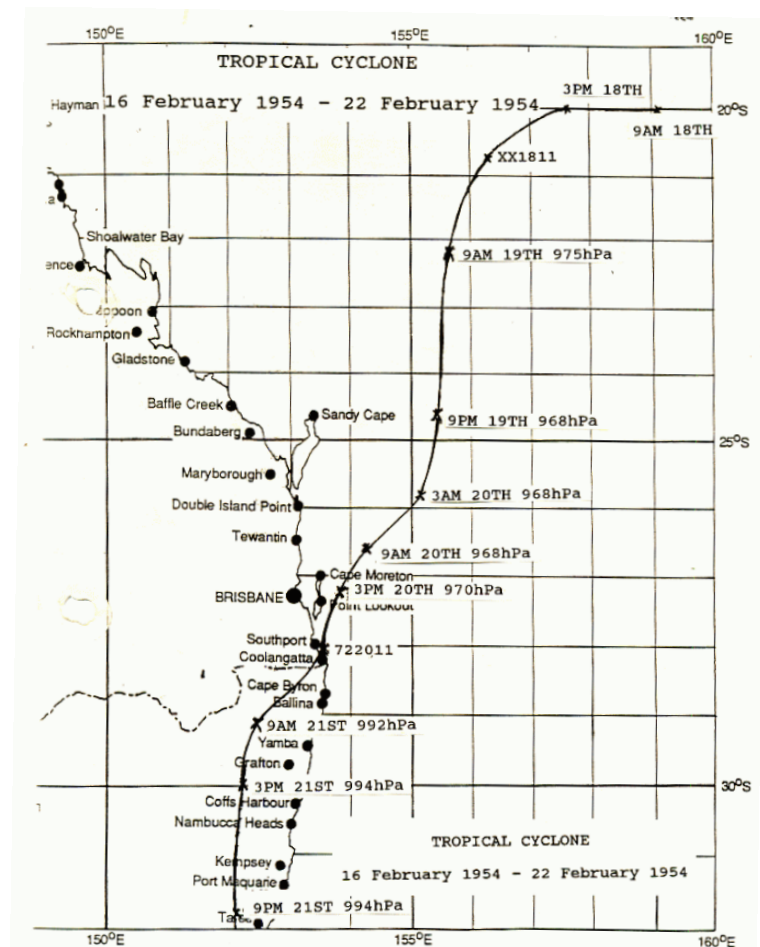


Figure 2-15 Track and central pressures of the February 1954 cyclone

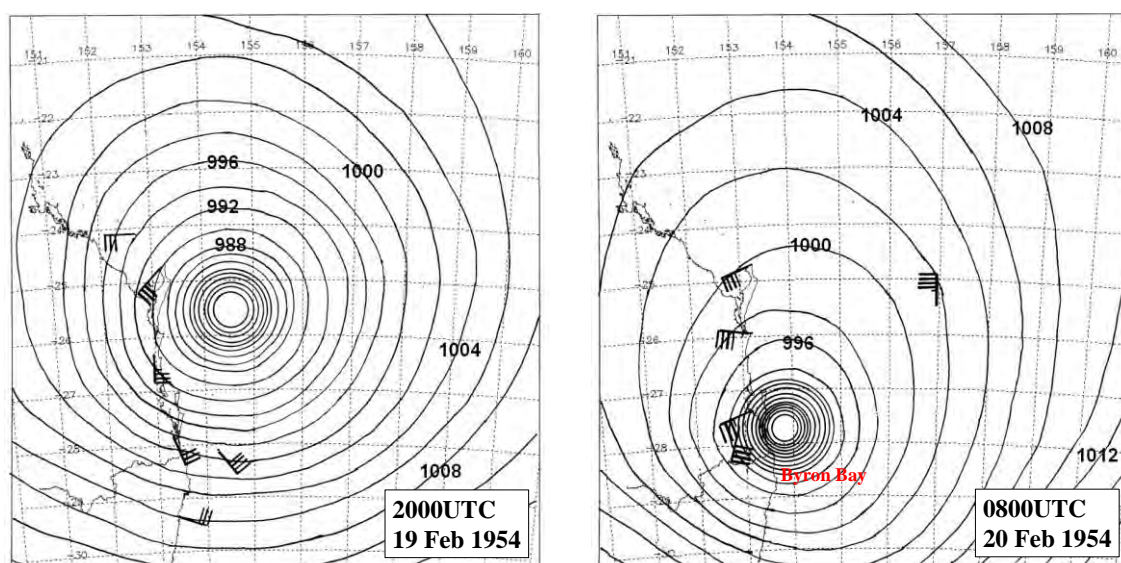


Figure 2-16 1954 cyclone synoptic charts



**Figure 2-17 Erosion at Palm Beach during 1954 cyclone**

Aerial photographs taken two years later in 1956 show the prominent nearshore bar that would have been formed migrating shoreward under the calmer swell waves. Figure 2-18 shows the beach and nearshore bathymetric pattern at Currumbin and Currumbin Creek and Figure 2-19 shows Palm Beach.



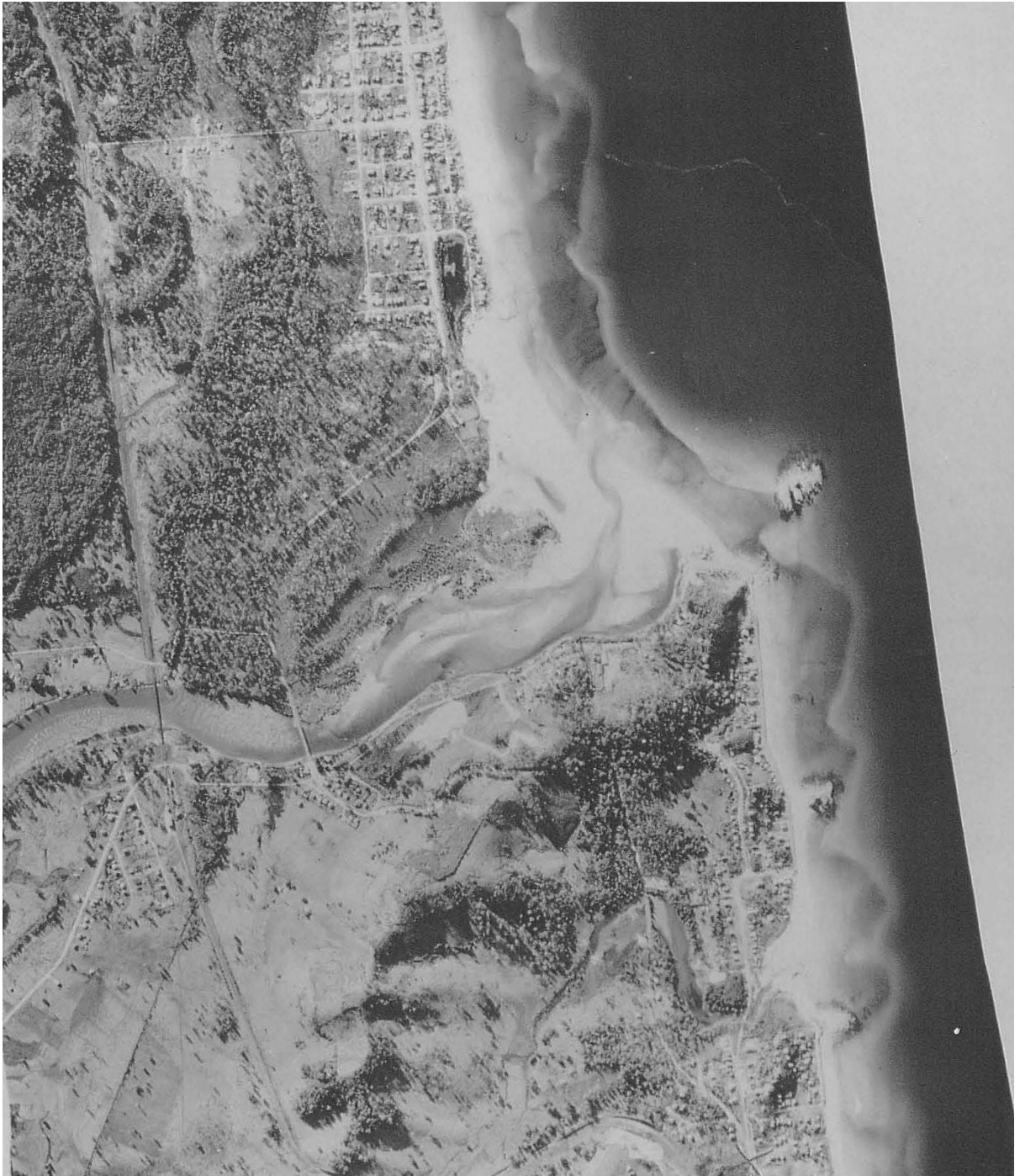


Figure 2-18 Tugun to Currumbin aerial photo 1956

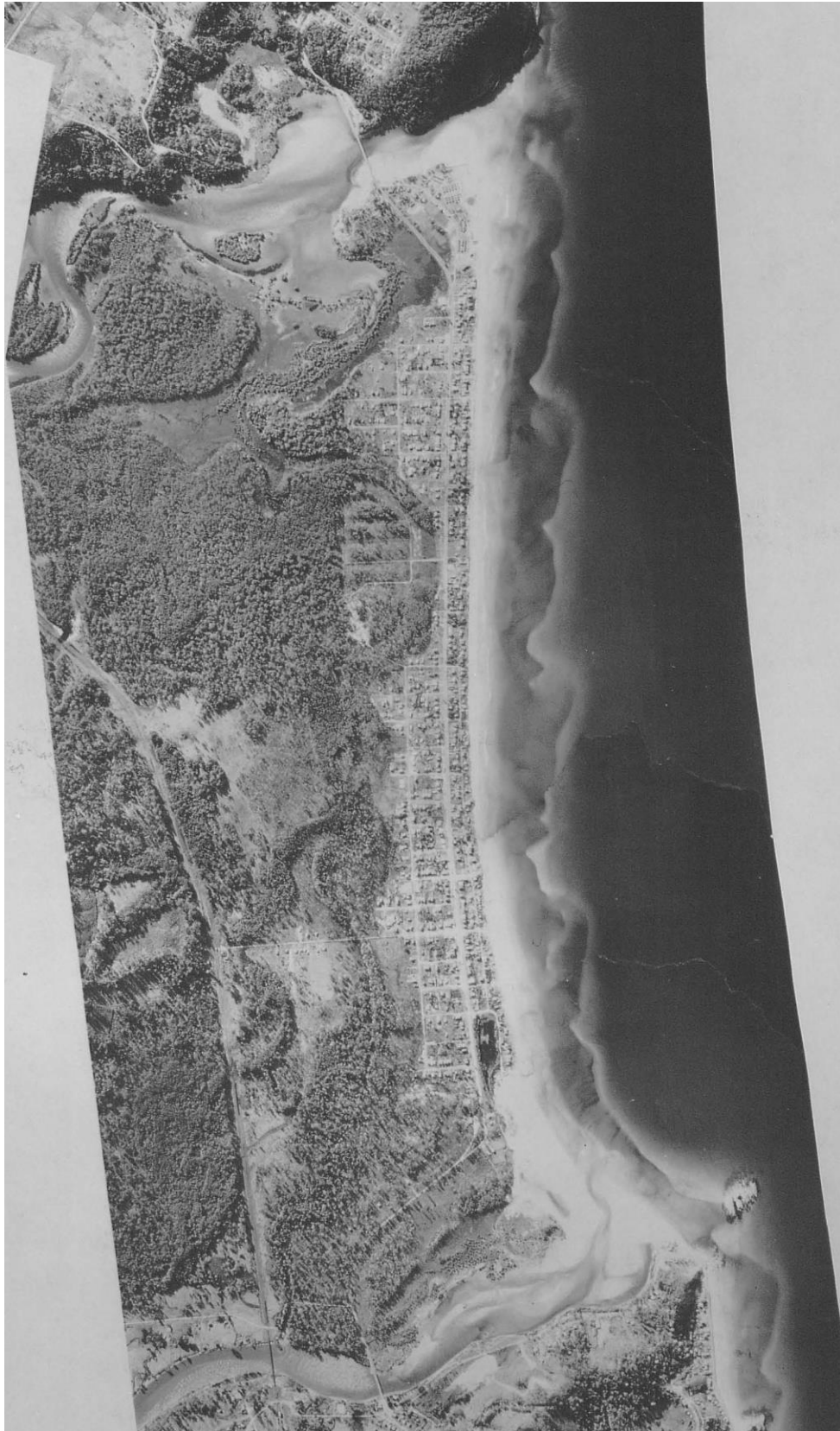


Figure 2-19 Palm Beach 1956



## 2.4 1960 to 1985

The 25 year period 1960 to 1985 saw considerable change to the southern Gold Coast beaches with the construction of training walls, groynes and seawalls. The reader is referred to the web site [www.tweedsandbypass.nsw.gov.au/historical-images](http://www.tweedsandbypass.nsw.gov.au/historical-images) for a photographic history of the Tweed – southern Gold Coast area.

Most particularly, the beach system was impacted substantially and permanently by construction of the Tweed River training walls during 1962 – 1964. This caused accretion along Letitia Spit and at the Tweed River mouth of about 8 million cubic metres of sand, with a corresponding loss from the southern Gold Coast beaches (Macdonald and Patterson, 1984; Roelvink and Murray 1992). While the loss at Gold Coast occurred initially within the nearshore littoral zone of alongshore sand transport, it manifest fully at the upper beach areas in the cyclones of 1967 when there was a major transfer of sand from the beaches and dunes to the depleted nearshore area (Delft Hydraulics Laboratory, 1970). Seawalls were constructed or upgraded during 1968 to limit the dune recession and Coolangatta and Kirra beaches were completely stripped of sand back to those walls.

In response, the Queensland Government constructed the Kirra Point groyne in 1972 to assist in restoring Coolangatta beach. This led to additional erosion at Kirra where further major dune recession occurred during cyclones in 1972. Up to 80 metres width of dune was lost there where formerly a caravan park had been located, destroying sections of the former seawall and requiring its large-scale reconstruction and extension northward to North Kirra. Another smaller rock groyne was constructed at Miles Street aimed at maintaining some sand in front of the Kirra surf club pavilion in 1975. The Coolangatta Creek outlet was converted from a natural ephemeral flow channel to a large concrete pipe outlet, which effectively became a minor groyne structure. Later, in 1985, a 110m long sandbag groyne was established at North Kirra, although its dimensions were such that it had relatively minor impact on the overall eroded beach there.



Figure 2-20 Overview of works and responses at southern Gold Coast 1982 (BPA Beach Conservation January 1985)

About 0.76 million cubic metres of sand were pumped to Kirra from the lower reaches of the Tweed River during 1974-75 in an attempt to offset the erosion there. However, that quantity was too small relative to the losses that had occurred by then and it was quickly dispersed alongshore and offshore leaving little visible benefit. Furthermore, the dredge area in the Tweed River infilled with beach system sand transported by tidal flow through the entrance and, over time, that nourishment represented no net gain to the eroded beaches.



**Figure 2-21 Eroded status of Kirra 1983; Coolangatta Creek outlet foreground**



**Figure 2-22 Southern Gold Coast 1984; Severe erosion from Kirra to Bilinga**

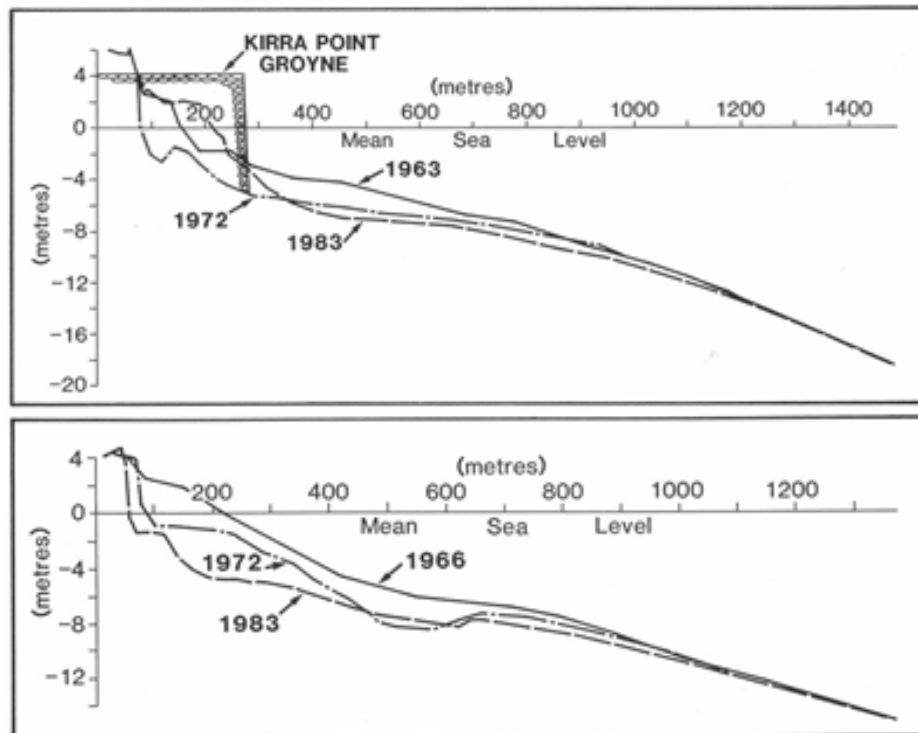


Figure 2-23 Progressive erosion to approx. 12-13m depth updrift (top) and downdrift (bottom) Kirra Point groyne

Despite the massive volume of the erosion, it had extended only to about Bilinga by 1983, with no evidence that it had affected Currumbin 20 years after Tweed River training wall construction (Figure 2-24).

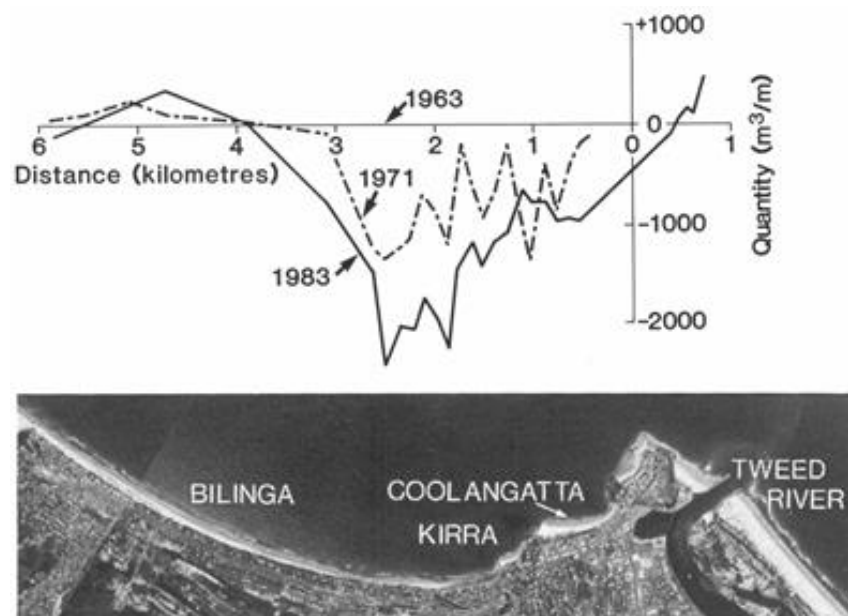


Figure 2-24 Distribution of downdrift erosion to 1983 (Macdonald & Patterson, 1984)



Throughout the early to mid 20<sup>th</sup> century, the beach at Currumbin was continually eroded back to the seawall protecting the esplanade road, which had been constructed further seaward than the natural dune alignment. Waves and sand transport passed through the gap between Currumbin Rock and the mainland (Figure 2-26). This led to implementation in 1973 of a recommendation of the Delft Report (Delft Hydraulics Laboratory, 1970) to connect across to the Rock with a groyne, to trap sand along Currumbin Beach. This also forced all of the alongshore transport of sand to pass around the seaward side of Currumbin Rock, causing a major accretionary change to the bathymetry at and near the mouth of Currumbin Creek.



Figure 2-25 Currumbin beach with revetment protection of road 1969 (top) and c1970 (bottom)





**Figure 2-26 Waves and sand transport between Currumbin Rock and the mainland 1950 (top) and 1969 (bottom)**



**Figure 2-27 Northward migration of Currumbin Creek channel 1965**



**Figure 2-28** Currumbin Rock groyne constructed in 1973 and accreted Currumbin Beach

It was the intention of the Delft Hydraulics Laboratory and Beach Protection Authority at the time in recommending the groyne construction that nourishment sand from an external source would be placed either directly to fill Currumbin Beach or on Palm Beach to offset the downdrift erosion. That was not undertaken initially and there is little doubt that the beaches at both Palm Beach and Burleigh were adversely affected. Groynes were constructed at Palm Beach during the mid 1980s and Burleigh experienced severe erosion during winter storms in both 1983 and 1984. With construction of the northern training wall at Currumbin Creek in 1981, (Figure 2-30), repeated annual dredging of around 40,000 to 75,000 cubic metres of sand from the creek and placement on Palm Beach was undertaken to clear creek shoaling and to counter this beach erosion, but never amounted to a sufficient volume to offset the amount accumulated along Currumbin Beach.



**Figure 2-29** Currumbin Creek Entrance in 1981. The rock groyne had been in place since 1973 and the northern training wall has not yet been constructed.



**Figure 2-30 Currumbin Creek mouth and northern training wall, constructed in 198**

Severe cyclones continued to affect the Gold Coast during this period, with substantial events in 1967, 1972, 1974 and 1976. The Delft Report (Delft Hydraulics Laboratory, 1970) thoroughly documents the impacts of the 1967 cyclones that caused major erosion at Coolangatta / Kirra exacerbated by the effects of the Tweed River training walls and north from Broadbeach / Surfers Paradise. Erosion at Palm Beach in 1967 and 1972 is illustrated in Figure 2-31 and Figure 2-32.





Figure 2-31 Erosion at Palm Beach during 1967 cyclone



Figure 2-32 Erosion at Palm Beach during 1972 cyclones

Cyclone Pam in February 1974 was a very large intense cyclone which passed 500 km to the east of Brisbane. However a 0.68m storm surge was recorded on the Moreton Bay gauge and combined with the king tide of 7<sup>th</sup> February reached 3.13 m (a record). Along the open coast the beaches were already severely eroded due to earlier cyclones. At Palm Beach residents had to abandon their houses and units as seawater overtopped boulder walls and surged through these premises. Long period swells of 13.1 second period with a significant wave height of 3.8 m were recorded. Damage to the Kirra surf club associated with the wave overtopping is shown in Figure 2-35.

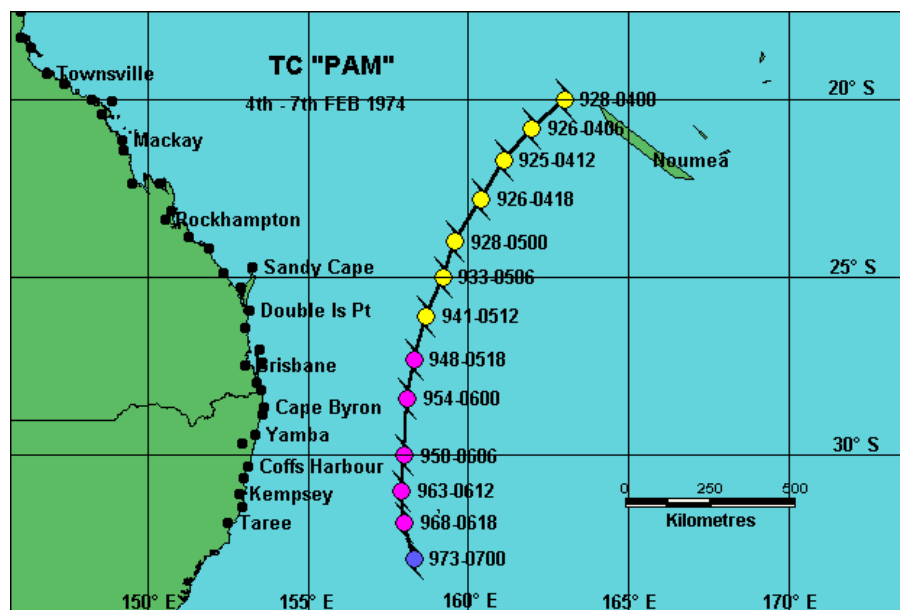


Figure 2-33 Cyclone Pam track and central pressures



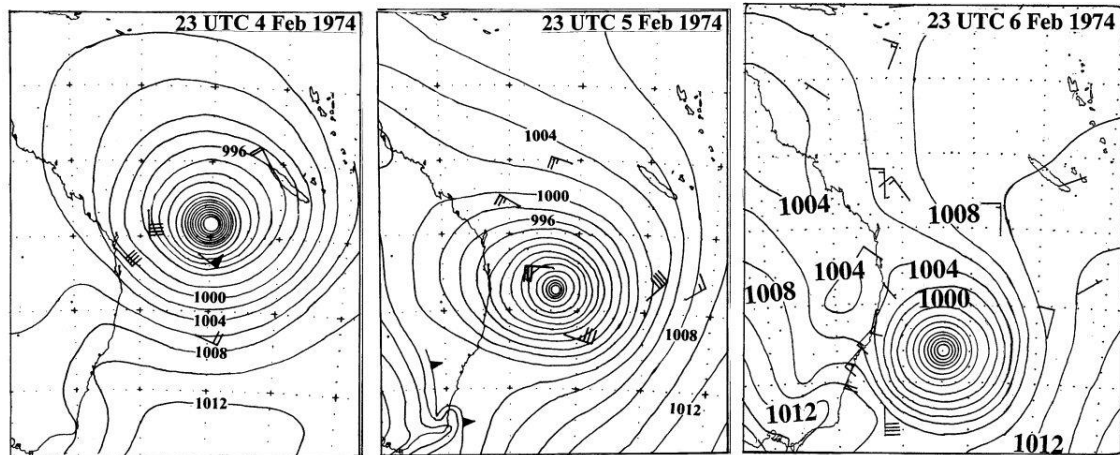


Figure 2-34 Cyclone Pam synoptic charts

### Damage at Kirra from *Pam's* waves



Figure 2-35 Kirra pavilion damage from cyclone Pam in 1974

## 2.5 1985 to 1993

The period from 1985 brought a change in management strategy away from construction of hard structures to an emphasis on beach nourishment. In particular, recognising that the impacts of the Tweed River training walls were increasingly severe at the southern beaches, the City Council and Queensland Government implemented major beach nourishment along the Kirra to Bilinga area. This involved placement of 0.315 million cubic metres (215k onshore and 100k nearshore) at North Kirra during 1985, associated with the sandbag groyne, and 5.15 million cubic metres in stages nearshore off Kirra to Tugun during 1988 to May 1990.

Additionally, about 300,000 m<sup>3</sup> were placed on Burleigh beach during March 1985, offsetting the adverse effects that the groynes at Currumbin, Palm Beach and Tallebudgera had caused there.

Analysis of the survey data by Roelvink and Murray (1992) showed that, to that time, about 7.6M m<sup>3</sup> had accumulated along Letitia Spit and at the Tweed River bar and about 7.2M m<sup>3</sup> had eroded from the southern Gold Coast beaches. They also found that the natural bypassing of sand past the river mouth then had increased to more than 300,000 m<sup>3</sup>/year.

Negotiations between the states reached agreement on the sand bypassing project that would ensure both adequate navigation at the Tweed River mouth and delivery to Queensland of the required supply of sand, estimated to average 500,000 m<sup>3</sup>/year. Agreement was also reached on the net deficit of sand still experienced by the Gold Coast beach system and that the bypassing project would make up that deficit initially in establishing the bypassing program.

## 2.6 1993 to 2001

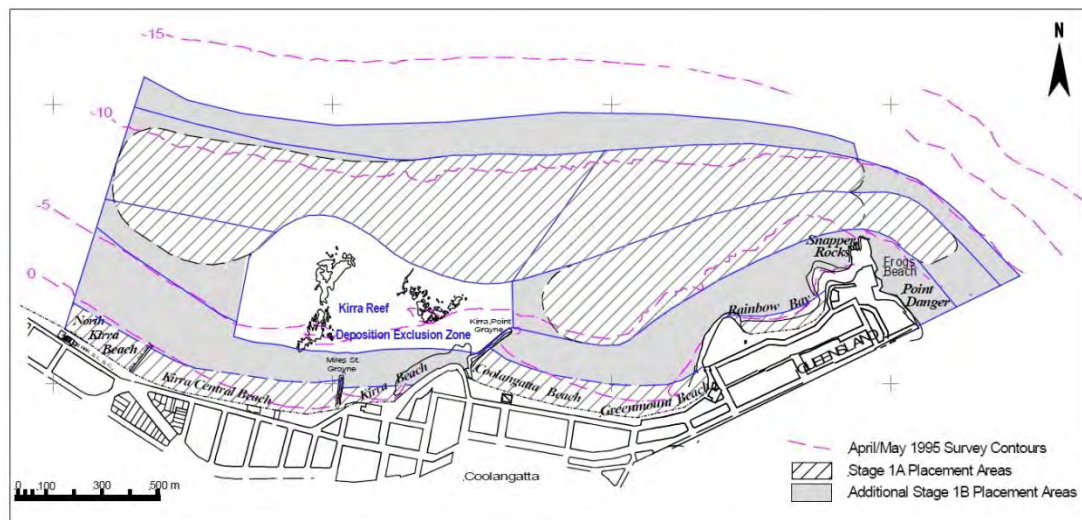
The bypassing project considerations were formalised in the NSW Tweed River Entrance Sand Bypassing Act 1995 which outlines the Deed of Agreement (DOA) between NSW and Queensland. The Deed of Agreement provided for the facilitation of agreements between the states with regard to improving the navigability of the Tweed River entrance and the bypassing of sand around that entrance to maintain and enhance the attributes of the southern Gold Coast beaches.

The DOA specified the Contract Quantity of sand to be made up and bypassed as follows:

- a) *2 million cubic metres (representing the required quantity of initial dredging and nourishment assessed in 1990);*
- b) *0.55 million cubic metres (representing an allowance for the losses since 1990);*
- c) *A quantity representing the volume of sand which would have been naturally transported between the completion of the first phase of the initial dredging and nourishment and the commencement of the operation of the permanent bypassing system, calculated at the rate of 500,000 cubic metres per annum; and*
- d) *The long term average net littoral transport (currently assessed as 500,000 cubic metres per annum) from the commencement of the operation of the permanent bypassing system.*

Stage 1 initial entrance dredging that commenced in 1995 aimed at achieving a baseline start point for the bypassing at which the Gold Coast beaches had experienced an overall net zero loss of

sand due to the training walls. Stage 1A dredging involved initially 2.25Mm<sup>3</sup> sand from April 1995 to August 1996 and then a further 800,000m<sup>3</sup> from September 1997 to May 1998, transferred from the river mouth to the beaches as shown in Figure 2-36 (Boswood *et al*, 2001). This dredging was carried out consistent with the Environmental Impact Statement/Impact Assessment Study completed in 1994 by Acer Wargon Chapman (1994).



**Figure 2-36 Stage 1 dredging placement areas (Boswood *et al*, 2001)**

Because of the time delay between Stage 1A and completion of the EIS/EIA (Hyder *et al*, 1997) for the bypassing project, a further Stage 1B dredging transferred an additional 800,000m<sup>3</sup> of sand from the mouth to the nearshore areas to augment Stage 1A.

The EIS/EIA for the bypassing made assessments of the coastal processes taking place and outlined a range of generic bypassing system options to provide the basis for both determination of environmental impacts and consideration of design and operational aspects to be dealt with should approval to proceed with bypassing be given. The basis of the EIS/EIA was that a proposal had been prepared for Stage 2 of the Tweed River Entrance Sand Bypassing Project that would comprise the design, manufacture, supply, delivery and commissioning of a sand bypassing system, and the continuing operation of that system for a nominal period of 25 years. It did not specify the nature of the system, which was the subject of a design and construct tender process in which the trestle-based sand pumping system now established was chosen.

Because of the delay in establishing the permanent bypassing system after completion of the Stage 1B dredging in May 1988, additional pre-commissioning dredging was undertaken involving delivery of 324,000m<sup>3</sup> from the entrance in September 2000 and a further 532,000m<sup>3</sup> by May 2001, at which time the sand pumping system commenced.

## 2.7 2001 to 2009

Implementation of the bypassing using the trestle system represents Stage 2 of the project. Pumping commenced with trials of the system from March to May 2001 during which about 250,000 m<sup>3</sup> were pumped and proceeded under the contract in May 2001.

Provision was made in the form of a Supplementary Increment that formed part of the Annual Increment of the amount bypassed, to make up the assessed deficit in the supply to Queensland of the alongshore transport captured at the mouth in the intervening period between Stage 1 and pre-commissioning dredging and commencement of bypass pumping. The DOA specified that, during the first six Annual Periods (years), the Supplementary Increment was an additional quantity equivalent to 550,000 m<sup>3</sup> plus the volume that would be transported between the Initial Dredging Component and commencement of operation of the System, calculated at 500,000 m<sup>3</sup>/yr.

For the long-term operation, the ongoing Annual Increment to the Contract Quantity implicitly requires that the quantity of sand to be collected and delivered to Queensland in the bypassing operation each year would equal the 'Long Term Average' (LTA) rate, being the average annual net alongshore transport of sand supply to Letitia Spit MINUS the quantity that leaks to Queensland by natural means. On that basis, the quantity of sand leaving the northern end of Letitia Spit should, after completion of the Supplementary Increment, must equal the quantity being supplied from the south.

Figure 2-37 summarises the volumes dredged and pumped annually over the period from 1995 when Stage 1A dredging commenced to the end of the first 6 Annual Periods in 2006 (BMT WBM, 2008). About 5.3M m<sup>3</sup> were bypassed by pumping and dredging in the 6 years 2001 to 2006, at an average of about 886,000 m<sup>3</sup>/year. In the first review of the LTA completed in 2009 (BMT WBM, 2011), it was determined that the bypassing over the first 6 years was excessive due to an overestimated Supplementary Increment quantity.

There is little evidence in the survey data that the effect of the over-supply of sand had extended north of North Kirra by 2005 (see also Figure 2-38). However, the combined benefit of the initial nourishment in 1988-90 and the bypassing was such that the beaches north to Currumbin appeared in good condition at that time (Figure 2-39 and Figure 2-40).

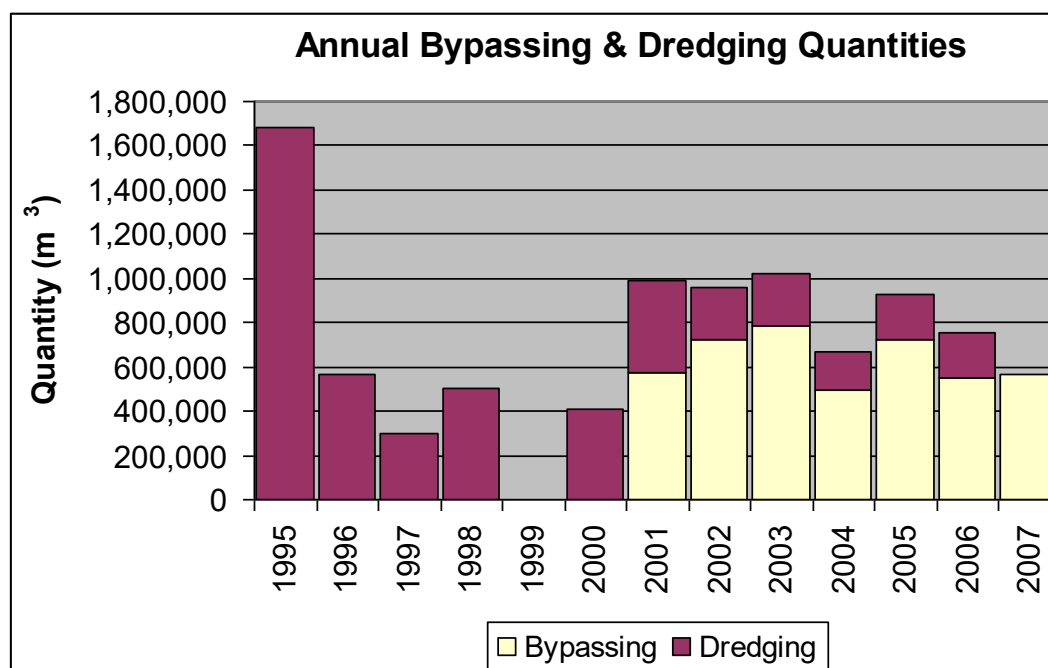


Figure 2-37 Annual dredging and pumping from 1995 to the end of the first 6 annual periods





Figure 2-38 Southern Gold Coast with excessive sand at Kirra to North Kirra



Figure 2-39 Bilonga, Tugun and Currumbin 2005



Figure 2-40 Currumbin Creek mouth 2005

## 2.8 2009 to 2016

After 2009, the rate of sand bypassing was scaled back substantially in order to restore a more reasonable longer term balance and reduce the over-supply to the Gold Coast. This can be seen in the pattern of bypassing in Figure 2-41. From 2009 to 2016 the average rate of bypassing was about 432,000 m<sup>3</sup>/year, almost entirely achieved by jetty pumping.

Over this period, the mass of sand at Kirra – Bilinga only slowly became distributed alongshore towards the north in a diffusive manner (Figure 2-42). By 2011 there was evidence in the surveyed quantities (Figure 2-43) that the accretionary perturbation was beginning to increase beach profile volumes north of the Kirra / Bilinga embayment. The northward re-distribution of sand can also be observed in aerial photography comparing the 2011 and 2015 shoreline alignments (Figure 2-43).

Currumbin Creek entrance continues to be subject to sand infilling due to natural wave and tide-driven processes, which is managed by annual dredging programs. Substantial sand

accumulations have occurred historically (e.g. Figure 2-29) and also more recently as observed during 2011 (Figure 2-44). The rate and spatial distribution of Currumbin Creek entrance shoaling has always been highly variable, as can be seen in the oblique aerial photographs taken at approximately yearly intervals from 2013 to 2015 (Figure 2-45 to Figure 2-47).

The question of how the Currumbin system may respond to a re-instated (increased) rate of sand supply is one of the motivations for the commissioning of this study. This report explores these processes further, as set out in the ensuing chapters.

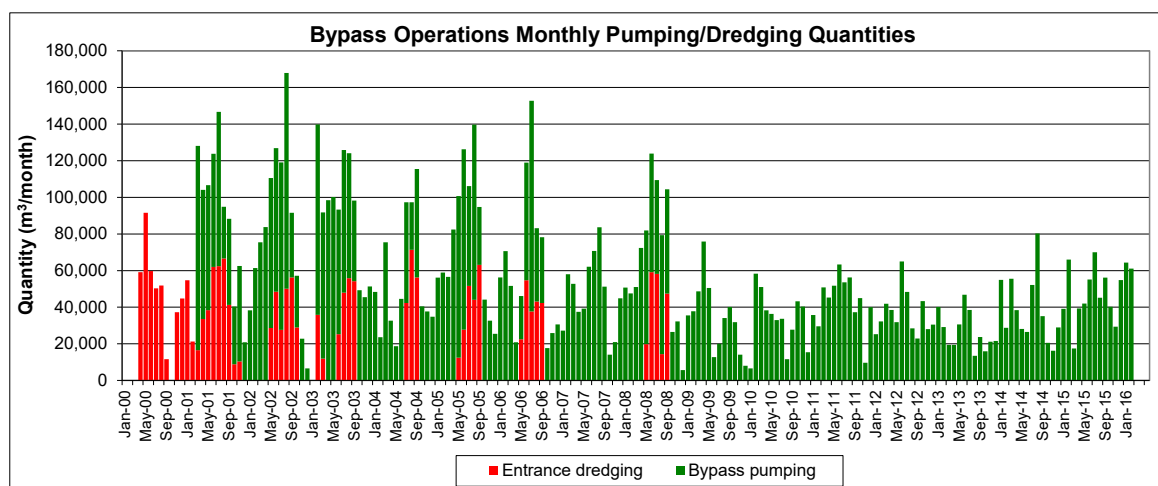


Figure 2-41 Monthly dredging and pumping 2000 – 2016 (BMT WBM, 2016)

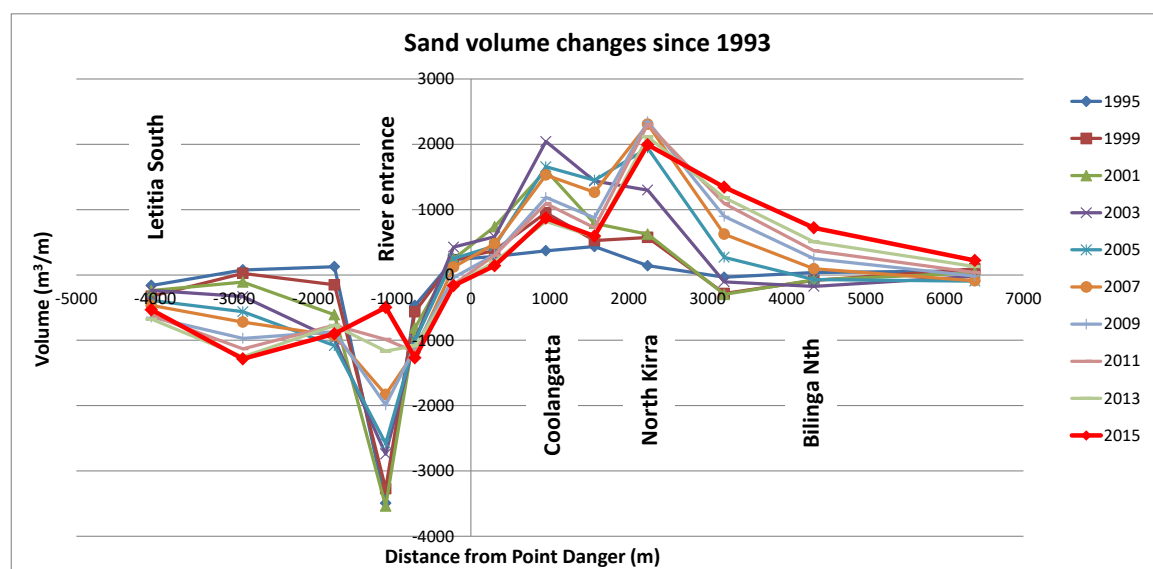


Figure 2-42 Alongshore distribution of change in sand quantities in NSW & Qld since 1993





Figure 2-43 Kirra to Currumbin Aerial Photography  
13 April 2011 (Top); 26 July 2015 (Bottom)





Figure 2-44 Currumbin Creek mouth 2011



Figure 2-45 Currumbin Entrance, 18 April 2013





Figure 2-46 Currumbin Entrance, 2 February 2014



Figure 2-47 Currumbin Entrance, 3 March 2015



## 3 Profile Evolution

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### 3.1 Methodology

A dataset of beach profile survey datasets for the study area has been collected over several decades by state and local government agencies and has been most recently collated and maintained by the City of Gold Coast. While some limited data is available from miscellaneous surveys undertaken prior to 1960, the first comprehensive survey of the entire Letitia Spit and Gold Coast system was first undertaken in 1966 as part of the Delft Hydraulics Laboratory investigations into coastal erosion on the Gold Coast (DHL, 1970). The survey lines established during this study have been used in subsequent surveys and provide a valuable dataset for coastal evolution analysis. Surveys occurred somewhat intermittently through the 1970s and 1980s before a more regular and comprehensive annual program was established as part of the Southern Gold Coast Beach Nourishment Project in the late 1980s and early 1990s and have been continued as part of Tweed River Entrance Sand Bypassing Project monitoring commitment.

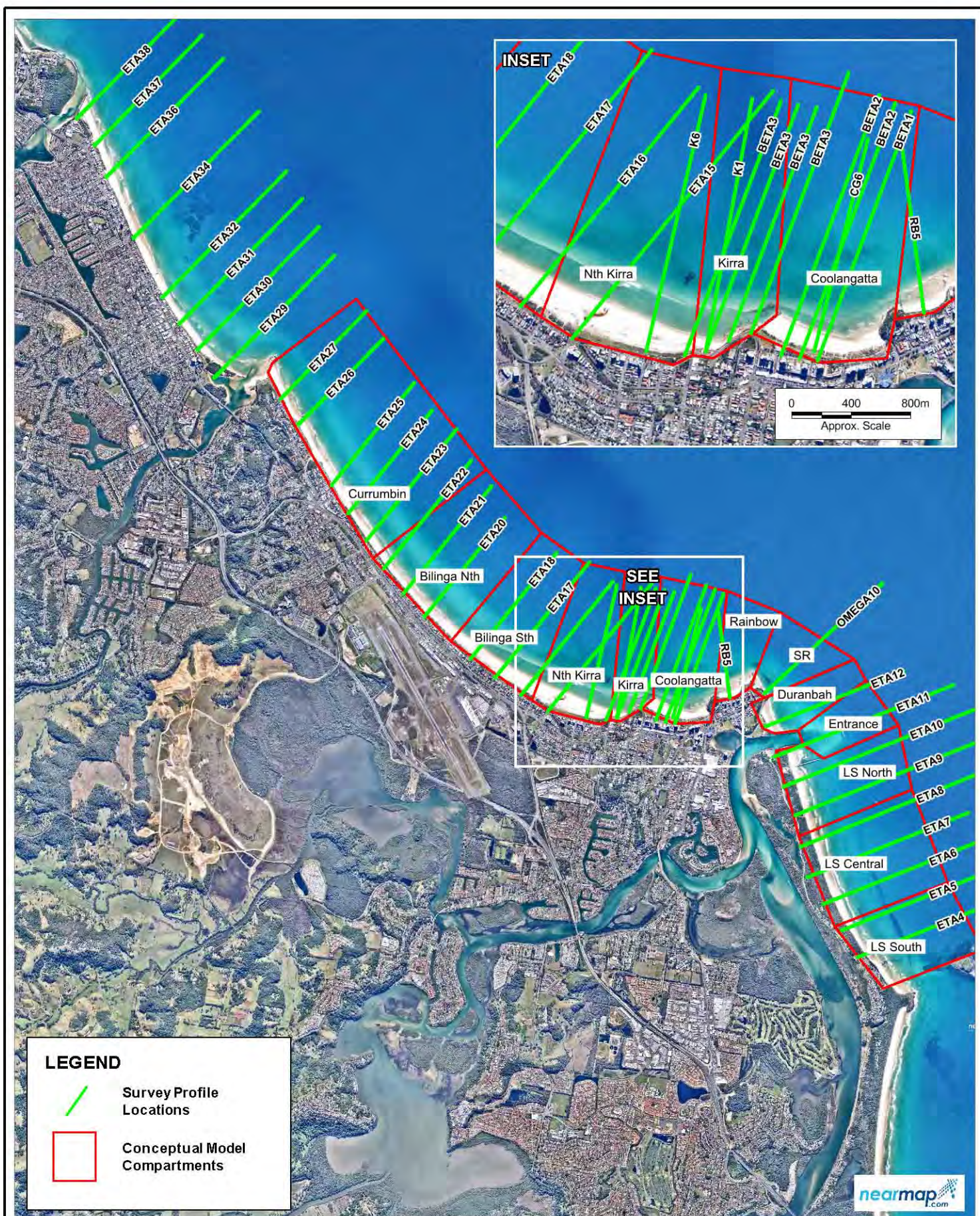
The following methodology has been applied to the survey profile analysis:

- Plotting of all survey profiles corresponding to a particular eta-line.
- Removal of incomplete or otherwise compromised profile data from further analysis.
- Volume integration between the following limits (determined individually for each eta-line):
  - point landward of the most eroded dune scarp; and
  - defined depth beyond which the profile appears to remain reasonably static (typically around -15 m AHD).
- Plotting of volume change (per metre) timeseries for selected eta-lines. The 1966 survey is used as the baseline volume against which change is tracked.
- Plotting of profiles corresponding to key dates.
- Plotting of alongshore distribution of volume change (since 1966) for key dates.

The surveyed profile changes since 1966 for certain key profiles are described in Section 3.2 and the alongshore distribution of volume changes is summarised at key reporting times in Section 3.3. Spatial maps of bed elevation change since 1966 derived from the survey profile dataset are included in Appendix B.

The profile volume analysis undertaken here has been used to cross-check numbers derived by the Roelvink and Murray (1992) southern Gold Coast littoral sand supply study which covered the period from 1962 to 1989, and the volume analyses underpinning the TRESBP LTA assessments which cover the period from 1993 to 2015 (BMT WBM, 2009; 2015). A continuous and consistent set of compartment volume changes since 1962 were required as inputs to the conceptual model analysis detailed in Section 4.





Title:  
**Survey profile locations and conceptual model compartments**

Figure:

**3-1**

Rev:

**A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.



0 1 2km  
Approx. Scale



## 3.2 Profile response

### 3.2.1 Letitia Spit

Noting that the Tweed River entrance training wall extensions commenced in 1962, it was estimated that by 1966 approximately 1.0M m<sup>3</sup> of sand had already been accumulated on Letitia Spit (Roelvink and Murray, 1992). The post-1966 evolution of the Eta 8.00 profile, which is located approximately 1.2 km south of the training walls, is shown in Figure 3-2. By 1993 the upper beach profile had accreted by 150 m and volumes had increased by 1600 m<sup>3</sup>/m. Accretion peaked at 2000 m<sup>3</sup>/m in 1997 before the profile started to recede in response to the TRESBP Stage 1 dredging which had commenced in 1995. The rate of recession accelerated with the commencement of TRESBP Stage 2 dredging in 2000, and subsequently declined following completion of the supplementary increment period in 2007. The current (2015) profile has receded to within 240 m<sup>3</sup>/m of the 1966 baseline volume.

### 3.2.2 Coolangatta

The evolution of the Beta 2.40 profile, which is located on Coolangatta Beach around 150 m updrift (east) of the Kirra Point groyne, is shown in Figure 3-3. The Kirra Point groyne constructed in 1972 helped to stabilise the upper beach profile, however the profile below -5 m AHD continued to drop until 1983, at which time the profile volume had been reduced by 730 m<sup>3</sup>/m (relative to 1966).

The profile volume recovered rapidly with the commencement of TRESBP Stage 1 in 1995 and further increased with Stage 2 commencing in 2000. In 2003 the profile volume peaked at 1400 m<sup>3</sup>/m above the 1966 baseline, however much of the additional volume was located below low tide level. The profile volume has since reduced, with most of the sand loss from below -5 m AHD. Since 2009 the profile volume has remained relatively stable around 300 m<sup>3</sup>/m above the 1966 baseline, with this residual increase in profile volume probably attributable to the Kirra Point groyne effects.

### 3.2.3 Kirra and North Kirra

The Kirra and North Kirra beach compartments were the most heavily impacted by the post-1962 reduced sand supply. McDonald and Patterson (1984) and Roelvink and Murray (1992) reported that at North Kirra (Beta 4.8) the upper beach profile was eroded by 5.0 m vertically and that corresponding peak volumetric losses (circa 1985) were in excess of 2,000 m<sup>3</sup>/m. Unfortunately, the Beta 4.00 to 5.00 profile lines have not been re-surveyed since 1990, and therefore the Beta 3.30 and Eta 15.00 survey profiles have been selected to illustrate the Kirra and North Kirra profile response.

The evolution of Beta 3.30, which is located around 150 m downdrift (west) of the Kirra Point groyne, is shown in Figure 3-4. The upper part of this section is the rocky Kirra Point, which limited the potential shoreline recession but by 1983 the profile had lost 1400 m<sup>3</sup>/m below 0 m AHD. The section recovered with the late-1980's nourishment and following the mid-1990's TRESBP stage 1 dredging the profile volume was similar to the 1966 baseline. Following commencement of TRESBP stage 2 the profile volume peaked at around 500 m<sup>3</sup>/m before reducing and stabilising from 2010 onwards.

## Profile Evolution

The evolution of Eta 15.00, which is located in the North Kirra compartment, is shown in Figure 3-5. Whereas Beta 3.30 is located on Kirra point, Eta 15.00 is located within the Kirra embayment where profile volume fluctuations are expected to be more pronounced. From 1966 to 2001 the Eta 15.00 profile volume evolution was broadly similar to Beta 3.30, however following commencement of TRESBP stage 2 the profile continued to accrete across the elevation range from the sub-aerial berm height at around 1.5 m AHD through to -7 m AHD. The profile volume peaked around 2009 at around 1800 m<sup>3</sup>/m (above 1966) and by 2015 had reduced to 1500 m<sup>3</sup>/m.

### 3.2.4 Bilinga

The evolution of Eta 17.00, which is located in the South Bilinga compartment around 1.8km downdrift (north-west) of Kirra Point, is shown in Figure 3-6. The onset of the erosion impacts was delayed relative to the updrift Kirra compartments and the impacts were much less severe, peaking at just over 800 m<sup>3</sup>/m below 1972 levels (1972 is a more representative baseline than 1966 at this location). Profile volumes were stabilised close to 1972 levels following the late 1980s beach nourishment and TRESBP Stage 1 dredge placement. Following commencement of TRESBP Stage 2 the volumes increased rapidly until around 2011, after which the rate of increase has reduced. The profile volume is currently around 1500 m<sup>3</sup>/m above 1972 levels.

The evolution of Eta 21.00, which is located in the North Bilinga compartment, is shown in Figure 3-7. Relative to the updrift compartments, the onset of erosion impacts were delayed and magnitude of impacts were less severe, peaking at 580 m<sup>3</sup>/m in 1989 (noting that the section wasn't surveyed in the mid-1980s). At this section the effects of the Southern Gold Coast Beach Nourishment Project to re-instate the profile volume can be clearly seen around 1990. The profile volume remained relatively stable between 1990 and 2010, when the additional sand supply from the TRESBP Stage 2 became apparent as a steady rate of increase. The profile volume is currently 650 m<sup>3</sup>/m above 1966/1972 levels. While the upper sub-aerial profile has accreted around 50 m from its most eroded state in the late 1980s, much of the additional volume is located in a sand "lobe" between -5 and -10 m AHD. Evidence of this sand lobe can be seen in the 2015 aerial photograph (Figure 2-43).

### 3.2.5 Currumbin

The evolution of Eta 24.00, which is located in the southern (Tugun) section of the Currumbin compartment, is shown in Figure 3-8. This profile is located around 700 m south of Flat Rock, which acts as a natural control point. At this location the erosion impacts only become apparent after 1985, peaking at 480 m<sup>3</sup>/m before the nourishment project re-instated volumes around 1990. The profile volume remained stable between 1990 and 2013, since which time an increasing trend has become apparent. The profile volume is currently 320 m<sup>3</sup>/m above 1966 levels. Very little change is apparent in the upper profile, with most of the accretion occurring in a sand "lobe" between -4 and -10 m AHD. Evidence of this sand lobe can be seen in the 2015 aerial photograph (Figure 2-43).

The evolution of Eta 27.00, which is located on Currumbin beach between Elephant Rock and Currumbin Rock is shown in Figure 3-9. The construction of the Currumbin Rock groyne in 1973 had a significant impact the section of beach between Currumbin Rock and Elephant Rock with the upper profile beach accreting 70m at Eta 27.00 and profile volumes increasing by around



## Profile Evolution

1000 m<sup>3</sup>/m. After 1980 the profile volume timeseries exhibits a somewhat cyclical trend with volumes reducing by around 500 m<sup>3</sup>/m in the early-1990s before recovering by 2000 and again reducing by around 500 m<sup>3</sup>/m by 2010. Since 2013 the profile volumes appear to be steadily increasing.

### 3.2.6 Palm Beach

The evolution of Eta 30.00, which is located towards the southern end of Palm Beach, is shown in Figure 3-10. This profile has been heavily influenced by the updrift construction of the Currumbin Rock groyne in 1973 and the Currumbin Creek northern training wall in 1981. The combined effect of these two changes caused a re-alignment of the southern section of Palm Beach, which is apparent in the 500 m<sup>3</sup>/m volume gain between the late 1970s and early 1980s. Profile volume declined slightly in the period from 1995 to 2002, quite possibly due to reduced sand supply from the south. However, this far north of Point Danger the erosion response is much less obvious (and severe) than further south in the Kirra embayment. Since 2002 the profile volume has increased to around 800 m<sup>3</sup>/m above the 1966 baseline profile.

The evolution of Eta 32.00, which is located about 250 m south of the southern Palm Beach groyne, is shown in Figure 3-11. At this location, there has not been much variation observed in the overall profile volume since 1966. However, this part of Palm Beach is considered an erosion hotspot due to historical development within the active beach zone. The A-line seawall was established following the 1967 storms and during the 1970s and 1980s there was often limited beach width seaward of the seawall. Since then the upper beach width has recovered, however some sand volume has been lost from the deeper profile between -7 and -12 m AHD.

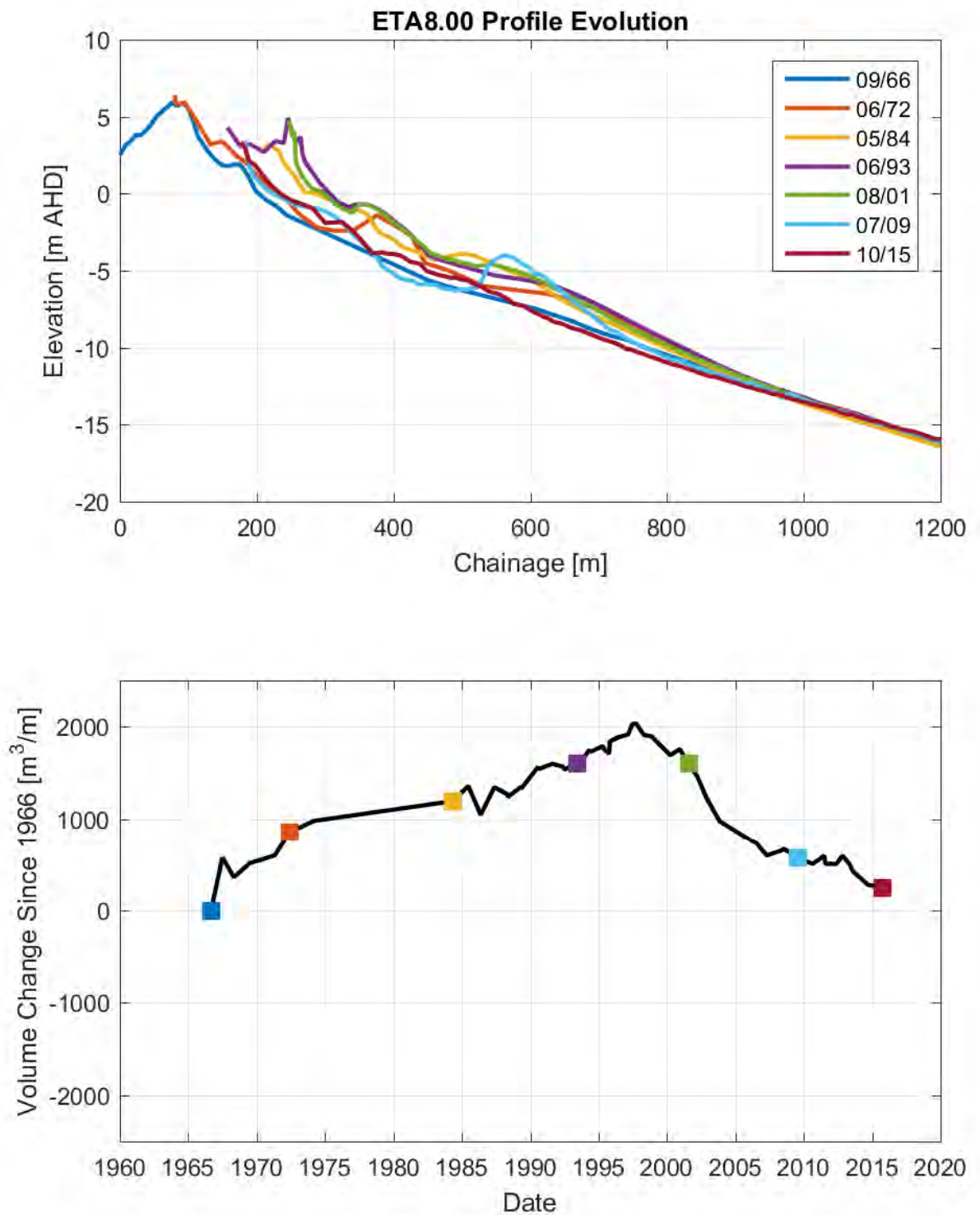


Figure 3-2 Letitia Spit profile evolution

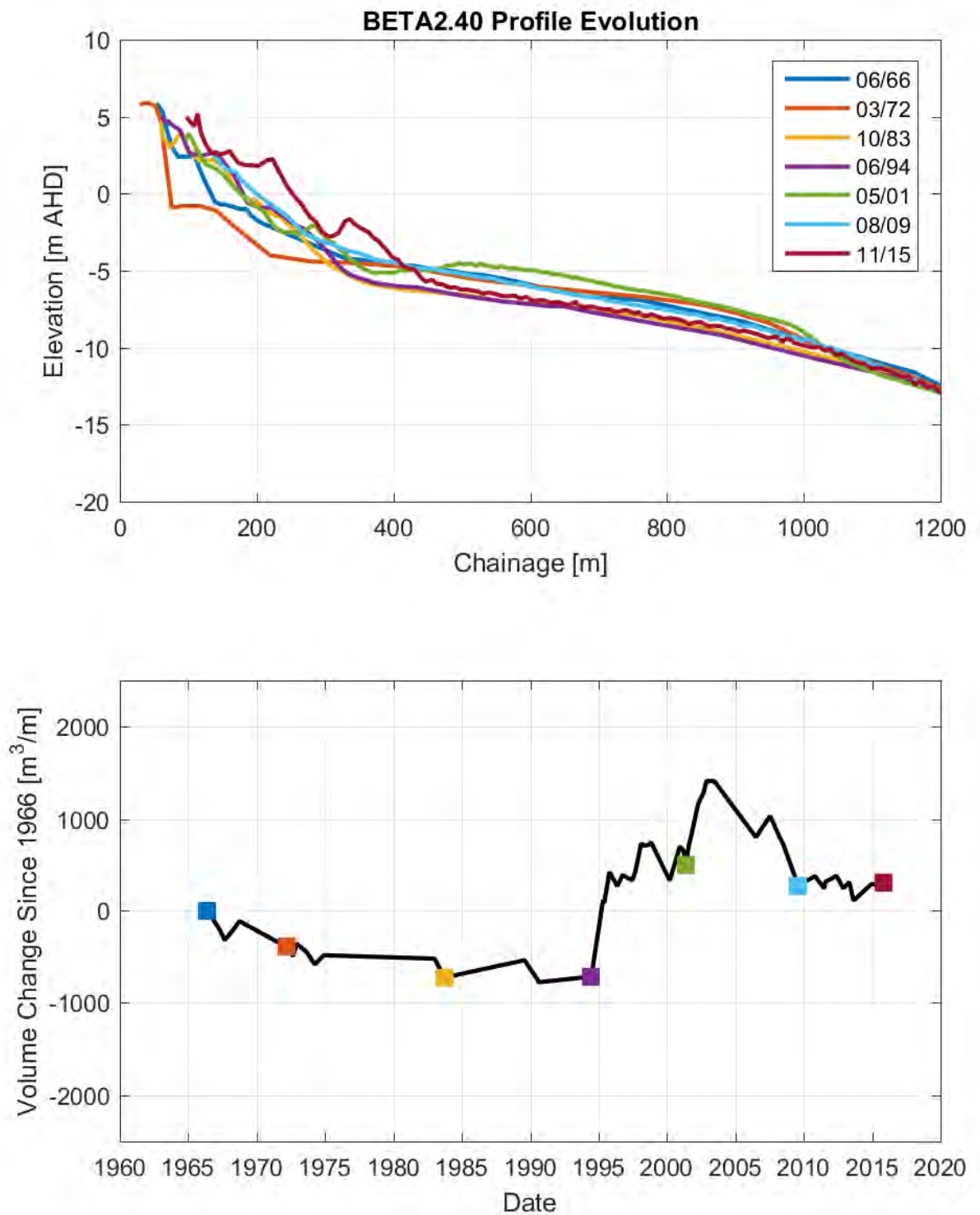


Figure 3-3 Coolangatta profile evolution

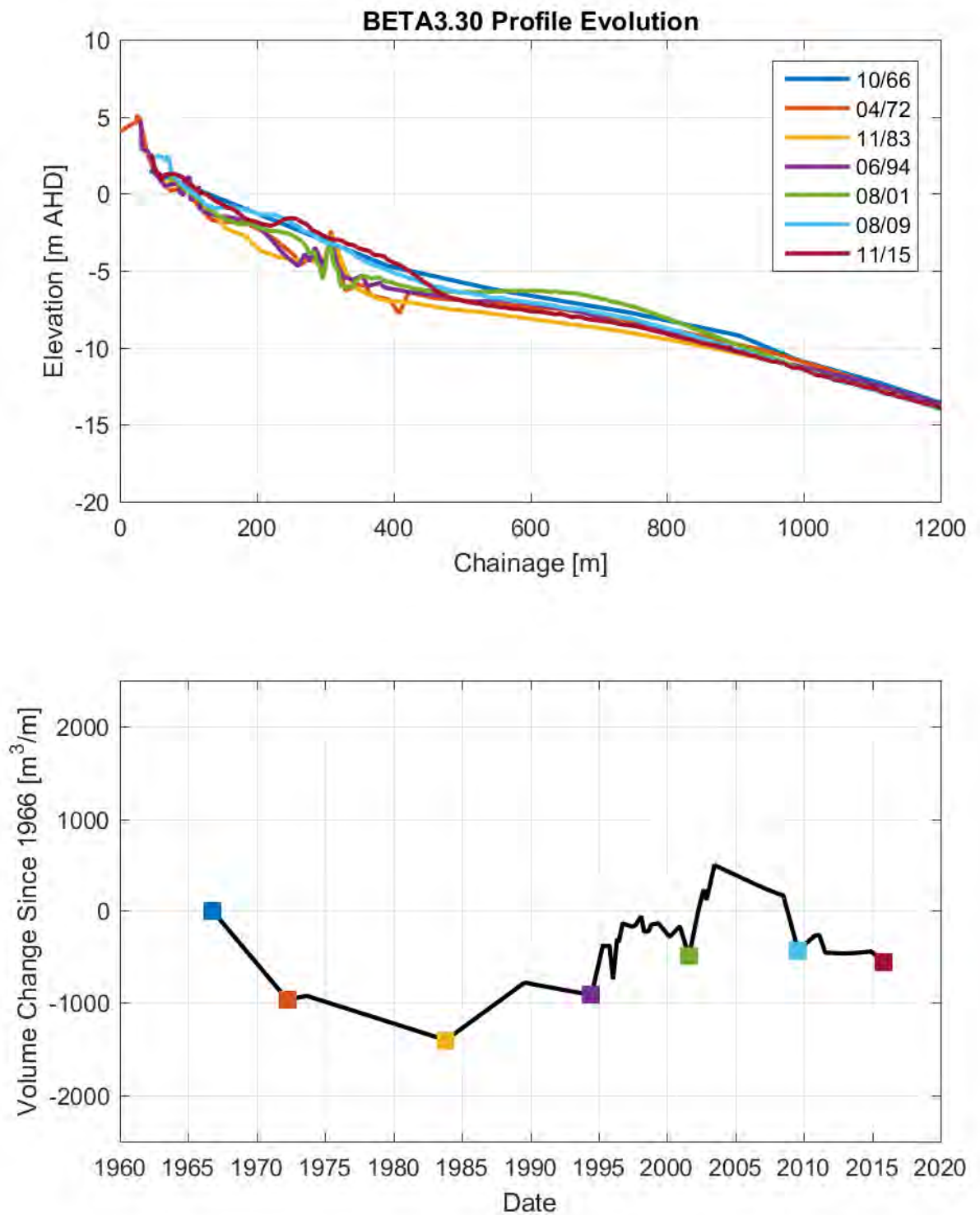


Figure 3-4 Kirra profile evolution



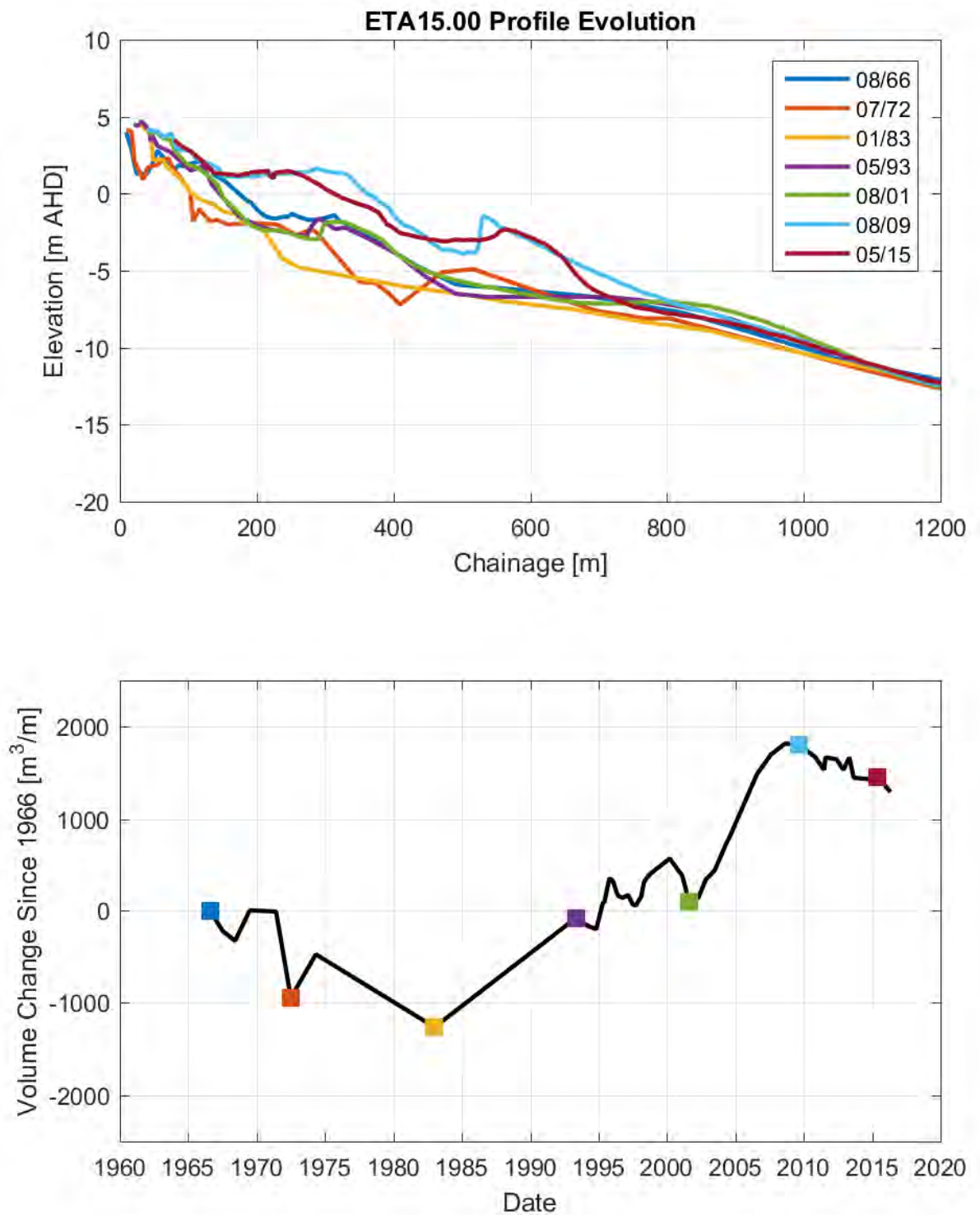


Figure 3-5 North Kirra profile evolution

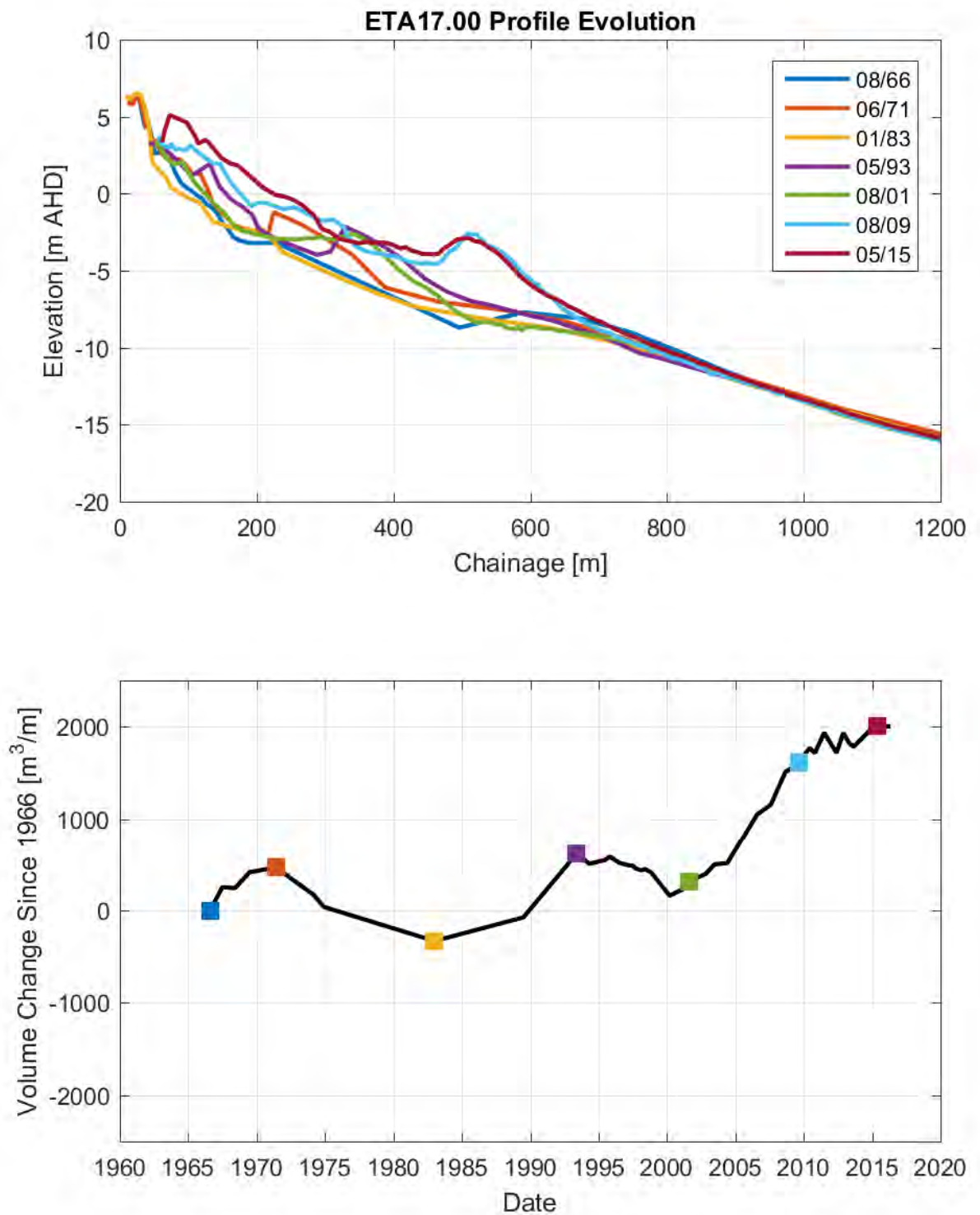


Figure 3-6 South Bilinga profile evolution

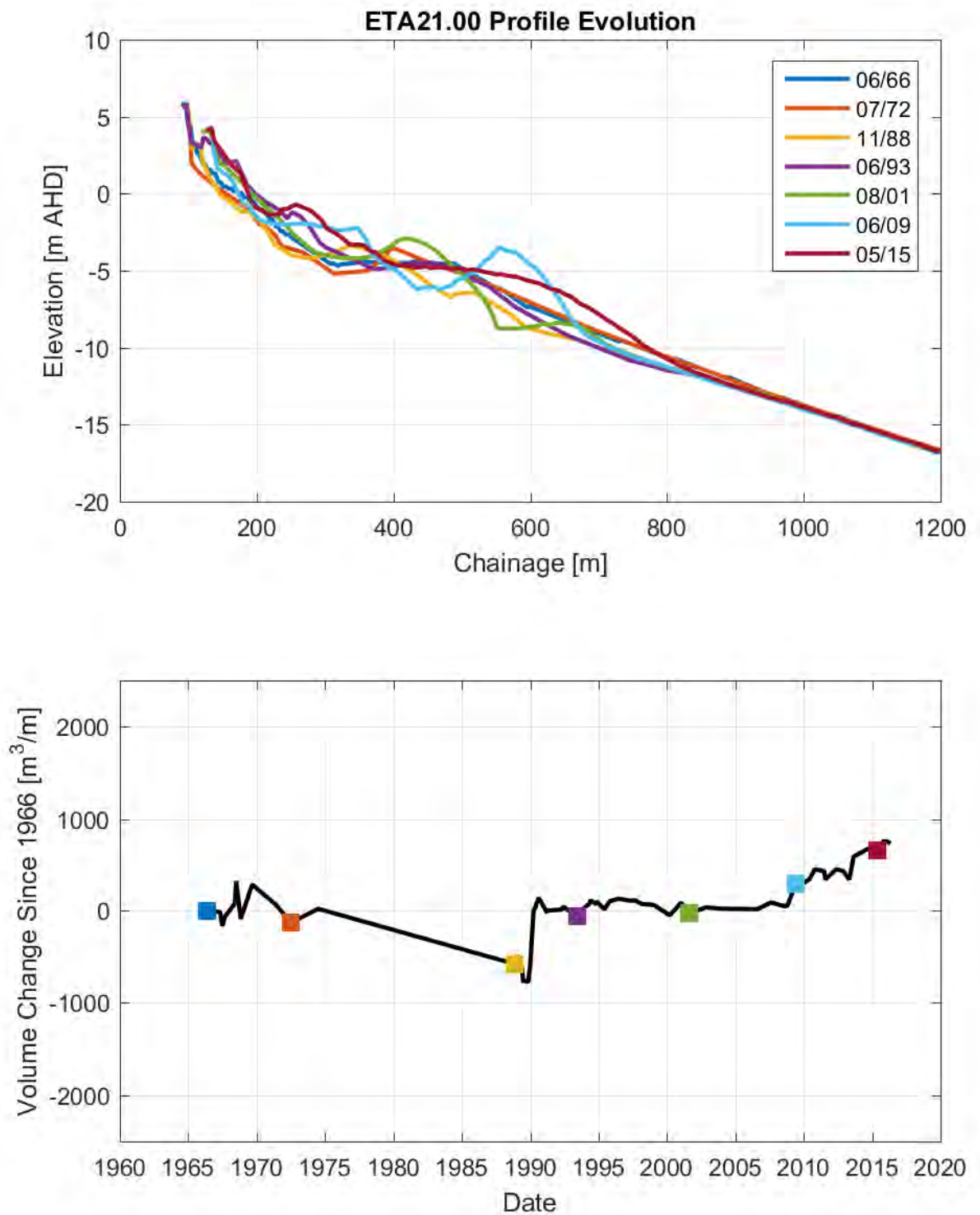


Figure 3-7 North Bilinga profile evolution

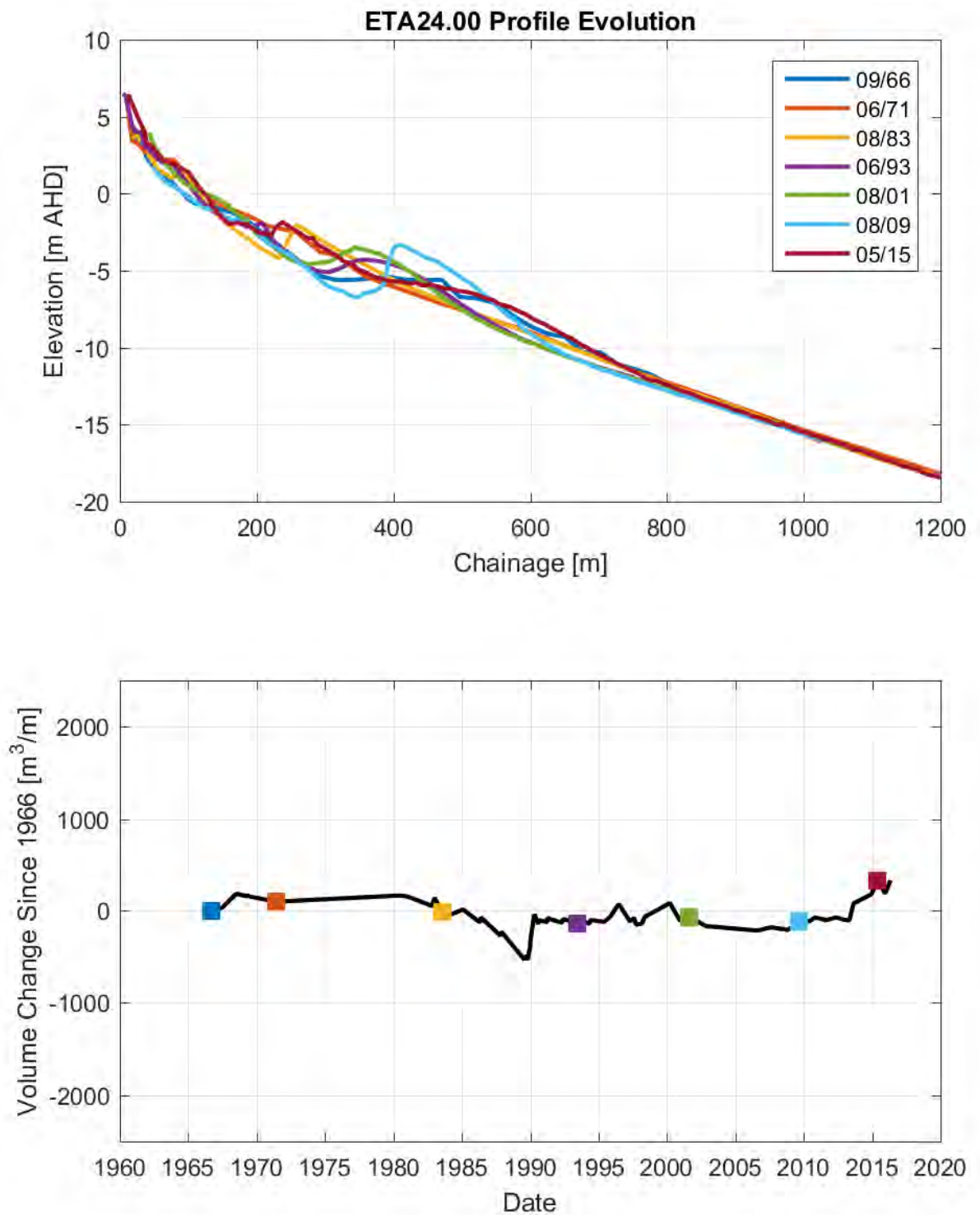


Figure 3-8 Tugun profile evolution



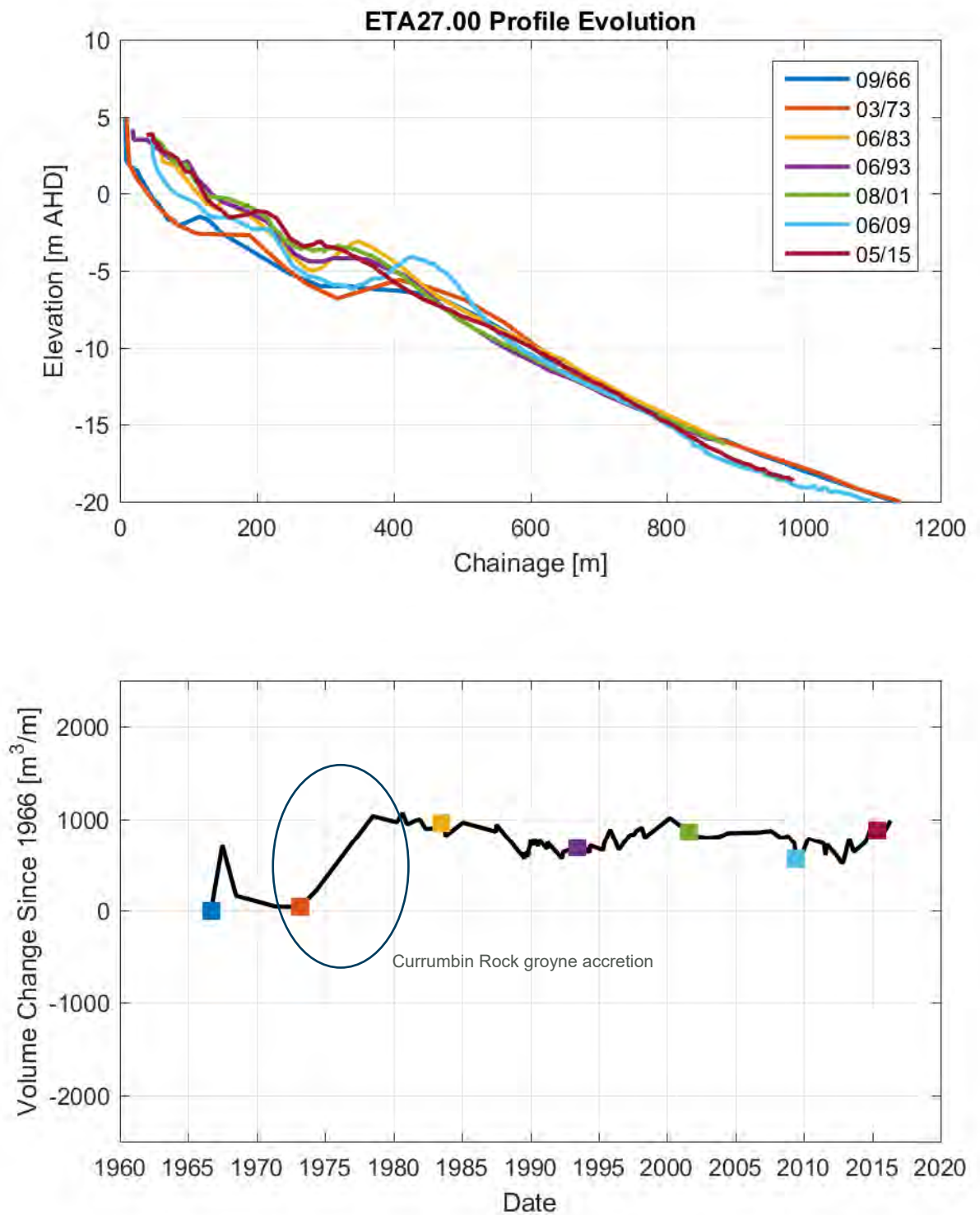


Figure 3-9 Currumbin profile evolution

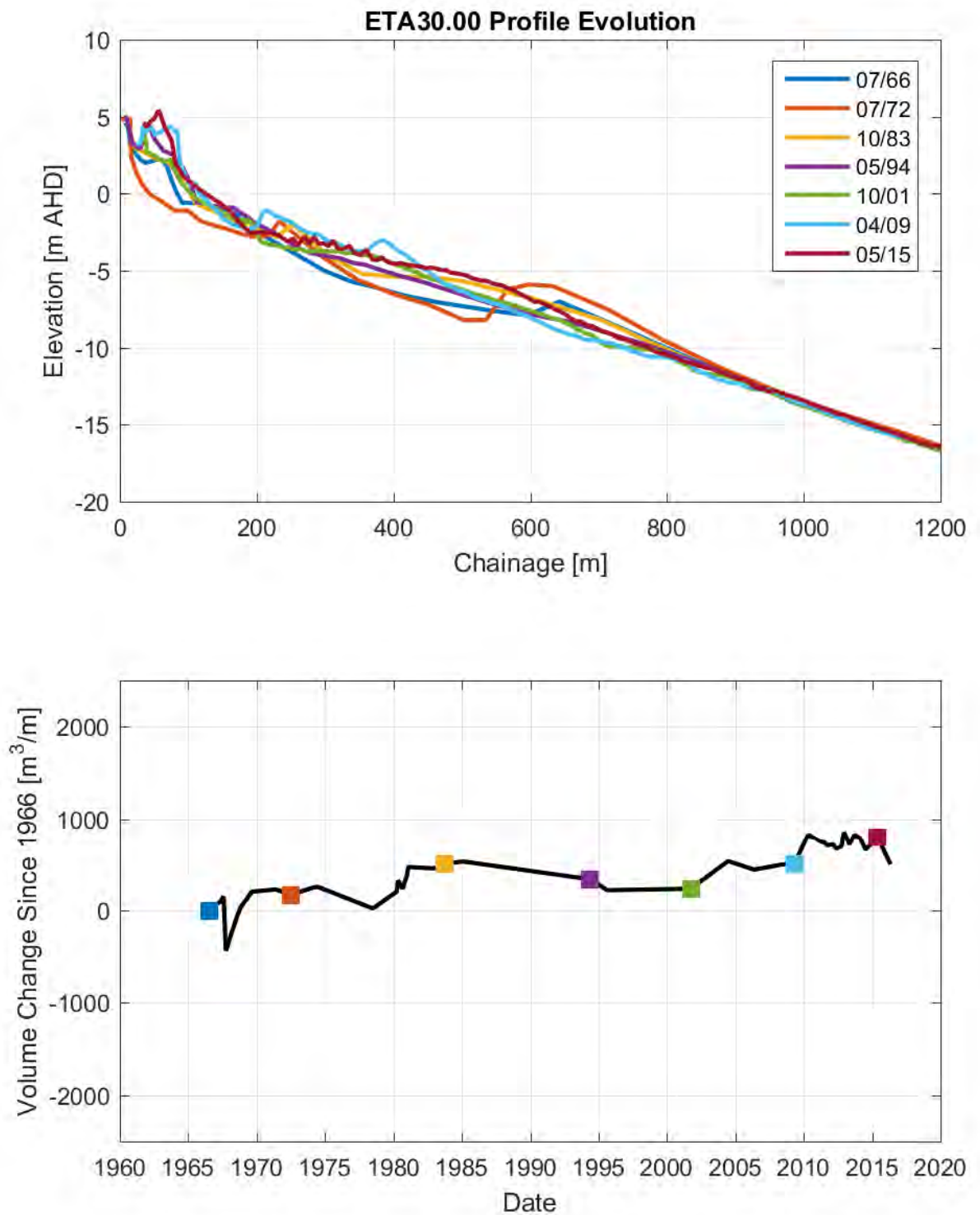


Figure 3-10 Palm Beach South profile evolution

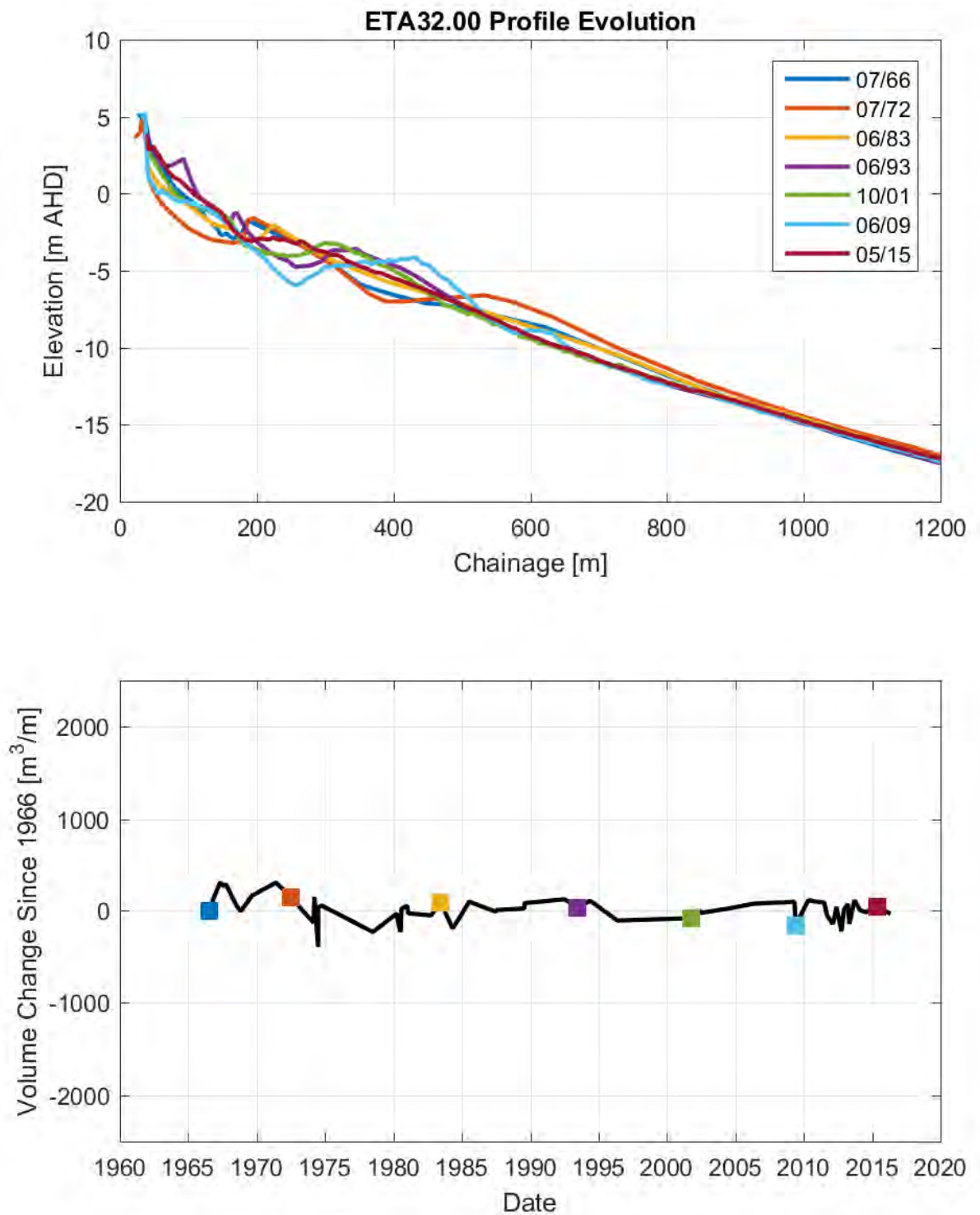


Figure 3-11 Mid Palm Beach profile evolution



### 3.3 Alongshore distribution

The profile analysis is summarised in Figure 3-12, which shows the alongshore distribution of profile volume changes (relative to 1966) at key reporting timings. Key features in this figure include:

- Letitia Spit accretion up until 2001 (TRESBP Stage 2).
- Letitia Spit retreat from 2001 to 2016.
- Accretion related to Currumbin Rock groyne construction in 1973.
- Erosion of around 2,000 m<sup>3</sup>/m in the Kirra embayment by 1983.
- Replenishment from the Southern Gold Coast Nourishment Project (circa 1990) from Kirra to Bilinga.
- Replenishment from TRESBP Stage 1 dredge placement from Snapper to Kirra (1995-1998).
- By 2009 volumes within Kirra embayment were up to 1900 m<sup>3</sup>/m above 1966 baseline.
- By 2016 the northward dispersal of sand from the Kirra embayment can be seen extending to Tugun but not as far as Currumbin Rock.

## Profile Evolution

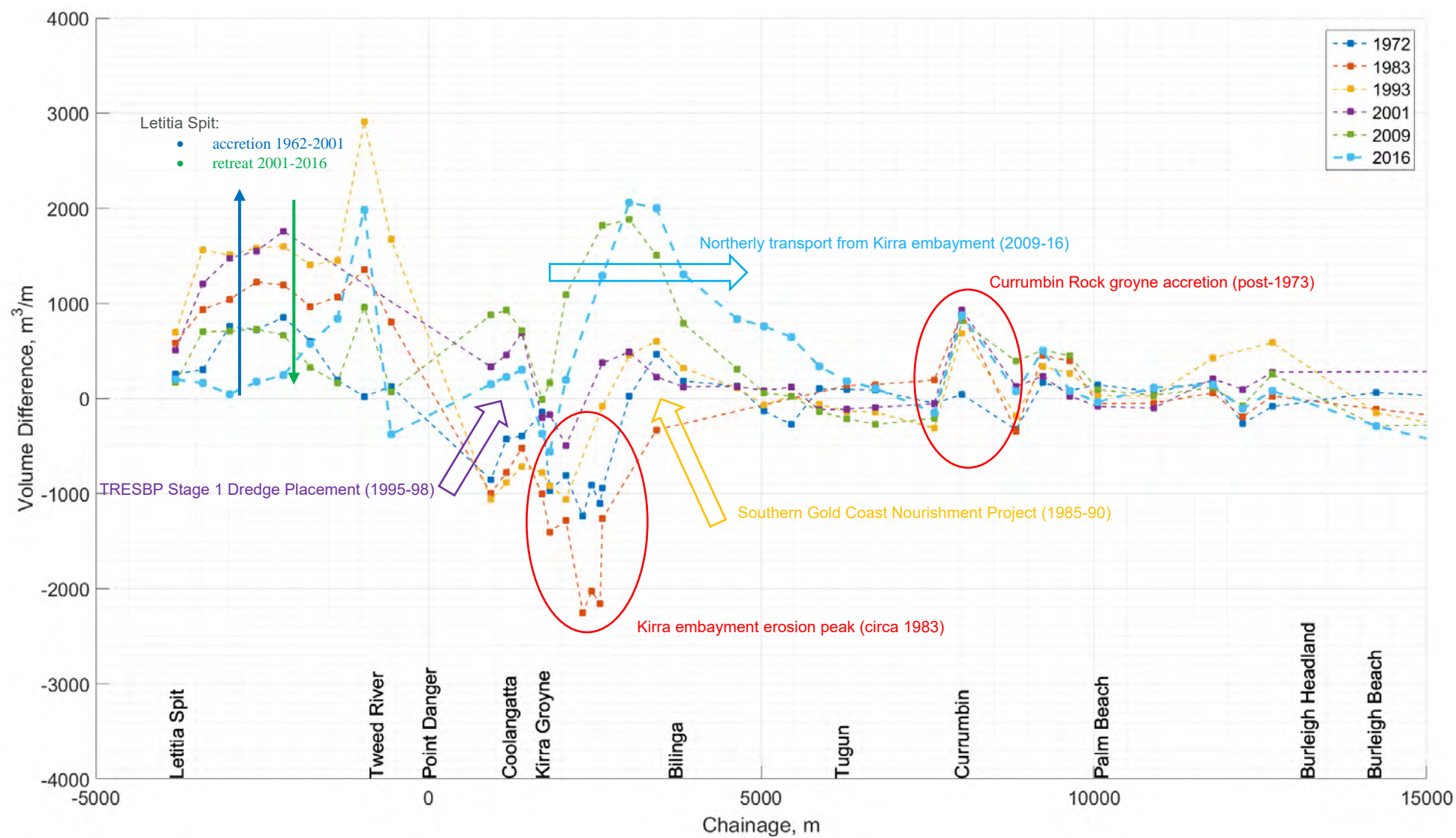


Figure 3-12 Surveyed alongshore volume trends relative to 1966

## 4 Conceptual Model

### 4.1 Methodology

The conceptual model that has been developed for this study is at the highest level a sediment budget for the littoral system from Fingal Head to Currumbin. The conceptual model principally documents sand volume changes over time, within sub-compartments of the overall littoral system. With additional knowledge (or assumptions) about the transport in (or out) and any sources (or sinks) the sediment mass balance can be solved for the transport out (or in). Sources/sinks can include natural processes adding/subtracting sand from the natural littoral system, such as exchange with estuaries. They may also be due to human intervention, such as from dredging and placement, nourishment from external sand sources and jetty pumping.

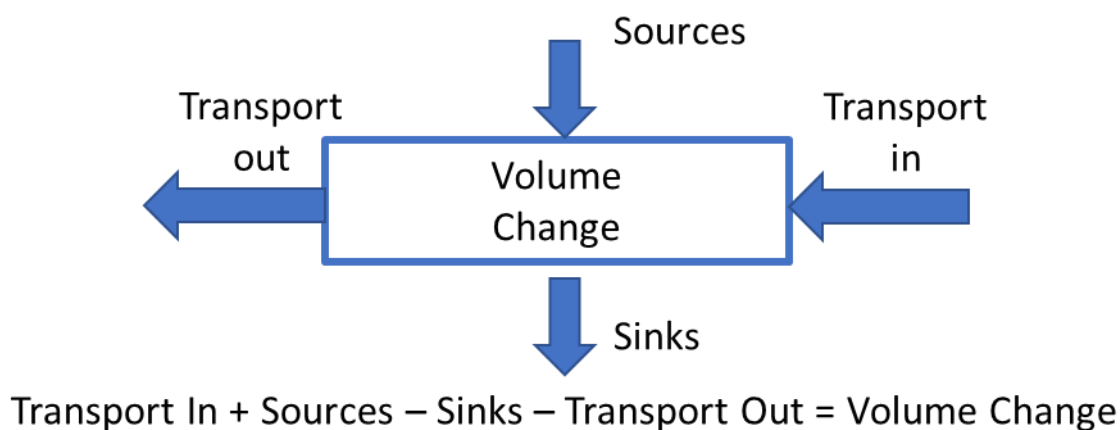


Figure 4-1 Sediment budget model

The sediment budget equation can be solved consecutively through upcoast (or downcoast) sub-units. The compartments used in the current conceptual model are shown in Figure 3-1 and are the same as those used in the “LTA” assessments (BMT WBM 2009, 2015). The conceptual model has been derived for the following six sub-periods:

- 1962 to 1972
- 1972 to 1983
- 1983 to 1993
- 1993 to 2001
- 2001 to 2009
- 2009 to 2015

The 1962 starting date immediately precedes the commencement of construction of the Tweed River training wall extensions. Subsequent dates are at approximately 10-year spacings and have been chosen to coincide with reasonably comprehensive survey datasets. For the period from 1962 to 1989 the conceptual model inputs have been derived from the Roelvink and Murray (1993)



analysis, with some minor changes due to different sub-compartment boundary locations. Inputs include compartment volume changes, natural system source / sink quantities and nourishment quantities.

The Roelvink and Murray analysis assumed as the necessary sand budget boundary condition, that sediment was supplied around Fingal headland at a rate of 500,000 m<sup>3</sup>/year. Based on subsequent analysis (Patterson et al, 2011) 550,000 m<sup>3</sup>/year has been assumed as the corresponding sediment budget model boundary condition in the current assessment for the period from 1962 to 1993.

From the period from 1993 to 2015 the conceptual model inputs have been derived from the recently updated “LTA” analysis (BMT WBM, 2015). The inputs include compartment volume changes, natural source / sink quantities, nourishment quantities, dredge-bypassing quantities and jetty pumping quantities.

The “LTA” analysis computed a time-varying monthly sand transport rate at Currumbin as a boundary condition to the sediment budget model and from there integrated the sediment budget equation south towards Fingal. The “LTA” analysis was undertaken using a monthly timestep and therefore provided a more detailed picture of short to medium term variability in the system than the assessment presented here. The current assessment should be entirely consistent with the LTA assessment over the period 1993 to 2015, except for the temporal granularity of the output.

The conceptual model compartment volume change, bypassing and nourishment quantity inputs are comprehensively documented in Appendix A and are summarised in Table 4-1 below.

**Table 4-1 Conceptual Model Inputs Summary (1,000 m<sup>3</sup>)**

Period to Year	Volume Change Since 1962			Bypassing to QLD		QLD
	NSW	QLD	Total	Dredge**	Pumping**	N'ment
1962						
1972	3.32	-2.61	0.71			
1983	6.40	-4.19	2.21			0.77
1993	8.86	-1.27	7.58			5.47
2001	7.42	0.50	7.93	3.53		
2009	5.20	3.41	8.61	1.58	5.22	
2015	4.98	4.28	9.25		2.74	
<b>TOTAL</b>				<b>5.11</b>	<b>7.96</b>	<b>6.24</b>

\*\* Bypassing volumes include component to Duranbah

## 4.2 Compartment Volume Changes

The compartment volume changes since 1962 are presented in Figure 4-2 and Figure 4-3. Notable features include:

- Substantial accretion of Letitia Spit following the training wall extension in 1962. By 1993 there was 6.9M m<sup>3</sup> accretion of Letitia Spit.

- Infilling of the Tweed River in the period 1962 to 1993 accounted for a 1.4M m<sup>3</sup> loss to the littoral system. After 1993 the rate of Tweed River infilling substantially reduced and then marginally reversed.
- The Tweed River entrance ebb tide bar (Entrance compartment) accreted by 2.8M m<sup>3</sup> by 1993.
- By 1993 the total volume of sand accumulation across the NSW compartments was 8.9M m<sup>3</sup>.
- In 1973 the construction of the Currumbin Rock groyne “trapped” approximately 0.8M m<sup>3</sup> in the Currumbin compartment north of Elephant Rock (Macdonald and Patterson, 1983). Corresponding losses would have been transferred north to Palm Beach and Burleigh.
- Pumping of 0.77M m<sup>3</sup> of sand from the lower Tweed River with placement at Kirra in 1974/75 would only have had temporary benefits as this volume would have been replaced from the littoral system.
- Total Queensland erosion peaked around 1983 with a 4.2M m<sup>3</sup> deficit across all compartments (MacDonald and Patterson, 1985). This erosion was most strongly felt in the Kirra embayment (North Kirra compartment).
- In 1985 0.3M m<sup>3</sup> nourishment was undertaken at Kirra and in 1988/99 1.6M m<sup>3</sup> was placed from Kirra Point through to Bilinga South (Murray et al. 1993). This sand was sourced from an offshore “borrow” area.
- By 1989, “gross” Queensland erosion estimated as the sum of measured losses, replacement nourishment and excluding Currumbin Rock groyne gains was 7.2M m<sup>3</sup>, which is in accordance with the analysis of Roelvink and Murray (1993).
- During 1989/1990 the Southern Gold Coast Nourishment Project undertook placement of 3.6M m<sup>3</sup> of sand (sourced from offshore “borrow” areas) between Kirra and Tugun (Murray et al. 1993).
- In 1993, following completion of the Southern Gold Coast Nourishment Project, a total of 6.2M m<sup>3</sup> of nourishment had been undertaken since 1962 with the net result being that the net volume deficit in Queensland was reduced to 1.3M m<sup>3</sup>.
- From 1995 to 1998 the TRESBP Stage 1 dredging bypassed 3.0M m<sup>3</sup> from NSW (predominantly the Entrance compartment) to nearshore placement areas in Queensland. An additional 0.5M m<sup>3</sup> of dredging occurred in 2000/01 as part of TRESBP Stage 2 but prior to commissioning of the jetty pumping system (BMT WBM, 2009).
- Prior to commencement of jetty pumping the volume from Point Danger to Currumbin had been re-instated close to 1962 levels (in fact increased by 0.5M m<sup>3</sup>).
- During March 2001, the TRESBP jetty pumping system was commissioned. From 2001 to 2009 the jetty pumped 5.2M m<sup>3</sup> at an average rate of 630,000 m<sup>3</sup>/year (BMT WBM, 2009).
- During the 2001 to 2009 period 1.6M m<sup>3</sup> was bypassed to Queensland by dredging activities (BMT WBM, 2009).

- During the period 2001 to 2009 the average bypassing rate from the combination of both pumping and dredging was 820,000 m<sup>3</sup>/year. By 2009 there was a net gain of 3.4M m<sup>3</sup> to Queensland relative to 1962. The initially high rate of Stage 2 bypassing was a legislative requirement of the first 6-years of system operation as specified by the Supplementary Increment of the Deed of Agreement (BMT WBM, 2010).
- During the 2009 to 2015 period the jetty pumped 2.7M m<sup>3</sup> at an average rate of 430,000 m<sup>3</sup>/year (BMT WBM, 2015).
- There was no bypassing undertaken by dredging operations during the 2009 to 2015 period. During this period the Tweed River ebb tide bar accreted by approximately 0.4M m<sup>3</sup> at an average rate of 60,000 m<sup>3</sup>/year.
- As of 2015 there is 9.2M m<sup>3</sup> more sand in the Fingal to Currumbin system than there was in 1962. During this period, there was 6.2M m<sup>3</sup> of nourishment placed into the system, which leaves an additional 3.0M m<sup>3</sup> which has accumulated in the system at a rate of 56,000 m<sup>3</sup>/year. This finding is discussed further in Section 4.5.

### 4.3 Derived Longshore Transport

Longshore transport rates between sub-compartments, derived by solving the sediment budget equation, are presented in Figure 4-4. The approximate long term average sand transport rate through the system, estimated at 550,000 m<sup>3</sup>/year, is also shown for reference (labelled as the “pre-1900” rate). It should be noted that the pre-1900 system would have exhibited significant variations averaged over 10-year periods away from a long-term average as a result of natural climatic variability. However, the southern Gold Coast system post-1962 has been significantly impacted by anthropogenic interventions, and the signature of these perturbations are very clearly seen in the derived longshore transport rates. Notable features in Figure 4-4 include:

- The reduction in transport along Letitia Spit corresponding to the sediment accretion in these compartments as a result of the Tweed River training wall extension in 1962.
- The reduction in transport leaving the Entrance compartment corresponding to the substantial accretion of the ebb tide bar following 1962. In the period from 1962 to 1972 the average longshore transport leaving the entrance compartment was 240,000 m<sup>3</sup>/year, which is less than half the “pre-1900” average rate. In the 1972 to 1983 period, the entrance natural bypassing had increased to 280,000 m<sup>3</sup>/year, and to 340,000 m<sup>3</sup>/year from 1983 to 1993.
- Entrance natural bypassing rates were subsequently reduced to 310,000 m<sup>3</sup>/year during the 1993 to 2001 period due to the commencement of entrance dredging and bypassing operations as part of TRESBP Stage 1. From 2001 to 2009 the Entrance natural bypassing rates were very substantially reduced to 50,000 m<sup>3</sup>/year as a direct result of the very high rate of bypassing from pumping and dredging. With reduced pumping and no dredging in the 2009 to 2015 period, Entrance natural bypassing rates increased again to 150,000 m<sup>3</sup>/year.
- Corresponding to the reduced supply from NSW longshore transport rates in the Queensland compartments were also reduced well below “pre-1900” rates after 1962. The most severe longshore transport reductions occurred closest to the border and became less severe with



distance northward (see also Figure 4-5). The gradual northward migration of the longshore transport reductions can also be seen in these figures.

- Transport rates north of Point Danger began to be re-instated by nourishment activities and TRESBP Stage 1 in the period from 1989 to 2001.
- During the period from 2001 to 2009, a very substantial increase in longshore transport rates to well above “pre-1900” rates is observed across the Snapper to North Kirra compartments (see also Figure 4-5). This period corresponds to the commencement of TRESBP Stage 2 bypassing, including the “supplementary increment”, during which the average rate of bypassing by mechanical means (dredging and jetty pumping) was 820,000 m<sup>3</sup>/year.
- During the 2009 to 2015 period the zone of elevated longshore transport rates has both moderated and migrated northwards. Increased longshore transport can be identified leaving both the South Bilinga and North Bilinga compartments.

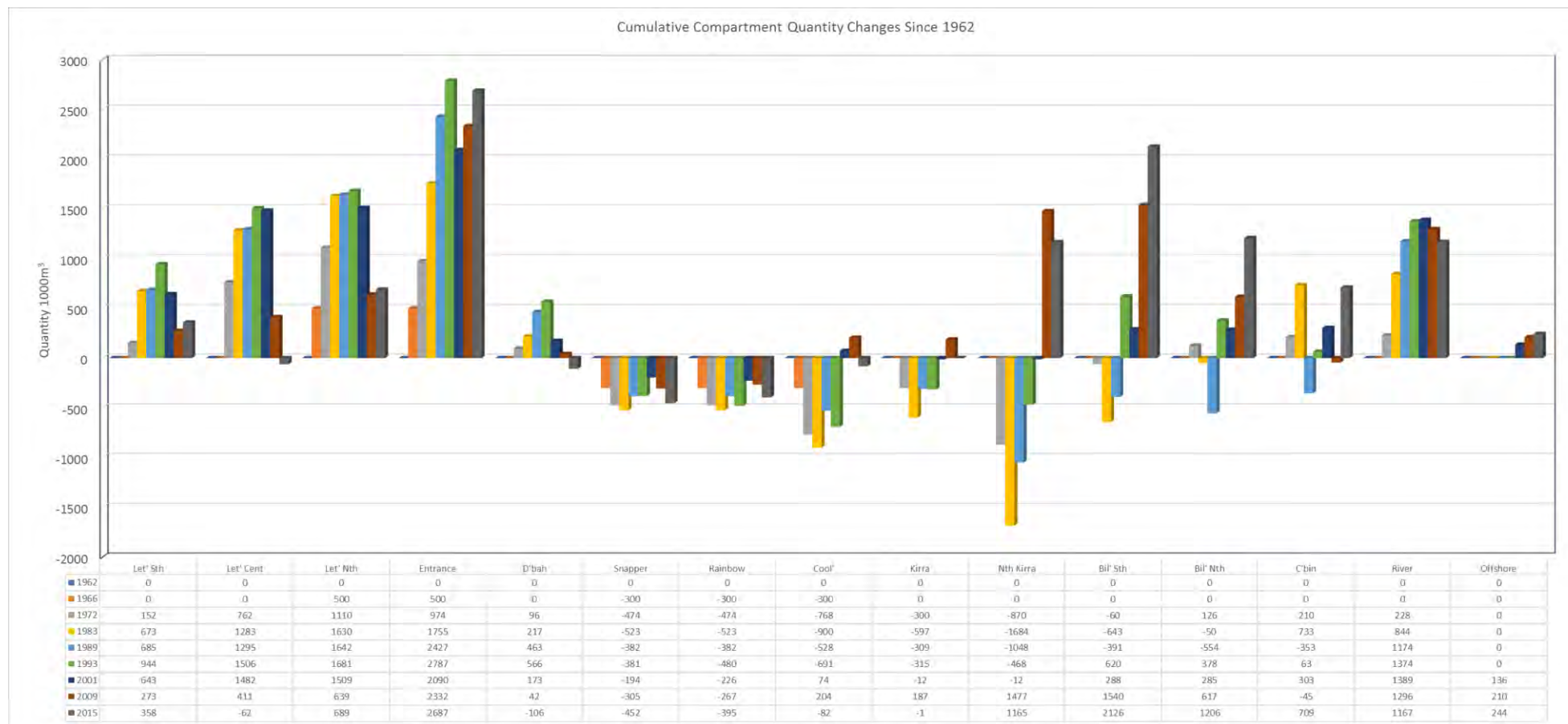
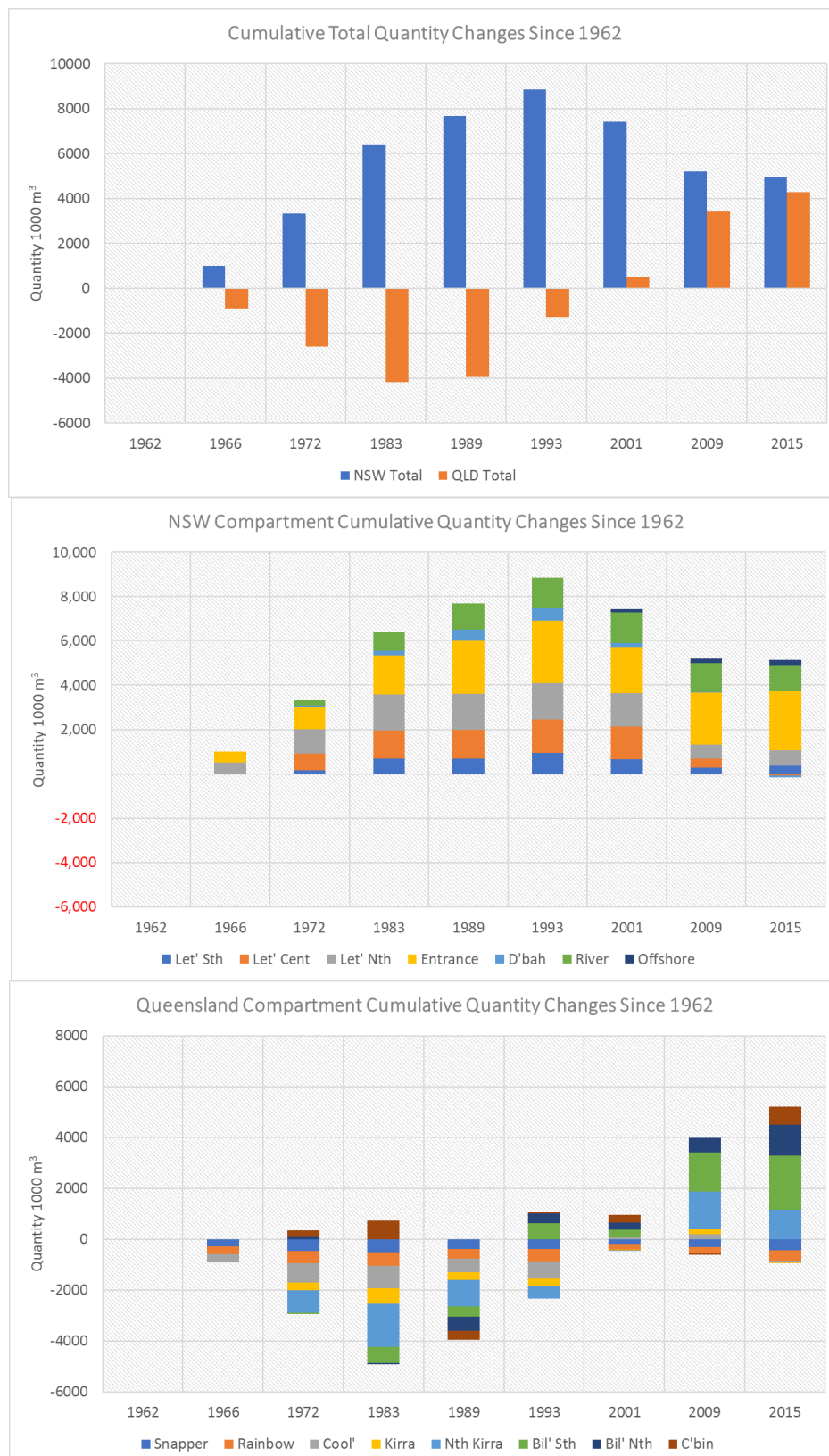


Figure 4-2 Cumulative Compartment Sand Volume Changes Since 1962



**Figure 4-3 Cumulative Total Sand Volume Changes Since 1962**  
NSW/QLD totals (top); NSW compartments (middle); QLD compartments (bottom)

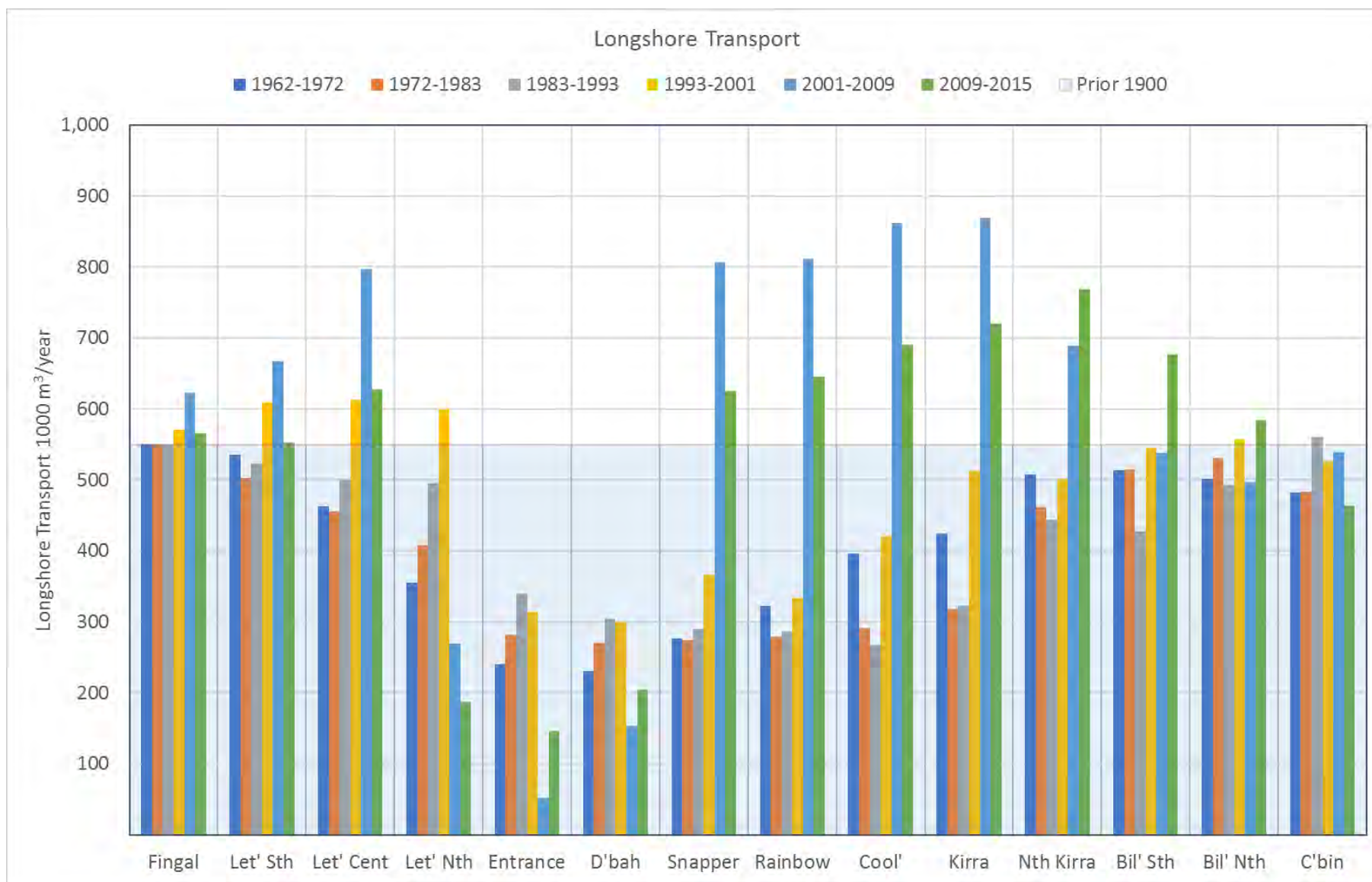
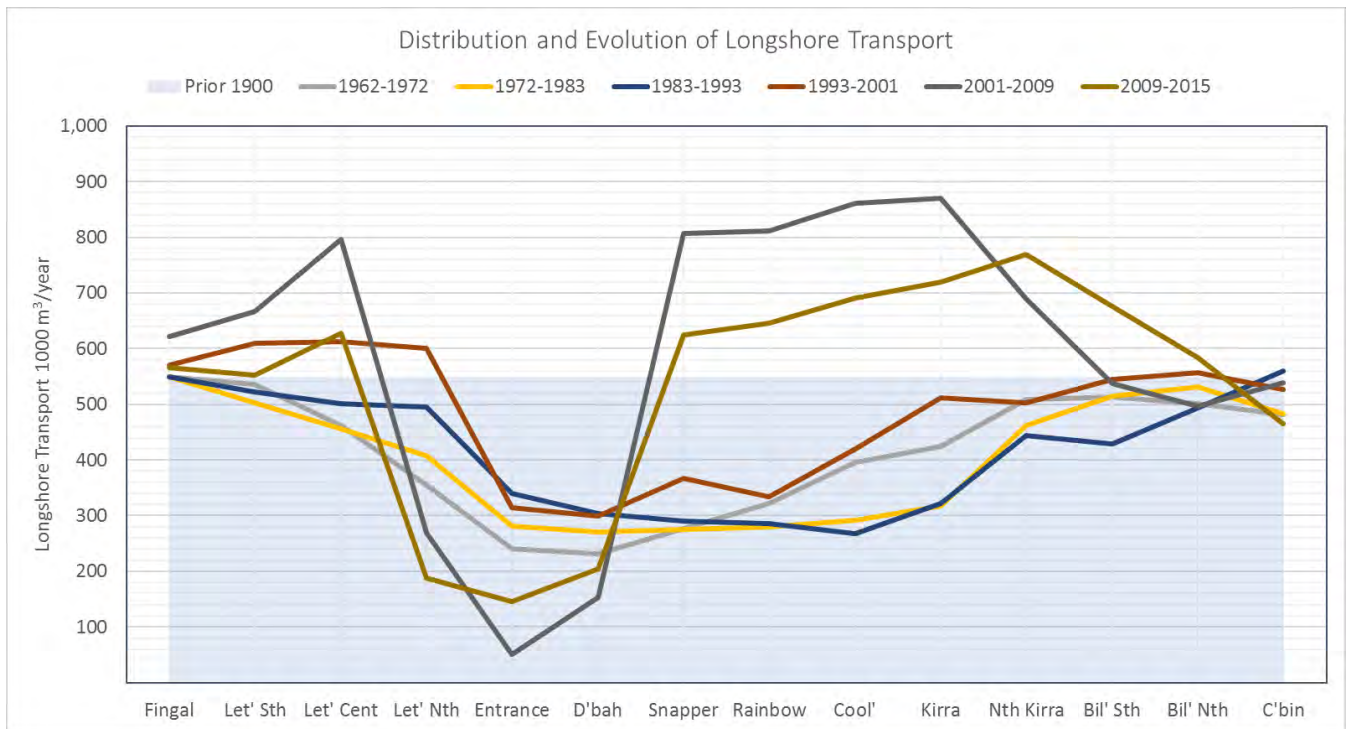


Figure 4-4 Derived Longshore Transport Rates Leaving Each Compartment





**Figure 4-5 Distribution and Evolution of Longshore Transport**

## 4.4 Sand Budget Model

The southern Gold Coast system sand budget is presented for each of the six analysis periods in Figure 4-6 through to Figure 4-11. The 1962 to 1972 and 1972 to 1983 periods illustrate the sand accumulation along Letitia Spit, the Tweed River and its ebb tide bar. The 1962 to 1983 figures also show the corresponding reduced transport rates around Point Danger and erosion along the southern Gold Coast beaches.

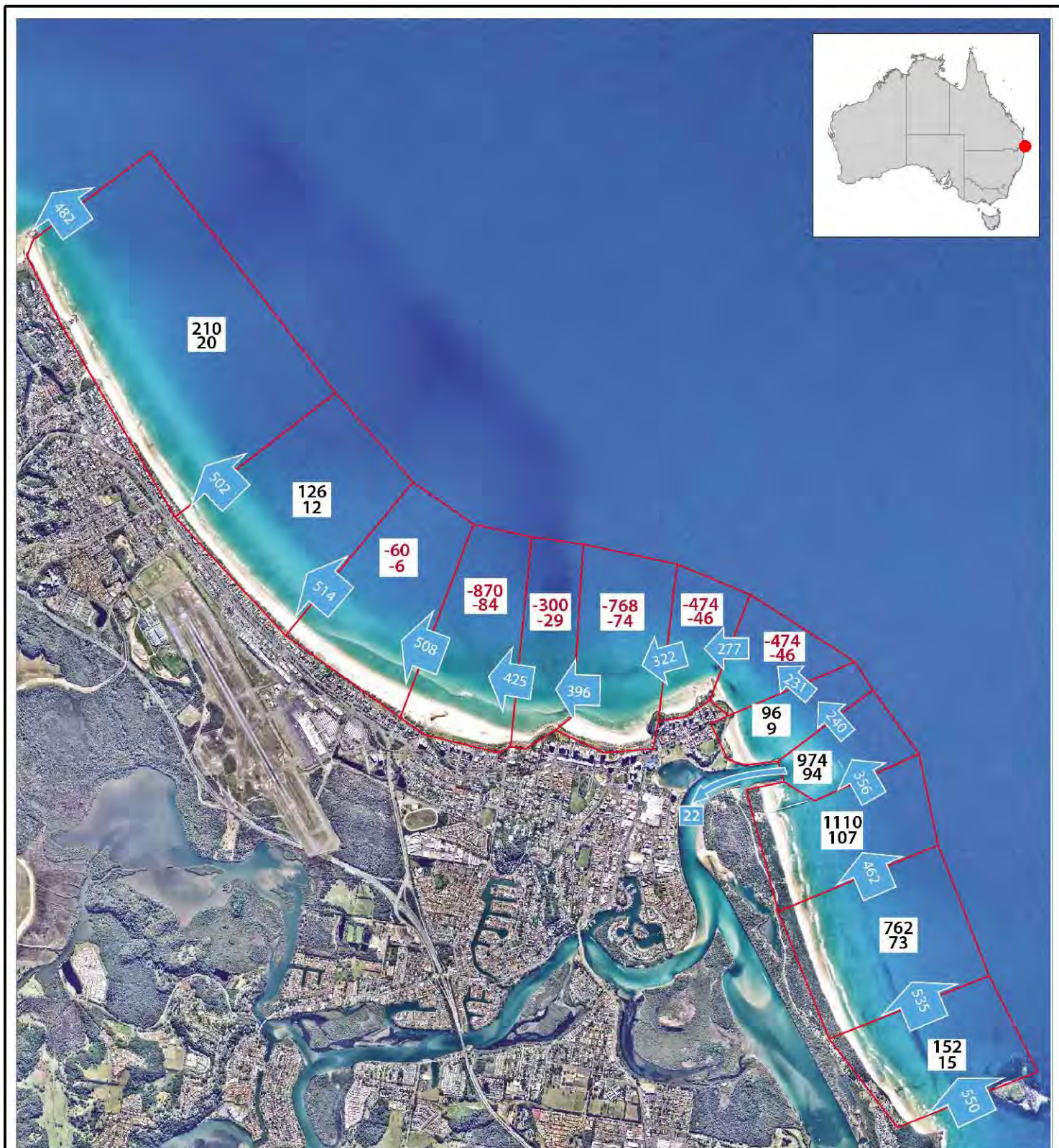
The 1983 to 1993 figure shows the initial response of the southern Gold Coast to mass sand nourishment of 5.5M m<sup>3</sup> imported into the littoral system from offshore “borrow” areas. During this period sand continued to accumulate on the Tweed River bar and along Letitia Spit, however natural bypassing of Point Danger had increased to well over half the long-term natural supply rate.

The 1993 to 2001 figure shows the TRESBP Stage 1 bypassing of sand dredged mainly from the Tweed River Entrance and placed from Snapper to North Kirra. The rate of natural bypassing was only slightly reduced by the Entrance dredging. Longshore transport north from Kirra was close to the long-term average due to the re-instated compartment sand volumes from the combination of both nourishment and bypassing activities.

The 2001 to 2009 figure shows the significant volume increases following the commencement of TRESBP Stage 2. Significant quantities of sand accumulation occurred in the Kirra embayment as seen in the North Kirra and Bilinga South compartment volume increments. Transport out of the North Kirra compartment at 690,000 m<sup>3</sup>/year was higher than the long-term average but was well below the much higher rates of delivery (>800,000 m<sup>3</sup>/year) from updrift compartments. It is also noteworthy that despite significant dredging of the Tweed River Entrance during this period, there was still a substantial increase in the volume within this compartment.

The 2009 to 2015 figure shows the response of the system to the reduced total Point Danger bypassing rates, which were now much closer to the long-term average (though still slightly higher – refer discussion in Section 4.5.3). Compartment volumes reduced from Duranbah through to North Kirra as this sand was transferred through to the Bilinga and Currumbin compartments. Longshore transport rates were about 25% above the long-term average through Snapper to Bilinga South.





## LEGEND

<div><div>a</div><div>b</div></div>	Compartment volume change a. Cumulative since 1962 1,000 m <sup>3</sup> b. Rate since 1962 1,000 m <sup>3</sup> /yr		Nourishment 1,000 m <sup>3</sup> /yr		Jetty bypassing 1,000 m <sup>3</sup> /yr
	Transportation rate 1,000 m <sup>3</sup> /yr		Dredge bypassing 1,000 m <sup>3</sup> /yr	Ariel Imagery by	

Title:  
**Sand Budget Conceptual Model 1962 to 1972**

Figure:  
**4-6**

Rev:  
**A**

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Approx. Scale



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## LEGEND

<div><div>a</div><div>b</div></div>	Compartment volume change a. Cumulative since 1962 1,000 m³ b. Rate since 1972 1,000 m³/yr		Nourishment 1,000 m³/yr		Jetty bypassing 1,000 m³/yr
	Transportation rate 1,000 m³/yr		Dredge bypassing 1,000 m³/yr	Aerial Imagery by	

Title:  
**Sand Budget Conceptual Model 1972 to 1983**

Figure:  
**4-7**

Rev:  
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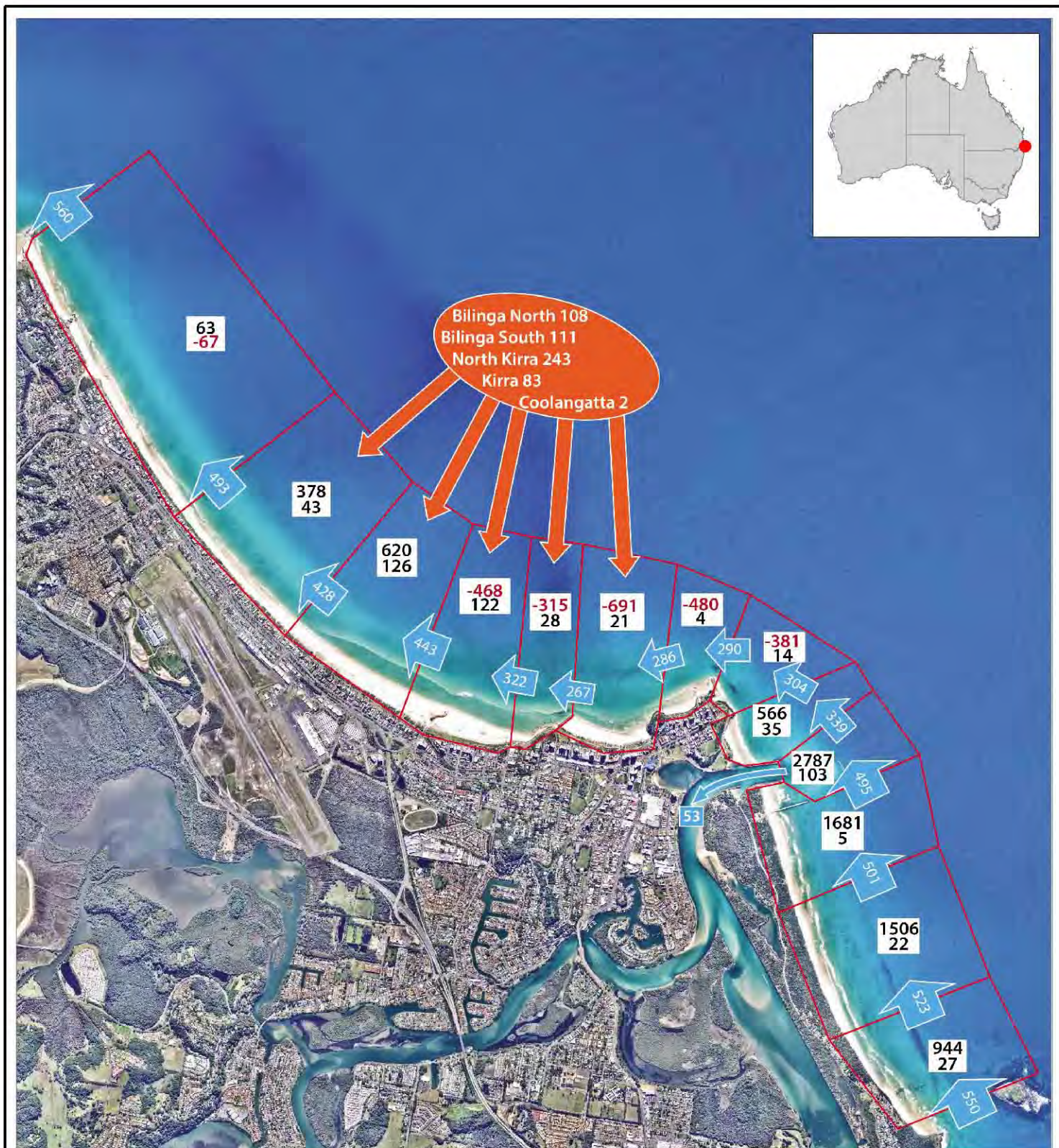


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## LEGEND

<div style="border: 1px solid red; padding: 2px;">a</div> <div style="border: 1px solid red; padding: 2px;">b</div>	<b>Compartment volume change</b> a. Since 1962 1,000 m <sup>3</sup> b. Since 1983 1,000 m <sup>3</sup> /yr		Nourishment 1,000 m <sup>3</sup> /yr		Jetty bypassing 1,000 m <sup>3</sup> /yr
	<b>Transportation rate</b> 1,000 m <sup>3</sup> /yr		Dredge bypassing 1,000 m <sup>3</sup> /yr	Ariel Imagery by	

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**Sand Budget Conceptual Model 1983 to 1993**

Figure:  
**4-8**

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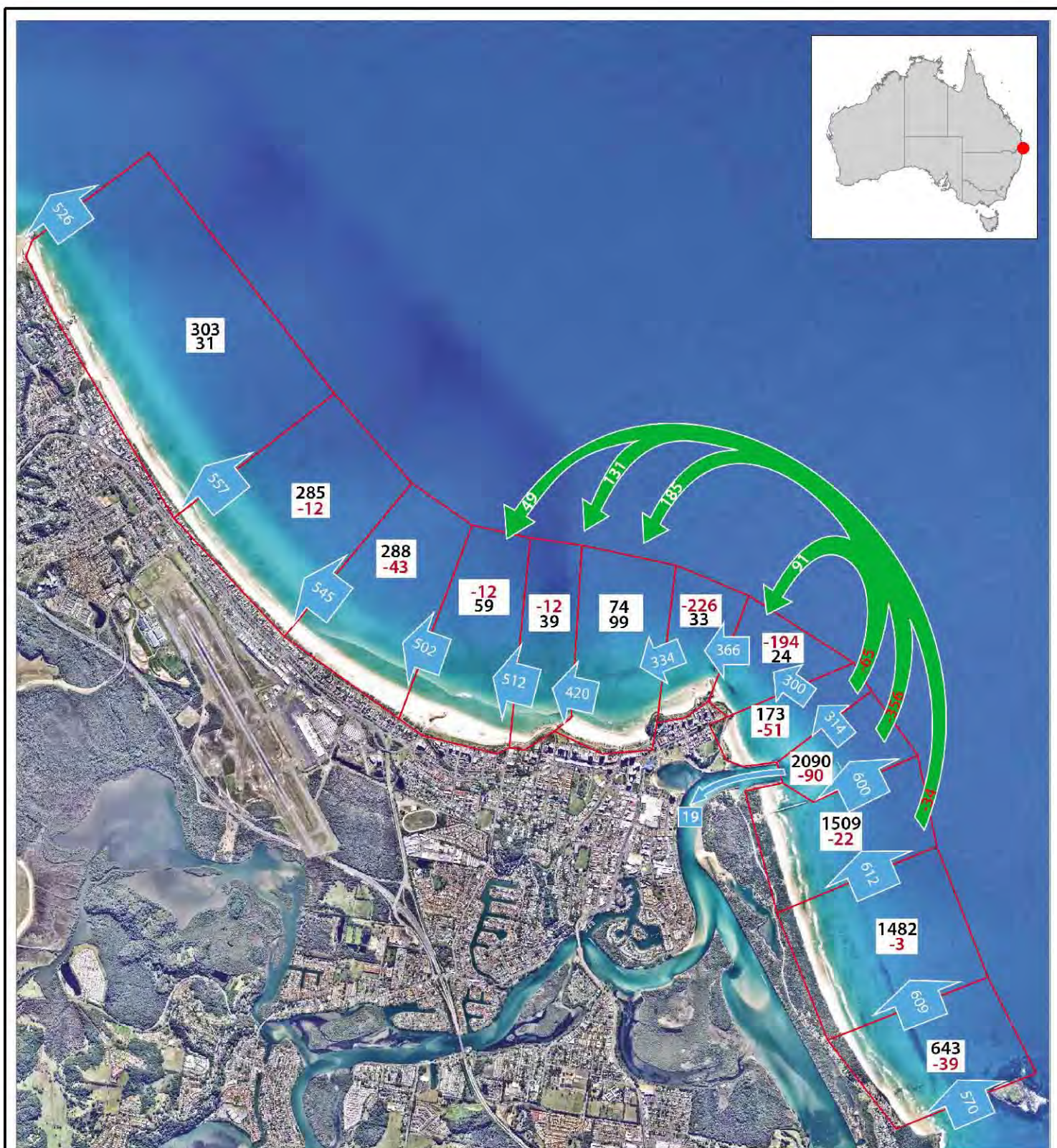


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## LEGEND

<div style="border: 1px solid red; padding: 2px; display: inline-block;">a b</div>	Compartment volume change a. Cumulative since 1962 1,000 m <sup>3</sup> b. Rate since 1993 1,000 m <sup>3</sup> /yr		Nourishment 1,000 m <sup>3</sup> /yr		Jetty bypassing 1,000 m <sup>3</sup> /yr
	Transportation rate 1,000 m <sup>3</sup> /yr		Dredge bypassing 1,000 m <sup>3</sup> /yr		

Title:  
**Sand Budget Conceptual Model 1993 to 2001**

Figure:  
**4-9**

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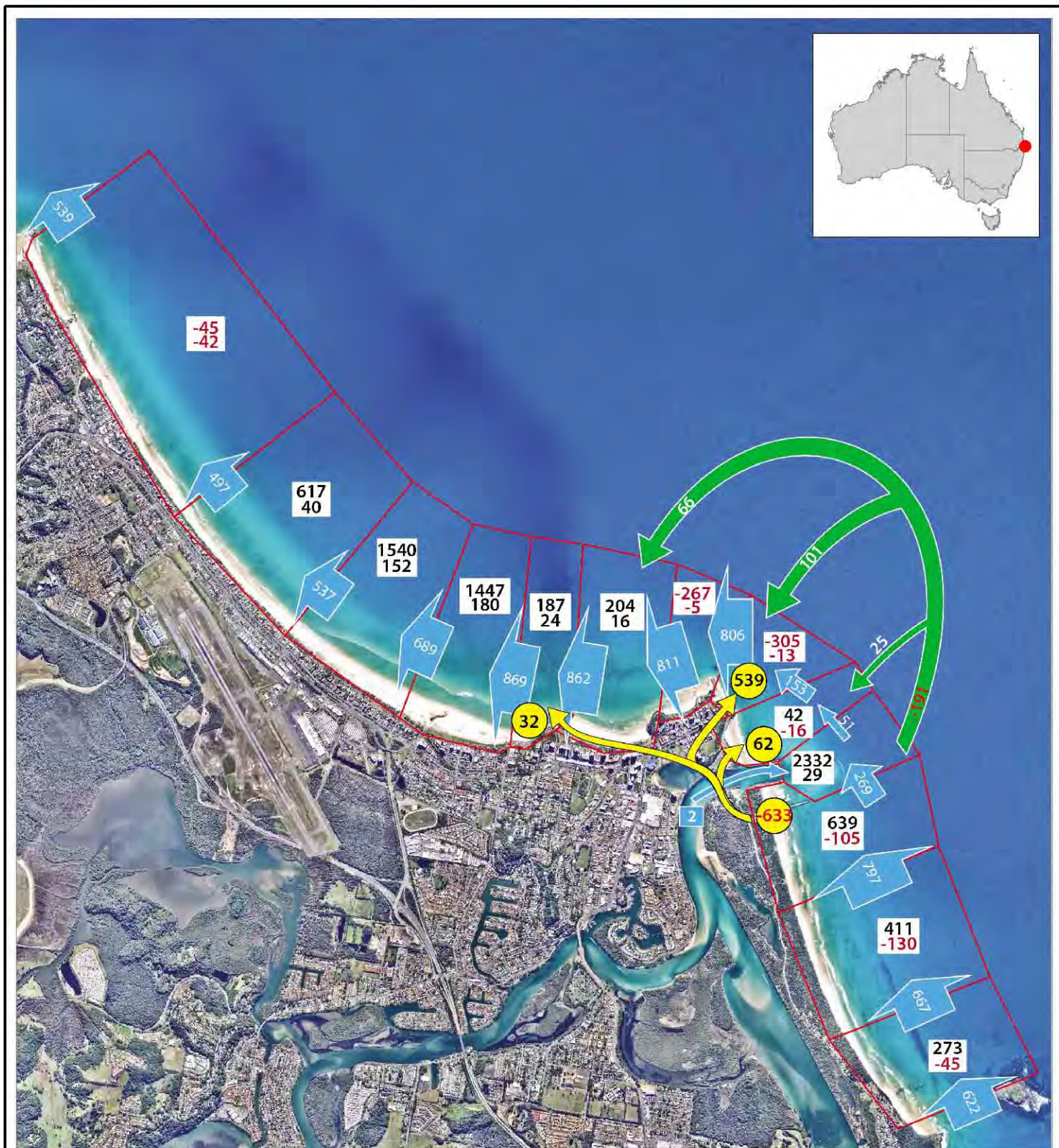


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Approx. Scale



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## LEGEND

<div style="border: 1px solid red; padding: 2px; display: inline-block;">a b</div>	<b>Compartment volume change</b> a. Cumulative since 1962 1,000 m <sup>3</sup> b. Rate since 2001 1,000 m <sup>3</sup> /yr	 Nourishment 1,000 m <sup>3</sup> /yr	 Jetty bypassing 1,000 m <sup>3</sup> /yr
 346	<b>Transportation rate</b> 1,000 m <sup>3</sup> /yr	 Dredge bypassing 1,000 m <sup>3</sup> /yr	Ariel Imagery by 

Title:  
**Sand Budget Conceptual Model 2001 to 2009**

Figure:  
**4-10**

Rev:  
**A**

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Approx. Scale



Filepath: I:\B22132\_I\_at\_Currumbin\DRG\COA\_014\_170301\_SandTransportation\_2001-2009.wor





## LEGEND

<div style="border: 1px solid red; padding: 2px; display: inline-block;">a b</div>	Compartment volume change a. Cumulative since 1962 1,000 m <sup>3</sup> b. Rate since 2009 1,000 m <sup>3</sup> /yr		Nourishment 1,000 m <sup>3</sup> /yr		Jetty bypassing 1,000 m <sup>3</sup> /yr
	Transportation rate 1,000 m <sup>3</sup> /yr		Dredge bypassing 1,000 m <sup>3</sup> /yr	Ariel Imagery by	

Title:  
**Sand Budget Conceptual Model 2009 to 2015**

Figure:  
**4-11**

Rev:  
**A**

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## 4.5 Discussion

The following section discusses in further detail some of the findings from the sand budget model of the southern Gold Coast.

### 4.5.1 Fingal to Currumbin Sand Transport Differential

The latest “LTA” analysis report (BMT WBM, 2015) highlighted a finding that over the period from 1995 to 2015 the transport of sand into the system by longshore transport at Fingal averaged over 70,000 m<sup>3</sup>/year higher than the transport out of the system by longshore transport at Currumbin. The current analysis extending back to 1962, indicates that this appears to be part of a longer-term trend. This is illustrated in Figure 4-12, which shows that the transport differential from Fingal to Currumbin has been positive (higher input at Fingal than out at Currumbin) for five of the six analysis periods and that over the entire 54-year period has contributed 3.0M m<sup>3</sup> of additional sand into the system at an average annual rate of 56,000 m<sup>3</sup>/year.

Noting that this result is entirely a function of the overall system sand budget calculations as determined by the underpinning survey data analysis, possible explanations could include the following:

- (1) Survey error;
- (2) Survey analysis error;
- (3) Net longshore transport at Currumbin has been reduced from the long-term average over this period by updrift sand supply reductions;
- (4) Real transport differential that is part of a long-term cyclic pattern;
- (5) Not fully accounting for sand volumes imported into the system;
- (6) Transport differential that is due to geological timescale processes related to the Holocene transgression (e.g. Patterson, 2013).

It is considered unlikely that this result is substantially a function of survey error, given that these trends have been identified over a very long timescale during which the Gold Coast survey profiles have been regularly replicated and have demonstrated a reasonably good level of “closure” at depths in the range -15 m AHD to -20 m AHD. This result does rely on survey data analysis undertaken as part of the Roelvink and Murray (1992) and BMT WBM (2009, 2015) assessments. As part of the current study independent checks have been made which supported the earlier analysis results (refer Section 3 and Appendix A). However, these checks have focussed on the offshore beach system “Eta-line” surveys and have not been exhaustive in re-assessing volumes accumulating on the Tweed River bar or in the lower Tweed River (based on Tomlinson and Hranislevic published analyses).

It is considered likely that the transport out of the Currumbin compartment will have been somewhat reduced in the period after 1962 by earlier extraction or loss of sand from the littoral system north of Fingal, related to for instance:

- 1880 Tweed River entrance training wall construction and subsequent growth of Letitia Spit;
- Pre-1960 reclamation within the lower Tweed River and Coolangatta Swamp;

- Post-1960 updrift works, as detailed in this study.

However, the quantum of the reduction due to updrift supply reduction as a result of anthropogenic works and whether it accounts for the entire 56,000 m<sup>3</sup>/year difference remains an open question.

It is plausible that more sand has been imported into the littoral transport system by dredging activities than has been accounted for in this analysis. This may be due to inaccuracies in dredge logs associated with the circa 1990 mass-nourishment program. It may also be associated with a proportion of the TRESBP Stage 1A delivery of dredged sand being sourced from outside the active littoral system. Inspection of dredge log summaries from TRESBP Stage 1A, suggest that 0.55M m<sup>3</sup> may have been sourced from deeper than -15 mAHD. Whether some or all of this was from outside the active system would need to be confirmed by analysis of entrance surveys over the period from 1993 to present.

It is plausible that a naturally occurring transport gradient may contribute part of the derived transport differential. If it is a part of a climate driven cycle then by definition it will at some point reverse with a period of relatively lower transport around Fingal headland, which would have implications for TRESBP operations. If the transport differential is in fact a relatively permanent feature of the Fingal to Currumbin system, then this too would have implications for long-term TRESBP operations, raising the question whether all of this surplus sand should be bypassed to Queensland. The possible contribution of natural mechanisms to the derived transport differential remains an open question that would require consideration of a larger study area (extending south of Fingal and north of Currumbin) and longer timeframes in order to resolve.

#### 4.5.2 1962 to 2015 Sand Volume Summary

Having undertaken a detailed sand budget analysis, it is worthwhile taking another look at a broad breakdown of volume changes over the period from 1962 to 2015, as shown in Figure 4-15. During this period, there was an increase of 9.2M m<sup>3</sup> over the entire system from Fingal to Currumbin. Within NSW, Letitia Spit accounts for +0.9M m<sup>3</sup>, the lower Tweed River estuary for +1.2M m<sup>3</sup> and the Tweed River Entrance for +2.9M m<sup>3</sup> for a total of +5.0M m<sup>3</sup>. In Queensland, there has been an overall increase in sand between Point Danger and Currumbin of +4.2M m<sup>3</sup>.

Considering the sources of the 9.2M m<sup>3</sup> increase in the system, 6.2M m<sup>3</sup> can be attributed to nourishment while the remaining 3.0M m<sup>3</sup> can be attributed to the transport differential between Fingal and Currumbin.

#### 4.5.3 Sand Delivery to Queensland

A key role of TRESBP is to operate a sand delivery system that effectively re-instates the natural supply of sand to the southern Gold Coast beaches. It is therefore instructive to look at the effective sand delivery to Queensland for each of the conceptual model periods, as shown in Figure 4-13, including a breakdown of the following sand delivery mechanisms:

- Natural longshore transport past Point Danger (minus bypassing to Duranbah);
- Nourishment of southern Gold Coast beaches using imported sand;
- Sand bypassing to Duranbah (both dredge bypassing and jetty pumping);



- Bypassing to Queensland by dredge delivery; and
- Bypassing to Queensland by jetty pumping delivery.

The total delivery to Queensland by both natural and artificial means is the sum of all of the above mechanisms. The derived transport into Letitia Spit (Fingal transport) is shown in Figure 4-13 for comparative reference. During the 1962 to 1972 period sand delivery to Queensland was only by natural longshore transport, which was substantially reduced by the Tweed River entrance construction. Natural bypassing increased in the 1972 to 1983 period and was supplemented by some nourishment sand sourced from the lower Tweed River, however a substantial deficit remained (compared to the Fingal transport). During the 1983 to 1993 period mass nourishment from offshore was employed in order to offset the cumulative deficit since 1962.

Bypassing operations, firstly by dredge alone during the 1993 to 2001 period, then by a combination of pumping and dredging from 2001 to 2009 and by pumping alone from 2009 to 2015 were undertaken as part of TRESBP Stage 1 and Stage 2. The objective being to provide a continuous mechanism to bypass the ongoing sand feed into the system at Letitia spit to Queensland. In the first six years of jetty pumping from 2001 a second objective was to compensate for outstanding cumulative losses, which had been defined in the Deed of Agreement “supplementary increment”. The “supplementary increment” overestimation has been discussed previously in BMT WBM (2010).

The “Long Term Average” or “LTA” has a formal definition in the 1998 Deed of Agreement between NSW and Queensland, as: *“the long term average annual net littoral transport of sand that would, in the absence of any artificial actions to influence it, cross a line perpendicular to the coastline, situated one kilometre south of the southern training wall at the Tweed River entrance and extending to the 20 metre depth contour, less the annual net quantity of sand which, after the commissioning of the System, crosses that line and reaches Queensland, or the coastal waters of the State of Queensland as defined in the Coastal Waters (State Powers) Act, 1980 (Cth), by natural means”* (Patterson et al. 2010). The “LTA” is the legislated target quantity for TRESBP sand delivery over the longer term.

Even though this analysis extends some 36 years before the TRESBP Deed of Agreement it is instructive to look at how the “LTA” quantity has responded over the period from 1962 to 2015. Following the methodology in the LTA assessment reports (BMT WBM 2009; 2015) the “LTA” is calculated as:

#### **“LTA” = Transport into Letitia South – Point Danger Natural Bypassing**

Where natural bypassing is calculated as the longshore transport past Point Danger (out of the Duranbah compartment) minus the artificial bypassing into the Duranbah compartment (BMT WBM, 2009). The derived transport into Letitia South is used instead of a transport derived one kilometre south of the southern training wall, as it was demonstrated that at this location longshore transport had been strongly influenced by “artificial actions” such as the training wall extension and subsequent bypassing (BMT WBM, 2009).

Figure 4-14 shows the derived “LTA” quantity for the six periods assessed in the conceptual model analysis as well as the transport into Letitia South (Fingal Transport), the Point Danger Natural

Bypassing and the artificial “Delivery” to Queensland (including nourishment). Also shown is the calculated difference between the “LTA” quantity and the (artificial) “Delivery” quantity. The intention of the Deed of Agreement is that (following the “supplementary increment”) TRESBP will “Deliver” on average (over the longer term) a quantity of sand equal to the “LTA”.

The cumulative difference between the “Delivery” quantity and the “LTA” from 1962 to 2015 is also included in Figure 4-14. This shows the initial substantial “Delivery - LTA” deficit which occurred following 1962 but prior to commencement of nourishment and TRESBP operations. Due to both nourishment and TRESBP operations, the size of the cumulative “Delivery - LTA” deficit had been reduced to -1.2M m<sup>3</sup> by 2001. Following the TRESBP Stage 2 “supplementary increment” period, in 2009 the cumulative “Delivery - LTA” volume was now a 1.0M m<sup>3</sup> surplus above the rate of supply into Letitia Spit since 1962. The period from 2009 to 2015 also contributed a further positive increment to the cumulative “Delivery - LTA” volume surplus, with the rate of increase averaging 36,000 m<sup>3</sup>/year. As of 2015 the cumulative “Delivery - LTA” volume was 1.2M m<sup>3</sup>.

There is a conceptual difficulty with using a historically derived “LTA” quantity as a target for future operations which is due to the fact that the derived “LTA” quantity is very much a function of bypassing operations. This dependence is due to the feedback that artificial bypassing has on natural bypassing rates. This can be clearly seen in the very high value of the “LTA” for the 2001 to 2009 period (560,000 m<sup>3</sup>/year) in Figure 4-14. It is important to note that during this period the (artificial) “Delivery” quantity exceeded the “LTA” quantity by a very substantial 270,000 m<sup>3</sup>/year. It is apparent from this period that the target sustainable “LTA” would need to be based on a period where the “Delivery” quantity and the “LTA” are close to balanced.

The 2009 to 2015 period was closer to meeting the objective of (artificial) “Delivery” being equivalent to transport into Letitia South minus Point Danger natural bypassing. However, with artificial bypassing by 100% jetty pumping at an average rate of 432,000 m<sup>3</sup>/year and natural bypassing having increased to 170,000 m<sup>3</sup>/year it still exceeded the transport into Letitia Spit by a quantity averaging 36,000 m<sup>3</sup>/year.

#### 4.5.4 Entrance Growth

A second key objective of the TRESBP is to maintain a safe, navigable entrance to the Tweed River. This objective requires monitoring of entrance depths and periodic maintenance dredging to ensure these remain sufficient for safe navigation.

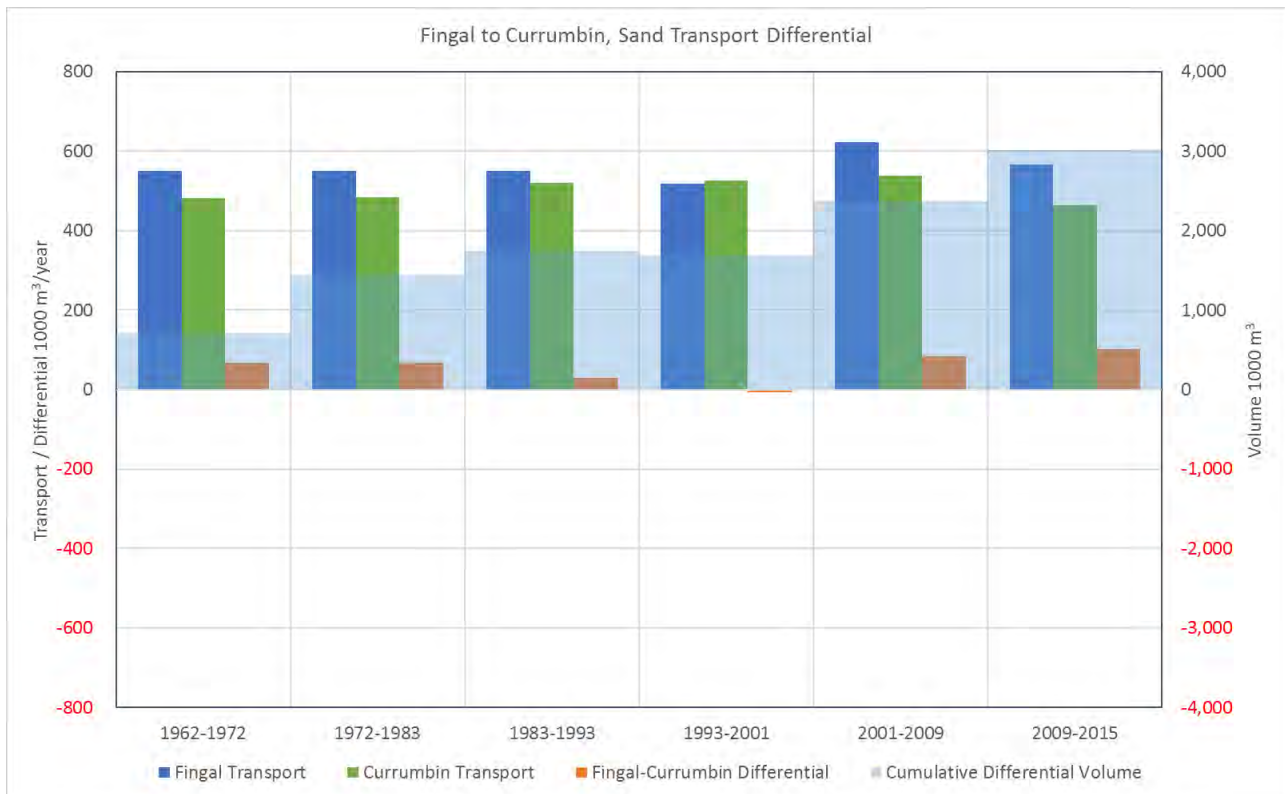
As seen in Figure 4-16 there has been substantial accretion of the Tweed River ebb tide bar since 1962. In 1993, the volume within this compartment was 2.8M m<sup>3</sup> more than the baseline prior to the 1962 training wall extension. TRESBP Stage 1 dredging reduced the accumulated volume to 2.1M m<sup>3</sup> by 2001, with dredge logs indicating that 2.8M m<sup>3</sup> was removed directly from this compartment to achieve this 0.7M m<sup>3</sup> net reduction, implying substantial infill during this period.

During the period from 2001 to 2009 the entrance volume increased by 0.24M m<sup>3</sup> despite 1.6M m<sup>3</sup> of dredging from this compartment as well as the initially high rate of jetty bypassing (630,000 m<sup>3</sup>/year). It was estimated in the 2015 LTA re-assessment that about 30% of transport into Letitia North leaks through the trestle system, contributing to accumulation of sand in the entrance and natural bypassing towards Duranbah.

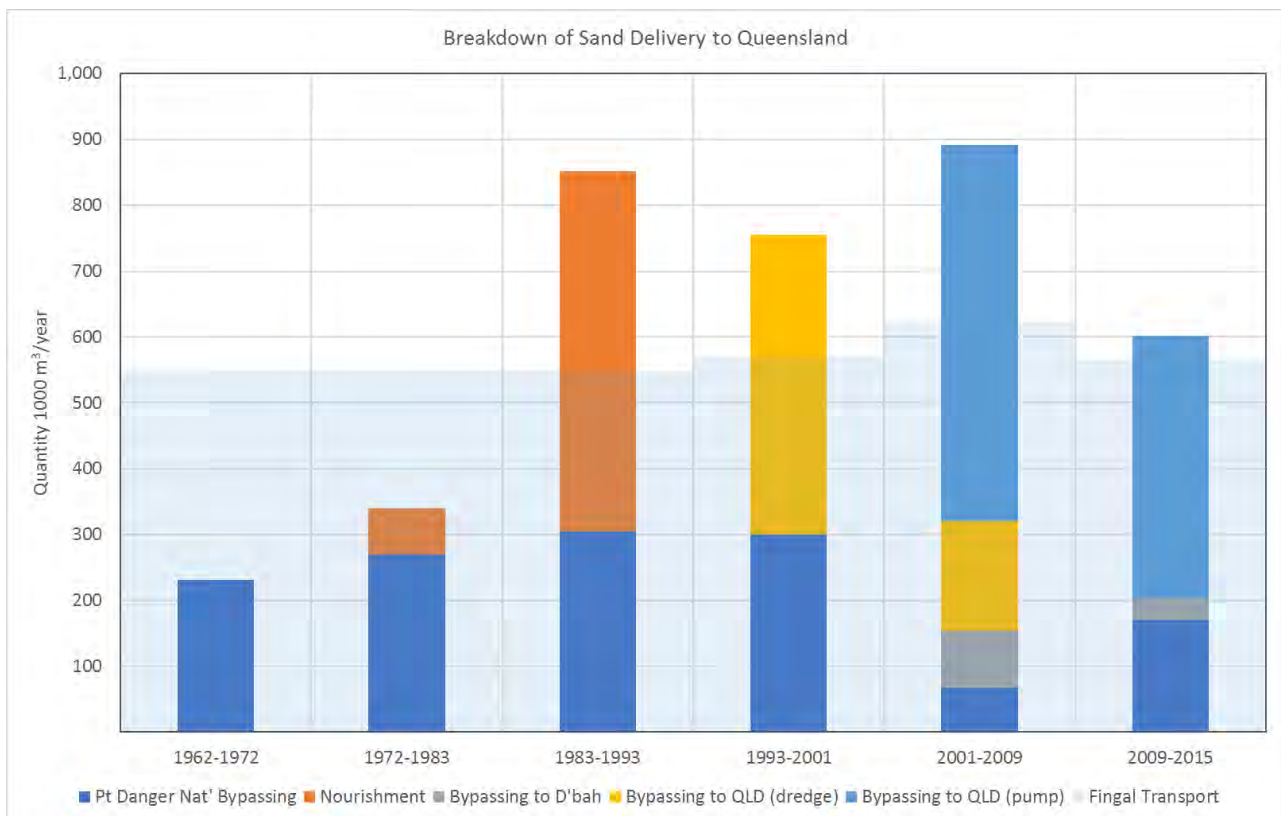
From 2009 to 2015 there was no dredging and a jetty pumping rate of 432,000 m<sup>3</sup>/year. During this period the entrance (plus offshore sink) accumulated 0.39M m<sup>3</sup> at an average rate of 61,000 m<sup>3</sup>/year. Relative to 1962, the Entrance compartment had accumulated 2.7M m<sup>3</sup> by late 2015 (reaching similar levels to 1993). It is understood that towards the end of 2015 the maintenance of safe navigable depths at the Tweed River entrance became an issue requiring maintenance intervention and that in April 2016 there was a 42,000 m<sup>3</sup> dredging campaign undertaken.

Given that the Entrance compartment continues to accrete and that the current levels appear to be reaching a limit where safe navigability is at risk of being compromised it is likely that periodic dredging of the entrance will again be required as part of the TRESBP operations. The quantum of dredging required could vary substantially from year to year but most likely will need to exceed 60,000 m<sup>3</sup>/year on average in combination with jetty pumping at an average rate of around 400,000 m<sup>3</sup>/year. An overall artificial bypassing rate of 460,000 m<sup>3</sup>/year would accommodate a natural bypassing rate of around 100,000 m<sup>3</sup>/year in order to balance with the long term average sand delivery into Letitia Spit.





**Figure 4-12 Derived Transport Differential and Resulting Volume Accumulation Between Fingal and Currumbin**



**Figure 4-13 Breakdown of Total Sand Delivery to Queensland**

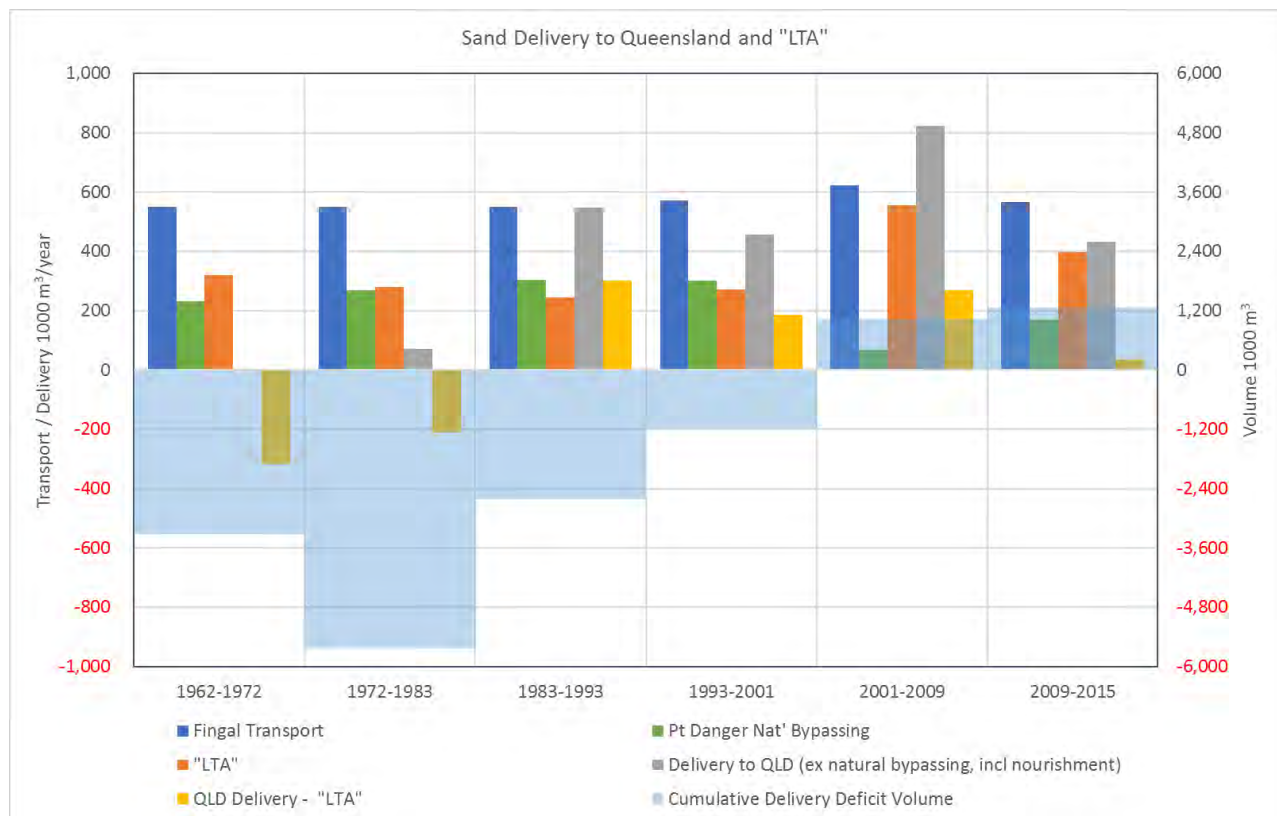


Figure 4-14 Artificial Sand Delivery to Queensland and Comparison with "LTA".

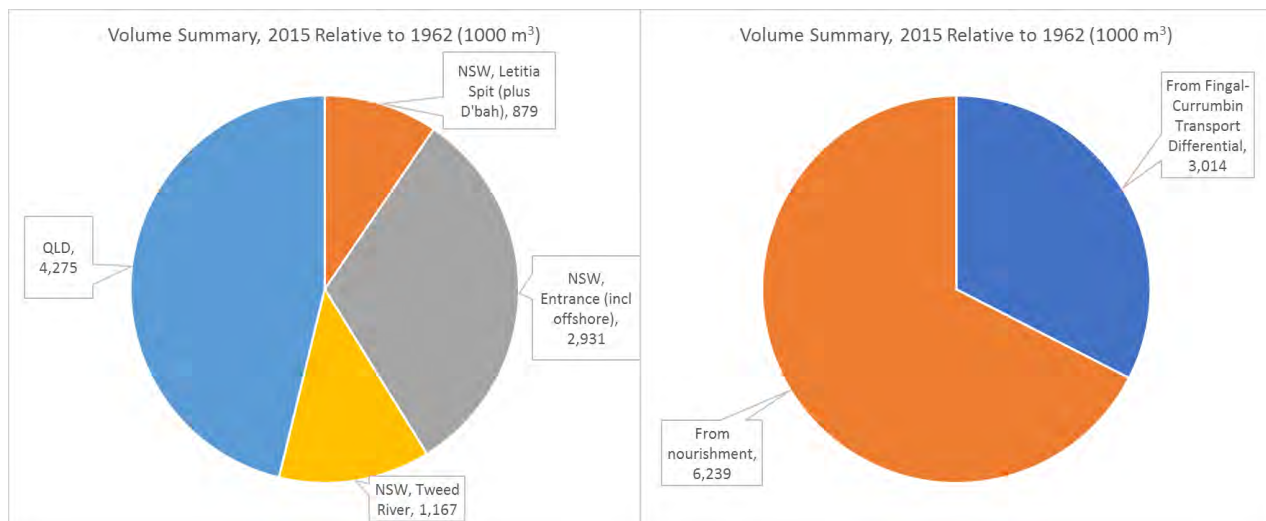


Figure 4-15 Breakdown of the Additional 9.2M m³ of Sand in the Fingal to Currumbin Compartment (2015 relative to 1962)

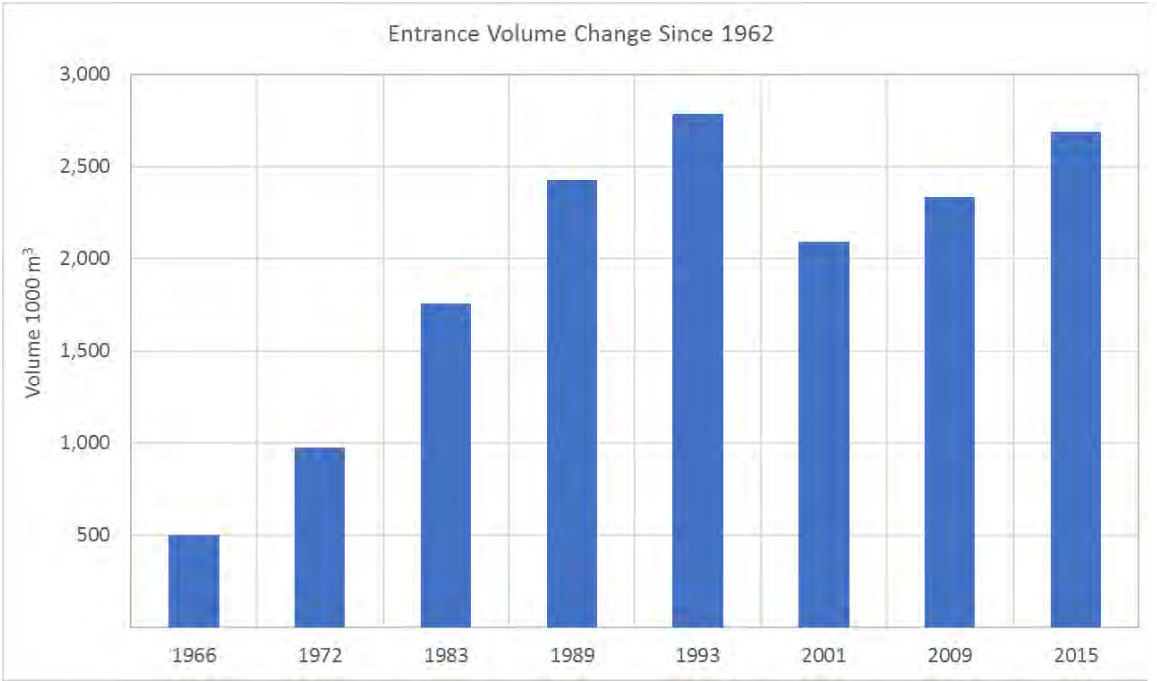


Figure 4-16 Tweed River Entrance Compartment Volume Change Since 1962



## 5 Shoreline Evolution Model

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The conceptual model sand budget analysis has been supported by undertaking numerical shoreline evolution modelling analysis. A numerical shoreline evolution model is also conceptually a sand budget model, however rather than calculate longshore transport rates from measured volume changes (and source/sink terms), the shoreline evolution model predicts both longshore transport rates and volume changes by simulating the wave driven longshore transport processes.

The shoreline evolution modelling helps with interpretation and understanding of the observed coastal evolution, plus provides a means for forecasting future evolution trends. Process-based numerical models also facilitate the exploration of hypothetical “what if” scenarios that can further aid system understanding and inform the selection of future management options.

### 5.1 EVO Model

The shoreline evolution model (EVO) used in this assessment was developed as part of a suite of coastal process models for City of Gold Coast as described in BMT WBM, 2013. The EVO model inputs have been updated and extended based on the review of inputs to the southern Gold Coast conceptual model (Section 4 of this report).

EVO is a shoreline evolution model that can represent the response to a range of processes of varying timescales:

- Short term processes (e.g. storm response);
- Medium term processes (e.g. long-shore transport gradients); and
- Long term processes (e.g. sea level rise).

Key features of EVO are:

- Suitability for medium- to long-term simulations (years to centuries);
- Continuous (timeseries) forcing by offshore wave climate and water levels;
- Represents complex shorelines using a flexible Curvilinear grid;
- Offshore wave transformation tables, e.g. based on SWAN simulations;
- Coupled long-shore and cross-shore shoreline response;
- Representation of controls e.g. Groynes and Headlands; and
- Representation of seawalls and reefs.

The Gold Coast EVO model extends approximately 50km from Letitia Spit in the south to Jumpinpin in the north as shown in Figure 5-1. Offshore wave boundary conditions are derived from the Point Lookout waverider buoy measurements, which provide the necessary directional data post 1996. For simulations outside the period 1997-2012, the available wave data has been looped. Representative offshore water level boundary conditions are derived from the Gold Coast Seaway tide gauge measurements. A constant 550,000m<sup>3</sup>/annum sediment supply rate is input to the southern model boundary, while the northern model boundary is pinned. The Gold Coast

model is run using an hourly timestep in order to have sufficient temporal resolution to respond to storm events.

Mechanical bypassing by both dredging and trestle systems is included as sink/source terms model while nourishment from offshore borrow areas are included as source terms only. An offshore supply of sand to the Spit (north of Narrowneck) as identified in Patterson (2012) has also been included as a littoral zone source. During the simulation the littoral zone structural works (e.g. Tweed River training walls) were dynamically added to the model.

The key model inputs related to natural controls and source/sink terms are summarised in Appendix C.

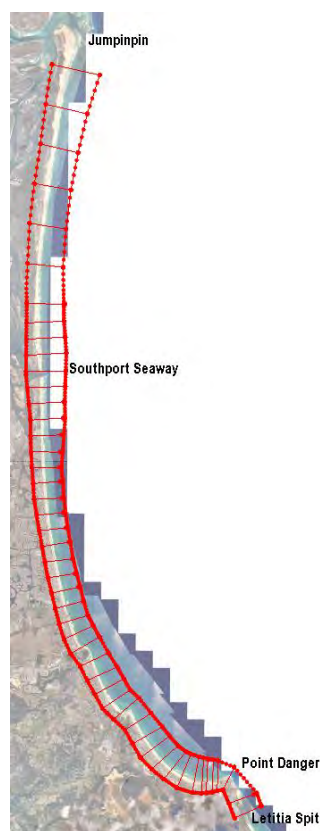


Figure 5-1 EVO Gold Coast Model Domain

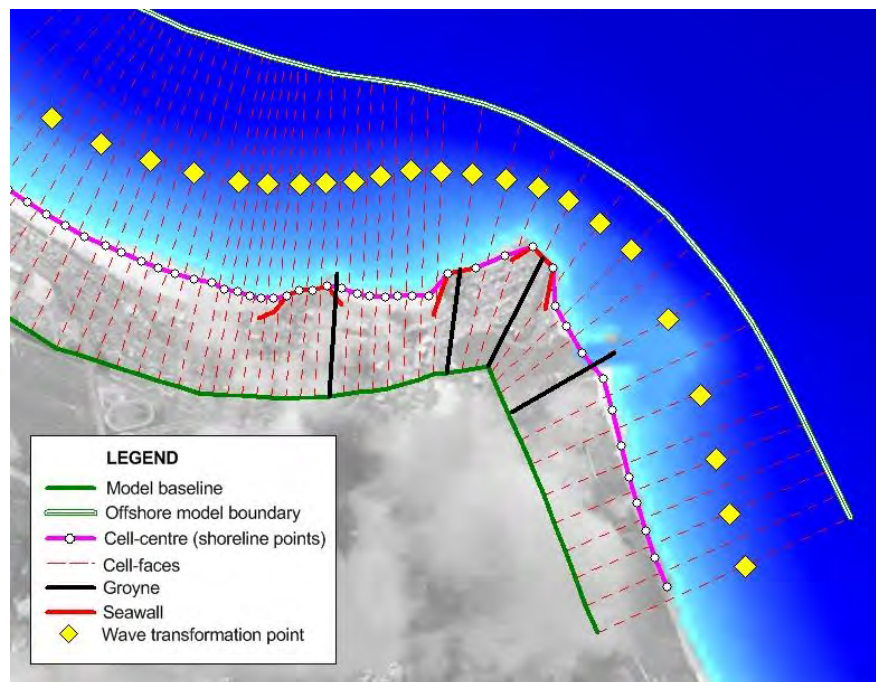


Figure 5-2 Model Domain at Point Danger

## 5.2 Methodology

For the current study a hindcast simulation has been undertaken for the period from 1900 to 2016, which includes the substantial coastal works post 1962. The hindcast also includes the effects of early 20<sup>th</sup> century Letitia Spit accretion, Tweed River reclamation and Coolangatta sand extraction (refer Section 2.3), as these are surmised to have already depleted sand volumes within the southern Gold Coast system before the Tweed River wall extension in 1962.

The hindcast simulation end point was then used as the starting point for a forecast simulation extending to the year 2100 (entire hindcast/forecast simulation period was from 1900-2100). The forecast simulation assumed:

- Average supply of sand to Letitia Spit at 550,000 m<sup>3</sup>/year;
- Offshore wave climate based on 1997-2016 Point Lookout measurements;
- Tweed River bypassing (pumping plus dredging) at an average rate of 490,000 m<sup>3</sup>/year;
- No further sand imported into the system;
- Sea Level Rise was not included in the forecast.

Under these assumptions both Letitia Spit and southern Gold Coast sand volumes remained relatively constant (see Figure 5-3).

## 5.3 Results

The predicted volume changes south of Point Danger (NSW) and between Point Danger and Currumbin (southern Gold Coast - QLD) from 1960 to 2020 are shown in Figure 5-3. The predicted volumes reflect the hindcast/forecast inputs and assumptions, and are shown to be reasonably

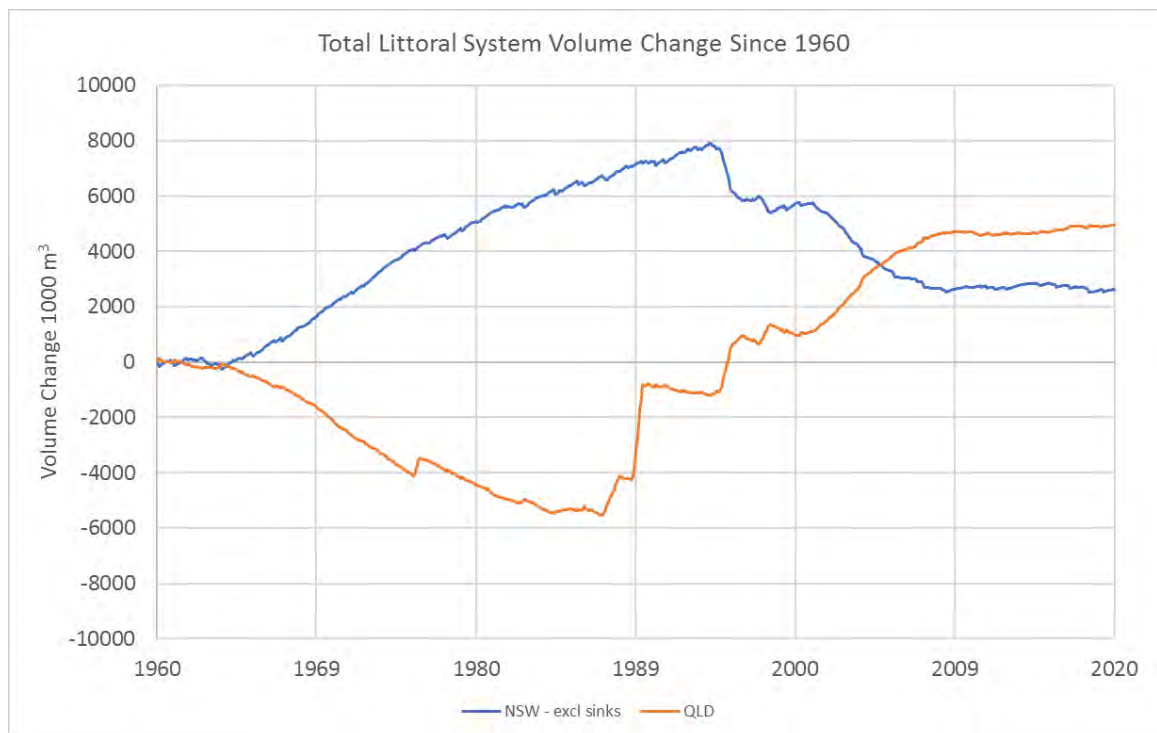


consistent with the quantitative conceptual model derivation in Section 4. The broad-scale volume trends show:

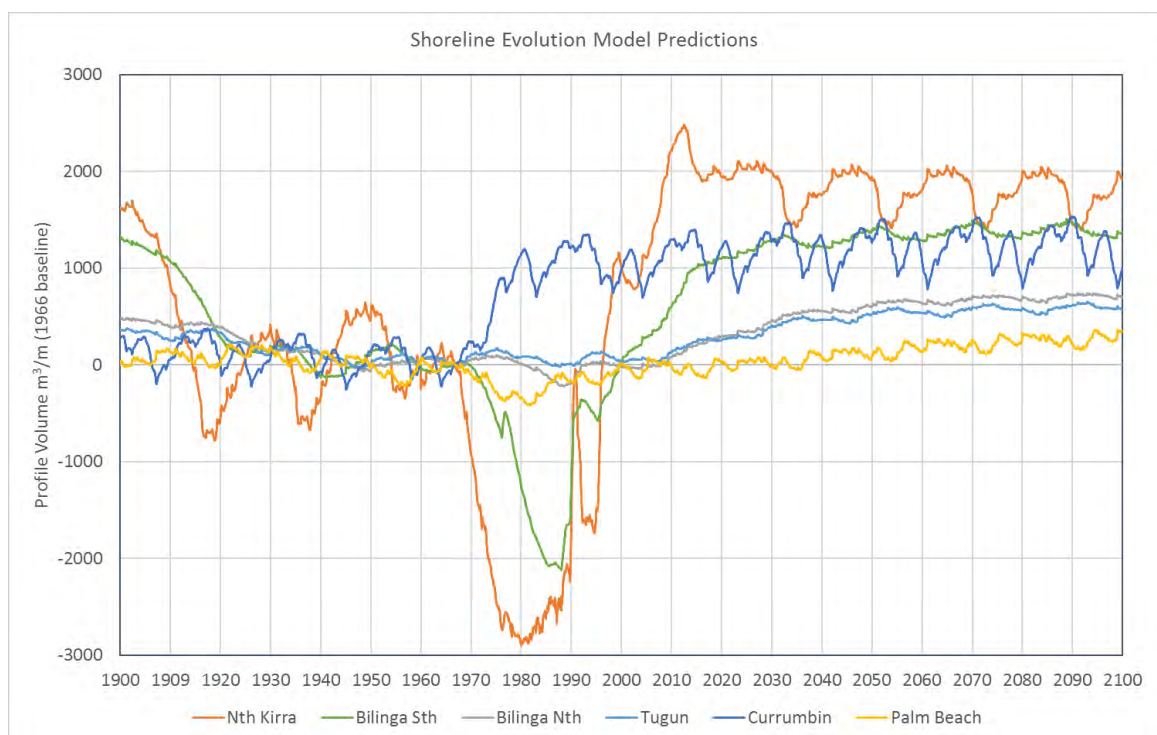
- Accumulation of around 8M m<sup>3</sup> in the NSW active littoral system by the early 1990s.
- Net erosion in the southern Gold Coast approaching 6M m<sup>3</sup> by the late 1980s;
- Recovery of the southern Gold Coast volumes with the mass importation of sand in the late 1980s and early 1990s.
- Commencement of bypassing in the mid 1990s, resulting in further recovery of southern Gold Coast sand volumes and Letitia Spit reductions.
- Rapid volume changes (Letitia Spit erosion / Gold Coast accretion) in the first 8 years of TRESBP Stage 2 operation (2001-2009).
- Volume distribution relatively stable post 2009, with southern Gold Coast system with a surplus of 4.2M m<sup>3</sup> (refer Section 4.5.2).

The modelled local profile volume predictions at five locations within the southern Gold Coast system and at Palm Beach just to the north are shown in Figure 5-4. The following key trends were observed in these predictions:

- Kirra / Bilinga embayment volumes were already depleted in 1960 due to accretion of Letitia Spit (as a result of original Tweed River entrance training walls) and substantial reclamation in the lower Tweed River;
- The sand supply reductions post 1962 were acutely experienced at North Kirra and to a lesser extent Bilinga South;
- Currumbin Beach accreted substantially due to the Rock Groyne construction in 1973, which reduced sand supply northward to Palm Beach;
- North Kirra profile volumes “overshoot” during the “Supplementary Increment” period (2001 to 2007) before reducing slightly;
- Forecast profile volumes are generally similar with pre-1900 levels (except for Currumbin), however these volumes are higher than those experienced during most of the 20<sup>th</sup> century;
- The overall system has a greater volume of sand than pre-1900 due to the substantial importation from offshore supplies that occurred in the 1980/90s. However, this volume is well dispersed through the system by 2030.



**Figure 5-3** The predicted total littoral system volume changes over the period from 1960 to 2020. The increase in volume within QLD is in good agreement with Section 4 analysis.



**Figure 5-4** Shoreline evolution model predictions (hindcast and forecast)

## 6 Future Evolution Trends

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As described in previous sections of this report, the southern Gold Coast system has been severely disrupted from its “pre-1900” natural state over the course of the last 130 years. The Tweed River Entrance Sand Bypassing Project was commenced in the mid-1990’s with a key objective being to re-instate the natural delivery of sand from Letitia Spit to the southern Gold Coast.

During the initial period of TRESBP Stage 2 operation the legislated requirement for a “supplementary increment” resulted in a total rate of sand supply north of Point Danger of 890,000 m<sup>3</sup>/year, which is some 60% higher than the estimated natural long term average rate. This rate of supply into the Kirra embayment clearly exceeded the capacity for longshore transport northward and consequently a substantial accumulation of sand was observed, most obviously in the North Kirra compartment.

Since 2009 when the total rate of supply north of Point Danger was substantially reduced there has been a net reduction in sand volume in the compartments from Point Danger to North Kirra. The longshore transport capacity from these compartments in an accreted state was greater than the 600,000 m<sup>3</sup>/year being delivered around Point Danger.

It is expected that the ongoing TRESBP operation over the period from 2015-2025, will approach the Deed of Agreement target such that the total supply north of Point Danger will be close to the long-term average of the quantity supplied by natural processes to Letitia Spit. This quantity was estimated at 573,000 m<sup>3</sup>/year in the 2015 LTA re-assessment (BMT WBM, 2015), and in the current study has been assumed to be approximately 550,000 m<sup>3</sup>/year.

Based on these assumed supply rates, it is expected that sand will continue to disperse from the southern portion of the Kirra embayment (North Kirra and Bilinga South compartments), with volumes correspondingly expected to continue increasing in the Bilinga North and Currumbin compartments to the north. Importantly, both the rate and final magnitude of profile volume increase is expected to be much lower in the northern compartments. Unlike the compartments from Snapper to North Kirra, the northern compartments are not expected to exhibit a volume peak and subsequent substantial reduction. Instead it is expected that Bilinga North and Currumbin compartment volumes will continue to trend upwards and gradually approach a new more accreted state in equilibrium with the re-instated (increased) supply. Noting that supply has probably been reduced by interruption and extraction since 1880, it could well be that this equilibrium position is more accreted than the circa-1960 alignment.

The expected trends are well illustrated in the shoreline evolution model predictions shown in Figure 5-4. In this figure the volume change predictions have been set relative to a 1966 baseline. Due to the modelled pre-1960 supply interruptions, this baseline is already eroded relative to the “natural” state. The offset between 2100 and 1900 model predictions are due to the 4.2M m<sup>3</sup> additional sand in the system (Section 4.5.2). Beyond 2025 it is expected that this additional quantity of sand would be well “dispersed” both throughout and further north of the southern Gold Coast system.

At Currumbin (between Elephant Rock and Currumbin Rock) the magnitude of changes related to the re-instated supply are expected to be small relative to the changes experienced further south in



## Future Evolution Trends

the Kirra embayment, and certainly much smaller than the change that was imposed by the Currumbin Rock groyne construction in 1973. The re-instatement of supply to Palm Beach is also expected to contribute a slowly accumulating positive additional profile volume. The slow rate of accumulation (over several decades) due to the supply re-instatement would be imperceptible in the context of Currumbin and Palm Beach sediment transport processes, in particular storm-driven erosion/accretion cycles.

Considering the survey profile analysis results described in 3.2, and in particular the 2015/16 survey profiles for Bilinga North and Tugun, it is apparent that the northward sand feed out of the Kirra embayment and into the Bilinga North and Currumbin compartments is occurring predominantly as a sand lobe between -5 and -10 m AHD. This sand feed is preceding any accretion response of the upper beach.

This observation means that in the vicinity of Currumbin additional volumes are likely to be initially weighted towards the outer profile and in the longer term distributed across the entire active profile. This in turn means that shoreline accretion benefits of the additional volumes will be very subtle as they would tend to be either located offshore of the sub-aerial beach or spread across the entire profile from around +2 to -13 m AHD. As an example, under this scenario a 500 m<sup>3</sup>/m volume increase would correspond to a 33 m shoreline accretion. This is in contrast to the southernmost section of the Kirra embayment where additional volumes accumulated mainly between +2 and -7 m AHD, which combined with the large volume changes (~2000 m<sup>3</sup>/m) contributed to very substantial shoreline accretions of the order of 200 m.

The available evidence suggests that Currumbin and Palm Beach will experience modestly higher sand supply over future years than has been the case over recent history (since the 1960s). An upper-bound estimate is that longshore transport rates at Currumbin may increase by up to 10% as a result of sand supply re-instatement.

However, this long-term prognosis needs to be considered in the context of the substantial variability of sand supply that has occurred (and will continue to occur) at much shorter timescales due to natural wave climate variability. This wave climate variability leads to annual longshore transport rates varying year to year by up to +/-50% of long term averages. This natural variability will, for instance, continue to lead to periodic episodes of sand accumulation within Currumbin Creek entrance, with substantial year to year variability in the sand volumes requiring dredging. Also, the natural occurrence of storm erosion will continue to be a concern for the vulnerable section of Palm Beach, where there is an insufficient sand volume buffer in front of the A-line seawall defences. These two circumstances are unlikely to be vastly different to observed conditions during the last decade or so, though it is reasonable to expect small (imperceptible) increases in long term average Currumbin Creek entrance dredging requirements and some modest accretion along Palm Beach in response to the re-instated sand supply.

## 7 Conclusions and Recommendations

A southern Gold Coast quantitative sand transport conceptual model for the period from 1962 to 2015 has been derived primarily from analysis of historical beach profile survey datasets. This conceptual model has been used to assess the coastal system changes in the vicinity of Currumbin that can be attributed to:

- (1) extension of the Tweed River entrance training walls in 1962;
- (2) the re-instatement of sand supply by TRESBP Stage 1 (from 1995) and Stage 2 (from 2000).

Prior to TRESBP Stage 1 the sand budget assessment has shown that 8.9M m<sup>3</sup> had accumulated across the survey compartments within NSW (relative to 1962). Letitia Spit accretion accounted for +4.1M m<sup>3</sup>, the Entrance and Duranbah +3.4M m<sup>3</sup> and the lower Tweed River +1.4M m<sup>3</sup>. At the same time the Queensland volume deficit had already been substantially offset by the southern Gold Coast nourishment project/s, which had imported 6.2M m<sup>3</sup> from offshore sand supplies into the active littoral system. In 1993 the total volume within the littoral system from Point Danger to Currumbin was -1.3M m<sup>3</sup> relative to the 1962 baseline.

The period from 1993 to 2009, which included the Stage 1 dredging and the first 9 years of Stage 2 operations, also saw the Queensland volume deficit become +3.4M m<sup>3</sup> increase (relative to 1962). A majority of the additional sand volume added to Queensland during this period had accumulated in the Kirra / Bilinga embayment. The rate of sand delivery during the initial period of TRESBP Stage 2 operations as required by the legislated “supplementary increment” was in hindsight excessive in the context of the longshore sand transport capacity of the natural system.

By 2015 there was a total increase of 9.2M m<sup>3</sup> over the entire system from Fingal to Currumbin relative to 1962. Within NSW, Letitia Spit accretion accounts for +0.9M m<sup>3</sup>, the lower Tweed River estuary for +1.2M m<sup>3</sup> and the Tweed River Entrance for +2.9M m<sup>3</sup> for a total of +5.0M m<sup>3</sup>. In Queensland, there has been an overall increase in sand volumes between Point Danger and Currumbin of +4.2M m<sup>3</sup>. Considering the sources of the 9.2M m<sup>3</sup> increase in the system, 6.2M m<sup>3</sup> can be attributed to nourishment from offshore sand supply sources while the remaining 3.0M m<sup>3</sup> can be attributed to an inferred transport differential between Fingal and Currumbin.

During the most recent 2009 to 2015 period, sand bypassing was entirely by jetty pumping at an average rate of 432,000 m<sup>3</sup>/year. During this same period, the Tweed River entrance compartment accumulated sand at an average rate of 61,000 m<sup>3</sup>/year and by late 2015 had reached a total volume similar to 1993 (i.e. prior to TRESBP Stage 1). Aside from the increased risk of compromised entrance navigability, the accreted entrance also allowed for natural bypassing to increase to 170,000 m<sup>3</sup>/year. Hence, during this period where the rate of bypassing was intentionally reduced, the total rate of delivery to Queensland (including natural bypassing) still exceeded the transport into Letitia Spit. This finding suggests the requirement for entrance dredging and bypassing as part of the ongoing sustainable operation of the TRESBP.

Shoreline evolution modelling of the period from 1900 to 2100 has been undertaken to analyse and help understand the observed historical trends and to help derive a future prognosis (based on certain assumptions). Results from this modelling are in good agreement with observations of southern Gold Coast response during the period from 1962 to 2015. Looking forward, the model

## Conclusions and Recommendations

predictions indicate that the substantial volume accretion (4.2M m<sup>3</sup>), which predominantly accumulated in the Kirra / Bilinga embayment since 2001, will continue to be dispersed gradually northwards. This will have the effect that Currumbin and Palm Beach will experience a re-instated (increased) sand supply.

At Currumbin, the magnitude of changes related to the re-instated supply are expected to be relatively minor and certainly much smaller than the change that was imposed by the Currumbin Rock groyne construction in 1973. Currumbin entrance will continue to experience natural infilling, with a substantial year to year variability in volumes and spatial distributions. The re-instatement of supply to Palm Beach is also expected to contribute a small but positive additional profile volume. However, without additional intervention, Palm Beach will likely continue to remain vulnerable to short-term storm erosion events due to the insufficient sand supply buffer in front of the A-line seawall defences.



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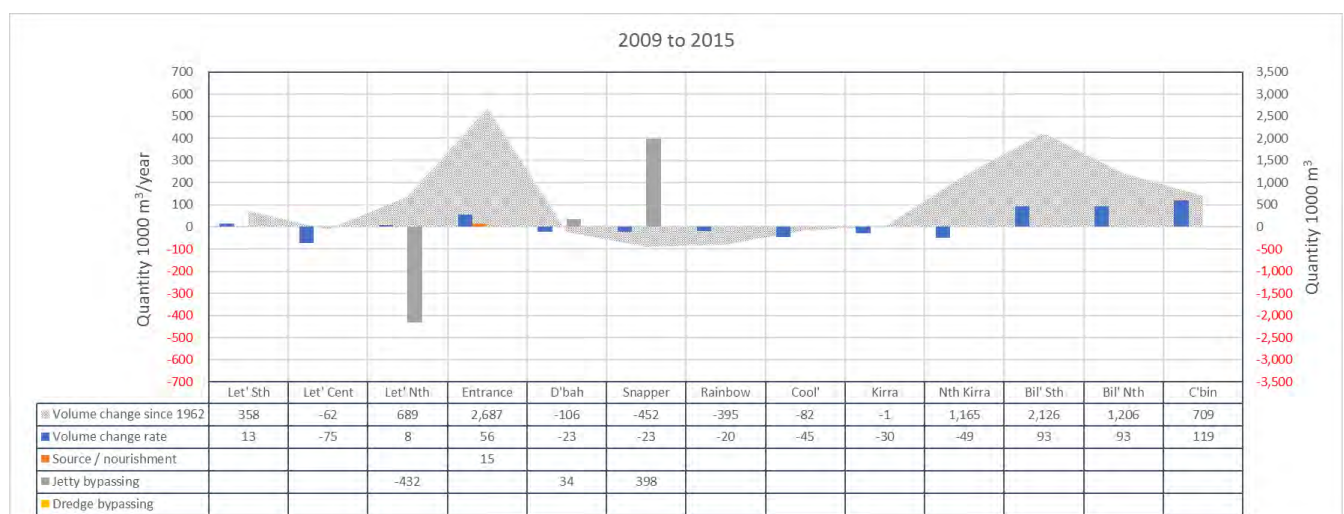
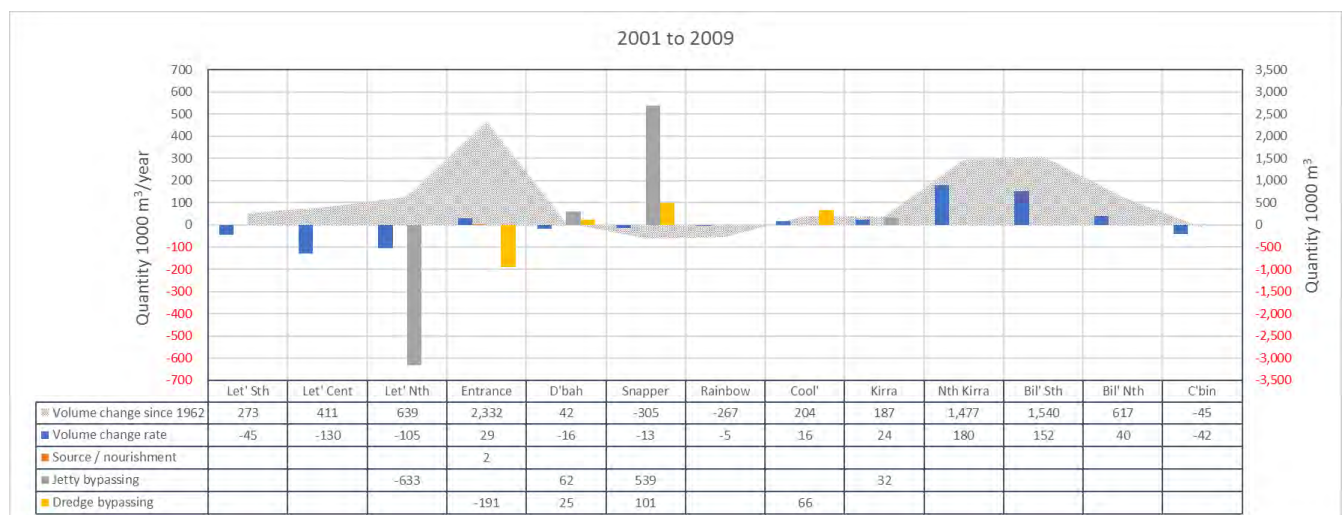
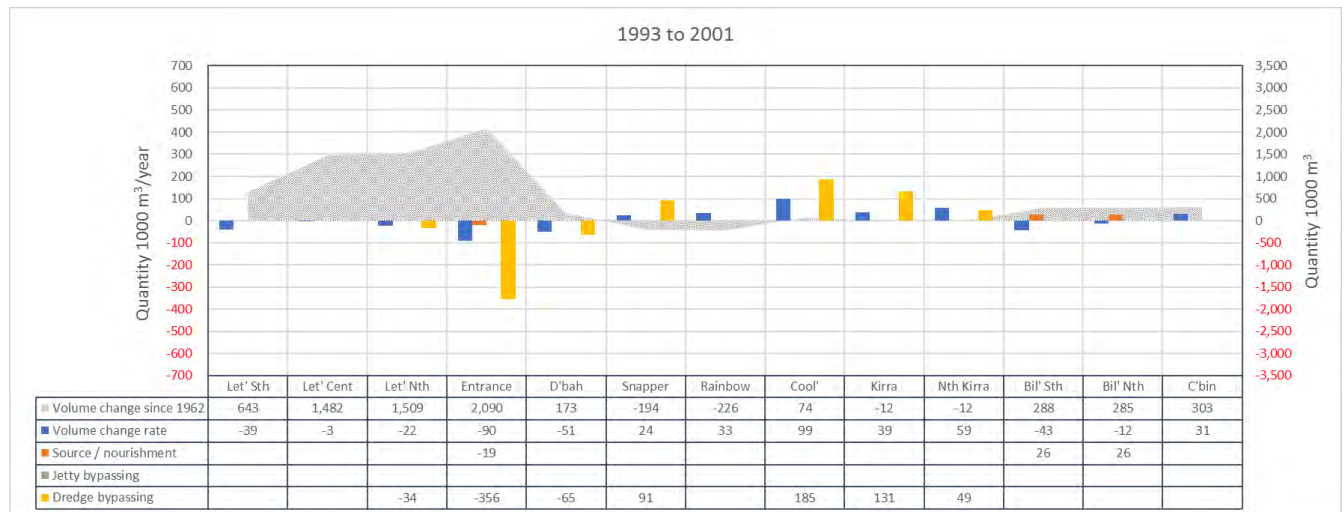
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## Appendix A Conceptual Model Inputs

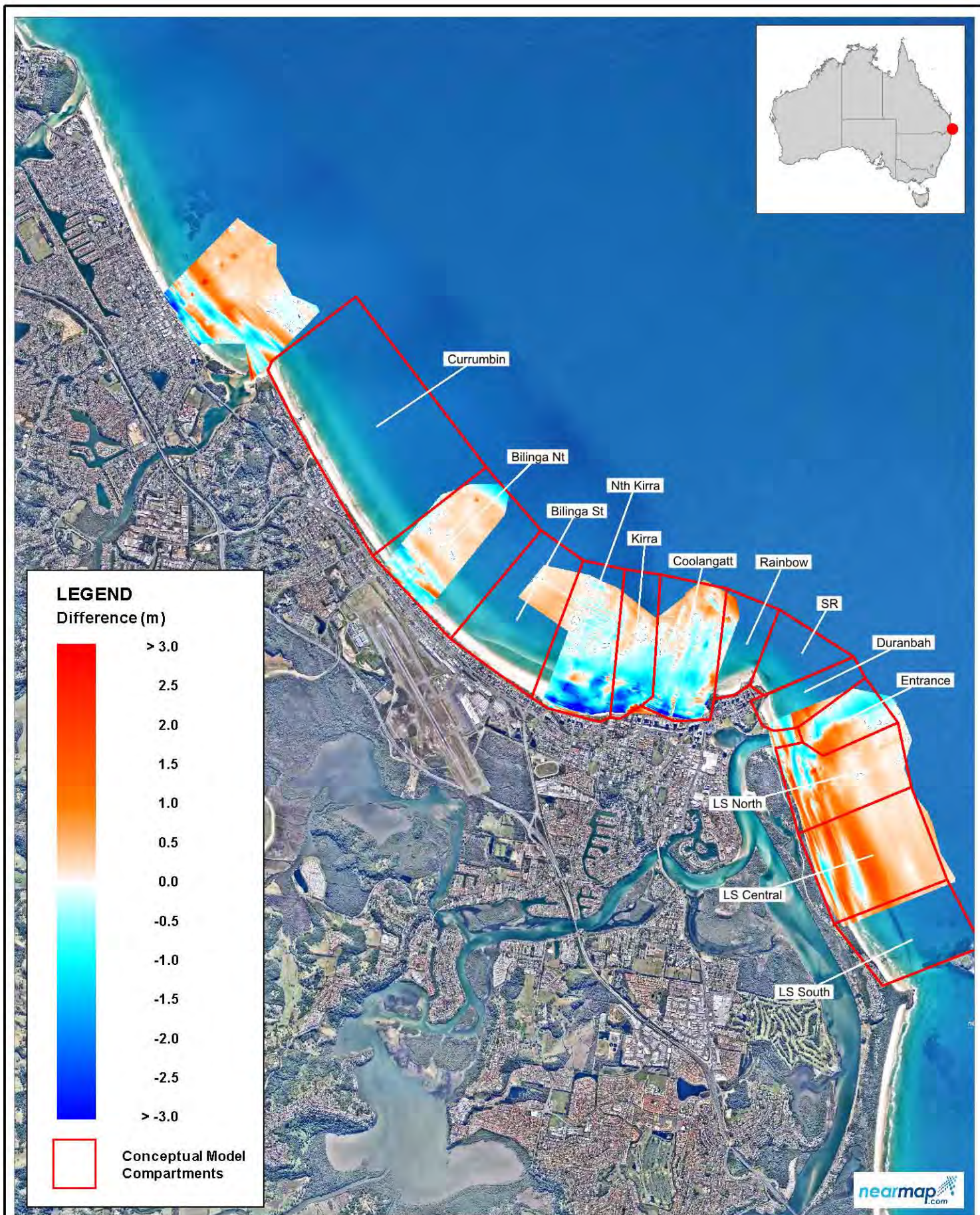






## Appendix B    Survey Analysis





Title:  
**Survey Difference Plot 1972 - 1966**

Figure:

**B-1**

Rev:

**A**

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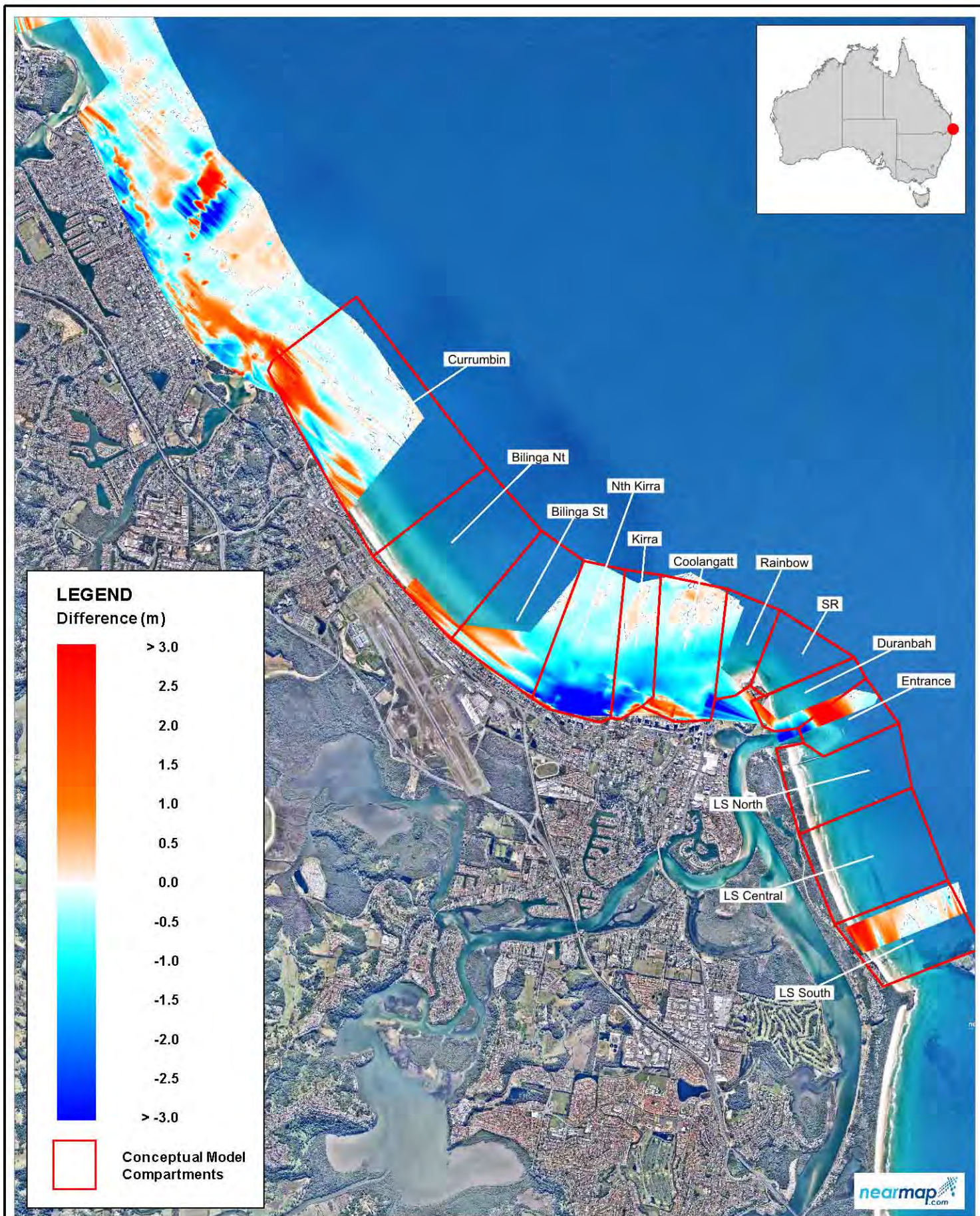


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Approx. Scale



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Title:  
**Survey Difference Plot 1983 - 1966**

Figure:

**B-2**

Rev:

**A**

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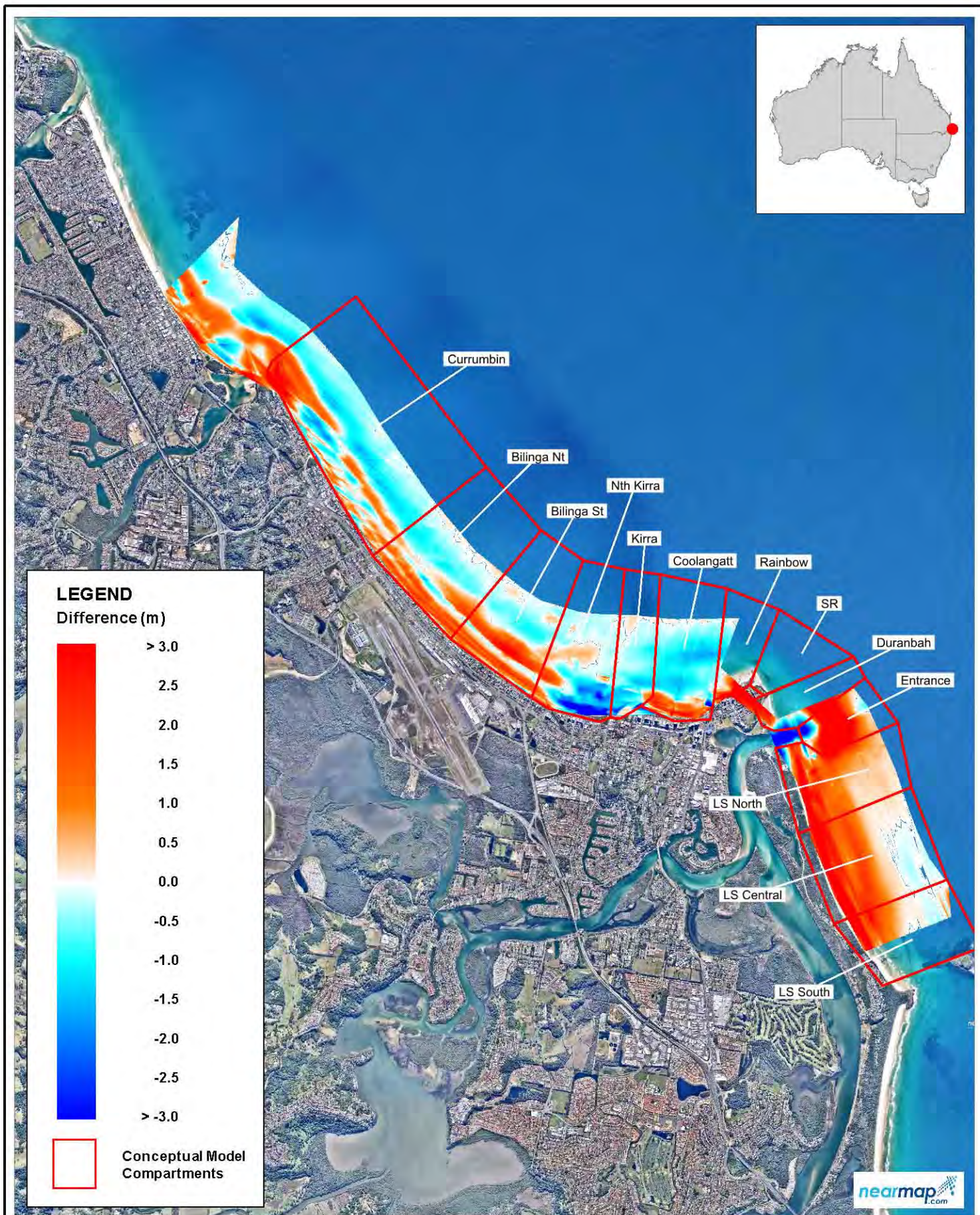


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Title:  
**Survey Difference Plot 1993 - 1966**

Figure:  
**B-3**

Rev:  
**A**

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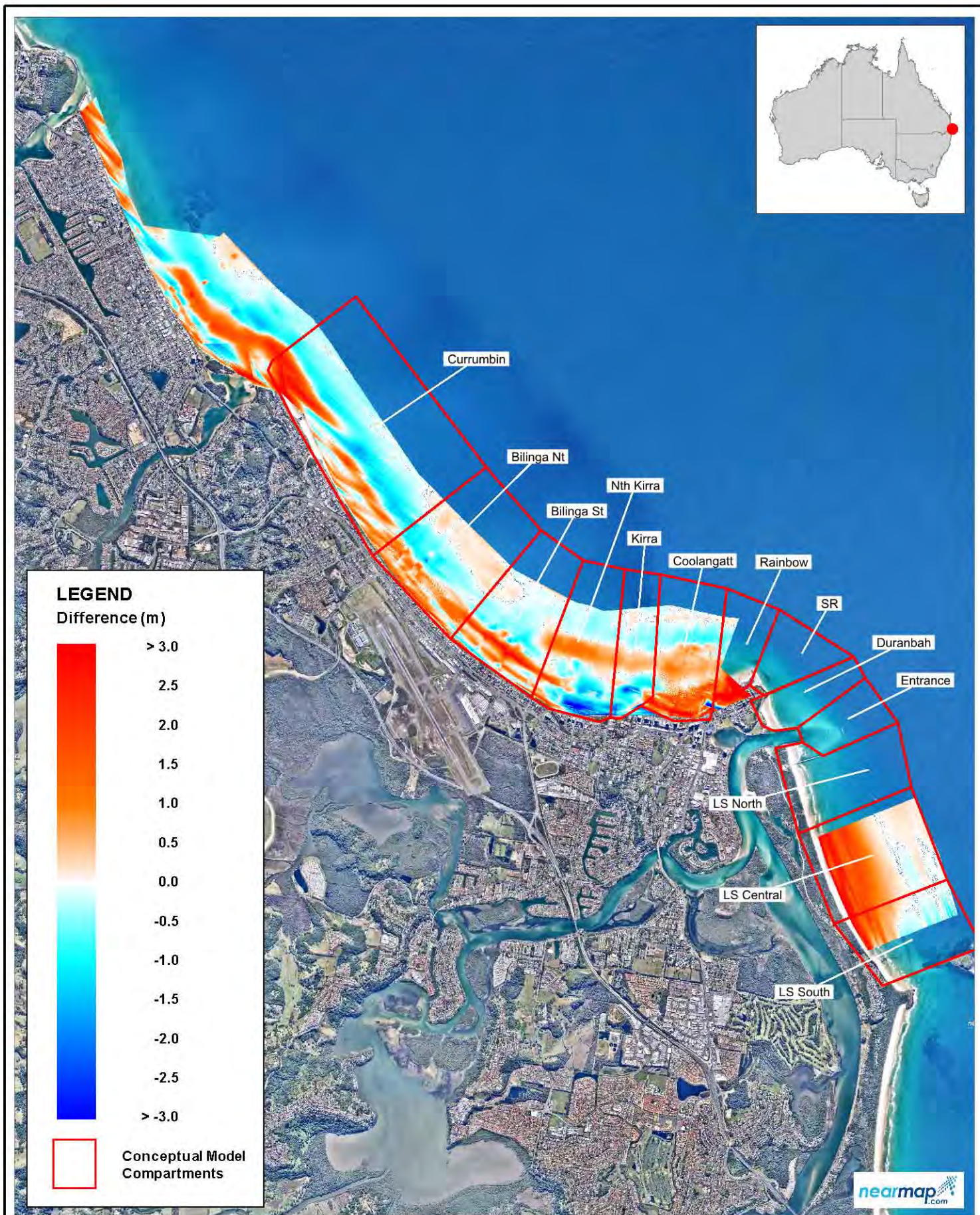


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Approx. Scale

 **BMT WBM**  
www.bmtwbm.com.au

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Title:  
**Survey Difference Plot 2001 - 1966**

Figure:

**B-4**

Rev:

**A**

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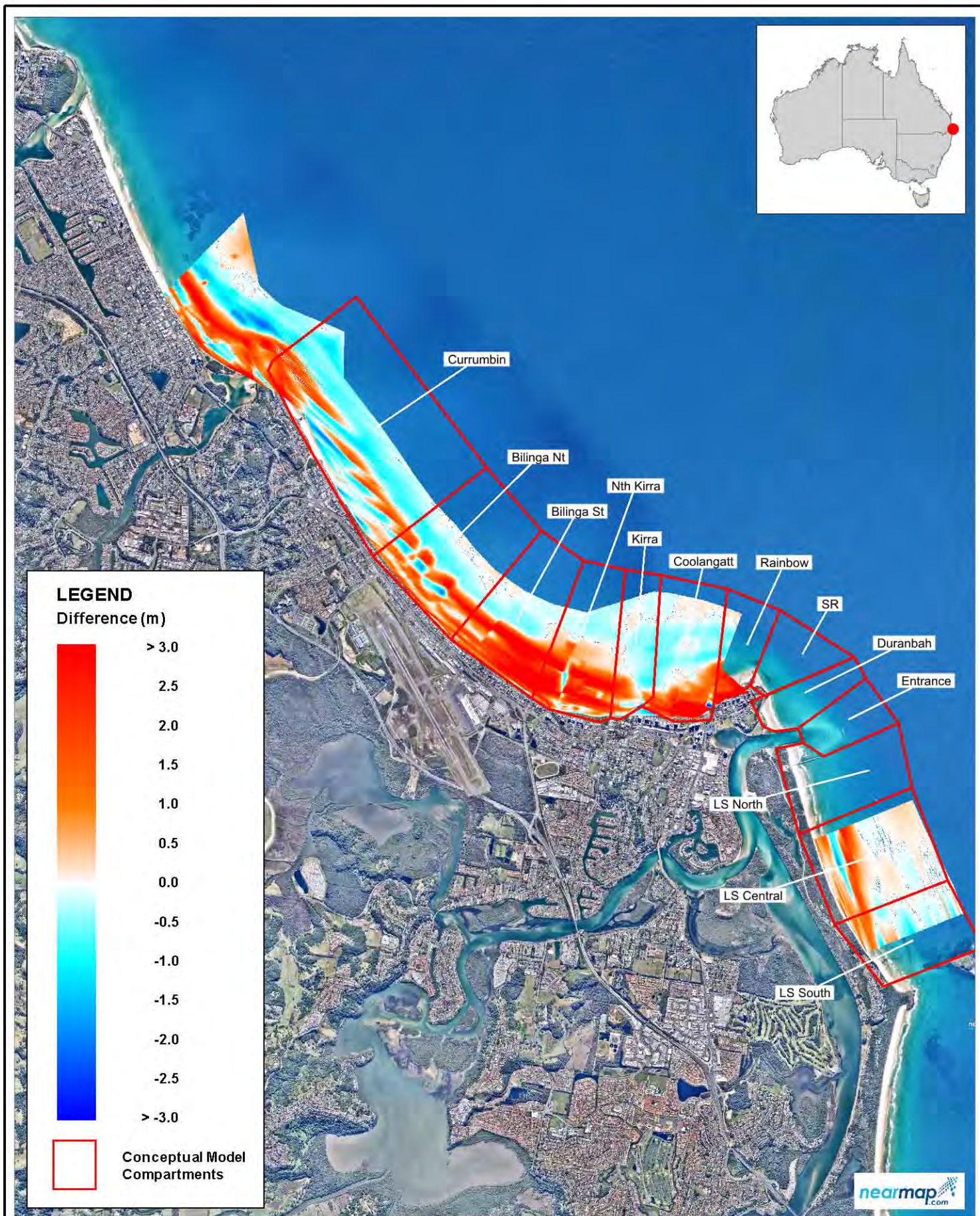


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Approx. Scale



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Title:  
**Survey Difference Plot 2009 - 1966**

Figure:  
**B-5**

Rev:  
**A**

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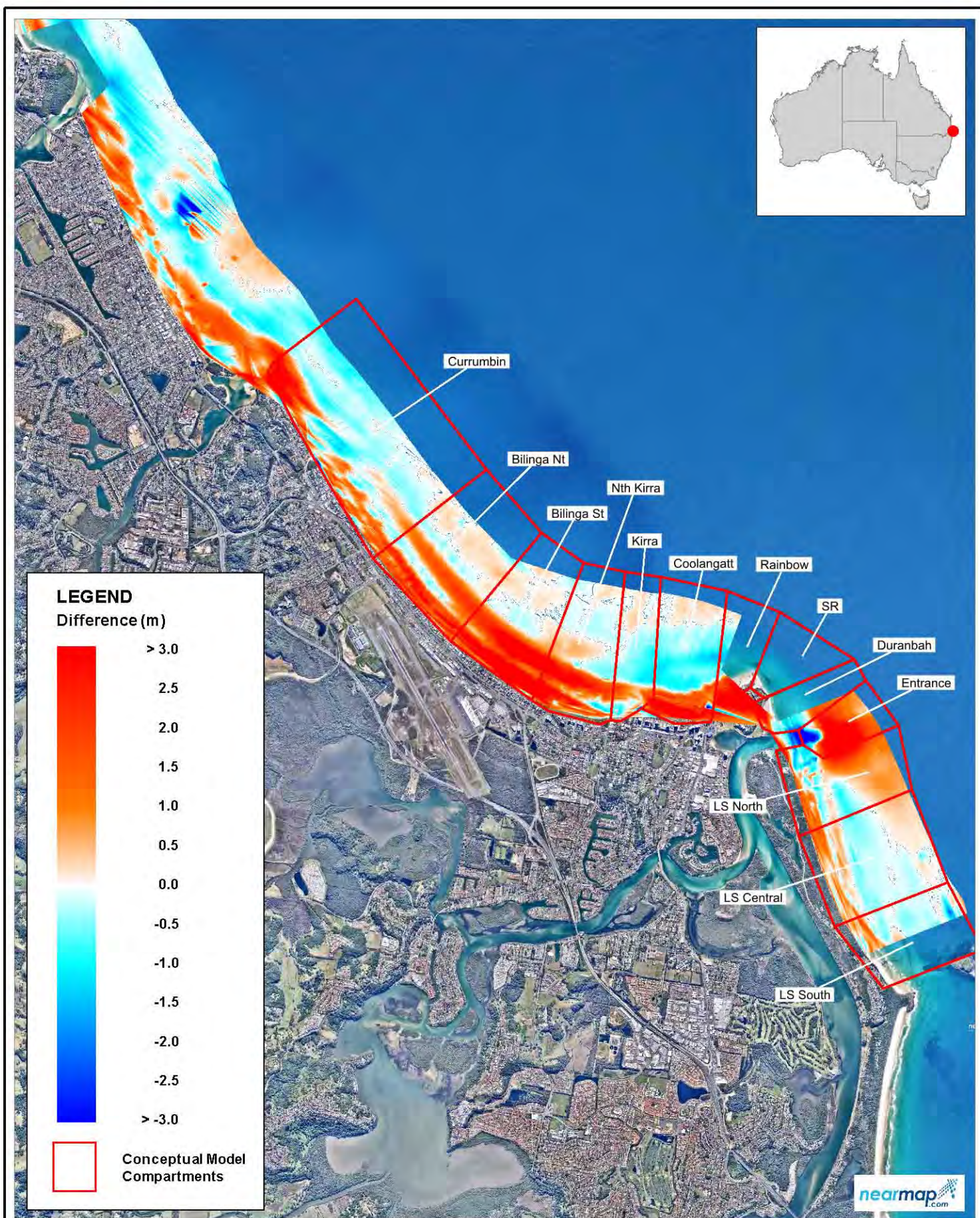


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Approx. Scale



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Title:  
**Survey Difference Plot 2016 - 1966**

Figure:  
**B-6**

Rev:  
**A**

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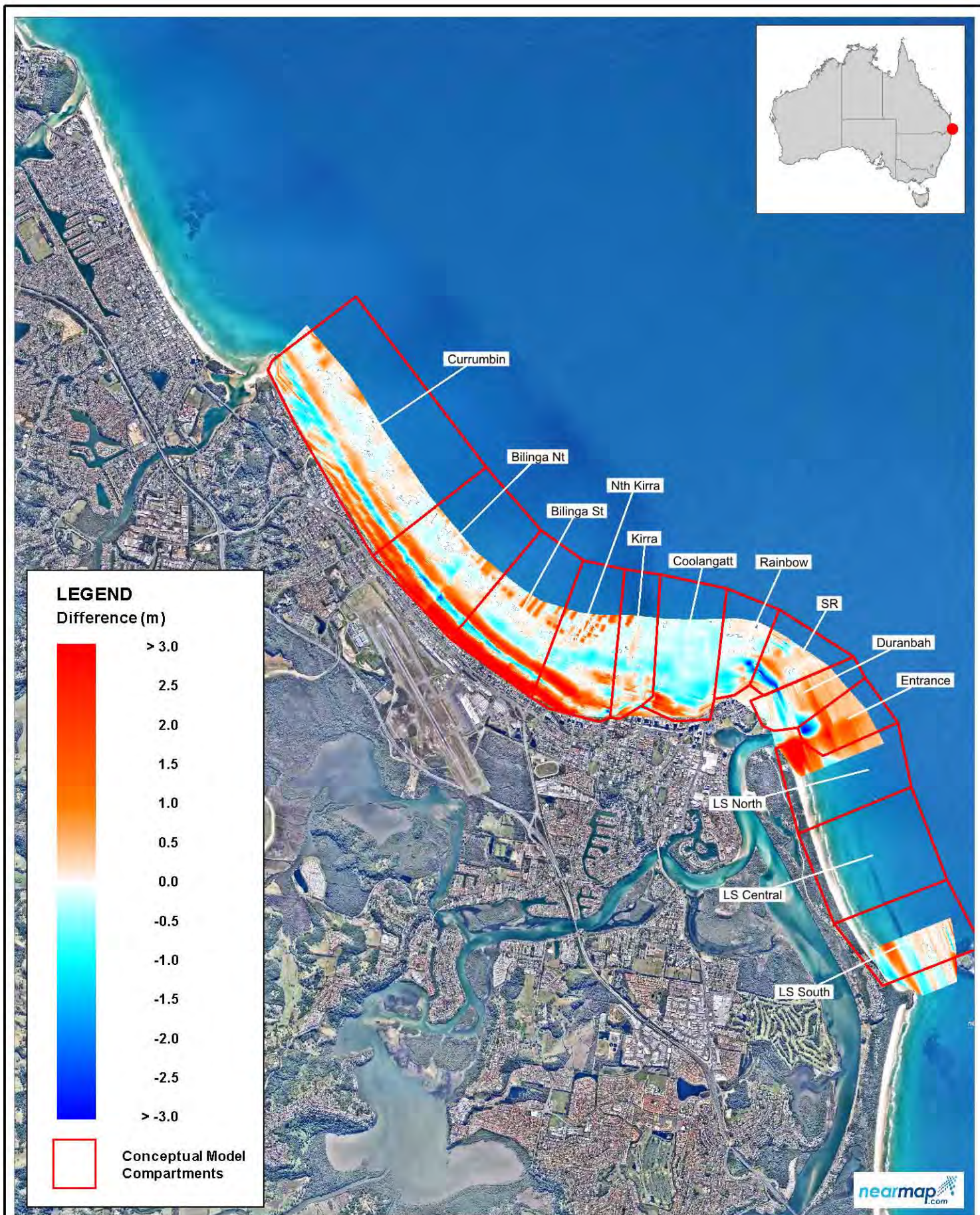


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Title:  
**Survey Difference Plot 1993 - 1989**

Figure:  
**B-7**

Rev:  
**A**

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Approx. Scale



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## Shoreline Evolution Model Inputs

## Appendix C Shoreline Evolution Model Inputs

chainage	groyne_x	start_time	end_time	Comment
1783.3	600	01/01/0000 00:00	01/01/9999 00:00	Point Danger at Duranbah
1916.89	845	01/01/0000 00:00	01/01/9999 00:00	Point Danger at Snapper Rocks
2192.24	705	01/01/0000 00:00	01/01/9999 00:00	Greenmount Hill
3090.4	745	01/01/0000 00:00	01/01/9999 00:00	Kirra Point (Headland)
3285.88	650	01/01/0000 00:00	01/01/9999 00:00	Kirra Point (Headland)
9243.86	740	01/01/0000 00:00	01/01/9999 00:00	Flat Rock - Currumbin
9842.56	765	01/01/0000 00:00	01/01/9999 00:00	Elephant Rock - Currumbin
10619.09	920	01/01/0000 00:00	01/01/1973 00:00	Currumbin Rock (natural control)
15182.26	855	01/01/0000 00:00	01/01/9999 00:00	Burleigh Headland
15380.11	925	01/01/0000 00:00	01/01/9999 00:00	Burleigh Headland
18166.44	575	01/01/0000 00:00	01/01/9999 00:00	Little Burleigh
33389.94	910	01/01/0000 00:00	01/01/1986 00:00	Nerang River entrance - pseudo control
1382.54	675	01/01/1900 00:00	01/01/1963 00:00	Tweed River Southern Training Wall
1382.54	915	01/01/1963 00:00	01/01/9999 00:00	Tweed River Southern Training Wall (shortened by 60m IAT 8/1/17)
2992.66	785	01/01/1972 00:00	01/01/9999 00:00	Kirra Point Groyne
3577.25	630	01/01/1975 00:00	01/01/9999 00:00	Little Kirra Groyne
10619.09	970	01/01/1973 00:00	01/01/9999 00:00	Currumbin Groyne
14984.41	830	01/01/1978 00:00	01/01/9999 00:00	Tallebudgera Groyne (extended by 10m DCP 27/8/13)
12591.34	600	01/01/1984 00:00	01/01/9999 00:00	Palm Beach Groyne South (extended by 10m DCP 27/8/13)
13589.18	660	01/01/1984 00:00	01/01/9999 00:00	Palm Beach Groyne North (extended by 10m DCP 27/8/13)
33389.94	1200	01/01/1986 00:00	01/01/9999 00:00	Gold Coast Seaway

## Shoreline Evolution Model Inputs

ID	Start_Chai	End_Chair	Start_Time	End_Time	Rate	Volume	Description			
1	1400	1500	01/01/1910	01/01/1950	-20000		Tweed R infill			
2	3000	5000	01/01/1930	01/01/1940	-50000		Coolangatta swamp & Kirra fill			
3	1400	1500	01/01/1950	01/01/1966	-80000		Greenbank Island reclamation			
4	1400	1500	01/01/1966	01/01/1993	-38000		Tweed R infill			
5	4000	5000	01/03/1976	01/06/1976		765000	Kirra nourishment from Tweed			
6	1400	1500	01/03/1976	01/01/1989	-20000		Tweed R accelerated infill			
7	1400	1500	01/01/2001	01/01/2016	13000		Tweed R source			
8	1400	1500	01/01/2001	01/01/2016	-40000		Tweed entrance bar growth			
9	16200	17200	01/03/1985	01/08/1985		300000	Burleigh Nourishment			
10	3500	5000	01/01/1985	01/01/1986		315000	Kirra Central/North Nourishment			
11	2500	3500	01/01/1988	01/01/1989		213000	Coolangatta/Kirra Nourishment			
12	3500	5000	01/01/1988	01/01/1989		514000	Kirra Central/North Nourishment			
13	5000	7000	01/01/1988	01/01/1989		832000	Bilinga Nourishment			
14	3000	7000	01/11/1989	01/06/1990		3200000	Kirra to Tugun Nearshore Nourishment			
15	5000	7000	01/11/1989	01/06/1990		400000	Bilinga to Tugun offshore nourishment			
16	1200	1800	01/04/1995	01/01/1996		-1680000	Tweed Bar Dredging			
17	2000	5000	01/04/1995	01/01/1996		1680000	Tweed Bar Dredging Placement			
18	1200	1800	01/01/1996	01/09/1996		-560000	Tweed Bar Dredging			
19	2000	5000	01/01/1996	01/09/1996		560000	Tweed Bar Dredging Placement			
20	1200	1800	01/10/1997	01/06/1998		-800400	Tweed Bar Dredging			
21	2000	5000	01/10/1997	01/06/1998		800400	Tweed Bar Dredging Placement			
22	1200	1600	01/01/2000	01/04/2001		-480000	Tweed Bar Dredging			
23	2000	3500	01/01/2000	01/04/2001		480000	Tweed Bar Dredging Placement			
26	1200	1600	01/04/2001	01/01/2006	-939500		Tweed Bypassing (incl bar dredging)			
27	2000	2500	01/04/2001	01/01/2006	811000		Tweed Bypassing Placement - Snapper			
28	2500	5000	01/04/2001	01/01/2006	55600		Tweed Bypassing Dredge Placement - Rainbow to Ki			
29	1500	1750	01/04/2001	01/01/2006	72900		Tweed Bypassing Placement - Duranbah			
30	1200	1350	01/01/2006	01/01/2009	-699000		Tweed Bypassing			
31	2000	2500	01/01/2006	01/01/2009	591000		Tweed Bypassing Placement - Snapper			
32	1500	1750	01/01/2006	01/01/2009	108000		Tweed Bypassing Placement - Duranbah			
33	1200	1350	01/01/2009	01/01/2012	-441000		Tweed Bypassing			
34	2000	2500	01/01/2009	01/01/2012	399000		Tweed Bypassing Placement - Snapper			
35	1500	1750	01/01/2009	01/01/2012	42000		Tweed Bypassing Placement - Duranbah			
36	1200	1350	01/01/2012	01/01/2016	-444000		Tweed Bypassing			
37	2000	2500	01/01/2012	01/01/2016	412000		Tweed Bypassing Placement - Snapper			
38	1500	1750	01/01/2012	01/01/2016	32000		Tweed Bypassing Placement - Duranbah			
39	1200	1350	01/01/2016	01/01/2100	-490000		Tweed Bypassing			
40	2000	2500	01/01/2016	01/01/2100	450000		Tweed Bypassing Placement - Snapper			
41	2500	5000	01/01/2016	01/01/2100	0		Tweed Bypassing Placement - Kirra 1			
42	1500	1750	01/01/2016	01/01/2100	40000		Tweed Bypassing Placement - Duranbah			
43	12000	14000	01/03/2005	01/06/2005		400000	Palm Beach nourishment			
44	33300	34000	01/01/1985	01/01/2100	0		Seaway Sink			
45	24600	29600	01/01/1974	01/01/1975		1500000	Surfers Nourishment			
46	24600	28000	01/01/1985	01/01/1986		450000	Surfers Nourishment			
47	24600	28000	01/01/1999	01/01/2000		1100000	Surfers Nourishment			
48	27500	28000	01/01/1980	01/01/2006		800000	Narrowneck Nourishment (building-site fill)			
49	28500	33000	01/01/1950	01/01/1980	100000		Spit Sandlobe supply			
50	28500	33000	01/01/1980	01/01/2010	60000		Spit Sandlobe supply			
51	28500	33000	01/01/2010	01/01/2030	40000		Spit Sandlobe supply			
52	28500	33000	01/01/2030	01/01/2100	30000		Spit Sandlobe supply			
53	33000	33300	01/01/1986	01/01/1994	-450000		Seaway Bypassing			
54	34000	34400	01/01/1986	01/01/1994	450000		Seaway Bypassing Placement			
55	33000	33300	01/01/1994	01/01/2002	-575000		Seaway Bypassing			
56	34000	34400	01/01/1994	01/01/2002	575000		Seaway Bypassing Placement			
57	33000	33300	01/01/2002	01/01/2012	-685000		Seaway Bypassing			
58	34000	34400	01/01/2002	01/01/2012	685000		Seaway Bypassing Placement			
59	33000	33300	01/01/2012	01/01/2030	-590000		Seaway Bypassing			
60	34000	34400	01/01/2012	01/01/2030	590000		Seaway Bypassing Placement			
61	33000	33300	01/01/2030	01/01/2100	-580000		Seaway Bypassing Placement			
62	34000	34400	01/01/2030	01/01/2100	580000		Seaway Bypassing Placement			



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