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Tweed River Entrance Sand Bypassing

Reassessment of Long Term Average Annual Net Sand Transport Rate 2015

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Re-assessment of Long Term Average Annual Net Sand Transport Rate 2015

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Prepared For:	NSW Land & property Management Authority
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Title :	Tweed River Entrance Sand Bypassing Re-assessment of Long Term Average Annual net Sand Transport Rate 2015
Author :	D C Patterson
Synopsis :	This report describes the results of the re-assessment of the Long Term Average (LTA) sand transport rate at Letitia Spit to September 2015. The re-assessment strategy as outlined follows that of the previous reassessment to 2009 (BMT WBM 2011) and includes analysis of wave-induced sand transport rates and interpretation of the results of the surveys quantifying quantities of sand in various compartments of the system. This provides incremental monthly data on the LTA, natural bypassing from NSW to Qld and sand transport rates along lower Gold Coast, Letitia Spit and at Snapper Rocks. Discussion of the trends and uncertainties in the analyses is presented.

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EXECUTIVE SUMMARY

Background

An updated reassessment of the Long Term Average (LTA) sand transport rate for the Tweed River Entrance Sand Bypassing Project (TRESBP) has been undertaken to extend the previous 2009 reassessment to 2015, 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 TRESBP 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 2015, including the period of Stage 1 initial entrance dredging that commenced in 1995, 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 CERC and Queens sand transport relationships were utilised, with the same coefficients as were used in the previous analysis. The sand transport results from the Queens relationship are presented in this report.

The analysis undertaken is based on analysis of the respective surveyed sand quantities and component sand transport rate values, determined in a monthly time series format from the available data. 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.

LTA and Sand Transport Rates

The component monthly LTA values for the period of the operations and monitoring analysed varied significantly over time, depending on the rates of sand transport and the bypassing rates implemented. In particular, the trend in the LTA over the past 5 years has responded to reduced sand bypassing without a need for entrance dredging to maintain the channel depth. This results in increased natural bypassing and a reduction in the LTA.

The LTA averaged approximately 509,000 to 513,000m^3/yr for the bypassing period 2001 to 2009 but has reduced significantly to about 475,000-490,000m^3/yr when averaged over the period 2001-2015. At the same time, the component sand transport processes over the period 2001 to 2015 involved an average annual net longshore transport into Letitia Spit of about 588,000 m^3/yr and natural bypassing of about 100,000m^3/yr.

The natural bypassing had initially been reduced by both the Stage 1 initial dredging at the river entrance in the mid to late 1990s and the relatively high rates of sand bypassing operations in 2001 to 2009. The pre-bypassing natural bypassing rate of 322,000m^3/yr determined for the period 1995 to 2000 had been reduced to about 40,000m^3/yr for the period 2001 to 2009 as a result of the bypassing activities. However, it has subsequently increased to 100,000m^3/yr as a result of reduced bypassing. There is evidence that this may be somewhat too high as the need for entrance dredging has recently been identified to meet depth requirements.

The analysis undertaken indicates that the long term average annual longshore sand transport past Fingal over the period 1995 to 2015 is approximately 575,000m^3/yr, higher than previously estimated. However, the average rate at Currumbin is only 503,000m^3/yr. This long term discrepancy, derived solely on from the surveyed volumes, has not been explained and requires further research.

There is a leakage of sand through the jetty system, determined to be about 30%. However, there has been no evident requirement to dredge sand entering the entrance channel until recently, yet to be implemented. This indicates that this leakage has in part deposited in the ‘entrance’ compartment and in part passed through as the natural bypassing.

Recommendations

Contrary to the previous findings, the assessed LTA rate from the long term context analysis has reduced to about 475,000-488,000m^3/yr compared with 510,000 for the period 2001-2009. This result is derived because the evidence suggests that the river entrance depth criterion can be satisfied with a higher leakage of sand past the bypassing system than previously determined. However, the recently identified need for dredging means that this LTA rate may be somewhat too low

Accordingly, a reassessed LTA rate of about 490,000m^3/yr may be adopted, subject to sustained achievement of suitable entrance depth.

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 in order to maintain suitable and sufficient accuracy and reliability for future reassessments. This reassessment has identified potential errors in the surveyed volumes that need to be carefully reviewed in the context of the progressive time series volumes in each compartment.

1 INTRODUCTION

1.1 Background

1.1.1 Overview

BMT WBM was commissioned to undertake an updated reassessment of the Long Term Average (LTA) sand transport rate to 2015 for the Tweed River Entrance Sand Bypassing Project. This has been completed using the same strategy and analysis parameters as for the previous 2009 reassessment. 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 reassessment, the sand bypassing system had been in operation since April 2001, with over 14 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 been lower.

This report sets out the results of the reassessment to 2015, 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 is presented.

1.1.2 Legislative provisions

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 via either the trestle system or entrance dredging and 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. Clearly, 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 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.

1.2 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 2015, 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.

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.

1.3 LTA Reassessment Strategy

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). However, the DOA included provision also for an initial 6 year period of Supplementary Increment to be delivered to compensate for accumulation of sand at the entrance between 1990 and the commencement of operation of the bypassing system in April 2001 to offset ongoing sand losses from the southern Gold Coast beaches. Inclusion of this quantity, approximately 1.66 million cubic metres, in the delivery via the jetty system has affected the way in which the coastal system has responded and was considered in the previous LTA reassessment to 2009 (BMT WBM 2011). By 2015, the influence of the Supplementary Increment is expected to have diminished and the effects of the bypassing strategy adopted after 2009 will be evident.

The LTA reassessment strategy pursued in this study is the same as that implemented in the previous reassessment. It is based on time series (monthly/annual) analysis of the LTA components over the 2001-2009 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.

1.3.1 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 (Figure 1-1) shows that:

Net Quantity Change = Transport in – Natural Bypassing – Sand Pumping/Dredging + River supply

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

LTA = Transport in – Natural Bypassing (1a)

LTA = Pumping/Dredging (total) + Net Quantity Change – River supply (1b)

(Note: The net quantity change along Letitia Spit has been negative over the bypassing period)

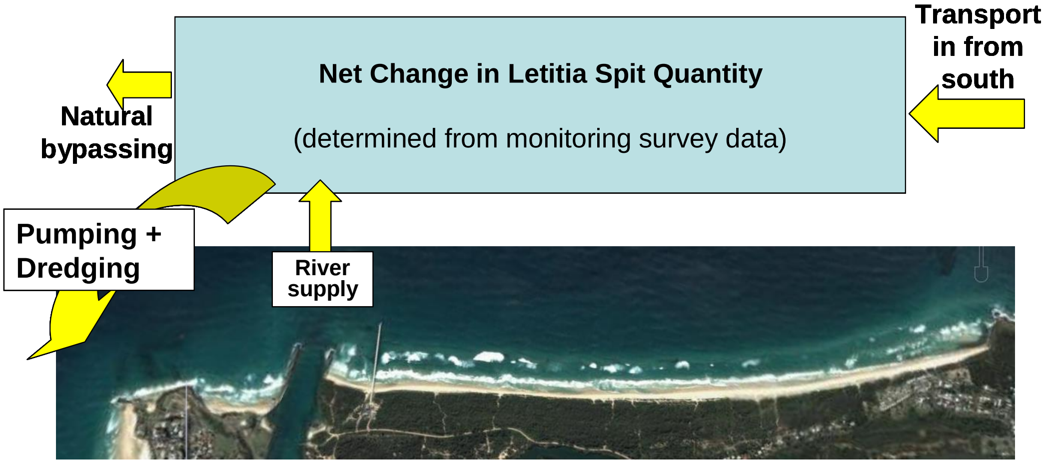


Figure 1-1 Conceptual sand budget for Letitia Spit

As such, direct 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).

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.

A summary analysis of 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 is presented and discussed in Chapter 3. The results of the LTA analysis based on Equation 1b are presented in Chapter 4.

1.3.2 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^3/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 1-2, 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).

Natural Bypassing = $Tran_{Currumbin}$ + ΔQ (Qld) – Sand Pumping/Dredging (total) (2a)

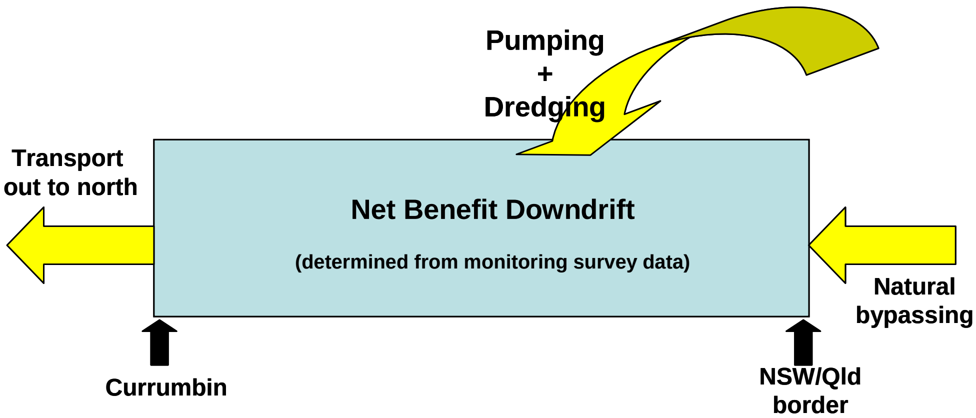


Figure 1-2 Conceptual quantification of natural bypassing

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.

Total transport at NSW/Qld border = $Tran_{Currumbin}$ + ΔQ (Qld) – Pumping/Dredging (Qld) (2b)

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.

A summary analysis of 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 sand bypass system operation is presented and discussed in Chapter 2. Longshore sand transport (LST) rates calculated for Currumbin are described in Chapter 3. The LTA rates derived from the data using Equation 1b and from calculated LST rates are presented in Chapter 4.

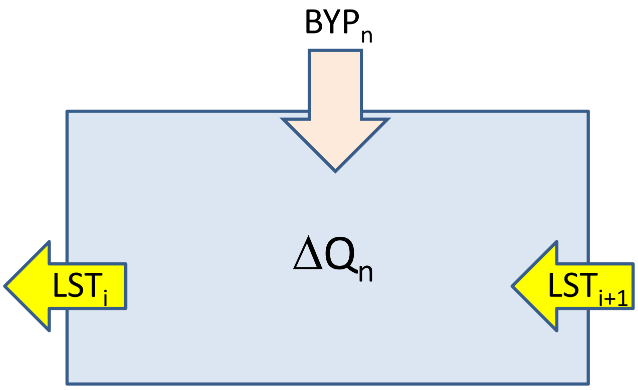
Analysis of natural bypassing rates across the NSW/Qld border is presented in Chapter 5.

1.3.3 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.

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 1-3. The LST rates for Letitia Spit and the entrance area are calculated from sand budget components as shown in Figure 1-4.



$$LST_{i+1} = LST_i + \Delta Q_n - BYP_n$$

Figure 1-3 Conceptual sand budget for LST calculations

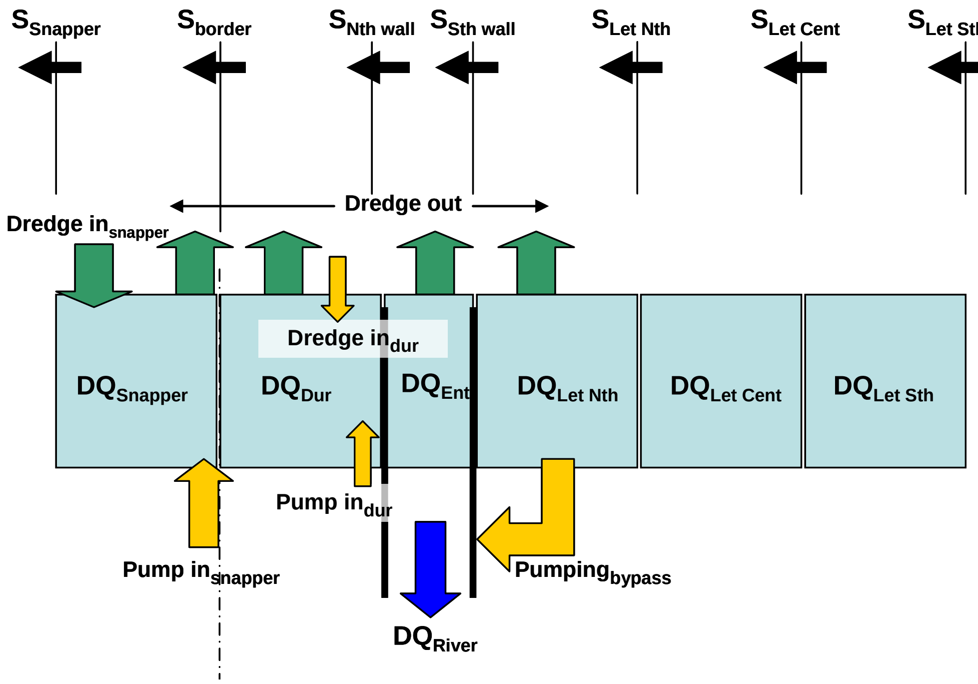


Figure 1-4 Conceptual sand budget for Letitia transport calculations

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.

1.3.4 Bypassing and Dredging rates

The history of bypassing and dredging rates is shown in Figure 1-5. It can be seen that there has been no dredging of the river entrance channel since 2009. This is surprising and significant as the bypass pumping rate has been reduced in that time, expected to allow somewhat greater leakage of sand through to the entrance.

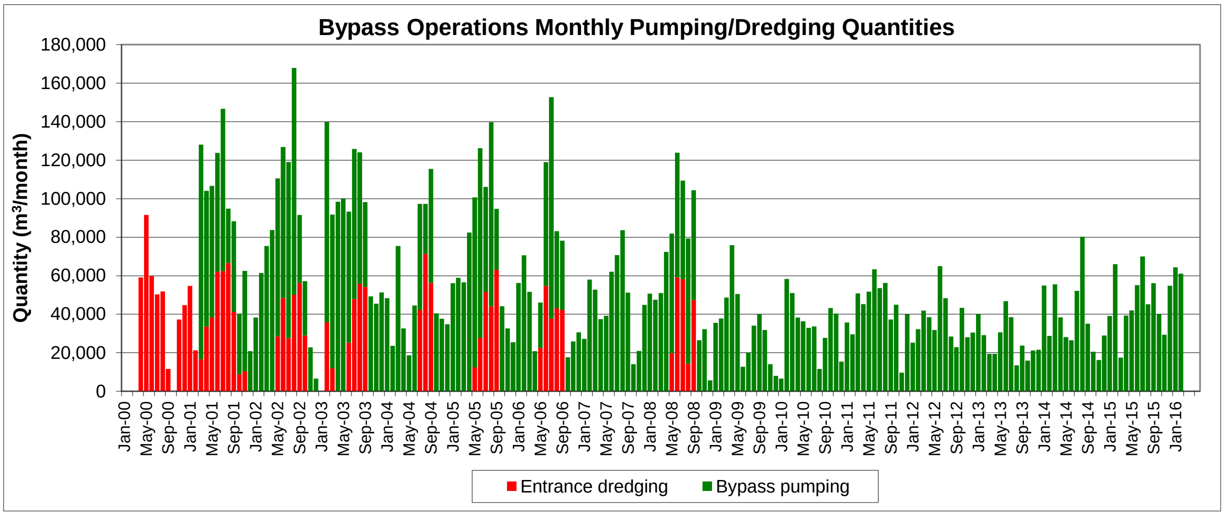


Figure 1-5 Bypass pumping and entrance channel dredging monthly rates

1.3.5 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:

- 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 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.

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.

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.

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 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 LTA reassessment (BMT WBM 2011) has shown the longer term annual average net transport to be about 500,000m^3/yr or possibly up to 550,000m^3/yr. The methodology used in the previous LTA reassessment has been applied again in this extension of the reassessment to 2015.

2 SAND QUANTITY CHANGES DERIVED FROM SURVEYS

2.1 Monitoring Program Surveys

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

The surveys have been carried out regularly, at least once per year, and analysed by the NSW Department of Lands 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 October 2015 along Letitia Spit and November-December 2015 north from Snapper Rocks to Currumbin, within the various analysis compartments outlined in Section 2.2.

2.2 Surveyed Quantities

2.2.1 Analysis Compartments

Sand quantity analyses have been undertaken by NSW Department of Lands to determine progressive changes within various compartments within the overall study region from Fingal to Currumbin. Those compartments are shown in Figure 2-1 and have been used in the present study either separately or in combination for the purpose of LTA and sand transport calculations. The survey lines covering Letitia Spit and the entrance area are shown in Figure 2-2.

Additionally, surveys have been undertaken of the quantities of sand within the Tweed River to identify changes there associated with movement of sand to or from the river reaches. Those surveys that comprehensively cover the whole system (Figure 2-3), including the entrance area, extend over the period since February 2000, showing a gradual reduction (export) of sand. Prior to that time, only approximate data are available indicating a small and progressively reducing upstream movement of sand.

Further, review of the surveyed quantity changes over the longer term of the data identifies a slight movement of sand to deeper water beyond 20m depth offshore from the river entrance that is estimated to have been about 18,000m^3/yr for the period 1993 to 2000, 12,300m^3/yr from 2000 to 2005 and only about 5,000m^3/yr from 2005 to date. While relatively minor, it is of the same order as the river quantities and has been accounted for in the assessments as a progressive loss from the 'entrance' compartment.

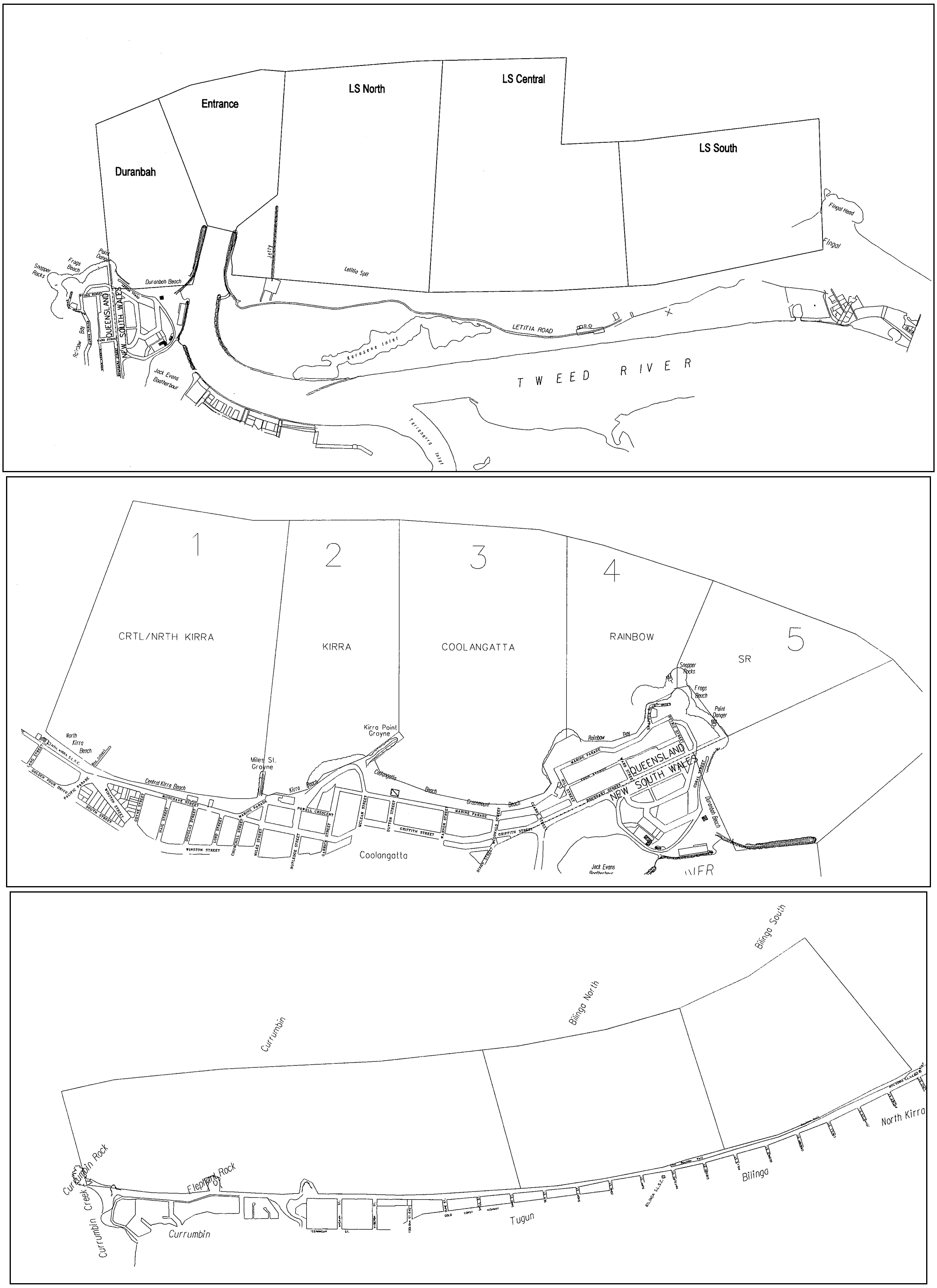


Figure 2-1 Sand quantity calculation compartments

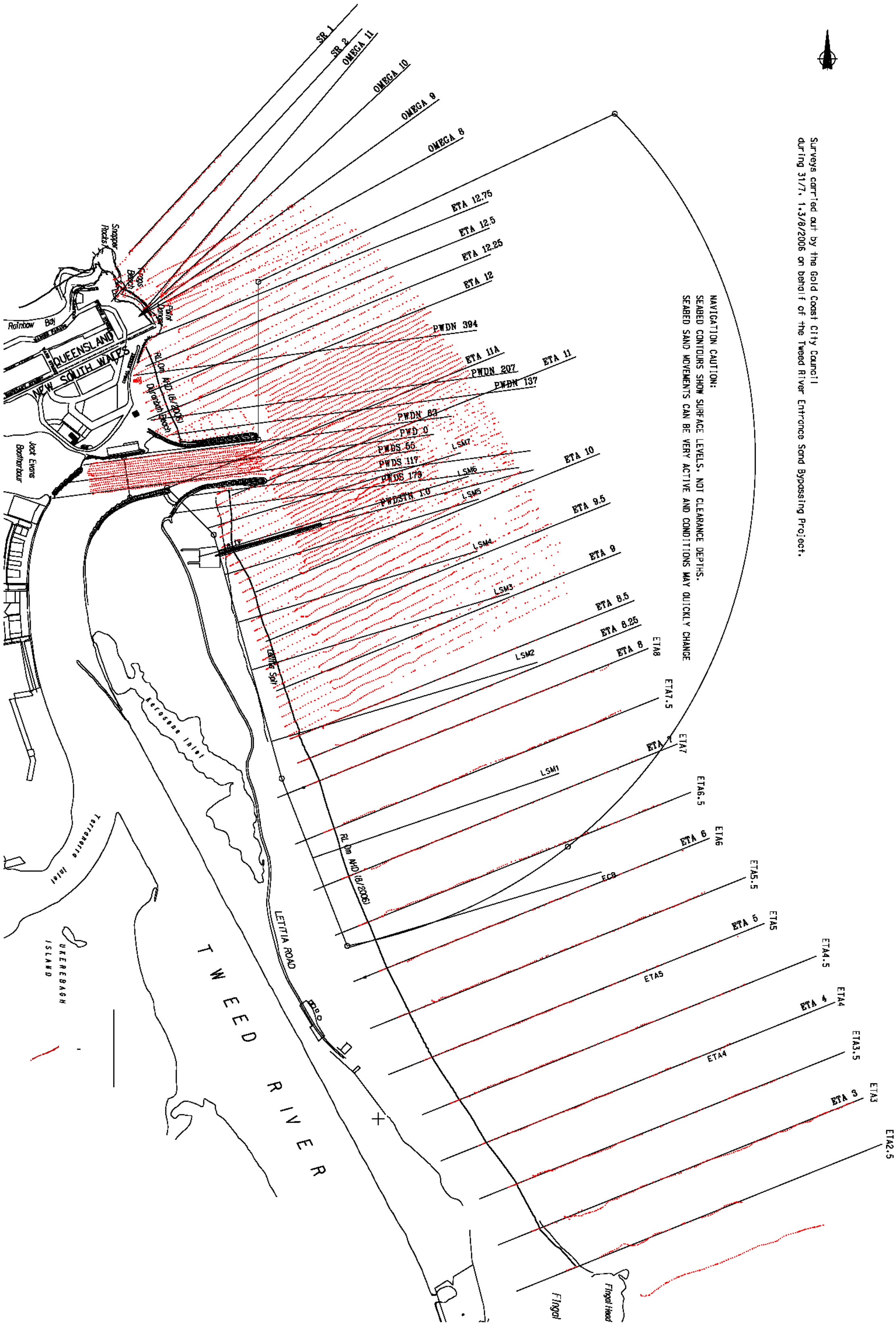


Figure 2-2 Survey profile lines – Letitia Spit and river mouth area

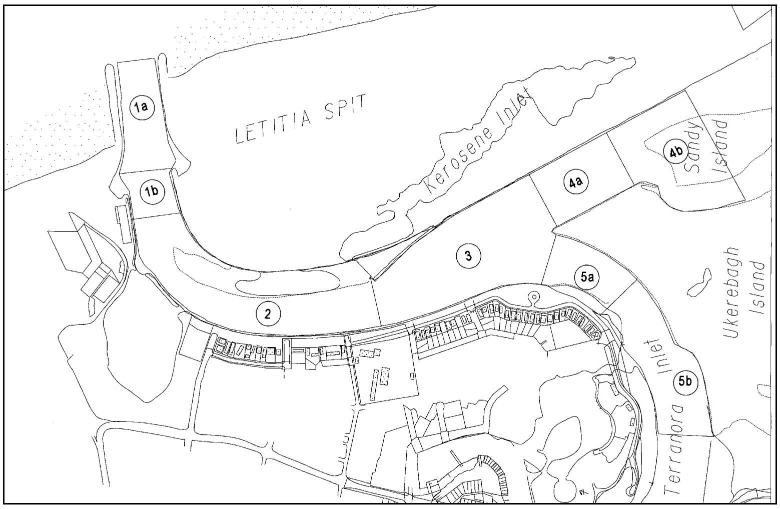


Figure 2-3 Survey compartments within Tweed River

2.2.2 Monthly Time Series

Monthly time series of the quantity changes within each of the analysis compartments have been determined on the basis of:

- The survey data for the dates as listed in **Error! Reference source not found.**; and
- A monthly breakdown of the known quantities of dredging and bypass pumping removed from and placed into each of the various compartments respectively.

This has been achieved by a procedure in which it is adopted that, between each date of survey within each compartment, the measured change is the result of a combination of the known artificial inputs and/or outputs and an assumed underlying constant rate change in sand volume for the period between surveys.

The results of this analysis to December 2015 are shown in Figure 2-4 to Figure 2-7 for the individual compartments and in Figure 2-8 for the combined NSW compartments (top) and Queensland compartments (bottom). The smoothing of the monthly trends with respect to the surveyed quantities is evident. The long term trends in volume changes are now clearly evident. Within NSW, there has been an overall reduction in volumes along Letitia Spit, with:

- An initial decrease by about 1.25M m3 to 2008 at Letitia North followed by recovery and stabilisation back to a net loss of 1M m3 by 2015,
- A progressive loss of sand at Letitia Central after 2001 to about 1.5M m3 by 2013, with an apparent indication of stabilising over the past 2 years,
- A loss of about 0.3M m3 at Letitia South prior to bypassing in 2001 followed by slow fluctuations and further net loss of about 0.2M m3 to 2015, with the period from 2009 showing a slight net gain of sand, indicating that the volume changes there are related more to the supply past Fingal than to the behaviour along Letitia Spit;

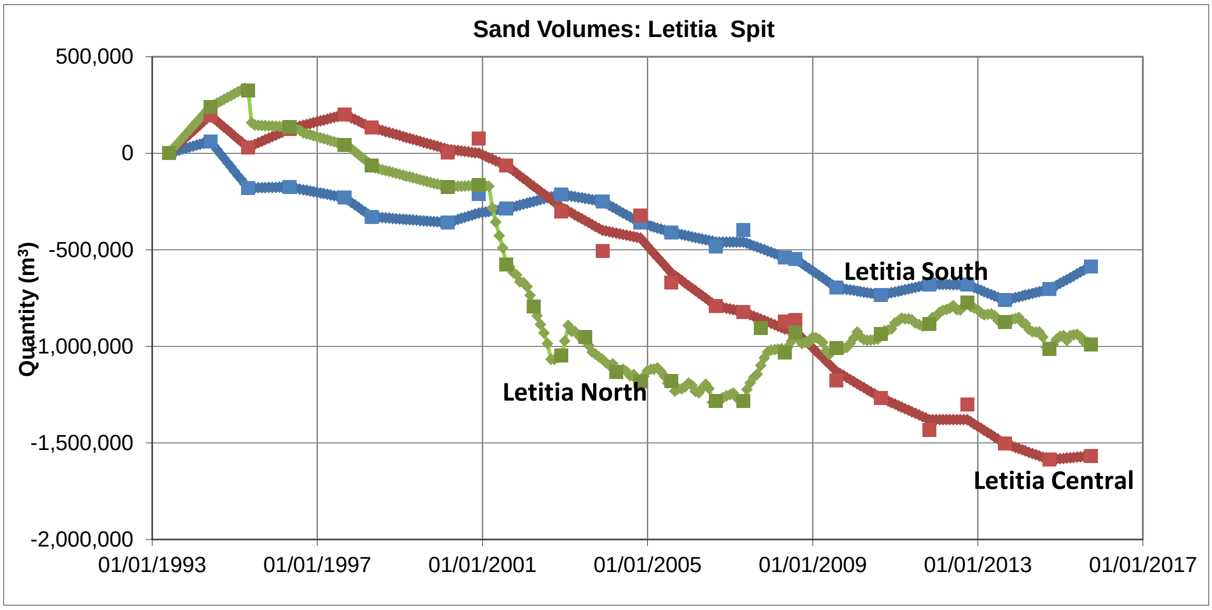


Figure 2-4 Sand volume changes along Letitia Spit

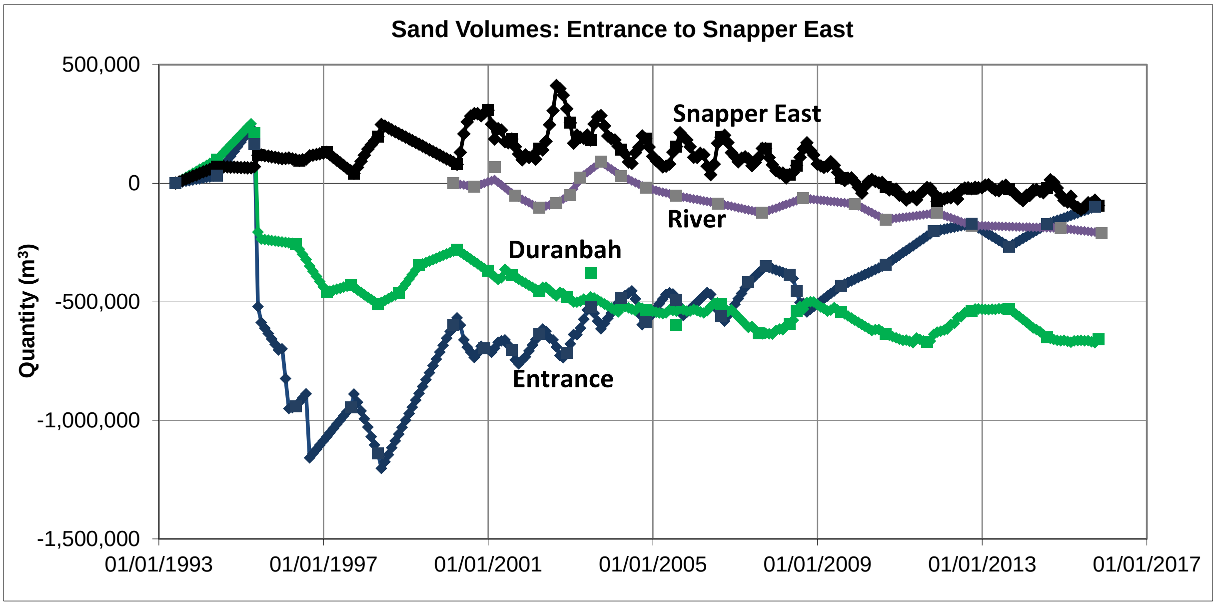


Figure 2-5 Sand volume changes at the entrance, Duranbah and Snapper Rocks East

The significant reductions in sand volume associated with dredging within the entrance and at Duranbah during 1995 to 1997 were followed by significant re-accumulation prior to bypassing. Subsequently since bypassing commenced, the entrance has accumulated about 0.6M m^3 and Duranbah lost about 0.2M m^3 to 2015.

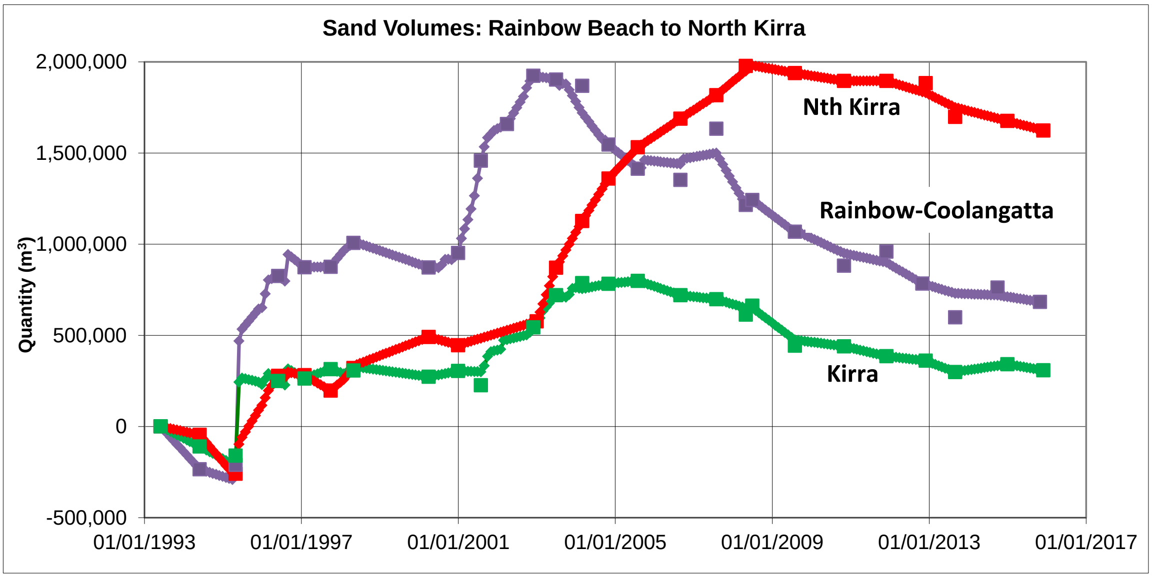


Figure 2-6 Sand volume changes Rainbow bay to North Kirra

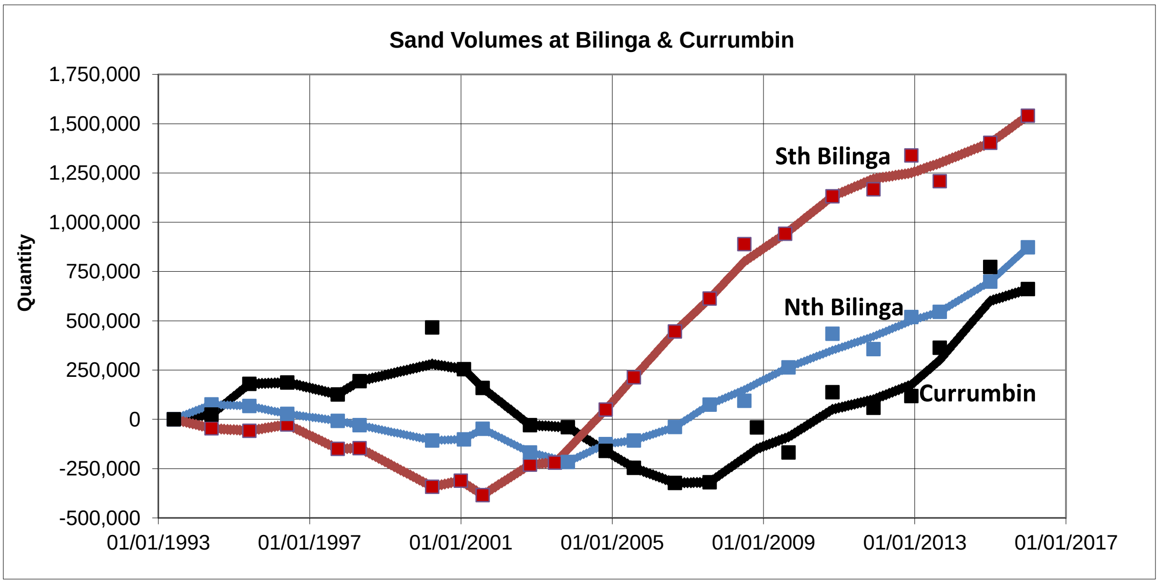


Figure 2-7 Sand volume changes Bilinga South to Currumbin

North of the Qld/NSW border, there has been:

- an overall negligible change in volume at Snapper East, following an initial slight increase prior to commencement of bypassing in 2001 and then a gradual decrease to date.
- An initial rapid increase of about 1M m3 at Rainbow-Coolangatta from 2001 to 2003, followed by a steady reduction there such that the net change from 2001 to 2015 is a loss of about 0.25M m3, representing a net gain of about 0.75M m3 since 1993.
- Reversal of the initial gains of sand after 2001 at Kirra and North Kirra, resulting in about zero net change at Kirra and a residual net change of 1.1M m3 at North Kirra.
- Progressively delayed increases in sand volume north from Bilinga South to Currumbin with as yet no evidence of stabilisation there.

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

NSW. The resulting total cumulative quantity changes since 1993 are shown in Figure 2-10. This figure illustrates the progressive reduction of a net quantity of approximately 3.88million cubic metres from Letitia Spit and the entrance/river areas (including Duranbah) and a corresponding gain of about 5.54million cubic metres to Gold Coast beaches.

Provision has been made in the quantities for a 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. However this cannot be properly quantified as not all of the surveys extend sufficiently far offshore. The surveys within the Queensland areas show that there is no loss or gain of sand across the 20m depth limit of the surveys there, with no measurable change in the bed levels at water depths greater than about 15m. While there may be some survey error at such depths, it is of a random rather than systematic nature.

2.2.3 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:

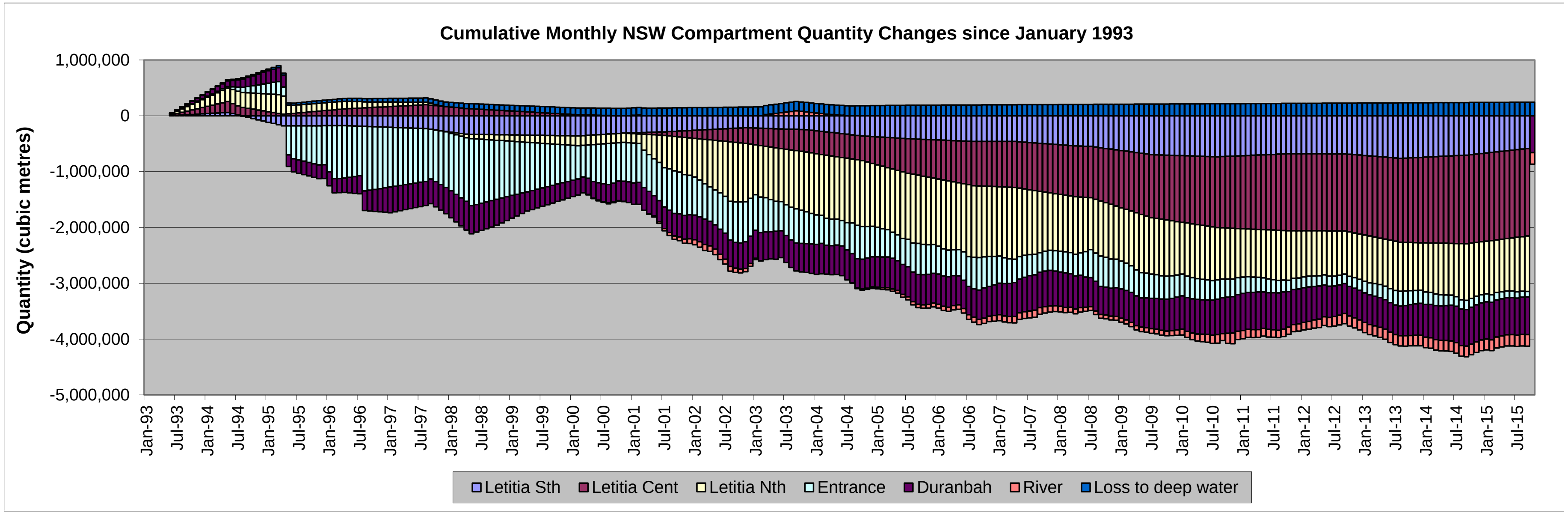
- Insufficient spatial resolution of the survey sampling; and/or
- Measurement error or inaccuracy.

However, 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 to minimise any impacts on the 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.



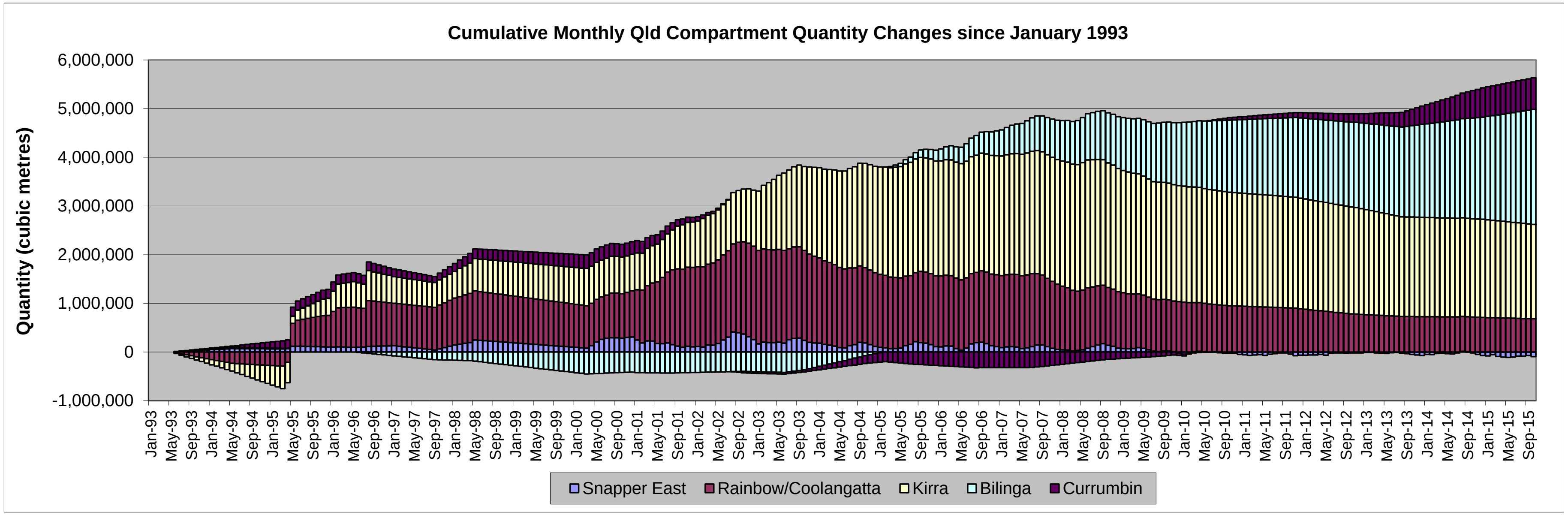


Figure 2-8 Cumulative monthly compartment quantity changes in NSW (top) and Qld (bottom)

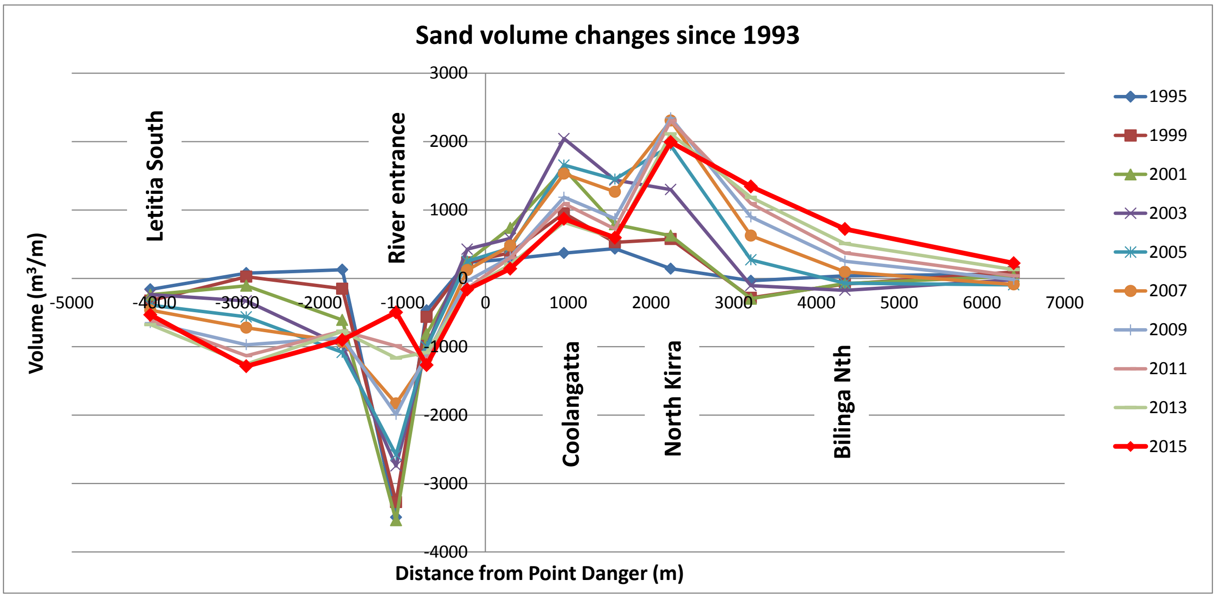


Figure 2-9 Alongshore distribution of change in sand quantities in NSW & Qld since 1993

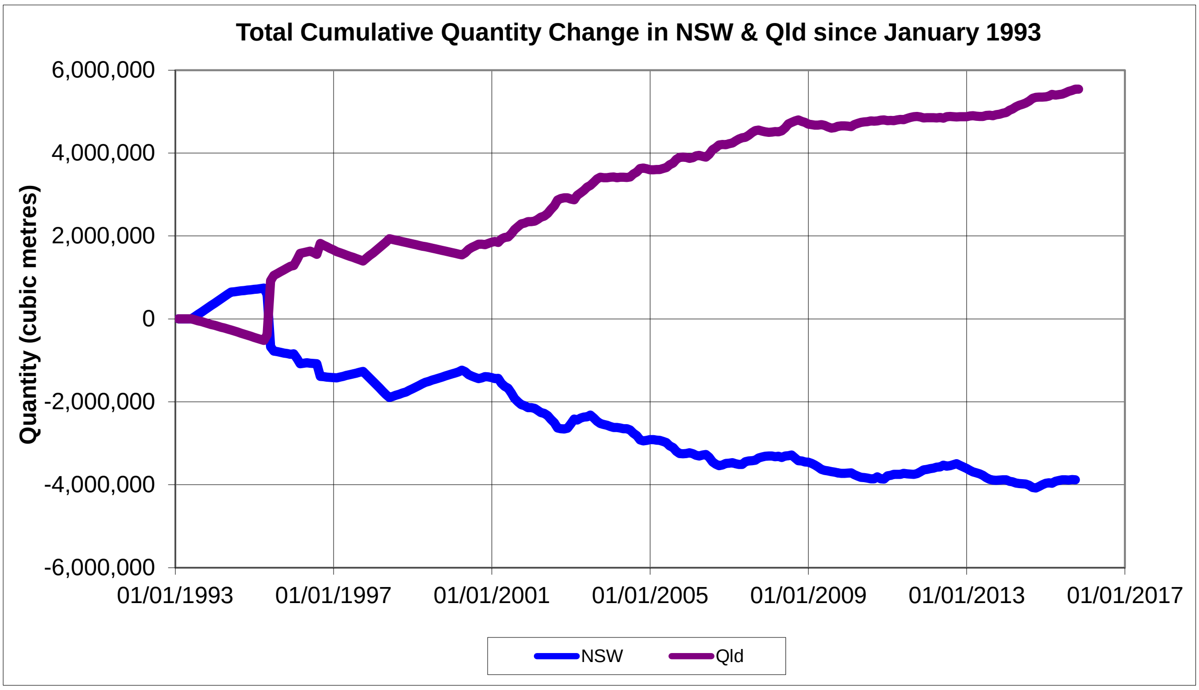


Figure 2-10 Cumulative total change in sand quantities in NSW & Qld since 1993

3 LONGSHORE SAND TRANSPORT RATES

3.1 Previous LST analysis

A considerable amount of previous research has been undertaken into the wave climate and longshore sand transport (LST) regime in the Tweed River mouth and lower Gold Coast region, with somewhat varied results. A LST rate of 500,000m^3/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 previous LTA reassessment (BMT WBM 2011) represents the most comprehensive analysis of LST rates to 2009, providing:

- Time series rates at Currumbin calculated directly from the recorded Tweed directional wave data, from which monthly and annual average rates were derived;
- Monthly and average annual rates at Snapper Rocks (Point Danger), the Qld/NSW border and along Letitia Spit, derived from the Currumbin rates together with surveyed compartment sand volume changes using the methodology illustrated schematically in Figure 1-3;
- Monthly and annual rates calculated at a location about 1,000m south of the river entrance directly from the recorded Tweed directional wave data.

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) reassessment showed that the 1-dimensional LST calculation methods of CERC formula (US Army Corps of Engineers 1984, 2002; Smith et al 2003) and the 'Queens' formula (Kamphius 1991) can be applied with good reliability. These formulations may be expressed in several ways, the most suitable for application here as follows:

CERC $Q_l = K_1 H_b^2 C_g \sin(2\alpha_b)$

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_1 = Dimensionless Coefficient

K_q = Coefficient typically (approx 1.33 for m^3/s or 41x10^4 for m^3/yr)

H_b = Breaking significant wave height

T_p = Spectral peak energy period

C_g = Wave group velocity

ρ_s = Density of sediment

ρ = Density of water

g = Acceleration of gravity

n = Sediment porosity

γ = Wave breaker index

α = Wave breaking angle

m_b = Nearshore profile slope

D_{50} = Median sediment grain size

The CERC formula relies on the dimensionless coefficient K_1 for calibration. The Queens formula contains explicit dependence on grain size, beach slope and wave period that is not included in the CERC formula and depends also on calibration. The coefficient K_q may be considered together with several of the constant parameters as part of the calibration process. For example, adopted values of porosity (0.35 to 0.4), salinity (25 to 35 ppt) and effective beach slope may all affect the outcome. For a beach with barred profile that affects the position of wave breaking, depending on wave height and tide level, specification of a single slope value may not be valid.

Comparisons between the Queens formula and the CERC equation from various sources (Smith 2006; Huchzermeyer 2005; Wang et al 2002) indicate that the Queens formula is preferred over an un-calibrated CERC equation. However, if the CERC equation is calibrated using recorded/estimated littoral drift volumes, both methods provide comparable results. Figure 3-1 shows a comparison of the monthly transport rates derived from both the CERC and Queens formulae for the Currumbin site, based on the Tweed recorded waves, for the period 1995 to 2008. This shows close agreement between the two methods. While the Queens method has been applied consistently in this study in terms of the calculated time series transport rates derived from the wave data, the results and study outcomes would be essentially identical using CERC.

Additionally, comparison of results of the calculation of transport at Currumbin using both Brisbane and Tweed recorded wave data as the basis of calculations shows close agreement, as shown in Figure 3-2 and Table 3-1. As such, use of the Tweed data as the primary basis of calculation for both Letitia Spit and Currumbin is justified. It can be seen that the annual average transport rates vary significantly, depending on the period covered, but lie typically in the range 500,000-550,000m^3/yr. The result for Currumbin to 2008 at 506,000m^3/yr is lower than that to July 2009 at 527,000m^3/yr because of the period high easterly waves during 2009.

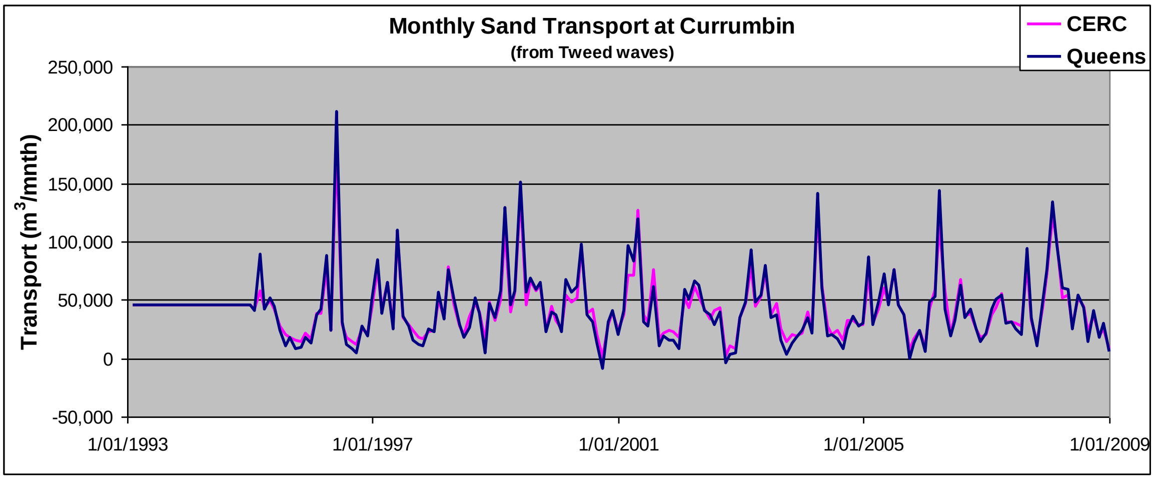


Figure 3-1 Comparison of CERC and Queens formulae at Currumbin

Table 3-1 Calculated transport at Currumbin

Annual Average Net Transport at Currumbin (m^3/yr)		
Period of Calculation	**From Brisbane waves**	**From Tweed waves**
1995 to 2008		506,000
1995 to 2009		527,000
1995 to 2000		511,000
1997 to 2009	553,000	540,000
2001 to 2009	548,000	537,000

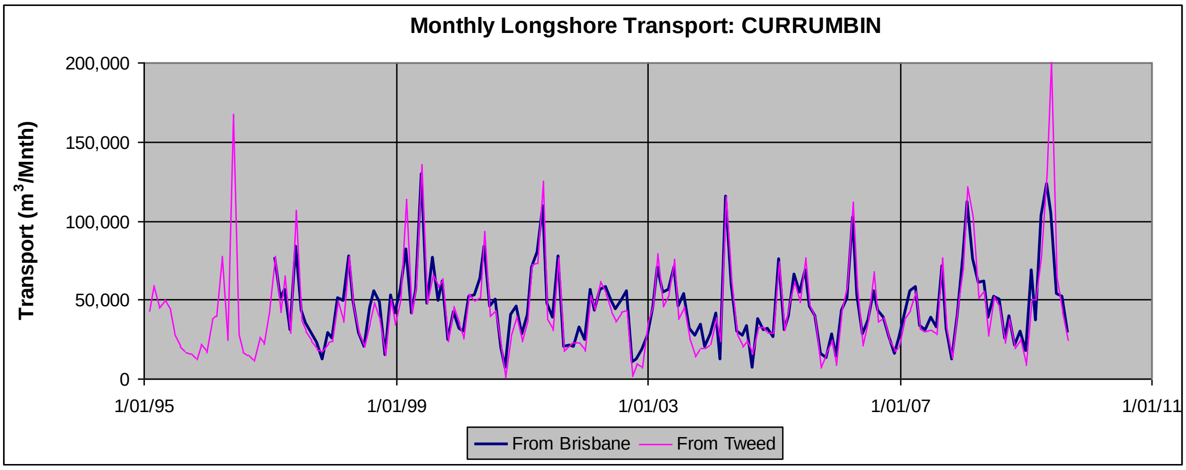


Figure 3-2 Currumbin monthly transport from Tweed & Brisbane waves

Theoretical transport rates at Letitia Spit were calculated for a location 1,000m south of the southern training wall, consistent with the Deed of Agreement. At that location, the alignment of the shoreline has varied significantly since 2001 as a direct result of the sand bypass operations. As such, the transport rates there are not consistent with the natural supply to Letitia Spit past Fingal nor with the Deed of Agreement definition of the LTA which requires that the inflow LST rate be unaffected by the bypassing. For the previous reassessment, the shoreline alignment variation was determined from a combination of the surveys and aerial photography, as illustrated in Figure 3-3.

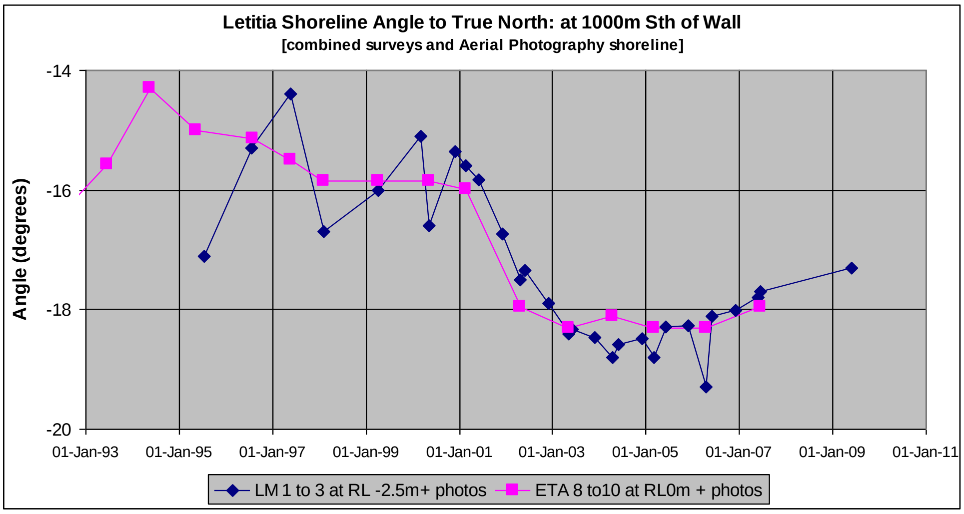


Figure 3-3 Variation in shoreline alignment at Letitia Spit

The calculated monthly transport rates for Letitia Spit are presented in Figure 3-4 and Table 3-2, utilising the shoreline angles shown in Figure 3-3. While there is reasonable agreement between the results from the two wave recorders, there are periods of significant difference (eg early 1999), leading to differences in the annual average results. The results for this site based on the Tweed recorder are preferred.

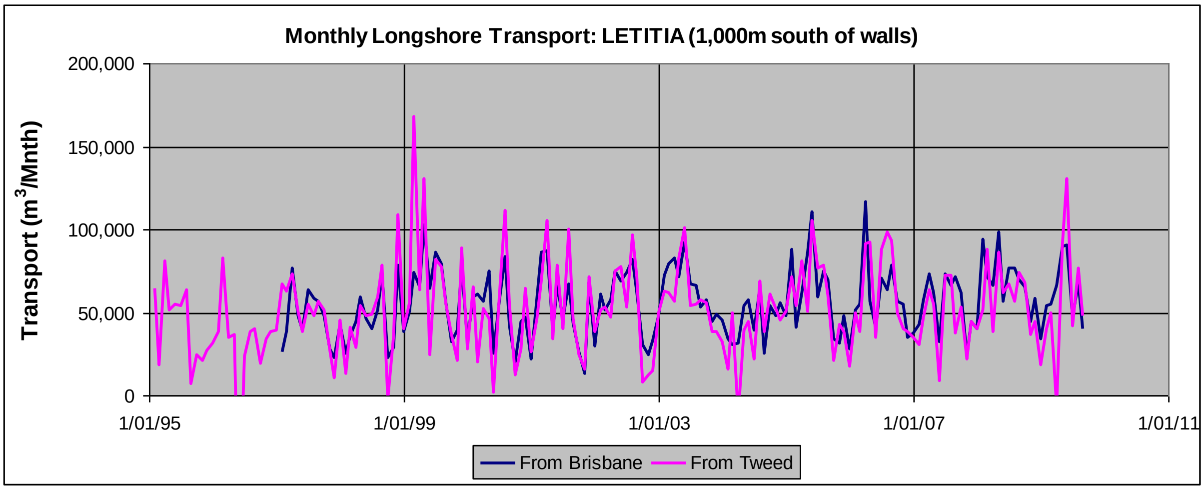


Figure 3-4 Letitia Spit transport from Tweed & Brisbane waves

Table 3-2 Calculated transport at Letitia 1,000m South of Walls

Annual Average Net Transport at Letitia Spit (m^3/yr)		
Period of Calculation	**From Brisbane**	**From Tweed**
1995 to 2008		605,000
1995 to 2009		610,000
1995 to 2000		558,000
1997 to 2009	669,000	640,000
2001 to 2009	696,000	646,000

It is significant that, apart from the result for 1995-2000 prior to bypassing, these transport rates are significantly higher than those at Currumbin as a direct consequence of the changed shoreline alignment.

3.2 LST Rates extended to 2015

3.2.1 LST Calculated Theoretically from Wave Data

The wave data record and the compartment sand volumes have now been extended to 2015, facilitating extension of the previous work to cover the period 1996 to 2015. This utilises the Tweed recorded data as the basis of theoretical calculations at Currumbin and Letitia Spit, together with the Queens formulation with the same calibration of coefficients as those applied previously.

It has been assumed that the shoreline alignment at Currumbin remains unchanged from that adopted previously. Also, based on satellite imagery, it has been adopted that the alignment at Letitia Spit 1,000m south of the entrance has remained at about -18 degrees as measured in 2008-09.

The calculated Currumbin monthly rates are shown in Figure 3-5, with the annual and progressive trend rates since 1995 shown in Figure 3-6. April-May 2009 stands out as unusually high rates. The long term average rate for the period January 1995 to December 2015 is 503,000m^3/year, consistent with the previous assessment.

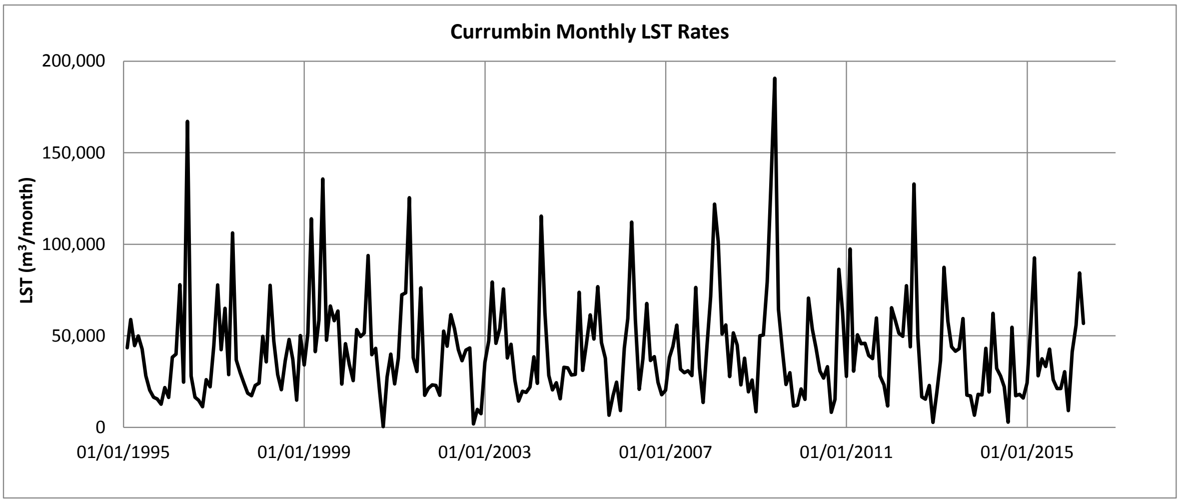


Figure 3-5 Monthly LST rates at Currumbin

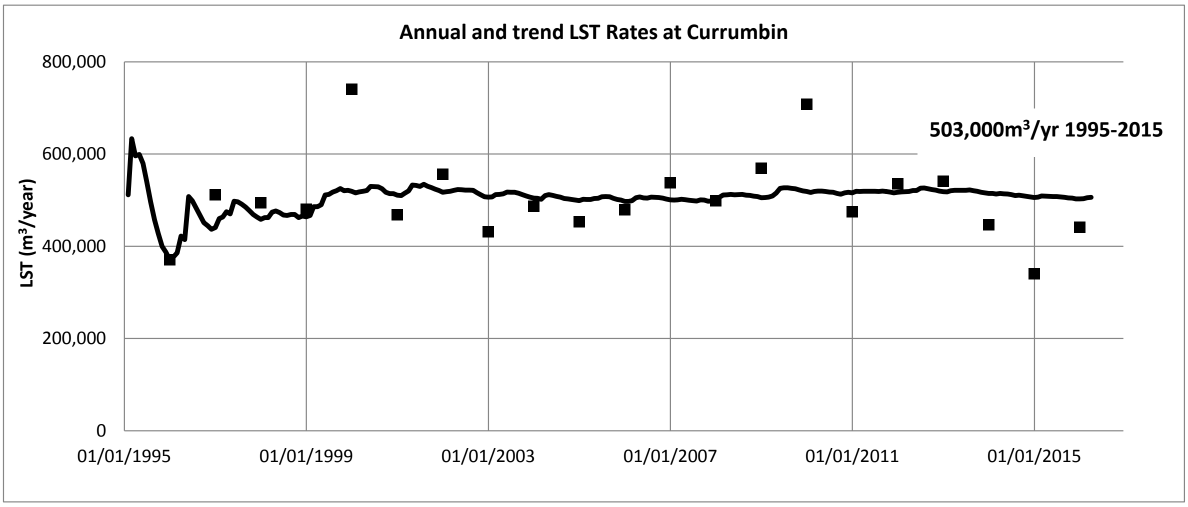


Figure 3-6 Annual and long term trend LST rates at Currumbin

LST at Letitia Spit 1,000m south of the entrance calculated theoretically directly from the Tweed wave data are shown in Figure 3-7 and Figure 3-8 as monthly and annual rates respectively.

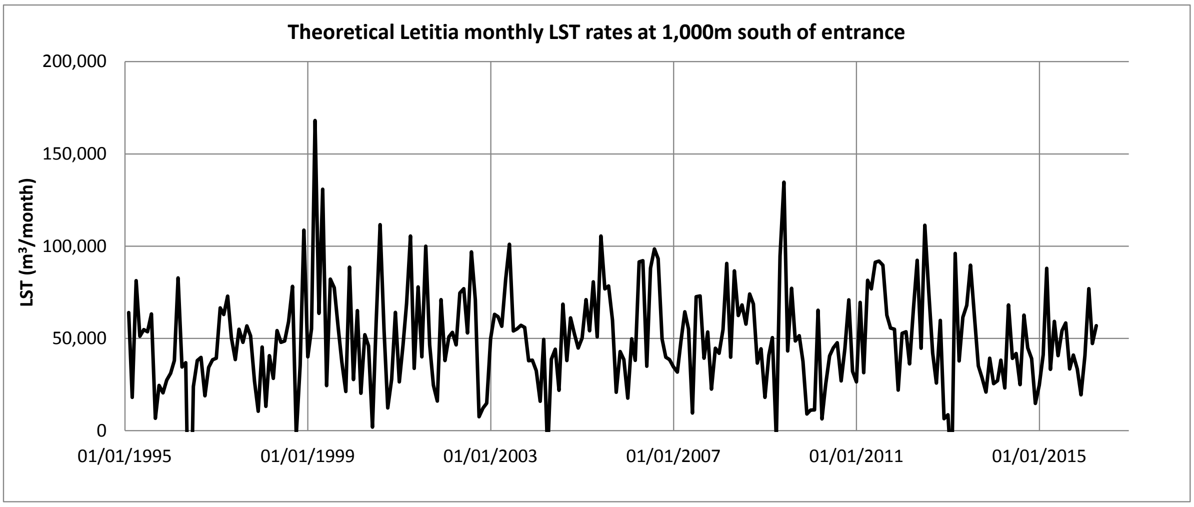


Figure 3-7 Monthly LST rates at Letitia Spit at 1,000m south of river entrance

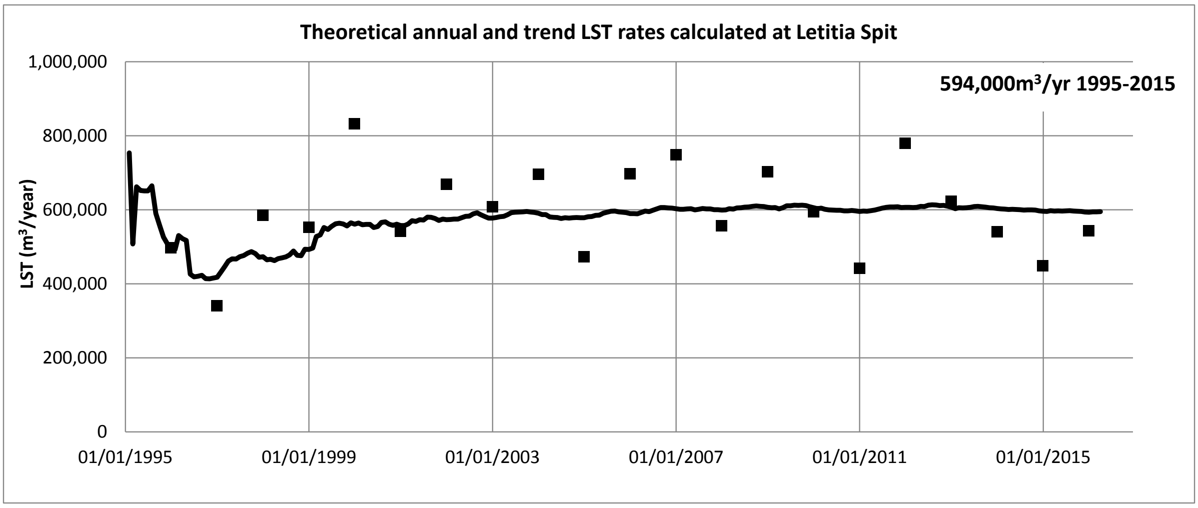


Figure 3-8 Annual & trend LST rates at Letitia Spit at 1,000m south of river entrance

3.2.2 Rates Derived from Survey Data

The monthly net sand transport rates at the various locations along the lower Gold Coast and Letitia Spit and at Snapper Rocks have been calculated using the methodology illustrated schematically in Figure 1-3 and Figure 1-4.

Based on the Currumbin rates, the LST for various locations along the Queensland lower Gold Coast have been determined using the method illustrated in Figure 1-3, as shown in Figure 3-9 as monthly rates and in Figure 3-10 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.

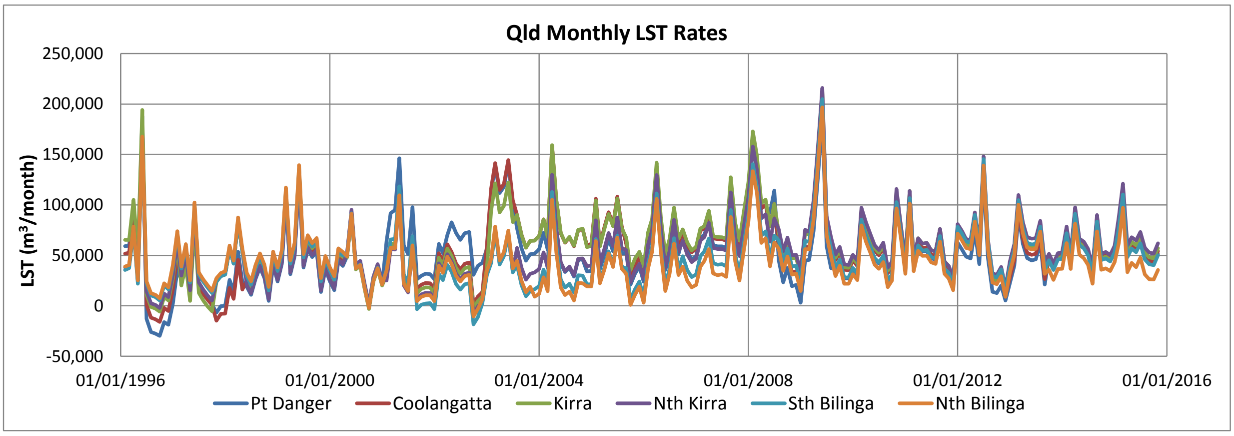


Figure 3-9 Monthly LST rates at lower Gold Coast: Pt Danger to North Bilinga

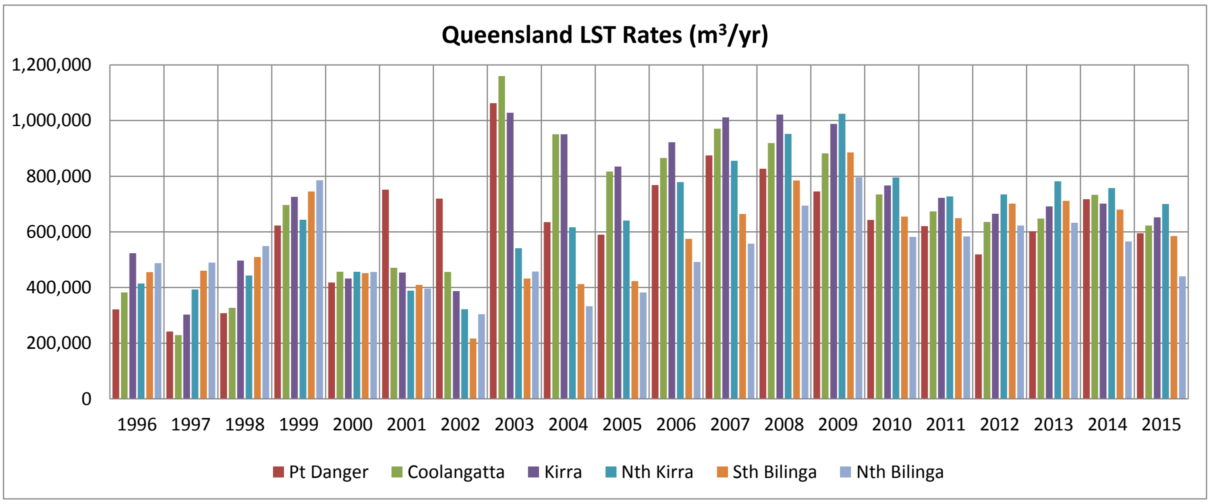


Figure 3-10 Annual and long term trend LST rates at Currumbin

The LST rates derived for Snapper Rocks at Point Danger, at the Qld/NSW border and along Letitia Spit are illustrated in **Error! Reference source not found.** and listed in **Error! Reference source not found.**.

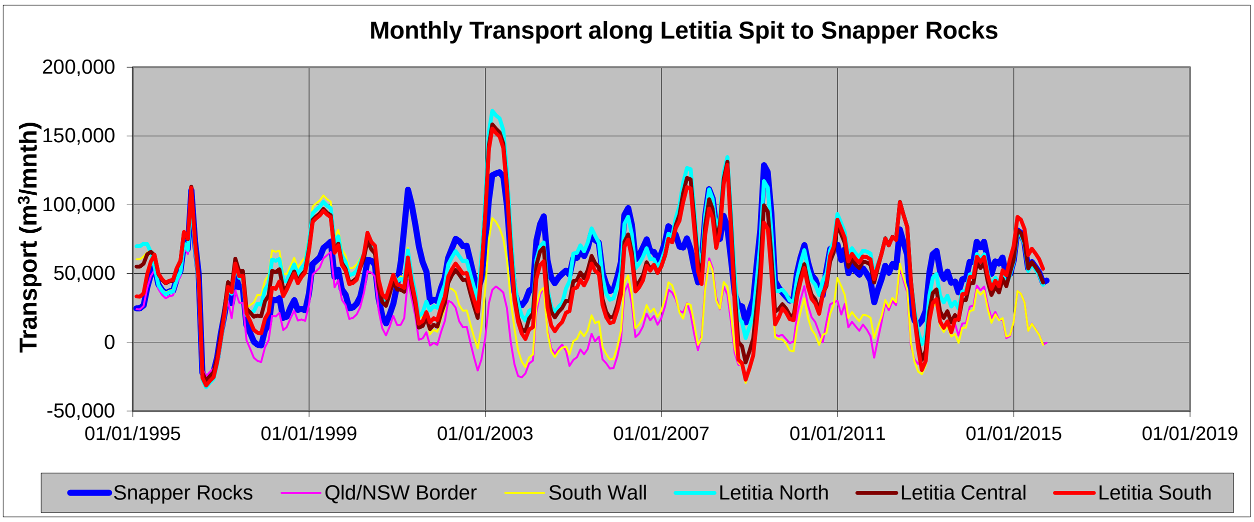


Figure 3-11 Monthly net transport along Letitia Spit

Table 3-3 Calculated transport at Letitia Spit

Period of Calculation	Average Annual Net Transport at Various Letitia Locations (m^3/yr)					
	Snapper	North Wall	South Wall	Letitia Nth	Letitia Cent	Letitia Sth
1995 to 2000	393,700	306,400	626,400	591,700	575,500	539,900
1995 to 2009	622,000	141,300	396,900	691,500	606,600	565,500
1995 to 2015	625,600	147,500	342,800	677,700	597,800	574,100
2001 to 2009	775,000	31,300	243,900	758,000	627,400	582,500
2009 to 2015	650,600	165,100	210,900	645,900	563,000	566,500
2001 to 2015	719,500	82,884	227,400	712,600	606,900	588,000

Locations south of the training walls at Letitia North and Letitia Centre show significantly higher average annual net transport rates after sand bypass operations commenced in 2001 than had prevailed prior to that time. There was an induced increase in transport particularly at Letitia North as a result of the sand bypass system operations in altering the shoreline alignment.

The derived LST rate at Letitia South for the period 1995 – 2015 is 574,100m^3/yr, about 14% higher than the calculated rate of 503,000m^3/yr for the same period at Currumbin, on which those Letitia Spit rates are based. This may be because of error in the survey data used to derive the Letitia Spit rates or that there was indeed a greater rate of transport coming past Fingal than occurred at Currumbin over that period. These results indicate the LST at Fingal South is consistently close to or greater than 550,000m^3/yr, potentially about 575,000 to 580,000m^3/yr.

Notably, the average annual transport rate of 594,000m^3/yr calculated theoretically at Letitia Spit directly from the Tweed wave data at 1,000m south of the entrance over the period 1995 to 2015 is significantly less than the 677,700m^3/yr for Letitia North in Table 5-2. It is closer to the rate for Letitia central (597,800m^3/yr). This may mean that the effect of the bypassing on the shoreline alignment is greater than that show in Figure 3-3 or, again, that there is error introduced in the survey volumes.

3.2.3 Theoretical Versus Derived Rate at 1,000m South of Walls

The rate of longshore sand transport at the location 1,000m south of the southern training wall has been affected significantly by the sand bypass system activities. The shoreline alignment there has shifted significantly (Figure 3-3) and the transport rate increased accordingly. On the basis that the southern boundary of Letitia North is located approximately at the location 1,000m 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 3-4 and illustrated in Figure 3-12.

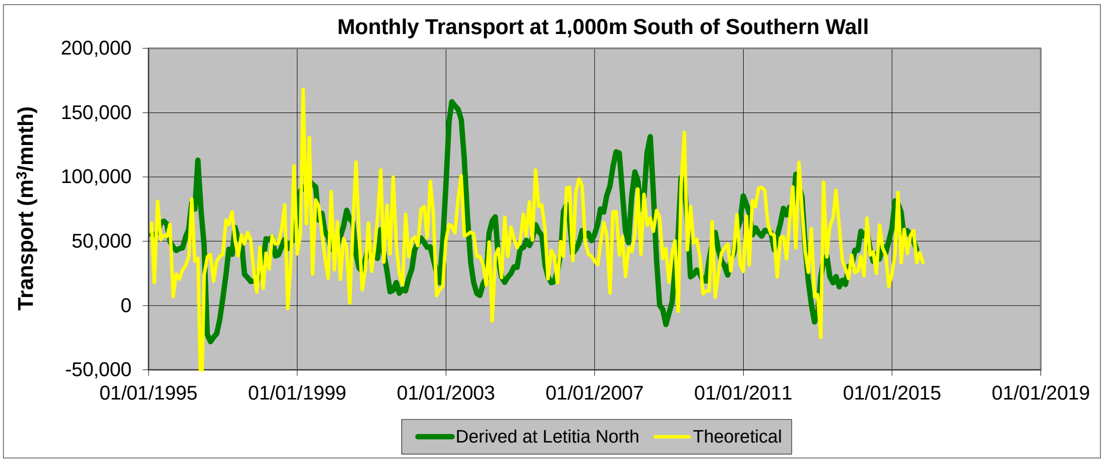


Figure 3-12 Monthly net transport 1,000m south of southern training wall

Table 3-4 Transport rates 1,000m South of Walls

Annual Average Net Transport at 1,000m south of walls (m^3/yr)		
Period of Calculation	**Derived from Surveys & Currumbin Transport**	**Theoretical from Waves**
1995 to 2000	591,700	557,900
1995 to 2009	691,500	606,100
1995 to 2015	677,700	594,000
2001 to 2009	758,000	638,300
2001 to 2015	712,600	608,100

It can be seen that there are significant differences between the derived and theoretical rates at certain times while quite close agreement is evident at other times. The periods of difference appear to involve short term (months) of transport spikes that are difficult to explain other than by processes acting there that the theoretical approach does not cater for. In particular, the derived rates, notably in 2003, indicate a 'slug' like pattern of behaviour, possibly related to mechanisms involved in the movement of sand through the gap between Cook Island and the mainland at Fingal. Such a slug pattern of behaviour is indicated also in Figure 3-13 and Figure 3-14 which compares the cumulative and trend LST rates at Letitia as derived from the data and from theory.

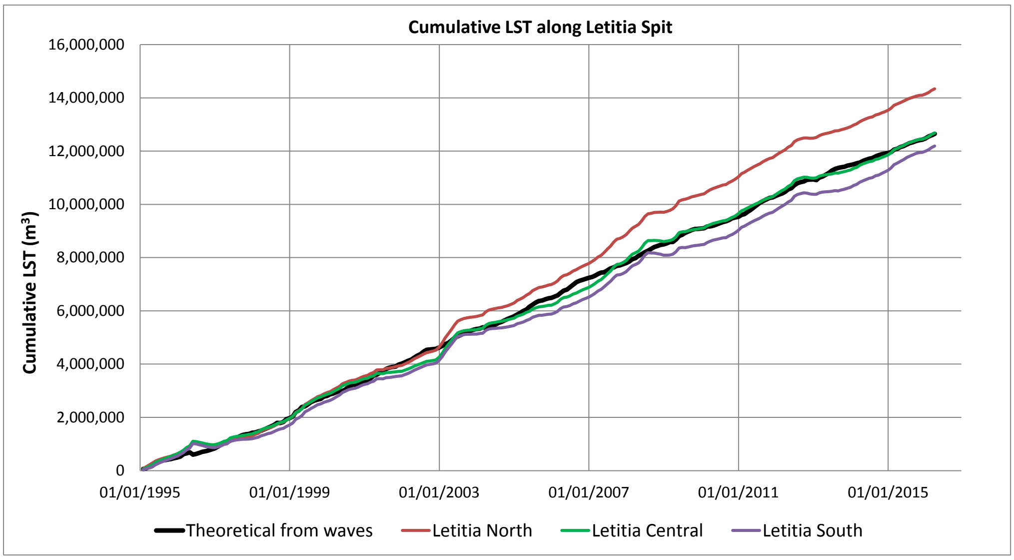


Figure 3-13 Cumulative sand transport at Letitia Spit

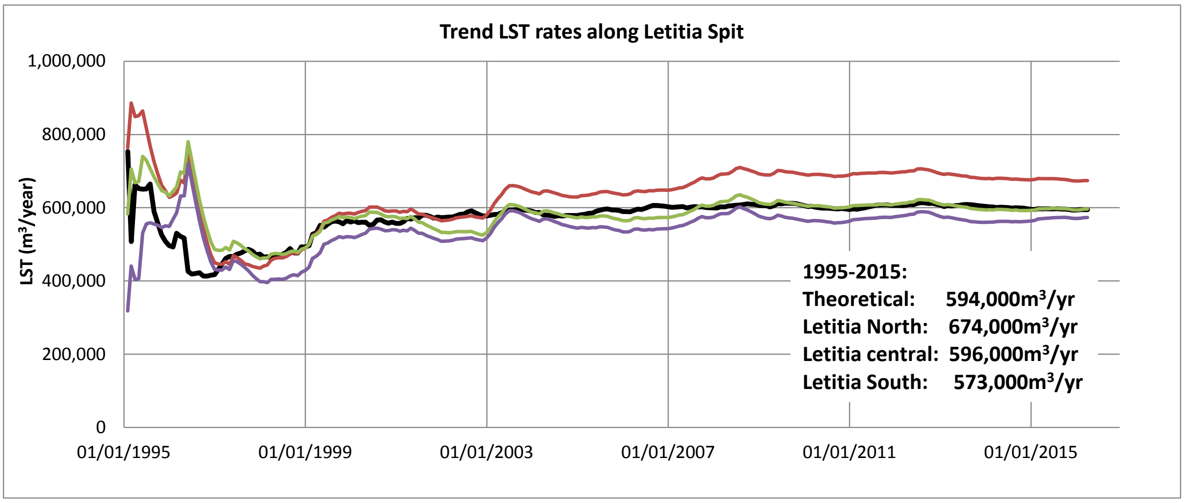


Figure 3-14 LST trends at Letitia Spit

4 LTA AND NATURAL BYPASSING RATES

4.1 LTA from Equation 1b based on survey data

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.

It is clear that, at that location, the natural sand transport patterns have been influenced 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 that the natural transport rate further south nearer to Fingal has been influenced much less or not at all by the sand bypassing operations.

As such, 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 calculated monthly LTA increments are shown in Figure 4-1. The average annual rate of these values since 2001 indicates the LTA based on the actual behaviour over the 15 years of sand bypassing operations. Comparison of the monthly values derived from Equation 1b with the bypass system delivery (pumping + dredging) undertaken over the period is shown in Figure 4-2. The annual rate comparison is shown in Figure 4-3.

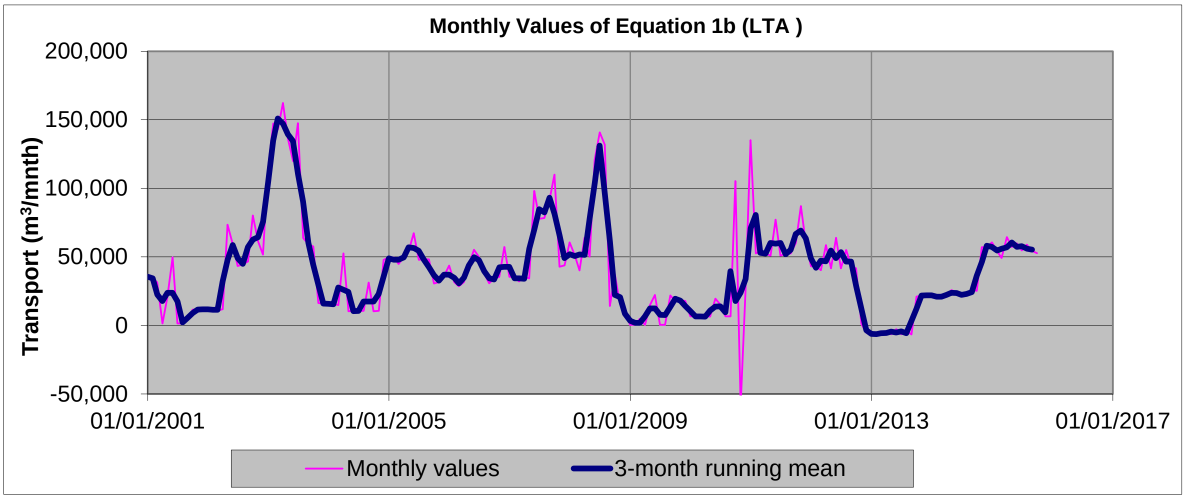


Figure 4-1 Monthly analysis of Equation 1b (LTA)

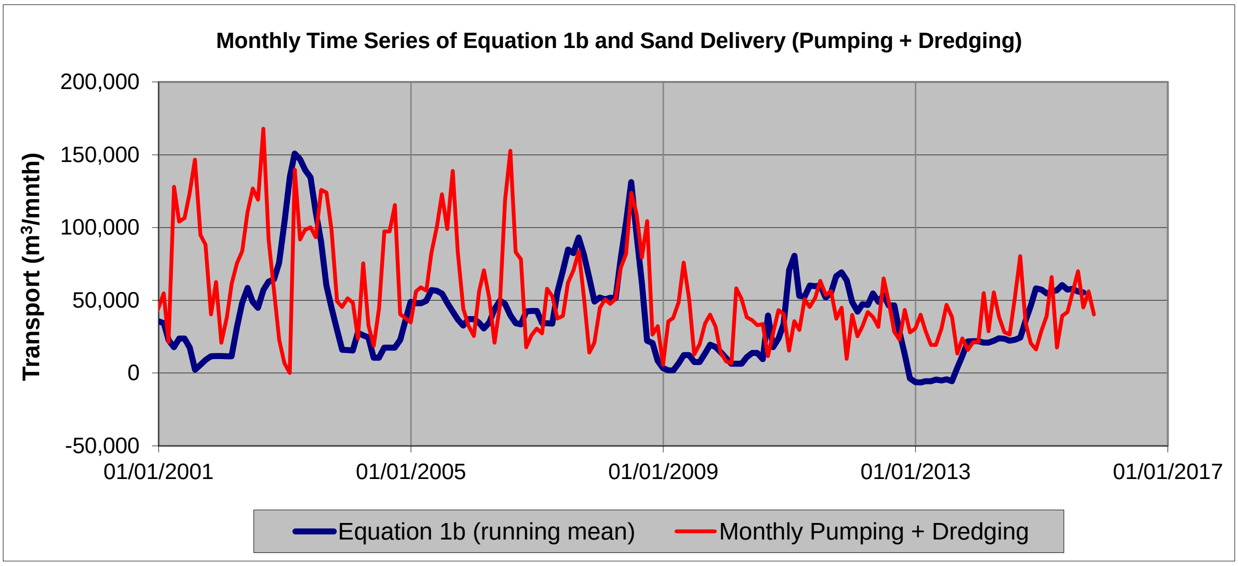


Figure 4-2 Monthly time series of Equation 1b and sand delivery undertaken

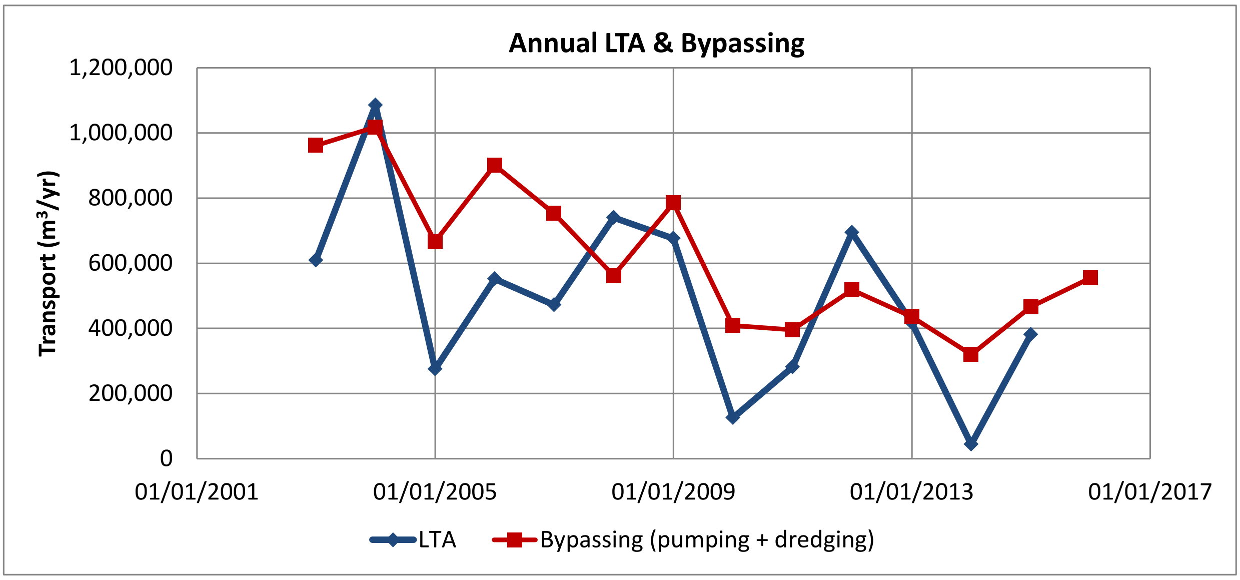


Figure 4-3 Annual time series of LTA from Equation 1b and total bypassing

The average annual LTA rate thus derived for the period from January 2001 to July 2015, covering the period of sand bypass operations, is 478,000m^3/yr. This is about 30,000m^3/yr less than the previous reassessment.

The average annual rate of total bypass pumping plus dredging decreased significantly since 2009, with no entrance dredging being undertaken at all, but has increased again over the last 2 years. The natural bypassing would thus be expected to have increased, as confirmed in Figure 4-4. To the extent that this may occur without triggering the need for entrance dredging suggests an acceptably lower LTA. However, the need for some dredging has been identified recently.

LTA trend rates for both periods from 2001 to 2015 and from 2008 to 2015, following cessation of the supplementary bypassing, have been determined, as shown in Figure 4-5.

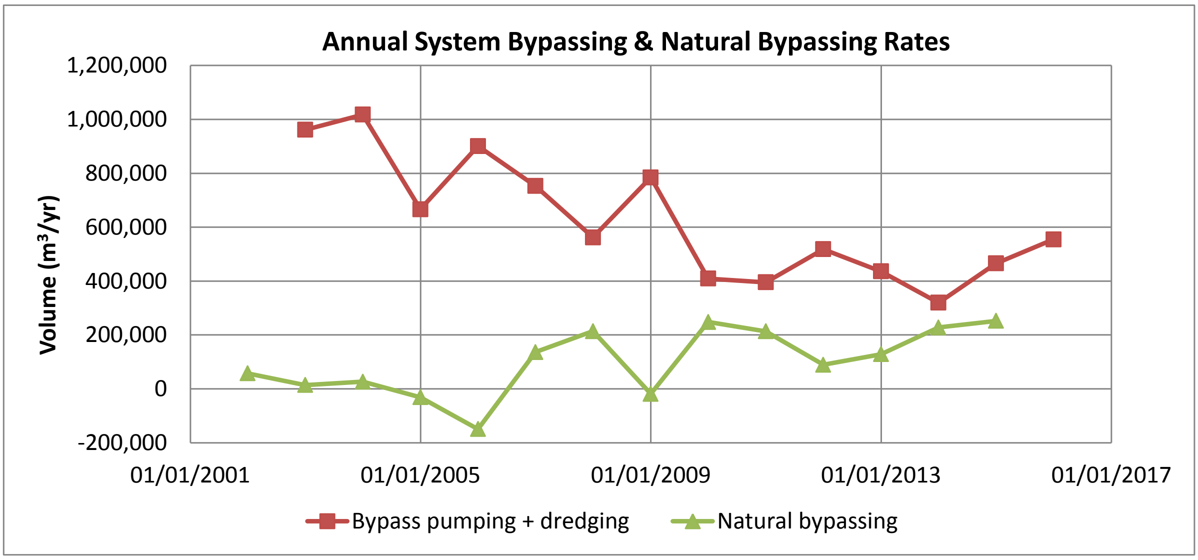


Figure 4-4 Annual time series of total system bypassing & natural bypassing

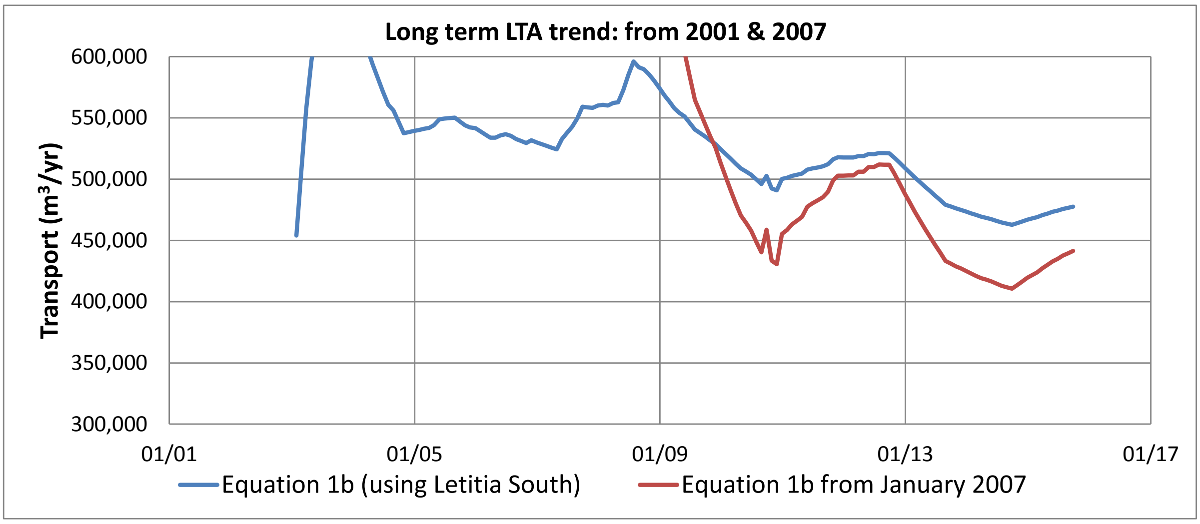


Figure 4-5 LTA trends from 2001 and 2007

4.2 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 calculated 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 4-6.

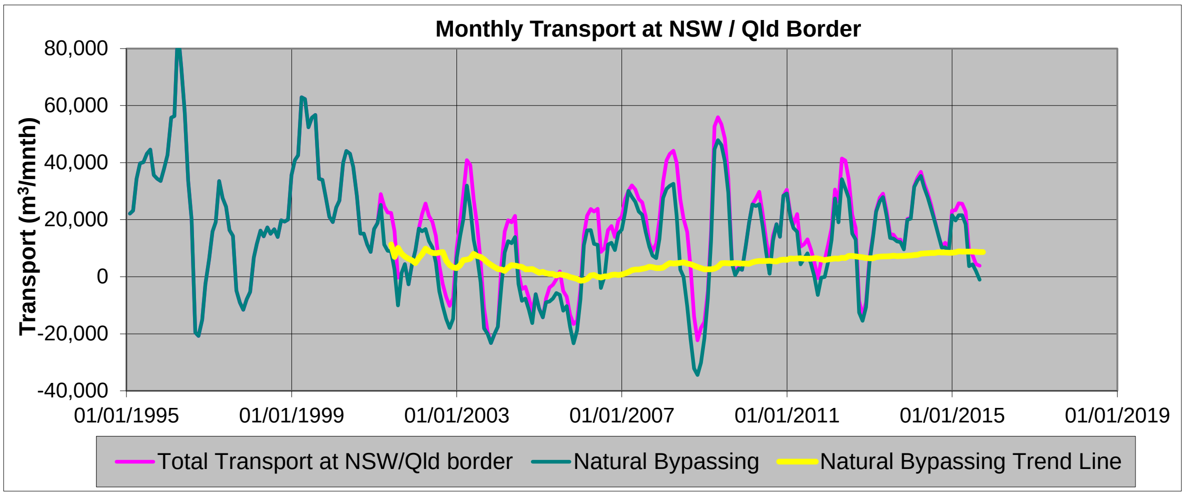


Figure 4-6 'Natural Bypassing' and total transport at NSW/Qld border

These rates show a clear trend of marked reduction in natural bypassing after commencement of the sand bypass operations in 2001. However, a significant increasing trend is evident after about 2007, associated with the reduced bypassing rate and increased leakage past the bypass system and entrance over that period.

These results indicate the progressive sand transport rates at the border as listed in Table 4-1. This indicates the natural bypassing rate has averaged about 103,000m^3/yr since bypassing commenced in 2001, but a higher rate of about 165,000m^3/yr since 2008. The trends of natural bypassing over the two periods 2001-2015 and 2008-2015 are illustrated in Figure 4-4.

Table 4-1 Calculated transport at NSW/Qld Border

Annual Average Net Transport at NSW/Qld Border (m^3/yr)		
Period of Calculation	**Natural Bypassing**	**Total Transport**
1995 to 2000	318,600	318,600
2001 to 2007	38,400	106,900
2007 to 2015	167,000	217,400
2001 to 2015	103,400	165,000

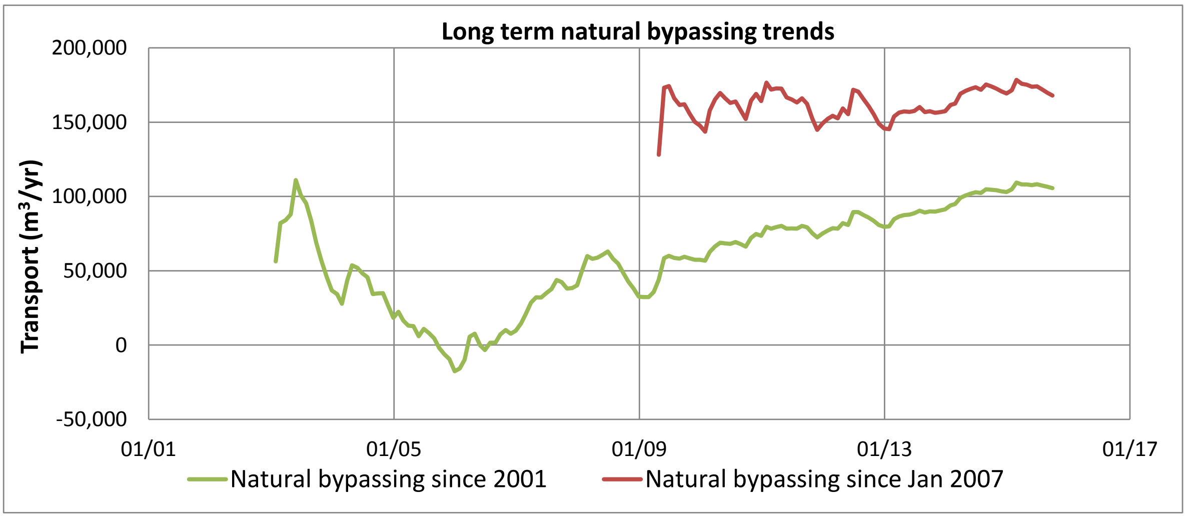


Figure 4-7 Natural Bypassing trends from 2001 and 2007

5 DISCUSSION AND RECOMMENDATIONS

5.1 Longshore Sand Transport

The rates of longshore sand transport into Letitia Spit past Fingal have varied substantially over the period since 1995. However, the average annual transport there has been relatively uniform when assessed over several years, recalculated in this study at 574,100m^3/yr for 1995 to 2015 and 588,000m^3/yr from 2001 to 2015 (Figure 5-1). This is somewhat higher than the rates derived in the previous reassessment and the long term context average net transport rate of about 550,000m^3/yr.

The rate of bypassing has fluctuated less but has declined significantly since 2009 following the previous reassessment of the LTA (Figure 5-1). The high rates of bypassing during 2001 to 2007 correspond to the requirement to include a supplementary increment to the LTA over the first 6 years of operation.

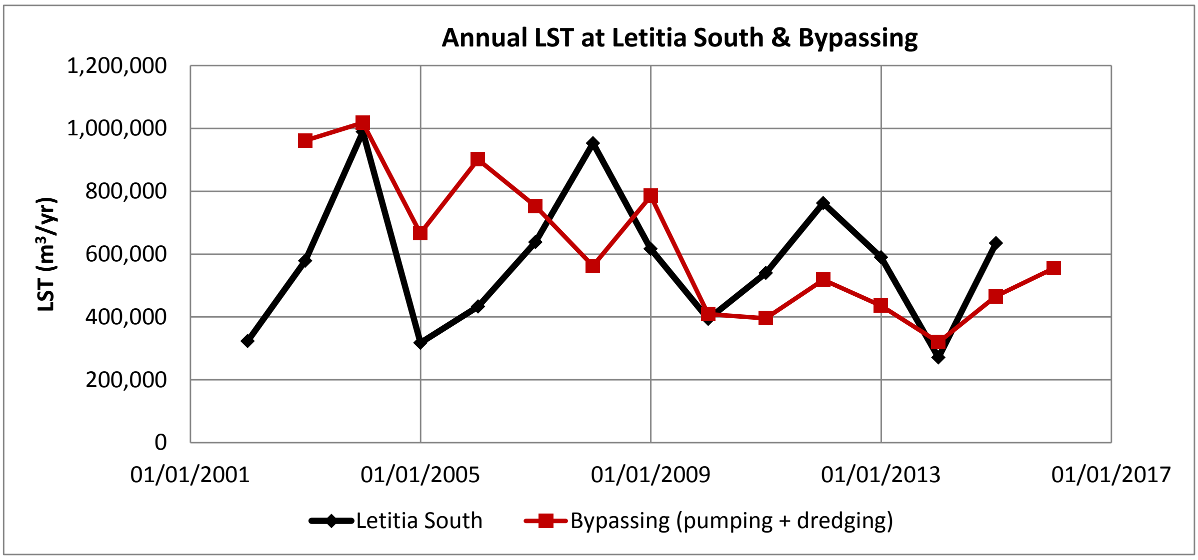


Figure 5-1 Calculated annual LST at Letitia South & bypassing since 2001

The rate of transport along the northern part of Letitia Spit has been substantially affected by the sand bypass system activities through changes in the shoreline alignment (Figure 3-3). Rates of transport into Letitia North, approximately 1,000m south of the southern training wall, increased from about 650,000m^3/yr for 1995 to 2000 to 758,000m^3/yr for 2001 to 2009 and subsequently decreased to 645,900 over 2009 to 2015. The shoreline re-alignment that has occurred suggests that the sand bypassing operations have been a dominant contributor to these changes.

The data indicates that the net sand transport to the north at Currumbin is less than that coming into Letitia Spit at Fingal. As a result, there has been an overall net gain of sand, determined from the surveys to be about 1.4 million m^3 since the start of 1995, equivalent to an annual rate of 70,000m^3/yr. This gain has occurred predominantly along the Gold Coast between North Kirra and Bilinga (Figure 2-6 and Figure 2-7), with significant an increasing gains also within the 'Entrance' compartment (refer Figure 5-2) and near Currumbin (Figure 2-7).

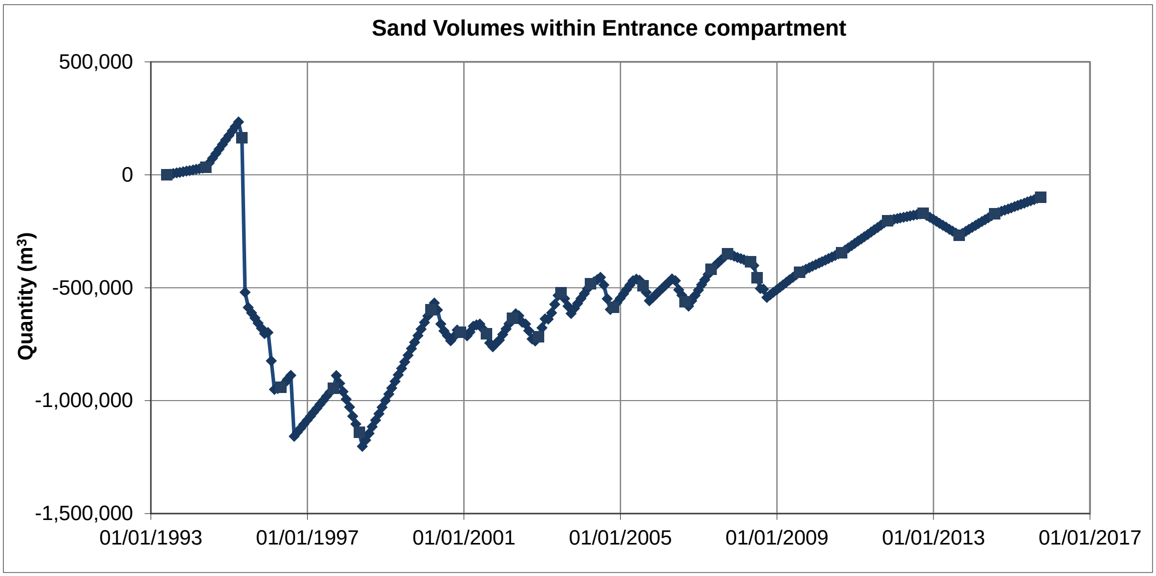


Figure 5-2 Sand volumes within the 'entrance' compartment

It must be noted that this difference in LST rates is derived from this analysis via the imbalance in the surveyed quantities and does not relate to any theoretical calculation of LST. In the long term context, it is unlikely to be sustainable. In the previous reassessment, the equivalent net gain of about 0.5M m^3 over 1995 to 2009 was attributed to shorter term high rates of transport from Dreamtime Beach. However, the presently determined increased imbalance cannot be explained and requires further research. It may result from issues with the surveyed volumes, possibly related to low level bed depletion over a wide area in deeper water that is not accurately measured. Alternatively, the LST rates may actually not balance, requiring understanding of why that may be.

5.2 Natural Bypassing and LTA Trends

Both the natural bypassing and the monthly/annual components of the LTA have been significantly influenced by:

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

Time series plots of their variation are shown in Figure 5-3.

The natural bypassing was reduced initially by both the Stage 1 initial dredging and the sand bypass system activities over the first 6-8 years. However, after 2009 when the rate of bypassing was reduced, it has increased again as more sand moved past the system.

The average annual natural bypassing rate of about 40,000m^3/yr for the period 2001 to 2007 has increased to about 100,000m^3/yr for 2001 to 2015. The corresponding natural bypassing rate for the period 2007 to 2015 averages about 165,000m^3/yr.

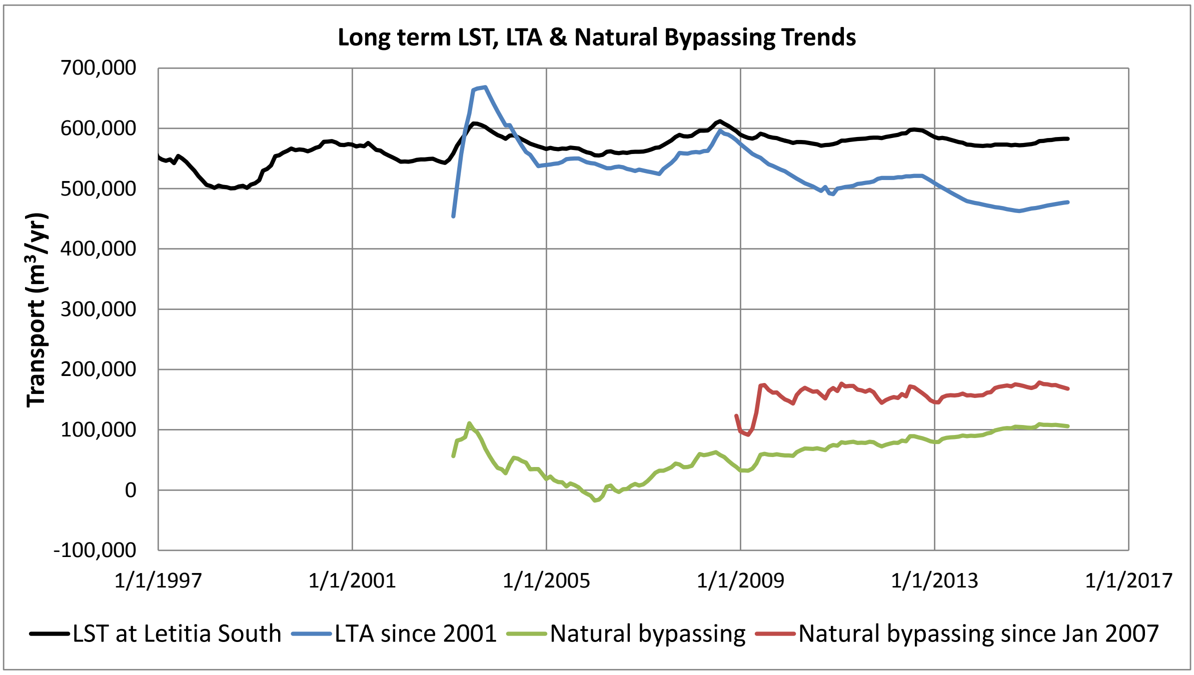


Figure 5-3 Trend of natural bypassing

5.2.1 Bypass system efficiency

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 the Letitia North compartment. The leakage rate expressed as a percentage of the transport into Letitia North is shown in Figure 5-4. This indicates that, overall to 2015, about 30% of the transport into Letitia North will leak through the trestle system.

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 5-5. This suggests that the proportion of the leakage sand that needs to be dredged to maintain the navigational requirement of the channel has reduced to about 50%, trending down since 2007 as the amount of dredging reduced and ceased after 2008.

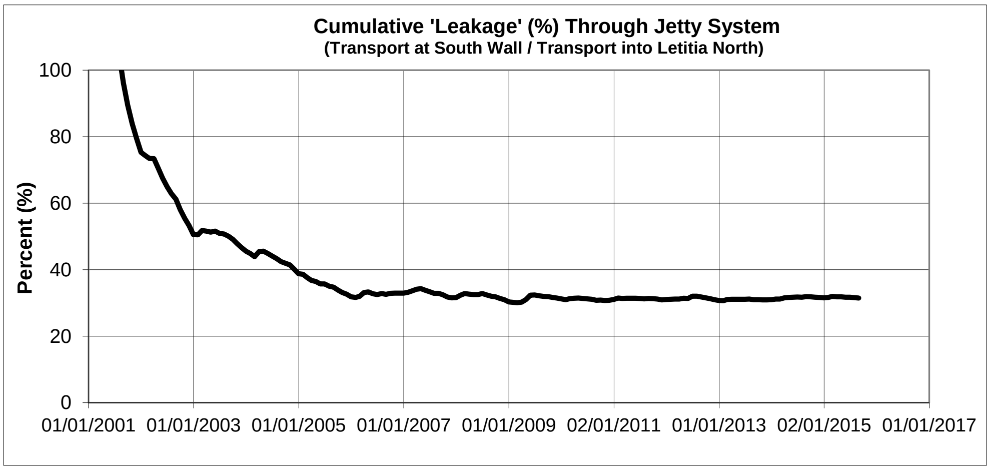


Figure 5-4 Trend of % leakage through jetty system

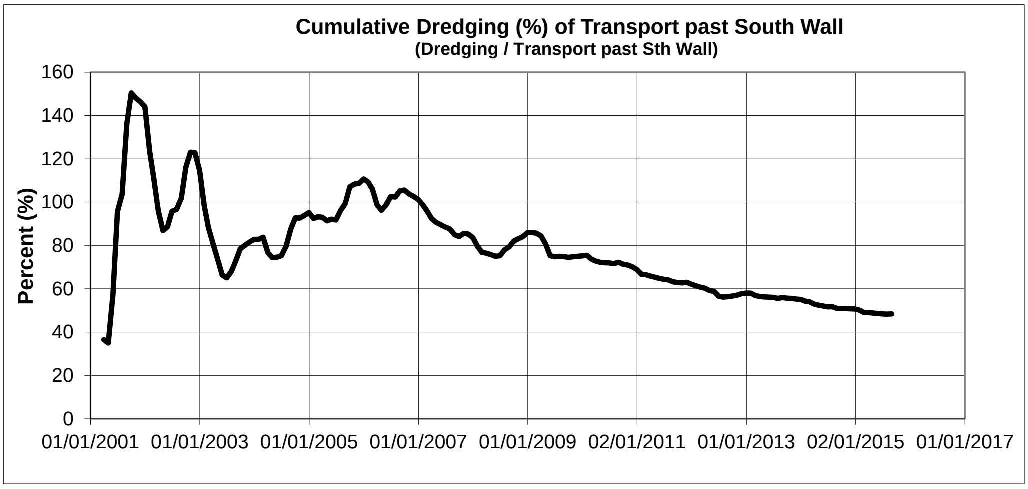


Figure 5-5 Trend of % dredging of sand leakage

5.2.2 LTA Rate Discussion and Recommendation

The LTA must be based on its definition under the legislation. The LTA rate depends on both the prevailing average annual net sand transport through the coastal system and the natural bypassing of sand to Queensland (among other factors), which in turn is dependent on sand bypassing system operations. That is, it depends intimately on the jetty pumping/entrance dredging rates required to satisfy the channel depth criterion.

The average annual net sand transport through the coastal system was assessed in the previous reassessment at most probably about 550,000m^3/yr, based on the Letitia South rates. This updated reassessment indicates that the LST inflow of sand past Fingal has averaged about 574,000m^3/yr from 1995 to 2015 while the LST at Currumbin has been only about 503,000m^3/yr. This mismatch over 20 years has not been explained.

The calculated LST rate at Fingal averaged about 588,000m^3/yr over the period 2001 to 2015.

The natural bypassing rate needs to be considered in the context of the bypassing activities since 2001 that would provide entrance channel depths that satisfy the navigable criteria. It is clear that the bypassing rate was higher than needed through 2001 to 2009 but appears to have been too low since then. As a result, the assessed natural bypassing rate was low at about 40,000m^3/yr to 2009 but has increased to about 165,000m^3/yr over the past 6 years and averages 100,000m^3/yr through 2001-2015.

However, there is evidence that the bypassing may not have been sufficient to satisfy the entrance channel depth criteria during the past 6 years and dredging is now needed. That is supported by the continuing accumulation of sand in the ‘Entrance’ compartment. Additional entrance dredging would be expected to decrease the natural bypassing rate.

The natural bypassing is affected substantially by the bathymetry of the entrance channel, as determined by the leakage past the trestle system and deposition in the entrance. Isopach plots of volume changes in the entrance area since 2009 are shown in Figure 5-6 to Figure 5-11. These show that the inner bar accumulated considerable sand during 2010-11, forming a pathway for sand to feed the natural bypassing at the higher rate identified. The subsequent accumulation has been further offshore and has most probably not impeded the navigable channel.

The assessed LTA rate derived from the LST and natural bypassing rates are in the range (574,000 – 100,000) = 474,000m^3/yr to (588,000 – 100,000) = 488,000m^3/yr.

That is, based on this approach, the LTA rate would be in the range 475,000 to 490,000m^3/yr compared with 510,000m^3/yr derived in the previous reassessment to-2009. However, given that entrance dredging is needed but as yet not undertaken, it is considered appropriate to adopt the higher rate in this range. Accordingly, a reassessed LTA rate of 490,000m^3/yr is recommended.

The proportion of the LTA that would be pumped compared with that dredged could vary substantially, depending on the ability of the jetty pumping system to intercept the longshore transport. For optimum utilisation of the jetty system infrastructure, the operational target jetty pumping rate should be as high as possible, up to the LTA rate. Nevertheless, some dredging to achieve suitable conditions in the entrance channel will most probably be needed because the jetty system will not achieve a 100% interception rate. The average annual increments to the total sand delivery, being the pumping plus channel dredging, need to match the LTA over the longer term, while catering also for temporal variability.

Ongoing monitoring and review of the operations are needed to assess progressively how the system operations are trending and, in particular, the development of a longer term pattern of dredging and its influence on the natural bypassing rates to deliver the LTA in the longer term.

The monitoring to date has been comprehensive and invaluable as a data source for this reassessment of the LTA. This reassessment has identified potential errors in the surveyed volumes that need to be carefully reviewed in the context of the progressive time series volumes in each compartment.

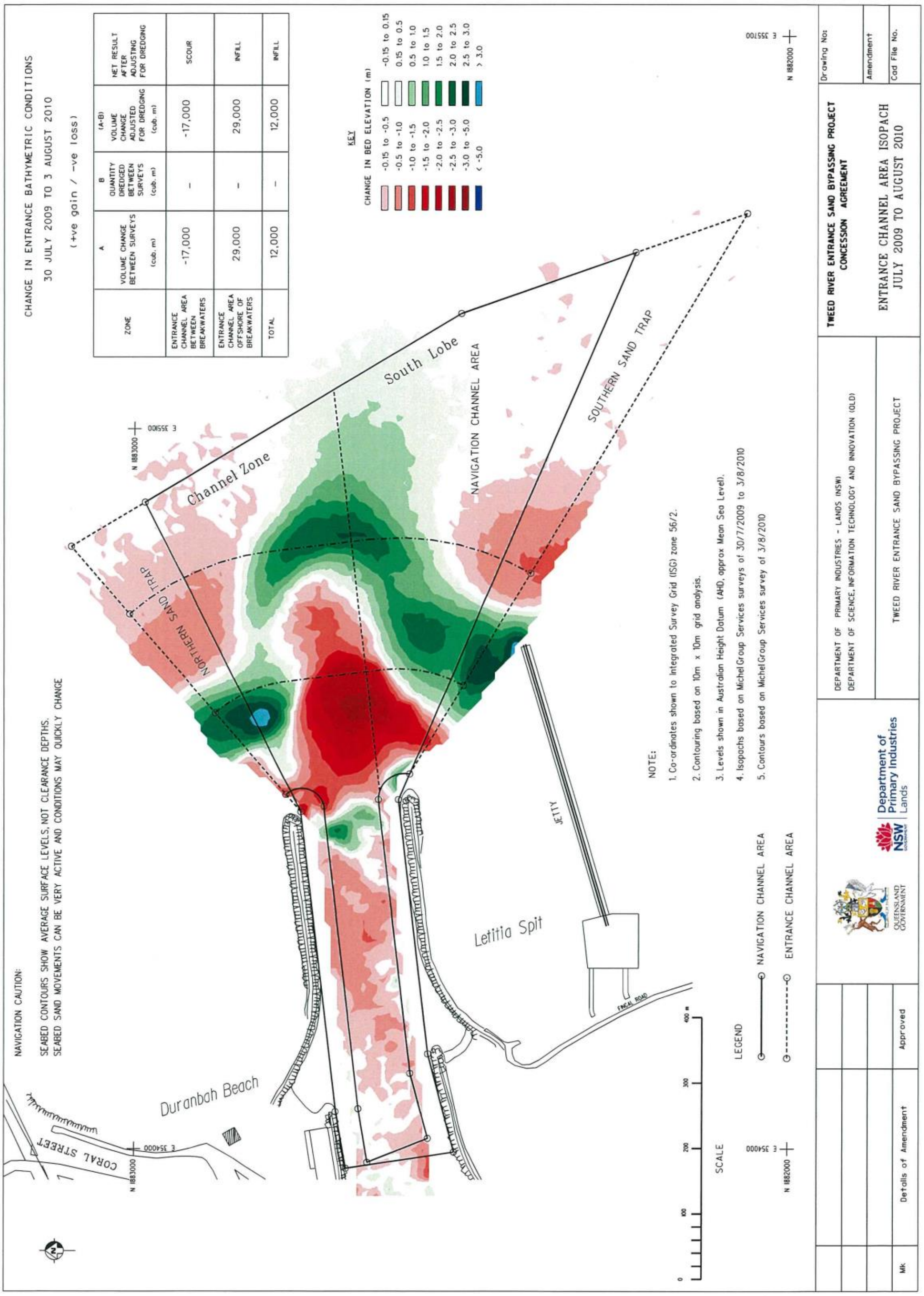


Figure 5-6 Isopach of volume change 2009-2010

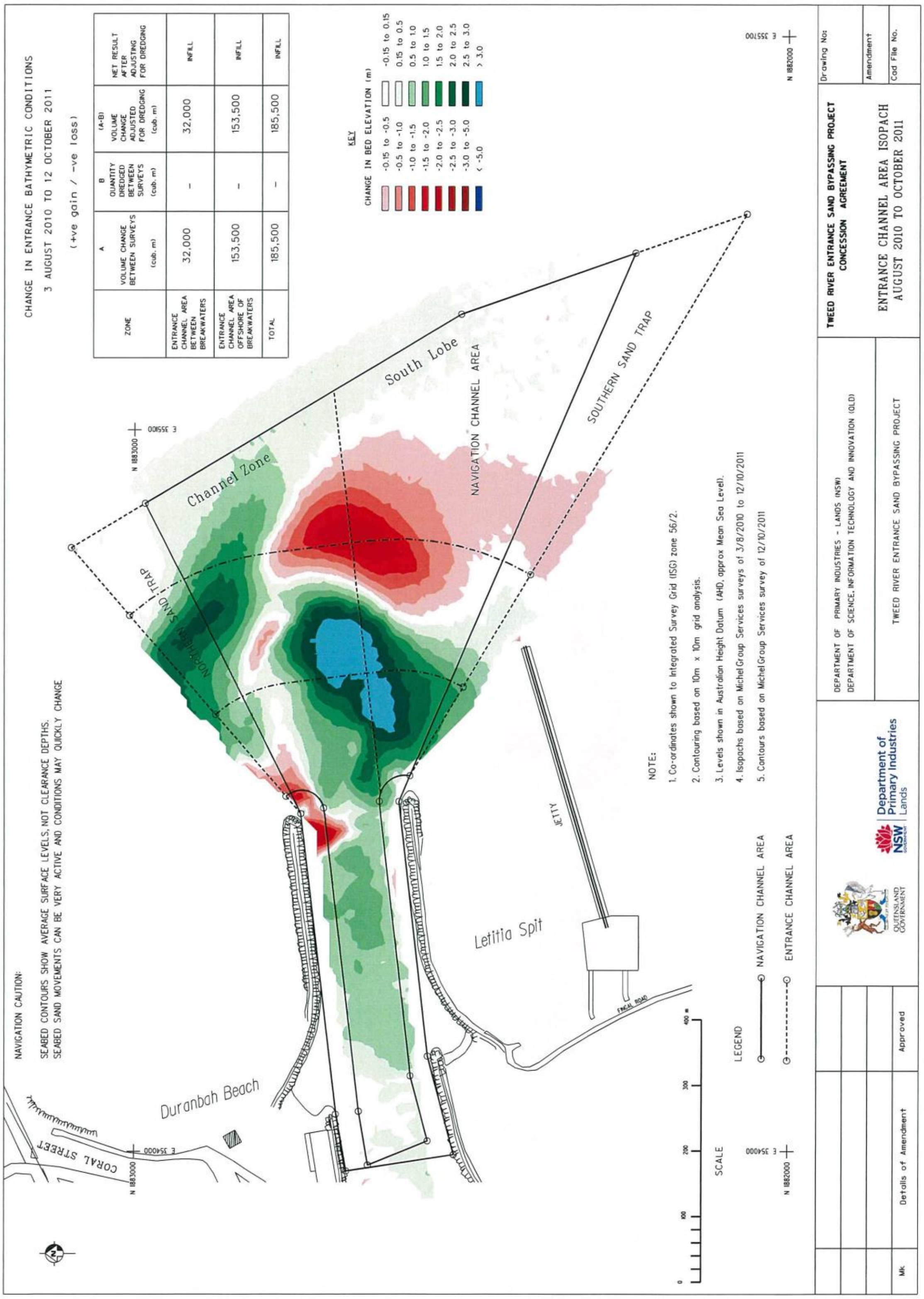


Figure 5-7 Isopach of volume change 2010-2011

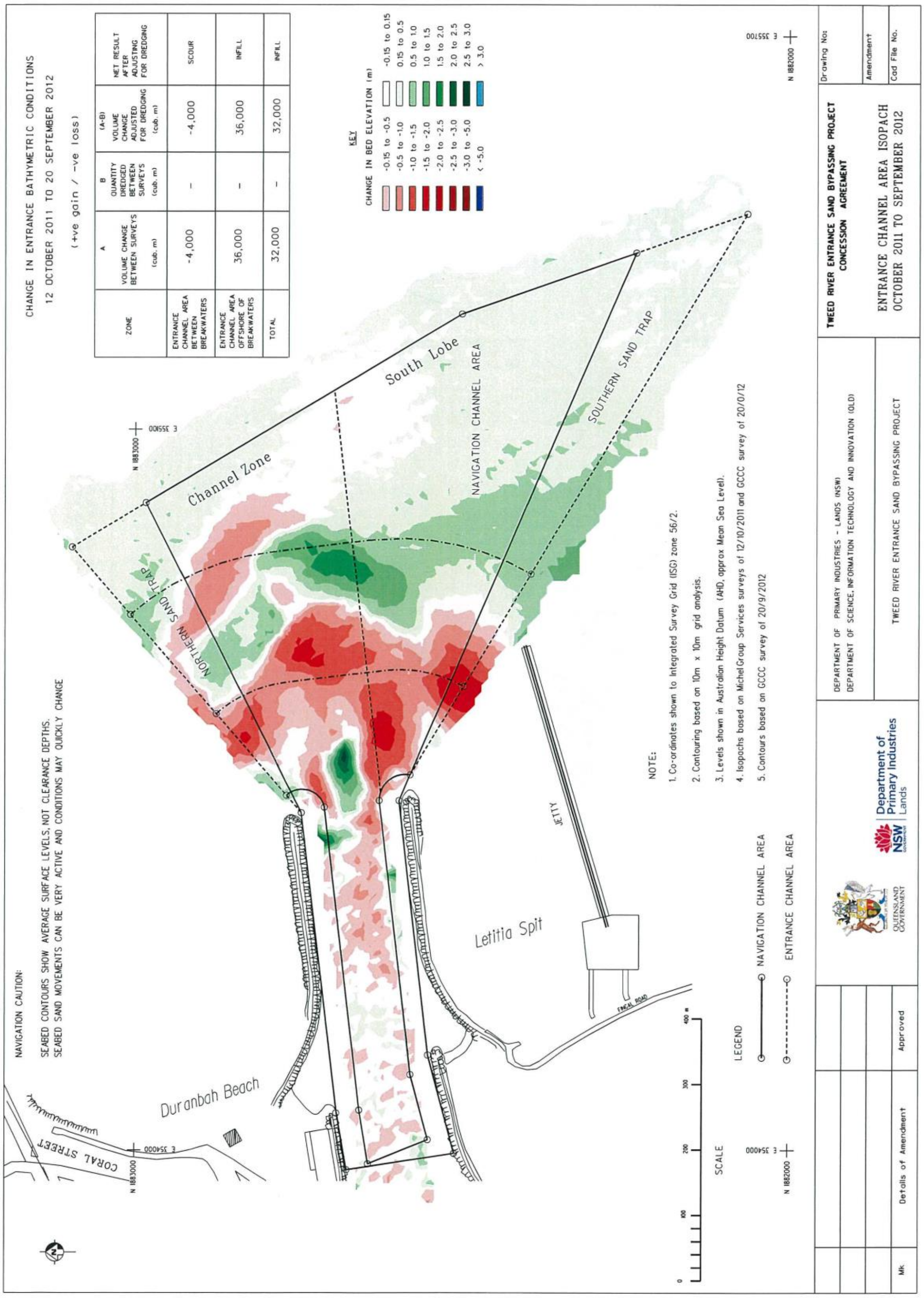


Figure 5-8 Isopach of volume change 2011-2012

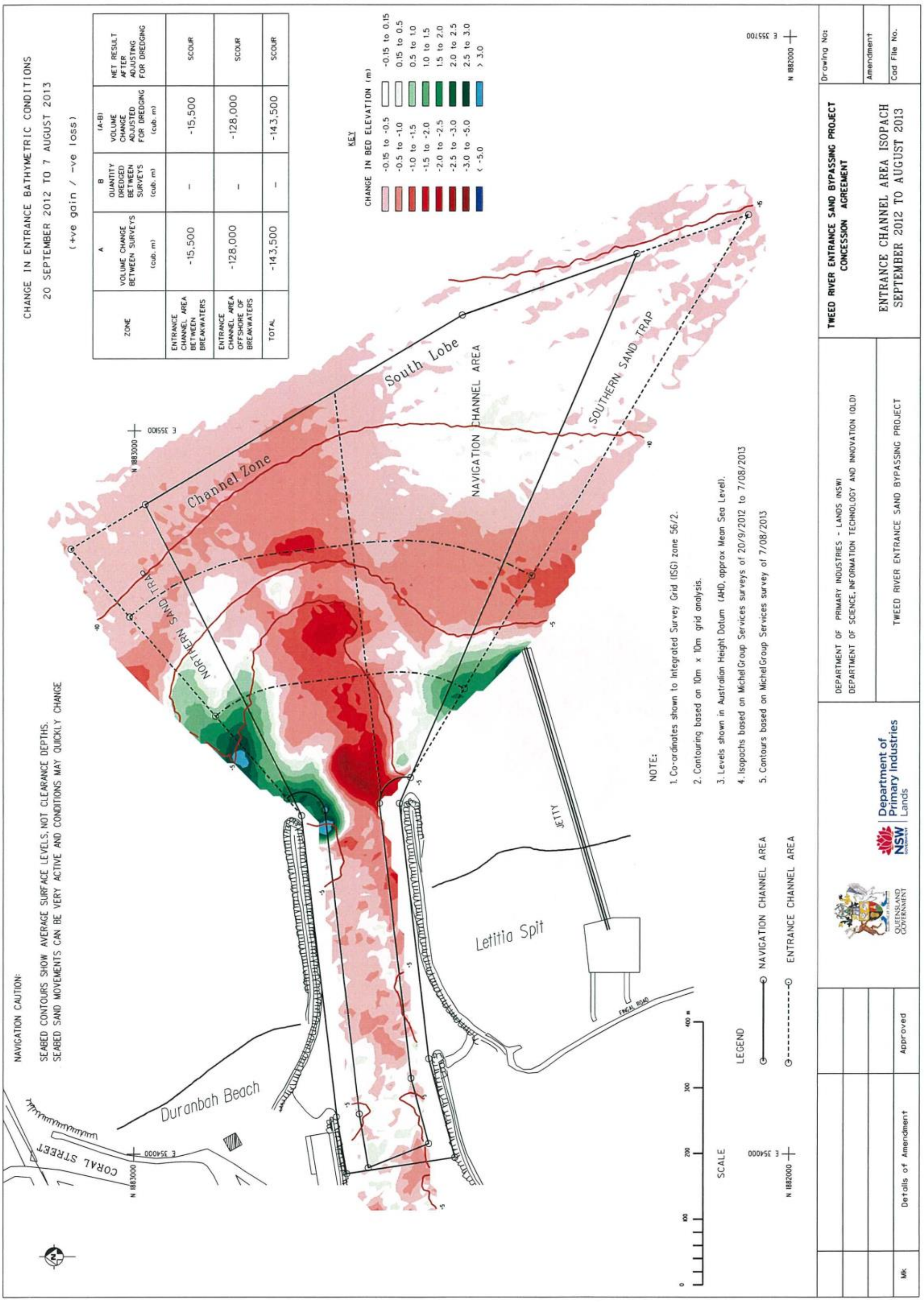


Figure 5-9 Isopach of volume change 2012-2013

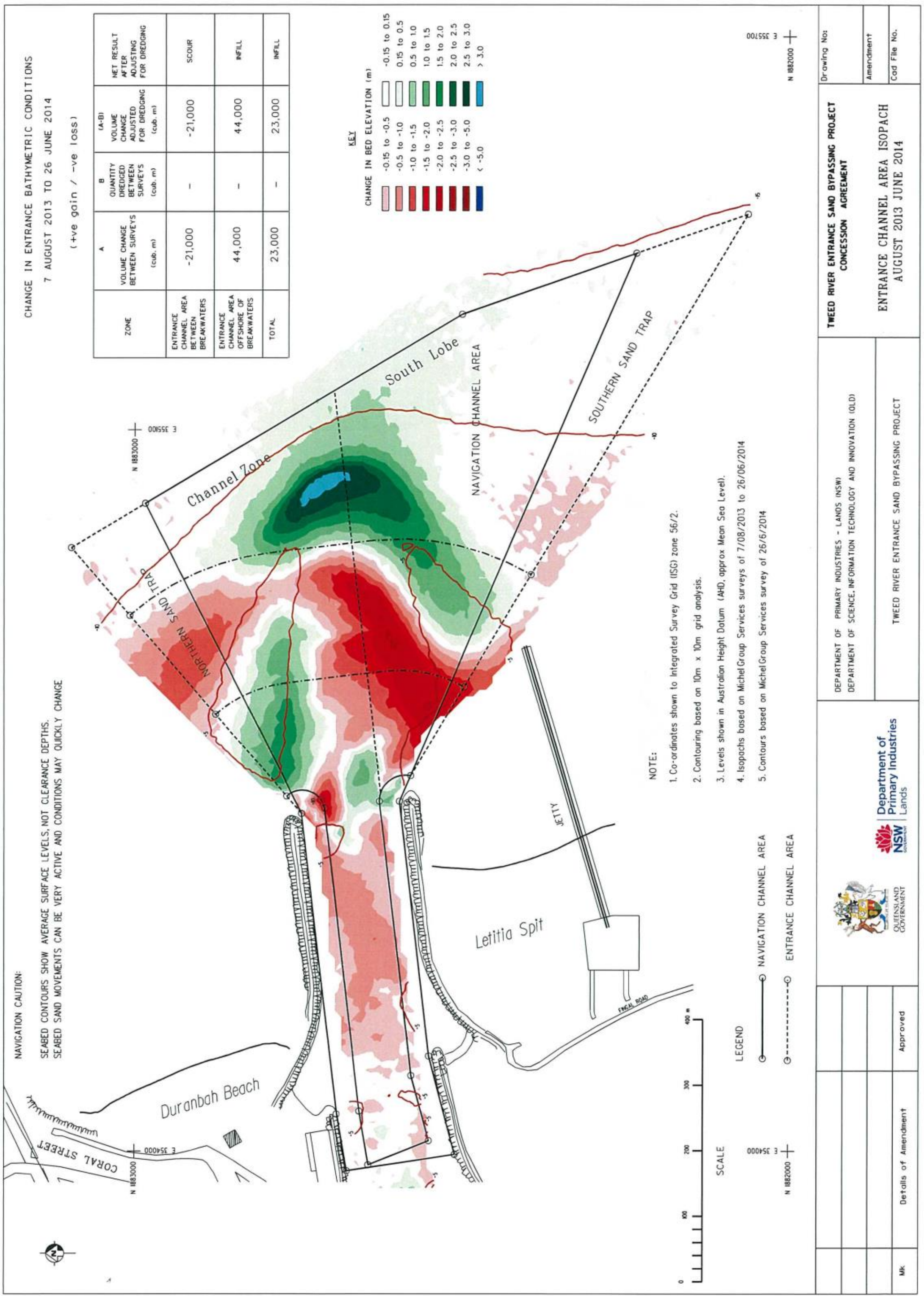


Figure 5-10 Isopach of volume change 2013-2014

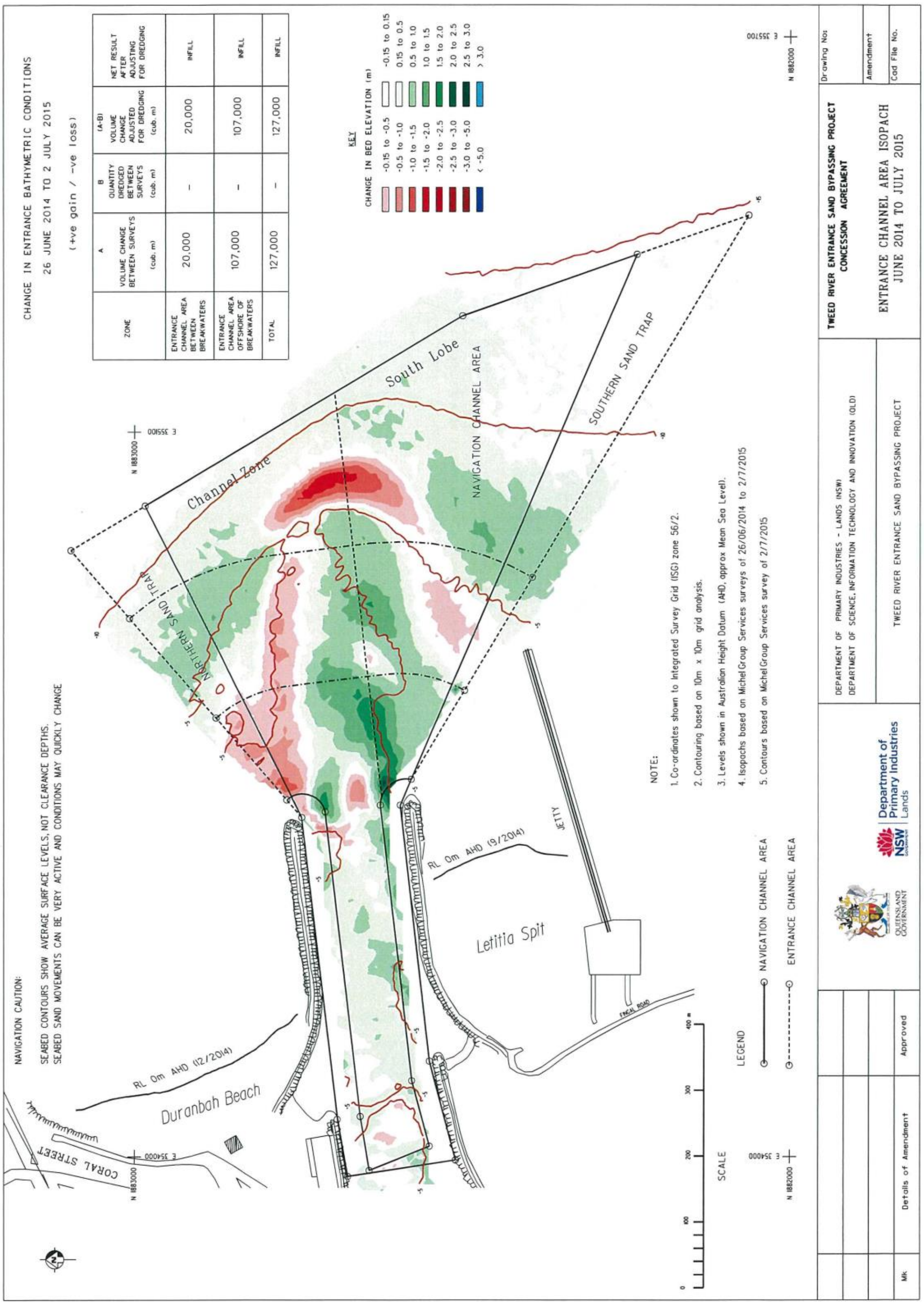


Figure 5-11 Isopach of volume change 2014-2015

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