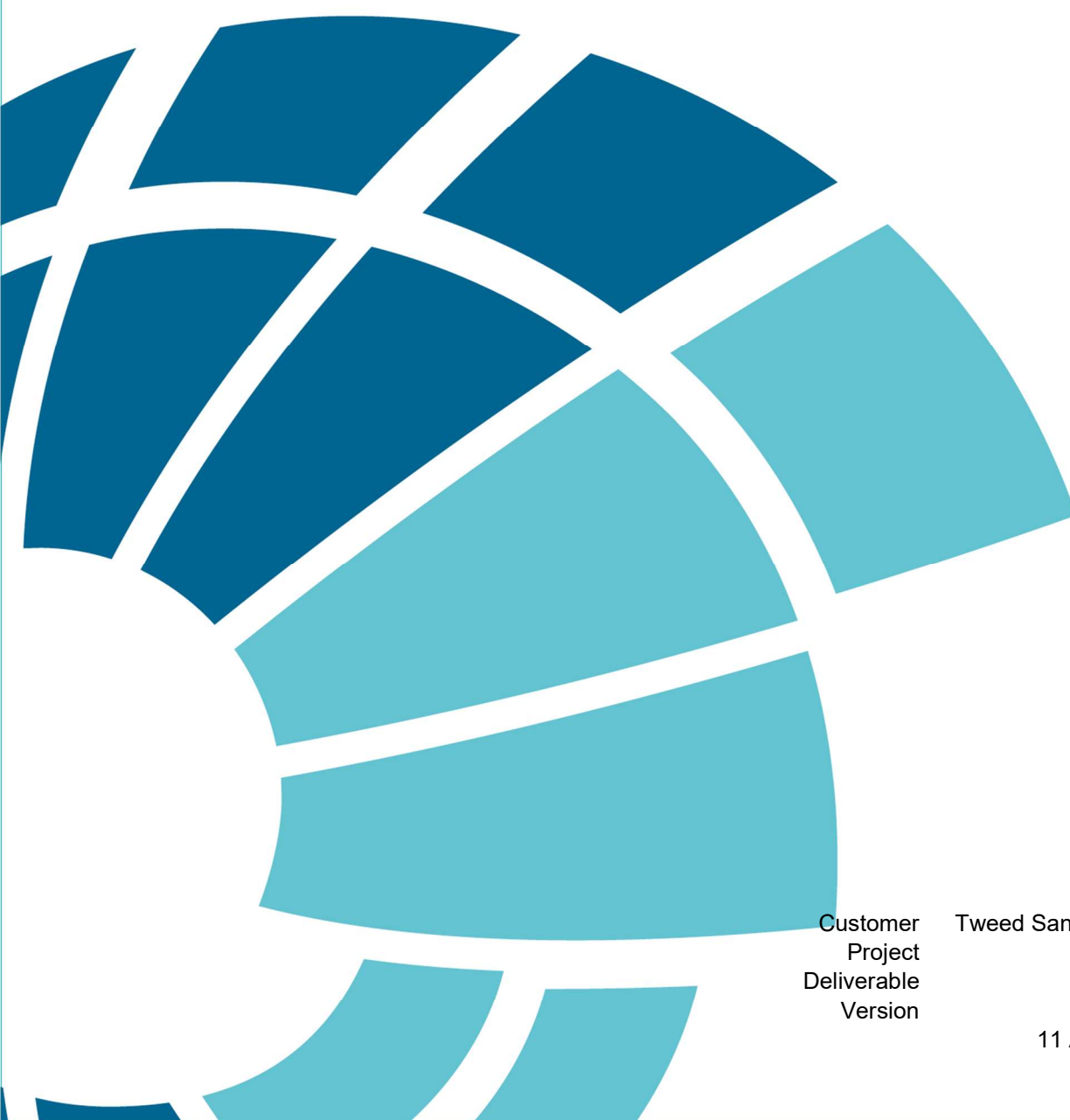


# Re-assessment of Long-term Average Annual Net Sand Transport Rate 2024



Customer	Tweed Sand Bypassing
Project	003589
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## Executive Summary

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### Background

The Long-Term Average (LTA) is the quantity of sand defined in the Tweed River Entrance Sand Bypassing Project Deed of Agreement and required to be bypassed over the longer term by use of the Tweed Sand Bypassing (TSB) jetty mounted pumping system and entrance dredging.

An updated reassessment of the LTA sand transport rate for the TSB project has been undertaken to extend the previous 2020 reassessment to the beginning of 2025, using the same methodology. The LTA has been determined on the basis of its definition under the legislation. 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 sand bypassing system is operated.

The assessment strategy adopted makes maximum use of the considerable survey data obtained from the monitoring program implemented over the period from 1993 to 2020, including the period of Stage 1 initial entrance dredging that commenced in 1995, and through the period of sand bypassing operations that commenced in 2001.

The LTA assessment method was determined on the basis of its definition in the Deed of Agreement as (essentially) the long-term average of the sand transport into Letitia Spit minus the natural bypassing to Queensland. This may be expressed in terms of the net sand volume change along the Letitia Spit/Tweed River entrance coastal unit, accounting for the gain or loss to or from the river, and the volumetric rate of the bypass system pumping and entrance dredging.

Additionally, the component sand transport rates at various locations along Letitia Spit and the natural bypassing have been updated. This necessarily required calculation of a reference sand transport rate at Currumbin, at the northern end of the monitoring survey compartments, being less subject to complexities in wave propagation and sand transport processes than other locations. The previously utilised SWAN wave propagation parameters and sand transport calculation procedure was adopted.

The analysis is undertaken with a monthly timestep based on interpolating the surveyed sand quantities and integrating the monthly sand transport rates. Thus, the variability and prevailing trends of behaviour have been identified, particularly in the context of patterns relating to the period prior to and since the sand bypassing operations commenced in 2001.

Previous LTA assessments have been undertaken for the periods up to 2009, 2015 and 2020. While the 2024 LTA assessment has maintained a consistent methodology with the earlier assessments, there has been a major upgrade in the analysis platform for the 2024 assessment from Excel spreadsheets to Python-based calculations. A standalone Python-based tool has been developed and delivered to Tweed Sand Bypassing as part of this 2024 LTA project.

### Survey Trends

The intention of the Tweed Sand Bypassing LTA objective has been to re-instate the natural sand supply from Letitia Spit to the Gold Coast. The survey trends indicate that the trend of reducing sand volumes for NSW compartments since jetty pumping commenced in 2001 had ceased by 2015. In 2024 the NSW total cumulative volume change is at a net 4.0M m<sup>3</sup> loss relative to 1993. The current volume represents a 0.5M m<sup>3</sup> loss relative to the previous assessment in 2019.

Sand volume increases along the Qld compartments have also reached a maximum around 2015 and have since stabilised at a total net 5.1M m<sup>3</sup> gain since 1993. The current total Qld compartment volume is 0.1M m<sup>3</sup> gain relative to the previous assessment in 2019.

## LTA and Sand Transport Rates

The component monthly LTA values for the period of the analysed operations and monitoring varied significantly over time, depending on the rates of sand transport and the bypassing rates and methods implemented. Understanding how the LTA quantity varies over both the long and short term helps inform the operational requirements to satisfy the Deed of Agreement.

A below-trend period of annual transport occurred from 2015-2020 before returning to a near-median transport year in 2021 and a high transport year in 2022. Both 2023 and 2024 were close to the long term average transport.

The analysis undertaken indicates that the long-term average annual longshore sand transport past Fingal over the period 1995 to 2024 is approximately 553,000 m<sup>3</sup>/yr. The corresponding average rate at Currumbin is assessed to be 524,000 m<sup>3</sup>/yr. The long-term discrepancy between Fingal and Currumbin transport rates, which is derived solely from the net sand volume increase within the coastal compartment between Fingal and Currumbin over this period, has been noted in previous assessments and while still evident, it has reduced since 2015.

The LTA averaged 497,000 m<sup>3</sup>/yr for the bypassing period 2001 to 2024, which is equal to the previous assessment. While average annual net longshore transport into Letitia Spit has reduced, the natural bypassing trend has also substantially reduced since 2015. A lower LTA of 484,000 m<sup>3</sup>/yr is derived by averaging over the period from 2007 to 2019, which doesn't include the supplementary increment (2001 to 2006).

There is a leakage of sand through the jetty system, determined through the LTA analysis to be about 23% of the Letitia Spit longshore transport. This leakage is in part deposited in the entrance compartment and is in part passed northwards as natural bypassing. The natural bypassing rate had previously trended upwards during the period from 2009 to 2015 when there was no entrance dredging. Since 2016, in total, there has been 1.10M m<sup>3</sup> dredged from the Tweed River entrance and a noticeable reduction has been observed in the long-term trend rate of natural bypassing. The 2001 to 2015 natural bypassing trend rate had increased to around 124,000 m<sup>3</sup>/yr but has reduced to 49,000 m<sup>3</sup>/yr, averaged over the period from 2001 to 2024. The average annual rate of entrance dredging over the period from 2001 to 2024 was 115,000 m<sup>3</sup>/yr. Over the recent period where dredging has recommenced (2016 to 2024) the average annual rate of entrance dredging was 122,000 m<sup>3</sup>/yr.

## Recommendations

Despite the recently below trend longshore transport and the re-commencement of entrance dredging, the assessed LTA rate has remained relatively stable since the 2015 re-assessment. The 2025 re-assessment LTA best estimate is 500,000 m<sup>3</sup>/yr ( $\pm 20,000$  m<sup>3</sup>/yr), comprised of bypass pumping at around 425,000 m<sup>3</sup>/yr and bypass dredging of around 75,000 m<sup>3</sup>/yr. These LTA components are based on the re-assessed long-term transport into Letitia Spit of approximately 550,000 m<sup>3</sup>/yr and a natural bypassing rate of approximately 50,000 m<sup>3</sup>/yr.

Climate change has the potential to drive long-term impacts on longshore sediment transport supply into Letitia Spit. At the same time, future Sea Level Rise projections are likely to create additional demand for sand supply to maintain existing levels of amenity along the Gold Coast beaches. The Tweed Sand Bypassing project will operate into the future in the context of these evolving climate change pressures.

The monitoring to date has been comprehensive and invaluable as a data source for this reassessment of the LTA and should be continued at the present level of detail and frequency in order to maintain suitable and sufficient accuracy and reliability for future reassessments. Large Tweed River flood events in 2016 and 2022 exported significant volumes of sand from the river and highlighted the need for ongoing regular surveys of the lower Tweed River in order to track the sand exchange between the estuary and the littoral system.

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# 1 Introduction

## 1.1 Background

### 1.1.1 Overview

BMT has been commissioned to undertake an updated reassessment of the Long-term Average (LTA) sand transport rate to the end of 2024 for the Tweed Sand Bypassing Project. This has been completed using the same strategy and similar analysis parameters as for the previous 2020, 2015 and 2009 reassessments. The focus of the study is on the LTA and its component processes of longshore littoral sand transport and natural bypassing to Queensland beaches, incorporating analysis and review of resulting coastal changes along both the Letitia Spit/Tweed River entrance area and the downdrift southern Gold Coast beaches.

At the time of this 2024 reassessment, the sand bypassing system has been in operation since April 2001, with over 23 years of operational experience and considerable monitoring data available. Prior to commencement of the sand bypassing operations, initial Stage 1 dredging that commenced in 1995 was used to transfer sand accumulated at the Tweed River entrance to Queensland. In the first six annual periods, a higher rate of bypassing was implemented to include the Supplementary Increment as required. Since 2007, the rate of bypassing has operated broadly in line with the requirement to match the LTA quantity.

This report sets out the results of the reassessment to the end of 2024, including discussion of the strategy and updated information on the coastal processes relating to the LTA and natural bypassing from NSW to Qld. Discussion of the key issues and uncertainties in the analyses are presented.

### 1.1.2 Project History

The Tweed Sand Bypassing Project (previously Tweed River Entrance Sand Bypassing Project – TRESBP) is a joint initiative of the New South Wales and Queensland state governments to maintain a navigable entrance to the Tweed River and provide an ongoing supply of sand to the southern Gold Coast beaches. The project has been ongoing for approaching 30 years, marked by the milestones in Table 1.1.

The Project officially commenced in 1995 with the Stage 1A dredging of 2.25M m<sup>3</sup> of sand from the Tweed River entrance and placement between Point Danger and Kirra, followed by a smaller scale Stage 1B dredging of 0.8M m<sup>3</sup> between 1997 and 1998. Stage 2 of the project was subsequently awarded as a Design and Construct contract to McConnell Dowell and commenced with entrance dredging in 2000 and commissioning of the sand bypassing jetty system in March 2001. Since then sand bypassing has continued through pumping supplemented by intermittent dredging campaigns.

Table 1.1 Tweed Sand Bypassing Project Milestones

Date	Project Milestone
1995-1996	TRESBP Stage 1A dredging
1997-1998	TRESBP Stage 1B dredging
2000-ongoing	TRESBP Stage 2.
March 2001	TRESBP Stage 2 jetty commissioned.
October 2024	Project operations transferred to government

Over the Project duration the sand bypassing operations have progressed through a number of distinct operational “epochs”, which are referred to in this (and previous) LTA assessments and reporting. These epochs and previous LTA reports are summarised in Table 1.2.

Table 1.2 Tweed Sand Bypassing Project Epochs

Project Epoch / LTA Report	Overview
1995-2000	TRESBP Stage 1A/1B dredging.
2001-2007	TRESBP Stage 2 jetty commissioned. Supplementary increment period.
2001-2009	Stage 2 period of high total bypassing (pumped and dredged) primarily due to supplementary increment.
2011	First LTA report (BMT WBM, 2011), covering period from 1995 to 2009.
2009-2015	Reduced rate of jetty bypassing and no entrance dredging. Period between first and second LTA reports.
2016	Second LTA report (BMT WBM, 2015), extending analysis period to 2015.
2016-2024	Period between second and fourth (this) LTA reports. Entrance dredging re-instated in 2016. Major Tweed River floods occur in 2017 and 2022.
2020	Third LTA report (BMT, 2019), extending analysis period to 2019.
2024	Fourth LTA report (this report), extending analysis period to 2024.

### 1.2 Project Objectives

Under the Deed of Agreement (DOA), the LTA is defined 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”.

In summary, the LTA is the quantity of sand required to be bypassed over the longer term by use of the TSB jetty mounted pumping system and entrance dredging. The LTA may be expressed as the long-term average of:

The LTA may be expressed as the long-term average of:

**Natural net longshore sand transport at Letitia Spit – Natural bypassing to southern Gold Coast**

Each of these transport components varies from year to year and the requirement to bypass the LTA is achieved through annual bypassing of the LTA as defined above as best assessed for, and during, the annual period.

While the LTA may be adopted as the target quantity for TSB sand transport at the beginning of the annual operational period, it is the actual varying quantities as above that become the operational target for transporting by the pumping and dredging system during the year.

Furthermore, the natural bypassing to Gold Coast depends intimately on the nature and effectiveness of the sand bypassing system operations, as well as the net sand transport along Letitia Spit.

Neither of the transport rates that define the LTA can be measured directly. They must be determined from other factors that have been measured in the extensive monitoring program implemented to date and/or by suitable and sufficient modelling analysis of the component sand transport rates.

The 1995 Deed of Agreement specified that re-assessment of the LTA should happen at 10 year intervals, or more frequently. This report represents the fourth re-assessment of the LTA (Table 1.2).

### 1.3 Study Scope

The aim of the study is to reassess the Long-term Average Annual Net Sand Transport Rate (LTA) in the most comprehensive and meaningful way feasible to the extended date of October 2024 taking maximum advantage of the data and knowledge now available. More broadly, the study also aims to advance the present status of knowledge of the sand transport processes relating to the LTA for application to ongoing management of the bypassing system.

This latest LTA reassessment study covers the Tweed Sand Bypassing Project area as defined in the Exhibit 10 (Placement) and Exhibit 11 (Removal) figures, shown in Figure 1 1 and Figure 1 2 respectively. The study considers the Project period from prior to Stage 1A in 1995 to the end of the 2024 calendar year.

The study outcomes thus include detailed analysis of the LTA component processes as defined in the Deed of Agreement and related processes of the bypass pumping and dredging and net changes in coastal compartment quantities both annually and over the longer term. In particular, the inter-active causes and effects between these processes are identified within the limits of feasible accuracy.

Further, the study seeks to provide information on prevailing trends in the processes and LTA to assist in future management of the system.

### 1.4 Report Outline

- Chapter 2 provides describes the detailed methodology for the LTA re-assessment.
- Chapter 3 details the pumping and dredging operations undertaken by the project since 2001.
- Chapter 4 presents and discusses the changes in sand quantities within the various compartments along Letitia Spit and around the entrance area surveyed as part of the monitoring of the bypass system operations.
- Chapter 5 presents the results of Longshore sand transport rate calculations for the study area.
- Chapter 6 details the results of the LTA analysis, including assessment of the rate of natural bypassing across the NSW/Qld border.
- Chapter 7 discusses the re-assessment results in the context of the project objectives.

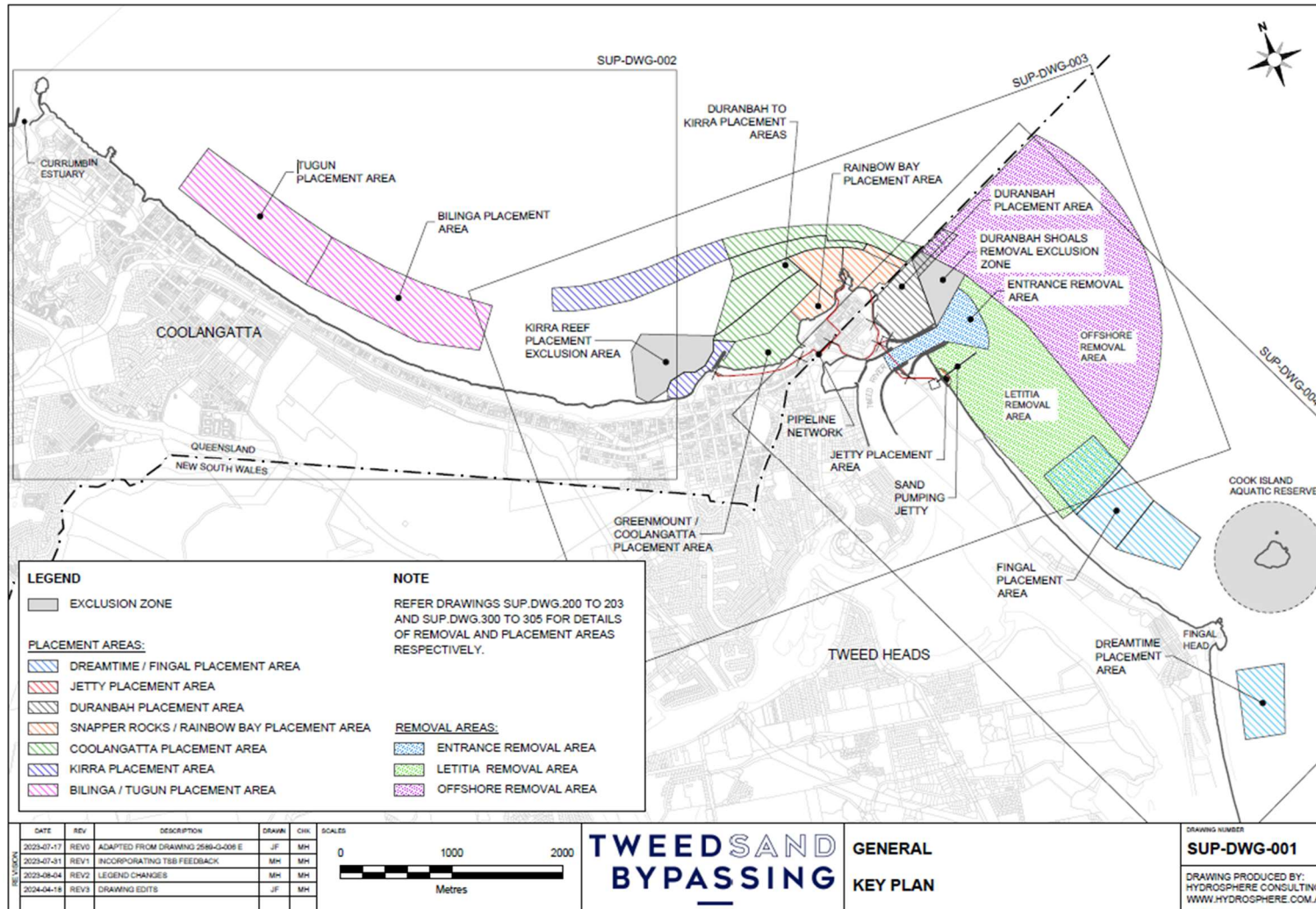


Figure 1.1 Tweed Sand Bypassing Project Area (Key Plan)

## 2 LTA Re-assessment Methodology

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### 2.1 Introduction

There is a direct relationship between the LTA and the way in which the sand bypass system is operated, since the operations and efficiency of the system affect the nature and extent of any natural bypassing. Broadly, the average annual target delivery by the system (pumping plus dredging quantity) should equal the LTA under the Deed of Agreement (DOA). By 2025, the sand bypass jetty system has been operating for nearly 24 years.

The LTA reassessment strategy pursued in this study is the same as that implemented in the previous reassessments. It is based on time series (monthly/annual) analysis of the LTA components (refer Section 1.2) over the 2001-2024 period of sand bypass operations together with the longer context of the previous dredging that commenced in 1995 and the surveyed changes in sand quantities since 1993.

The general approach adopted involves consideration of the whole range of available data and information of relevance and significance to quantifying the processes that have taken place to date. While it is recognised that individual theoretical calculations and/or monitoring data sets are subject to errors that need to be understood and dealt with appropriately, the overall sediment budget comprising inputs, outputs and quantity changes within designated control volumes need to be consistent. Both local and regional sand budgets need to make consistent sense temporally and spatially in quantifying the LTA components. Accordingly, this study is based on applying a consistent LTA calculation methodology from 1993 to present day, as described below.

### 2.2 Relevant Datasets

#### 2.2.1 Monitoring Program Surveys

Comprehensive survey monitoring has been undertaken as part of the Tweed Sand Bypassing project since 1995, commencing with the Stage 1 initial dredging undertaken at that time to restore sand quantities to Queensland and establish improved Tweed River entrance navigation conditions. These surveys follow and augment surveys undertaken by the Queensland Beach Protection Authority since 1966 and City of Gold Coast for monitoring of beach nourishment programs.

The surveys have been carried out regularly, at least once per year, and analysed by Tweed Sand Bypassing in terms of sand quantity changes along the section of coast from Fingal to Currumbin and shifts in the location of the shoreline and various contours along Letitia Spit. While the surveys prior to 2000 are not as comprehensive in their spatial extent as those since then, useful survey information is available for dates up to December 2024, within the various analysis compartments outlined in Section 2.5.

Additionally, surveys have been undertaken of the quantities of sand within the Tweed River to identify changes associated with movement of sand to or from the river reaches. Those surveys that comprehensively cover the whole system (Figure 2 2), including the entrance area, extend over the period since February 2000, showing a gradual reduction (export) of sand. Allowance has been made for channel maintenance dredging within the Tweed River compartments, such that any quantities removed by dredging are not included as a quantity being naturally exported to the offshore littoral system.

### 2.2.2 Tweed Sand Bypassing Pumping and Dredging

Monthly jetty pumping volumes for since March 2001 is collated and published on the Tweed Sand Bypassing project website (<https://www.tweedsandbypass.nsw.gov.au/>). The volumes are provided for each system outlet location (Duranbah, Snapper Rocks East, Kirra, Greenmount and Snapper Rocks West). Since 2004, only the Duranbah and Snapper Rocks East outlets have been utilised.

Tweed River entrance dredging volumes and placement locations have also been tracked monthly since April 2000 and are published on the project website. The designated placement areas referred to in the dredging quantity summary are shown in Figure 1.1. Since 2019 these include compartments for backpassing to Letitia Spit and Dreamtime beach.

### 2.2.3 Wave Data

Directional wave data is used in this study to calculate longshore transport rates at Currumbin and Letitia Spit. The data summarised in Table 2.1 has been collated for use in this study. The wave data is generally supplied with a 30-minute frequency.

Table 2.1 Directional Wave Data

Location	Data Period	Depth (m)	Capture (%)	Use in this study
Tweed Heads	1995-01 to 2025-01	22	92.1	Primary offshore dataset, intermediate depth
Gold Coast	2007-07 to 2025-01	17	97.4	Secondary offshore dataset used for gap filling
Point Lookout (Brisbane)	1996-11 to 2025-01	70	95.5	Deep water dataset
Tweed Offshore	2020-02 to 2025-01	60	98.2	Deep water dataset
Bilinga	2021-05 to 2025-01	18	99.5	
Palm Beach	2017-07 to 2024-09	23	99.3	

### 2.2.4 Other Datasets

In addition to the primary datasets used in undertaking the LTA Re-assessment the following data has been provided to support interpretation and reporting:

- Aerial imagery
- Tweed Jetty data
- Monthly longshore transport rates at Letitia Spit calculated independently using Litpack software

### 2.3 LTA Definition and Calculation Approach

Under the Deed of Agreement, the LTA is given as the long-term average annual value of:

#### Natural net longshore sand transport at Letitia Spit – Natural bypassing to southern Gold Coast (1)

Each of these transport rates varies from year to year. Neither of these transport rates can be measured directly and must be determined from other factors that have been measured in the extensive monitoring program implemented to date and/or calculated from theoretical modelling.

If it is assumed that all sand pumping/dredging, including that placed at Duranbah, is effectively delivered directly to Queensland, then consideration of the sand budget for Letitia Spit plus Duranbah (Figure 2.1) shows that:

$$\text{Net Quantity Change} = \text{Transport in} - \text{Natural Bypassing} - \text{Sand Pumping/Dredging} + \text{River supply}$$

Re-arrangement thus gives, considering long-term average values:

$$\text{LTA} = \text{Transport in} - \text{Natural Bypassing} \tag{1a}$$

$$\text{LTA} = \text{Pumping/Dredging (total)}^* + \text{Net Quantity Change}^{**} - \text{River/offshore supply} \tag{1b}$$

\* Pumping/Dredging (total) is the amount removed from NSW compartments and transferred to Queensland or Duranbah, i.e. not including backpassing quantities.

\*\* Net Quantity Change is total change in the New South Wales compartments including Duranbah.

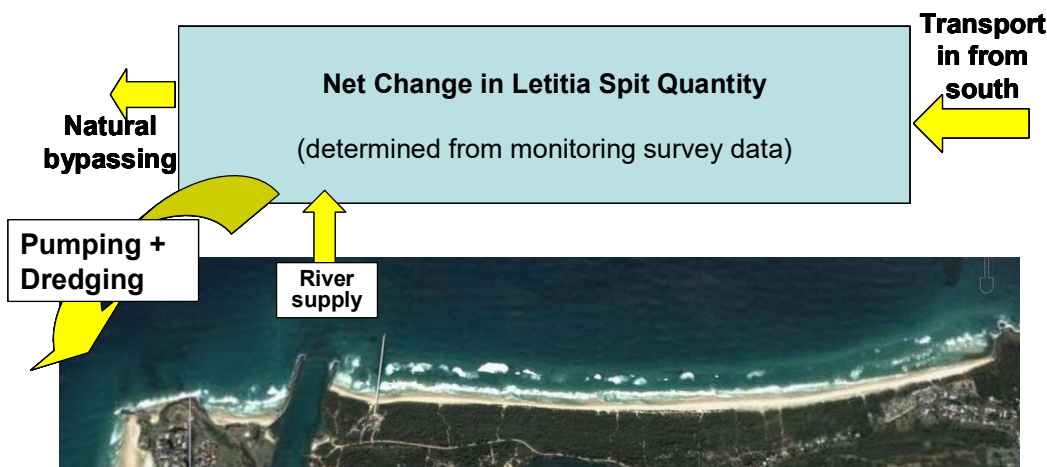


Figure 2.1 Conceptual sand budget for Letitia Spit

As such, assessment of the LTA may be achieved directly from the bypass system sand delivery records and measured survey data using equation (1b), at least as averaged over the period of available monitoring data, provided the quantity calculation compartments are chosen such that the transport in along Letitia Spit is sufficiently compatible with that at the location defined in the Deed of Agreement (DoA), that is 1 km south of the Tweed River entrance southern training wall, and importantly satisfies the “...absence of any artificial actions to influence it” requirement.

The variability of the progressive annual components of the (Transport in – Natural Bypassing) rates over the period of operation to date may be determined by analysis of the annual records of pumping/dredging sand delivery and the net quantity change along Letitia Spit. An estimate of the LTA may be made on the basis of averaging these annual components, provided:

- The annual periods used correspond to periods when the objectives of both states are met; and
- The period involved is sufficiently long.

### 2.4 Natural Sand Bypassing to Queensland

The total sand supply to the Queensland beach system will include that sand transported by waves and currents as natural bypassing in addition to the sand pumped and dredged directly to Queensland or via Duranbah as part of the bypass system pumping/dredging operations and previous dredging activities. The location of natural bypassing is taken as the alignment of the NSW-Qld border, consistent with the provisions of the DOA.

It is likely that there was significant natural bypassing of sand prior to and during the initial stages of the Stage 1 dredging and into the early period of the sand bypass system operations. Investigations prior to the works (Roelvink & Murray 1992) indicate that, at that time, the rate of natural sand bypassing of Point Danger was about 350,000-400,000 m<sup>3</sup>/yr. This would have been slowly increasing at the time, but probably would have reduced as dredging commenced and the flow of sand from the south was intercepted.

Using the sand budget as illustrated in Figure 2.2, together with adjustment for the fact that not all of the transport across the NSW/Qld border is ‘natural bypassing’ but results from sand bypassed to Duranbah, quantification of the natural bypassing of sand can be achieved on the basis of the available monitoring survey data to quantify the net benefit to the southern Gold Coast area, together with:

- The known pumping and dredging quantities, and
- Knowledge of the longshore transport out to the north at Currumbin.

This leads to Equation (2a).

$$\text{Natural Bypassing} = \text{TranCurrumbin} + \Delta Q (\text{Qld})^* - \text{Sand Pumping/Dredging (total)}^{**} \quad (2a)$$

\*  $\Delta Q (\text{Qld})$  is the total volume change in the Queensland compartments (does not include Duranbah).

\*\* Sand Pumping/Dredging (total) is the amount removed from NSW compartments and transferred to Queensland or Duranbah, i.e. not including backpassing quantities.

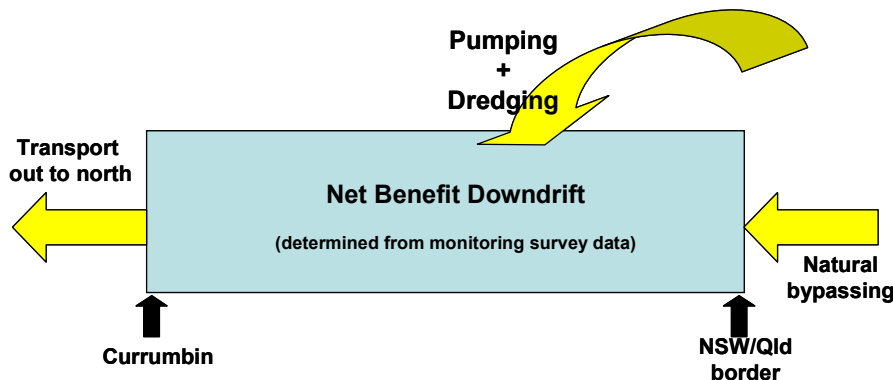


Figure 2.2 Conceptual quantification of natural bypassing

The total sand transport past the NSW/Qld border is the ‘natural bypassing’ plus the sand placed at Duranbah, for reasons outlined above, and is given by Equation 2b in which the Pumping/Dredging quantities are those delivered directly to Queensland and exclude the placement at Duranbah.

$$\text{Total transport at NSW/Qld border} = \text{TranCurrumbin} + \square Q (\text{Qld}) - \text{Pumping/Dredging (Qld)}^* \quad (2b)$$

\* Sand Pumping/Dredging(Qld) is the amount removed from NSW compartments and transferred to Queensland, excluding amount placed at Duranbah or any backpassing quantities.

For this analysis, the net sand transport out to the north at Currumbin over the years covered by the monitoring is needed. It varies continuously with the incident wave conditions and has to be determined by theoretical means using the available directional wave data and conventional wave propagation and longshore transport calculation procedures.

## 2.5 Survey Analysis Compartments

Sand quantity analyses have been undertaken by Tweed Sand Bypassing to determine progressive changes within various compartments within the overall study region from Fingal to Currumbin. Those compartments are shown in Figure 2.3 and have been used in the present study either separately or in combination for the purpose of LTA and sand transport calculations.

Tweed River surveys have been analysed to derive source/sink quantities associated with movement of sand between the river reaches and the coastal littoral system. The survey analysis compartments shown in Figure 2.4 cover the whole lower estuary system. Allowance has been made for channel maintenance dredging within the Tweed River compartments, such that any quantities removed by dredging are not included as a quantity being naturally exported to the offshore littoral system.

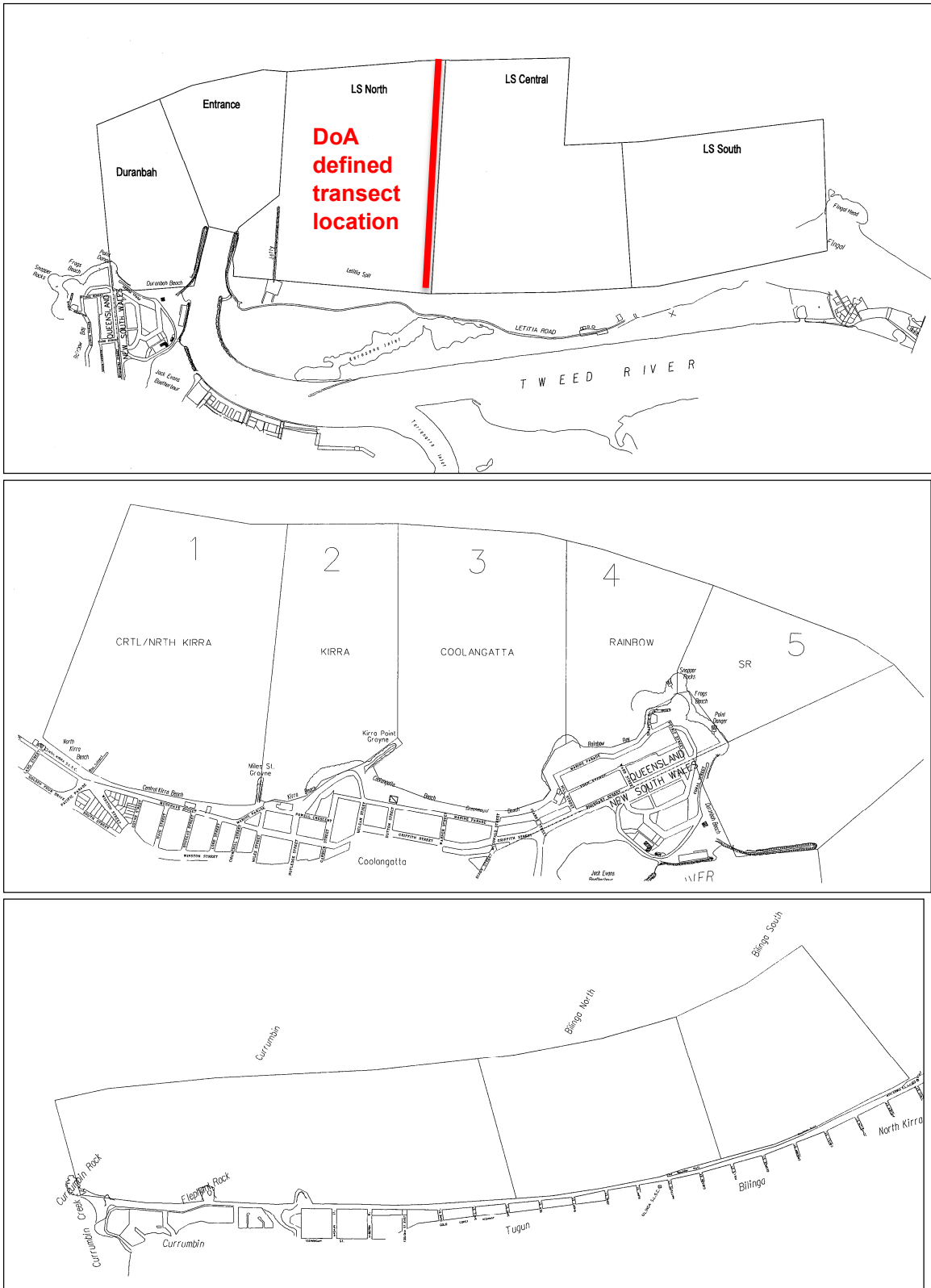


Figure 2.3 Sand quantity calculation compartments

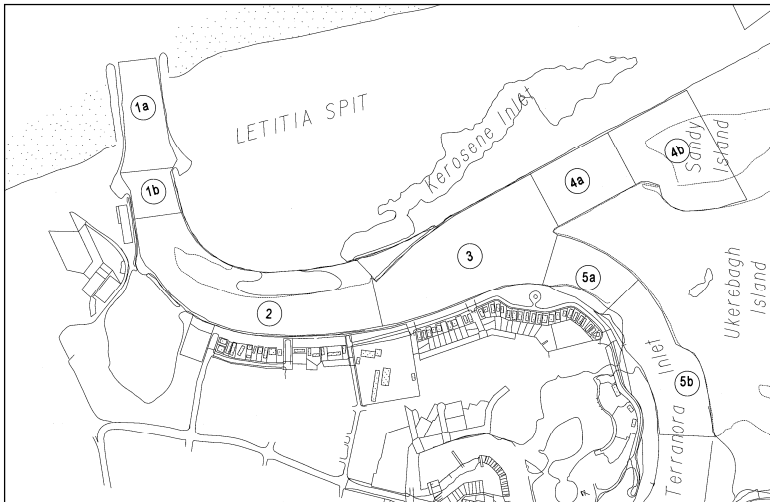


Figure 2.4 Survey compartments within Tweed River

## 2.6 Calculation of Longshore Sand Transport Rates

Longshore sand transport rates have been calculated using two systematic approaches, namely:

- Theoretical analysis based on recorded directional wave data with wave propagation and sand transport modelling; and
- Analysis of the incremental rates into each of the survey compartments along the entire study area based on sand budget considerations.

### 2.6.1 Theoretical Calculations

Theoretical calculations of longshore sand transport rates directly from the recorded Tweed directional wave data, from which monthly and annual average rates were derived. These calculations were undertaken for a cross-shore transect at Currumbin which was used as a sand budget model “boundary condition”. A longshore sand transport timeseries was also derived for a Letitia Spit location about 1,000 m south of the river entrance, which was used for comparison with the derived sand budget rates at the same location.

Reference is made to BMT WBM (2011) for a detailed description of the wave climate and the SWAN wave propagation model(s), validation and analysis used in that study and incorporated again in this reassessment.

Directional wave recording undertaken at the Tweed Waverider location since 1995 represents the longest available comprehensive data set for the region. The Tweed site was chosen to be sufficiently inshore to avoid the need for wave transformation past the Fingal Reef, while sufficiently offshore to be applicable along much of Letitia Spit and the Tweed River mouth area. As such, it does not represent deep water conditions, but is directly applicable as the basis for LST calculations at both Letitia Spit and, via transformations based on SWAN propagation modelling, at Currumbin.

The previous BMT WBM (2011; 2016; 2020) reassessments reviewed both CERC formula (US Army Corps of Engineers 1984, 2002; Smith et al 2003) and the ‘Queens’ formula (Kamphuis, 1991) for deriving theoretical LST rates at Currumbin and along Letitia Spit. The review concluded that both of these formulations are mathematically very similar and yield essentially the same results when they are “calibrated” to available site-specific information regarding transport rates (BMT WBM, 2011). The

'Queens' formula (reproduced below) has been adopted as the consistent methodology for application in this (and previous) LTA re-assessments.

**Queens**      
$$Q_l = K_q \left[ \frac{\rho}{\rho_s(1-n)} \right] L_o^{1.25} T_p^{-1} H_b^2 m_b^{0.75} D_{50}^{-0.25} \sin^{0.6}(2\alpha_b)$$

where:

$K_q$  = Coefficient typically (approx 1.33 for m<sup>3</sup>/s or 41×10<sup>4</sup> for m<sup>3</sup>/yr)

$H_b$  = Breaking significant wave height

$L_o$  = Offshore wave length

$T_p$  = Spectral peak energy period

$\rho_s$  = Density of sediment

$\rho$  = Density of water

g = Acceleration of gravity

n = Sediment porosity

$\alpha_b$  = Wave breaking angle

$m_b$  = Nearshore profile slope (constant value)

$D_{50}$  = Median sediment grain size

### 2.6.2 Sand Budget Calculations

The incremental LST rates derived from sand budget considerations, utilising the surveyed quantities together with known dredging and pumping rates and the calculated LST rates at Currumbin, are based on the conceptual considerations illustrated in Figure 2.5. The LST rates for Letitia Spit and the entrance area are calculated from sand budget components as shown in Figure 2.6. These calculations are performed on a monthly timestep by interpolating volume change quantities derived from less frequent (approximately 6-monthly) surveys.

The LST rates derived in this manner are inclusive of all longshore transport processes, including the cross-embayment pathway which is active within the southern Gold Coast embayment (Jacobs, 2017, 2019).

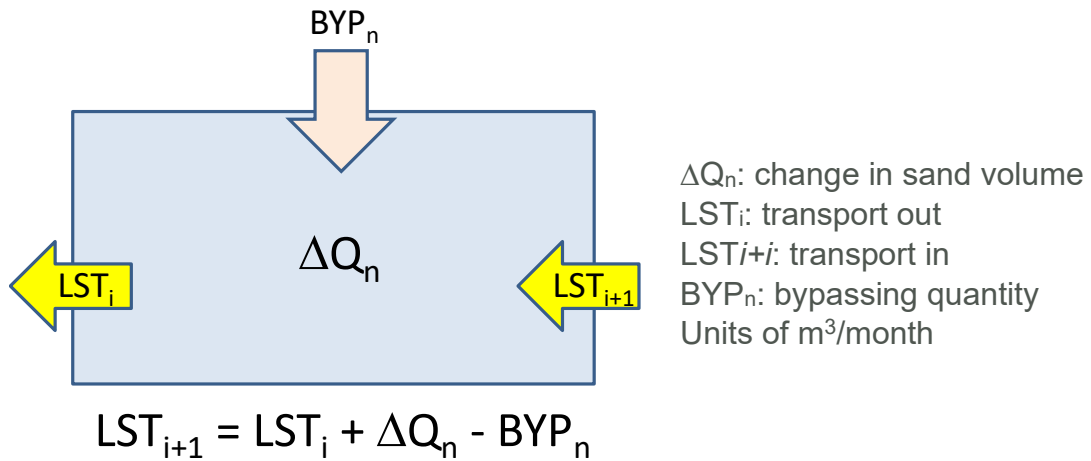


Figure 2.5 Conceptual sand budget for LST calculations

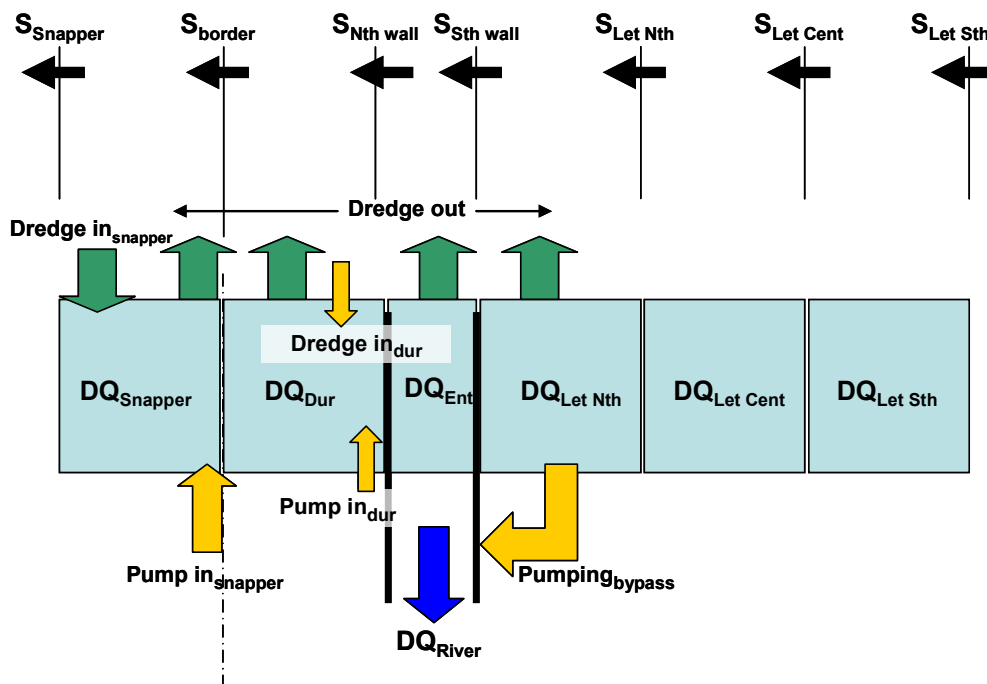


Figure 2.6 Conceptual sand budget for Letitia transport calculations

The Letitia Spit rates of transport have been affected to varying degrees by the bypass dredging and pumping operations. Only the transport at Letitia Sth might be reasonably consistent with that occurring “in the absence of any artificial actions to influence it” as per the LTA definition. That is, apart possibly from Letitia Sth these rates cannot be used directly in the LTA calculation. Some adjustment for the effects of the pumping and dredging operations on the shoreline alignment would need to be made if they are to be used in that way.

## 2.7 Uncertainty and Calibration Issues

There are uncertainties and error margins in the calculation of the LTA and the sand transport rates. In principle, errors may be introduced through:

### Surveyed quantities (Level 1 certification):

- Systematic errors such as incorrect datum correction or equipment calibration;
- Random errors in taking each depth sounding;
- Spatial sampling error if the survey coverage is insufficiently refined.

### Sand bypass system quantities:

- Systematic errors in sediment concentration and/or flow measurements in the bypass jetty delivery system;
- Errors in estimating the equivalent sand volumes in the dredge hopper.

### Longshore transport calculated from wave data:

- Random errors in wave data sampling;
- Wave data deficiency in representation of coexistent wave trains as a single height, period and direction combination based on the spectral peak values;
- Systematic error inherent in the wave transformation analysis;
- Errors in the theory for predicting breaking wave conditions;
- Systematic error inherent in choice of representative shoreline alignment;
- Error in the theory for calculating sand transport;
- Calibration error.

The sensitivity of the LTA to such errors together with calibration of the coefficients in the sand transport calculation relationships involved have been taken into consideration in the assessments made. Broadly, the transport rates derived need to fit consistently with sand budget quantities measured and calculated, providing a basis on which the LTA and sand transport rates may be correlated and rationalised.

The LTA may be estimated directly from the survey data and sand bypass operations (pumping and dredging) quantities via Equation 1b. As such, the potential error in the LTA is subject only to the errors in the quantities derived from the surveys and bypassing system. Considerable design control has been incorporated in measuring the pumping and dredging quantities and it is expected that errors in those quantities are relatively minor, though not able to be quantified. Survey quantity errors ( $\pm 0.15$  m according to survey contract) are likely to be significant but are random rather than cumulative. Thus, these errors will become relatively less significant when averaged over a progressively longer time-frame. As of the 2024 re-assessment, the LTA estimate is based on sand budget analysis over a 30-year timeframe and the potential error attributable to survey inaccuracy is estimated to be less than  $\pm 5\%$ .

Any gross survey errors may be identified by reviewing the time-series of quantities within each compartment, with changes in areas subject to major extraction or placement of sand more directly related to those activities, whereas more remote areas experience slower progressive change. Review of the survey quantities has been undertaken in this manner and some discrepancies identified and corrected, mainly by applying a smoothing of change trends. This smoothing is only significant at the monthly analysis timescale and is not expected to have a significant bearing on the cumulative LTA estimate.

A relatively minor but significant loss of sand to deep water beyond the limit of the calculation compartments in the vicinity of the river entrance was identified and has been accounted for in the assessments undertaken. The 2024 LTA re-assessment has assumed that the rate of loss of sand to deep water has continued at the same rate as previously assessed in 2015.

Determination of the component sand transport and natural bypassing rates is dependent on theoretical calculation of sand transport from the wave data for at least one location. Currumbin, at the northern end of the study area (Figure 2.3), is considered the most suitable location for the reference calculations because it is a relatively exposed site for wave propagation and is not subject to significant natural changes in shoreline alignment or sand transport process anomalies that may be affected by the sand bypass system operations.

There will be error in the calculated sand transport at Currumbin for the reasons outlined above. However, systematic error there should be acceptably minimal provided wave propagation to the site is sufficiently reliable and sand transport relationship coefficients are suitably calibrated. Considerable previous investigation including the 2009/15 LTA reassessments (BMT WBM 2011; 2016) has shown the longer term annual average net transport to be about 500,000 m<sup>3</sup>/yr or possibly up to 550,000 m<sup>3</sup>/yr. The methodology used in the previous LTA reassessment has been applied again in this extension of the reassessment to the end of 2024.

## 2.8 Changes from 2020 Assessment

The 2024 LTA assessment has maintained a consistent approach with the 2020 and earlier assessments, however the analysis has been migrated to a Python-based solution for the most recent assessment. The key changes of the 2024 LTA assessment are:

- Longshore transport calculations performed at the input wave data frequency (30-minutes) before being aggregated to monthly
- Minor changes to manual survey adjustments included in previous assessments
- Manual adjustments of Tweed River survey volumes before and after the 2017 and 2022 floods to avoid sand budget calculation “aliasing” errors
- Calculations updated to flexibly handle backpassing operations and separately report “Total Pumping and Dredging” and “Delivery to Queensland”
- 2001 baseline date has been adopted as 1 April 2001 in order to be consistent with project milestones (calculations previously assumed 1 January 2001)

## 3 Pumping and Dredging Rates

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### 3.1 Stage 1 (1993 to 1998)

Stage 1 initial entrance dredging that commenced in 1995 aimed at achieving a baseline start point for the bypassing. Stage 1A dredging involved initially 2.25M m<sup>3</sup> sand from April 1995 to August 1996 and then a further 800,000 m<sup>3</sup> from September 1997 to May 1998, transferred from the river mouth to the Gold Coast beaches. A further Stage 1B dredging transferred an additional 800,000 m<sup>3</sup> of sand from the mouth to the nearshore areas to augment Stage 1A. The total Stage 1 dredging volume was 3.05M m<sup>3</sup>.

### 3.2 Stage 2 (2000 to Ongoing)

The history of bypassing and dredging rates since January 2000 is shown in Figure 3.1. The years from 2001 to 2007 included the Supplementary Increment above the LTA and transfer of sand to Queensland was undertaken through a combination of pumping and entrance compartment dredging.

As of the end of December 2024 the total volume of sand pumped since 2001 was 12.0M m<sup>3</sup> at an average rate of 503,000 m<sup>3</sup>/yr. From 2007 the average pumping rate has been 451,000 m<sup>3</sup>/yr.

From April 2000 to September 2007, which included the Supplementary Increment period, dredging removed 2.06M m<sup>3</sup> at an average annual rate of 275,000 m<sup>3</sup>.

There was no significant dredging of the entrance from late-2007 to mid-2016, however maintenance campaigns have been reinstated since April 2016 in order to manage the volume of sand accumulating in the entrance compartment. Since April 2016 a further 1.10M m<sup>3</sup> has been dredged at an average rate of 125,000 m<sup>3</sup>/yr.

The 2019 dredge campaign was the first to undertake backpassing of sand from the entrance compartment to placement areas to the south along Letitia Spit or at Dreamtime beach. From July 2019 to December 2024, 150,000 m<sup>3</sup> sand has been backpassed at an average rate of 27,000 m<sup>3</sup>/yr.

As of the end of December 2024 the total Stage 2 dredging volume is 3.16M m<sup>3</sup>.

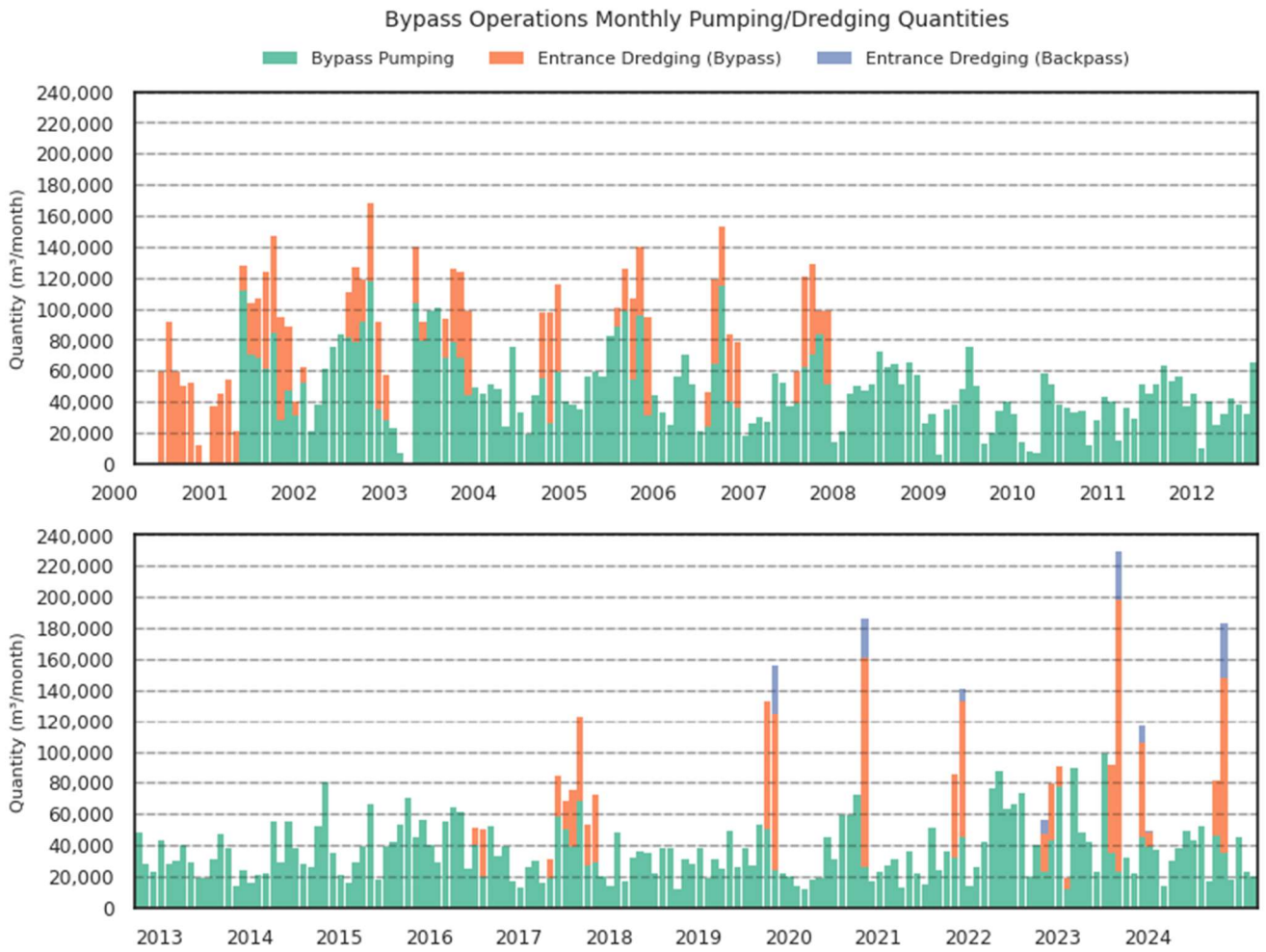


Figure 3.1 Bypass pumping and entrance channel dredging monthly rates

## 4 Sand Quantity Changes Derived from Surveys

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### 4.1 Survey Quantity Accuracy

By necessity, it is assumed for the purpose of the calculation of the LTA and natural bypassing that the quantities derived from the surveys undertaken are sufficiently accurate, within acceptable limits. However, errors may arise due to:

- Insufficient spatial resolution of the survey sampling; and/or
- Measurement error or inaccuracy.

Scrutiny of the sequential time series of sand volumes derived from the surveys is undertaken to ensure there are no anomalous individual surveys. As well, the volume trends are checked and smoothed as appropriate (where short-term fluctuations are evident) to minimise any impacts on the monthly transport rates derived. Overall errors in the quantities to be used for the LTA analysis will be minimised due to:

- The random nature of errors in individual depth readings associated with wave motion;
- The independence of measurements undertaken each day over the extended period of each survey exercise, leading to 'averaging out' of any systematic errors on any specific day; and
- The independence of each survey such that any errors in any survey will be offset over time.

Additionally, the progressive changes in the quantities derived for each compartment have been reviewed to identify and ensure close scrutiny of any apparent discrepancies. Several survey results were checked on that basis and some errors corrected. The compartment volume data show relatively smooth progressive changes in final total quantities, without any obvious 'random' variability from one survey to the next, with the significant short term variations clearly associated with dredging and placement events.

The analysis procedure may have some error due to occasional mismatches in the timing of surveys in the respective compartments, sometimes resulting from delays due to bad weather during the progress of the survey campaigns. This may result in sand identified in a compartment at one time moving into an adjacent compartment yet to be surveyed. While this is unavoidable, the monthly time series approach adopted for the analysis minimises the errors introduced.

### 4.2 Loss to Deep Water

Provision has been made in the sand budget analysis for a small but ongoing net loss of sand to deep water within the NSW compartments in the vicinity of the entrance at the varying rates (as above) determined from the survey data. The net rate of loss was previously estimated to have been about 18,000 m<sup>3</sup>/yr for the period 1993 to 2000, 12,300 m<sup>3</sup>/yr from 2000 to 2005 and only about 5,000 m<sup>3</sup>/yr from 2005 to date (refer Table 1.2 for project epoch context). The reducing trend since 2000 is likely related to a reduction in natural bypassing of the entrance as a result of the jetty system.

The ongoing rate of sand loss to deep water has not been re-evaluated in the 2024 LTA re-assessment as the regular surveys do not extend further offshore than the 20m depth contour. Due to its small relative magnitude, any inaccuracy in this quantity is not expected to significantly alter the LTA quantity estimate.

### 4.3 Monthly Time Series

#### Letitia Spit

There has been an overall reduction in volumes along Letitia Spit since the baseline survey of 1993, with key trends summarised below:

- An initial decrease by about 1.25M m<sup>3</sup> to 2008 at Letitia North followed by recovery and stabilisation back to a net loss of between 0.8 and 1M m<sup>3</sup> over the period from 2009 to 2025,
- A progressive loss of sand at Letitia Central after 2001 to about 1.5M m<sup>3</sup> by 2014, followed by stabilisation until 2025, albeit with minor periods of accretion and loss (2017 to 2023),
- A loss of about 0.3M m<sup>3</sup> at Letitia South prior to bypassing in 2001 followed by slow fluctuations with the lowest volume occurring around 2013 followed by a strong recovery of 0.5M m<sup>3</sup> to around 2001 levels by around 2019. This is followed by a period of accelerating loss before stabilising.

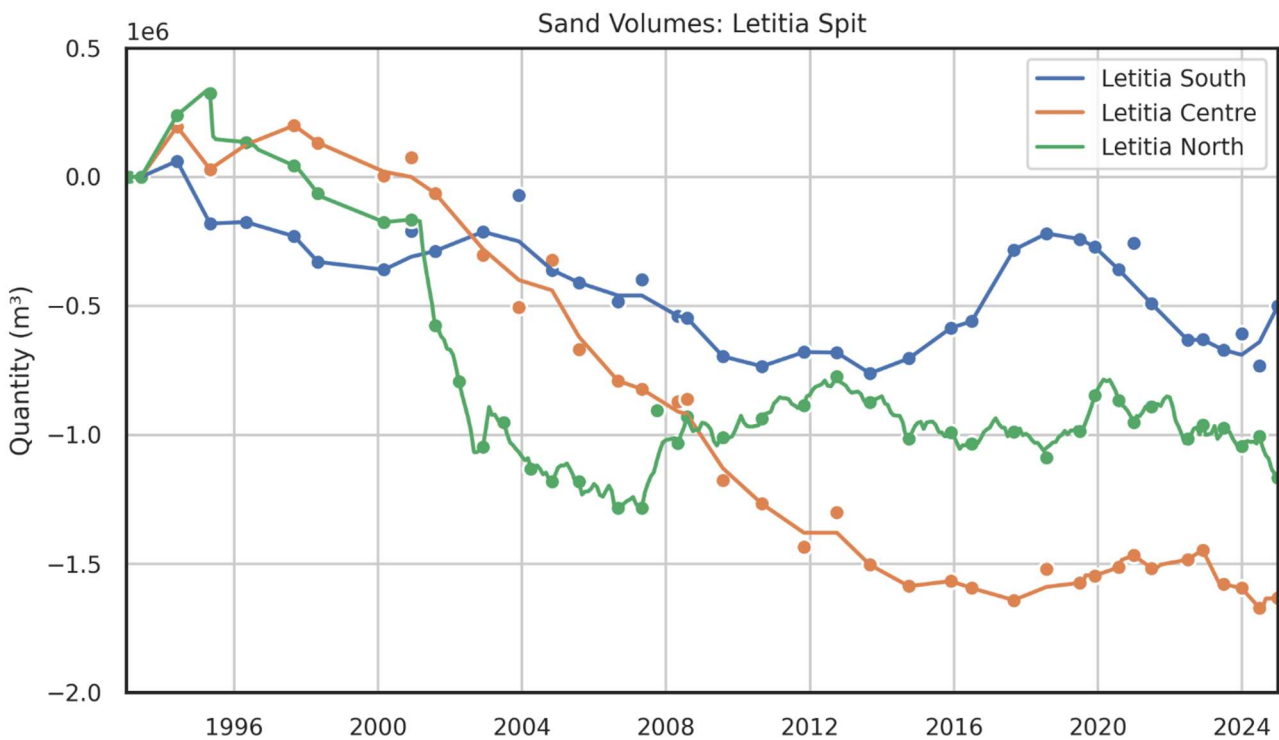


Figure 4.1 Sand volume changes along Letitia Spit

#### Tweed River and Entrance

- The significant reductions in entrance compartment sand volume associated with dredging within the compartment during 1995 to 1997 were followed by significant re-accumulation prior to bypassing.
- Subsequently since bypassing commenced in 2001 and particularly while entrance dredging did not occur from 2009 to 2016 the sand volume within the entrance compartment has steadily increased back to 1993 levels (0.6M m<sup>3</sup> above 2001 levels) by 2017.

- Reductions associated with recent entrance dredging campaigns are evident since 2017, however total volumes remain close to 1993 levels.
- Sand volumes in the River compartments have exhibited a slowly reducing trend since around 2003 and are presently around 0.75M m<sup>3</sup> below 1993 levels. Of particular note are the large losses in sand in the River compartment due to flooding associated with Ex TC Debbie (2017) and the 2022 ECL event.

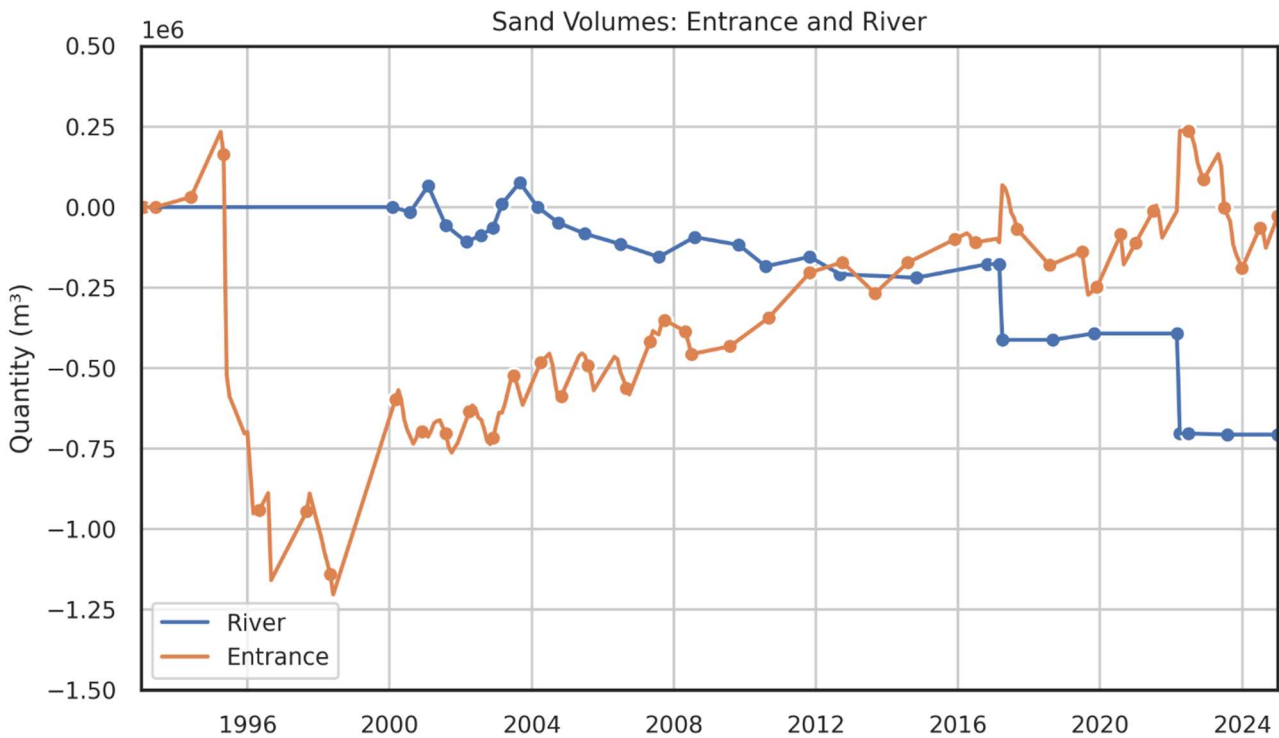


Figure 4.2 Sand volume changes at the Tweed River entrance

### Point Danger

The Duranbah compartment is included in NSW, while Snapper Rocks East is the southernmost compartment in Queensland. The following trends have been evident:

- The significant reductions in Duranbah compartment sand volume associated with dredging within the compartment during 1995 to 1997 were followed by rapid re-accumulation prior to bypassing.
- Volumes at Duranbah reduced again following commencement of Stage 2 dredging in 2000.
- Duranbah volumes have achieved a “dynamic” stability since around 2005.
- An overall negligible change in volume at Snapper East, following an initial slight increase prior to commencement of bypassing in 2001, a gradual decrease to 2012 and a stable trend since.

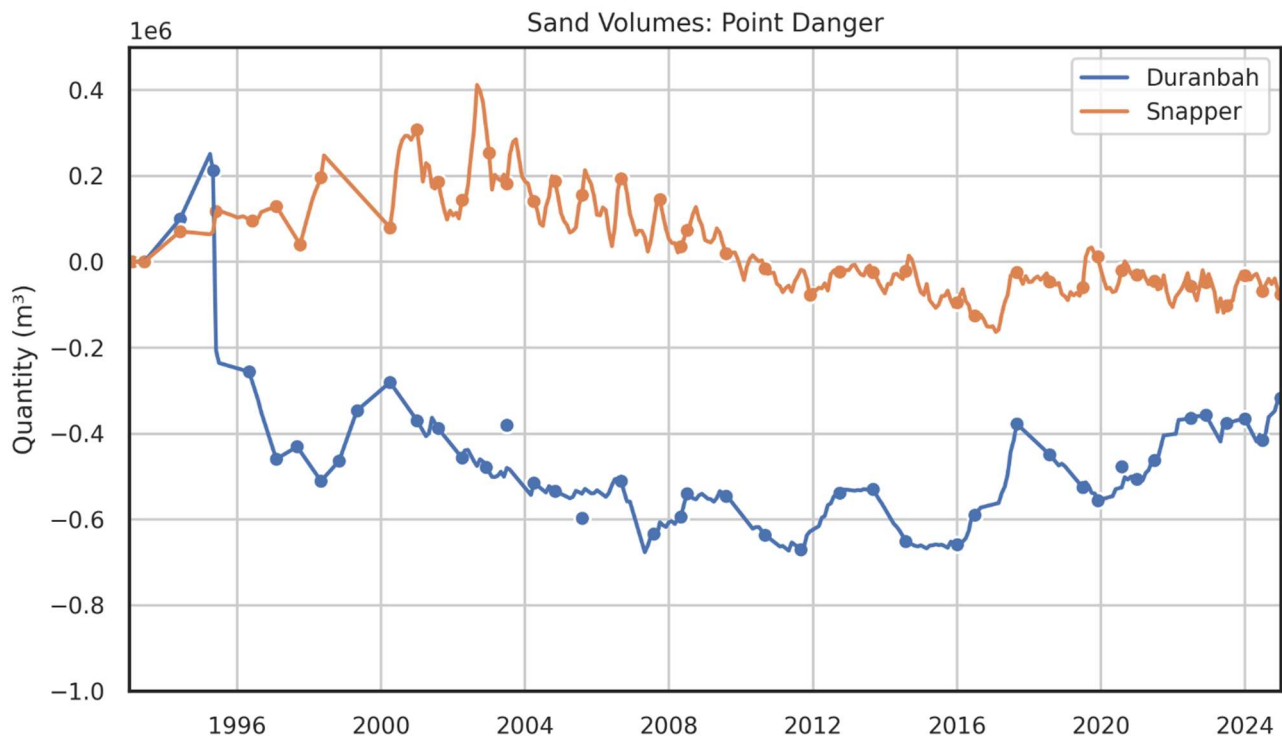


Figure 4.3 Sand volume changes at Point Danger

### Rainbow Bay to Kirra

The compartments from Rainbow Bay to Kirra are immediately north (downdrift) of the pumping system outlet at Snapper Rocks east and have been the main recipients of dredged sand placement. The volume trends in these compartments have therefore responded to the changing operations of the Tweed Sand Bypassing project from Stage 1 onwards:

- Substantial sediment volume gains associated with the Stage 1A dredge placement commencing in 1995.
- An initial rapid increase of about 1M m<sup>3</sup> at Rainbow-Coolangatta from 2001 to 2003 (following Stage 2 commissioning), followed by a steady reduction to 2017 and a more recent slight rebound such that the net change from 2001 to 2015 is a loss of about 0.3M m<sup>3</sup>, representing a net gain of about 0.7M m<sup>3</sup> since 1993.
- Reversal of the initial gains of sand after 2001 at Kirra and North Kirra, resulting in a small 0.1M m<sup>3</sup> reduction since 2001 at Kirra and a residual net change of 1M m<sup>3</sup> at North Kirra.

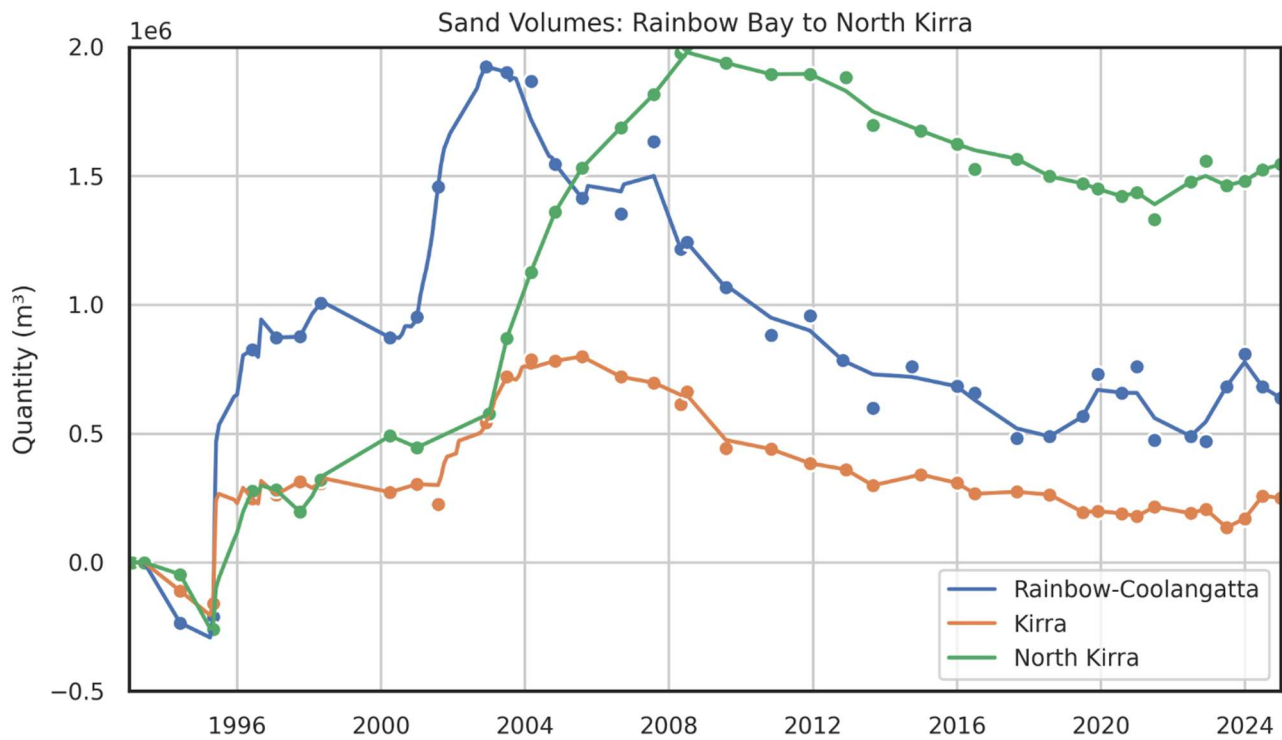


Figure 4.4 Sand volume changes Rainbow Bay to North Kirra

### Bilinga to Currumbin

The Gold Coast beaches from Bilinga to Currumbin have generally not received much in the way of direct sand placement from the Tweed Sand Bypassing project, however the compartment volumes have responded to the re-instated sand supply:

- Increases at South Bilinga evident from 2001 and stabilised by 2015 at around 1.4M m<sup>3</sup> above the 1993 volume.
- Accretionary response at North Bilinga evident from 2004 and stabilised by 2015 at around 0.9M m<sup>3</sup> above the 1993 volume.
- Accretionary response at Currumbin evident from 2008 and stabilised by 2015 at around 0.7M m<sup>3</sup> above the 1993 volume.

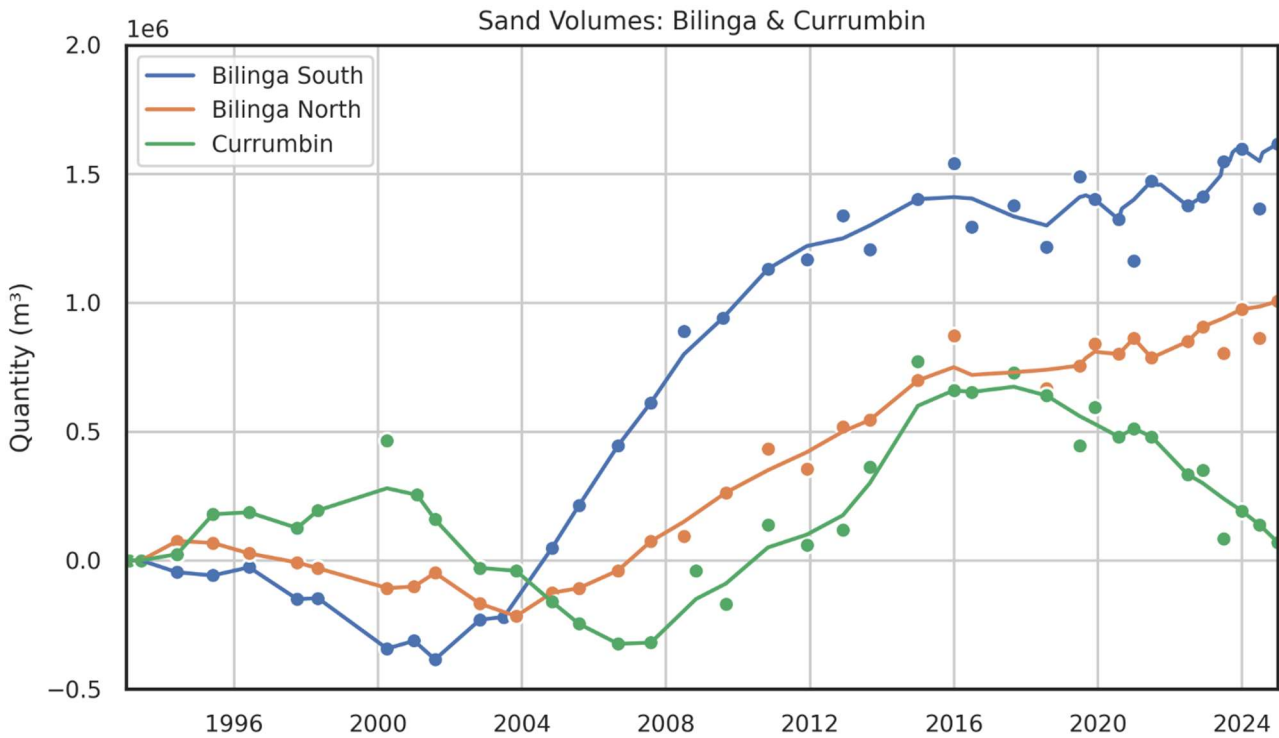


Figure 4.5 Sand volume changes Bilinga South to Currumbin

#### 4.4 NSW & Queensland Totals

The results of this analysis from the baseline survey of 1993 to December 2024 are shown in Figure 4.7 for the combined NSW compartments (top) and Queensland compartments (bottom).

The resulting total cumulative quantity changes since 1993 are shown in Figure 4.7. This figure illustrates the progressive reduction of a net quantity of approximately 3.47M m<sup>3</sup> from Letitia Spit and the entrance/river areas (including Duranbah) and a corresponding gain of about 5.02M m<sup>3</sup> to Gold Coast beaches. Notably, there is a 1.54M m<sup>3</sup> overall gain of sand volume in the study area from Fingal to Currumbin.

The progressively reducing trend in NSW and increasing trend in Queensland was clearly evident from 2001 and particularly through the Supplementary Increment period from 2001 to 2007. The rates of change can be seen to moderate with the reduced rate of bypassing from around 2009. Both the NSW and Queensland absolute change quantities have now reduced from peak levels which occurred around 2014/15, which is evidence that the system response to the introduction of bypassing has now reached a level of stability.

#### 4.5 Alongshore Distribution

The alongshore distributions of sand quantity changes for various dates since 1993 are shown in Figure 2-9 and again reflects the significantly greater retention of sand in Queensland than is depleted from NSW.

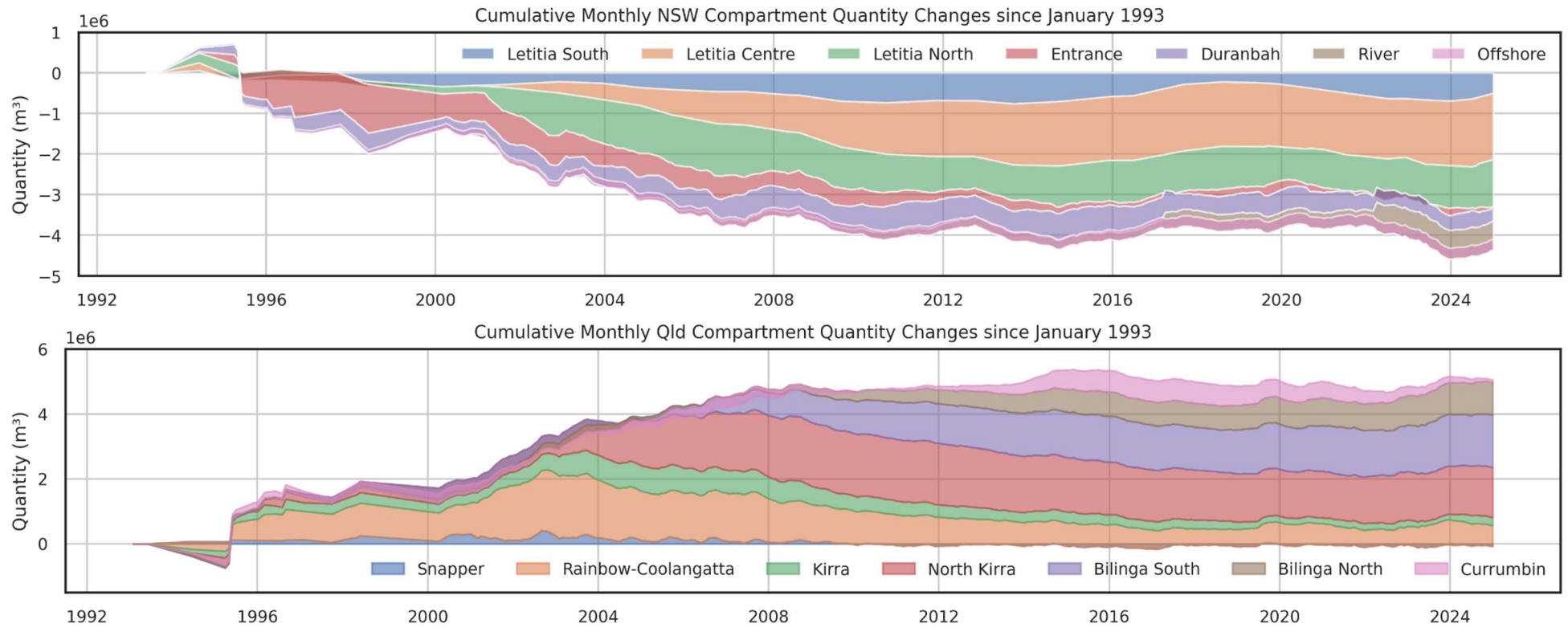


Figure 4.6 Cumulative monthly compartment quantity changes in NSW (top) and Qld (bottom)

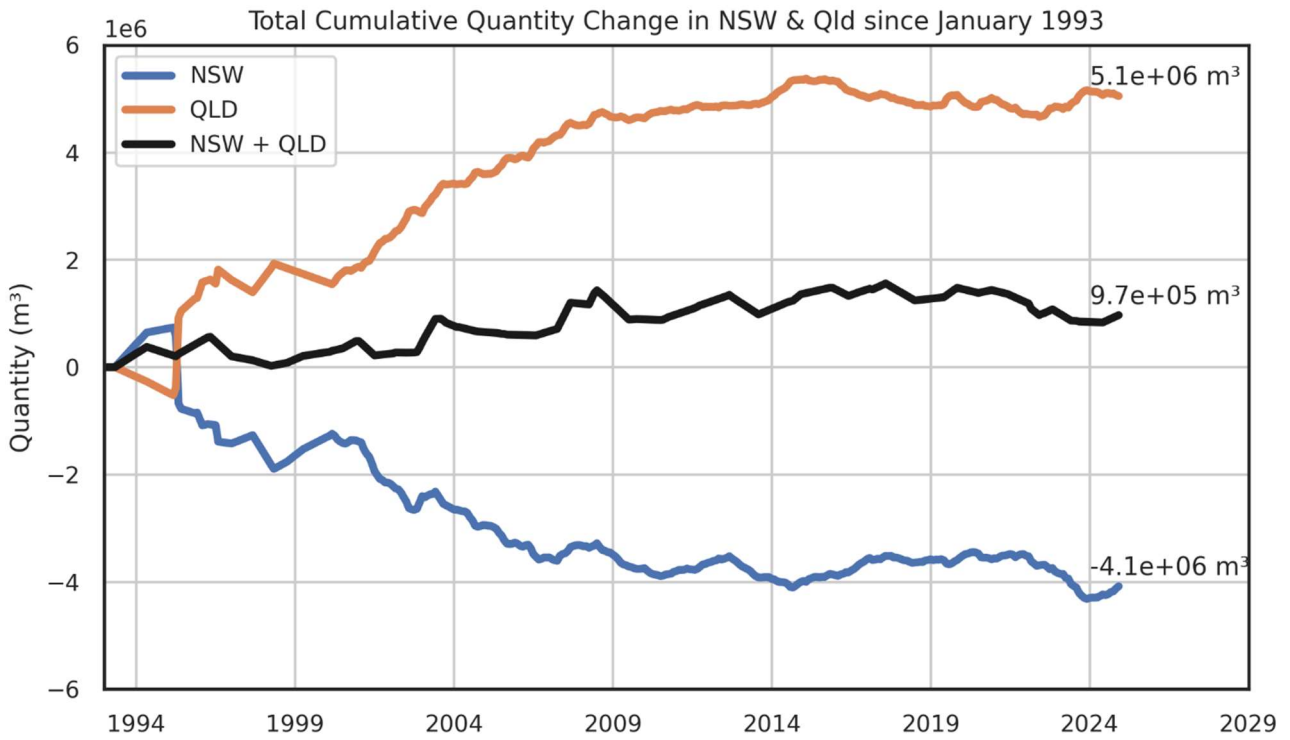


Figure 4.7 Cumulative total change in sand quantities in NSW & Qld since 1993

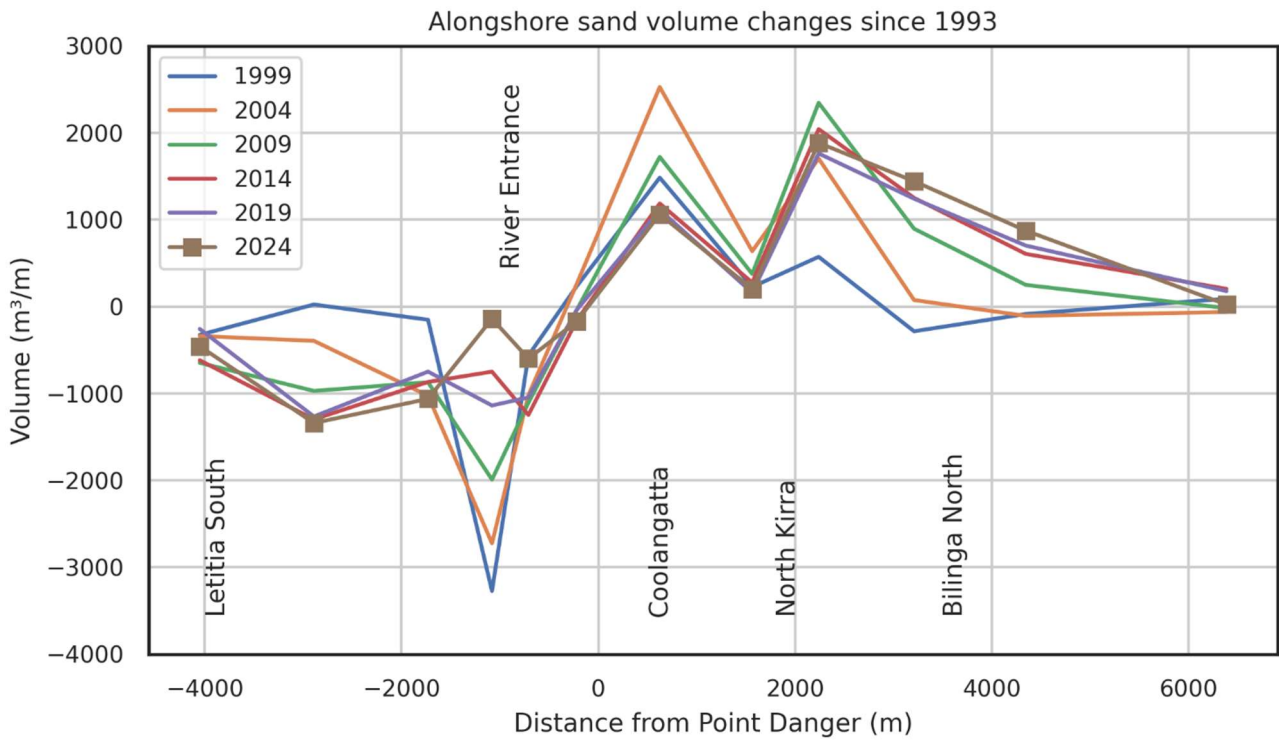


Figure 4.8 Alongshore distribution of change in sand quantities in NSW & Qld since 1993

## 5 Derived Longshore Sand Transport Rates

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### 5.1 Background

A LST rate of 500,000 m<sup>3</sup>/yr was adopted as the most reasonable best estimate for the initial design of the TRESB system and was used in the Deed of Agreement as the LTA rate, with provision for progressive re-assessment following additional data collection and experience with the sand bypass operations.

The wave data record and the compartment sand volumes have now been extended to the end of 2024, facilitating extension of the previous work to cover the period 1996 to 2024. This utilises the Tweed recorded data as the basis of theoretical calculations at Currumbin and Letitia Spit, together with the Queens formulation.

### 5.2 Currumbin LST

The input parameters for the Currumbin LST calculation using the Queens formula were reviewed for the 2024 re-assessment as the average transport rate calculated for the 1995-2019 period (494,000 m<sup>3</sup>) was trending lower than expected. From this review the shoreline alignment at Currumbin was revised in order to yield slightly higher calculated transport rates.

The monthly Queens formula calculated longshore transport rates at Currumbin are shown in Figure 5.1, with the annual and long term average rates shown in Figure 5.2. The long-term average rate for the period January 1995 to December 2024 is 524,000 m<sup>3</sup>/year.

### 5.3 Gold Coast LST

Based on the Currumbin rates, the LST for various locations along the Queensland lower Gold Coast have been determined using the sand budget method, as shown in Figure 5.3 as monthly rates and in Figure 5.4 as annual rates. The relatively high rates of transport past Point Danger during 2001 to 2003 following commencement of bypassing, with the additional make-up quantities pumped at that time are evident. Also evident are the relatively high rates of transport along the whole lower Gold Coast since 2003. These are associated with the effects of greater than equilibrium quantities of sand in the littoral system there resulting from the over-bypassing undertaken during 2001-2006.

A below-trend period of annual transport occurred from 2015-2020 before returning to a near-median transport year in 2021 and a high transport year in 2022. Both 2023 and 2024 were close to the long-term average transport.

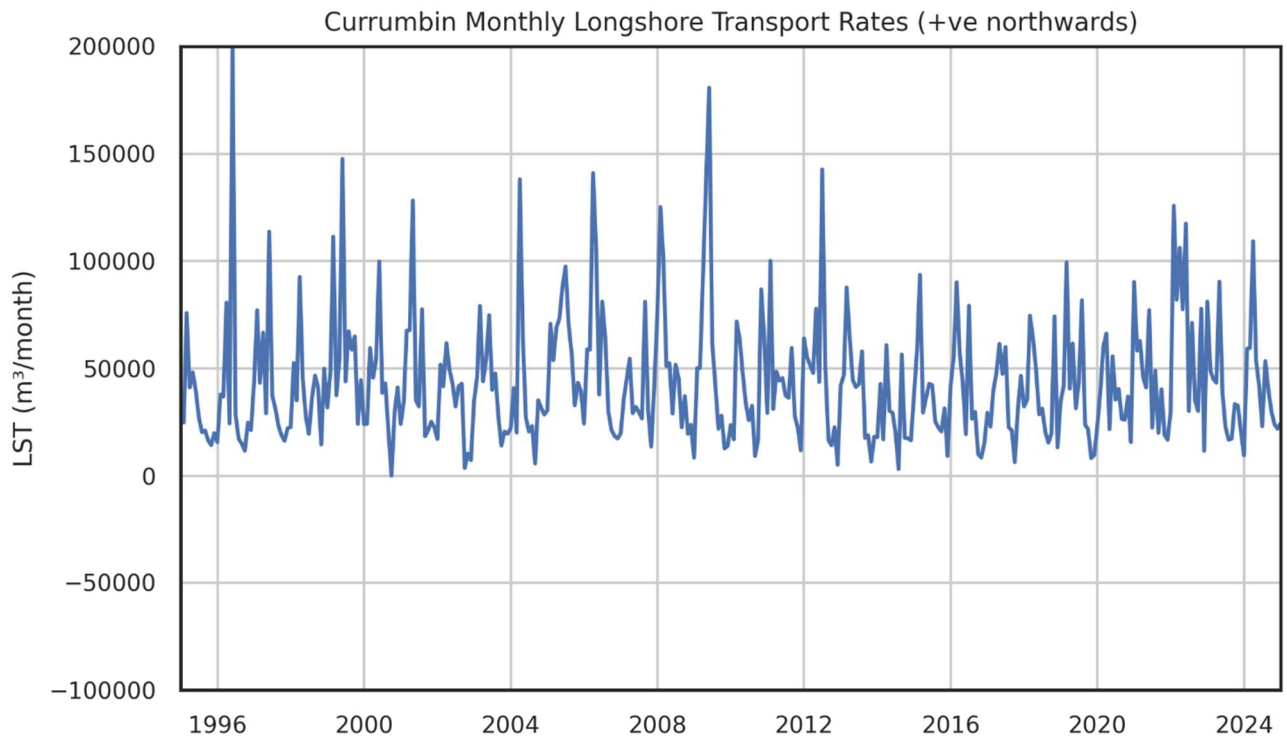


Figure 5.1 Monthly LST rates at Currumbin

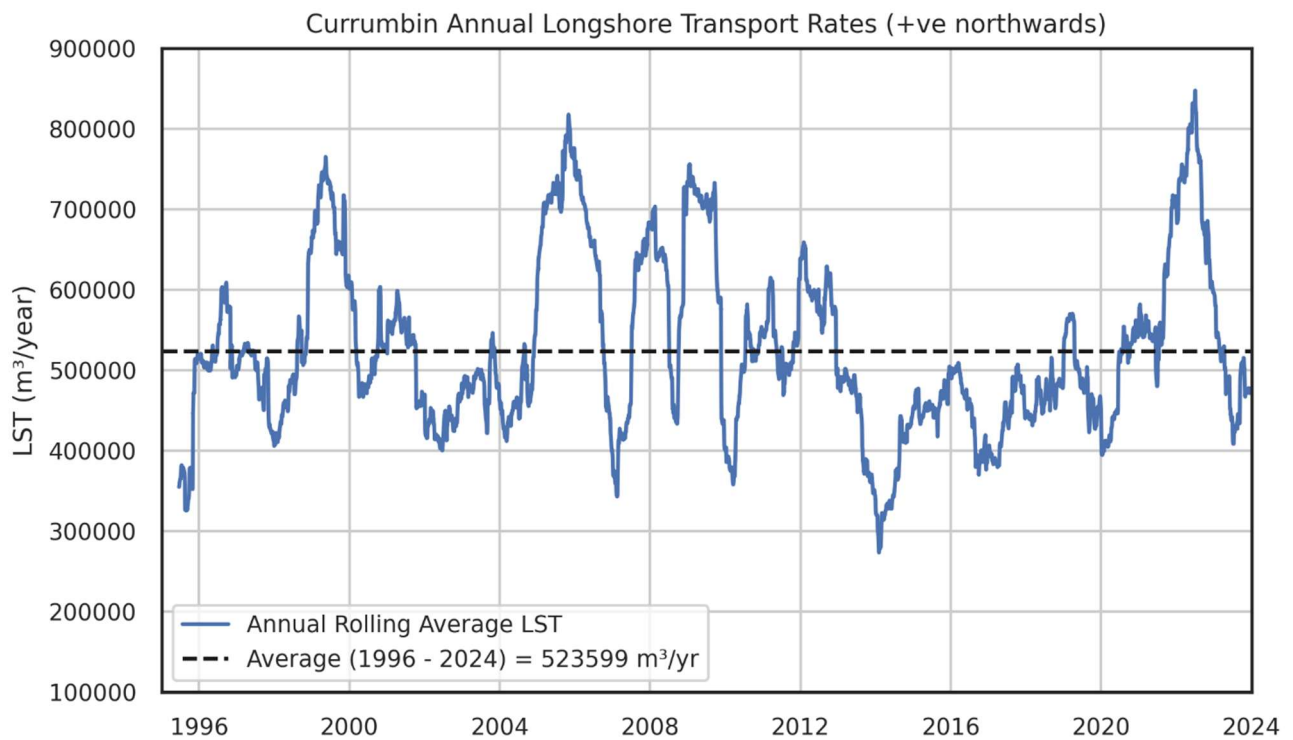


Figure 5.2 Annual (rolling mean) and long term average LST rates at Currumbin

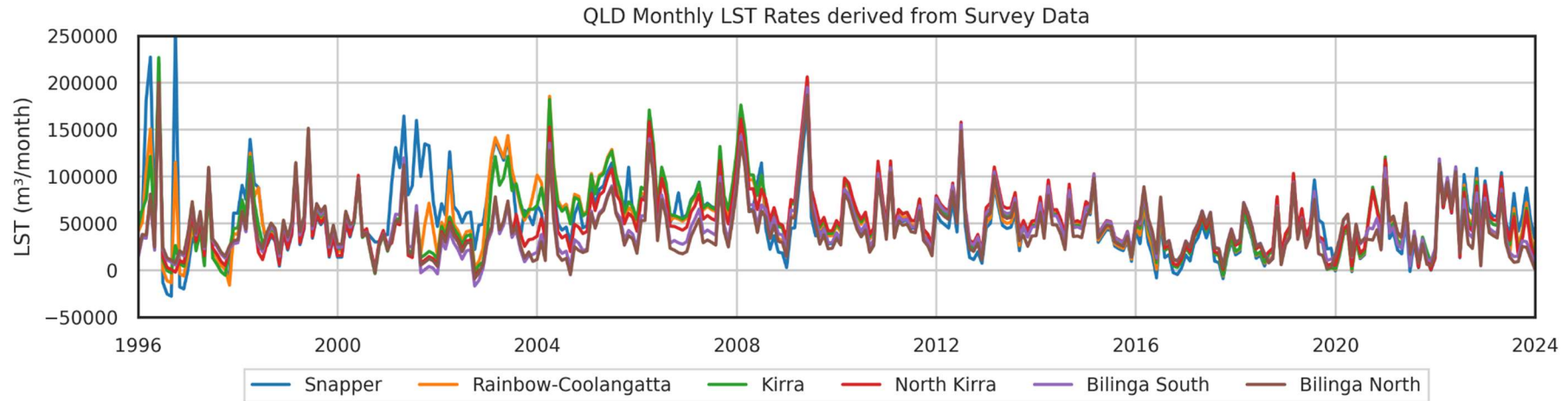


Figure 5.3 Monthly LST rates: Pt Danger to North Bilinga

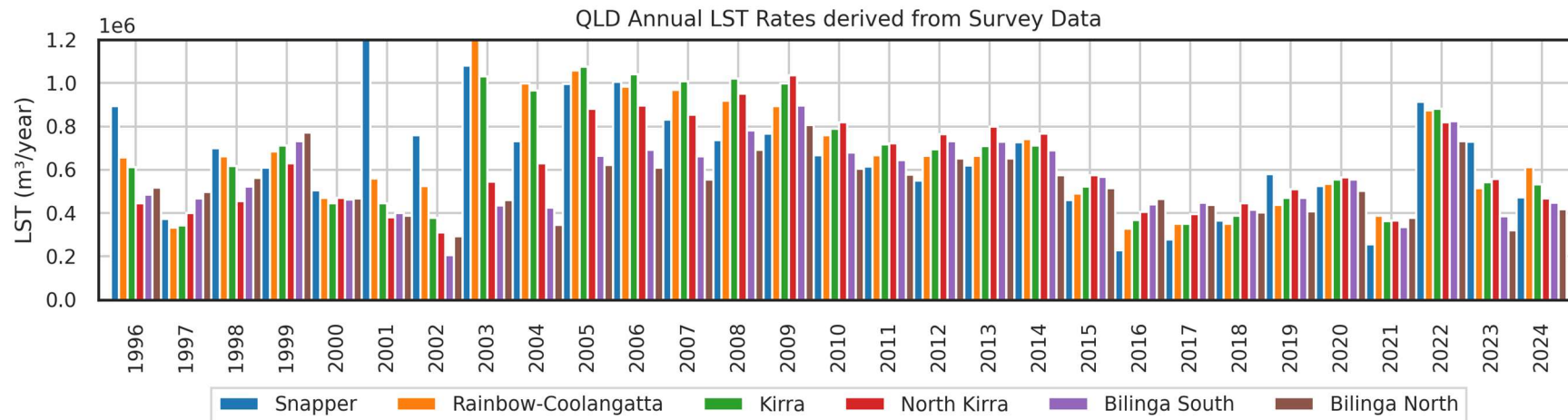


Figure 5.4 Annual LST rates: Pt Danger to North Bilinga

### 5.4 Letitia Spit and Point Danger LST

The LST rates derived for Snapper Rocks at Point Danger, at the Qld/NSW border and along Letitia Spit are illustrated in Figure 3 9 and listed in Table 3 1.

Table 5.1 Calculated transport Point Danger to Letitia Spit

Period of Calculation*	Average Annual Net Transport at Various Letitia Locations (m <sup>3</sup> /yr)					
	Snapper	North Wall	Sth Wall	Letitia Nth	Letitia Cnt	Letitia Sth
1995 to 2000	402,000	330,000	643,000	602,000	589,000	536,000
1995 to 2009	653,000	169,000	425,000	721,000	636,000	595,000
1995 to 2025	586,000	107,000	268,000	628,000	566,000	553,000
2001 to 2009	823,000	72,000	280,000	799,000	667,000	622,000
2001 to 2025	633,000	55,000	174,000	634,000	560,000	552,000
2009 to 2025	538,000	58,000	122,000	547,000	500,000	507,000

\* Refer to Table 1.2 for further description of Tweed Sand Bypassing project epochs.

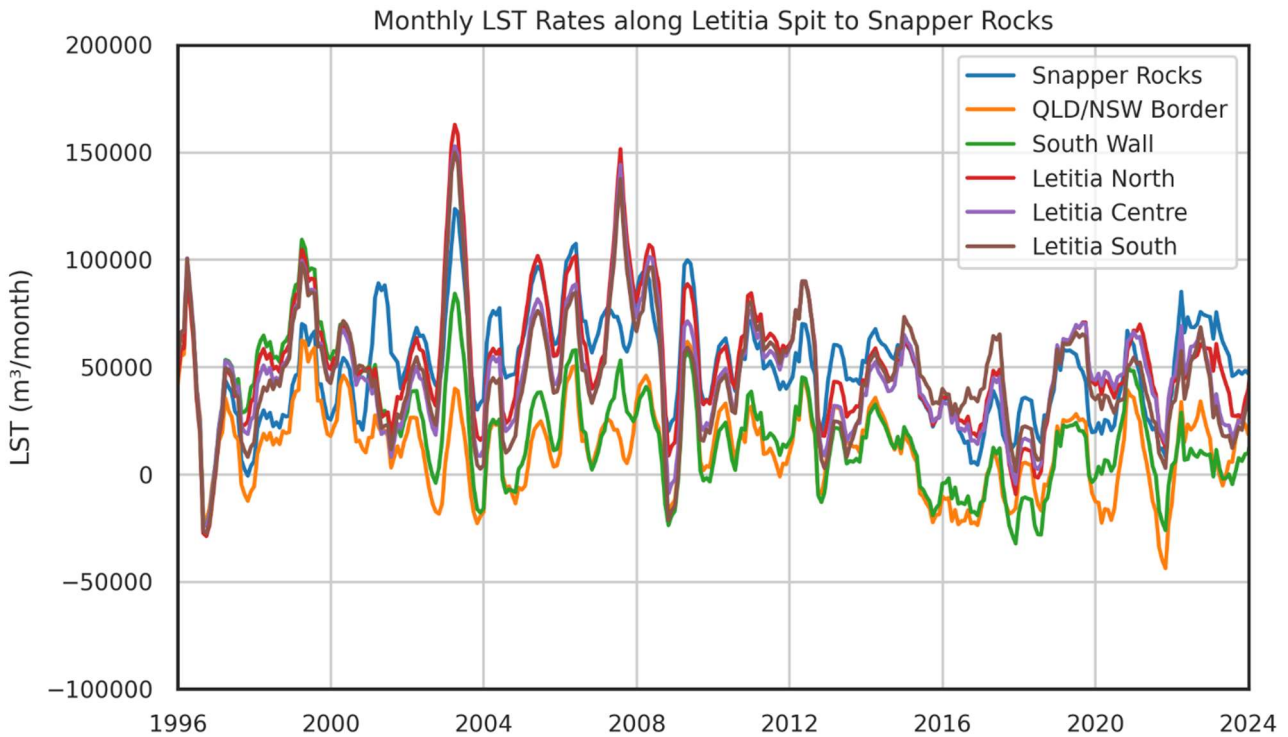


Figure 5.5 Monthly net transport at Point Danger

#### 5.4.2 Letitia Spit Theoretical rates

The Queens formula calculated Letitia Spit monthly rates are shown in Figure 5.6, with the annual and long term average rates shown in Figure 5.7. It has been assumed that the shoreline alignment at Letitia Spit remains unchanged from that adopted previously. The long-term average rate for the period January 1995 to December 2024 is 580,000 m<sup>3</sup>/year.

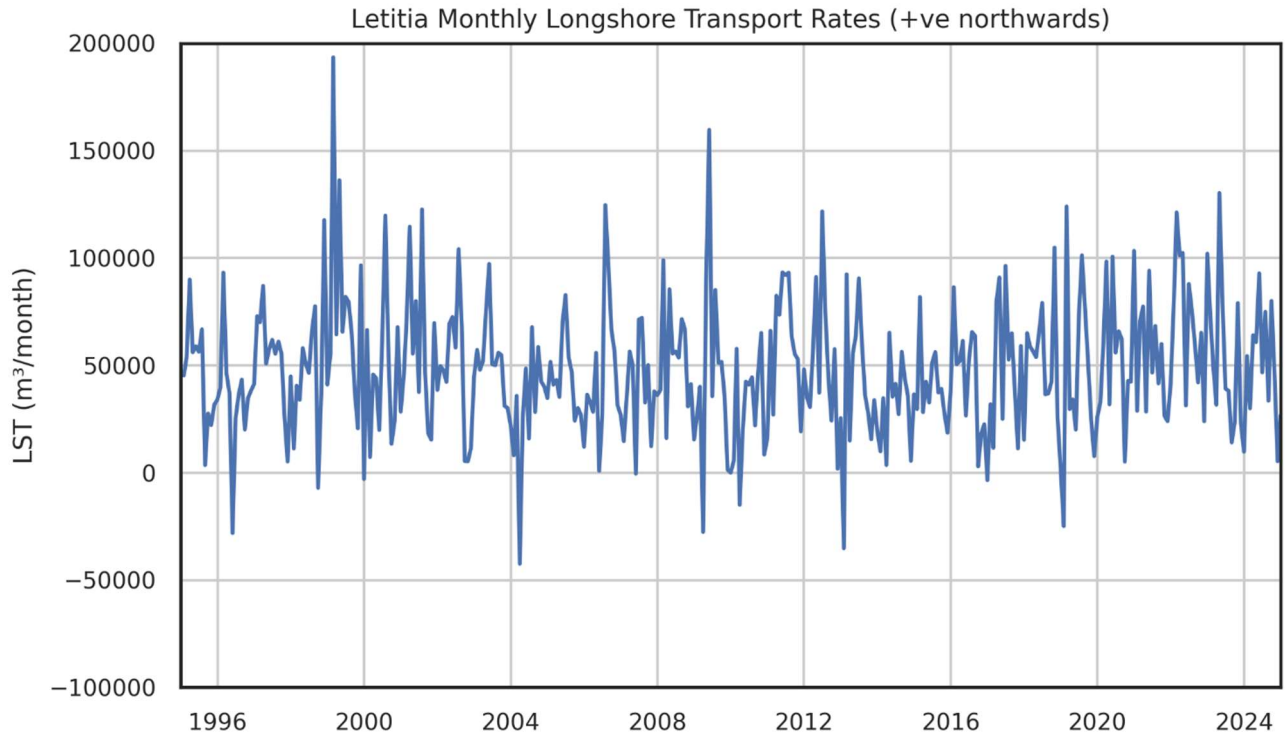


Figure 5.6 Monthly LST rates (Queens formula) at Letitia Spit

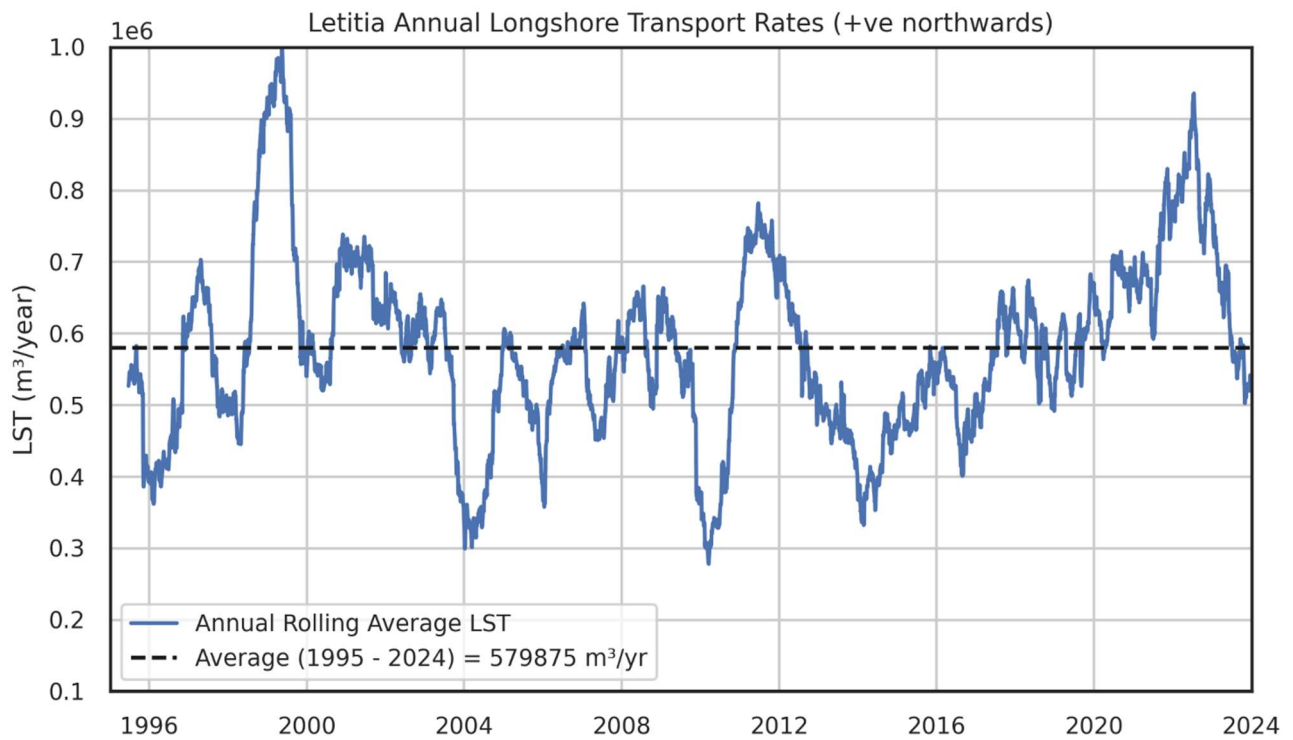


Figure 5.7 Annual (rolling mean) and long term average LST rates (Queens formula) at Letitia Spit

### 5.4.3 Theoretical Versus Derived from Sand Budget

On the basis that the southern boundary of Letitia North (Figure 2 1) is located approximately at the location 1,000 m south of the walls, the derived transport rate there may be correlated directly with that calculated theoretically from the Tweed wave data. This comparison is listed in Table 5.2 and illustrated in Figure 5.8.

Table 5.2 Transport rate comparison 1,000 m South of Walls

Period of Calculation*	Annual Average Net Transport at 1,000m south of walls (m <sup>3</sup> /yr)	
	Derived from Surveys & Currumbin Transport**	Theoretical from Waves
1995 to 2000	602,000	628,000
1995 to 2009	721,000	581,000
1995 to 2025	628,000	581,000
2001 to 2009	799,000	564,000
2001 to 2025	634,000	575,000
2009 to 2025	547,000	583,000

\* Refer to Table 1.2 for further description of Tweed Sand Bypassing project epochs.

\*\* Derived transport corresponds to Letitia North in Figure 2.3

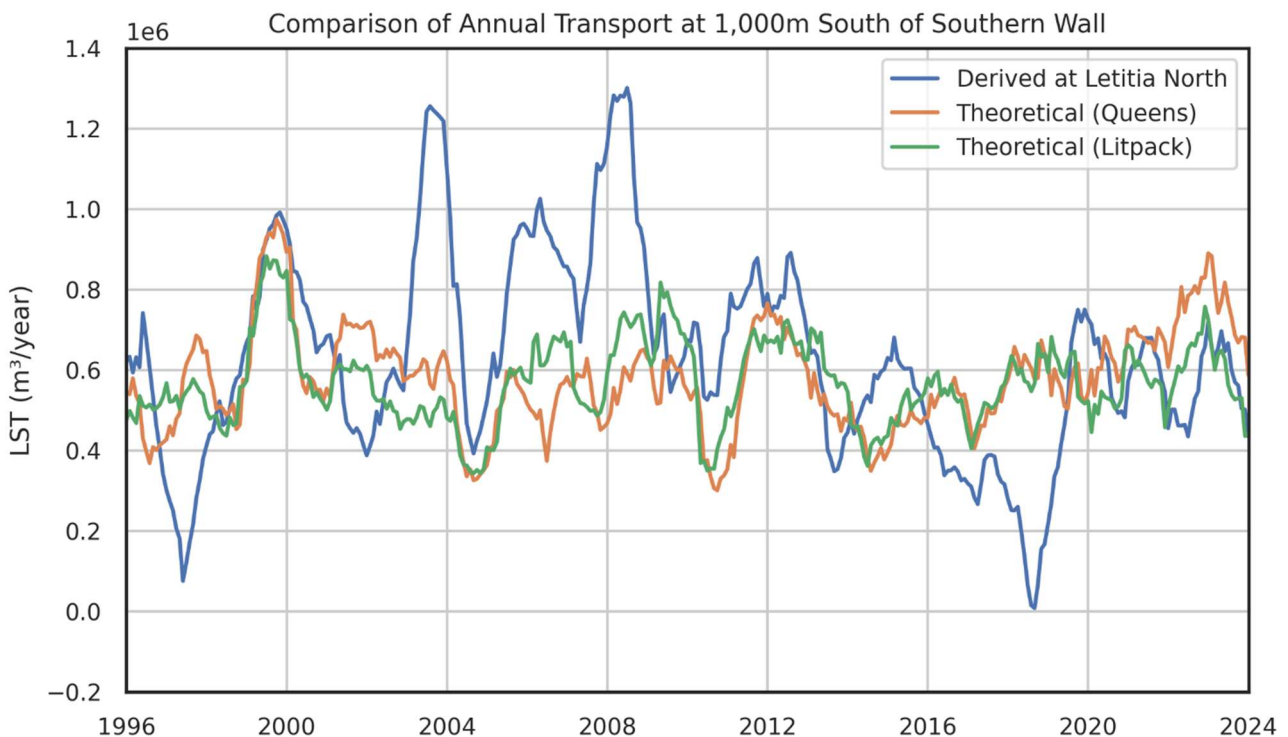


Figure 5.8 Monthly net transport 1,000 m south of southern training wall

The Letitia Spit transport rates derived from survey data analysis and theoretical Currumbin transport exhibit some notable differences from the theoretically derived transport. The average annual transport rate of 581,000 m<sup>3</sup>/yr calculated theoretically at Letitia Spit directly from the Tweed wave data at 1,000 m south of the entrance over the period 1995 to 2024 is significantly less than the 628,000 m<sup>3</sup>/yr

for Letitia North in Table 3 1. The higher derived rate at Letitia North reflects the project-related increase in transport at this location during the period from 2001 to 2015.

Periods of 'slug'-like transport are also evident in the derived rates along Letitia Spit shown in Figure 5.8. While errors in individual survey datasets could contribute to this type of behaviour in the derived transport rates, there is independent evidence (Silva et al. 2020) to corroborate 'slug'-like transport variability around Fingal headland into the Letitia South compartment.

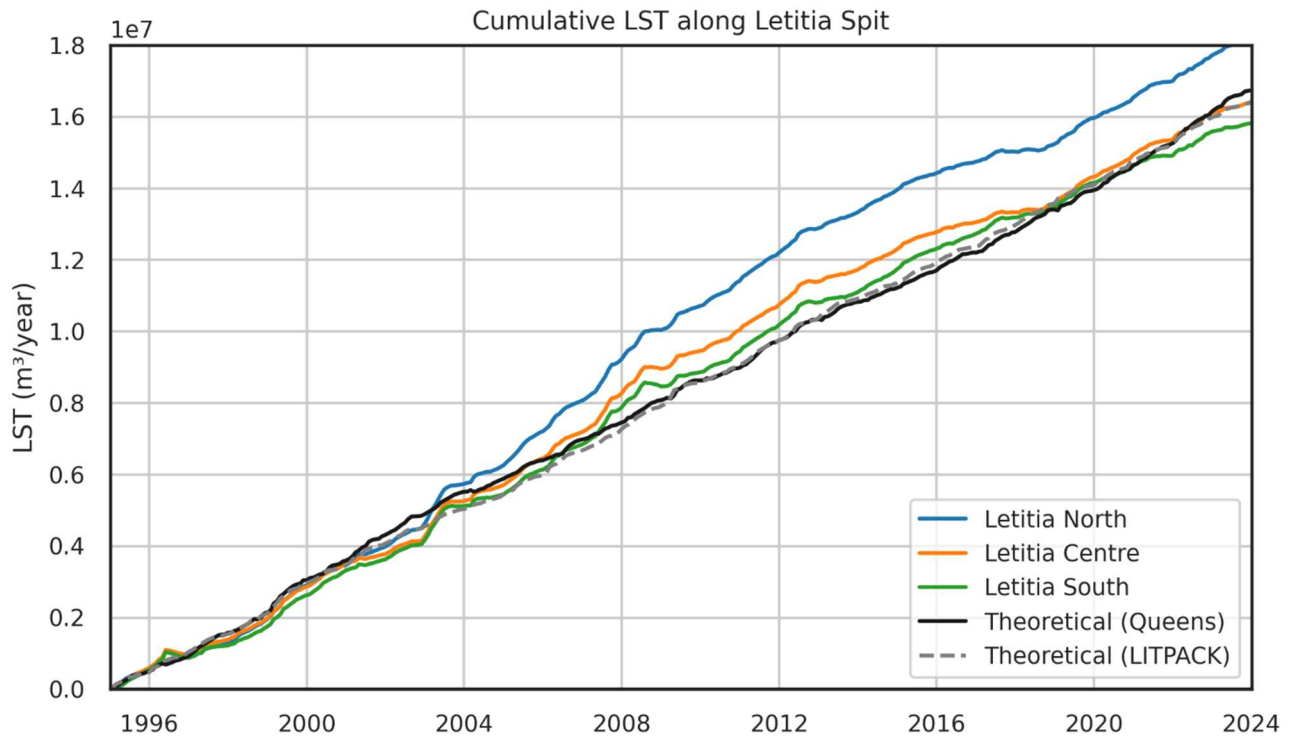


Figure 5.9 Cumulative sand transport at Letitia Spit. Theoretical is from Queen’s formula applied to Letitia Spit, other rates have been derived from survey.

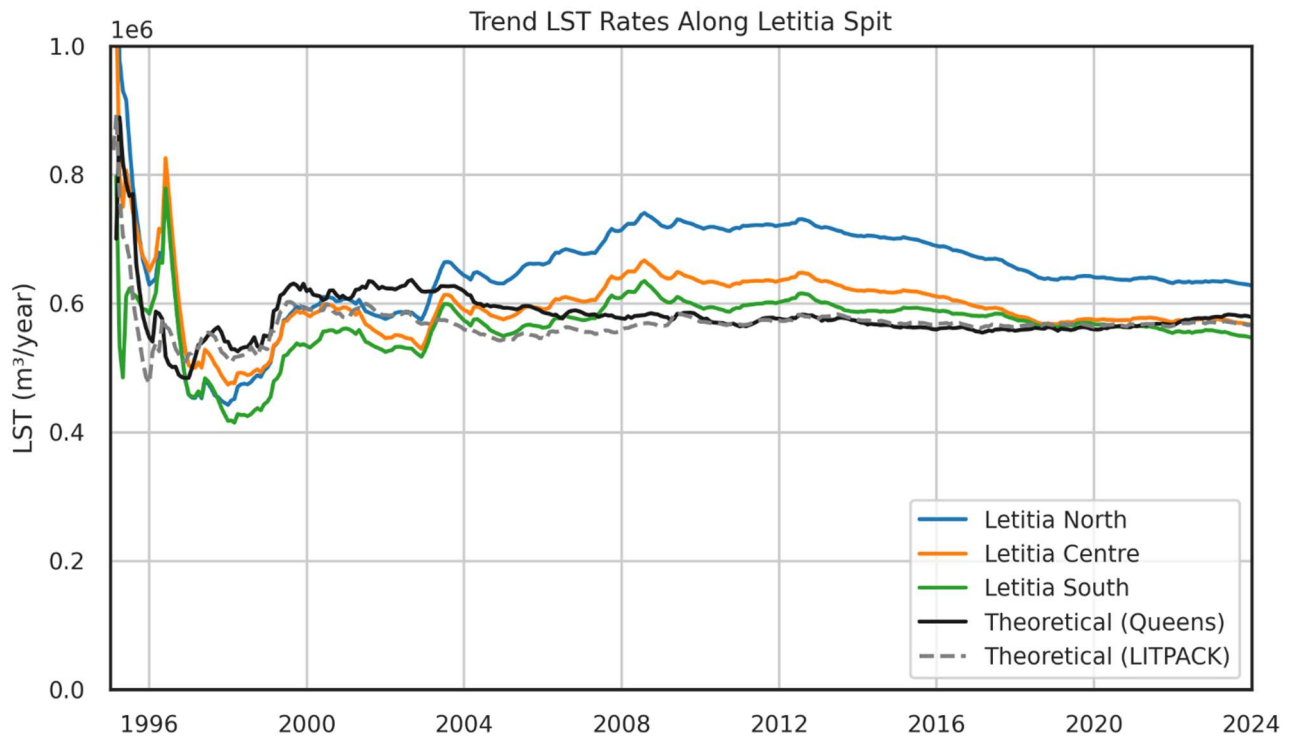


Figure 5.10 LST trends at Letitia Spit Theoretical is from Queen’s formula applied to Letitia Spit, other rates have been derived from survey.

## 6 LTA and Natural Bypassing Rates

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### 6.1 LTA from Equation 1b

The Deed of Agreement requires that the Annual Increment (yearly target sand delivery) for the sand bypass system is equal to the LTA, subject to provision for an initial Supplementary Increment over the first 6 years from 2001 to 2006. The LTA definition specifies that the location for the net littoral sand transport is ‘...a line perpendicular to the coastline, situated one kilometre south of the southern training wall’. The LTA involves the transport that would cross that line ‘...in the absence of any artificial actions to influence it’.

The LTA is affected by the bypassing itself in terms of the natural bypassing that is acceptable while maintaining suitable entrance channel conditions. As such, the LTA calculations have been based on behaviour since bypassing commenced in 2001. However, it is clear that, at the specified location one kilometre south of the southern training wall (Figure 2.3), the ‘natural’ sand transport patterns have been influenced since 2001 by the sand bypassing operations, evidenced by the retreat of the shoreline as well as reduced quantity of sand in the nearshore profile south from there.

It is probable based on the seemingly de-coupled volume trends in the Letitia South compartment (Figure 4.1) that the natural transport rate nearer to Fingal has been influenced much less or not at all by the sand bypassing operations. However, the Letitia South compartment volumes are evidently influenced by a “slug” delivery mechanism around Fingal headland and as such the sand delivery trends into Letitia Spit exhibit significant temporal variability.

To maintain consistency with previous LTA assessments, Equation 1b has been applied with respect to the whole length of Letitia Spit to the southern limit of the surveys (Letitia South compartment). The derived monthly LTA increments are shown in Figure 6.1. The average annual rate of these values since 2001 indicates the LTA based on the actual behaviour over the 24 years of sand bypassing operations up to 2025. Comparison of the monthly values derived from Equation 1b with the bypass system delivery (pumping + dredging) to Queensland undertaken over the period is shown in Figure 6.2. The annual rate comparison is shown in Figure 6.3.

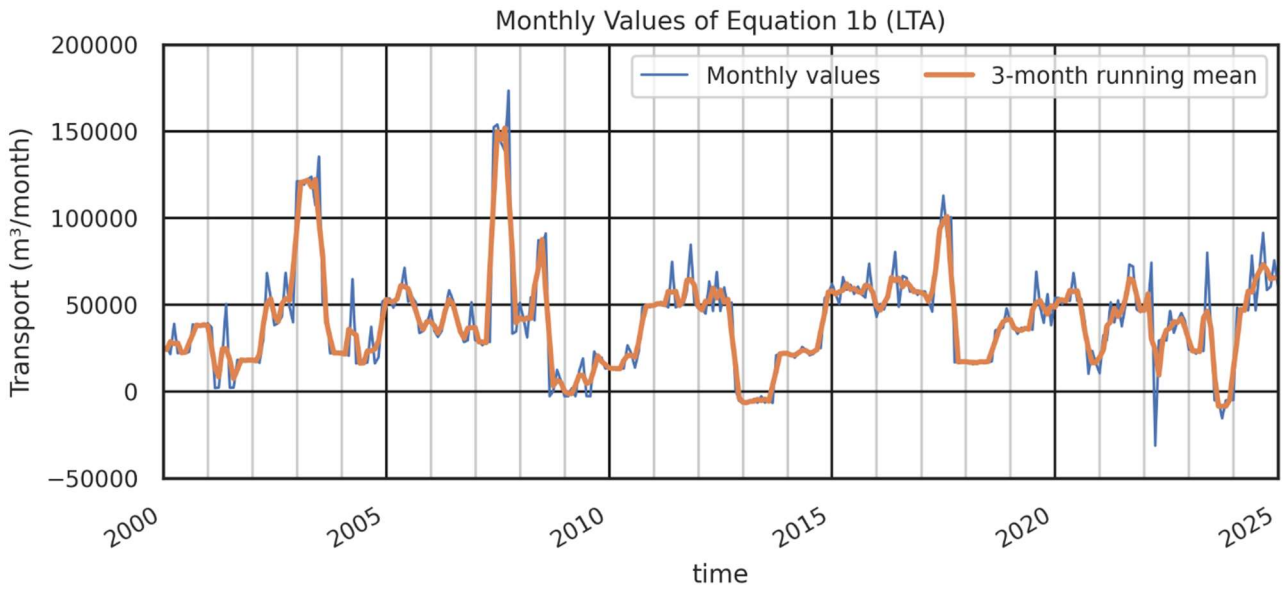


Figure 6.1 Monthly LTA (Equation 1b)

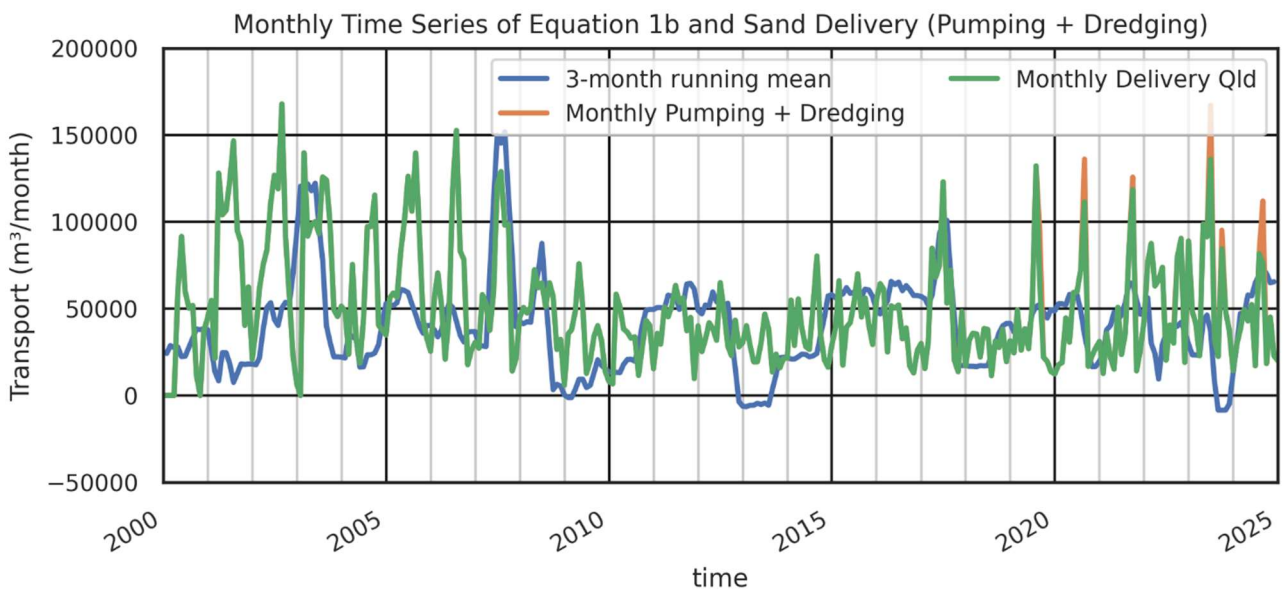


Figure 6.2 Monthly LTA and Sand Delivery\*

\* Sand delivery to Queensland, includes placement at Duranbah but excludes backpassing

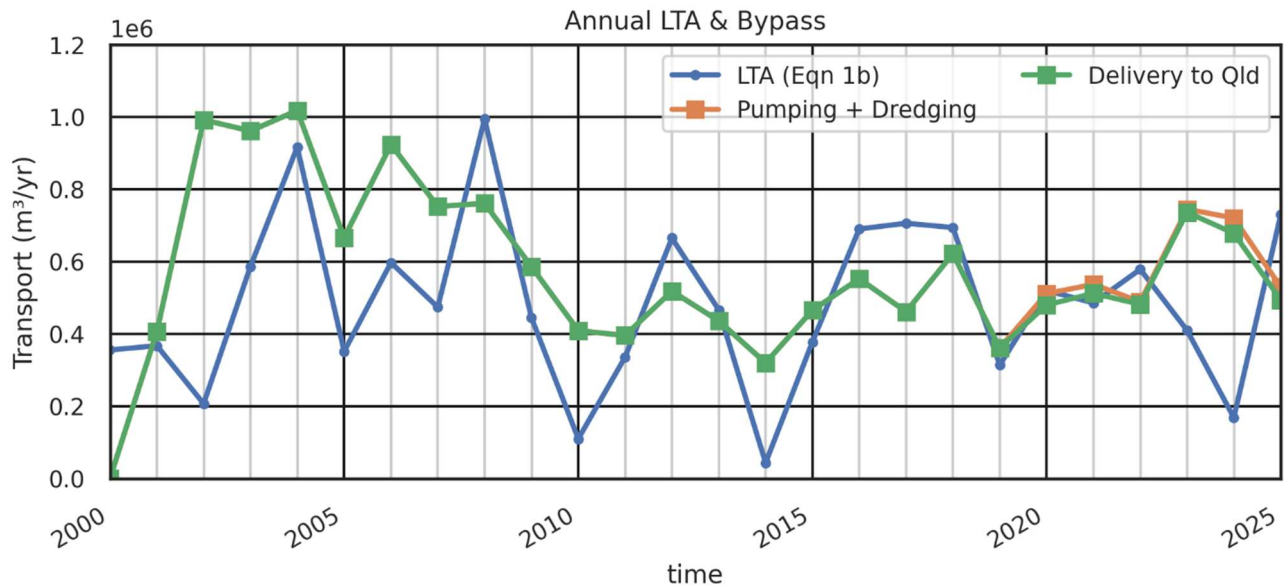


Figure 6.3 Annual LTA and Sand Delivery\*

The average annual LTA rate thus derived using Equation 1b for the period from April 2001 to December 2024, covering the period of sand bypass operations, is 497,000 m<sup>3</sup>/yr. This is equal to the previous reassessment (Table 6.1), and indicates a continued period of relative stability in transport conditions.

The LTA estimates (using Eq 1b) from the 2009, 2015 and 2020 re-assessment studies are summarised in Table 6.1. With the exception of 2009, the LTA Eq 1b values calculated for this report using the new Python-based analysis are within 1% of the previous calculations. Any difference in the assumptions from the previous assessments are discussed in Section 2.8 and account for the minor differences in Table 6.1.

The 2001 to 2009 period was heavily influenced by the supplementary increment period and therefore the LTA as directly calculated from Eq 1b is not consistent with the LTA requirement to be *‘in the absence of any artificial actions to influence it’*.

Notably, all of the LTA estimates have been within ±5% of the initial Deed of Agreement estimate of 500,000 m<sup>3</sup>/yr.

Table 6.1 Summary of LTA estimates from previous assessments

Reference	LTA Previous report	LTA Eq 1b (m <sup>3</sup> /yr)	Calculation Period
1995 Deed of Agreement	500,000	–	–
2009 LTA Re-assessment (BMT WBM, 2011)	509,000*	541,000	April 2001 to August 2009
2015 LTA Re-assessment (BMT WBM, 2016)	478,000	481,000	April 2001 to July 2015
2020 LTA Re-assessment (BMT, 2020)	497,000	504,000	April 2001 to January 2020
2025 LTA Re-assessment (this report)	–	497,000	April 2001 to January 2025

\* The LTA Eq 1b value calculated for the 2001 to 2009 period was heavily influenced by the supplementary increment period

LTA cumulative trend rates for both periods from 2001 to 2025 (see above) and from 2007 to 2025 (484,000 m<sup>3</sup>/yr), following cessation of the supplementary bypassing, have been determined, as shown in Figure 6.4. As discussed above, the LTA is a metric which can be influenced by the project operations in so much as these operations (pumping and dredging) can modify the quantity of natural bypassing that occurs. The total rate of bypassing during the supplementary increment period was by design significantly higher than the rate of natural transport into Letitia Spit. This high rate of bypassing had the secondary effect of suppressing the rate of natural bypassing, with the consequence that the LTA increments during this period were correspondingly inflated.

Since 2007 the total rate of bypassing has been more closely matched to the LTA and hence the latter exhibits a slightly lower value than the longer period. Increasing the balance of total bypassing due to dredging, has the potential to increase the LTA due to the secondary effect of reduced natural bypassing of the entrance. Entrance dredging re-commenced in 2016/17 it is probable that the trend LTA may still be adjusting upwards in response to the altered pumping/dredging split. This is because the trend LTA reflects a discrete period of environmental conditions and bypassing operations and should therefore be interpreted in terms of the likely future context.

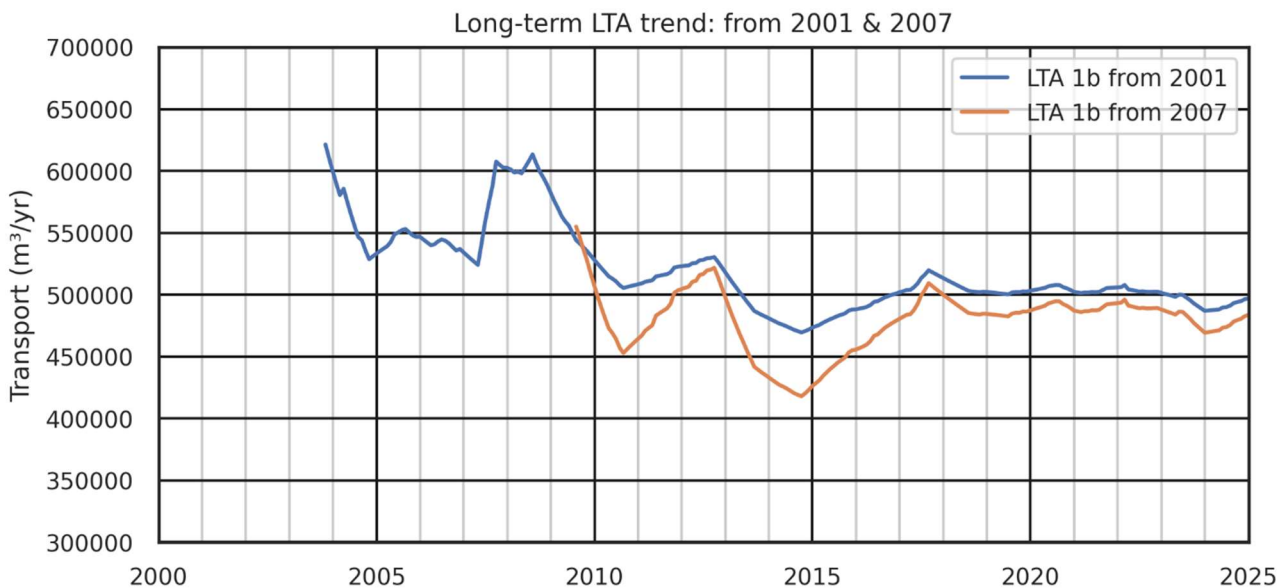


Figure 6.4 LTA Trends since 2001 and 2007

## 6.2 Natural Bypassing at NSW/Qld Border

The monthly increments of the 'natural bypassing' and the total wave-current driven sand transport at the NSW/Qld border have been derived using the monthly net sand transport rates at Currumbin and the monthly quantity changes along the Queensland beach system. The natural bypassing is adopted as the transport across the border minus the contribution from the sand pumped to Duranbah in the bypassing operation. The time series results are shown in Figure 6.5.

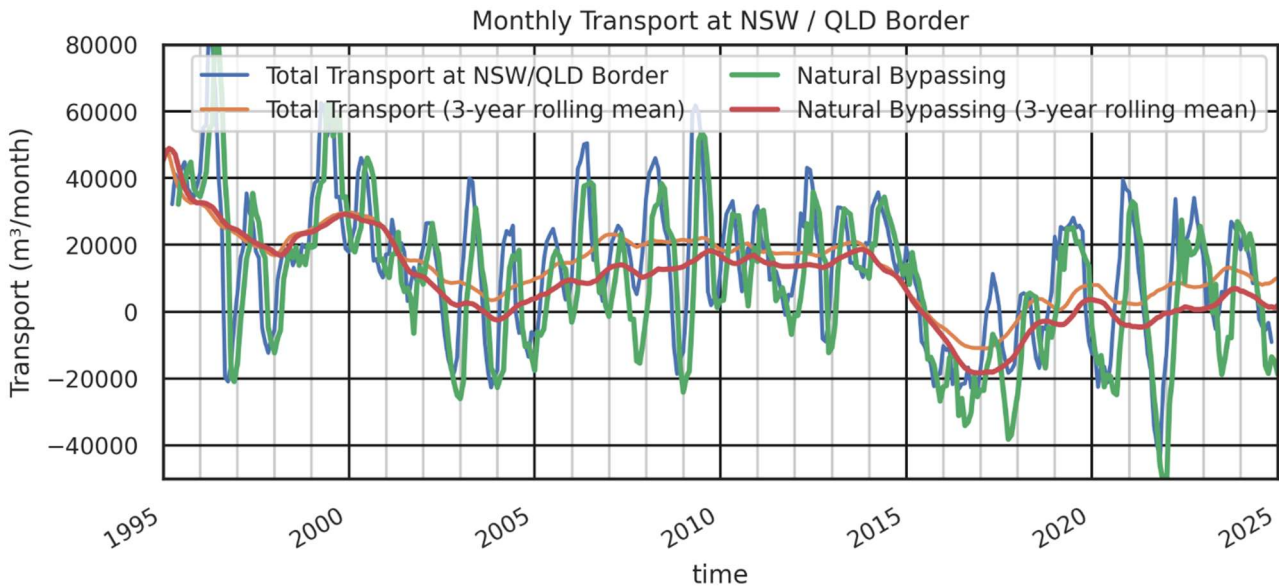


Figure 6.5 Monthly natural bypassing and total transport at NSW/Qld border

These rates show a trend (refer red line) of marked reduction in natural bypassing after commencement of the sand bypass operations in 2001. Subsequently an increasing trend is evident from 2007 to 2015, associated with the reduced bypassing rate and increased leakage past the bypass system and entrance over that period. Since 2015, there has been an apparent decreasing trend as discussed below.

The average annual rate of total bypass pumping and dredging decreased since delivery of the “supplementary increment” was completed by 2008. Furthermore, no entrance dredging occurred from 2009 to 2016 and the natural bypassing rate increased as a result (Figure 6.5). Periodic entrance dredging recommenced in 2016 and since then intermittent campaigns have cumulatively removed 1.10M m<sup>3</sup> from the Entrance compartment at an average rate of 122,000 m<sup>3</sup>/yr.

Since 2019, part of the entrance dredging component has been back-passed to approved placement areas offshore Letitia Spit and south of Fingal Head at Dreamtime Beach. In that time the total quantity of sand back-passed has been 150,000 m<sup>3</sup> at an average rate of 25,000 m<sup>3</sup>/yr.

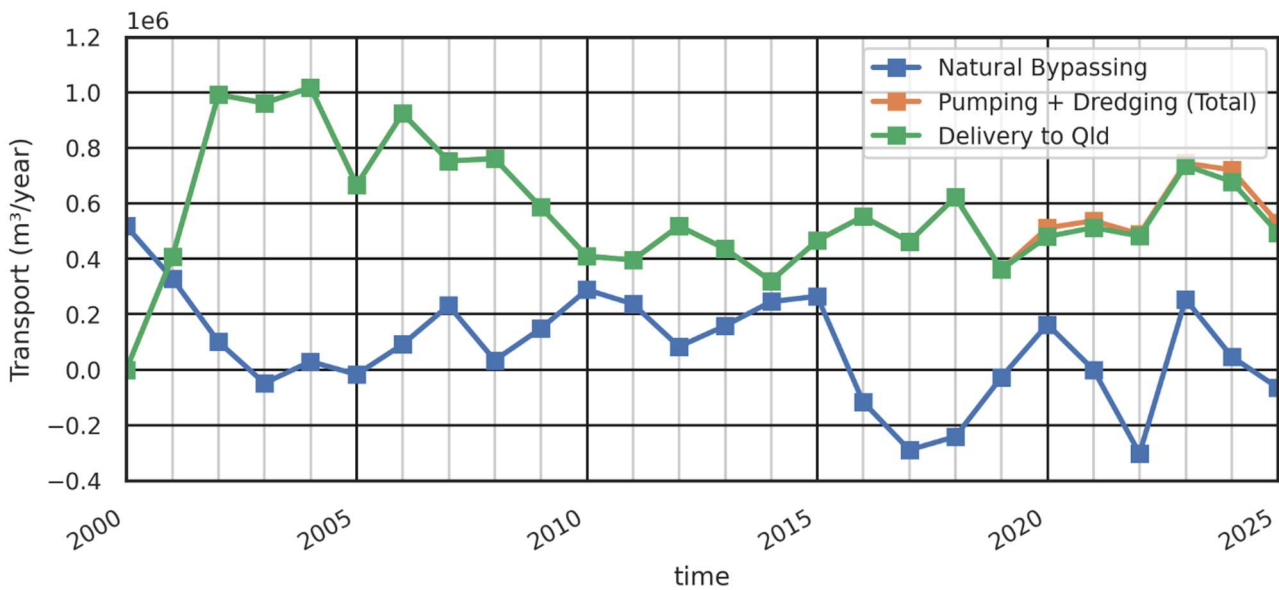


Figure 6.6 Annual natural bypassing and Sand Delivery

These results indicate the progressive sand transport rates at the border as listed in Table 6.2. This indicates the natural bypassing rate has averaged about 52,000 m<sup>3</sup>/yr since bypassing commenced in 2001, and a slightly lower rate of about 48,000 m<sup>3</sup>/yr since 2007. The cumulative trends of natural bypassing over the two periods 2001-2019 and 2007-2019 are illustrated in Figure 6.7. Of note is the significant reduction in the natural bypassing trend since 2015. As discussed above, the reduced natural bypassing trend is likely due to a combination of below trend wave energy and re-commencement of entrance dredging. A return to higher-energy wave climate may see the natural bypassing trend increase again in the future, while continuation of periodic entrance dredging campaigns to meet the entrance navigability objectives of the Project should help maintain lower natural bypassing rates.

Table 6.2 Calculated transport at NSW/Qld Border

Annual Average Net Transport at NSW/Qld Border (m <sup>3</sup> /yr)		
Period of Calculation	Natural Bypassing	Total Transport
1995 to 2001	330,000	330,000
2001 to 2007	49,000	121,000
2001 to 2025	49,000	117,000
2007 to 2025	48,000	114,000

Refer Section 2.4 for definition of natural bypassing and total transport

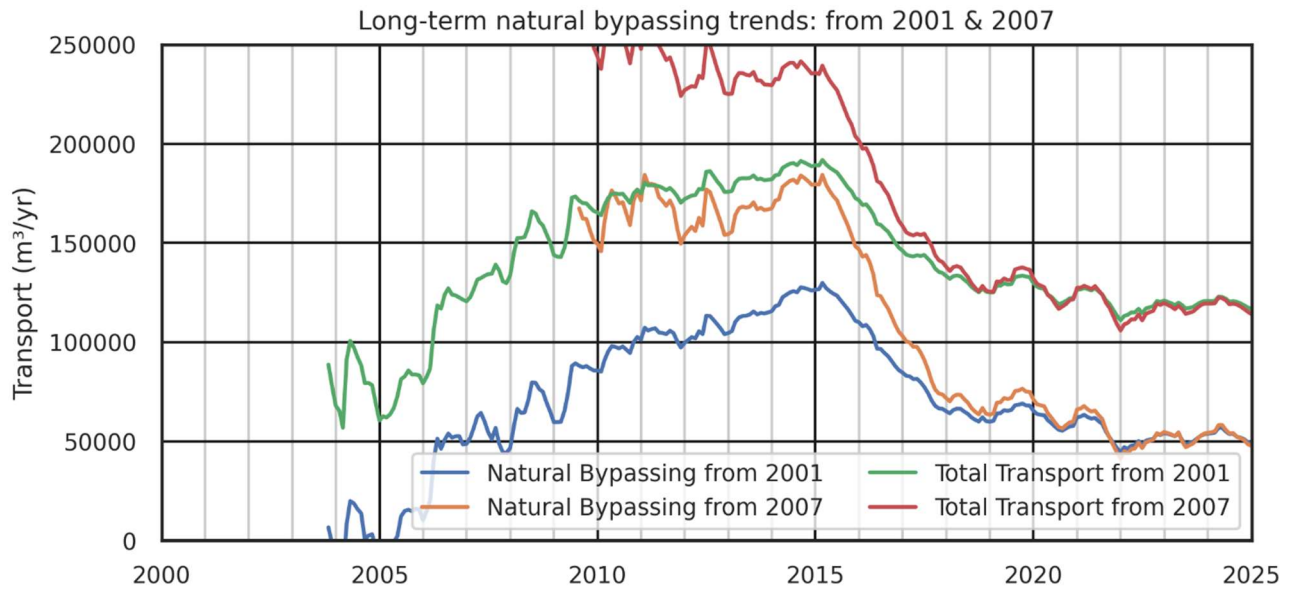


Figure 6.7 Natural Bypassing trends from 2001 and 2007

### 6.3 Sensitivity Assessment

The LTA is a quantity that is sensitive to input data uncertainties and error margins as discussed in Section 2.7. As the LTA is a long-term average quantity it is also subject to the natural variability that is inherent in the longshore transport rate and natural bypassing rates. As discussed in Section 2.1 the LTA quantity, as defined in the DoA, is also dependent on the bypassing and dredging operations that affect the rate of natural bypassing.

The long-term trends of LTA since 2001 (and 2007) are shown in Figure 6.4. Having now converged to a value somewhere around 500,000 m<sup>3</sup>/yr, since 2020 the trends are still oscillating by up to ±20,000 m<sup>3</sup>/yr around the 2025 LTA value. This highlights that even after 24-years of operation the LTA quantity is still sensitive to the calculation period, which is primarily due to the natural variability inherent in the LTA and is irrespective of any input data uncertainties.

## 7 Discussion and Recommendations

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### 7.1 Longshore Sand Transport

This study has re-calculated the average annual longshore sand transport into Letitia Spit as 553,000 m<sup>3</sup>/yr for the 30-year period from January 1995 to December 2024. This quantity has only changed very slightly from the 546,000 m<sup>3</sup>/yr calculated in the previous re-assessment study for the period 1995 to 2019 (BMT WBM, 2020).

Following a review of the shoreline angle used in the Queens formulation the annual transport at Currumbin has been re-calculated as 524,000 m<sup>3</sup>/yr for the 1995 to 2025 period.

The transport gradient from Letitia to Currumbin discussed in previous LTA re-assessments (2016, 2019) has been progressively diminishing to its current value of 29,000 m<sup>3</sup>/yr. This gradient is calculated as a direct result of the net gain of sand volume in the Letitia South to Currumbin system. This net gain (NSW+Qld) is currently 1.02M m<sup>3</sup> having peaked at 1.59M m<sup>3</sup> in 2017.

### 7.2 LTA and Bypassing

The LTA is defined as...

#### **Natural net longshore sand transport at Letitia Spit – Natural bypassing to southern Gold Coast**

and is the Deed of Agreement quantity that should be bypassed over the longer term by the Tweed Sand Bypassing jetty mounted pumping system and entrance dredging.

The calculated annual LST at Letitia South and Bypassing (pumping + dredging) are compared for the period 2001 to 2025 in Figure 7.1. The natural LST can be seen to vary strongly from year to year in a range from 208,000 m<sup>3</sup>/yr in 2021 up to 1,029,000 m<sup>3</sup>/yr in 2007. The high rate of bypassing during 2001 to 2007 includes the supplementary increment to the LTA. Since 2009 the rate of bypassing has remained in a range from 320,000 m<sup>3</sup> during the low transport year of 2013 up to 736,000 m<sup>3</sup> (plus an additional 8,600 m<sup>3</sup> back-passing) in 2022.

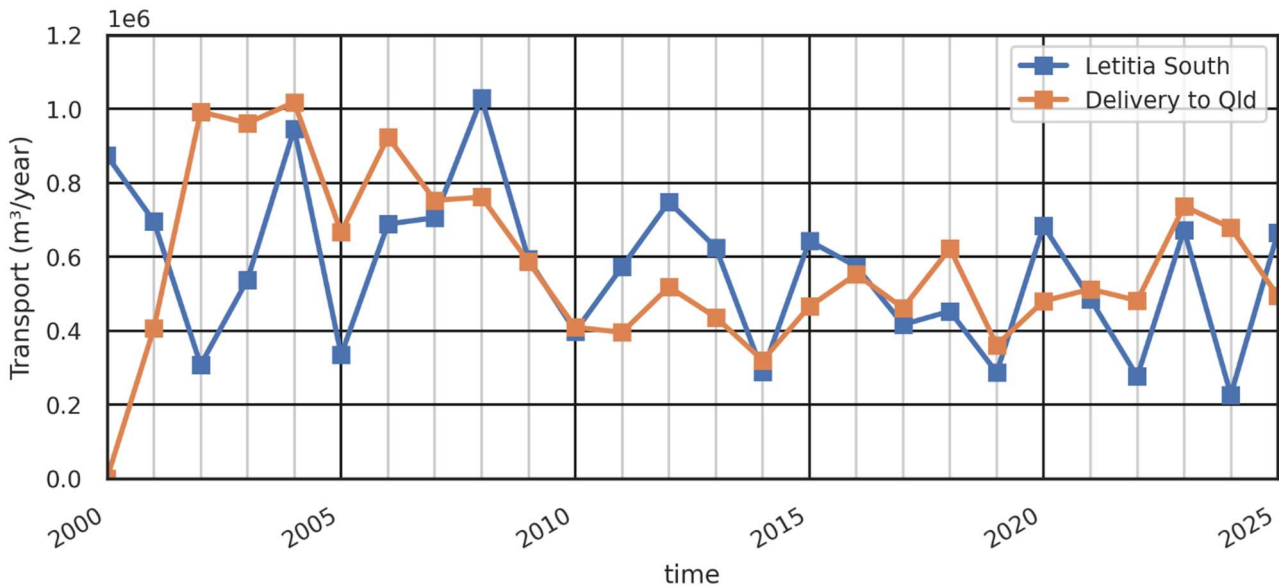


Figure 7.1 Calculated annual LST at Letitia South & bypassing since 2001

The monthly/annual components of the LTA account for the natural bypassing to Queensland. The natural bypassing quantity and LTA increments have been calculated since 2001, and are significantly influenced by both:

- Natural variability of the longshore transport processes; and
- The sand bypassing system activities.

The cumulative trend rates of LST, LTA and natural bypassing quantities are shown in Figure 7.2 for the period since 2001. Also shown are the trend rates since 2007, following completion of the supplementary increment. While LST has trended downwards since the previous re-assessment was completed, the LTA has trended slightly higher as a result of a significant reduction in the natural bypassing trend. The period from 2009 to 2016 did not include any entrance dredging and consequently the natural bypassing trend rate increased during this period. Since 2016, there has been 1.10M m<sup>3</sup> of entrance dredging and this has likely contributed (in part) to the downward trend in natural bypassing.

Comparing the cumulative bypassing rate (comprising pumping plus dredging) with the cumulative LTA trend (Figure 7.3) demonstrates that the Deed of Agreement requirement has been successfully achieved over the 13 years from January 2007. The long-term trend value of LTA that has achieved this outcome is 497,000 m<sup>3</sup>/yr since 2001, or the slightly lower value of 484,000 m<sup>3</sup>/yr since 2007. This estimate implies a natural bypassing rate in the range of 40,000 – 60,000 m<sup>3</sup>/yr.

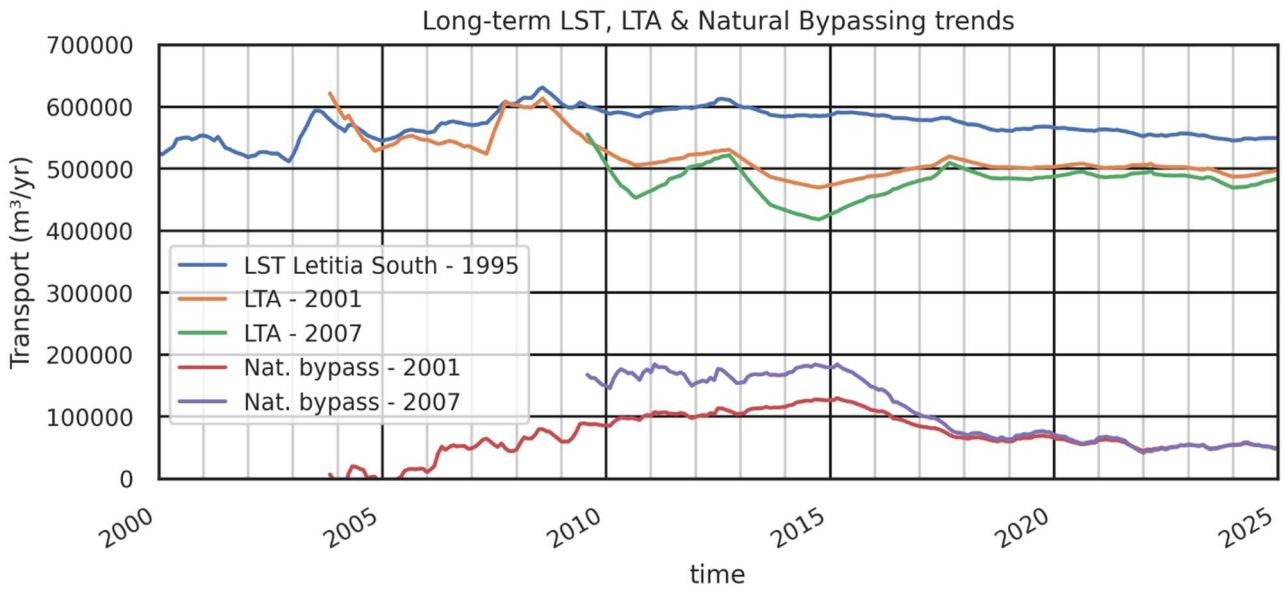


Figure 7.2 Cumulative Trend Rates of LST, LTA and Natural Bypassing

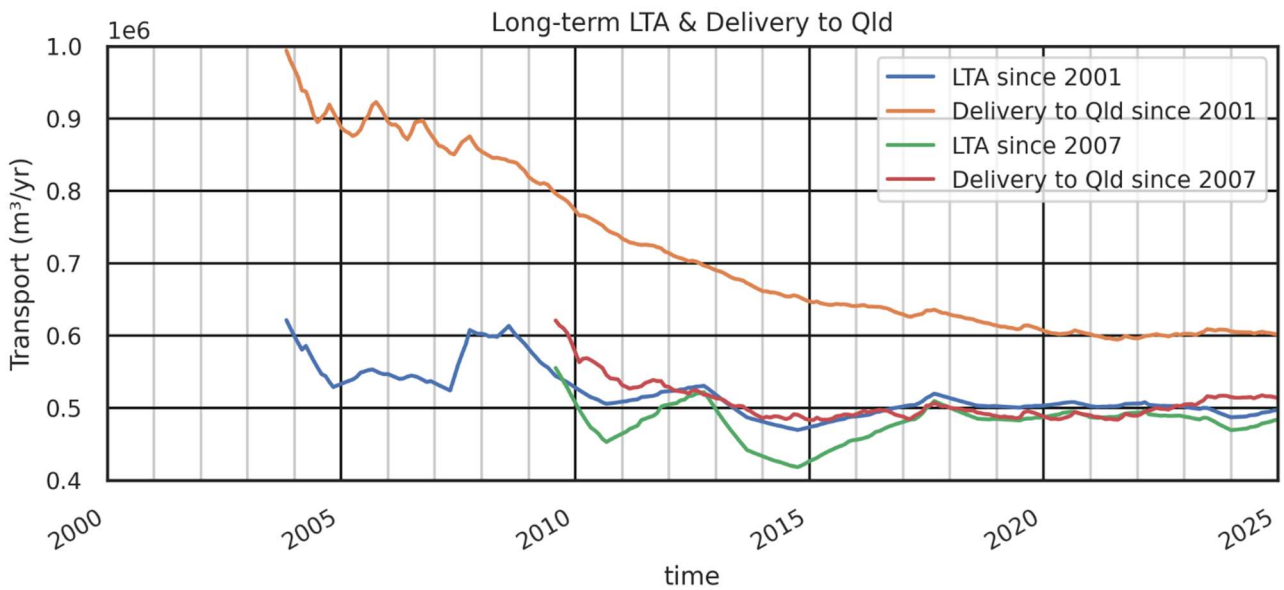


Figure 7.3 Cumulative Trend Rates of LTA & Delivery to Qld

### 7.3 Entrance Dredging Requirement

Tweed River entrance navigability will depend on sand bar configurations and wave conditions; however it is reasonable to expect that higher entrance sand volumes will correlate with a higher risk of navigability constraints. Sand volumes within the entrance compartment are currently at 1995 levels, having been reduced by over 1.0M m<sup>3</sup> during Stage 1a dredging. Since 2016, there has been 1.10M m<sup>3</sup> of entrance dredging at an average rate of 122,000 m<sup>3</sup>/yr in order to approximately maintain entrance volumes and satisfy legislated navigability objectives. It is notable that this period included two large flood events in 2017 and 2022, which exported an estimated 546,000 m<sup>3</sup> of sand from the lower Tweed

River estuary into the littoral system. It is possible that higher rates of maintenance dredging would be required following significant river flooding and this may be reflected in the average rate since 2016.

An estimate of the proportion of the longshore transport intercepted by the jetty system has been made on the basis of the longer term cumulative ratio of the leakage, taken to be the transport past the south wall, to the transport into Letitia North is shown in Figure 7.4. This indicates that overall, to December 2024, about 23% of the transport into Letitia North has leaked through the trestle system. The estimated cumulative leakage has trended downward from around 30% since 2015 (BMT WBM, 2016).

As well, an estimate of the amount of dredging required to maintain the entrance channel as a percentage of the transport of sand into the channel past the south wall has been made, as shown in Figure 7.5. The current value of this metric reflects the operational history of the project and has trended upwards from around 50% in 2015 to about 67% in 2019 as a consequence of the recent dredging campaigns.

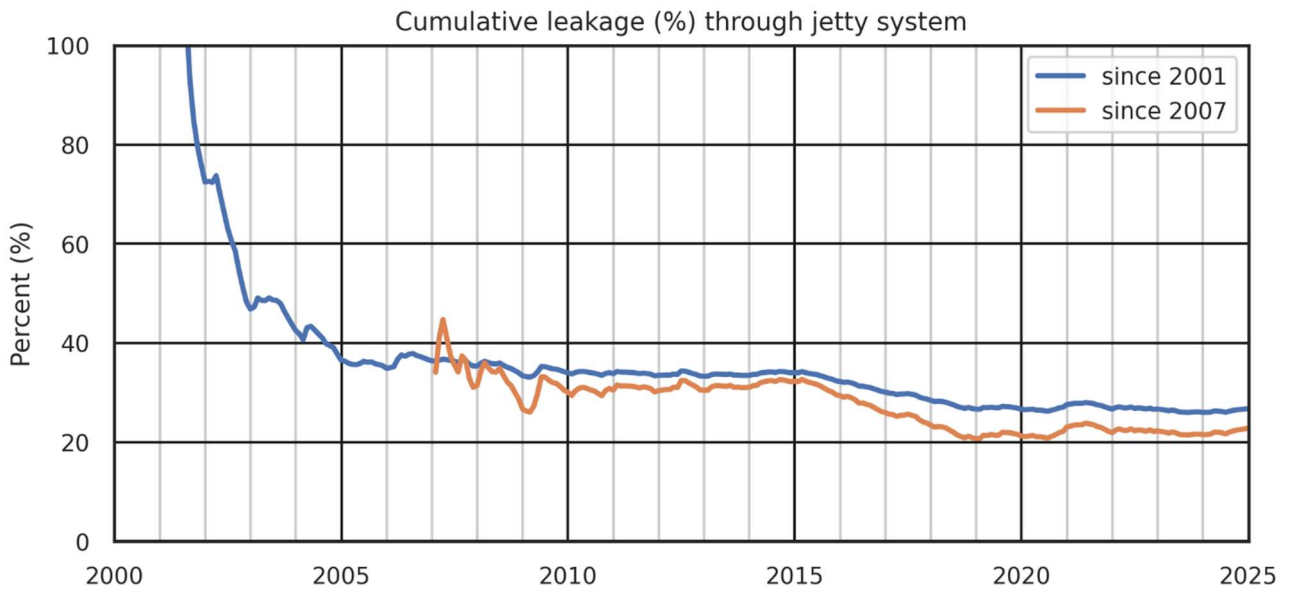


Figure 7.4 Cumulative trend of % leakage through jetty system

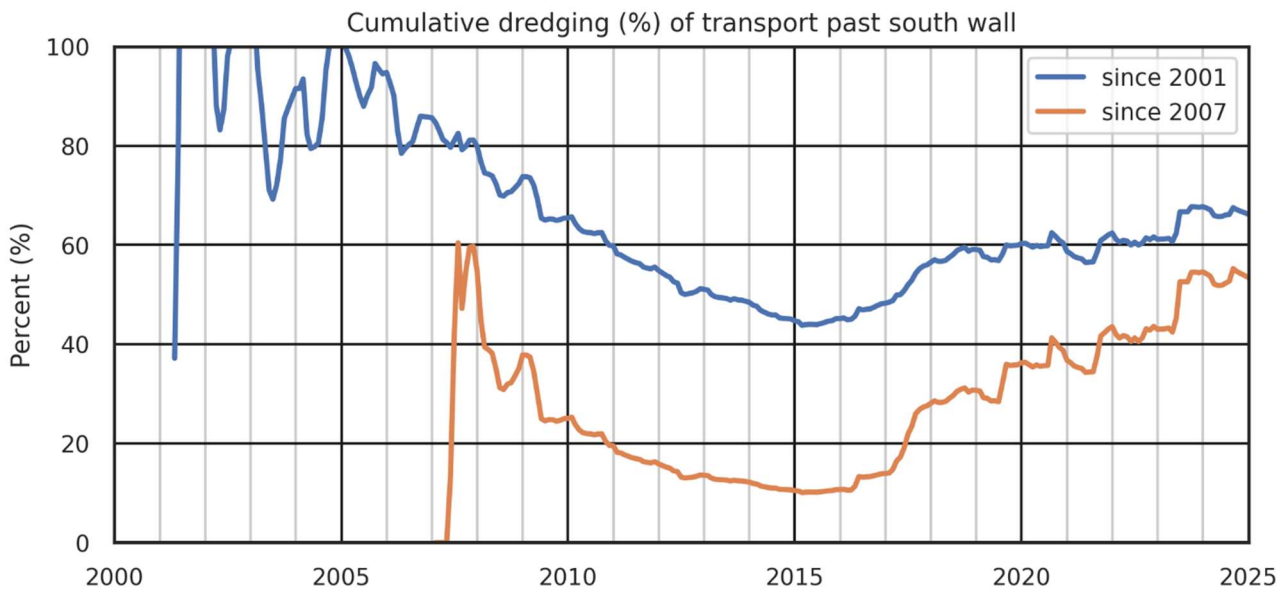


Figure 7.5 Cumulative trend of % dredging of sand leakage

### 7.4 2025 LTA Summary

In this study the long-term trend values of the Letitia Spit LST and LTA rates have been updated using available data to December 2024. Given that the LTA as defined in the DoA is a quantity that depends not only on the environmental LST quantity but also on the modes and rates of bypassing operations, the estimated split between dredging and pumping quantities consistent with the LTA estimate have been included as supplementary information:

- Letitia Spit LST: 550,000 m<sup>3</sup>/yr (±20,000 m<sup>3</sup>/yr)
- LTA: **500,000 m<sup>3</sup>/yr** (±20,000 m<sup>3</sup>/yr), split between
  - Dredging: 60% of 23% of 550,000 = 75,000 m<sup>3</sup>/yr
  - Pumping: 425,000 m<sup>3</sup>/yr
- Natural Bypassing: 50,000 m<sup>3</sup>/yr

If higher rates of entrance dredging should be required in order to meet entrance navigability criteria, then either; the rate of pumping should be reduced accordingly; or, the surplus dredging quantity should be back-passed in order that total bypassing to Queensland does not exceed DoA requirements.

The 2024 LTA re-assessment is notably similar to the previous 2019 assessment (490,000 m<sup>3</sup>/yr) and appears to be quite stable now that it is based on approximately 24 years of monitoring data. This long-term convergence of the LTA estimate is expected. However, the project bypassing requirements will continue to experience substantial short-term and inter-annual variability in Letitia Spit longshore transport rates. This is discussed further below.

### 7.5 Natural Variability

The LTA is specified in the DoA as the quantity used to derive the target quantity for TSB sand delivery to Queensland over the long term. However, shorter term operational targets over time periods down to years and months should to the extent possible follow the natural variability of the LTA over these timescales. However, this natural variability isn't known in advance and furthermore can't be directly

measured and estimates using Eq 1b will be highly uncertain over monthly to annual timescales due to the nature of the inherent errors discussed in Section 2.7.

At the end of a monthly period TSB derive monthly estimates of LST at Letitia Spit using the LITPACK software and measured wave data for that period. This modelled LST estimate can be used to derive a monthly LTA increment estimate by subtracting an allowance for the natural bypassing. The timeseries of monthly LTA increments estimated using LITPACK is shown in Figure 7.6. Monthly increments vary from a minimum of around 0 up to a maximum of 190,000 m<sup>3</sup>/month. Considering the 12-month running mean, the annual LAT (LITPACK) increments over this period vary from a minimum of 292,000 m<sup>3</sup>/yr up to a maximum of 765,000 m<sup>3</sup>/yr, which is a variation of more than ±200,000 m<sup>3</sup>/yr around the long term average.

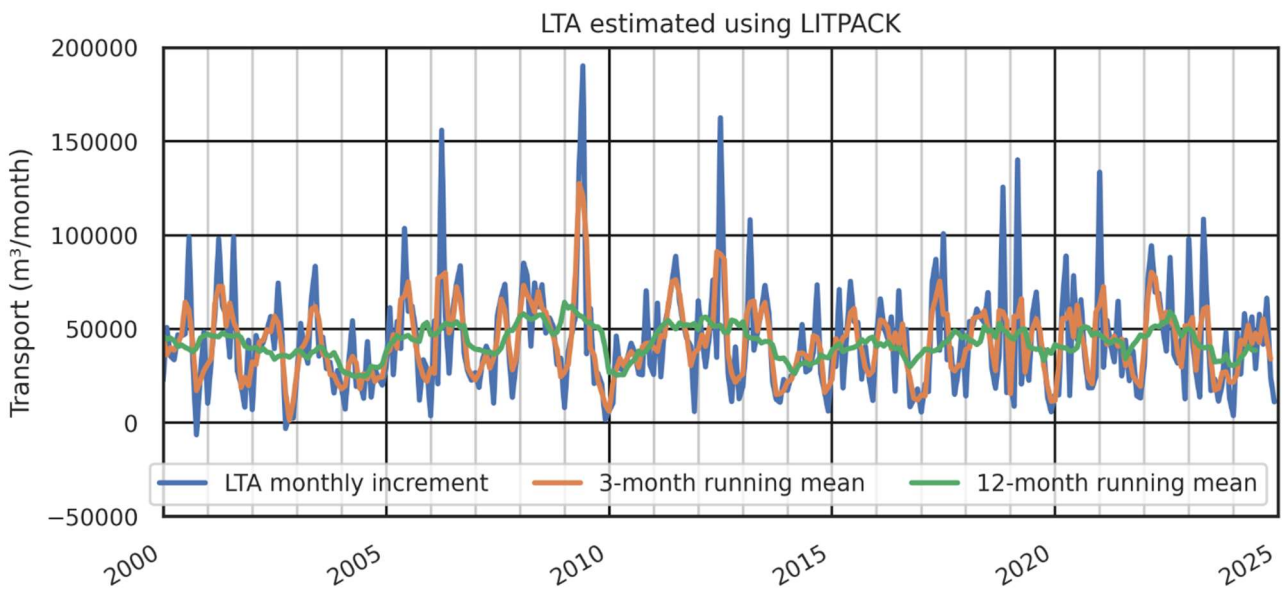


Figure 7.6 Timeseries of LTA estimated using LITPACK

### 7.6 Long-term Trends

The LTA is primarily driven by the directional wave climate offshore of Letitia Spit, which will be influenced by global climate phenomena such as El Nino-Southern Oscillation (ENSO) cycles. It is therefore expected that the LTA will be statistically correlated with the Southern Oscillation Index (SOI) used to track ENSO. In order to investigate this hypothesis, the LTA (LITPACK estimate) and SOI timeseries are plotted together in Figure 7.7. The visual trends evident in this figure supports the correlation hypothesis and furthermore suggests that higher than average LTA increments are more likely to occur during positive SOI phases (La Nina) and vice-versa during negative SOI phases (El Nino).

Multi-year periods of above and below trend LTA increments are also evident in Figure 7.7. The existence of these extended above/below trend periods help to illustrate why it is important for TSB to estimate and track the LTA on an ongoing basis rather than waiting for LTA reviews to be undertaken every 5-years. The estimated LTA (LITPACK) increments can be used to identify consistently above (or below) trend LTA periods and guide the target delivery increments to approximately match the LTA across these above/below trend periods.

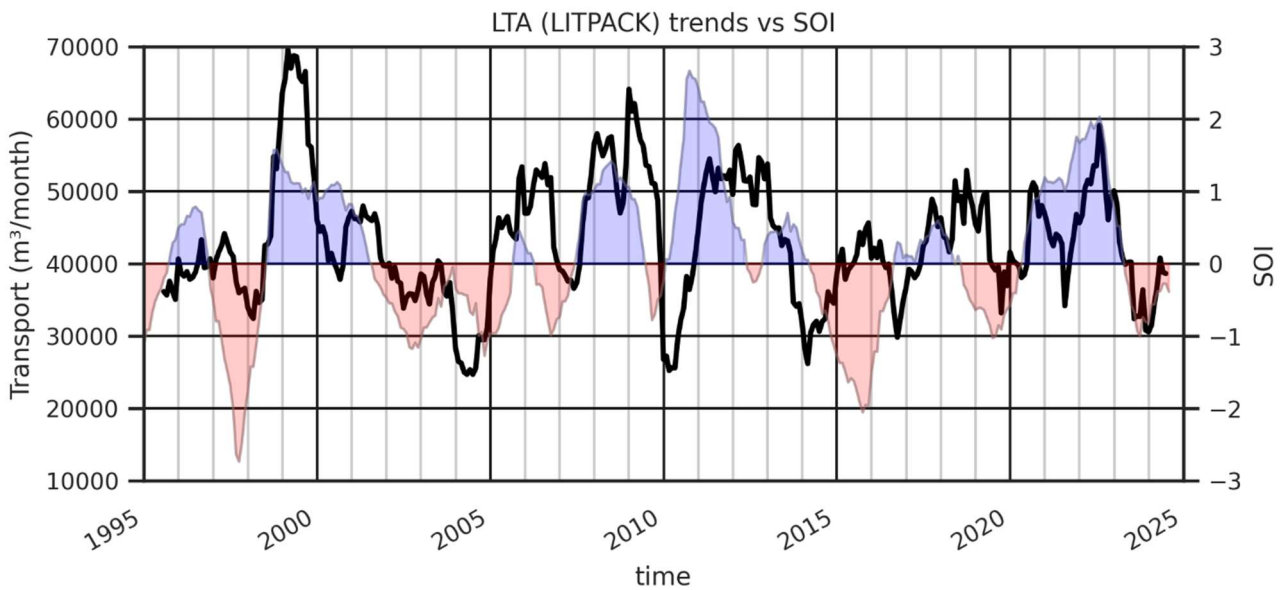


Figure 7.7 LITPACK LTA trends versus SOI. A 12-month moving average has been applied to both LTA and SOI.

### 7.7 Climate Change

The present rate of Sea Level Rise (SLR) is around 3.6 mm/year and is exhibiting an accelerating trend (IPCC, 2019). Planning studies in Australia are commonly adopting future SLR projections of up to 0.8 m by 2100.

These projected trends are expected to impact on coastal systems such as Letitia to Currumbin by driving profile evolution to maintain “equilibrium” with the rising sea level. The “Bruun” rule is a simple model used in coastal engineering to predict how unconstrained coastal profiles may maintain equilibrium with SLR by translating both upward and shoreward. In reality, beach systems are often constrained by features such as natural headlands and by shore protection structures such as seawalls. This means that profile adjustment to SLR is unlikely to occur in accordance with the Bruun rule but may exhibit substantial alongshore variability.

Modelling studies such as Patterson (2013) have predicted that SLR can significantly alter the longshore sand transport regime along a section of coastline constrained by headlands. Headlands will tend to stabilise the cross-shore position of updrift profiles while transferring a corresponding volume deficit onto downdrift profiles. It is possible that such a response to SLR could result in reduced longshore transport supply into Letitia Spit due to accumulation of sediment at updrift headlands (Fingal, Cudgen, etc.). The Tweed River entrance and lower estuary may also tend to accumulate more sand as a morphological response to SLR.

Future climate change trends may also impact on the wave climate (Morim et al, 2018), although the projected trends in terms of wave energy and directionality are less certain than the SLR trends. Any such significant trends would have implications for longshore transport rates and associated shoreline response.

Additional sand nourishment may be required in future to mitigate SLR induced recession where there is a seawall limiting landward translation, as is largely the case for Gold Coast beaches. In the absence of additional nourishment, it would be expected that upper beach sand volumes would be gradually reduce as a result of SLR, with inevitable loss of beach amenity.

It appears likely from the above considerations that future climate change creates additional risks, uncertainties and potentially opportunities that may influence future Tweed Sand Bypassing project objectives.

### **7.8 Future Recommendations**

Accurate calculation of the LTA fundamentally relies upon the input datasets described in Section 2.2 of this report. The monitoring to date has been comprehensive and invaluable as a data source for this reassessment of the LTA and should be continued at the present level of detail and frequency to maintain suitable and sufficient accuracy and reliability for future reassessments. Large Tweed River flood events in 2016 and 2022 exported significant volumes of sand from the river and highlighted the need for ongoing regular surveys of the lower Tweed River to track the sand exchange between the estuary and the littoral system. Surveys of the river can occur less frequently than the 6-monthly coastal compartment surveys and would probably be sufficient if they occurred on a regular 2-yearly basis.

## 8 References

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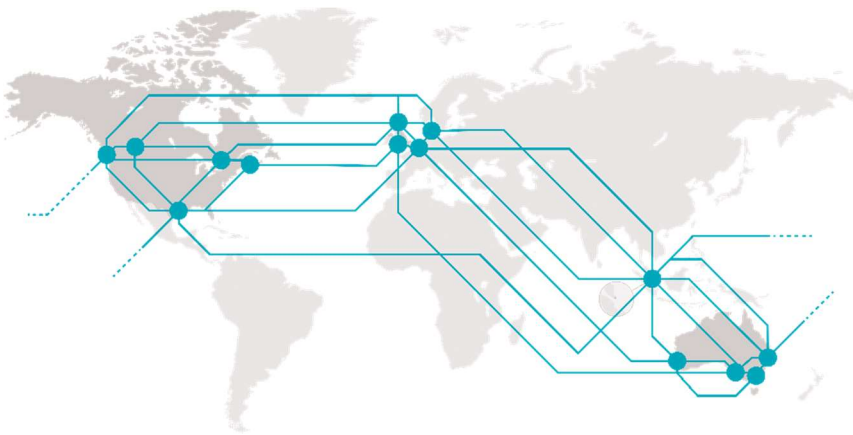
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