REPORT

Snapper Rocks East Sand Tracing Study

Interpretative Report

Client: NSW Department of Industry (Crown Lands)

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1 Introduction

1.1 General

Tweed Sand Bypassing (TSB) is a joint initiative of the New South Wales and Queensland State Governments (the Parties). The Project has two objectives:

- to establish and maintain a safe, navigable entrance to the Tweed River; and
- to restore and maintain the coastal sand supply to the beaches on the southern Gold Coast of Queensland.

The two objectives are of equal importance and are to be achieved in perpetuity.

In order to meet its objectives, TSB operates by pumping sand from the fixed jetty at Letitia Spit to designated outlets on the northern side of the Tweed River (predominately the Snapper Rocks East outlet). Occasionally, a floating dredge is used to clear sand from the Tweed River Entrance bar. A map showing the key TSB infrastructure is provided in Figure 1.

The TSB has adopted a 2015-2024 Project Strategy. A priority of the Project Strategy over the five years from 2017 to 2021 is the rapid growth in knowledge and understanding of the TSB's operating environment and its interrelationships with and effects on coastal processes. The knowledge building is achieved through development and ongoing operation of a so-called Sand Transport Information System (STIS). This report aims to inform the STIS.

The NSW Department of Primary Industries – Crown Lands (Lands) engaged Royal HaskoningDHV (RHDHV) and ETS to undertake a sand tracing study to improve the understanding of sediment transport processes in the TSB study area, with particular emphasis on assessing the fate of sand discharged at the Snapper Rocks East (SRE) outlet. The study was undertaken over a 13-week period, commencing in late July 2017 with the final field exercise completed in late October 2017.

The study has been completed through a joint effort by RHDHV and ETS. ETS is a UK-based consultancy that specialises in environmental tracing, and in particular sediment tracing. RHDHV are leading the study and provide expertise in regard to the study planning, local coastal process understanding, analysis and interpretation of the results and reporting as well as undertaking all the field data collection. ETS have been involved in most aspects of the work from study inception and planning, tracer technology, analysis, interpretation and reporting.

RHDHV and ETS recently completed the Dredge Material Sand Tracing Study within the TSB area which focussed on the fate of dredge material placed within the designated dumping location off Duranbah Beach (RHDHV, 2017).

Figure 1: Location of TSB pipelines and outlets (source: TSB).

1.2 Study Scope

Blue tracer material was deployed by injected the material into the slurry tank of the TSB's sand pumping facility located on Letitia Spit during a daytime sand pumping event on 30 July 2017. The tracer material mixed within the sand slurry that was subsequently discharged at the SRE outlet.

Following the deployment of the tracer material, regular sampling was undertaken to ascertain the transport of the tracer material under natural processes. Samples were collected from within a sampling region extending from Duranbah Beach in the south to Kirra Beach in the north. Sampling activities covered a 13-week period until 23 October 2017. The sampling program comprised:

- Five (5) rounds of high frequency sampling on the beach and inner nearshore area, focussing on the key beach compartments in the study area (Duranbah, Froggies, Snapper Rocks, Rainbow Bay, Coolangatta and Kirra) – referred to herein as 'Temporal Sampling'; and
- One (1) round of sampling undertaken along numerous shore-normal transects in the study area, with samples collected across the beach between the Mean High Water (MHW) position and the outer nearshore zone (minimum bed level approximately -14 m Australian Height Datum, AHD) – referred to herein as 'Spatial Sampling'.

Laboratory analysis was undertaken on a selection of the samples collected to provide factual results in the form of spatial distributions of raw tracer count and tracer count per square metre. This factual tracer data, along with supplimentary information, was further analysed and interpreted to infer the sediment transport processes experienced by the blue tracer material in the 13-week period following its release into the neasrehsore environment.

For the single round of spatial sampling, analysis and interpretation was included for the red tracer material, which was deployed by TSB in May 2016 as part of the Dredge Material Sand Tracing Study and hence already present in the study area (RHDHV, 2017). A comparative assessment of the two tracers studies was undertaken and used to inform an overall conceptual sand movement model.

1.3 Study Objectives

The main objectives of the Snapper Rocks East (SRE) sand tracing study are to further understand:

1. The dominant sediment transport pathways from the point source discharge location at SRE.
2. Dispersal rates from SRE, through Duranbah Beach, Froggies Beach, Snapper Rocks, Rainbow Bay, Coolangatta and further downdrift.
3. Lag times from delivery via pumping to response times of adjacent beach compartments.

1.4 Structure of this Report

This report describes all tasks completed for this study and is outlined as follows:

- Background information including the description of the study area and details on the tracer/sand material are provided in **Section 2**.
- A timeline of the key study activities and a description of the tracer deployment, sampling and analysis are provided in **Section 3**.
- A factual presentation of the analysed tracer results is provided in **Section 4**.
- Supplementary information supporting the interpretation of the results is provided in **Section 5**.
- A summary of this study's findings and the inferred sediment transport processes are discussed in **Section 6**. This section also discusses the findings of the previous Dredge Dispersion Sand Tracing Study, or red tracer study (RHDHV, 2017) along with the blue tracer results.
- Conclusions of the sand tracing studies' findings are provided in **Section 7**.

This report was prepared with the understanding that this is primarily a document for internal use by the TSB organisation. It has been assumed that the reader has a level of knowledge of coastal dynamics, the TSB operations and the STIS Project Area in general.

2 Background Information

2.1 Site Characterisation

The Tweed River Entrance (TRE) is located on Australia's East Coast, at Longitude 153°33'E and Latitude -28°10'S, near the New South Wales (NSW) and Queensland (QLD) state border.

A recent study by Jacobs (2017) described the conceptual processes that govern sediment transport in the TSB study area. The dominant drivers for sediment transport were identified as being from:

- waves including the effects of longshore sand transport (or littoral drift) and cross-shore sand transport.; and
- currents including wave-driven currents, tidal currents, wind-induced currents and the East Australian Current (EAC).

An overview of the TSB study area as well as conceptualised sediment transport pathways and the various drivers are provided in Figure 2. The long term average net longshore sand transport in the study area has been estimated at 550,000m^3 per year toward the north (BMT WBM, 2016). The rates of longshore sand transport are highly variable in both space and time.

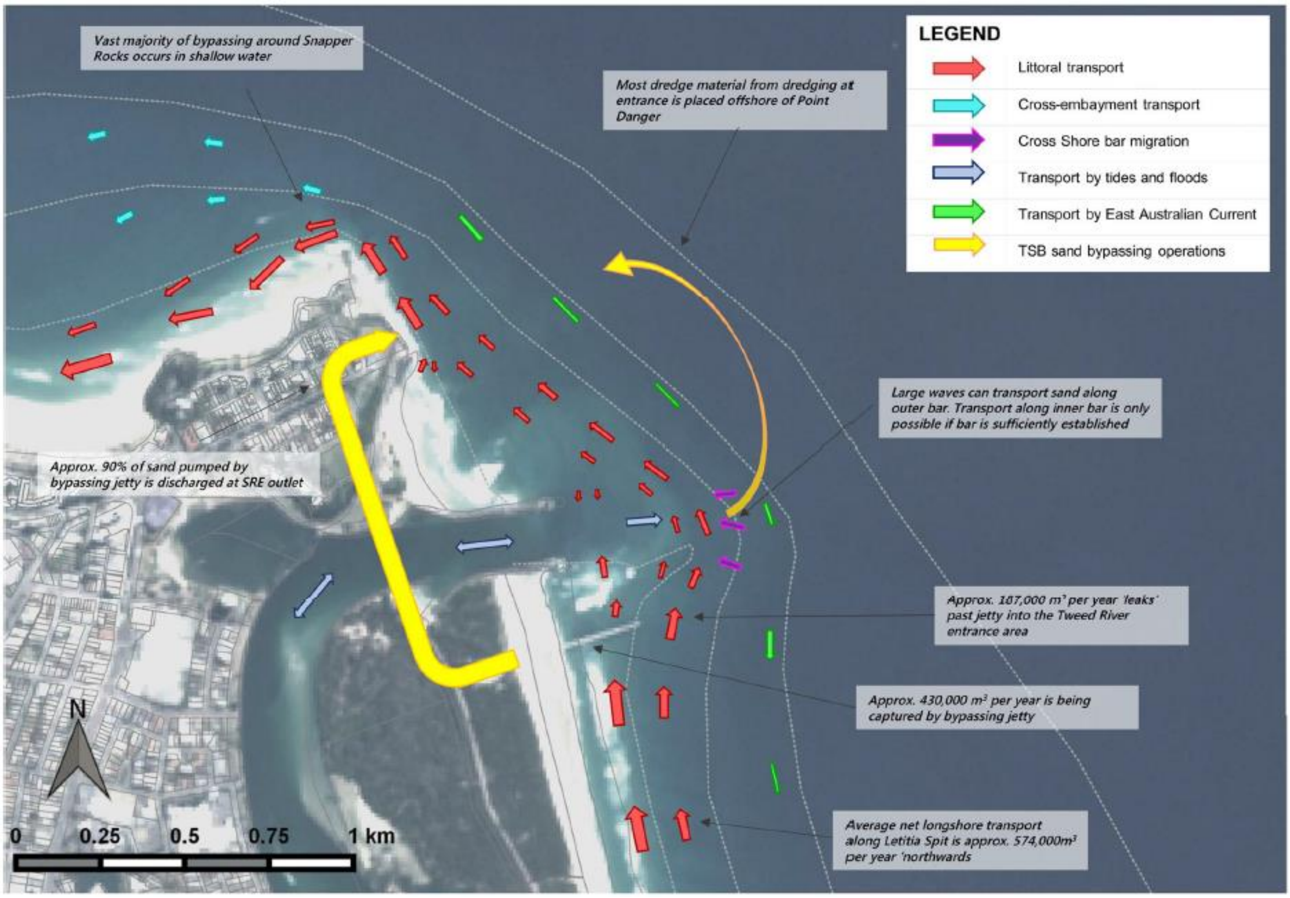

Figure 2: Conceptual sediment transport model for the Tweed River Entrance area developed by Jacobs (2017).

The configuration of entrance training works, strong tidal currents, a 2m tide range and fluvial flow regime of the Tweed River interact with ocean waves and the littoral sediment transport system to produce the dynamic TRE bar (i.e. ebb tide delta). The study area, including the seabed morphology, is show in Figure 3.

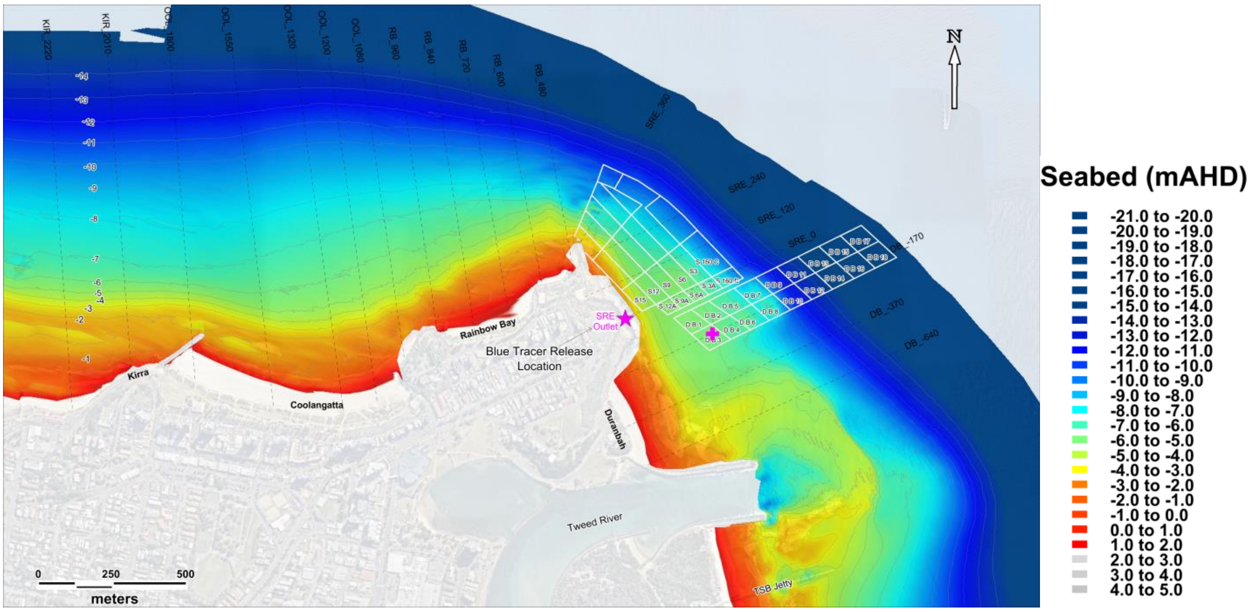

Figure 3: Morphology within the study area (source of bathymetry: July 2017 Coastal Survey).

The coastal margins adjacent to the TRE are:

- Letitia Spit and
- Duranbah Beach and Point Danger.

Letitia Spit, located to the south of the TRE, is a 3.3km long sandy coastal barrier that separates the lower Tweed River from the ocean. Prior to commencement of sand pumping operations, this area had been accreting due to the construction of the entrance training walls in 1962. Letitia Spit experienced erosion following the commencement of the TSB operations but in recent times it has been relatively stable.

North of the TRE, Duranbah Beach and the predominately rocky shoreline at Point Danger occupy the relatively short 850m stretch of coast that shares the general alignment of the southern margins. The NSW/QLD state border is located at Point Danger. This stretch of rocky shoreline terminates at Snapper Rocks, where the coastline takes a 90˚ bend into the southern Gold Coast embayment. The northern coastal margin was previously eroding but TSB operations have had a significant effect on sand reserves.

TSB transfers sand from the southern side of the TRE to the northern side via two mechanisms, dredging and pumping. The majority of sand transfer by the project is via pumping (82 per cent) with most of the pumped sand being discharged at the Snapper Rocks East (SRE) outlet (88 per cent). The SRE outlet is a fixed pipeline that discharges the sand as a slurry above mean sea level just off the cliff face of Point Danger (see report cover photo). In recent years the amount of sand transferred is via pumping is approximately 70 per cent of the average annual rate of longshore sediment transport (LST).

A floating dredge is occasionally used to transfer sand and maintain the navigation channel across the entrance bar. Dredging has been used to transfer around 1.59Mm^3 of sand since 2001, which is equivalent to 18 per cent of the total amount of sand transferred by the project. It is noted that the majority of dredging occurred in the first five years of the operation, between 2001 and 2006, when 1.13Mm^3 of sand was dredged.

Since 2006 only relatively modest amounts (460,000m^3) of sand have been transferred using a dredge, with the majority of this being placed in the Duranbah Beach placement area. The inner and centre Duranbah Beach placement areas, which was used in the 2017 dredging campaign (216,605m^3), ranges in depths from -5m to -15m, relative to Australian Height Datum (AHD).

2.2 Description of Tracer Material

This study used ETS' EcoTrace fluorescent sediment particle tracers. These tracers are designed to be transported like natural sediment, thus assimilating the processes of waves, currents and wind to give an integrated assessment of sediment transport. The tracers are a solid-state solution of fluorescent dyes in a thermoplastic polymer base.

The tracers are whole tracer particles and fluorescent throughout rather than a coating on natural sediment grains from the environment. Coated sediment grains can be abraded reducing recoverability and detection, whereas the ETS EcoTrace particles remain highly fluorescent and can be detected over long timescale projects in high energy environments even after some abrasion.

The Material Safety Data Sheet (MSDS) for the tracer material is provided in Appendix A. The EcoTrace particles do not contain any substances presenting a health hazard within the meaning of the Dangerous Substance Directive 67/548/EEC as amended by the Seventh Amendment 92/32/EEC, refer Appendix A. Testing has also been carried out on the EcoTrace particles to assess potential impacts with regard to ecotoxicology and human consumption, also described in Appendix A.

ETS used a generic sediment particle density of 2.65g/cm^3, equivalent to the density of silica, to provide comparable results of transport of the sediment tracers to natural sediment under typical conditions. The tracer particle density was measured by an external accredited laboratory Exova (Glasgow, UK), following procedures set out in British Standard BS812.

2.3 Particle Sizing

In order for the sand tracers to behave in the same way as the target sediment, it was important to ensure that the tracer particles had similar physical characteristics to the native sediment. This involved analysis of particle size distribution (PSD) data available for the study area prior to the selection of an appropriate tracer material from stocks readily available at the time of study commencement[1].

RHDHV (2017) presented PSD data for native sediments in the study area and used this to construct a target PSD curve for the tracer material. Based on ETS's available tracer stocks at the time of study commencement, the most suitable match was a blue coloured sand tracer. This tracer's quality assured (QA) PSD curve is compared to the target PSD curves in Figure 4. The main difference between the blue tracer and the native material was that the blue tracer contained a greater proportion of larger material (i.e. grain size exceeding 375 µm), as seen by the difference in the upper parts of the PSD curves in Figure 4.

Rather than physically adjusting the PSD of the blue tracer material prior to deployment (i.e. by manually reducing the proportion of oversized material through a process of regrading), the tracer results were

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[1] *Ideally, the tracer material would be manufactured to closely match the PSD of the native sediment. However, it was determined that stocks of tracer material available from ETS at the time of study commencement were characterised by appropriate PSD for the purposes of this study, as described in this section of the report.*

modified such that the effective PSD of the deployed tracer was consistent with the target PSD curves in Figure 4. A similar approach was adopted in RHDHV (2017). This method involved applying reduction factors of 0.5 and 0.8 to the tracer count results for the 'large' (375-500µm) and 'extra large' (>500µm) sand size classes, respectively. For a detailed description of the sample analysis process adopted for the sample analysis refer to Section 3.3.4.

As shown in Table 1, applying the above tracer count reduction factors effectively reduced the amount of 'live' tracer material from 515kg to 400kg. This quantity is considered to be sufficient for carrying out a sand tracing study in the TSB study area which meets the study objectives. Figure 4 also presents the effective tracer PSD curve following application of the reduction factor. It can be seen that the effective PSD of the deployed tracer material generally lies within the target range.

Deploying an excess quantity of tracer material and using reduction factors for the tracer count results is considered appropriate because once deployed the tracer particles mix with the native sediments and the movement of each tracer particle occurs independently of the tracer's PSD.

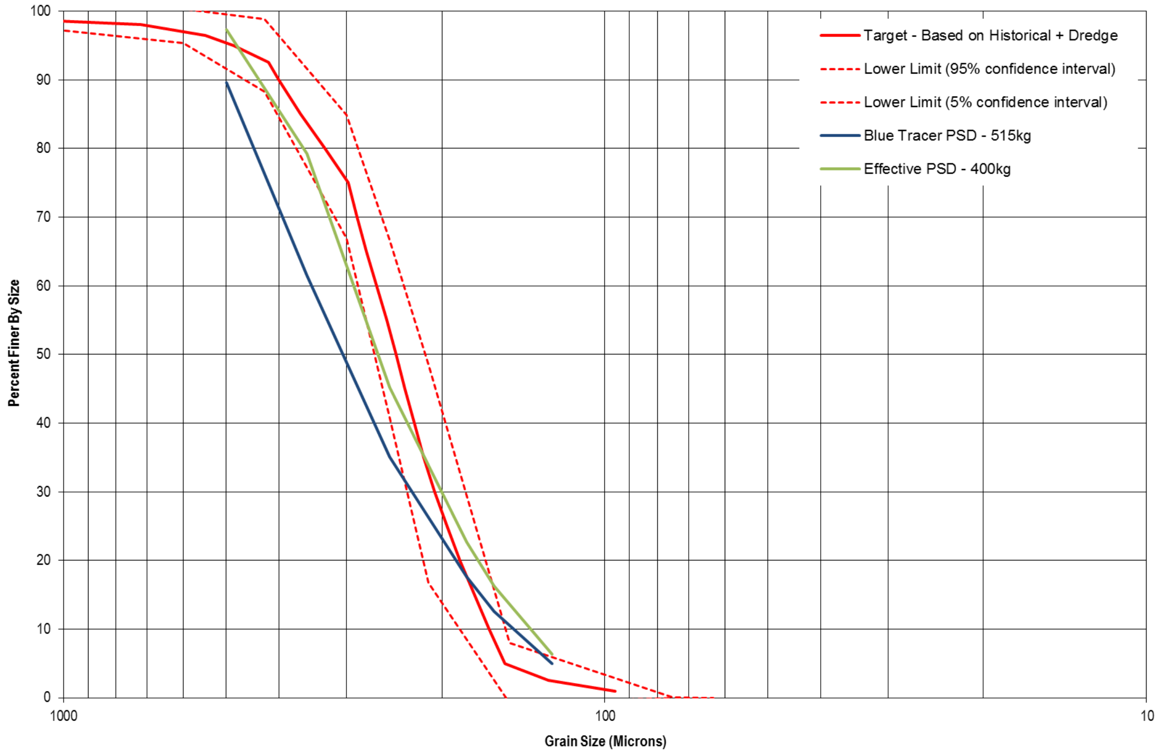

Figure 4: Target PSD (red), PSD of blue tracer (blue) and adjusted blue tracer sample (green)

Table 1: Tracer size classes, size distributions and adjustment factors that can be applied to raw tracer counts.

Tracer Size Class	**Class Size Range (µm)**	**Blue Tracer as Deployed**		**Adjusted Blue Tracer**		
		Percentage of total sample (%)	Weight (kg)	Percentage of total sample (%)	Weight (kg)	Count Reduction Factor
Extra Large	>500	10.4	53.6	2.7	10.7	0.8
Large	375 – 500	28.1	144.7	18.1	72.3	0.5
Medium	250 – 375	26.4	136.1	34.0	136.1	0
Small	125 - 250	30.1	155.1	38.8	155.1	0
Extra Small	<125	5.0	25.5	6.4	25.5	0
	Totals	100%	515 kg	100%	400 kg	

3 Methodology

3.1 Timeline of Key Activities

Table 2 provides a summary of the field activities completed during the study period along with the relevant dates of some of the supplementary data collection and storm events.

Table 2: Timeline of key activity dates and supplementary data collection

Date	Activity/ supplementary data capture	Time relative to blue tracer deployment
5 May 2016	Red tracer deployment (~6m depth)	-451 days (65 weeks)
30 July 2017	Maintenance dredging commences on the entrance bar	0 days
30 July 2017	Blue tracer deployment (SRE outlet)	0 days
26 to 31 July 2017	Bathymetric survey (annual survey)	-4 days/ +1 day
31 July to 1 August 2017	Sampling round 1 (week 1)	+1 day/ +2 days
9 August 2017	Sampling round 2 (week 2)	+10 days
15 August 2017	Maintenance dredging completed	+16 days
20 August 2017	Large wave event with H_{sig} > 2m, from ESE	+21 days
23 August 2017	Sampling round 3 (week 4)	+24 days
8 September 2017	Sampling round 4 (week 6)	+40 days
3 October 2017	Large wave event with H_{sig} > 2m, from ENE	+65 days
5 October 2017	Sampling round 5 (week 10)	+67 days
5 October 2017	Bathymetric survey (ETA lines)	+67 days
15 to 19 October 2017	Extended large wave event with H_{sig} up to 3m, from East	+77 days/ +80 days
23 October 2017	Sampling round 6 (week 13)	+85 days

3.2 Tracer Deployment

A total of 515kg of blue tracer material was injected into the slurry tank at the TSB sand pumping facility located on Letitia Spit (see Figure 5) on 30 July 2017 14:16 AEST. Deployment via the slurry tank provided an opportunity to relatively rapidly inject the tracer material into the TSB system over a one hour period which ensured that the tracer concentration in the pipe system was maximised (see Table 3).

A fallpipe was used to guide the tracer material into the slurry tank and minimise windblown losses. The bottom end of the fallpipe was submerged by around 50cm to ensure that all injected tracer material was well mixed in the slurry tank. A hose was used to wet the tracer as it passed through the fall pipe to further minimise windblown losses.

A total of 15 quality control samples were taken at the SRE pipe outlet at 10 minute intervals during and shortly after the deployment to provide an indication of tracer concentrations within the slurry discharge.

Quality control samples were also collected within the slurry tank (15 minutes after deployment) and at the overflow discharge pipe at the Lititia Spit jetty.

Table 3: Pumping statistics during deployment of the blue tracer material at the TSB Slurry Tank on 30 July 2017. (Note: the deployment duration was approximately 1 hour).

Tracer weight (kg)	Tracer volume (m^3)	30 July pumping volume (m^3)	30 July pumping duration (h)	TSB flow rate (m^3/hour)	Tracer/Sand ratio in pipe (-)
515	0.3	3,743	11.8	317	0.001 (1 part tracer to 1,000 parts sand)

Figure 5: Southern end of slurry tank at the Letitia Spit jetty where the blue tracer material was injected (photo credit: Heiko Loehr/ Isaac Smith).

3.3 Sampling

3.3.1 Sample Locations

In order to achieve the objectives of the study, two types of sampling were undertaken:

- *Temporal sampling:* Five (5) rounds of high frequency sampling on the beach and inner nearshore area, focussing on the key beach compartments in the study area (Duranbah Beach, Froggies Beach, Snapper Rocks, Rainbow Bay, Coolangatta Beach and Kirra Beach). Samples were taken from the surface of the seabed/beach at the selected transects. Typically samples were taken at two water depths in the nearshore and at the MSL contour on the beach. A total of 136 temporal samples were collected over the 13-week study period. Using an adaptive management approach, the extent of sampling was adjusted for each event.

- *Spatial sampling:* One (1) round of sediment sampling comprising a combination of beach and seabed grab samples collected across shore normal transects extending from Duranbah Beach to Kirra Beach. The spacing of transects varied throughout the sampling region, with a denser sampling grid in the vicinity of the SRE outlet and the key beach compartments. Samples were generally collected across the beach between the MHW position and the outer nearshore zone (minimum bed level approximately -14 m AHD). For this study, the spatial sampling included:

- 89 transect samples consisting of 5 to 7 samples along each of the 16 transects at the SRE outlet and north;
- an additional 19 samples south of the SRE outlet area (i.e. Duranbah Beach);
- giving an exercise total of 108 samples.

A map showing the sampling locations is provided in Figure 6.

3.3.2 Sampling Program

While a preliminary sampling schedule was identified, an adaptive management approach was adopted to determine the exact timing of sampling events. Theses sampling dates are presented Table 4. The adaptive management approach considered factors such as prevailing metocean conditions, visual observations of shoreline erosion/accretion, and assessment of preceding tracer results. For example, it should be noted that the timing of the spatial sampling (Round 6) was delayed by several weeks due to weather conditions that were unfavourable for collecting nearshore bed samples.

Table 4: Sampling dates during the 13-week study period.

Sampling Round	Date(s)	Activity
1	31 July 2017 and 1 August 2017	Round 1 Temporal Sampling (one day post-release)
2	9 August 2017	Round 2 Temporal Sampling(10 days post-release)
3	23 August 2017	Round 3 Temporal Sampling(4 weeks post-release)
4	8 September 2017	Round 4 Temporal Sampling (6 weeks post-release)
5	5 October 2017	Round 5 Temporal Sampling (10 weeks post-release)
6	23 October 2017	Spatial Sampling (13 weeks post-release)

3.3.3 Sample Collection

Sediment sampling was undertaken in a similar manner to that described in RHDHV (2017). This generally involved the collection of sediment samples as follows:

- Onshore (beach) sampling involved transferring sand from the upper 5 to 10cm of the beach surface into plastic containers using a stainless steel spoon.
- Surf zone samples (~2m depth) were collected using a 30cm long stainless steel dredge pipe with a 10 cm diameter opening. The end of the dredge pipe was covered with geofabric material to permit drainage whilst still trapping fine particles.
- Offshore samples were collected using a stainless steel Shipek grab sampler with bucket attachment. This type of grab sampler provides sediment from the top 10cm of the seabed (i.e. it is a surface sediment sampling method).

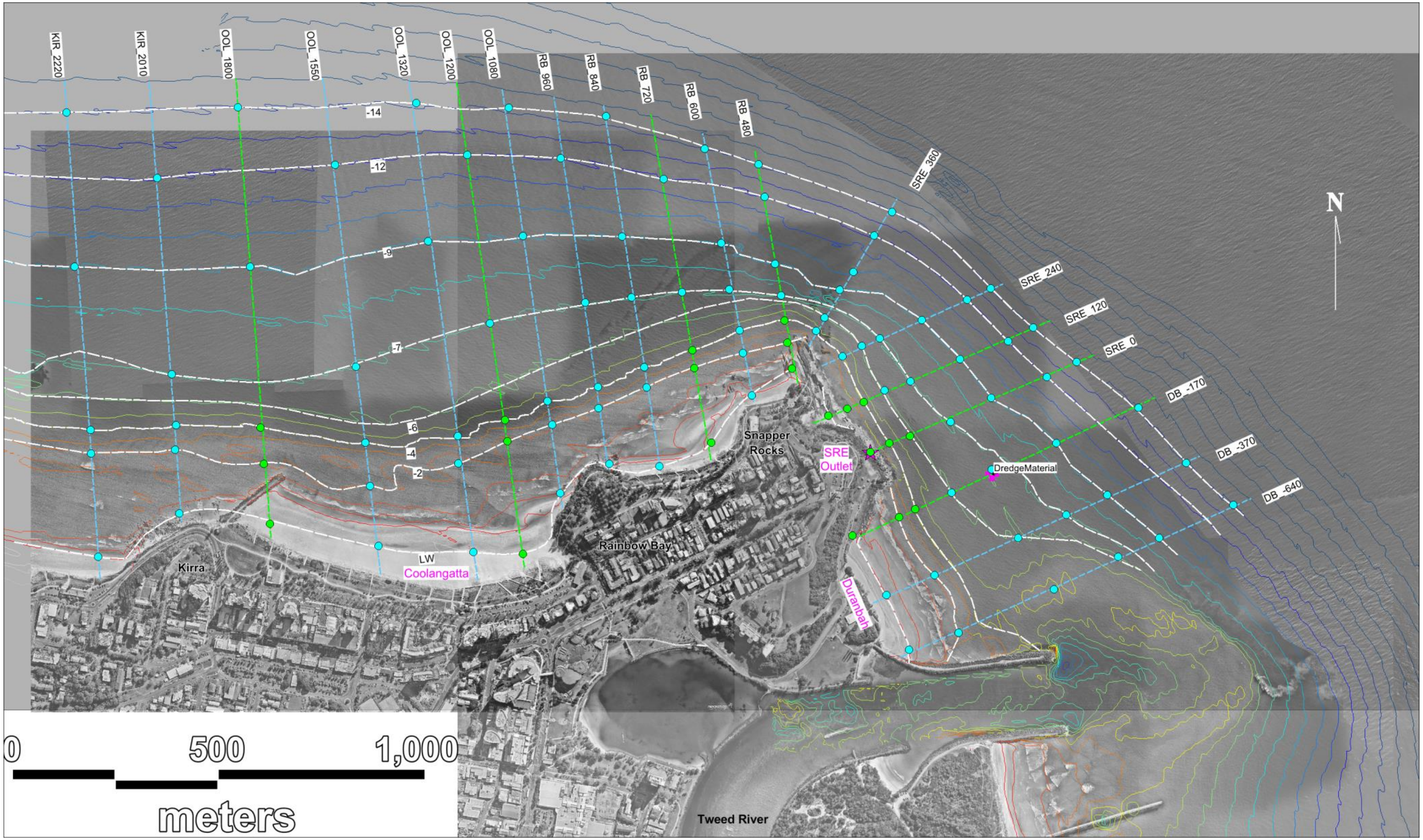

Figure 6: Sampling locations for the SRE sand tracing study.

Note: The temporal sampling locations and transects are shown in green. The additional sampling locations and transects used for the spatial sampling are shown in blue. Each sampling transect is labelled with (i) a code which indicates its beach compartment (e.g. OOL is used for Coolangatta) and (ii) the alongshore chainage, which based on zero being at the SRE outlet, positive chainage is in the downdrift direction with distances based on the -6m depth contour (e.g. DB_-170 is used to indicate the Duranbah Beach compartment with an alongshore chainage of -170m (i.e. 170m updrift of the SRE outlet). This alongshore chainage system is adopted throughout this report.

- All sampling equipment was rinsed in seawater following collection of each sample to minimise the risk of cross-contamination between sites. Each sample container was clearly labelled and stored in a plastic zip-lock bag to preserve the sample in the event that the plastic container was damaged prior to analysis. Photographs taken during the sampling fieldwork are provided in Figure 7.

Figure 7: Photos taken during fieldwork undertaking (left) vessel based sampling and (right) beach sampling.

3.3.4 Sample Analysis and Quality Control

All the collected samples were shipped to the ETS laboratory (ISO 9001 certified) in the UK. Due to scope constraints, it was not possible to analyse all of the collected samples. As set out in Table 5, 173 of the 241 collected samples were selected for analysis. The remaining 71 samples were set aside for possible analysis at a future date. The benefit of any future sampling would be to supplement the existing datasets. Locations of samples collected but not yet analysed are indicated on the tracer results spatial maps (Appendix B).

Table 5: Summary of sample collection and analysis quantities.

Sampling Round	Date(s)	Number of Samples		Tracer Recovery	
		Collected	Analysed	Recovery (count per square metre)	Relative recovery (compared to Sampling Round 1 (%))
1	31 July 2017 and 1 August 2017	33	20	19,900	100
2	9 August 2017	33	22	19,281	97
3	23 August 2017	27	21	14,472	73
4	8 September 2017	22	22	3,553	18
5	5 October 2017	21	21	2,958	15
6 (Spatial Sampling)	23 October 2017	108	97	7,715	39
TOTAL		**244**	**203**	**67,879**	**-**

Each sample was weighed and then examined for tracer particles on non-fluorescing paper using a magnifying fluorescent lamp. The total number of tracer particles present in each sample was counted and expressed as tracer counts (particles) per 100 grams of dry sediment. The tracer count per 100 grams was then converted into tracer particle counts per square metre. Repeat analyses were performed to ensure tracer count reliability (ETS-EHI 2007 and 2010). Tracer results presented herein are expressed in units of count per square metre (counts/m^2), and predominately referred to as tracer ‘concentrations’.

Grain size analyses were performed for all the recovered samples using a fluorescence microscope. Individual grains for each of these size bands were selected from the blue tracer stock. These individual grains were mounted on microscope slides and used as a reference slide to size each fluorescent tracer particle detected in the samples. The following five size bands were used in the analysis and are reported herein:

- ‘extra small’: <125 µm, i.e. equivalent to very fine sand;
- ‘small’: 125 - 250 µm, i.e. equivalent to fine sand;
- ‘medium’: 250 - 375 µm, i.e. finer fraction of medium sand;
- ‘large’: 375 - 500 µm, i.e. coarser fraction of medium sand; and,
- ‘extra large’: >500 µm, i.e. coarse sand.

Further details of the analysis protocol adopted by ETS are provided in Appendix A.

Reduction factors of 0.8 and 0.5 was applied to all ‘extra large’ and ‘large’ sized tracer counts to account for the difference between the native and tracer PSDs (refer Section 2.3). This correction was applied to all the final results presented herein (i.e. both the total count per square metre as well as the ‘extra large’ and ‘large’ size band counts per square metre).

4 Tracer Results

4.1 Preamble

Maps presenting the tracer counts per square metre for each of the sampling rounds are plotted in Appendix B along with a detailed description of each sampling round. Also presented in Appendix B is a similar set of maps showing the spatial distribution of the particle size results for the tracer material. The ‘extra-small (XS)’, ‘small’, ‘medium’, ‘large’ and ‘extra-large (XL)’ size bands adopted for this study correspond with the ‘real-world’ sediment size bands as described in Section 3.3.4.

Tracer results for all samples collected during the study period are also tabulated in Appendix B. This includes both the raw tracer count data and the calculated count per square metre data. The *raw tracer count* data represents the actual number of tracer particles recorded in each of the analysed samples, whereas the *tracer count per square metre* (also referred to in this report as *tracer concentration*) data is calculated from the raw counts as described in Section 3.3.4.

It should be noted that the detection limit of raw tracer counts in a viewed sample is one (1) individual tracer particle. The typical dry weight of a viewed sample is around 300 g, so the equivalent tracer detection limit is in the order of 500 parts per million (ppm) [2]. Furthermore, the corresponding tracer concentration for a raw count of one (1) particle in a viewed sample is less than 100 counts/m^2.

The above information should be considered when interpreting the tracer results presented herein. For example, reported tracer concentrations of up to around 100 counts/m^2 typically correspond with a raw tracer count of one (1) particle in a dry sediment sample weighing around 300 g. As such, caution should be taken when drawing conclusions from spatially isolated results. Rather, the tracer results are intended to be interpreted in a holistic manner that considers the spatial and temporal distribution of all results.

4.2 Tracer Counts

If at least one tracer particle, of any size class, was detected this has been termed ‘positive sample’ throughout this report. It was possible to have multiple size classes detected for a particular sample. A zero count indicates no tracer was observed in the sample.

A detailed analysis of the tracer results has been undertaken and is presented in the following sections.

4.3 Rates of Dispersal from SRE

In order to assess the rate of tracer dispersal from the SRE release site all samples taken along the SRE0 transect were integrated and normalised, see Figure 8. Normalising the observation was required as the number of samples per sampling event varied. It is also noted that the spatial sampling results (week 13) include sampling locations in deeper areas of the profile compared to the temporal sampling (week 1 to week 10). It can be seen in Figure 8 that:

- The tracer concentration at the SRE0 location (upper profile) peaked immediately following the tracer release.
- The tracer concentration in the nearshore area dropped to zero by week 6.
- The finer tracer material dispersed at a higher rate than the coarser material.

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[2] *Based on a particle size (D_{50}) of 80 µm and a particle density of 2.65g/cm^3.*

Based on these observations it is reasonable to assume that all of the 3,743m^3 of sand that was discharged via the SRE outlet on the 30 July 2017 had dispersed by week 6 sampling (8 September 2017), giving an overall rate of dispersal of 94m^3/day. However, the initial rate of dispersion (up until week 2) was more rapid at approximately 346m^3/day.

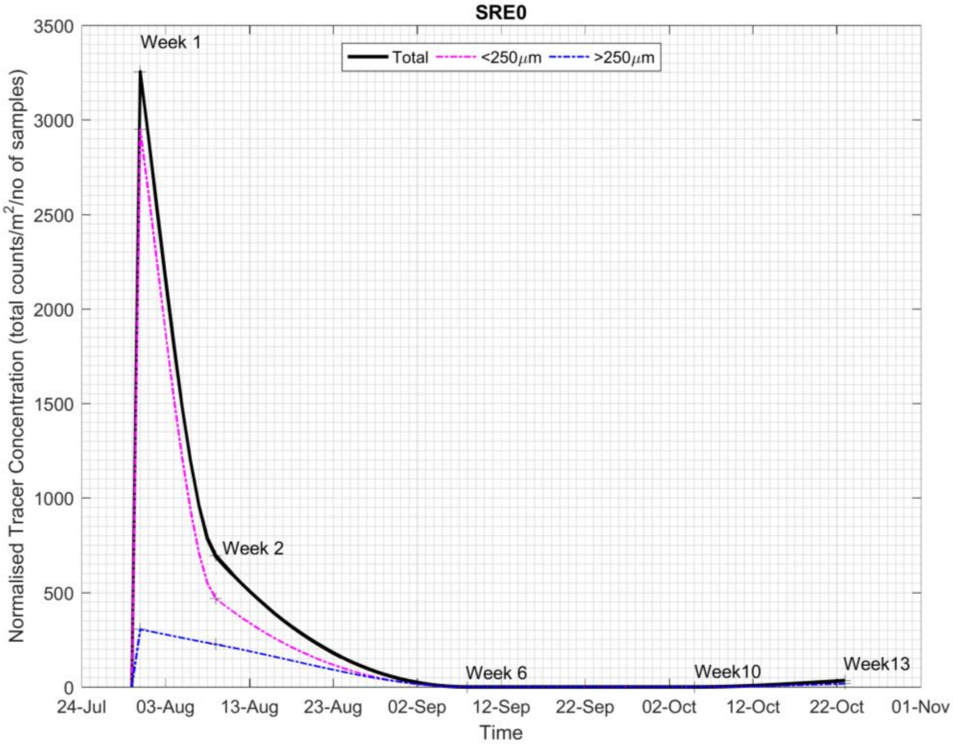


Figure 8: Time series of the average tracer concentration at the tracer release site (SRE0 transect).

Note: The coloured lines show the concentration of the different size fractions.

4.4 Alongshore Tracer Distribution

Plots showing the alongshore distribution of observed tracer concentration for each sampling event are shown in Figure 9. The alongshore tracer distribution profiles were calculated by integrating the tracer concentration along each of the sampling transects and normalising to allow comparison with varying number of samples per collection event. It can be seen in Figure 9 that from week 6 onwards sampling recovered a relatively low percentage of tracer in comparison to preceding sampling rounds. In order to better visualise the alongshore dispersal Figure 10 provides an adjusted version of the concentration profiles, whereby the concentrations have been factored by the inverse of relative sampling recovery rates (see Table 5).

It can be seen in Figure 9 and Figure 10 that:

- During week 1 sampling the bulk of the tracer material was found around the SRE release location. In comparison to the downdrift side, significantly higher tracer concentrations were found updrift of SRE at the northern end of Duranbah Beach. The southern part of Duranbah Bach was not sampled. Lower tracer concentrations were found over a larger extent on the downdrift side including Froggies Beach and Snapper Rocks. Further downdrift of RB480, no tracer was observed.

- By week 2 the bulk of the tracer material was located between Rainbow Bay and the northern end of Duranbah Beach. However, the tracer concentrations at the SRE outlet location were significantly lower than the surrounding sampling locations. It is assumed that the tracer material in this high-energy nearshore area is very active and also burial and dilution of tracer material at the SRE occurred due to ongoing nourishment by TSB. Low concentrations were evident at RB720 and further downdrift.
- The results for week 4 show that the tracer has dispersed over a widening alongshore distance. While the bulk of the material is still located between Rainbow Bay (RB720) and the northern end of Duranbah Beach (DB-170), sampling results for Coolangatta showed that the blue tracer had arrived at these downdrift locations. Tracer material was found as far downdrift as Kirra groyne (OOL1800).
- The tracer concentrations for week 6 were significantly lower than the previous sampling rounds. Also significant was that the tracer concentrations in the nearshore sampling area at Duranbah Beach and the SRE release location dropped to zero. The bulk of the tracer was found at Rainbow Bay (around RB480 and RB600) and Coolangatta (OOL1200), with some tracer and as far as Kirra Beach (KIR2220).
- As per week 6, the tracer recovery in week 10 was significantly lower than the early sampling rounds. The alongshore distribution was similar to the week 6 with the most notable differences being the (i) zero concentrations found at Kirra groyne and Kirra Beach and (ii) reappearance of tracer at the northern end of Duranbah Beach although this was at low concentrations.
- Week 13 results show that the bulk of the blue tracer has moved downdrift to Coolangatta. The lowest concentrations were found at the SRE release location as well as Froggies Beach and Kirra Beach. The lower tracer concentrations in the Rainbow Bay area suggest that the tracer material has moved out of this area. In order to allow a direct comparison to the temporal sampling rounds, only the upper profile (i.e. -4m depth profile and higher) samples for week 13 where used for the alongshore distribution presented in Figure 9 and Figure 10.

The relative distributions of tracer concentration for week 1 and week 13 are presented in Table 6.

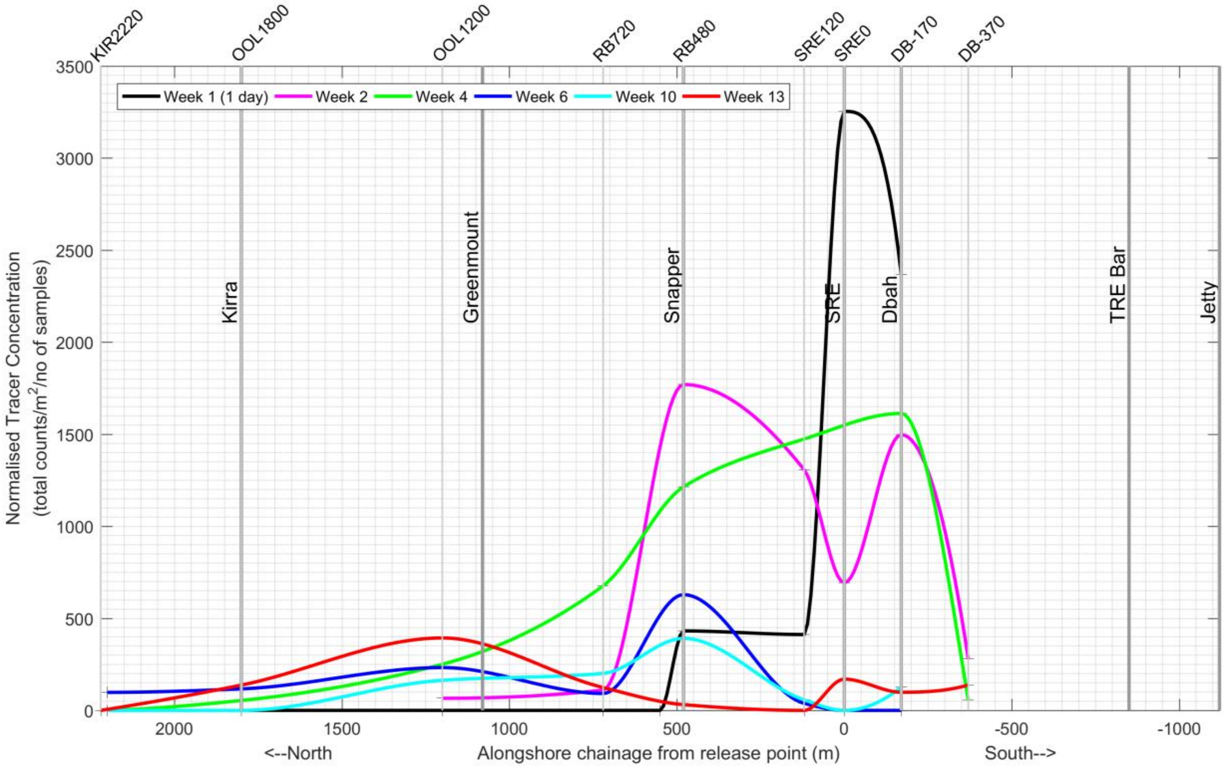


Figure 9: Alongshore tracer distribution either side of the SRE release location for each sampling event.

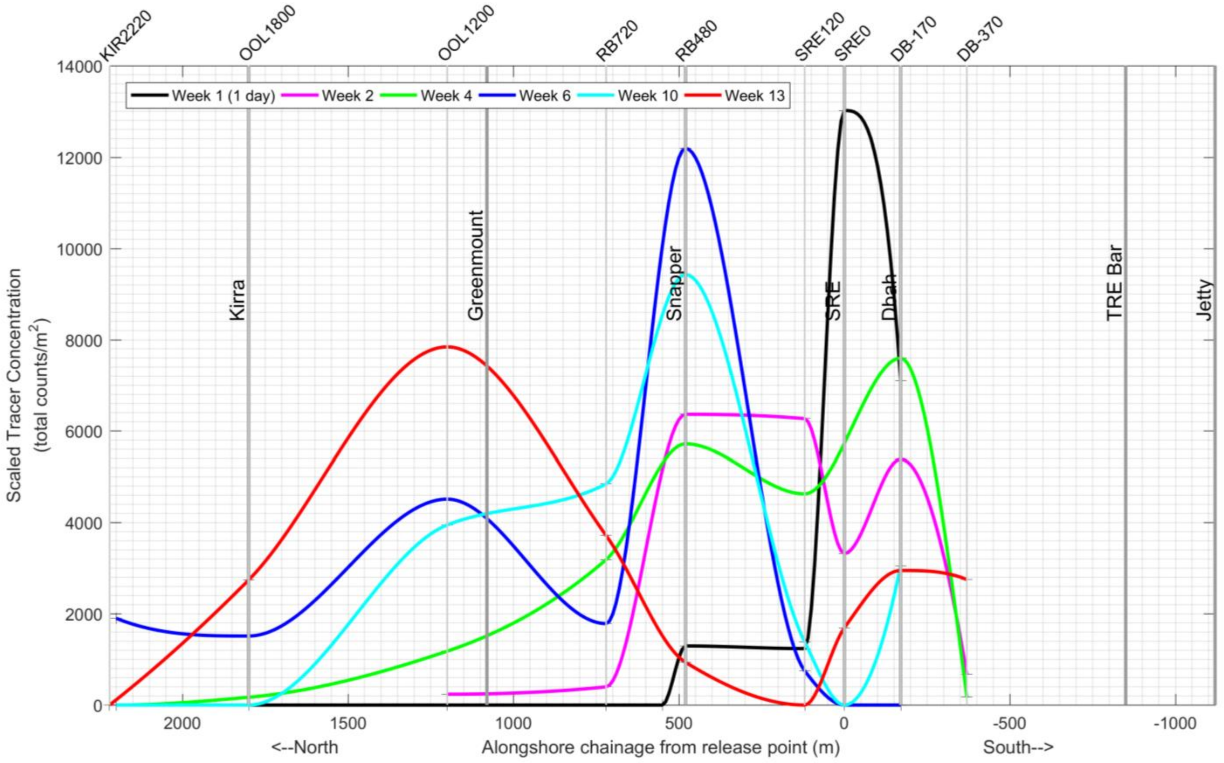


Figure 10: Scaled alongshore tracer distribution either side of the SRE release location for each sampling event.

Table 6: Summary of alongshore tracer distribution results.

Parameter	Alongshore area	Week 1	Week 13
Percentage of observed tracer distribution	Updrift of SRE0 (south)	31%	23%
	SRE (SRE0)	57%	2%
	Downdrift (north)	11%	75%

4.5 Cross-shore Tracer Distribution

To determine the cross-shore distribution of tracer concentrations all samples within a specified beach compartment were summed for each sampling depth (i.e. beach profile contour) in the week 13 results. The total tracer concentrations over the representative beach profile for each beach compartment are presented in Figure 11.

It can be seen in Figure 11 that:

- Generally, the majority of the tracer was found in the nearshore areas shallower than the ~ -7m depth contour.
- Some tracer was evident on the deeper areas of the beach profile at Kirra and Duranbah up to the ~9m contour.
- There was evidence of tracer material depositing on the sub-aerial beach at all beach compartments except near Snapper Rocks East/ Froggies Beach.

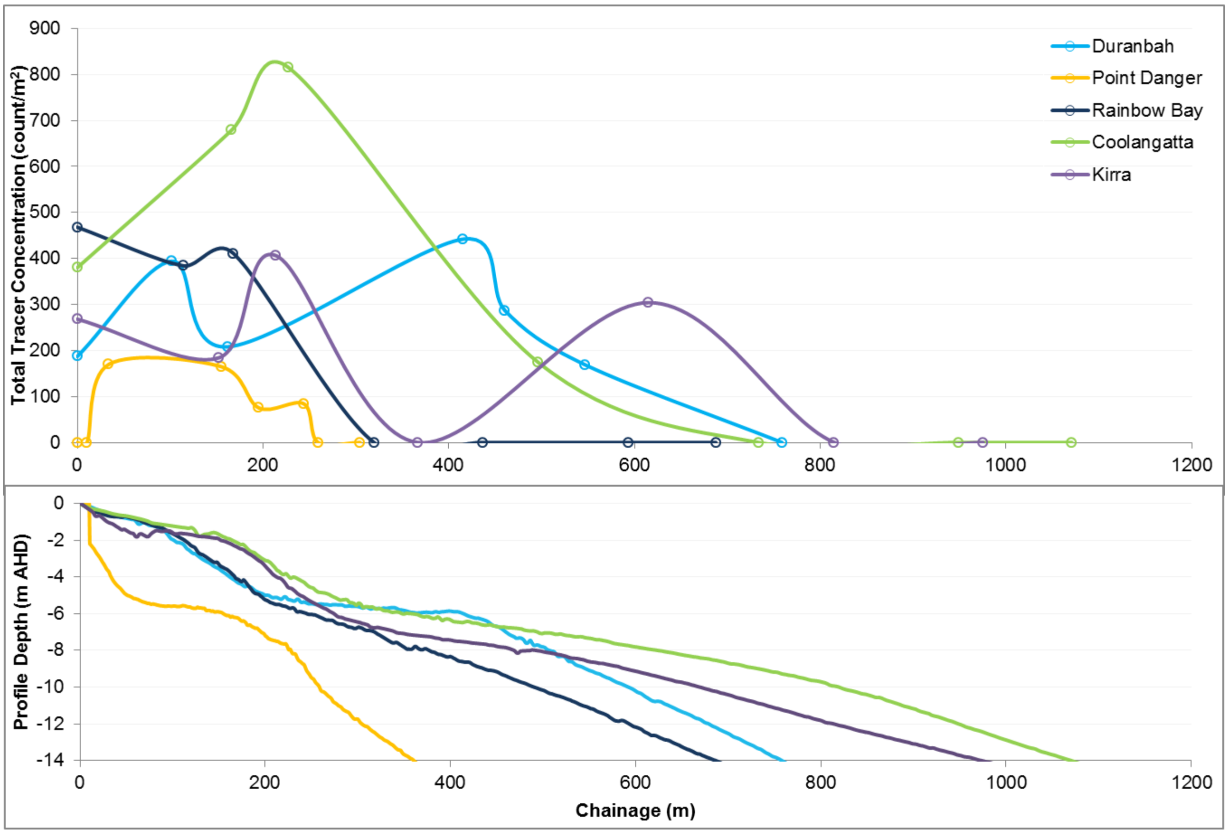


Figure 11: Week 13 cross-shore tracer distribution for key beach compartments.

Note: Beach profiles are based on representative transects taken from the July 2017 survey provided by TSB.

4.6 Response Times of Beach Compartments

To inform sand pumping operations, TSB are seeking to better understand the time it takes for sand that is delivered via the SRE outlet to move into the adjacent coastal compartments. Determining these lag times is one of the key objectives of this study. Using the blue tracer results lag times, from the release of tracer until it is observed in the following six main beach compartments, have been determined:

- Duranbah Beach (sample transect DB-170);
- Froggies Beach (sample transect SRE120);
- Snapper Rocks (sample transect RB480);
- Rainbow Bay (sample transect RB720);
- Coolangatta Beach (sample transect OOL1200); and
- Kirra Beach (sample transect OOL1800).

In order to determine the lag times the average tracer concentration along the sampled transects was plotted against time (see Figure 12). The estimated lag times, as presented in Table 6, were calculated for the following conditions:

- Initial arrival of tracer, where the tracer material was considered to have arrived at a certain beach compartment when the average tracer concentration exceeded an arbitrary threshold of 100counts/m^2.
- The response time of each beach compartment was based on the lag time to the peak tracer concentration as this is considered representative of when the bulk of the tracer material had arrived within the beach compartment.

Using the tracer concentration time series presented in Figure 12 an estimate was also made of the rate at which the tracer dispersed from each beach compartments. This is based on the time it takes for the tracer concentrations to reduce from the observed peak to 20 per cent of the peak concentration.

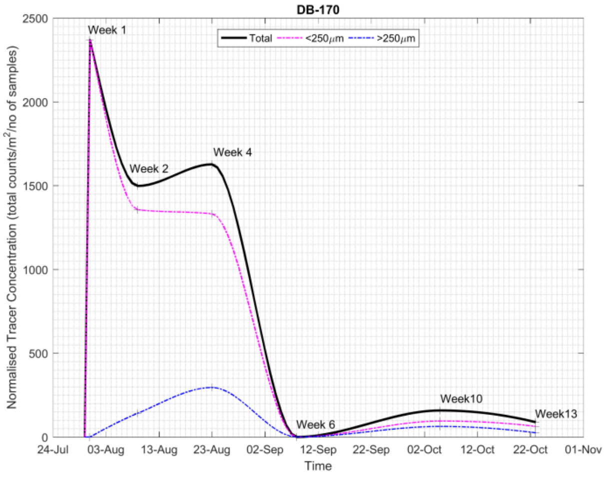
Table 7: Estimated lag times of tracer arrival, peak concentration and dispersal for each beach compartment within the study area.

Beach compartment	**Estimated lag times (post-release of the tracer)**		**Dispersal time** (post-tracer concentration peak)
	Initial arrival of tracer (concentration > 100 counts/m2)	**Main response** (peak of tracer concentration)	
Duranbah Beach	1 day	1 day	5 weeks
Froggies Beach	1 day	24 days	1 – 2 weeks
Snapper Rocks	1 day	10 days	8 -9 weeks
Rainbow Bay	10 days	24 days	7 – 8 weeks (based on the general decreasing trend)
Coolangatta Beach	24 days	24 days	Not observed
Kirra Groyne	40 days	Not observed	Not observed

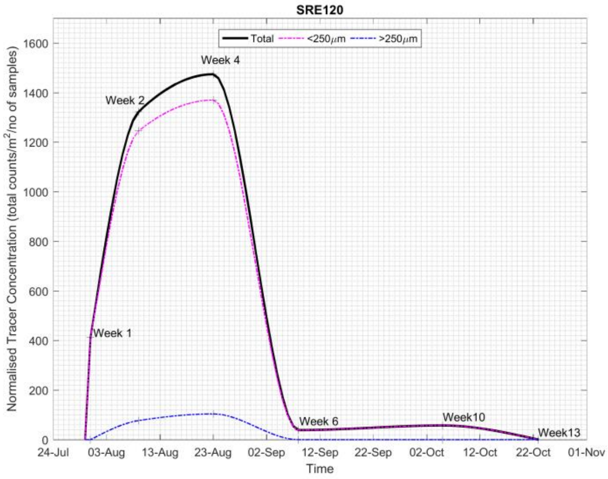
The use of the blue tracer results is considered a suitable approach to determining the time it takes for sand that is delivered via the SRE outlet to move into adjacent beach compartments. However, the following key limitations should be recognised:

- The lag times calculated for the tracer results are representative of the study period and the individual pumping event during initial tracer deployment.
- The temporal resolution of the tracer concentrations are governed by the timing of the sampling exercises undertaken.
- Temporal sampling included only the upper profile (i.e. -4m depth contour and above).

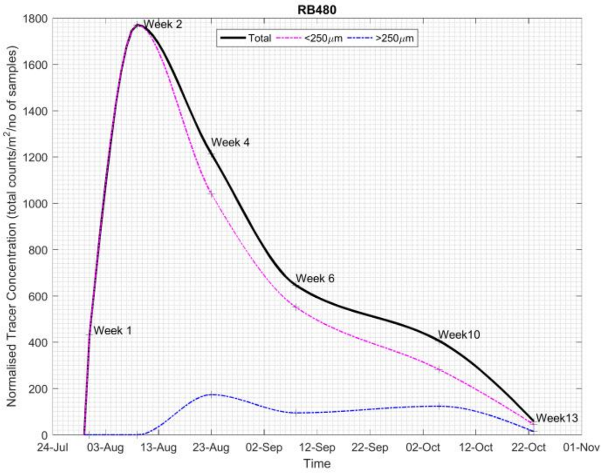
Duranbah Beach



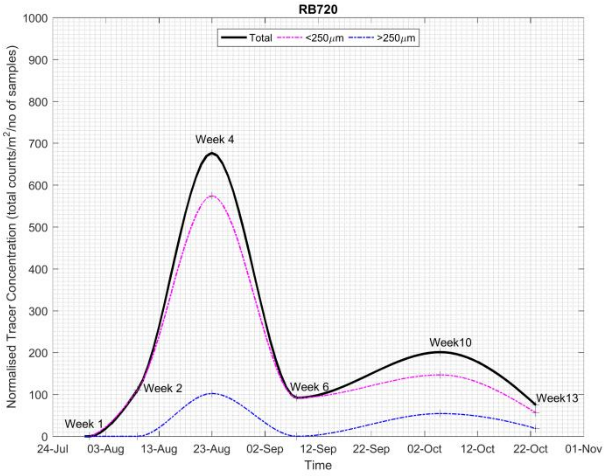
Froggies Beach



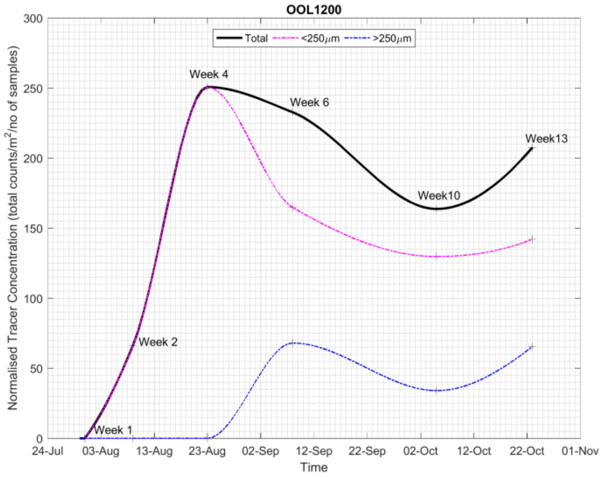
Snapper Rocks



Rainbow Bay



Coolangatta Beach



Kirra (groyne)

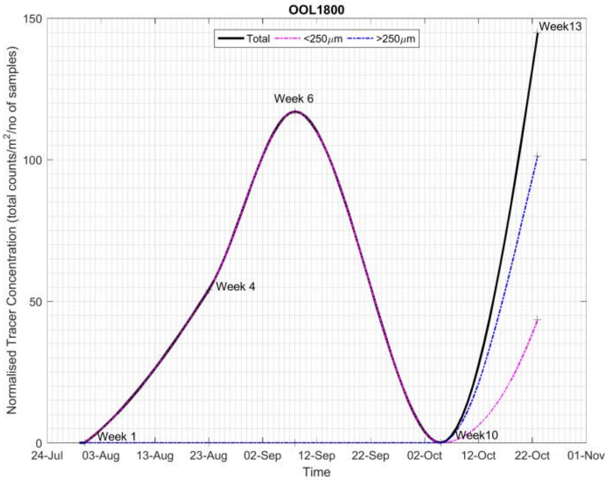


Figure 12: Tracer concentration time series for each beach compartment within the study area. The coloured lines show the concentration of the different size fractions.

4.7 Particle Size Results

A summary of the key particle size results is as follows:

- Extra large sized blue tracer particles were not recorded in any of the samples collected throughout the study period. This may be related to the relatively small number of such particles within the released tracer, i.e. compared to smaller size fractions which were more much ubiquitous in quantity. This observation also indicates that the sediment transport conditions that operated during the study period were less likely to mobilise coarse sand.
- Large sized blue tracer particles were generally recorded in a small proportion (less than 20 per cent) of the positive samples for each sampling round. Furthermore, the following is noted:
    - the majority of large sized blue tracer particles were recorded within around 200m of the release site, which indicates that these particles were not transported as widely as the smaller sized particles; and,
    - large particles were also recorded on the sub-aerial portions of Duranbah Beach and Rainbow Bay, providing evidence of onshore transport and deposition of coarser fractions during the study period.
- Medium sized blue tracer particles were generally recorded in around 40-50 per cent of the positive samples for each sampling round. It is evident that the medium sized particles were transported slightly more extensively than the large particles but not as much as the smaller sized particles. Furthermore, the following is noted:
    - onshore deposition of medium sized tracer particles occurred at several beach compartments within the study area during the study period, including Duranbah, Rainbow Bay and the eastern end of Coolangatta; and,
    - medium sized particles were recorded in several of the week 13 samples collected south-east of the release site, which indicates that this material may be transported towards the TRE bar.
- Small and extra small sized particles were the most commonly recorded size fractions recorded. This was most evident in the results for weeks 1, 2, 4, 6 and 10, wherein around 80-100 per cent of the positive samples included small and/or extra small sized particles. This provides evidence of preferential dispersion of this size fraction during the study period. In addition, the relative proportion of small sized blue particles generally increased with distance from the release site.
- It is noted that small and/or extra small sized blue tracer particles were recorded in around 50 per cent of the positive samples collected during week 13, which is a reduction from the earlier sampling rounds. Furthermore, a similar proportion of the positive samples for week 13 comprised medium sized particles. This indicates that the preferential dispersion of finer sized sand fractions observed in the earlier sampling rounds was less evident in week 13.

4.8 Spatial Sampling Tracer Map

In order to better visualise tracer dispersion, Voronoi polygons were fitted to the spatial sampling (week 13) results. Voronoi polygons represent the region of influence of each sample and are defined as being equidistance to nearest neighbouring sample. The results are presented in Figure 13. In this map it is important to note that the colour scale used is based on a log type scale, with each darker colour having a concentration ten times the preceding colour. Key observations from this tracer distribution map are discussed further in Section 6.1.

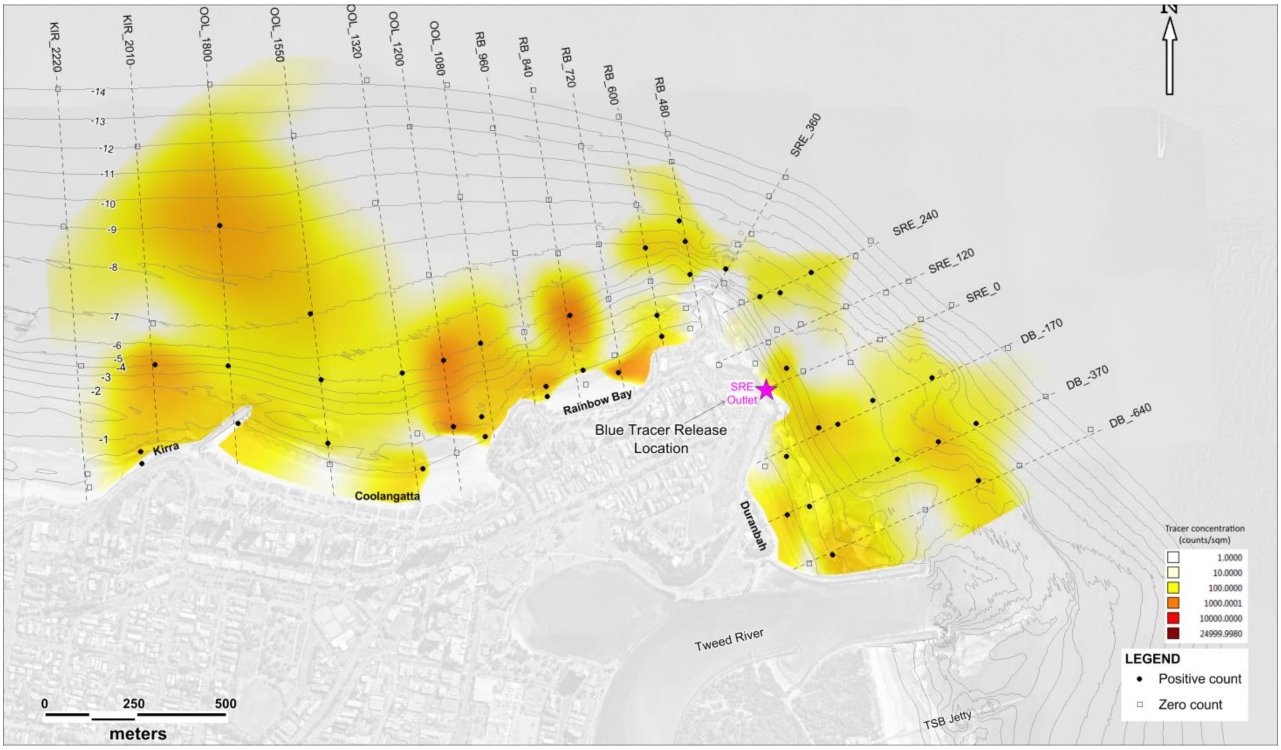


Figure 13: Interpolation of blue tracer concentrations derived from the spatial samples taken on 23 October 2017.

Note: colour scale used is based on a log type scale, with each darker colour having a concentration ten times the preceding colour.

5 Supplementary Information

5.1 Preamble

This section of the report presents information that supplements the sand tracing results. The supplementary information has been used to assist with the interpretation of the tracer results. The information that was reviewed as part of this study included:

- Dredging activities (July - August 2017);
- Metocean conditions during the study period;
- Morphological change during the study period based on comparison of bathymetric surveys; and
- Analysis of sand pumping records.

Furthermore, a summary of the red tracer study (Dredge Material Tracing Study, RHDHV, 2017) is provided in this section.

5.2 Available Data

An overview of the supplementary data that was available for this study is provided in Table 8 and Figure 14.

Table 8: Overview of supplementary data adopted in this study.

Dataset	Date(s)	Comment
Bathymetric survey	26 to 31 July 2017	'Whole of coast' survey including all ETA lines (pre study survey)
Bathymetric survey	5 October 2017	ETA line survey (mid study survey)
Tweed Heads wave rider buoy (WRB) (waves)	January 1995 to October 2017	Directional wave data at TWRB location (22m depth)
Tweed Heads WRB (currents)	July 2017 to October 2017	Currents data (top 1.5 m to sea surface) since July 2017 at TWRB location (22m depth) – *not quality controlled*
Dredging log	29 July and 15 August 2017	Log of Tweed River Entrance dredging
TSB SCADA data	1 July to 30 October 2017	Sand pumping volumes

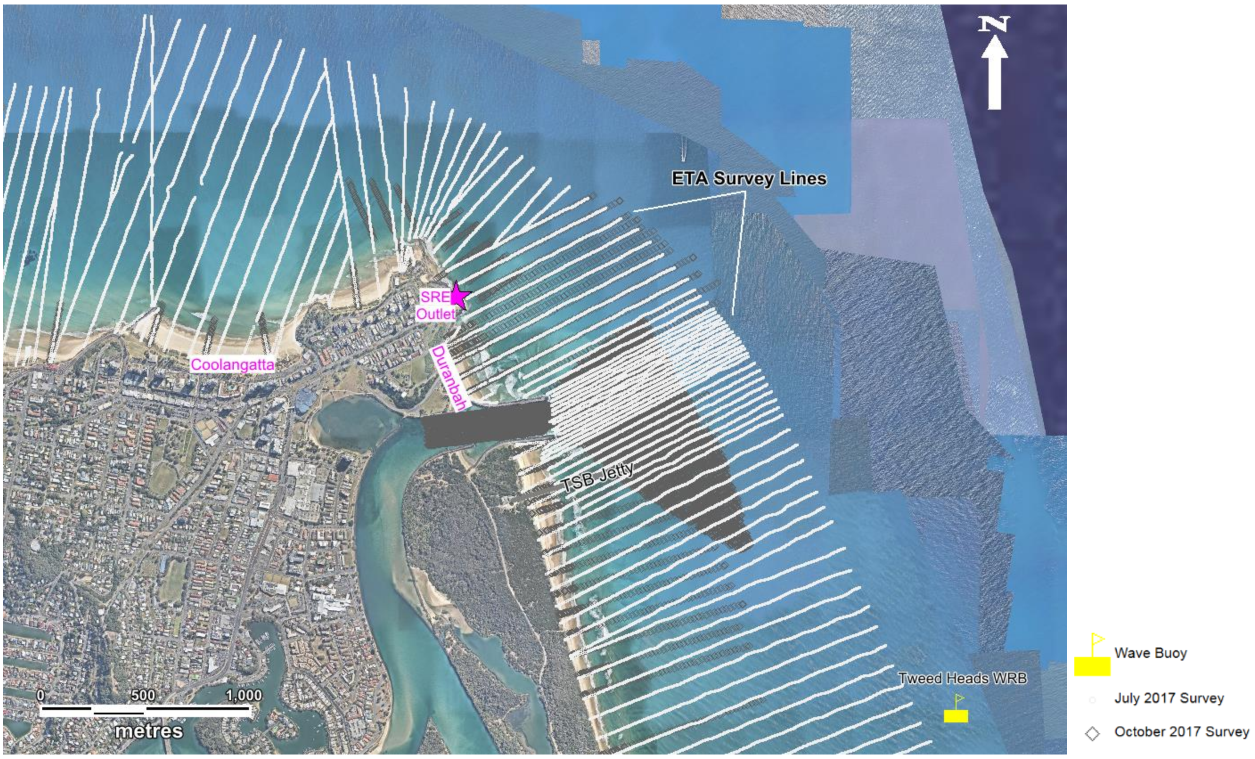


Figure 14: Map showing Tweed Heads WRB location and survey profiles (ETA lines) captured during study period.

5.3 Dredging Activities

To maintain navigation access dredging of the Tweed River Entrance was undertaken between 29 July 2017 and 15 August 2017. This coincided with the SRE sand tracing study which commenced on 30 July 2017. A total of 50,550m^3 was dredged from the Tweed River Entrance bar and placed immediately offshore off Duranbah Beach and Point Danger (see Figure 15 and Table 9). A previous dredging campaign comprising a total volume of 166,054m^3 was completed between 19 February and 11 July 2017 prior to the tracer deployment.

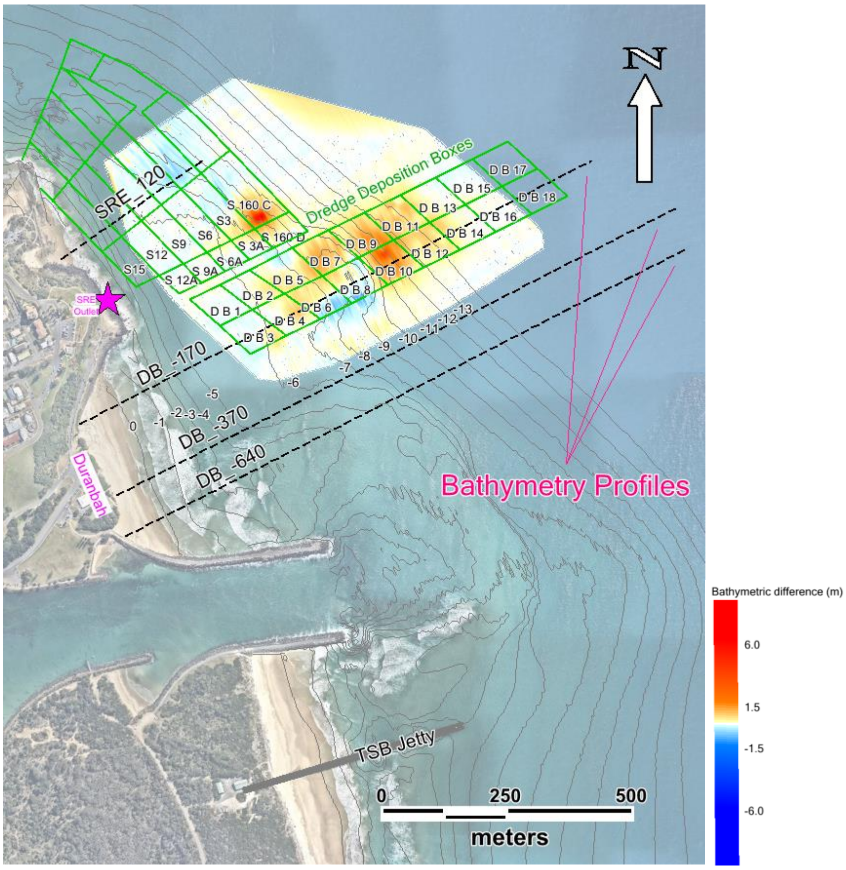


Figure 15: Bathymetric difference between pre and post dredging surveys within placement areas of the July/August 2017 campaign.

Table 9: Summary of daily dredge volumes and dump locations during the July/August 2017 dredging campaign.

Date	Total Dredge Volume (m^3)	Dump Locations
30/07/2017	3,911	DB7, DB6, DB5, DB2
31/07/2017	4,000	DB7, DB5, S3A
1/08/2017	3,988	S6A, DB5, DB6, DB7
3/08/2017	1,258	DB9
4/08/2017	1,472	S160C
5/08/2017	3,886	S160D, DB9, S160C, DB10, DB11
6/08/2017	2,900	S160C
7/08/2017	2,809	DB9, DB10
8/08/2017	4,505	DB10
9/08/2017	3,471	DB10, DB11, DB9
10/08/2017	3,102	DB11, DB09
11/08/2017	1,492	DB9, DB10
12/08/2017	4,347	DB12, DB10, DB11, DB12
13/08/2017	4,011	DB12, DB4
14/08/2017	3,944	DB4, DB2, DB3, DB12
15/08/2017	1,455	DB9, DB12

5.4 Metocean Conditions during the Study Period

The long term wave conditions at the study site were determined based on the 23-year wave record from the Tweed Waverider Buoy (TWRB). Table 10 presents the long term average (LTA) wave statistics as well as wave statistics for the SRE sand tracing study period. A time series plot showing the wave conditions and concurrent currents at the TWRB location (22m depth) during the study period is provided in Figure 16. The data shows that:

- The wave conditions during the study period are characterised by slightly less energetic conditions compared to the LTAs with the average significant wave height being 1.10m.
- The weighted average peak wave directions during the study period had a greater southerly component than the LTA averages being from east-south-east (ESE).
- Three wave events with significant wave heights greater than 2m occurred on 20 August 2017 (prior to week 4 sampling), 3 October 2017 (prior to week 10) and 15 October 2017 (prior to week 13).
- The first two-thirds of the study period (until 24 September 2017) can be characterised by typical winter wave conditions with average peak wave periods (T_p) of 10s and weighted peak average wave directions mostly between east and south-east (SE).
- The last third of the study period (after 24 September 2017) can be characterised by much more fluctuating wave conditions more typical of spring. The wave periods during this period were generally much lower (average T_p of 8s) with weighted peak wave directions varying between north-north-east (NNE) and south-east (SE).
- A dominant southward current persisted throughout the study period with occasional northward currents during periods of higher waves (greater than 1 to 1.5m significant wave height) coming from a SE direction.
- Maximum current speeds during the study period were up to 0.8 to 1m/s (potentially erroneous data) in a southward direction and up to 0.6m/s in a northward direction.

As part of the Dredge Material Sand Tracing Study, or red tracer study, an Acoustic Doppler Current Profiler (ADCP) was deployed to measure currents and waves in approximately 8m of water depth at a location nearby the dredge placement boxes that are offshore of Duranbah Beach (RHDHV, 2017). Harmonic analysis of the measured current speeds for the period from 24 June 2016 to 4 August 2016 has been completed as part of this study. The relative contribution of tidal-driven currents to the total measured current speeds was determined to be 45%. The analysis showed that the flood current flow in a south-easterly direction with speeds up to 0.4m/s. Ebb currents were generally very low (i.e. less than 0.1m/s) with variable directions (see Figure 17). As noted in RHDHV (2017), the tidal current speed asymmetry is attributed to the incoming radial tidal flows entering the TRE during flood tide, while the ebb tide jet does not influence this location. Other influences on the currents at this location appear to be wind and the East Australian Current (EAC). The influence of the EAC is documented in Helyer et al. (2011) with flow measurements indicating that the nearshore off Point Danger, at depths greater than 6m, there is a general south-easterly flow with flow speeds of 0.3-0.4m/s.

Table 10: Summary of wave statistics derived from the 23-year Tweed WRB record.

Parameter	**Statistic**	**Long-term (23 year record)**	**SRE Study Period (Jul to Oct 2017)**	**SRE Study Period (prior to 24 Sep)**	**SRE Study Period (after 24 Sep)**
H_s (m)	Average	1.24	1.10	1.03	1.24
	20%ile	0.84	0.74	0.71	0.78
	90%ile	1.85	1.67	1.52	2.31
	Max	7.52	2.98	2.48	2.98
T_p (s)	Average	9.4	9.5	10.2	8.2
	% of Time Sea (Tp<8s)	28%	31%	21%	50%
	% of Time Swell (Tp>8s)	72%	69%	79%	50%
Peak Wave Direction (PWD) (˚)	Weighted Average	86	98	111	84
	StDev	35	34	33	31

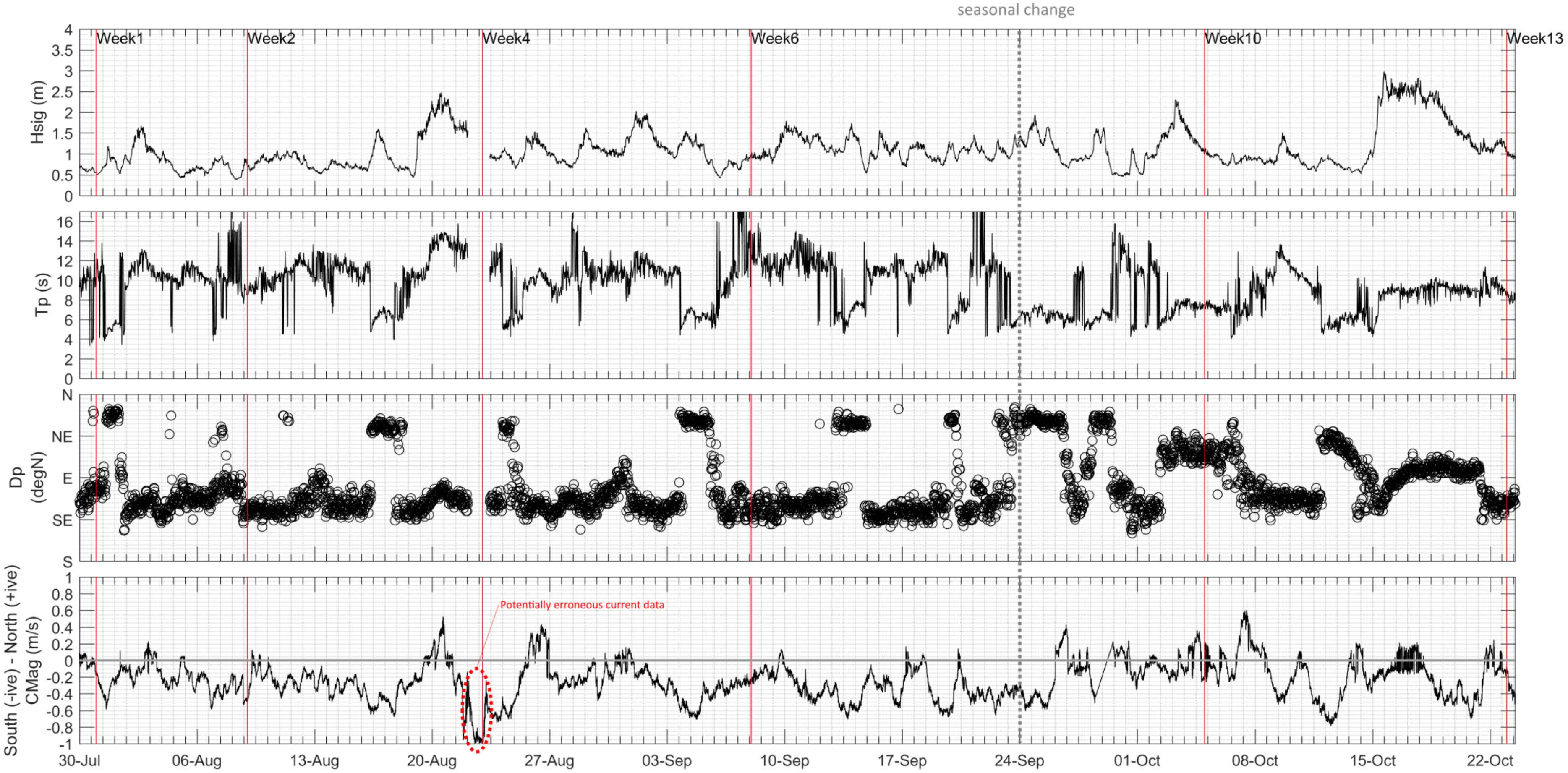


Figure 16: Time series of wave conditions (top three panels) and currents (bottom panel) derived from the Tweed Heads Waverider Buoy (Datawell MK4 at 22m depth) during the study period.

Note: The sand sampling dates are also shown (red lines).

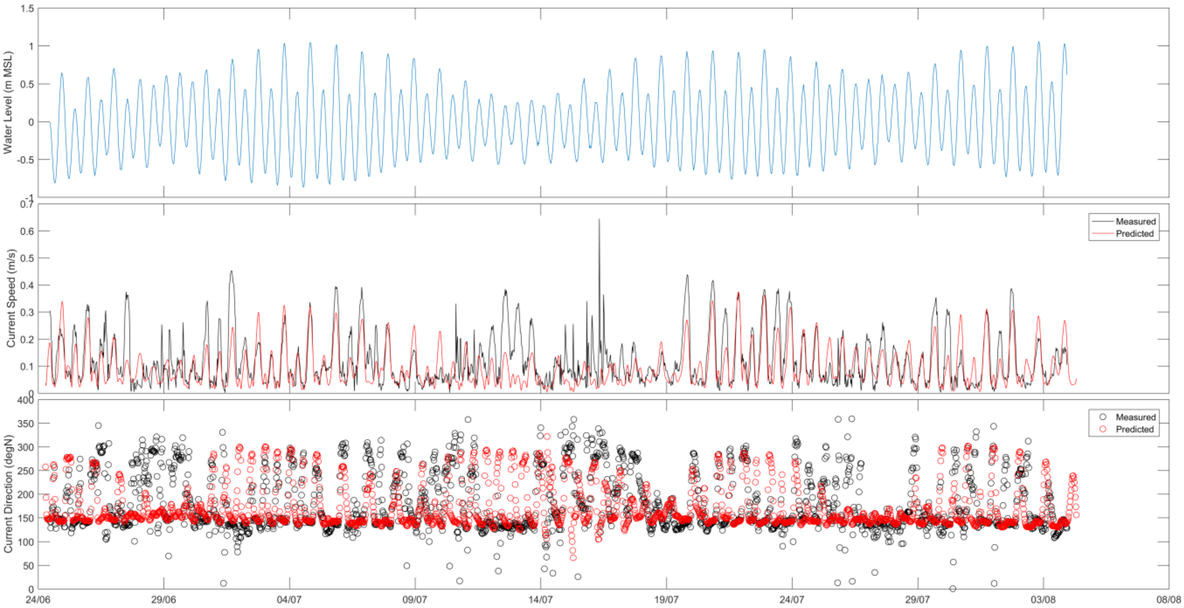


Figure 17: Measured total current speed (black) and predicted tidal current speed (red) based on harmonic analysis of the second ADCP deployment (~6m depth) during the red tracer study between 24 June 2016 to 4 August 2016.

5.5 Morphological Change Assessment

Based on the available repeat bathymetric and beach surveys, an analysis of the observed morphological change during the study period was undertaken.

5.5.1 Bathymetric Difference Maps

The survey data captured around the commencement date of the SRE sand tracing study (survey completed 31 July 2017) was compared with the survey data captured towards the end of the study period (5 October 2017). The bathymetric differences between these two surveys (for overlapping areas only) are presented in Figure 18. The October 2017 survey was undertaken 18 days before the final sampling exercise of this sand tracing study. As presented in Section 5.4, a large wave event with significant wave heights over 2m occurred during this final 18 day period which may have caused some additional bathymetric changes before the final sampling exercise. It can be seen in Figure 18 that:

- Significant accretion is evident within the dredge deposition boxes that were used during the dredging campaign in July and August 2017.
- Significant accretion occurred in the mid-profile depths (-3m to -5m AHD) off Duranbah Beach.
- Erosion is evident within in the nearshore areas between the SRE outlet and Snapper Rocks.
- The Tweed River Entrance bar predominantly shows erosion over the period. The lowering of the seabed in this area is likely to be a result of the July and August 2017 entrance dredging as well as continued reworking of the 150,000m^3 of sand deposited during the March 2017 flood event (Jacobs, 2017).

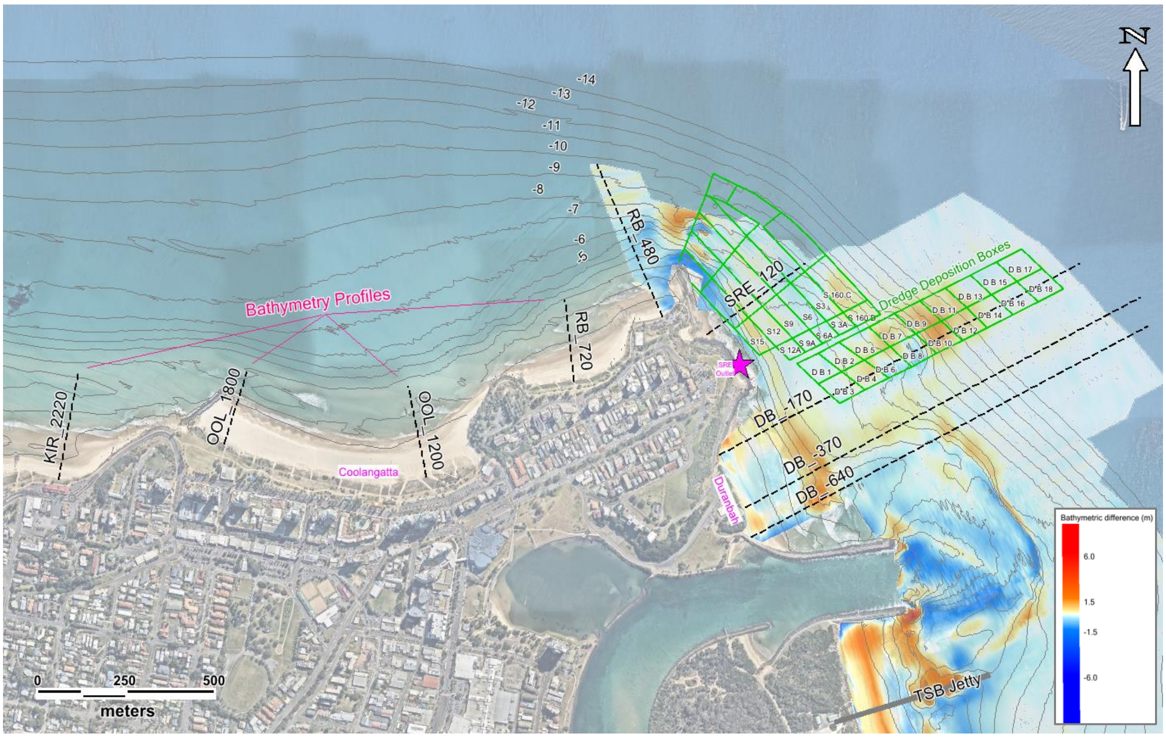
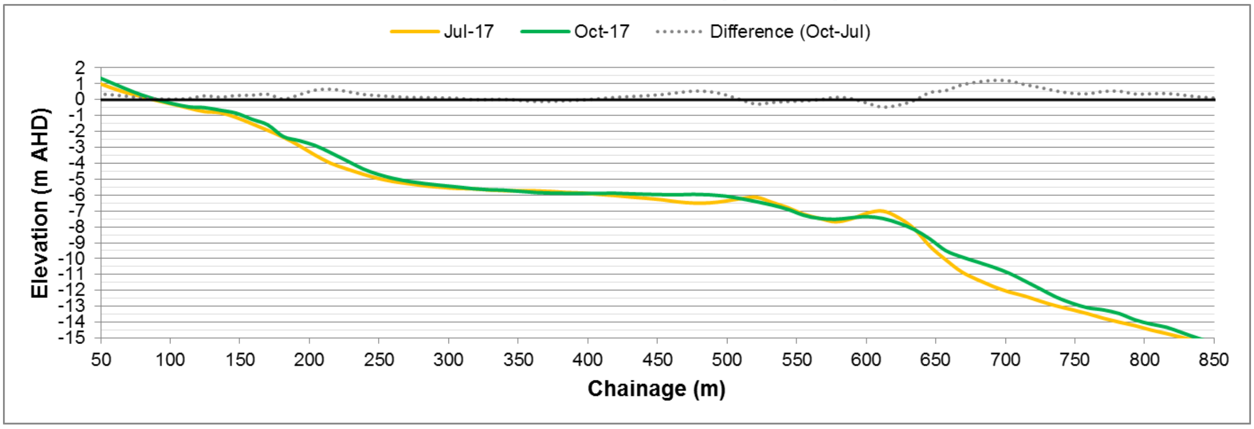


Figure 18: Bathymetric difference for areas with overlapping survey data between the end of July 2017 and 5 October 2017. Note: The profile locations used for comparison of individual beach profiles in the following sections are also shown.

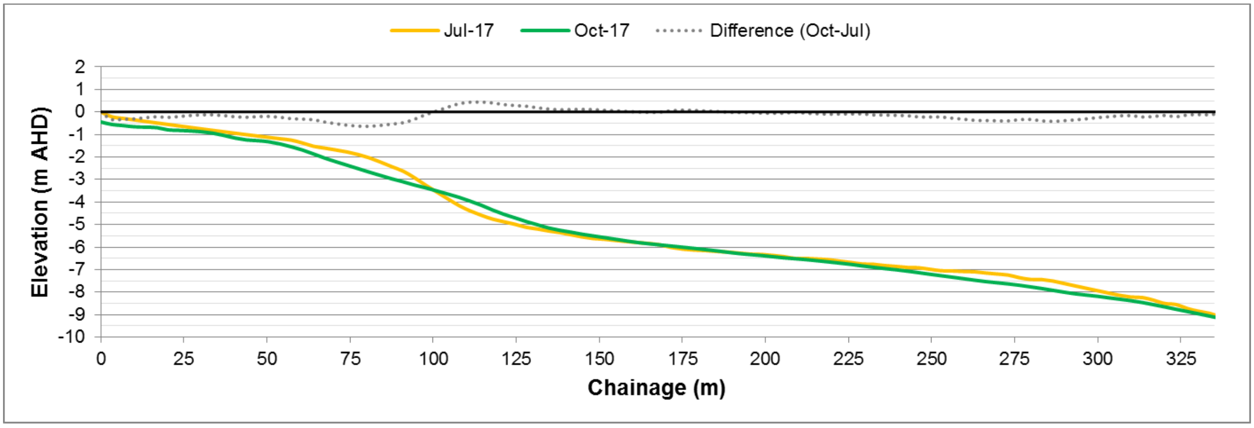
5.5.2 Changes to Beach Profiles

The morphological change during the study period was further assessed by comparing selected survey profiles from the July and October 2017 surveys. This includes the areas north of Snapper Rocks where only a few profiles were available in the October 2017 survey. The profile locations used for this analysis are shown in Figure 18. A selection of the beach profiles for both survey dates are provided in Figure 19 and Figure 20. A full set of bathymetric profiles is provided in Appendix D.

Duranbah Beach North (DB_-170)



Froggies Beach (SRE_120)



Rainbow Bay (RB_720)

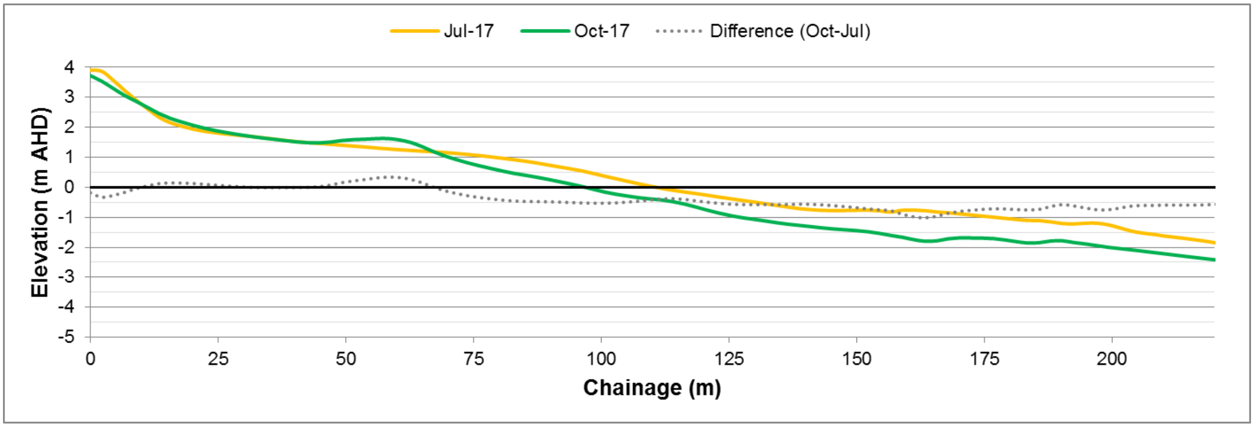
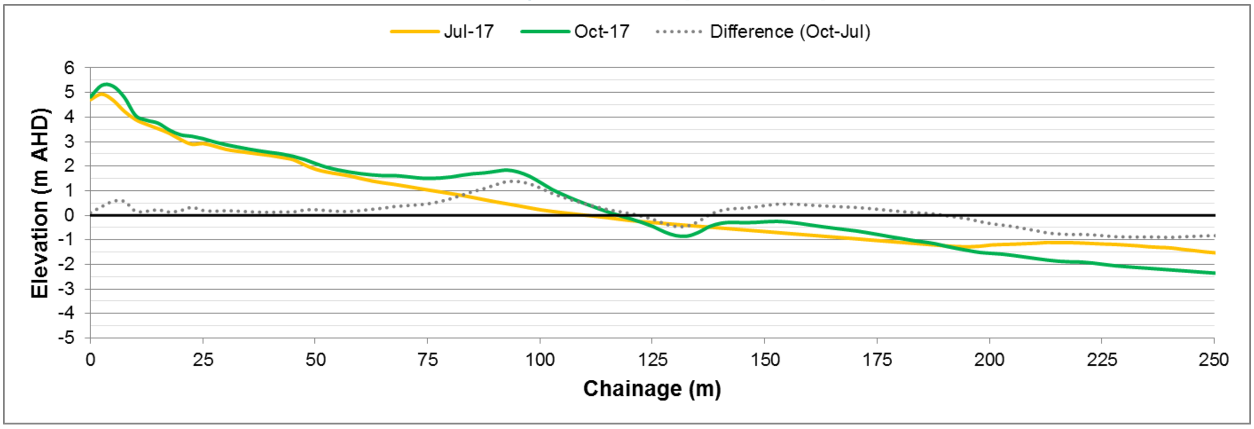


Figure 19: Beach profiles between Duranbah Beach and Rainbow Bay for July and October 2017 surveys.

Coolangatta Beach (OOL_1200)



Kirra Beach (KIR_2220)

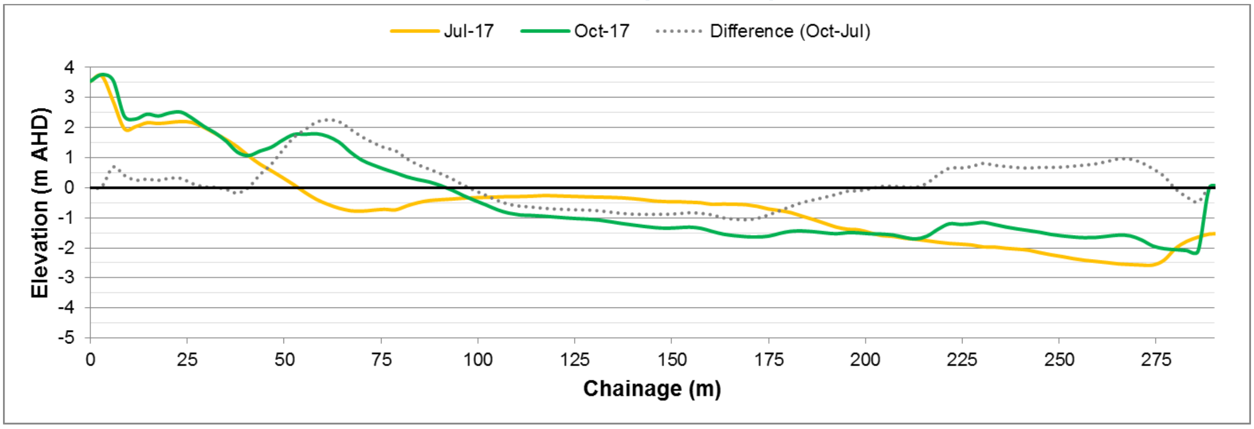


Figure 20: Beach profiles for Coolangatta Beach and Kirra Beach for July and October 2017 surveys.

5.5.3 Beach Photographs

Photographs of each beach compartment were taken during the collection of sand samples. The photographs are provided in Appendix E. These show the changes in beach conditions over the study period.

5.6 Sand Pumping Activity

Sand pumping volumes are recorded by the SCADA system incorporated in the TSB system. Daily data of the sand pumping volumes and discharge locations were provided by TSB (see Figure 21). A summary of the sand pumping volume between each of the sampling events is provided in Table 11.

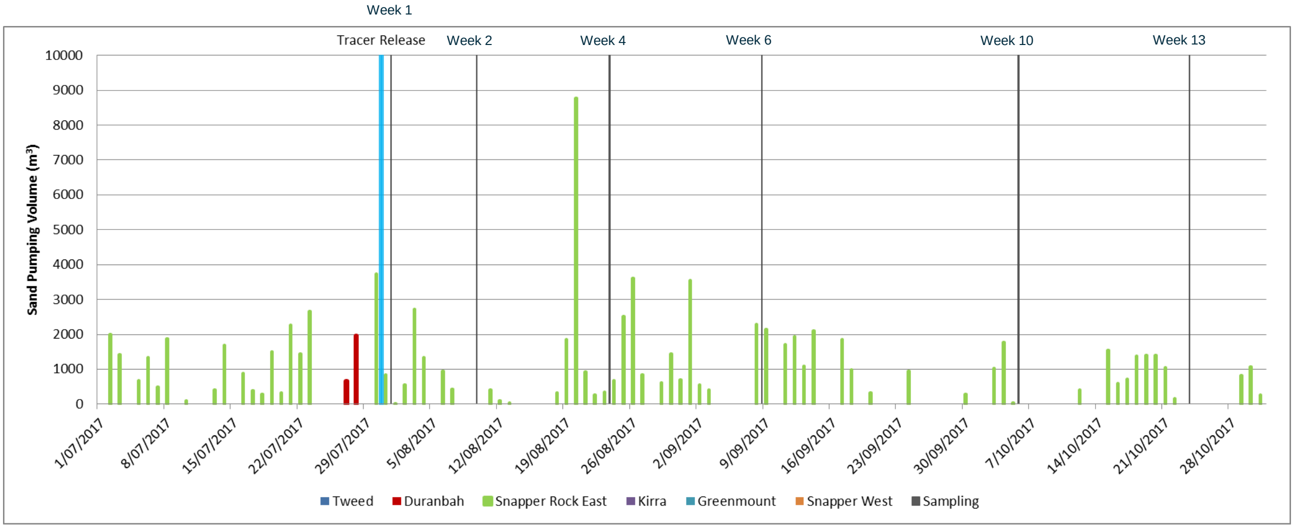


Figure 21: Daily sand pumping volumes and discharge locations recorded by TSB's SCADA system during the study period.

Table 11: Summary of sand pumping volumes during study period.

Time period	Sand pumping volume (m^3)	Cumulative sand pumping volume since study begin (m^3)
Week 1	4,590	4,590
Week 1 to week 2	10,593	15,183
Week 2 to week 4	23,631	38,814
Week 4 to week 6	40,829	79,643
Week 6 to week 10	57,052	136,695
Week 10 to week 13	65,728	202,423

5.7 Summary of Dredge Material Tracing Study

A previous sand tracing study focussing on improving the understanding of dispersal of dredge material following placement in the inner nearshore area of Duranbah Beach was completed by RHDHV in 2017. This sand tracing study was undertaken over the 9 month period between May 2016 and January 2017.

A total of 270kg of red tracer material was released at the Duranbah placement area in ~6m water depth via the dredge hopper of the Port Frederick TSHD. This method ensured that the tracer material fully experienced the key sediment dispersion processes that occur both during and following placement of dredge material in the TSB study area extending from the Letitia Spit jetty to Kirra (see Figure 22).

The red tracer results show that Duranbah place site is dispersive with sand dispersed in both cross shore and alongshore directions (see Figure 23). While alongshore dispersal was net northward, an opposing southward current significantly reduced the rate of northward supply. This southward directed current was observed in concurrent ADCP measurements in approximately 6m depth (AHD) near the tracer release location. Cross-shore transport by waves was found capable of transporting sediment in significant volumes over short periods depending on wave conditions. However, there was an onshore bias in sand transport particularly in low energy wave conditions.

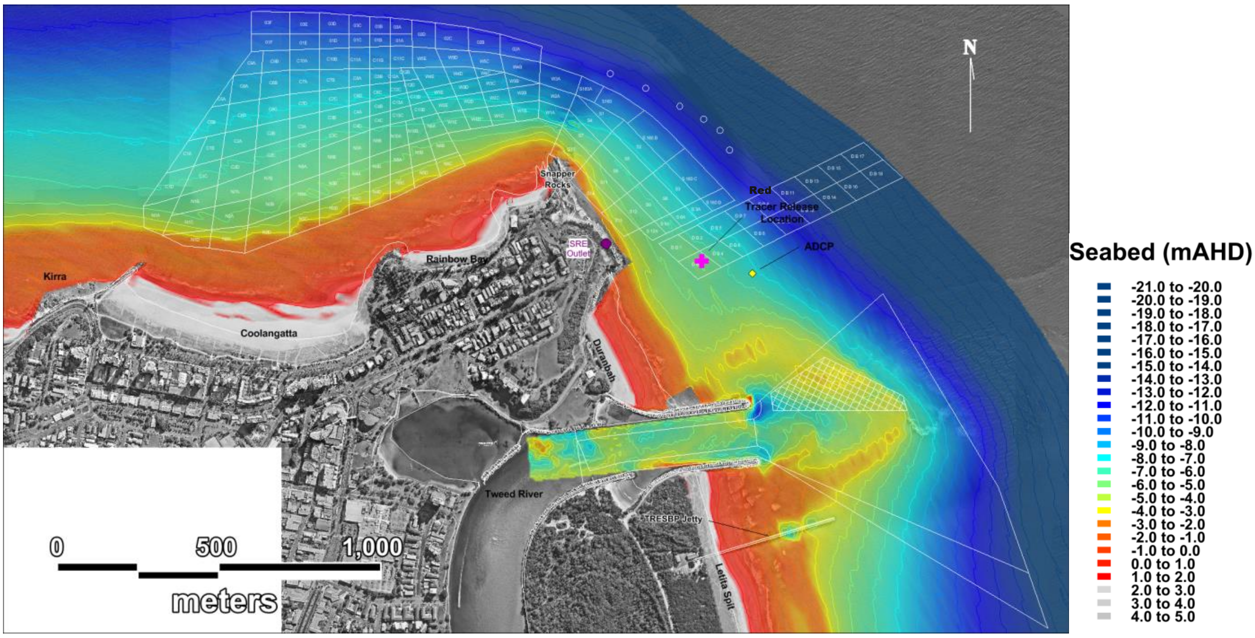


Figure 22: Morphology within the Dredge Material Tracing Study area (source of bathymetry: May 2016 Coastal Survey).

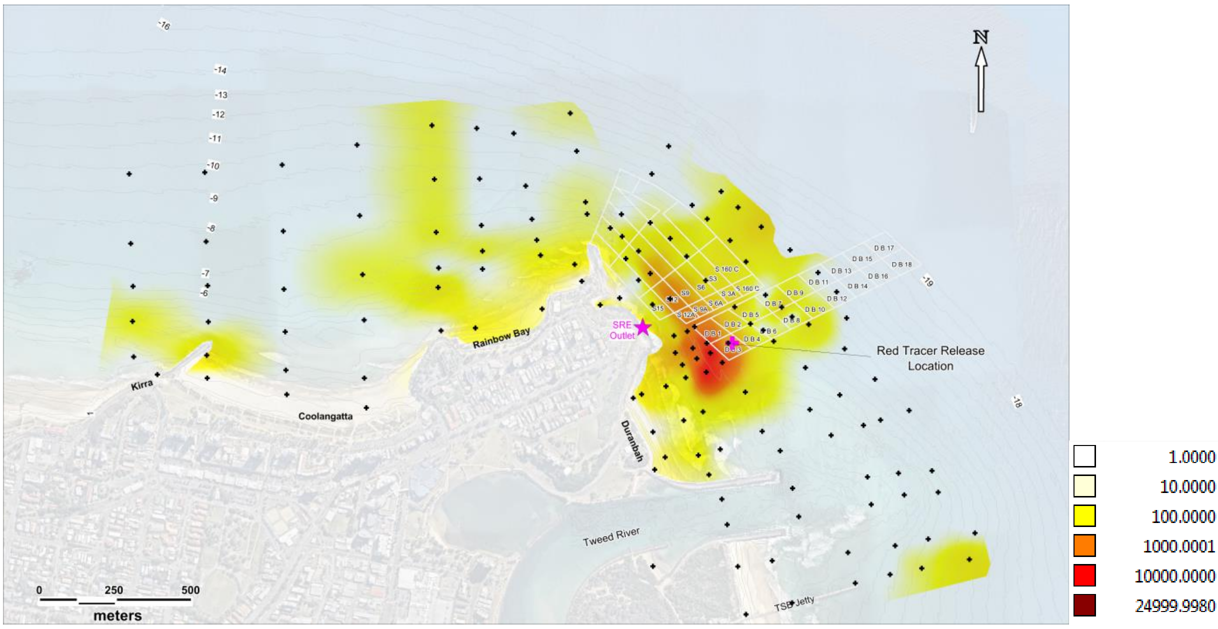


Figure 23: Interpolation of red tracer concentrations derived from the Round 3 samples taken on $27^{th}/28^{th}$ January 2017.

Note: colour scale used is based on a log type scale, with each darker colour having a concentration ten times the preceding colour. The black dots show all sampling locations.

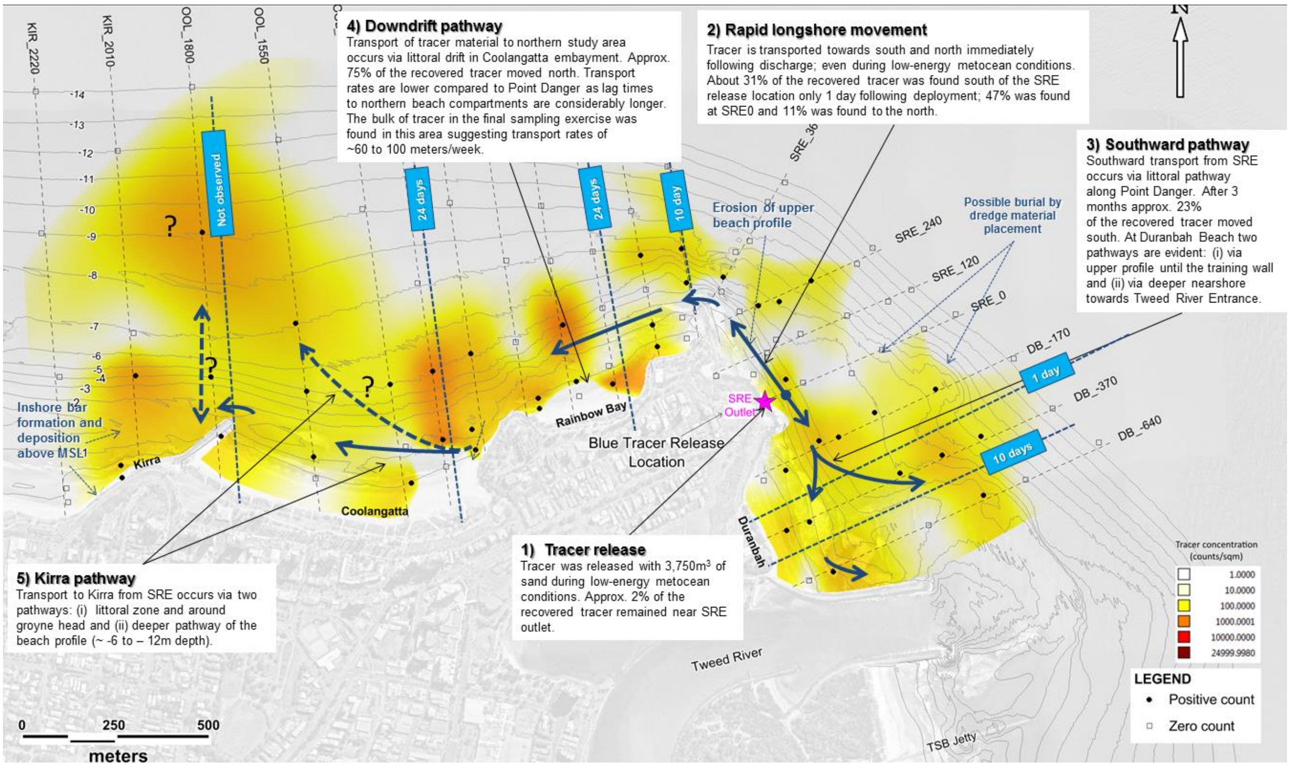
6 Discussion

The primary objective of this study was to improve the understanding of how sand moves following discharge from the Snapper Rocks East outlet. This section presents a discussion of the key observations gathered from the sand tracing results as well as the review and analysis of supplementary information.

6.1 Conceptual Sand Transport Model (Blue Tracer)

A conceptual model of sand transport processes has been developed based on the synthesis of the blue tracer results and the supplementary information. The conceptual sediment transport model presents the key mechanisms and pathways for sand movement following release from the Snapper Rocks East outlet. The boundary of the model is based on the extents of the spatial sampling exercise and includes the beach compartments of: Duranbah; Froggies; Rainbow Bay; Coolangatta and Kirra. The model extends to the -14m AHD depth contour, which corresponds to the deepest sampling locations. Limited sand movement would be expected beyond this depth. The sediment transport processes presented herein are based on the observed blue tracer results and are also based on the environmental conditions that were encountered during the period of tracer sampling.

The blue tracer conceptual sand transport model is presented in Figure 24 and described below where appropriate. A high-resolution print is provided in Appendix F.



1) Tracer release
Tracer was released with 3,750m³ of sand during low-energy metocean conditions. Approx. 2% of the recovered tracer remained near SRE outlet.

2) Rapid longshore movement
Tracer is transported towards south and north immediately following discharge; even during low-energy metocean conditions. About 31% of the recovered tracer was found south of the SRE release location only 1 day following deployment; 47% was found at SRE0 and 11% was found to the north.

3) Southward pathway
Southward transport from SRE occurs via littoral pathway along Point Danger. After 3 months approx. 23% of the recovered tracer moved south. At Duranbah Beach two pathways are evident: (i) via upper profile until the training wall and (ii) via deeper nearshore towards Tweed River Entrance.

4) Downdrift pathway
Transport of tracer material to northern study area occurs via littoral drift in Coolangatta embayment. Approx. 75% of the recovered tracer moved north. Transport rates are lower compared to Point Danger as lag times to northern beach compartments are considerably longer. The bulk of tracer in the final sampling exercise was found in this area suggesting transport rates of ~60 to 100 meters/week.

5) Kirra pathway
Transport to Kirra from SRE occurs via two pathways: (i) littoral zone and around groyne head and (ii) deeper pathway of the beach profile (~ -6 to – 12m depth).

Figure 24: Main sand transport mechanisms and pathways following release from Snapper Rocks East outlet.

1. Sand is discharged from the SRE release location as a slurry (above mean sea level). Pumping events typically vary from 1,000m^3 to 5,000m^3 with more sand pumped in winter months when southerly waves and higher rates of northward sand transport are more common. The blue tracer material was released during a routine delivery of approximately 3,750m^3 of sand pumped from

Letitia Spit via the TSB sand pumping system during relatively mild south-easterly wave conditions (significant wave height of just over 0.5m) on the 30 July 2017.

2. The tracer results have confirmed that the nearshore area around Snapper Rock East is highly dispersive with the movement of sand away from the outlet driven by littoral processes. Even during the mild metocean conditions observed in the first 1-2 days post-release, tracer was observed to move rapidly in both downdrift and updrift directions. During this initial sampling, tracer was observed within the embayment past Snapper Rocks, a distance downdrift of around 480m. Tracer was also observed at the northern end of Duranbah Beach, some 170m updrift of the outlet (sampling limit). Based on week 1 samples, 11 per cent was located downdrift, 31 per cent updrift and the remaining 57 per cent was at the Snapper Rock East outlet (SRE0).

   Tracer concentrations had greatly reduced 10 days post-release and had reduced to zero by week 6, indicating that all of the material that was pumped on the 30 July 2017 had dispersed.

   Indicative of the littoral drift process, sand transport was in close proximity to the shoreline with the majority of tracer observed in the upper profile above the -6m AHD depth contour. The exposed nature of Point Danger and the rocky shoreline means that even during mild conditions wave breaking is sufficient to suspend, entrain and rapidly transport sand (see Figure 25).

   These results are in-line with historical observations of TSB's operations. For example, discharge rates of more than 100,000m^3 per month were not uncommon in the initial years, but rarely resulted in a lasting deposition of sand around the SRE area.

3. There were two southward pathways inferred from the blue tracer results:

   (i) A shallow littoral pathway via the upper beach profile of Duranbah Beach. The mechanism for the southward movement of sand along this pathway are speculative but may be related to the highly refracted wave field in the lee of the TRE bar, general cross-shore transport (including rips and wave-driven currents) spreading sand across the beach and the effects of the semi-permanent rip that exits Duranbah Beach by flowing along the northern training wall.

   (ii) A deeper pathway offshore of the -6m AHD depth contour and outside the littoral zone where sand transport is driven by the observed flood dominant currents (see Section 5.4). These currents transport sand in a south-east direction towards the Tweed River Entrance bar.

   A significant portion of the tracer was observed along these updrift pathways. For example, at the end of the study period 23 per cent of the tracer was observed updrift of the SRE outlet. Moreover, the tracer reached the Duranbah transects relatively quickly within the first round of sampling 1 day post-release.

4. The downdrift (northward) pathway to Coolangatta was predominantly driven by littoral zone alongshore transport. This finding was supported by observations indicating sand moved in the shallow upper profile (generally above -4m AHD depth contour). When viewed over the 3 month study duration approximately 75 per cent of the observed tracer followed this littoral drift pathway. Other observations from the blue tracer results include:

   - Tracer found directly north of Snapper Rocks in water depths of up to -9m relative to AHD provides some evidence of wave-driven transport 'overshooting' the littoral zone as sand moves around the 90° bend in the shoreline. Within the Coolangatta embayment, however, tracer was not observed beyond the -6m AHD contour (i.e. see zero counts along the deeper depth contours through Rainbow Bay and Coolangatta in Figure 13). This suggests that no significant cross-embayment transport occurred during the blue tracer study period. The fact that there were no large storm events (significant wave height of > 3m) encountered during the study period and that it is these larger waves that would drive the movement of sand along the cross-embayment pathway may explain this observation.

- There was consistent deposition of tracer observed at the eastern end of Coolangatta Beach (i.e. transect OOL1200). This was also where the largest tracer concentrations were found at the end of the study period. This is an area where littoral currents (or ‘sweep’) begin to slacken after rounding the headland at Greenmount. Considering the bulk of the tracer material was found in this area at the end of the 13-week study period, a transport rate of around 60 to 100m per week was estimated. While this transport rate is indicative for the sand movement during the study period it is not necessarily representative of the long-term average bulk transport rates for this region and overall morphological change.

5. The blue tracer results were used to infer two sand transport pathways to Kirra:
   (i) The dominant littoral drift pathway driven by breaking waves and wave-driven currents across Coolangatta Beach and around Kirra Groyne.
   (ii) A deeper pathway was identified which transported tracer in a north-west direction before being deposited in depths beyond the -6m AHD contour. The mechanism for this transport pathway is not defined. This may be driven by an offshore divergence of the strong littoral drift current that is generated through Rainbow Bay, or as a result of cross-shore transport following the northerly swell event that occurred just prior to week 13 sampling or as a result of some unidentified mechanism.

While the conceptual processes model developed herein is useful to assist the TSB project team in regard to sand pumping operations and in the development of the STIS, it is not intended to be an overall quantified conceptual coastal processes model for the TSB project area.

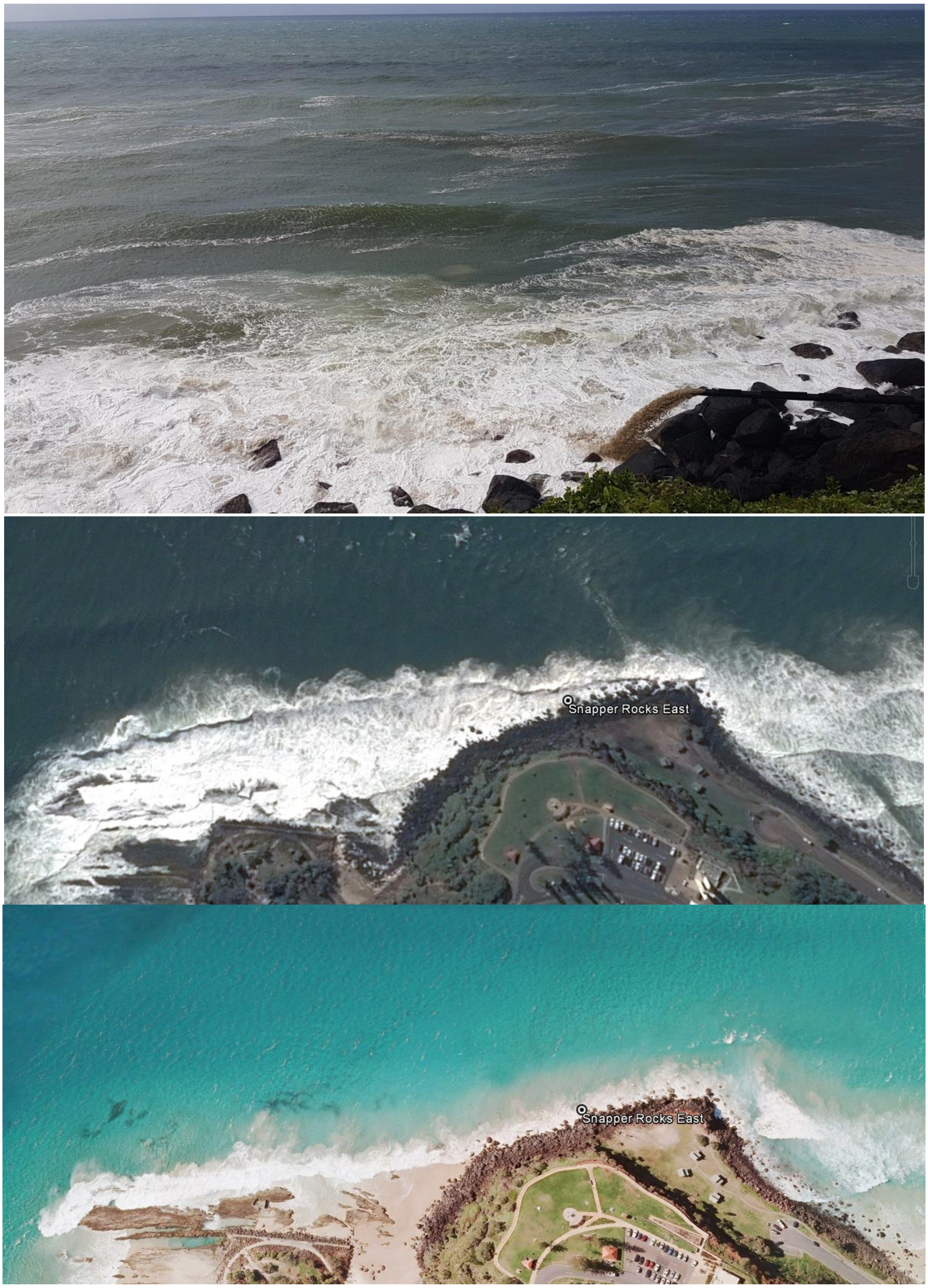


Figure 25: Snapper Rocks East outlet during high-energy wave conditions on 14 June 2017 (top) and 6 June 2016 (middle) and low-energy wave conditions on 26 June 2008 (bottom).

6.2 Comparison to Dredge Material Sand Tracing Study

A comparison between the key findings of this study and those from the Dredge Material Sand Tracing Study has been undertaken to present the combined outcomes in a holistic manner. The two sand tracing studies are complimentary as each focused on one of the two mechanisms used by TSB to transfer sand, i.e. sand pumping and dredging:

- The SRE tracer study focused on the fate of sand delivered by pumping and involved the release of a blue sand tracer via the Snapper Rock East outlet which is above mean sea level. The most comparable results are those from the spatial sampling completed in week 13 (3 months) post-release.
- The Dredge Material Tracing Study focused on the fate of sand placed by a floating dredge and involved the release of a red sand tracer via the dredges hopper at a location offshore of Duranbah Beach in approximately 6m water depth. Four rounds of spatial sampling results are available for comparison. These were collected 1 month, 1.7 months, 9 months and 20 months post-release. A summary of the red tracer study is provided in Section 5.7.

6.2.1 Alongshore Tracer Distribution

The alongshore distribution of tracer concentrations from the two tracer datasets are shown in Figure 26. The most notable difference is the rate of the observed alongshore dispersion. The bulk of the blue tracer moved approximately 1,200m downdrift of the SRE outlet over 3 months, while the bulk of the red tracer remained within 500m of its release location even 9 months post release. Other significant points include:

- As expected, both datasets showed net downdrift (northward) transport (57 per cent of the red tracer within 9 months post-release and 75 per cent of the blue tracer within 3 months post-release). The more rapid and stronger northward transport of the blue tracer was due to its release location in the littoral zone.
- However, both datasets showed a significant proportion of updrift (southward) transport (43 per cent of the red tracer 9 months post-release and 23 per cent of the blue tracer 3 months post-release). A comparatively greater proportion of the red tracer was moved in a southward direction because of the red tracers release location that is outside the zone of littoral drift and in an area where a south-easterly current is observed on the flood tide.
- The most recent red tracers results, taken some 20 months post-release more closely resembles the blue tracer alongshore distribution. However it should be noted that on-going placement of significant quantities of sand at the red tracer release site could potentially be masking any tracer that remains buried at this location.

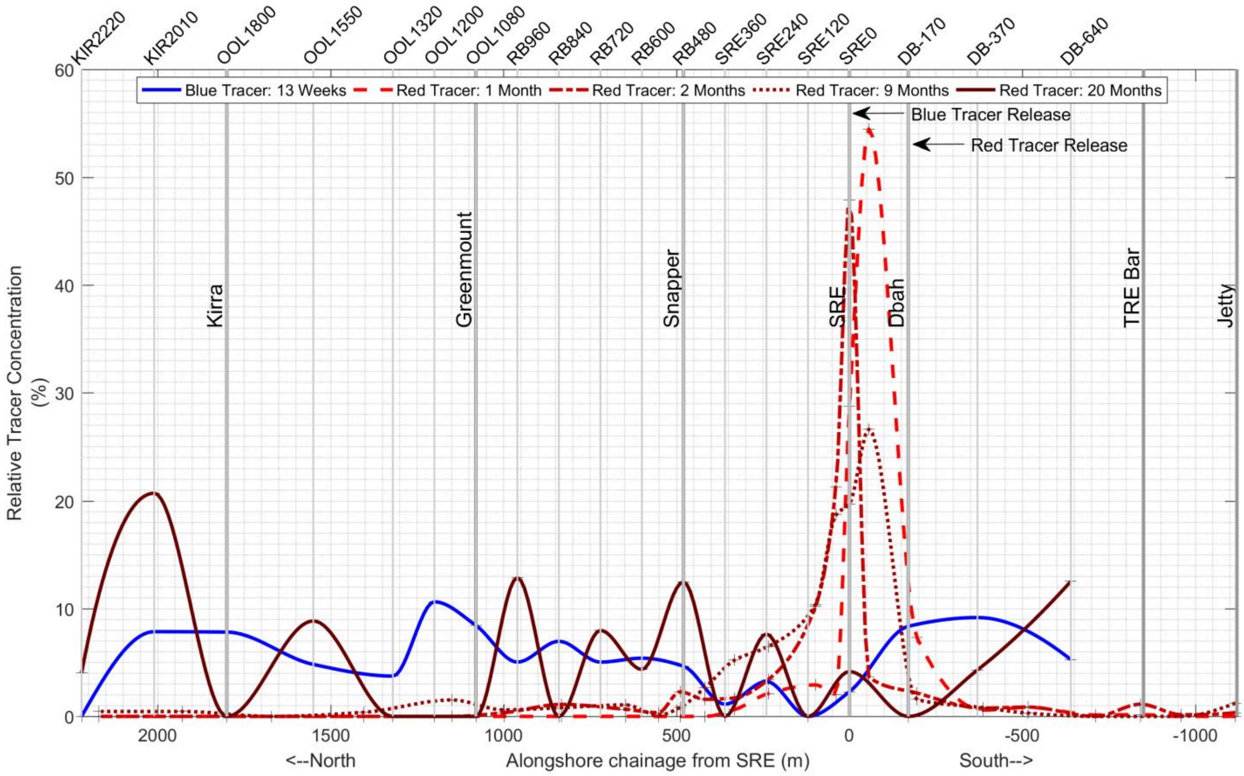


Figure 26: Comparison of alongshore distribution of relative blue and red tracer concentrations.

6.2.2 Cross-shore Tracer Distribution

The cross-shore distribution of red tracer 9 months post-tracer release is shown in Figure 27. As noted in RHDHV (2017), placement of sand, both via pumping and dredging, could have potentially masked (i.e. by burial) some of the red tracer. Red tracer on the upper profile of the Point Danger transects was potentially masked by sand placement via SRE outlet while in the Duranbah transect placement by dredging potentially masked tracer on the lower profile.

Figure 27 was developed using the same approach as for the blue tracers and can be compared to Figure 11 in Section 4.5. In comparison, the red tracer cross-shore distributions generally show much more tracer in the mid to lower parts of the beach profile. Given the different release depths, this would be expected close to the respective tracer release locations as it is clearly observed at Duranbah. However, further away from the release locations and within the Coolangatta embayment, the red tracer is more spread across the profile (Rainbow Bay) or located in the mid-profile depths (Coolangatta), whereas the bulk of the blue tracer was observed on the upper profile in these areas. With an exception at Kirra, where the blue tracer was also found near the -9m AHD depth contour while in the red tracer study observations suggested the red tracer was located closer to shore.

The deeper release depth along with the occurrence of a large wave event (June 2016) during the red tracer study provide the likely explanations for the higher proportion of red tracer observed on the mid- to lower profile within the Coolangatta embayment. These conditions seemed to promote some transport in a cross-embayment pathway. When sand is delivered to the upper profile, as is the case with the SRE outlet, sand transport is limited to the littoral drift pathway and higher volumes are moved.

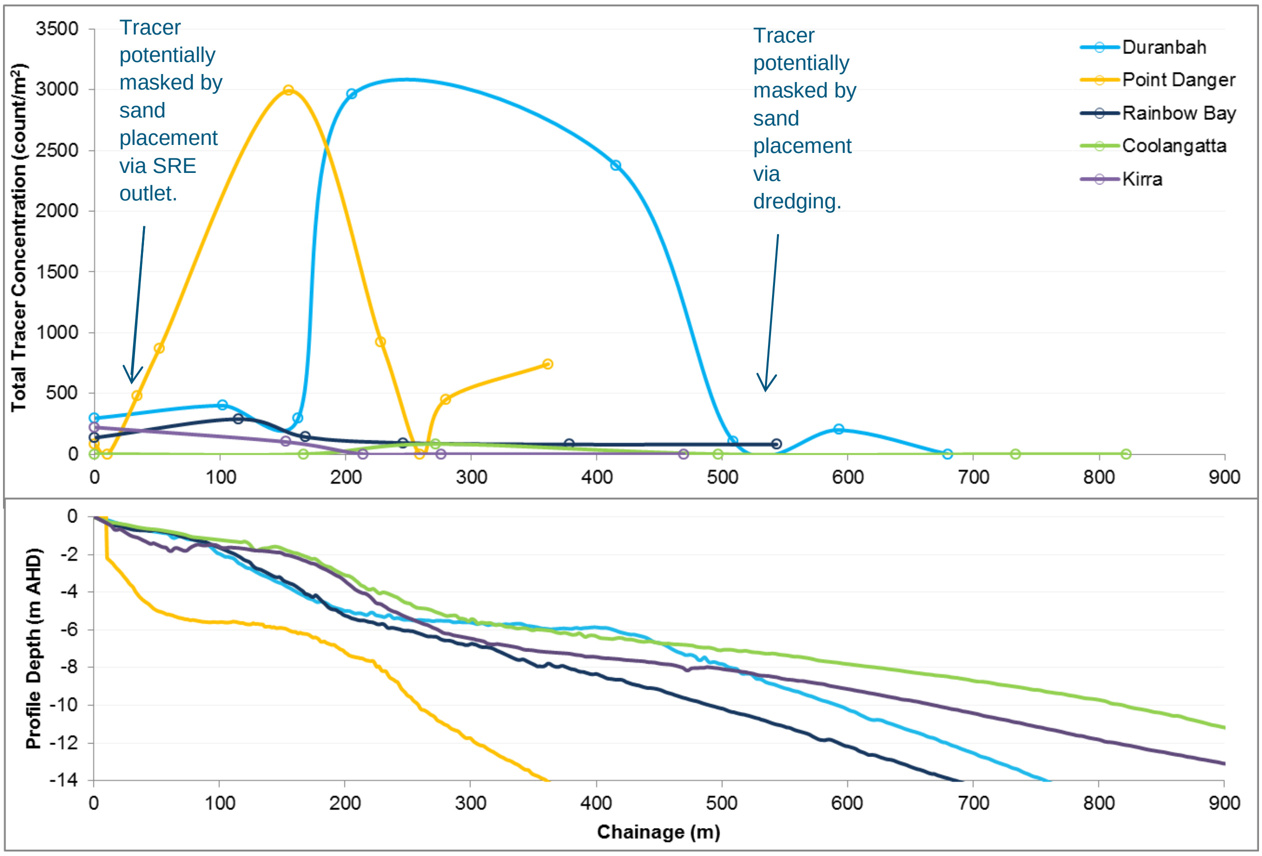


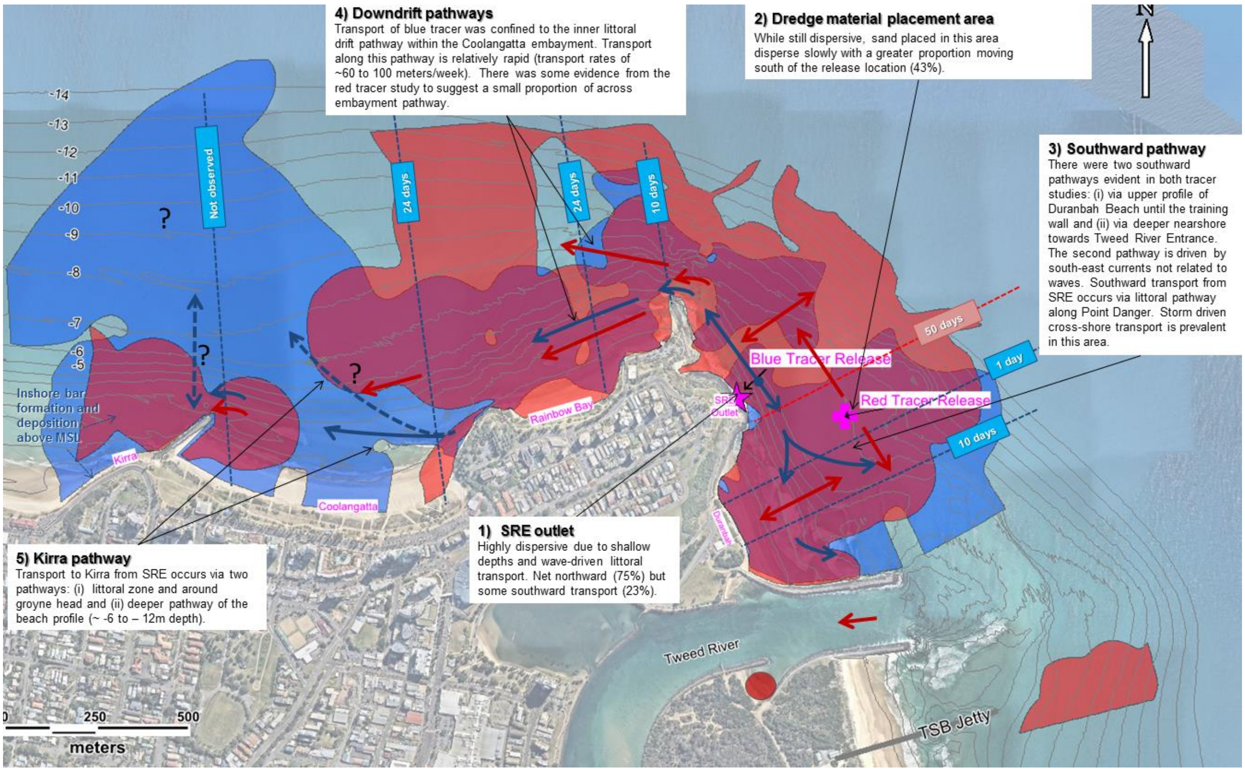
Figure 27: Cross-shore tracer distribution of the red tracer concentrations for each beach compartment.

6.2.3 Conceptual Sand Transport Model (Red and Blue Tracers)

Using the results from both the red and blue tracer studies a holistic conceptual model of sand transport processes has been developed. This builds on the conceptual sand transport model developed from the blue tracer results. The holistic conceptual sand transport model is presented in Figure 28 and described below where appropriate. A high-resolution print is provided in Appendix G.

- As a result of littoral drift transport, the SRE outlet is much more dispersive than the deeper Duranbah dredge placement area. The blue tracer was largely dispersed from the shallow release site after 6 weeks, while the red tracer was still present at the release site 9 months post-release.
- Red tracer was found at the 6m depth contour south of its release point. This southward pathway was consistently observed in both tracer studies, indicating that a proportion of the sand that is placed via both, dredging and pumping, may be reworked by the south-easterly flowing currents towards the Tweed River Entrance. As discussed above, a greater proportion of southward transport was inferred from the red tracer results suggesting a greater influence of the tidally influenced south-easterly flowing current observed at this deeper location. There remains uncertainty around the driving mechanism for this current and whether it is driven by localised tidal flows through the TRE or by a tidally modulated form of the EAC. This uncertainty may have implications on the fate of dredge placements and warrants further investigation.
- The deeper red tracer release location, in consideration of the metocean conditions experienced, suggest that a proportion of the red tracer potentially followed a cross-embayment pathway through the Coolangatta embayment. This was particularly observed in Round 2 and Round 3 tracer results from the Dredge Material Tracing Study (refer RHDHV, 2017). Round 2 results

showed (i) tracer updrift of Snapper Rocks distributed across the full profile and (ii) relatively modest concentrations on the lower profile just downdrift of the Snapper Rocks (i.e. offshore of 'Little Marley'). In Round 3 results, the red tracer was observed on the lower profile off Greenmount, suggesting tracer observed in deeper areas in Round 2 had been transported here. This transport was potentially driven by wave asymmetry (Stokes drift) at this location during the 7 month period as transport rates were slow when compared to the transport rates observed in the littoral drift pathway during the blue tracer study. While uncertainty remains, these observations support the notion that there is a greater chance of cross-embayment transport when sand is placed beyond the littoral drift zone (e.g. 6m depth AHD) and when storm waves occur.


4) Downdrift pathways
Transport of blue tracer was confined to the inner littoral drift pathway within the Coolangatta embayment. Transport along this pathway is relatively rapid (transport rates of ~60 to 100 meters/week). There was some evidence from the red tracer study to suggest a small proportion of across embayment pathway.

2) Dredge material placement area
While still dispersive, sand placed in this area disperse slowly with a greater proportion moving south of the release location (43%).

3) Southward pathway
There were two southward pathways evident in both tracer studies: (i) via upper profile of Duranbah Beach until the training wall and (ii) via deeper nearshore towards Tweed River Entrance. The second pathway is driven by south-east currents not related to waves. Southward transport from SRE occurs via littoral pathway along Point Danger. Storm driven cross-shore transport is prevalent in this area.

5) Kirra pathway
Transport to Kirra from SRE occurs via two pathways: (i) littoral zone and around groyne head and (ii) deeper pathway of the beach profile (~ -6 to – 12m depth).

1) SRE outlet
Highly dispersive due to shallow depths and wave-driven littoral transport. Net northward (75%) but some southward transport (23%).

Figure 28: Main sand transport mechanisms and pathways inferred from both red and blue tracer results.

Note: Blue tracer extents are based on spatial sampling undertaken 13 weeks (3 months) post-release, while the red tracer extents are based on spatial sampling undertaken 9 months post-release.

6.3 Limitations

There are a number of factors that need to be considered in the interpretation of the sand tracing results, including:

- Placement of dredged material in the dump boxes directly offshore of Duranbah during the study period may have had effect on the results.
- The regular and high volumes of sand pumped to SRE can dilute or bury tracer and potentially reduce the observed tracer presence in this area.
- Burial and dilution of the released tracer below detention limits may limit the time over which a tracer study can be continued.

- This study has adopted surface sampling of the seabed. Other methods such as collecting shallow cores were considered in the study design; however, previous studies have shown only minor benefit while undergoing significant extra sampling and analysis effort.

Despite the above limitations, sufficient tracer was recovered in all of the sampling rounds to draw findings suitable to fit the objectives of the study. Moreover, the interpretation of the results has considered the particular limitations that apply to this study area.

7 Conclusion

A sand tracing study focused on improving the understanding of sediment transport dispersal of sand being pumped through the Snapper Rocks East (SRE) as part of the Tweed Sand Bypassing (TSB) has been completed. The sand tracing study was undertaken over the 13 week period between 30 July 2017 and 23 October 2017.

The tracer results show that the SRE outlet is dispersive, with rapid alongshore sand transport. The net transport is northward, however in alignment to previous studies, an opposing southward transport was evident. The lag time of discharged material arriving at Kirra (northern end of study area) was found to be 40 days while the bulk of the material discharged through SRE on 30 June 2017 was located at Coolangatta, approximately 1200m from SRE, at the end of the 13-week study period.

The results of this study showed that the main sand transport pathways from SRE were confined to the littoral drift zone dominated by wave processes throughout the study area. In comparison, the results of a previous sand tracing study in this area showed that other sand transport pathways exist along the deeper areas of the beach profiles with a stronger influence of tidal currents and the East Australian Current.

A number of supplementary lines of evidence have been analysed to gain a better understanding of the observed sediment transport processes and/or to provide additional confidence in study outcomes.

The findings of this sand tracing study aided the development of a conceptual sand transport processes model to assist the TSB project team in regard to sand pumping operations and in the development of the STIS.

8 References

BMT WBM (2016). *Tweed River entrance sand bypassing reassessment of Long Term Average annual net sand transport rate.* 2015, R.B21627.001.03. Report prepared for Department of Primary Industries – Lands.

ETS and EHI (2007). *Final Report for Sediment Tracer Study at the SWS ODMDS, Mouth of the Columbia River.* Prepared on behalf of Moffatt and Nichol Engineers, Long Beach, CA, for US Army Corps of Engineers - Portland District.

ETS and EHI (2010). *Interim Report for Sediment Tracer Study for Proposed South Jetty Site, Mouth of the Columbia River*. Prepared on behalf of Moffatt and Nichol Engineers, Long Beach, CA, for US Army Corps of Engineers - Portland District.

Helyer, Z, C. Acworth, K. Nielsen (2011), *Acoustic Doppler Current Profiling from Kirra Beach to Cook Island – Field exercises by the Tweed River Entrance Sand Bypassing Project*, NSW Coastal Conference, 2011

Jacobs (2017). *Tweed Quantified Conceptual Sediment Transport Model*. Tweed River Entrance Sand Bypassing Project. Report prepared for Department of Primary Industries – Lands.

Royal HaskoningDHV [RHDHV] (2017). *Dredge Material Sand Tracing Study, Tweed River Entrance Sand Bypassing Project.* Revision 2 (Final). Prepared for Department of Primary Industries – Lands. M&APA1088R001F0.2.

Appendix A – Tracer Material Information

A1.1 Sample Analysis Method

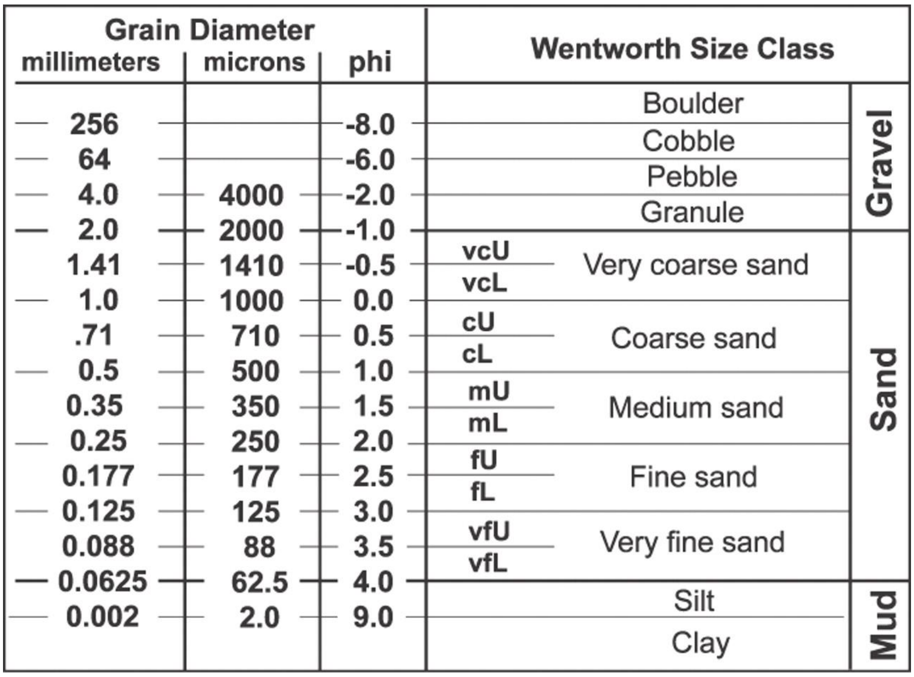
All the collected samples were shipped to the ETS ISO 9001 certified laboratory in the UK. All samples were analysed for fluorescent particle counts, which were then converted into particle counts per square metre of the grab area.

The following analysis protocol was used for each sample:

1. All samples that arrived in bags or sample containers were individually checked for integrity and wiped down to remove any possible source of contamination.
2. The samples were then placed in order (according to the log sheet provided by the field team and given a unique ETS number) following the ETS Standard Operating Procedure (SOP) 'QA003 Receipt of Samples' document.
3. The total wet mass of sediment sample received was recorded.
4. The total contents of each sample container were mixed until homogeneous and two sub-samples were then removed for analysis; namely approximately 20 g for wet to dry weight ratio calculations and approximately 500 g wet mass for tracer count analysis. The remainder of the sample was re-sealed and stored for any subsequent re-sampling if required.
5. Wet to Dry weight ratios
    i. A 30 mL weighing boat was labelled with a unique ETS reference number and weighed. The weight was recorded on a spreadsheet.
    ii. The 20 g sub-sample was transferred into the weighing boat and weighed. The mass was recorded on a spreadsheet. The sample was then dried to a constant mass in a drying oven.
    iii. Once dry, the sample was weighed immediately after being removed from the oven. The mass was recorded on a spreadsheet.
6. Tracer count analysis
    i. A foil tray was labeled and weighed. The mass was recorded on a spreadsheet.
    ii. The 500 g sub-sample was decanted into the foil tray.
    iii. The sample was then dried to a constant weight in a drying oven, normally overnight.
    iv. Once dry, the sample was weighed immediately after being removed from the oven. The weight was recorded on a spreadsheet.
    v. A smaller foil container was tared on the balance and 300 g of the dry sample was decanted into this and the sample weighed. The mass was recorded on a spreadsheet.
    vi. The 300 g sample was examined as a monolayer for all fluorescent particles on non-fluorescing material using a magnifying ultra-violet (UV) stereo inspection microscope. All fluorescent particle counts and size data were recorded on a spreadsheet.
7. All original paperwork, forms and printouts were kept in the relevant folder in the Laboratory in order to allow referral should the need arise. All data was then transferred and updated onto the ETS digital file server, with routine data backups every 24 hours.

Particle sizing of tracer particles detected in each sample was carried out manually, concurrently with counting the different colours of sand tracer particles. Initially, ETS sized a range of sand particles using a fluorescence microscope and a calibrated graticule to cover the size bands reported, including:

- ‘extra small’: <125 µm, i.e. equivalent to very fine sand (Wentworth grain size classification, see below);
- ‘small’: 125-250 µm, i.e. equivalent to fine sand (Wentworth grain size classification, see below);
- ‘medium’: 250-375 µm, i.e. finer fraction of medium sand (Wentworth grain size classification, see below);
- ‘large’: 375-500 µm, i.e. coarser fraction of medium sand (Wentworth grain size classification, see below); and,
- ‘extra large’: >500 µm, i.e. coarse sand (Wentworth grain size classification, see below).



Grain Diameter			Wentworth Size Class		
millimeters	microns	phi			
				Boulder	Gravel
256		-8.0			
				Cobble	
64		-6.0			
				Pebble	
4.0	4000	-2.0			
				Granule	
2.0	2000	-1.0			
			vcU	Very coarse sand	Sand
1.41	1410	-0.5			
			vcL		
1.0	1000	0.0			
			cU	Coarse sand	
.71	710	0.5			
			cL		
0.5	500	1.0			
			mU	Medium sand	
0.35	350	1.5			
			mL		
0.25	250	2.0			
			fU	Fine sand	
0.177	177	2.5			
			fL		
0.125	125	3.0			
			vfU	Very fine sand	
0.088	88	3.5			
			vfL		
0.0625	62.5	4.0			
				Silt	Mud
0.002	2.0	9.0			
				Clay	

Wentworth grain size classification

A1.2 Material Safety Data Sheet

See overleaf.

A1.3 Ecotoxicology and Human Health

See overleaf.

MATERIAL SAFETY DATA SHEET

Product name: **EcoTrace Fluorescent Tracer** **Page 1 of 3**
Printing date: **16/12/2014**

1. Product/Manufacturer's Details:

SERIES NAME:	EcoTrace Fluorescent Tracer
APPLICATION:	Particle tracing
MANUFACTURER'S NAME:	c/o ETS Worldwide Ltd., The Coach House, Bannachra, Helensburgh, Argyll, G84 9EF
TELEPHONE:	01389 711001
CONTACT:	Dr. Jonathan Marsh

2. Composition/Information on Ingredients

COMPOSITION:	Solid solution of fluorescent dyes in thermoplastic polymer base
HAZARDOUS INGREDIENTS:	Does not contain any substances presenting a health hazard within the meaning of the Dangerous Substance Directive 67/548/EEC as amended by the Seventh Amendment 92/32/EEC

3. First Aid Measures

GENERAL:	In all cases of doubt or when symptoms persist, seek medical attention. Never give anything by mouth to an unconscious person.
INHALATION:	Remove to fresh air, keep patient warm and at rest; if breathing is irregular or stopped, administer artificial respiration. Give nothing by mouth. If unconscious, place in recovery position and seek medical advice.
EYE CONTACT:	Irrigate copiously with clean fresh water for at least 10 minutes holding the eyelids apart and seek medical advice
SKIN CONTACT:	Wash skin thoroughly with soap and water or use recognised skin cleaner. Do NOT use solvents or thinners
INGESTION:	If accidentally swallowed give two glasses of water to drink. Do NOT induce vomiting. If symptoms persist seek medical advice

4. Fire Fighting Measures

EXTINGUISHING MEDIA:	Foam, CO_2 powders, water fog
PRECAUTIONS:	Exposure to decomposition products may cause a health hazard (Section 9)

5. Accidental Release Measures

PERSONAL PRECAUTIONS:	Refer to protective measures listed in Section 7. Avoid dust formation. Take precautionary measures against static discharges
METHODS FOR CLEANING UP:	Contain spillage with suitable dust binding materials such as sand/sawdust and dispose in accordance with Section 12. Clean affected areas with water/biodegradable surfactant solution – avoid use of solvents Refer to protective measures listed in Section 7. Avoid dust formation. Take precautionary measures against static discharges
METHODS FOR CLEANING UP:	Contain spillage with suitable dust binding materials such as sand/sawdust and dispose in accordance with Section 12. Clean affected areas with water

6. Handling and Storage

HANDLING: Avoid dust formation. Take precautionary measures against static discharges

STORAGE: Store in a dry well ventilated place away from sources of heat and direct sunlight. Keep away from sources of ignition. Keep away from strong oxidising agents and alkaline and acidic materials. Containers, which are open, should be closed and kept upright to prevent leakage and control contamination. Keep in original packaging.

7. Exposure Controls/Personal Protection

ENGINEERING MEASURES: Provide local exhaust ventilation if required. See exposure limits

EXPOSURE LIMITS:	SHORT TERM EXPOSURE LIMITS	LONG TERM EXPOSURE LIMITS
Total inhalable dust:	10 mg/m^3	10 mg/m^3
Respirable dust:	5 mg/m^3	5 mg/m^3

RESPIRATORY PROTECTION: Provide local extraction if required. See exposure limits. If exposure limits are likely to be exceeded then ensure that masks are used – EN 143 type P2 is recommended

HAND PROTECTION: Wear gloves

EYE PROTECTION: Wear goggles

GENERAL SAFETY & HYGIENE MEASURES: The usual precautions for the handling of chemicals must be observed

8. Physical and Chemical Properties

FORM: Coloured fine powder
SOFTENING POINT: Not applicable – Thermoset product
DECOMPOSITION POINT: Above 190°C
SOLUBILITY IN WATER: None
pH VALUE: 6–7.5 (5% in water @ 25°C)
SPECIFIC GRAVITY c. 1.0 up to 2.65 @ 20°C
FLASH POINT: Not applicable
ODOUR: Slight smell
VISCOSITY: Not applicable
BOILING POINT: Not applicable
VAPOUR DENSITY: Not applicable
VAPOUR PRESSURE: Not applicable
EXPLOSION HAZARD: Dust explosion hazard
MIN EXPLOSIBLE CONC: 67–75 g/M^3
MIN IGNITION ENERGY: 7–10 mJ

9. Stability and Reactivity

CONDITIONS CONTRIBUTING TO INSTABILITY: Product is stable under recommended storage and handling conditions. If exposed to elevated temperatures gas can be liberated – in these cases suitable control procedures should be implemented.

MATERIALS TO AVOID: Keep product away from strong oxidising agents, strongly alkaline and strongly acidic materials

HAZARDOUS DECOMPOSITION PRODUCTS: Fumes may contain oxides of sulphur, carbon and nitrogen.

10. Toxicological Information

ACUTE ORAL TOXICITY LD50:	More than 16 g/kg
ACUTE DERMAL TOXICITY LD50:	More than 23 g/kg
ACUTE DUST INHALATION LC50:	More than 4.4 mg/L (4 hours)*
EYE IRRITATION:	No significant irritation
HEAVY METAL CONTENT:	Typical Analysis Expressed in mg/kg Antimony <1, Arsenic <1, Barium <1, Cadmium <1, Chromium <1, Lead <1, Mercury <1, Selenium <2
FREE PRIMARY AROMATIC AMINE:	Less than 0.1% w/w typical analysis
NOTES:	The values for acute oral toxicity acute dermal toxicity and acute dust inhalation refer to tests conducted on representative samples. These tests resulted in NO DEATHS OF THE TEST ANIMALS.

11. Ecological Information

Tests have been carried out by CEFAS Weymouth and ETS Ltd. exposing Pacific Oysters to high concentrations of EcoTrace tracer particles. The results indicated <5% uptake of available tracer particles peaking at 2 hours after exposure followed by discharge in the faecal strands. EcoTrace particles were depurated when the oysters were placed in clean water over a 5 day period with trace levels remaining in the Oysters after depuration. Further details are available from ETS Ltd. The tracer has also been fed to *Daphnia* over a prolonged period by Alcontrol Laboratories who found no mortalities.

12. Disposal considerations

Waste and emptied containers should be disposed of in accordance with current regulations

13. Transport information

Considered as Non-Hazardous under Transport Regulations

14. Regulatory Information

LABELLING ACCORDING TO EU DIRECTIVES:	Not subject to labelling
NATIONAL LEGISLATION/ REGULATIONS:	This product is classified as NON-HAZARDOUS under the UK ‘Chemicals (Hazard Information and Packaging/Regulations’ CHIP Regulations

15. Other Information

The information in this MSDS is based on the present state of our knowledge and on current EU and National Laws. It is the responsibility of the user to ensure that their employees are aware of the content of this MSDS and also to ensure that any additional local rules and regulations are satisfied. The information contained herein is provided in accordance with the current legal requirement and should not be considered as a guarantee of the product’s properties or performance. The information in this Safety Data Sheet is pursuant to:

a) The Chemicals (Hazard Information and Packaging) Regulation 1994
b) Article 27 of the Dangerous Substances Directive – 67/548/EEC as amended by the Seventh Amendment – 92/32/EEC (Official Journal No. L154. 5 June 1992 P1)
c) Article 10 of the Dangerous Preparation Directive – 88/379/EEC (Official Journal No. L187. 16 July 1988 P14)
d) The Safety Data Sheets Directive – 91/155/EEC as amended by Directive 93/112/EEC (Official Journal No. L314. 16 December 1993, P38)

Uptake & Elimination Tests of EcoTrace Fluorescent Tracer particles By Pacific Oysters

ETS carried out tests in conjunction with CEFAS (a UK Government laboratory) in order to establish baseline information on the effect of releasing EcoTrace fluorescent tracer particles in close proximity to shellfish areas including oyster beds. The tests involved exposing oysters to a very concentrated level of EcoTrace particles and measuring the rate of uptake and concentration held within the oyster over time. Further tests were then carried out to assess whether the oysters retained or eliminated the tracer when added to clean water (depuration). CEFAS undertook the uptake and elimination trials at the Weymouth laboratories using tracer supplied by ETS.

The tests clearly indicate that tracer is taken up by the oysters. Maximum concentrations of tracer in the oysters occurred at Time 2 hours after exposure. The concentration of tracer measured in the oysters at Time 2 hours, expressed as a percentage of the total tracer in the circulation tank at Time 0 hours, ranged between 14-58%. Furthermore, the tests indicated that after the peak uptake at Time 2 hours, the oysters begin to export the tracer particles in faecal waste, with concentrations decreasing to between 1-3% in the oysters after 24 and 48 hours. During this time the oysters remained in the circulation tank continually exposed to tracer. Further testing indicated that the tracer particles were depurated when the oysters were placed in clean water, with concentrations after five days of 0.1-0.2% of the total tracer present in the exposure circulation tank. The full report is available on request.

Effect of Non-Metallic Products on the Quality of Portable Water

In 2000 samples of ETS' tracer were tested in accordance with the methods specified in;

1. BS6920: 1996 Suitability of non-metallic products for use in contact with water intended for human consumption with regard to their effect on the quality of the water.
2. Methods of Test and the Water Regulations Advisory Scheme Information Note and Guidance Note No- 9-01-02 Issue 1, June 1995, Requirements for the testing of non-metallic products for use in contact with portable water.
3. Water Regulation Advisory Scheme Instruction No Admin 7, January 1998 update amendments.

It is concluded that ETS' tracer particles satisfied the criteria set out in BS6920: Part 1: 1996 'Specification' and thus does comply with the requirements of the Water Regulations Advisory Scheme Tests of Effect on Water Quality for use with cold water. The report is available upon request.

Appendix B – Tracer Results

A summary of the key results for each sampling exercise is provided below.

Round 1 (Temporal) – Week 1
Positive counts[3] for the blue tracer were recorded in seven (7) of the 20 samples collected and analysed for the Week 1 sampling undertaken on 31 July 2017 and 1 August 2017 (i.e. 1-2 days following tracer release). A further 13 samples were collected during Sampling Round 1 which have been set aside for possible future analysis.

The majority of the positive samples were collected within around 200m of the SRE outlet , i.e. south of Snapper Rocks and in the inner nearshore region. All positive samples recorded relatively high tracer concentration with the highest tracer concentration recorded on the shoreline adjacent to the outlet. A positive tracer count was recorded in just one (1) of the 10 samples located downdrift of Snapper Rocks. This sample was collected on the shoreline immediately inshore of Snapper Rocks, at around 500m downdrift of the SRE outlet. Apart from the positive tracer counts collected on Duranbah Beach, the high positive counts clustered around the SRE were enclosed within samples which returned zero counts. Blue tracer was recorded at water depths of up to 6m directly offshore of the SRE outlet, however, zero tracer counts were recorded at the other three (3) nearby offshore sampling locations (at RL -6 and RL -8). These observations indicate that:

- Sampling completed during Week 1 covered the bulk of the blue tracer capturing the northern and offshore extents of the tracers' dispersion.
- The initial dispersion was predominately in the alongshore direction and relatively rapid with blue tracer transported by up to 200m in the updrift direction and up 500m in the downdrift direction within 2 days of being released. The moving up to with beyond Snapper Rocks was very limited during the first few days following tracer release.
- While some cross-shore transport of the blue tracer material occurred during and/or immediately following release this was limited to the area immediately offshore of the release site.

Positive and relatively high tracer counts were recorded in samples collected in the inner nearshore zone at the northern end of Duranbah Beach, including deposition on the sub-aerial portion of the profile. Such significant updrift transport of the blue tracer in the days immediately following release was not expected.

Round 2 (Temporal) – Week 2
Positive counts[3] for the blue tracer were recorded in 20 of the 22 samples collected and analysed for the Week 2 sampling undertaken on 9 August 2017 (10 days following tracer release). A further 11 samples were collected during Sampling Round 2 which have been set aside for possible future analysis.

Positive samples covered the extends of sampling from Duranbah Beach in the south (around 350m updrift of the release site) to the eastern end of Coolangatta Beach (around 1.2km downdrift of the release site). While there still appears to be significant amounts of blue tracer adjacent to the SRE outlet the concentrations are slightly lower than those observed in Week1. These results indicate that fairly extensive alongshore dispersion of the tracer material occurred within 10 days of the tracer release. In comparison to the Week 1 results, more extensive downdrift (net northwards) transport is evident in the Week 2 results.

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[3] *A positive sample means at least one tracer particle, of any size class, was detected. It was possible to have multiple size classes detected for a particular sample. A zero count indicates no tracer was observed in the sample.*

The Week 2 samples were predominantly collected inshore of the RL -4m contour, with the offshore limit of sampling extending to around RL -6m. The results generally indicate a reduction in tracer concentrations with distance offshore. As per the Week 1 results, blue tracer was recorded immediately offshore of the SRE outlet at around RL -6, although at a lower concentration in Week 2.

The relatively high blue tracer counts recorded immediately downdrift of the SRE outlet (SRE_120) had consistent concentrations across the inner nearshore profile, including deposition on Froggies Beach. This suggests that the blue tracer material was relatively uniformly distributed across the upper profile moving in a northwards direction from the outlet around 10 days following release.

The highest tracer concentration in the Week 2 samples was recorded on the shoreline at the northern end of Rainbow Bay. Blue tracer was also recorded near this location in Week 1 which indicates that the blue tracer material was transported fairly rapidly (i.e. within days of the release) around Snapper Rocks with deposition occurring on the sub-aerial beach.

Similar to the Week 1 results, relatively high tracer concentrations were recorded south of the release site in the inshore zone of Duranbah Beach, including deposition on the sub-aerial beach.

Round 3 (Temporal) – Week 4

Positive counts[3] for the blue tracer were recorded in 15 of the 21 samples collected and analysed for the Week 4 sampling undertaken on 23 August 2017. A further six (6) samples were collected during Sampling Round 3 which have been set aside for possible future analysis.

Relatively high concentrations of blue tracer were consistently recorded across the upper profile at Froggies Beach, Snapper Rocks and Rainbow Bay. Slightly lower concentrations were recorded further downdrift through Greenmount and Coolangatta. These results suggest that the main bulk of the tracer material was spread between the outlet and Rainbow Bay four (4) weeks following tracer release. The three zero counts observed at Kirra Beach (KIR2220), the downdrift drift extent of Week 4 sampling, suggest that the tracer had yet to be transport this far. However, positive counts were recorded as far downdrift as the western end of Coolangatta Beach (i.e. around 1.8km from the release site).

As per the previous rounds, high tracer concentrations were observed south of the release site in the inshore zone of Duranbah Beach, including deposition on the sub-aerial beach. This provides evidence of ongoing southwards (updrift) transport of the blue tracer during the four (4) week period following tracer release. Similar to previous rounds, tracer concentration recorded at the northern end of Duranbah Beach were amongst the highest blue tracer counts observed.

Round 4 (Temporal) – Week 6

Positive counts[3] for the blue tracer were recorded in 11 of the 22 samples collected and analysed for the Week 6 sampling undertaken on 8 September 2017. In comparison to the earlier sampling rounds, the Week 6 results showed a significant reduction in blue tracer concentrations throughout the sampling region.

The majority of positive samples for Week 6 were collected on the downdrift side of Snapper Rocks, extending to the limit of sampling region at the eastern end of Kirra Beach (i.e. around 2.2km downdrift of the release site). The highest tracer concentrations in Week 6 were recorded just west of Snapper Rocks, around 600m downdrift of the release site. Only one (1) positive sample was recorded south of Snapper Rocks which was collected on the shoreline at Froggies Beach. These observations indicate that the main bulk of the tracer had migrated north of the SRE outlet and around Snapper Rocks during the six (6) week period following release.

The Week 6 results present evidence of ongoing onshore deposition of the blue tracer material at the beach compartments downdrift of the release site (i.e. Froggies Beach, Rainbow Bay, Coolangatta Beach and Kirra Beach).

Unlike the previous sampling rounds, zero tracer counts were recorded at the SRE outlet and updrift of the release site towards Duranbah Beach.

Round 5 (Temporal) – Week 10

Positive counts[3] for the blue tracer were recorded in 10 of the 21 samples collected and analysed for the Week 10 sampling undertaken on 5 October 2017. As per the Week 6 results, the Week 10 results indicate an ongoing reduction in blue tracer concentrations throughout the sampling region due to continued longshore dispersion.

The highest tracer concentrations in Week 10 were once again recorded just west of Snapper Rocks, around 600 m downdrift of the release site. There was a general reduction in tracer counts moving west from Snapper Rocks to the eastern end of Coolangatta Beach, around 1.1 km downdrift of the release site. Unlike the Week 4 and Week 6 results, blue tracer was not recorded at the western extent of the study area near Kirra Beach during Week 10.

Relatively low tracer counts were recorded in the inshore zone just north of the release site, including the shoreline at Froggies Beach. These results suggest that dispersion of the tracer material from near the release site continued to occur around 10 weeks following its release, albeit in relatively low quantities.

Blue tracer material was once again recorded on the shoreline at the northern end of Duranbah Beach, as per the results for Weeks 1, 2 and 4.

Round 6 (Spatial) – Week 13

Positive counts[3] for the blue tracer were recorded in 44 of the 97 samples collected and analysed for the Week 13 sampling undertaken on 23 October 2017. A further 11 samples were collected during Sampling Round 6 which have been set aside for possible future analysis.

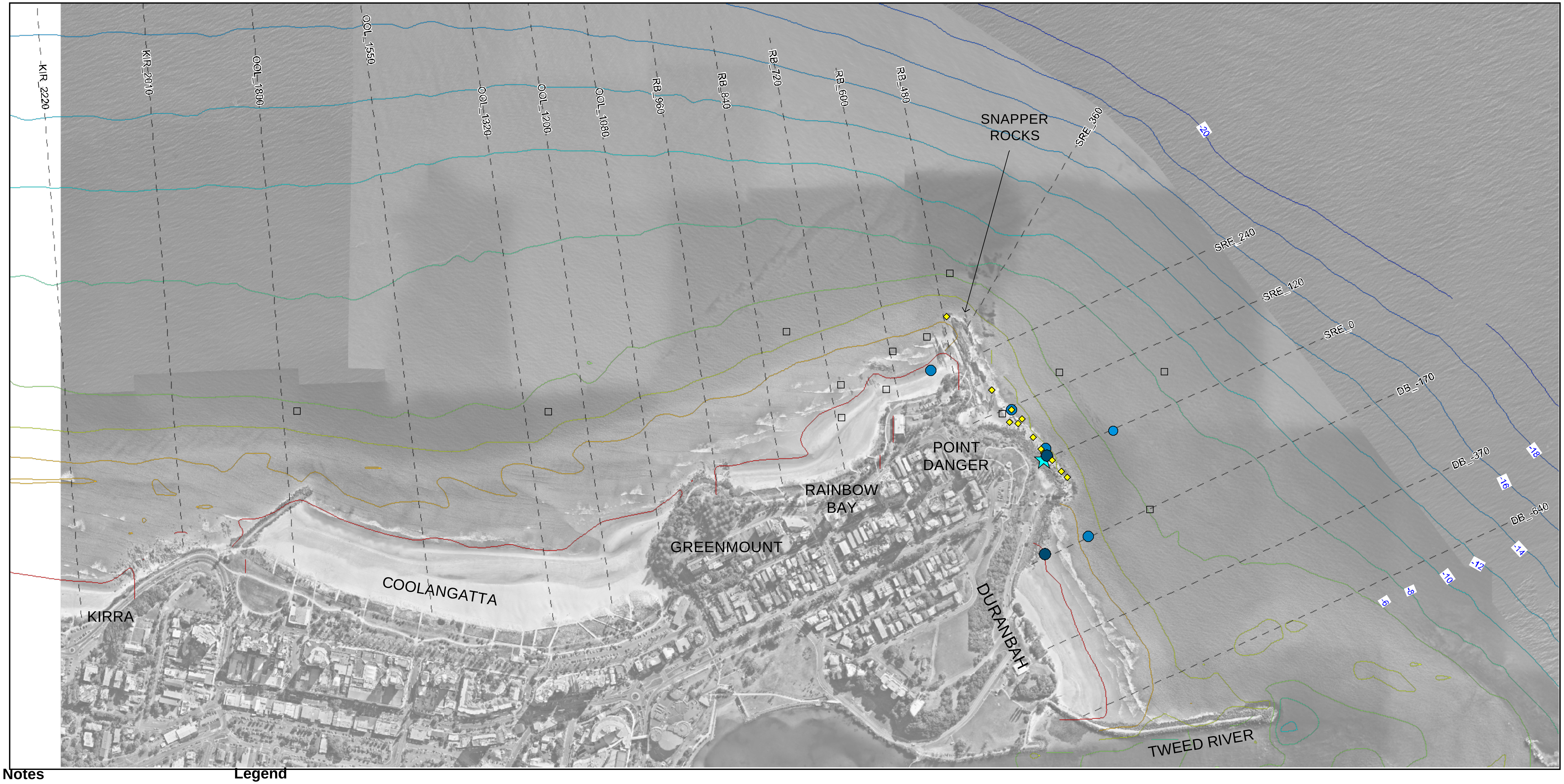
Week 13 sampling was undertaken throughout the study area extending between Duranbah Beach and Kirra Beach, with samples collected across the nearshore profile extending from the shoreline to a maximum water depth at around the RL -14m contour position. Blue tracer was generally recorded throughout the sampling region and primarily inshore of around RL -7, while some small positive counts were recorded at a maximum depth of around 9 m.

In comparison to earlier sampling rounds, relatively low tracer concentrations were recorded during the Week 13 sampling, consistent with ongoing dispersion of the released material.

In general, the Week 13 results indicate that significant alongshore dispersion of the tracer material occurred in a net northwards direction during the study period. Furthermore, this dispersion was predominantly confined to the inshore zone, with fairly limited cross-shore transport occurring to water depths beyond around RL -7. Indeed, the highest tracer counts were generally recorded along the shoreline and in the surf zone at each of the beach compartments north of the release site.

The Week 13 results also present evidence of southwards sediment transport, including deposition on the sub-aerial portion of Duranbah Beach. Positive counts were also recorded offshore of Duranbah Beach at water depths extending to around RL -9, which may be indicative of a sediment transport pathway from the tracer release site to the Tweed River Entrance (TRE) bar.

Tracer Maps - Counts per Square Metre



Notes

1. Aerial photograph sourced from Nearmap, taken 18/05/2016

2. Hydrosurvey dated May 2016

Legend

- - - - Sampling Transect

★ Tracer Release Location (SRE Outlet)

Count per square metre
(Number of sample in range)

●	3,000 to 10,000	(2)
●	1,000 to 3,000	(4)
●	500 to 1,000	(1)
●	100 to 500	(0)
●	1 to 100	(0)
□	0 to 1	(13)
◆	Sampled / Not Analysed	(13)

SAMPLING ROUND	1
DATE(s):	31 JULY 2017 & 1 AUGUST 2017
TIME SINCE TRACER RELEASE:	1-2 DAYS

PROJECT NO: PA1088

PROJECT TITLE: SRE Sand Tracing Study

CLIENT: Tweed Sand Bypassing

MAP 1B

BLUE TRACER
PARTICLE SIZE RESULTS
WEEK 1

NORTH

0 125 250m
Approx. Scale

SCALE 1:7,500

PAGE SIZE A3

CREATED BY: B.MACKENZIE

REVISION B

DATE 07/05/2018

FILEPATH \\HKA-SERVER\PUBLIC\CURRENT JOBS\~PA1088-102 - TRESBP Sediment Tracing

CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

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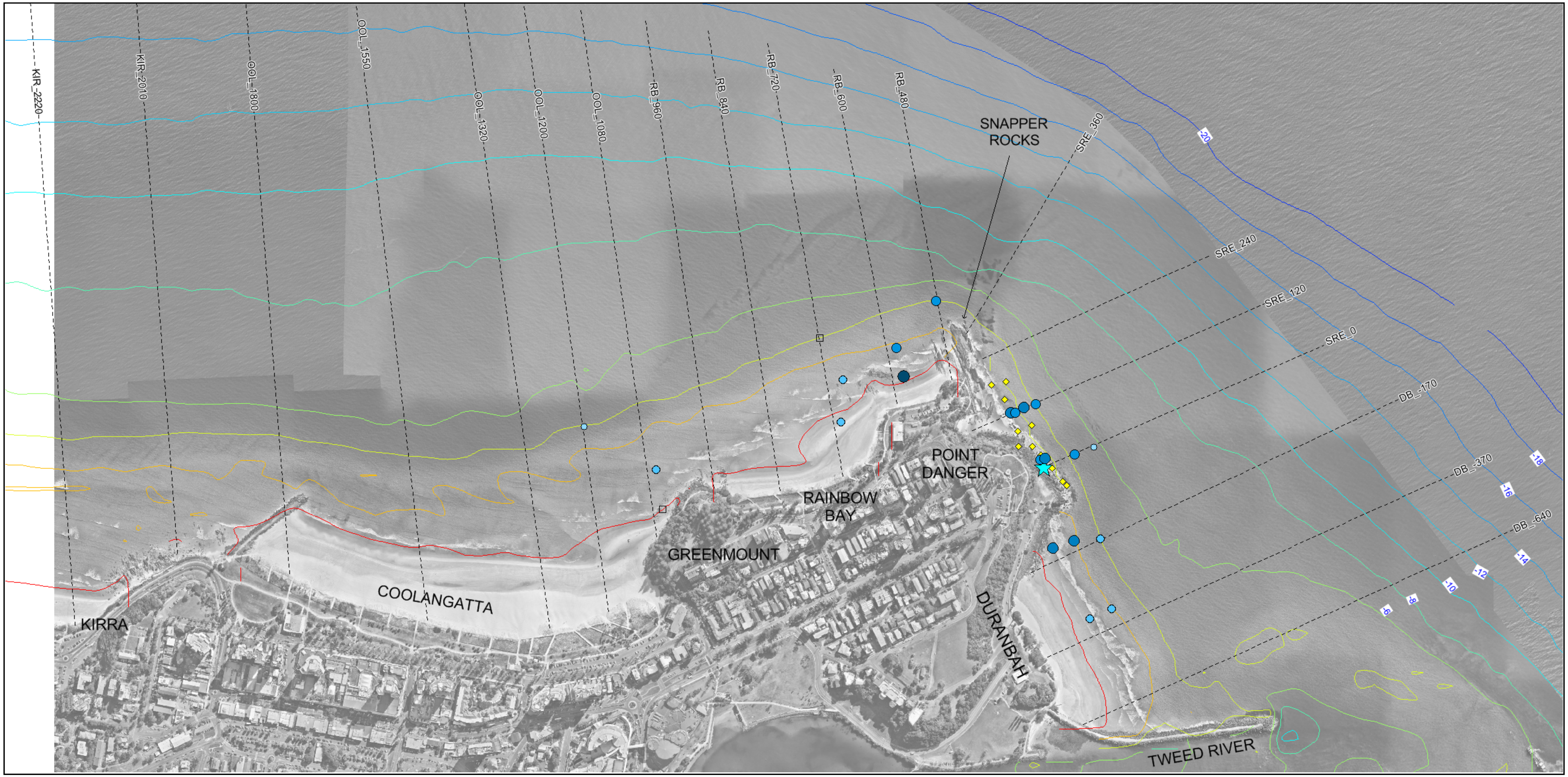

Notes

1. Aerial photograph sourced from Nearmap, taken 18/05/2016

2. Hydrosurvey dated May 2016

Legend

------ Sampling Transect

☆ Tracer Release Location (SRE Outlet)

Count per square metre
(Number of sample in range)

●	3,000 to 10,000	(1)
●	1,000 to 3,000	(5)
●	500 to 1,000	(6)
●	100 to 500	(6)
●	1 to 100	(2)
☐	0 to 1	(2)
◆	Sampled / Not Analysed	(11)

SAMPLING ROUND	2
DATE(s):	9 AUGUST 2017
TIME SINCE TRACER RELEASE:	10 DAYS

PROJECT NO: PA1088 PROJECT TITLE: SRE Sand Tracing Study CLIENT: Tweed Sand Bypassing

MAP 2A

BLUE TRACER
COUNT PER SQUARE METRE
WEEK 2

NORTH

0 125 250m
Approx. Scale

SCALE 1:7,500 PAGE SIZE A3

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CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

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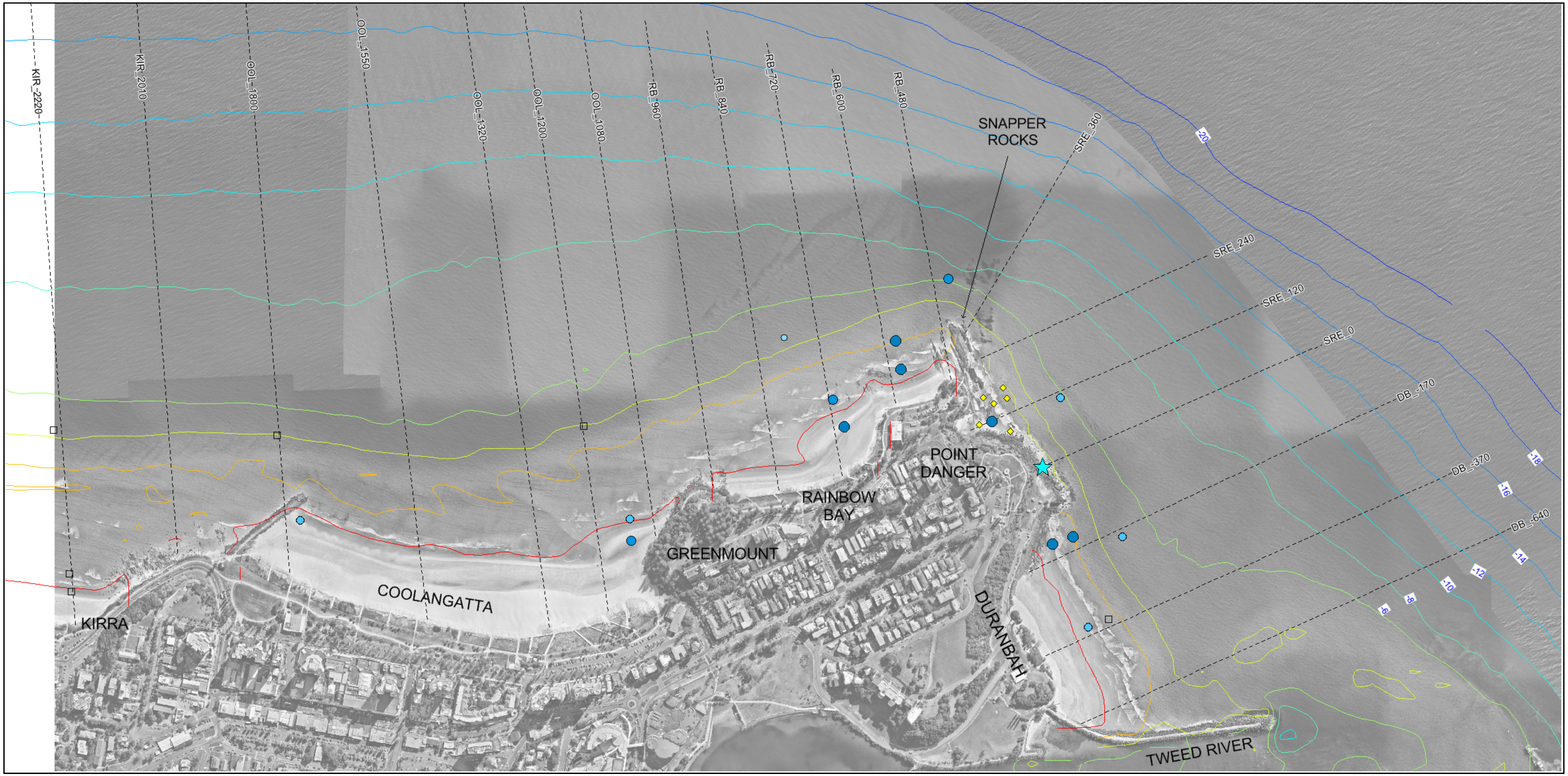

Notes

1. Aerial photograph sourced from Nearmap, taken 18/05/2016
2. Hydrosurvey dated May 2016

Legend

- - - - - - Sampling Transect

☆ Tracer Release Location (SRE Outlet)

Count per square metre
(Number of sample in range)

●	1,000 to 3,000	(6)
●	500 to 1,000	(3)
●	100 to 500	(5)
●	1 to 100	(1)
□	0 to 1	(6)
◆	Sampled / Not Analysed	(6)

SAMPLING ROUND	3
DATE(s):	23 AUGUST 2017
TIME SINCE TRACER RELEASE:	4 WEEKS

PROJECT NO: PA1088 PROJECT TITLE: SRE Sand Tracing Study CLIENT: Tweed Sand Bypassing

MAP 3A

BLUE TRACER
COUNT PER SQUARE METRE
WEEK 4

NORTH

0 125 250m
Approx. Scale

SCALE 1:7,500 PAGE SIZE A3

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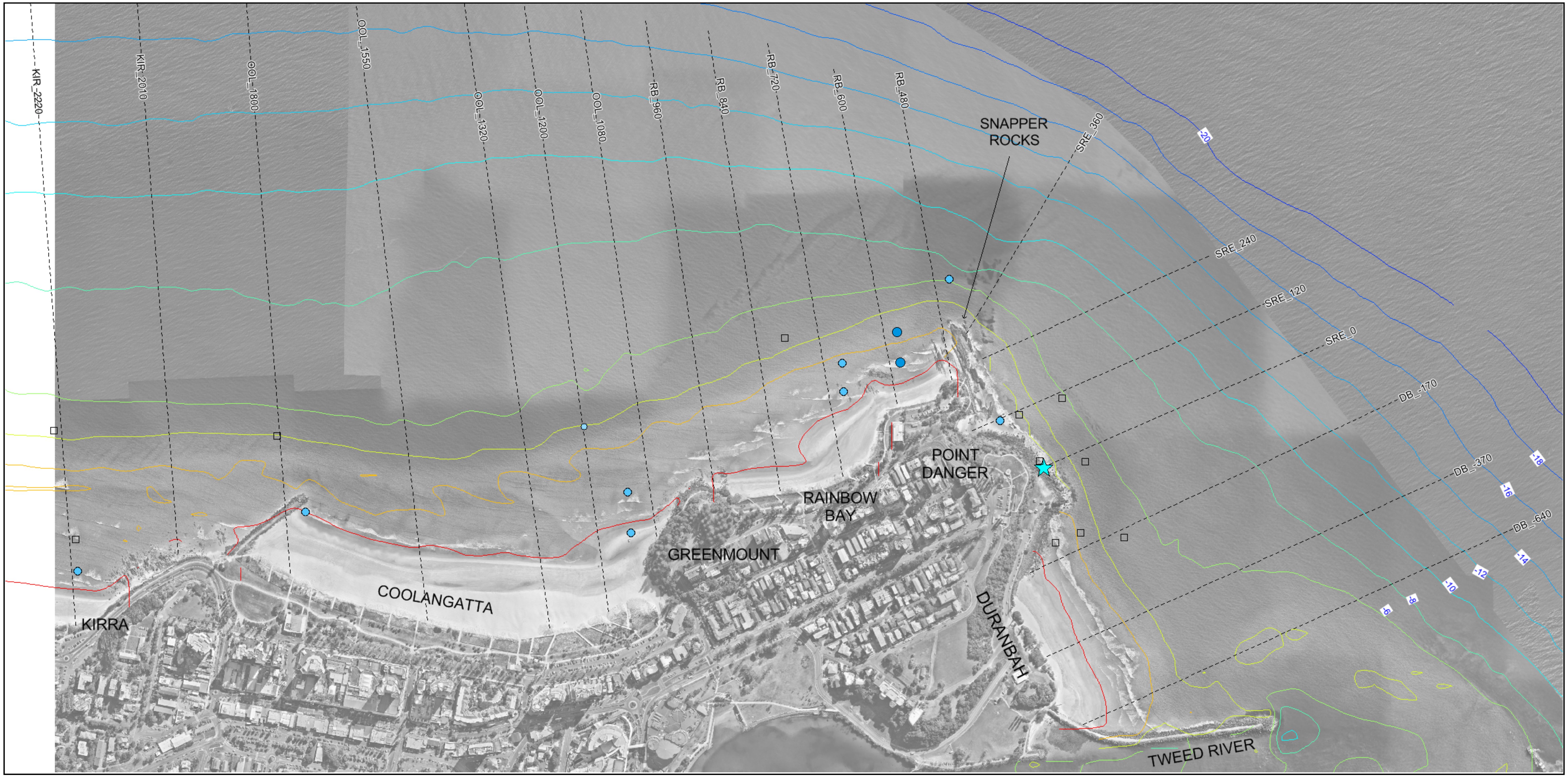
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56



Notes

1. Aerial photograph sourced from Nearmap, taken 18/05/2016
2. Hydrosurvey dated May 2016

Legend

- - - - - - Sampling Transect

★ Tracer Release Location (SRE Outlet)

Count per square metre
(Number of sample in range)

●	500 to 1,000	(2)
●	100 to 500	(8)
●	1 to 100	(1)
□	0 to 1	(11)
◆	Sampled / Not Analysed	(0)

SAMPLING ROUND	4
DATE(s):	8 SEPTEMBER 2017
TIME SINCE TRACER RELEASE:	6 WEEKS

PROJECT NO: PA1088 PROJECT TITLE: SRE Sand Tracing Study CLIENT: Tweed Sand Bypassing

MAP 4A

BLUE TRACER
COUNT PER SQUARE METRE
WEEK 6

NORTH

0 125 250m
Approx. Scale

SCALE 1:7,500 PAGE SIZE A3

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CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

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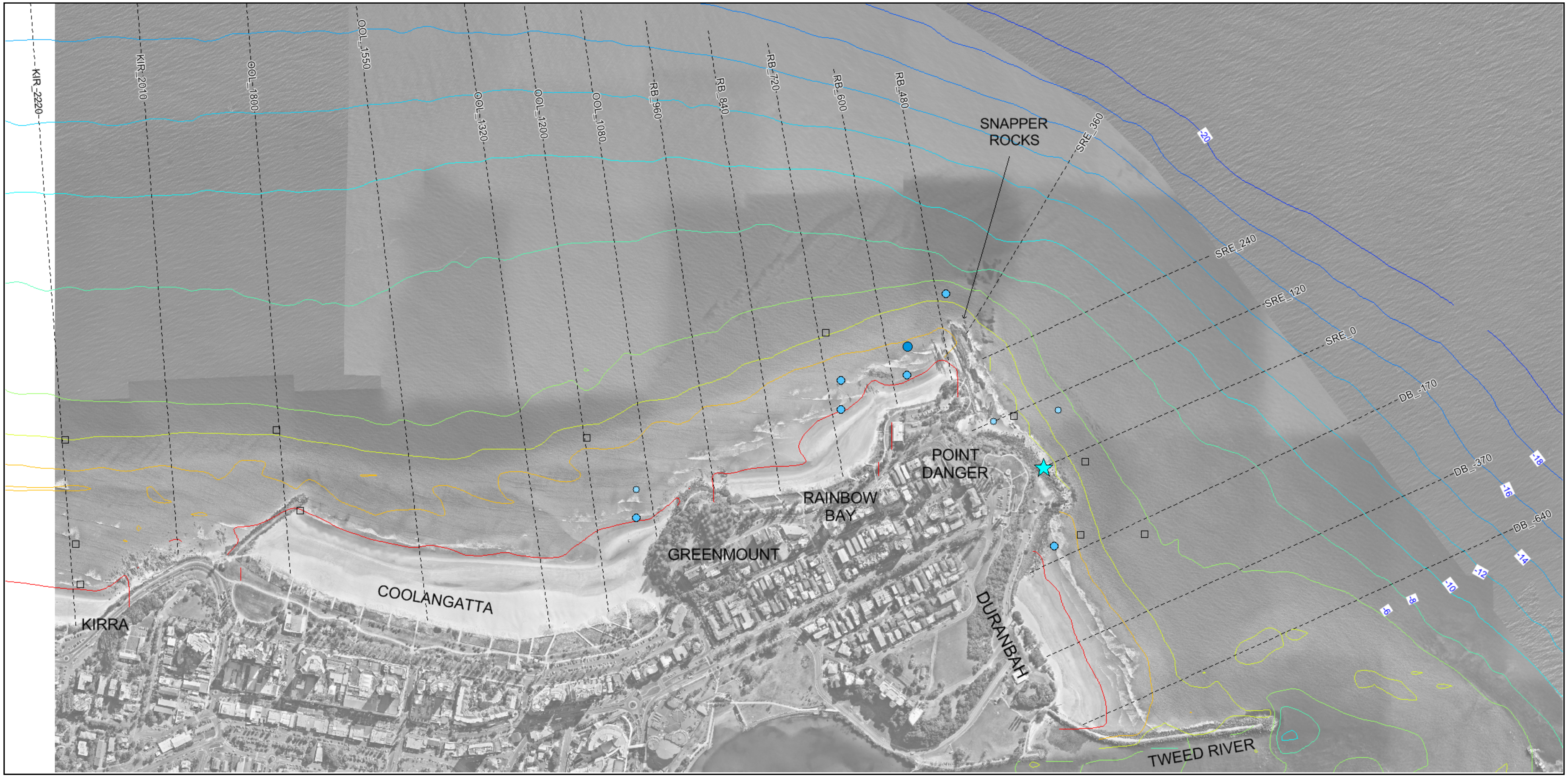

Notes

1. Aerial photograph sourced from Nearmap, taken 18/05/2016
2. Hydrosurvey dated May 2016

Legend

------ Sampling Transect

☆ Tracer Release Location (SRE Outlet)

Count per square metre
(Number of sample in range)

●	500 to 1,000	(1)
●	100 to 500	(6)
●	1 to 100	(3)
□	0 to 1	(11)
◆	Sampled / Not Analysed	(0)

SAMPLING ROUND	5
DATE(s):	5 OCTOBER 2017
TIME SINCE TRACER RELEASE:	10 WEEKS

PROJECT NO: PA1088 **PROJECT TITLE:** SRE Sand Tracing Study **CLIENT:** Tweed Sand Bypassing

MAP 5A

BLUE TRACER
COUNT PER SQUARE METRE
WEEK 10

NORTH

0 125 250m
Approx. Scale

SCALE 1:7,500 PAGE SIZE A3

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CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

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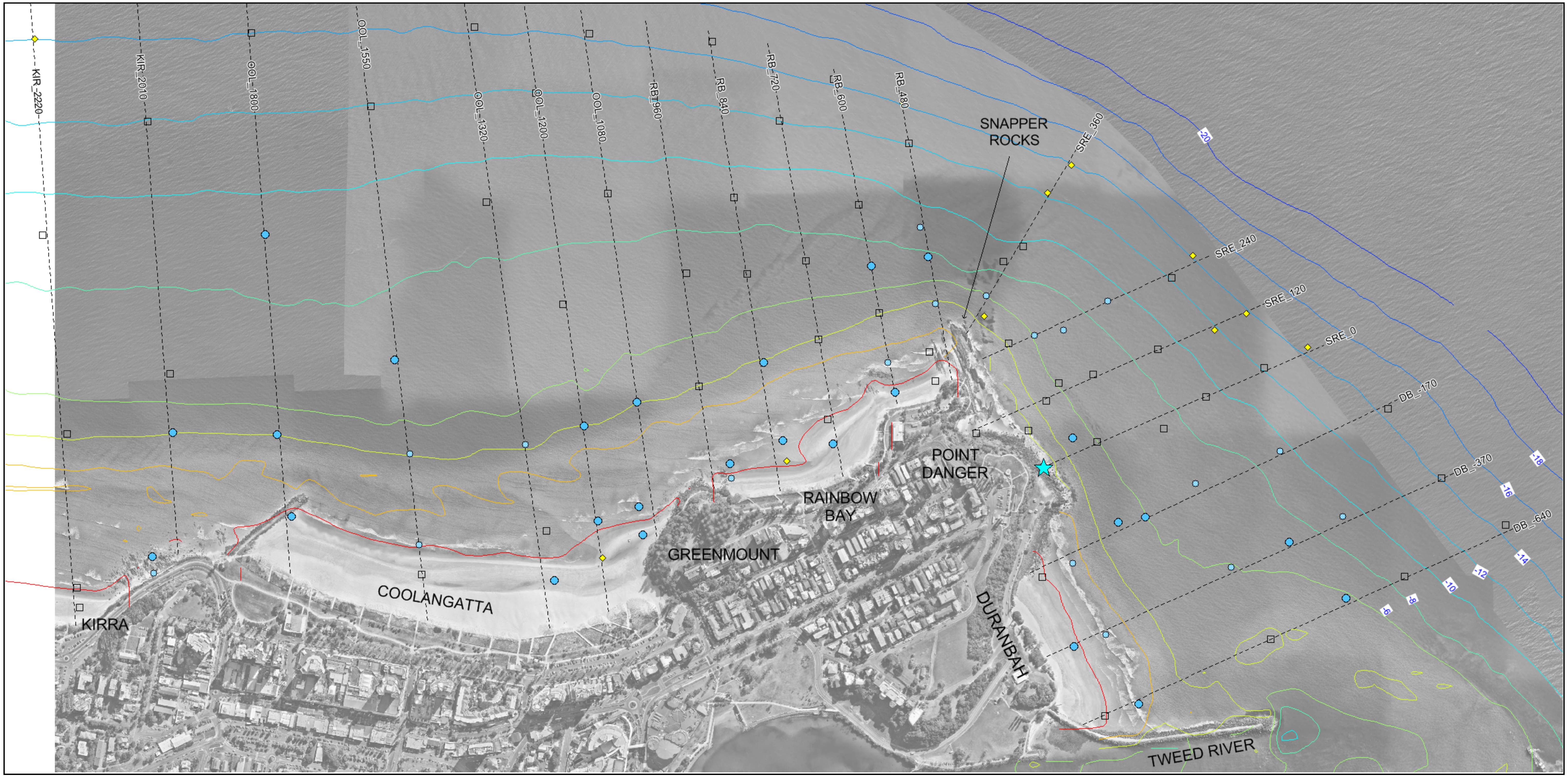

Notes

1. Aerial photograph sourced from Nearmap, taken 18/05/2016
2. Hydrosurvey dated May 2016

Legend

- - - - - - Sampling Transect

★ Tracer Release Location (SRE Outlet)

Count per square metre
(Number of sample in range)

●	100 to 500	(26)
•	1 to 100	(18)
☐	0 to 1	(53)
◆	Sampled / Not Analysed	(11)

SAMPLING ROUND	6
DATE(s):	23 OCTOBER 2017
TIME SINCE TRACER RELEASE:	12 WEEKS

PROJECT NO: PA1088 **PROJECT TITLE:** SRE Sand Tracing Study **CLIENT:** Tweed Sand Bypassing

MAP 6A

BLUE TRACER
COUNT PER SQUARE METRE
WEEK 13

NORTH

0 125 250m
Approx. Scale

SCALE 1:7,500 PAGE SIZE A3

CREATED BY: B.MACKENZIE REVISION B DATE 07/05/2018

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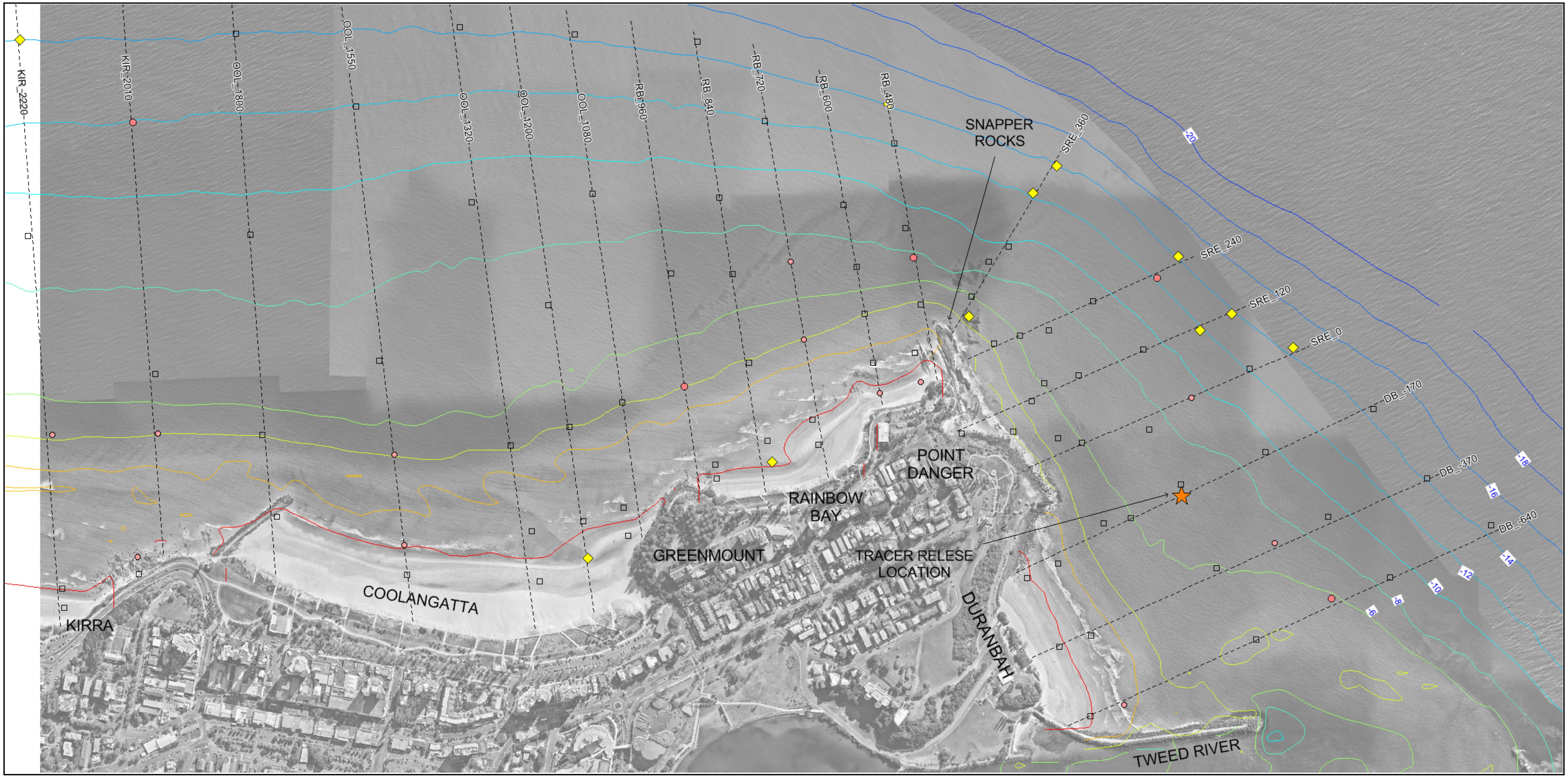

Notes

1. Aerial photograph sourced from Nearmap, taken 18/05/2016

2. Hydrosurvey dated May 2016

Legend

- - - - - - Sampling Transect

★ Tracer Release Location

Count per square metre
(Number of sample in range)

●	100 to 500	(5)
•	1 to 100	(13)
□	0 to 1	(79)
◆	Sampled / Not Analysed	(11)

SAMPLING ROUND	6
DATE(s):	23 OCTOBER 2017
TIME SINCE TRACER RELEASE:	20 Months

PROJECT NO: PA1088 PROJECT TITLE: TRSBP Sediment Tracing

MAP 7A

RED TRACER
COUNT PER SQUARE METRE
SPATIAL SAMPLING - 23 OCTOBER 2017

NORTH

0 125 250m
Approx. Scale

SCALE 1:7,500 PAGE SIZE A3

CREATED BY: B.MACKENZIE REVISION B DATE 07/05/2018

FILEPATH \\HKA-SERVER\PUBLIC\CURRENT JOBS\~PA1088-102 - TRESBP Sediment Tracing

CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

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Tabulated Tracer Results

Table B1: Tracer Results – Deployment Exercise (30 July 2017)

Sample ID	Dry Weight (g)		RAW TRACER COUNT IN SUB-SAMPLE						CALCULATED TRACER COUNT PER m^2					
	Whole Sample	Viewed Sub-Sample	Extra Small (<125)	Small (125-250)	Medium (250-375)	Large (375-500)	Extra Large (>500)	Total	Extra Small (<125)	Small (125-250)	Medium (250-375)	Large (375-500)	Extra Large (>500)	Total
Overflow	1145	0	77	66	1	0	0	**144**	5078140	4352691	65950	0	0	**9496781**
QC6	1245	3	54	26	3	0	0	**83**	535626	257894	29757	0	0	**823277**
QC7	1135	4	50	19	21	3	0	**93**	357068	135686	149968	10712	0	**664146**
QC3	1123	7	44	51	5	1	0	**101**	178527	206930	20287	2029	0	**409802**
QC2	996	6	47	30	7	1	0	**85**	194852	124374	29021	2073	0	**352392**
QC5	1244	9	54	37	3	0	0	**94**	184033	126097	10224	0	0	**320353**
QC4	422	4	49	26	2	0	0	**77**	127684	67751	5212	0	0	**200646**
QC1	1097	25	35	25	1	0	0	**61**	38485	27489	1100	0	0	**67074**
QC8	1215	114	38	14	1	0	0	**53**	10167	3746	268	0	0	**14180**
SRE100_2	974	290	8	12	2	0	0	**22**	672	1008	168	0	0	**1848**
SRE100_0	962	294	3	7	0	0	0	**10**	246	573	0	0	0	**818**
QC9	1276	291	2	3	1	0	0	**6**	219	329	110	0	0	**658**
Slurry Tank	982	298	4	3	0	0	0	**7**	329	247	0	0	0	**577**
DB-170_0	1080	289	0	0	0	0	0	**0**	0	0	0	0	0	**0**
DB-170_2	1158	271	0	0	0	0	0	**0**	0	0	0	0	0	**0**

Table B2: Tracer Results – Sampling Round 1 (31 July 2017 and 1 August 2017)

Date Sampled	Sample ID	Dry Weight (g)		RAW TRACER COUNT IN SUB-SAMPLE						CALCULATED TRACER COUNT PER m^2					
		Whole Sample	Viewed Sub-Sample	Extra Small (<125)	Small (125-250)	Medium (250-375)	Large (375-500)	Extra Large (>500)	Total	Extra Small (<125)	Small (125-250)	Medium (250-375)	Large (375-500)	Extra Large (>500)	Total
31-Jul-17	SRE0_0	1183	296	10	10	0	1	0	**21**	999	999	0	50	0	**2048**
	SRE0_4	1160	283	5	3	0	0	0	**8**	512	307	0	0	0	**820**
	DB-170_0	1181	288	5	2	0	0	0	**7**	513	205	0	0	0	**718**
	OOL1800_4	1123	277	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	OOL1200_4	919	286	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	RB720_0	1163	290	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	RB720_2	1167	290	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	RB720_4	1056	305	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	RB480_0	1170	306	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	RB480_2	1132	300	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	RB480_4	1035	305	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	RB550_0	1192	302	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	RB550_2	1300	307	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	SRE120_4	956	297	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	SRE0_6	1072	300	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	DB-170_2	1131	301	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	DB-170_4	1164	306	0	0	0	0	0	**0**	0	0	0	0	0	**0**
1-Aug-17	SRE0_1	904	116	11	35	6	0	0	**52**	2147	6830	1171	0	0	**10148**
	DB-170_0	1202	293	29	25	0	0	0	**54**	2975	2564	0	0	0	**5539**
	DB-170_2	1215	291	4	11	0	0	0	**15**	417	1148	0	0	0	**1565**
	RB480_0	1265	293	9	3	0	0	0	**12**	971	324	0	0	0	**1295**
	SRE120_2	1317	293	4	7	0	0	0	**11**	450	787	0	0	0	**1236**
	RB480_2	1348	277	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	RB480_4	1083	303	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	SRE120_0	1300	297	0	0	0	0	0	**0**	0	0	0	0	0	**0**

Table B3: Tracer Results – Sampling Round 2 (9 August 2017)

Sample ID	Dry Weight (g)		RAW TRACER COUNT IN SUB-SAMPLE						CALCULATED TRACER COUNT PER m^2					
	Whole Sample	Viewed Sub-Sample	Extra Small (<125)	Small (125-250)	Medium (250-375)	Large (375-500)	Extra Large (>500)	Total	Extra Small (<125)	Small (125-250)	Medium (250-375)	Large (375-500)	Extra Large (>500)	Total
RB480_0	1236	276	12	23	0	0	0	**35**	1344	2576	0	0	0	**3919**
DB-170_0	1233	251	4	14	2	0	0	**20**	491	1720	246	0	0	**2457**
SRE120_0	1331	285	6	8	1	1	0	**16**	700	934	117	58	0	**1810**
DB-170_2	946	265	3	15	2	0	0	**20**	268	1339	179	0	0	**1786**
SRE120_2	1171	285	5	12	0	0	0	**17**	513	1232	0	0	0	**1746**
SRE0_1	1313	294	2	5	3	3	0	**13**	223	558	335	167	0	**1284**
SRE120_4	848	286	5	6	1	0	0	**12**	371	445	74	0	0	**890**
RB480_4	1128	254	3	5	0	0	0	**8**	333	555	0	0	0	**888**
SRE0_0	1298	297	2	3	2	2	0	**9**	218	328	218	109	0	**874**
SRE120_3	756	289	4	8	0	0	0	**12**	262	523	0	0	0	**785**
SRE0_4	1017	281	2	4	0	0	0	**6**	181	362	0	0	0	**543**
RB480_2	1193	297	2	3	0	0	0	**5**	201	301	0	0	0	**502**
DB-370_0	1180	299	0	2	1	1	0	**4**	0	197	99	49	0	**345**
DB-170_4	931	279	2	1	0	0	0	**3**	167	83	0	0	0	**250**
RB720_2	1192	264	1	1	0	0	0	**2**	113	113	0	0	0	**226**
DB-370_2	1320	306	0	2	0	0	0	**2**	0	216	0	0	0	**216**
RB720_0	1260	296	1	0	0	0	0	**1**	106	0	0	0	0	**106**
OOL1200_2	1203	293	1	0	0	0	0	**1**	103	0	0	0	0	**103**
OOL1200_4	1169	306	1	0	0	0	0	**1**	95	0	0	0	0	**95**
SRE0_6	835	295	0	0	1	0	0	**1**	0	0	71	0	0	**71**
OOL1200_0	1237	295	0	0	0	0	0	**0**	0	0	0	0	0	**0**
RB720_4	1129	295	0	0	0	0	0	**0**	0	0	0	0	0	**0**

Table B4: Tracer Results – Sampling Round 3 (23 August 2017)

Sample ID	Dry Weight (g)		RAW TRACER COUNT IN SUB-SAMPLE						CALCULATED TRACER COUNT PER m^2					
	Whole Sample	Viewed Sub-Sample	Extra Small (<125)	Small (125-250)	Medium (250-375)	Large (375-500)	Extra Large (>500)	Total	Extra Small (<125)	Small (125-250)	Medium (250-375)	Large (375-500)	Extra Large (>500)	Total
SRE120_0	1198	288	6	16	2	0	0	**24**	624	1664	208	0	0	**2496**
DB-170_0	1354	280	3	11	5	0	0	**19**	363	1330	604	0	0	**2297**
DB-170_2	1068	269	5	14	2	0	0	**21**	496	1390	199	0	0	**2085**
RB480_2	1264	304	1	11	3	0	0	**15**	104	1144	312	0	0	**1560**
RB720_0	1229	298	2	9	2	0	0	**13**	206	928	206	0	0	**1340**
RB480_0	1221	293	4	5	2	0	0	**11**	417	521	208	0	0	**1146**
RB480_4	982	262	4	6	0	0	0	**10**	375	562	0	0	0	**937**
RB720_2	1187	294	0	5	1	0	0	**6**	0	505	101	0	0	**606**
OOL1200_0	1341	301	3	2	0	0	0	**5**	334	223	0	0	0	**557**
DB-170_4	997	300	3	2	0	1	0	**6**	249	166	0	42	0	**457**
SRE120_4	899	298	1	5	0	0	0	**6**	75	377	0	0	0	**452**
OOL1200_2	1167	299	0	2	0	0	0	**2**	0	195	0	0	0	**195**
DB370_0	1353	307	0	0	1	0	0	**1**	0	0	110	0	0	**110**
OOL1800_0	1341	309	0	1	0	0	0	**1**	0	108	0	0	0	**108**
RB720_4	1018	304	0	1	0	0	0	**1**	0	84	0	0	0	**84**
DB370_2	1267	303	0	0	0	0	0	**0**	0	0	0	0	0	**0**
KIR2200_0	1400	302	0	0	0	0	0	**0**	0	0	0	0	0	**0**
KIR2200_2	1274	307	0	0	0	0	0	**0**	0	0	0	0	0	**0**
KIR2200_4	1098	309	0	0	0	0	0	**0**	0	0	0	0	0	**0**
OOL1800_4	1147	297	0	0	0	0	0	**0**	0	0	0	0	0	**0**
OOL1200_4	1008	279	0	0	0	0	0	**0**	0	0	0	0	0	**0**

Table B5: Tracer Results – Sampling Round 4 (8 September 2017)

Sample ID	Dry Weight (g)		RAW TRACER COUNT IN SUB-SAMPLE						CALCULATED TRACER COUNT PER m^2					
	Whole Sample	Viewed Sub-Sample	Extra Small (<125)	Small (125-250)	Medium (250-375)	Large (375-500)	Extra Large (>500)	Total	Extra Small (<125)	Small (125-250)	Medium (250-375)	Large (375-500)	Extra Large (>500)	Total
KIR2200_0	1185	303	2	1	0	0	0	**3**	196	98	0	0	0	**293**
KIR2200_2	1119	303	0	0	0	0	0	**0**	0	0	0	0	0	**0**
KIR2200_4	997	310	0	0	0	0	0	**0**	0	0	0	0	0	**0**
OOL1800_0	944	303	1	2	0	0	0	**3**	78	156	0	0	0	**234**
OOL1800_4	958	302	0	0	0	0	0	**0**	0	0	0	0	0	**0**
OOL1200_0	1224	300	1	1	0	0	0	**2**	102	102	0	0	0	**204**
OOL1200_2	1223	300	0	2	2	0	0	**4**	0	204	204	0	0	**408**
OOL1200_4	1052	305	1	0	0	0	0	**1**	86	0	0	0	0	**86**
RB720_0	1023	296	0	2	0	0	0	**2**	0	173	0	0	0	**173**
RB720_2	1252	303	1	0	0	0	0	**1**	103	0	0	0	0	**103**
RB720_4	996	304	0	0	0	0	0	**0**	0	0	0	0	0	**0**
RB480 _0	1126	288	4	5	0	0	0	**9**	391	489	0	0	0	**880**
RB480_2	1248	304	3	3	1	1	0	**8**	308	308	103	51	0	**770**
RB480_4	972	310	0	2	1	0	0	**3**	0	157	78	0	0	**235**
SRE120_0	1317	284	0	1	0	0	0	**1**	0	116	0	0	0	**116**
SRE120_2	1012	300	0	0	0	0	0	**0**	0	0	0	0	0	**0**
SRE120_4	951	300	0	0	0	0	0	**0**	0	0	0	0	0	**0**
SRE0_0	1277	306	0	0	0	0	0	**0**	0	0	0	0	0	**0**
SRE0_4	1006	296	0	0	0	0	0	**0**	0	0	0	0	0	**0**
DB170_0	1315	304	0	0	0	0	0	**0**	0	0	0	0	0	**0**
DB170_2	1021	294	0	0	0	0	0	**0**	0	0	0	0	0	**0**
DB170_4	1105	302	0	0	0	0	0	**0**	0	0	0	0	0	**0**

Table B6: Tracer Results – Sampling Round 5 (5 October 2017)

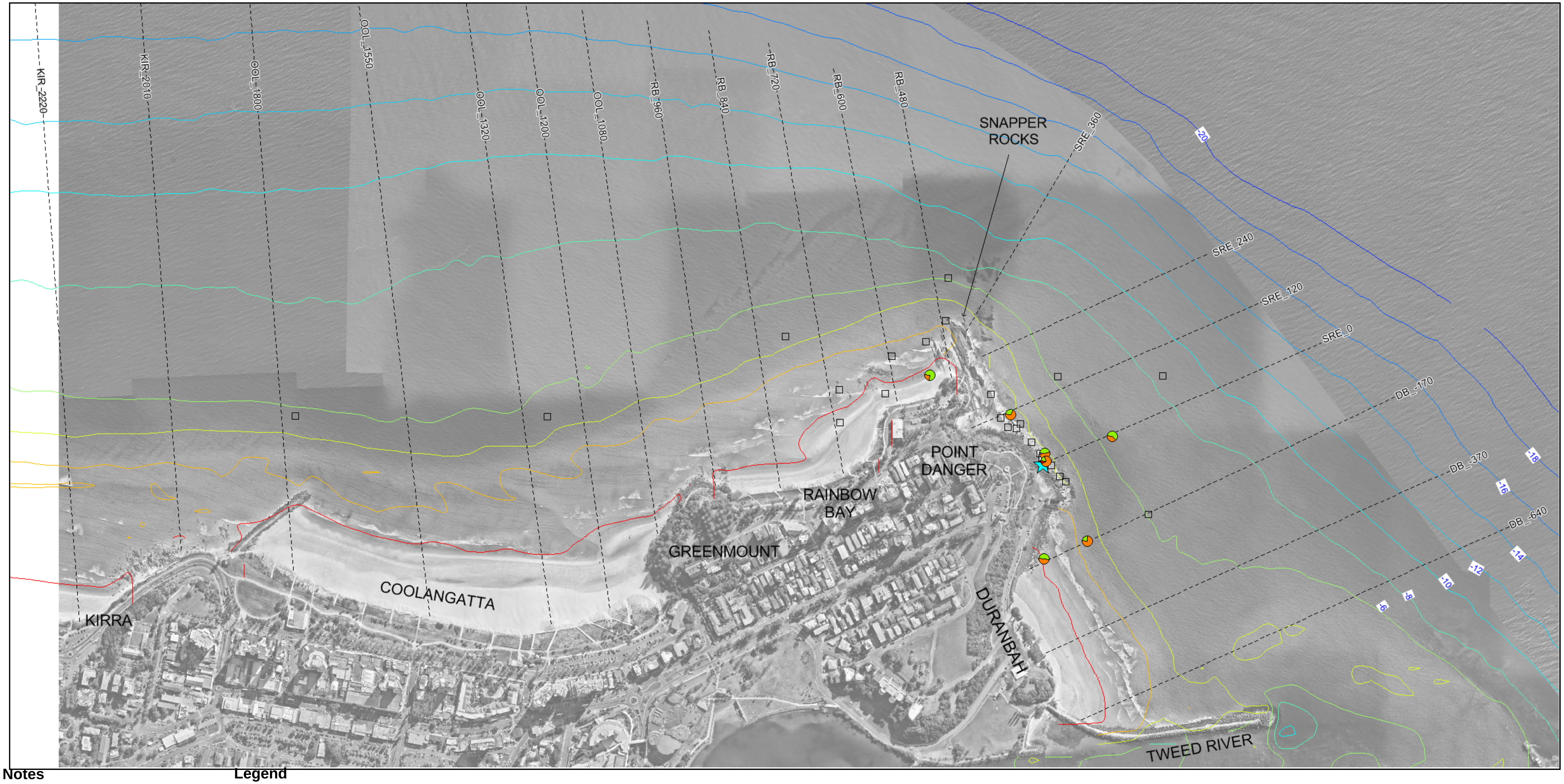
Sample ID	Dry Weight (g)		RAW TRACER COUNT IN SUB-SAMPLE						CALCULATED TRACER COUNT PER m^2					
	Whole Sample	Viewed Sub-Sample	Extra Small (<125)	Small (125-250)	Medium (250-375)	Large (375-500)	Extra Large (>500)	Total	Extra Small (<125)	Small (125-250)	Medium (250-375)	Large (375-500)	Extra Large (>500)	Total
RB480_2	1126	306	2	1	2	1	0	**6**	184	92	184	46	0	**506**
RB480_0	1157	306	1	3	1	0	0	**5**	95	284	95	0	0	**473**
OOL1200_0	1238	302	0	3	1	0	0	**4**	0	307	102	0	0	**410**
DB170_0	1154	304	1	2	0	2	0	**5**	95	190	0	95	0	**379**
RB720_0	1062	297	2	2	0	0	0	**4**	179	179	0	0	0	**357**
RB720_2	984	301	0	1	2	0	0	**3**	0	82	163	0	0	**245**
RB480_4	1092	283	0	2	0	0	0	**2**	0	193	0	0	0	**193**
SRE120_0	1049	302	0	1	0	0	0	**1**	0	87	0	0	0	**87**
SRE120_4	1019	300	0	1	0	0	0	**1**	0	85	0	0	0	**85**
OOL1200_2	1010	307	0	1	0	0	0	**1**	0	82	0	0	0	**82**
KIR2200_0	1143	291	0	0	0	0	0	**0**	0	0	0	0	0	**0**
KIR2200_2	1063	293	0	0	0	0	0	**0**	0	0	0	0	0	**0**
KIR2200_4	1149	300	0	0	0	0	0	**0**	0	0	0	0	0	**0**
OOL1800_0	995	307	0	0	0	0	0	**0**	0	0	0	0	0	**0**
OOL1800_4	1032	295	0	0	0	0	0	**0**	0	0	0	0	0	**0**
OOL1200_4	973	301	0	0	0	0	0	**0**	0	0	0	0	0	**0**
RB720_4	1033	305	0	0	0	0	0	**0**	0	0	0	0	0	**0**
SRE120_2	1112	309	0	0	0	0	0	**0**	0	0	0	0	0	**0**
SRE0_4	1018	295	0	0	0	0	0	**0**	0	0	0	0	0	**0**
DB170_2	1084	311	0	0	0	0	0	**0**	0	0	0	0	0	**0**
DB170_4	920	301	0	0	0	0	0	**0**	0	0	0	0	0	**0**

Table B7: Tracer Results – Sampling Round 6 (23 October 2017)

Sample ID	Dry Weight (g)		RAW TRACER COUNT IN SUB-SAMPLE						CALCULATED TRACER COUNT PER m^2					
	Whole Sample	Viewed Sub-Sample	Extra Small (<125)	Small (125-250)	Medium (250-375)	Large (375-500)	Extra Large (>500)	Total	Extra Small (<125)	Small (125-250)	Medium (250-375)	Large (375-500)	Extra Large (>500)	Total
RB840_2	1090	298	1	3	0	1	0	**5**	91	274	0	46	0	**411**
OOL1200_0	1213	308	1	3	0	0	0	**4**	98	295	0	0	0	**394**
OOL1200_2	1082	310	0	2	2	1	0	**5**	0	175	175	44	0	**393**
RB720_0	1155	309	2	1	1	0	0	**4**	187	93	93	0	0	**374**
OOL1800_4	1234	304	0	0	3	0	0	**3**	0	0	304	0	0	**304**
KIR2010_4	1043	300	1	2	0	1	0	**4**	87	174	0	43	0	**304**
RB960_0	1139	306	0	1	2	0	0	**3**	0	93	186	0	0	**279**
OOL1080_2	1105	288	1	0	1	1	0	**3**	96	0	96	48	0	**240**
DB-370_2	1080	302	1	0	1	1	0	**3**	89	0	89	45	0	**223**
DB640_2	1049	301	0	1	1	1	0	**3**	0	87	87	44	0	**218**
DB-170_0	1218	293	2	0	0	0	0	**2**	208	0	0	0	0	**208**
OOL1080_0	1167	297	1	0	1	0	0	**2**	98	0	98	0	0	**197**
OOL1080_0	1167	303	0	2	0	0	0	**2**	0	193	0	0	0	**193**
DB370_0	1137	304	1	1	0	0	0	**2**	94	94	0	0	0	**187**
KIR2010_2	1061	288	1	1	0	0	0	**2**	92	92	0	0	0	**184**
OOL1320_0	1106	302	0	2	0	0	0	**2**	0	183	0	0	0	**183**
RB600_4	1034	293	0	0	2	0	0	**2**	0	0	176	0	0	**176**
DB-170_2	1051	298	0	1	1	0	0	**2**	0	88	88	0	0	**176**
OOL1800_0	1081	309	1	1	0	0	0	**2**	87	87	0	0	0	**175**
OOL1550_4	1007	290	2	0	0	0	0	**2**	174	0	0	0	0	**174**
DB-640_2	1049	304	2	0	0	0	0	**2**	172	0	0	0	0	**172**
SRE0_4	1069	314	0	1	1	0	0	**2**	0	85	85	0	0	**170**
RB480_4	992	299	1	0	1	0	0	**2**	83	0	83	0	0	**166**
RB600_0	1081	300	0	0	1	1	0	**2**	0	0	90	45	0	**135**
RB840_0	1240	296	0	1	0	0	0	**1**	0	105	0	0	0	**105**
OOL1800_4	1234	305	0	0	1	0	0	**1**	0	0	101	0	0	**101**
DB-370_0	1137	301	1	0	0	0	0	**1**	94	0	0	0	0	**94**
RB480_2	1156	307	0	1	0	0	0	**1**	0	94	0	0	0	**94**
OOL1320_2	1155	307	0	1	0	0	0	**1**	0	94	0	0	0	**94**
RB960_0	1139	304	0	0	1	0	0	**1**	0	0	94	0	0	**94**
KIR2010_0	1119	300	0	1	0	0	0	**1**	0	93	0	0	0	**93**
OOL1550_0	1100	299	1	0	0	0	0	**1**	92	0	0	0	0	**92**
OOL1550_2	1111	304	0	0	1	0	0	**1**	0	0	91	0	0	**91**
RB600_0	1081	303	0	1	0	0	0	**1**	0	89	0	0	0	**89**
DB370_2	1080	308	0	0	1	0	0	**1**	0	0	88	0	0	**88**
DB170_2	1051	300	0	0	1	0	0	**1**	0	0	88	0	0	**88**
DB-370_6	1034	302	1	0	0	0	0	**1**	86	0	0	0	0	**86**
RB480_7	1040	304	0	1	0	0	0	**1**	0	85	0	0	0	**85**
SRE360_4	1027	305	1	0	0	0	0	**1**	84	0	0	0	0	**84**
SRE240_7	1032	308	0	1	0	0	0	**1**	0	84	0	0	0	**84**
DB-170_6	978	293	0	1	0	0	0	**1**	0	83	0	0	0	**83**
SRE240_4	1005	309	0	1	0	0	0	**1**	0	81	0	0	0	**81**
SRE240_6	923	307	0	1	0	0	0	**1**	0	75	0	0	0	**75**
DB-170_4	765	298	1	0	0	0	0	**1**	64	0	0	0	0	**64**
KIR2200_0	1058	310	0	0	0	0	0	**0**	0	0	0	0	0	**0**
KIR2200_2	1058	302	0	0	0	0	0	**0**	0	0	0	0	0	**0**
KIR2200_4	1001	302	0	0	0	0	0	**0**	0	0	0	0	0	**0**
KIR2010_7	1043	308	0	0	0	0	0	**0**	0	0	0	0	0	**0**
OOL1800_9	1200	304	0	0	0	0	0	**0**	0	0	0	0	0	**0**
OOL1550_7	1085	296	0	0	0	0	0	**0**	0	0	0	0	0	**0**
OOL1320_0	1106	299	0	0	0	0	0	**0**	0	0	0	0	0	**0**
OOL1320_4	1009	301	0	0	0	0	0	**0**	0	0	0	0	0	**0**
OOL1320_9	974	301	0	0	0	0	0	**0**	0	0	0	0	0	**0**
OOL1200_4	996	311	0	0	0	0	0	**0**	0	0	0	0	0	**0**
OOL1200_7	1045	290	0	0	0	0	0	**0**	0	0	0	0	0	**0**
OOL1080_4	1122	297	0	0	0	0	0	**0**	0	0	0	0	0	**0**
OOL1080_9	1129	310	0	0	0	0	0	**0**	0	0	0	0	0	**0**
RB960_2	1104	300	0	0	0	0	0	**0**	0	0	0	0	0	**0**
RB960_4	1045	297	0	0	0	0	0	**0**	0	0	0	0	0	**0**
RB960_7	996	303	0	0	0	0	0	**0**	0	0	0	0	0	**0**
RB840_4	969	291	0	0	0	0	0	**0**	0	0	0	0	0	**0**
RB840_7	975	305	0	0	0	0	0	**0**	0	0	0	0	0	**0**
RB840_9	973	294	0	0	0	0	0	**0**	0	0	0	0	0	**0**

Sample ID	**Dry Weight (g)**		**RAW TRACER COUNT IN SUB-SAMPLE**						**CALCULATED TRACER COUNT PER m^2**					
	Whole Sample	**Viewed Sub-Sample**	**Extra Small (<125)**	**Small (125-250)**	**Medium (250-375)**	**Large (375-500)**	**Extra Large (>500)**	**Total**	**Extra Small (<125)**	**Small (125-250)**	**Medium (250-375)**	**Large (375-500)**	**Extra Large (>500)**	**Total**
RB720_0	1155	303	0	0	0	0	0	**0**	0	0	0	0	0	**0**
RB720_2	1031	295	0	0	0	0	0	**0**	0	0	0	0	0	**0**
RB720_4	939	301	0	0	0	0	0	**0**	0	0	0	0	0	**0**
RB720_7	1016	290	0	0	0	0	0	**0**	0	0	0	0	0	**0**
RB600_2	1023	288	0	0	0	0	0	**0**	0	0	0	0	0	**0**
RB600_7	986	300	0	0	0	0	0	**0**	0	0	0	0	0	**0**
RB600_9	936	307	0	0	0	0	0	**0**	0	0	0	0	0	**0**
RB480_0	1120	297	0	0	0	0	0	**0**	0	0	0	0	0	**0**
RB480_9	1089	306	0	0	0	0	0	**0**	0	0	0	0	0	**0**
SRE360_6	1283	298	0	0	0	0	0	**0**	0	0	0	0	0	**0**
SRE360_9	1043	300	0	0	0	0	0	**0**	0	0	0	0	0	**0**
SRE240_9	938	298	0	0	0	0	0	**0**	0	0	0	0	0	**0**
SRE120_0	1131	300	0	0	0	0	0	**0**	0	0	0	0	0	**0**
SRE120_2	1092	298	0	0	0	0	0	**0**	0	0	0	0	0	**0**
SRE120_4	991	297	0	0	0	0	0	**0**	0	0	0	0	0	**0**
SRE120_6	924	296	0	0	0	0	0	**0**	0	0	0	0	0	**0**
SRE120_7	954	297	0	0	0	0	0	**0**	0	0	0	0	0	**0**
SRE0_4	1069	294	0	0	0	0	0	**0**	0	0	0	0	0	**0**
SRE0_6	1044	305	0	0	0	0	0	**0**	0	0	0	0	0	**0**
SRE0_7	1050	298	0	0	0	0	0	**0**	0	0	0	0	0	**0**
DB-170_7	1093	307	0	0	0	0	0	**0**	0	0	0	0	0	**0**
DB-37-_7	1009	307	0	0	0	0	0	**0**	0	0	0	0	0	**0**
DB-640_0	1192	290	0	0	0	0	0	**0**	0	0	0	0	0	**0**
DB-640_4	1072	305	0	0	0	0	0	**0**	0	0	0	0	0	**0**
DB-640_6	1077	301	0	0	0	0	0	**0**	0	0	0	0	0	**0**
KIR2200_9	1068	300	0	0	0	0	0	**0**	0	0	0	0	0	**0**
KIR2010_12	1013	305	0	0	0	0	0	**0**	0	0	0	0	0	**0**
OOL1550_0	1100	309	0	0	0	0	0	**0**	0	0	0	0	0	**0**
RB480_0	1120	303	0	0	0	0	0	**0**	0	0	0	0	0	**0**
SRE240_4	1005	294	0	0	0	0	0	**0**	0	0	0	0	0	**0**
SRE120_0	1131	303	0	0	0	0	0	**0**	0	0	0	0	0	**0**
SRE0_6	1044	297	0	0	0	0	0	**0**	0	0	0	0	0	**0**
DB170_0	1218	297	0	0	0	0	0	**0**	0	0	0	0	0	**0**
DB640_0	1192	297	0	0	0	0	0	**0**	0	0	0	0	0	**0**

Appendix C – Tracer Result Maps – Particle Size



Notes

1. Aerial photograph sourced from Nearmap, taken 18/05/2016
2. Hydrosurvey dated May 2016

Legend

- - - - - - Sampling Transect

☆ Tracer Release Location (SRE Outlet)

Particle Size:

🟩	XS
🟧	Small
🟥	Medium
🟪	Large
🟦	XL

SAMPLING ROUND	1
DATE(s):	31 JULY 2017 & 1 AUGUST 2017
TIME SINCE TRACER RELEASE:	1 DAY

PROJECT NO: PA1088 PROJECT TITLE: SRE Sand Tracing Study CLIENT: Tweed Sand Bypassing

MAP 1B

BLUE TRACER
PARTICLE SIZE RESULTS
WEEK 1

NORTH

0 125 250m
Approx. Scale

SCALE 1:7,500 PAGE SIZE A3

CREATED BY: B.MACKENZIE REVISION B DATE 07/05/2018

FILEPATH \\HKA-SERVER\PUBLIC\CURRENT JOBS\~PA1088-102 - TRESBP Sediment Tracing

CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

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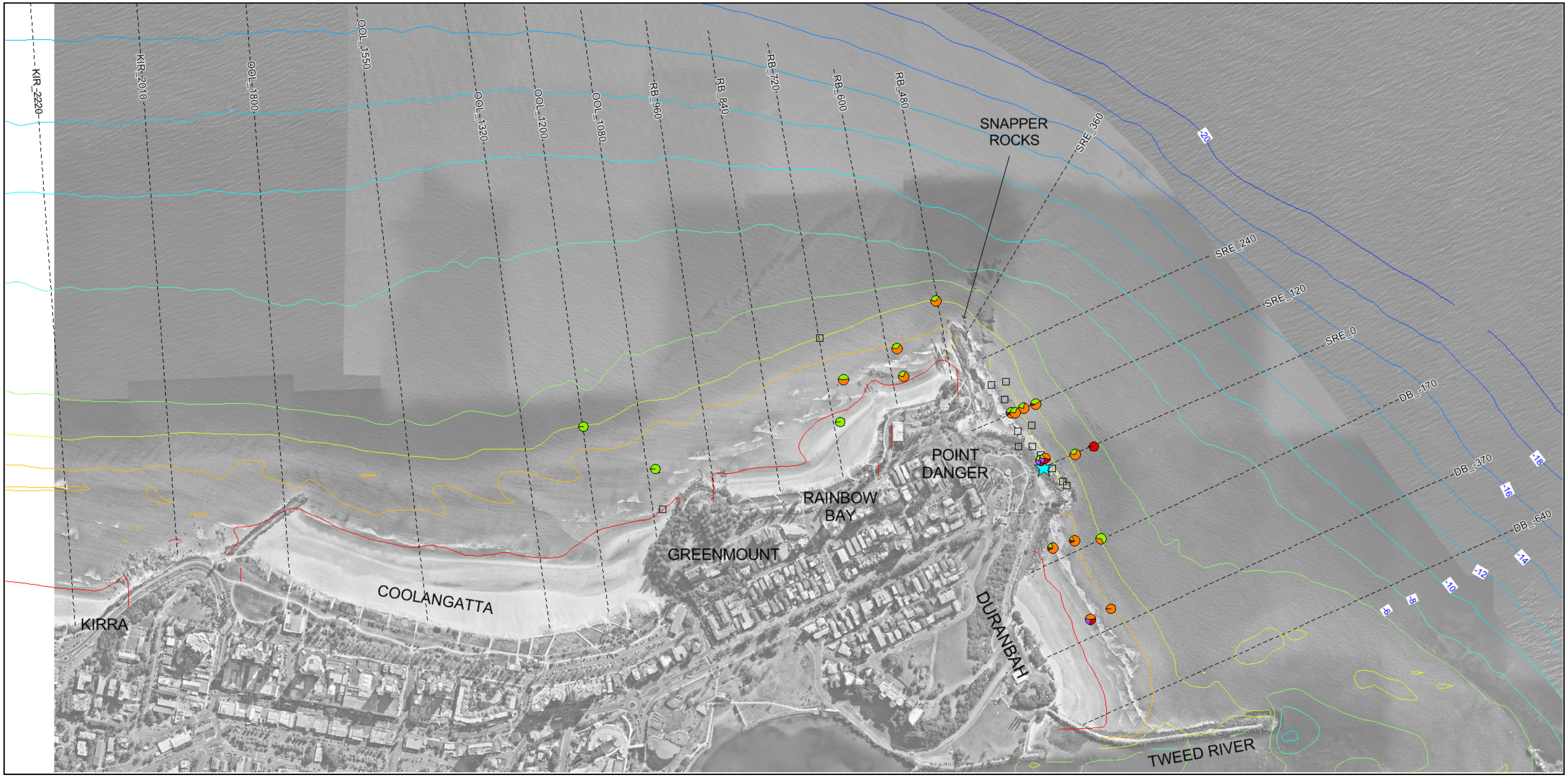

Notes

1. Aerial photograph sourced from Nearmap, taken 18/05/2016

2. Hydrosurvey dated May 2016

Legend

------ Sampling Transect

★ Tracer Release Location (SRE Outlet)

Particle Size:

●

🟩 XS

🟧 Small

🟥 Medium

🟪 Large

🟦 XL

SAMPLING ROUND	2
DATE(s):	9 AUGUST 2017
TIME SINCE TRACER RELEASE:	10 DAYS

PROJECT NO: PA1088 PROJECT TITLE: SRE Sand Tracing Study CLIENT: Tweed Sand Bypassing

MAP 2B

BLUE TRACER
PARTICLE SIZE RESULTS
WEEK 2

NORTH

0 125 250m
Approx. Scale

SCALE 1:7,500 PAGE SIZE A3

CREATED BY: B.MACKENZIE REVISION B DATE 07/05/2018

FILEPATH \\HKA-SERVER\PUBLIC\CURRENT JOBS\~PA1088-102 - TRESBP Sediment Tracing

CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

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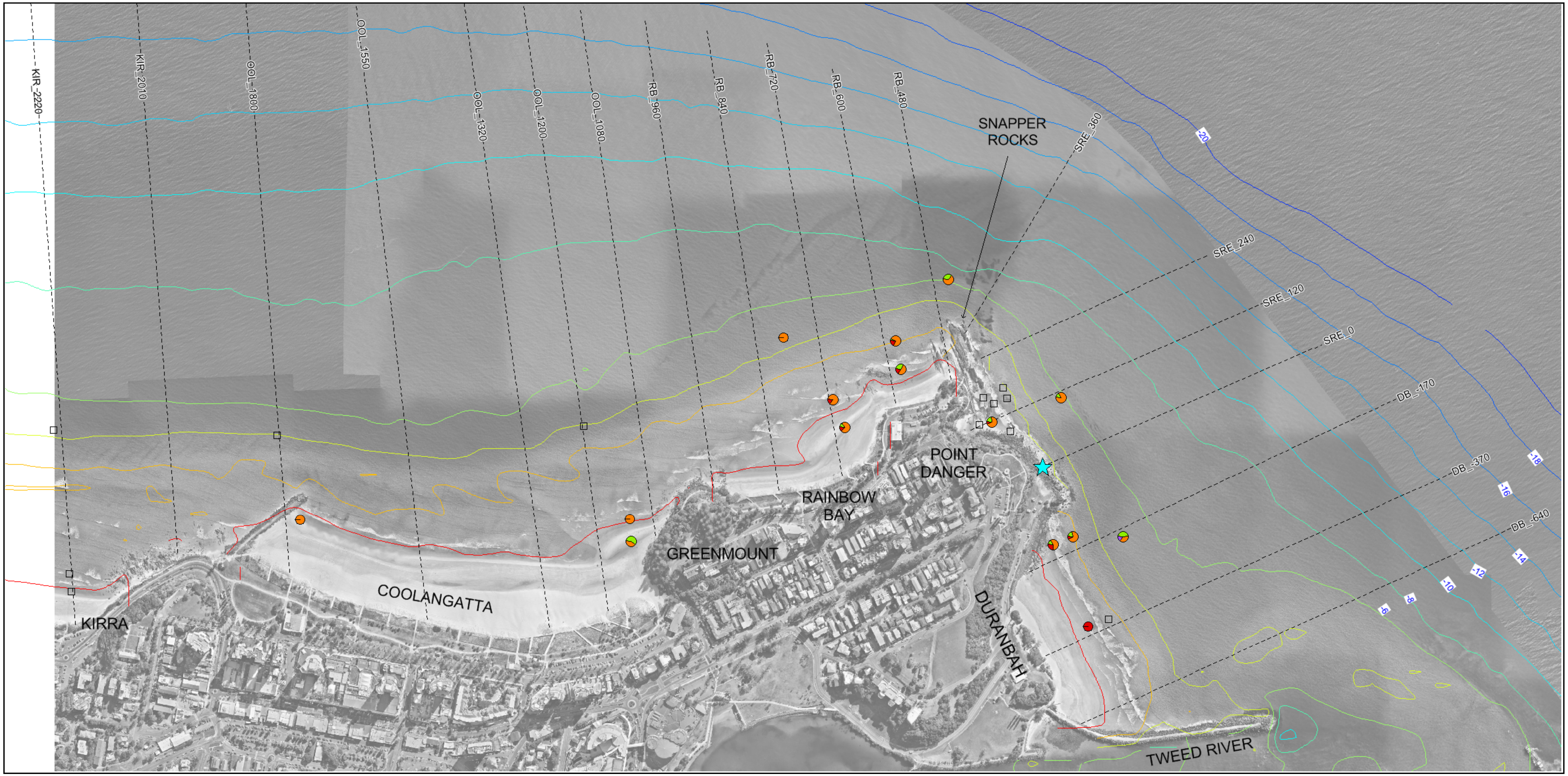


Notes

1. Aerial photograph sourced from Nearmap, taken 18/05/2016
2. Hydrosurvey dated May 2016

Legend

- - - - - - Sampling Transect

☆ Tracer Release Location (SRE Outlet)

Particle Size:

🟩 XS

🟧 Small

🟥 Medium

🟪 Large

🟦 XL

SAMPLING ROUND	3
DATE(s):	23 AUGUST 2017
TIME SINCE TRACER RELEASE:	4 WEEKS

PROJECT NO: PA1088 PROJECT TITLE: SRE Sand Tracing Study CLIENT: Tweed Sand Bypassing

MAP 3B

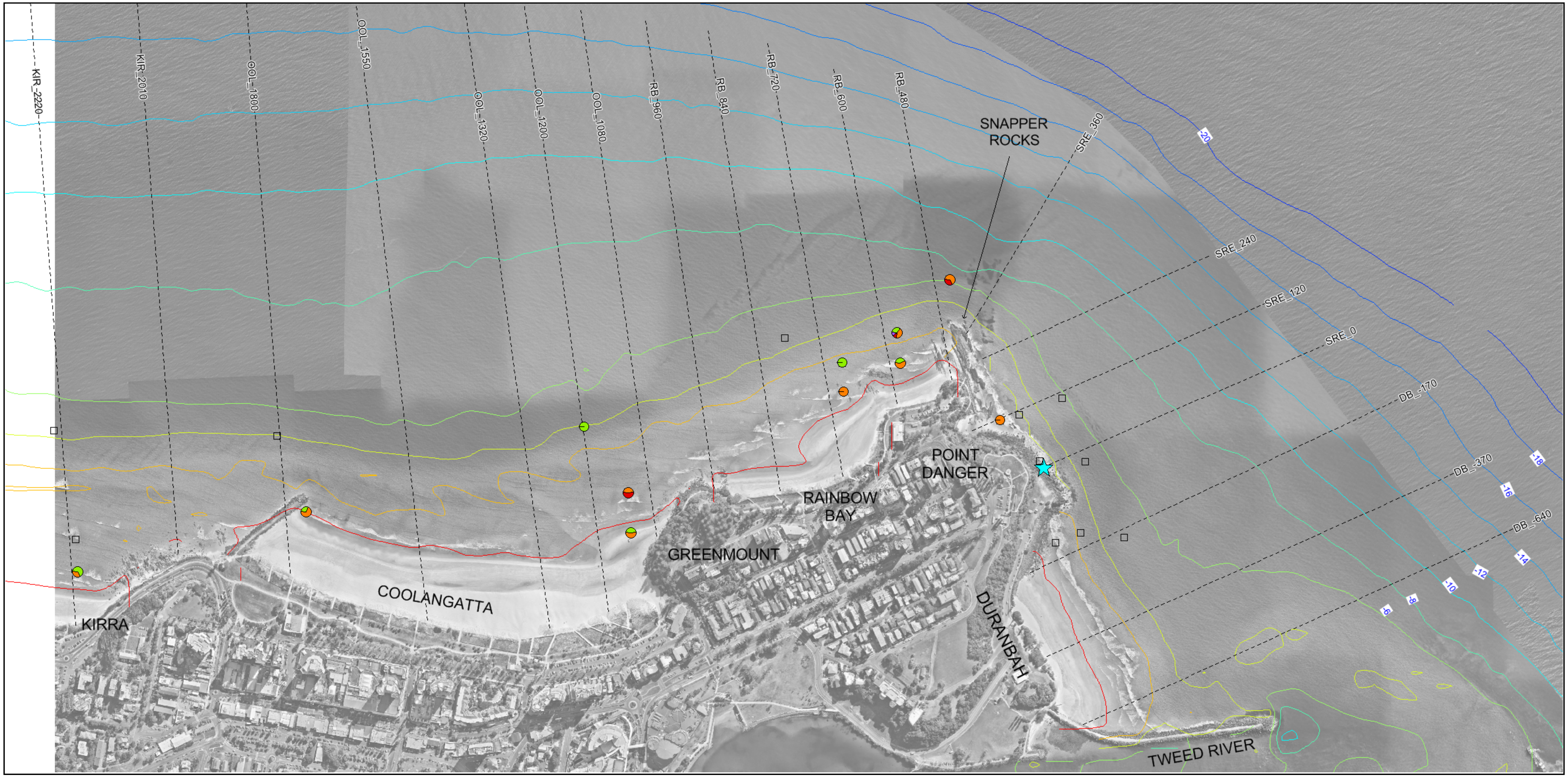
BLUE TRACER
PARTICLE SIZE RESULTS
WEEK 4

NORTH 0 125 250m Approx. Scale SCALE 1:7,500 PAGE SIZE A3

CREATED BY: B.MACKENZIE REVISION B DATE 07/05/2018

FILEPATH \\HKA-SERVER\PUBLIC\CURRENT JOBS\~PA1088-102 - TRESBP Sediment Tracing

CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56



Notes

1. Aerial photograph sourced from Nearmap, taken 18/05/2016
2. Hydrosurvey dated May 2016

Legend

- - - - - - Sampling Transect

★ Tracer Release Location (SRE Outlet)

Particle Size:

●

🟩 XS

🟧 Small

🟥 Medium

🟪 Large

🟦 XL

SAMPLING ROUND	4
DATE(s):	8 SEPTEMBER 2017
TIME SINCE TRACER RELEASE:	6 WEEKS

PROJECT NO: PA1088 PROJECT TITLE: SRE Sand Tracing Study CLIENT: Tweed Sand Bypassing

MAP 4B

BLUE TRACER
PARTICLE SIZE RESULTS
WEEK 6

NORTH

0 125 250m
Approx. Scale

SCALE 1:7,500 PAGE SIZE A3

CREATED BY: B.MACKENZIE REVISION B DATE 07/05/2018

FILEPATH \\HKA-SERVER\PUBLIC\CURRENT JOBS\~PA1088-102 - TRESBP Sediment Tracing

CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

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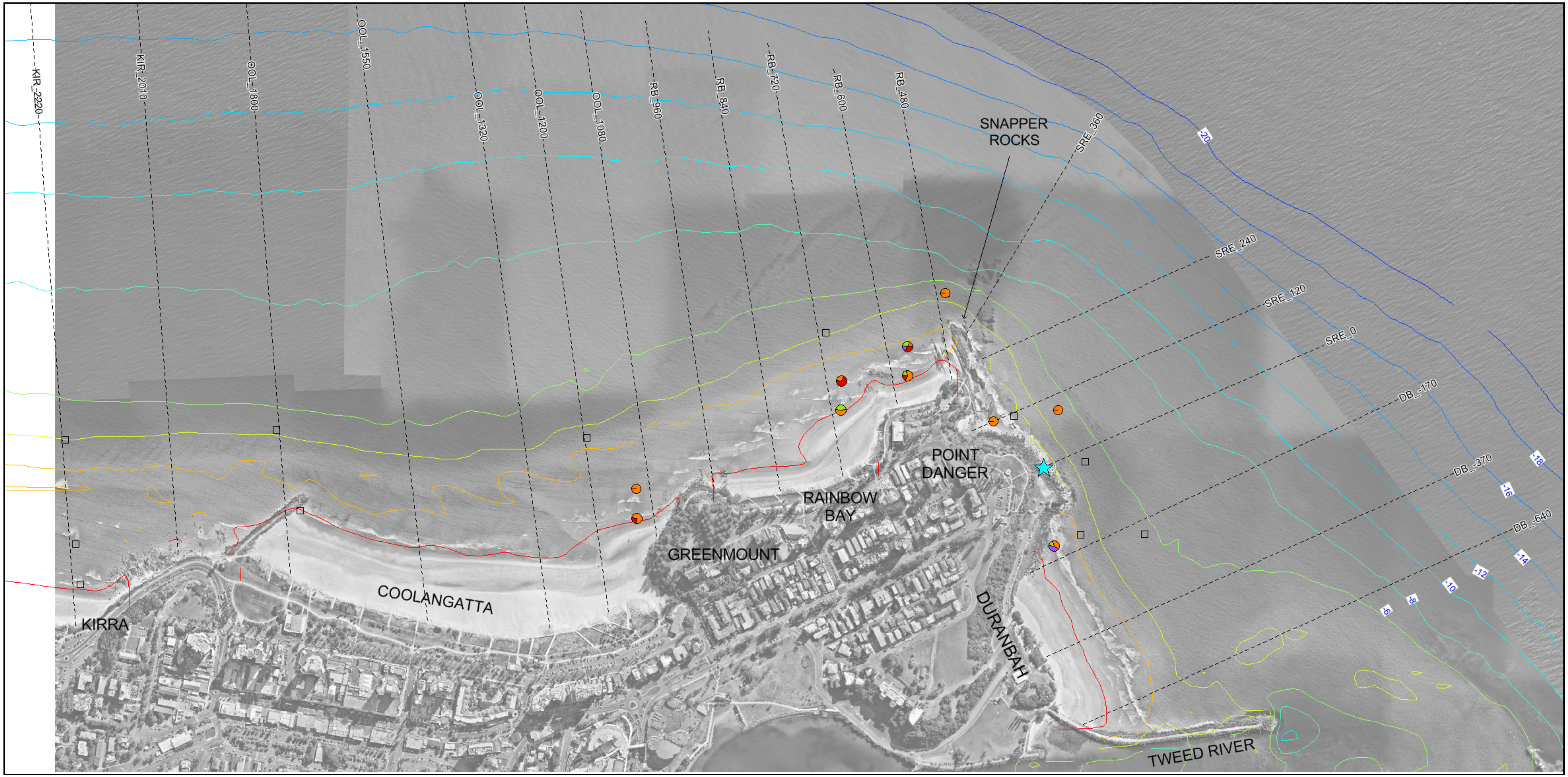


Notes

1. Aerial photograph sourced from Nearmap, taken 18/05/2016

2. Hydrosurvey dated May 2016

Legend

- - - - - - Sampling Transect

★ Tracer Release Location (SRE Outlet)

Particle Size:

●

🟩 XS

🟧 Small

🟥 Medium

🟪 Large

🟦 XL

SAMPLING ROUND	5
DATE(s):	5 OCTOBER 2017
TIME SINCE TRACER RELEASE:	10 WEEKS

PROJECT NO: PA1088 PROJECT TITLE: SRE Sand Tracing Study CLIENT: Tweed Sand Bypassing

MAP 5B

BLUE TRACER
PARTICLE SIZE RESULTS
WEEK 10

NORTH

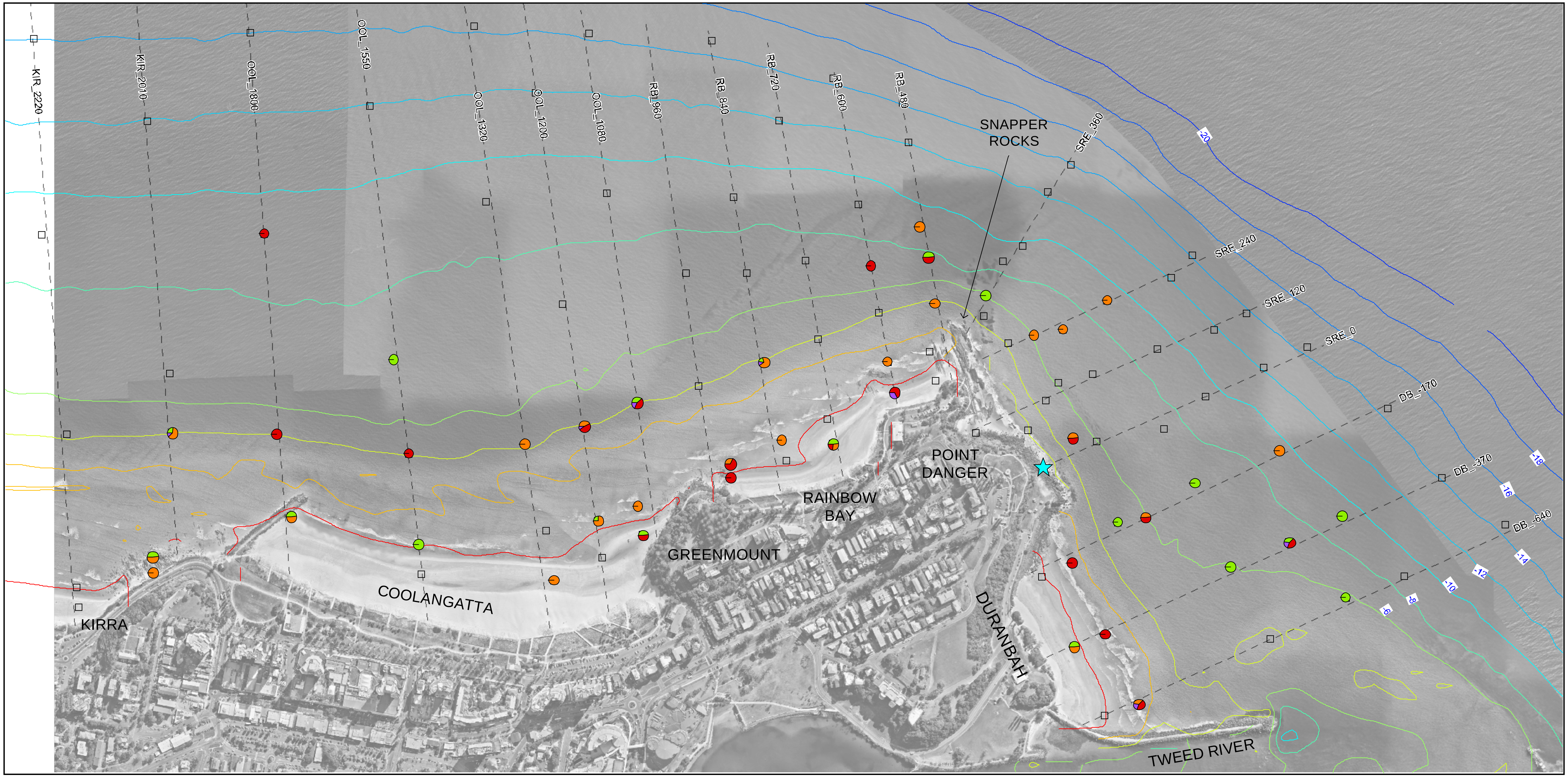
0 125 250m
Approx. Scale

SCALE 1:7,500 PAGE SIZE A3

CREATED BY: B.MACKENZIE REVISION B DATE 07/05/2018

FILEPATH \\HKA-SERVER\PUBLIC\CURRENT JOBS\~PA1088-102 - TRESBP Sediment Tracing

CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56



Notes

1. Aerial photograph sourced from Nearmap, taken 18/05/2016

2. Hydrosurvey dated May 2016

Legend

- - - Sampling Transect

☆ Tracer Release Location (SRE Outlet)

Particle Size:

🟩 XS
🟧 Small
🟥 Medium
🟪 Large
🟦 XL

SAMPLING ROUND	6
DATE(s):	23 OCTOBER 2017
TIME SINCE TRACER RELEASE:	12 WEEKS

PROJECT NO: PA1088 PROJECT TITLE: SRE Sand Tracing Study CLIENT: Tweed Sand Bypassing

MAP 6B

BLUE TRACER
PARTICLE SIZE RESULTS
WEEK 13

NORTH
0 125 250m
Approx. Scale

SCALE 1:7,500 PAGE SIZE A3

CREATED BY: B.MACKENZIE REVISION B DATE 07/05/2018

FILEPATH \\HKA-SERVER\PUBLIC\CURRENT JOBS\~PA1088-102 - TRESBP Sediment Tracing

CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

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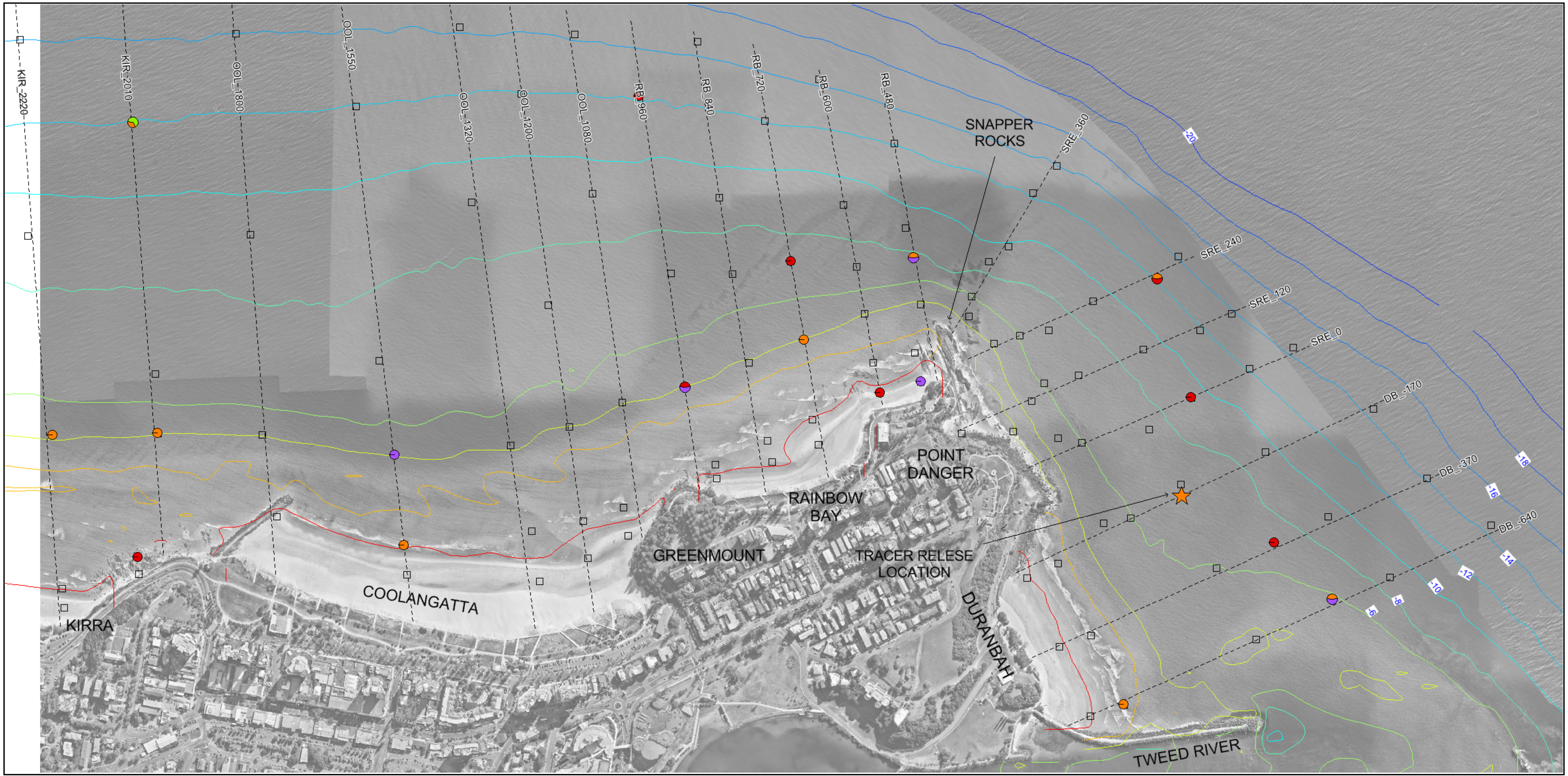

Notes

1. Aerial photograph sourced from Nearmap, taken 18/05/2016
2. Hydrosurvey dated May 2016

Legend

- - - - - - Sampling Transect

★ Tracer Release Location

Particle Size:

🟩 XS

🟧 Small

🟥 Medium

🟪 Large

🟦 XL

SAMPLING ROUND	6
DATE(s):	23 OCTOBER 2017
TIME SINCE TRACER RELEASE:	20 Months

PROJECT NO: PA1088 PROJECT TITLE: TRSBP Sediment Tracing

MAP 7B

RED TRACER
PARTICLE SIZE RESULTS
SPATIAL SAMPLING - 23 OCTOBER 2017

NORTH

0 125 250m
Approx. Scale

SCALE 1:7,500 PAGE SIZE A3

CREATED BY: B.MACKENZIE REVISION B DATE 07/05/2018

FILEPATH \\HKA-SERVER\PUBLIC\CURRENT JOBS\~PA1088-102 - TRESBP Sediment Tracing

CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

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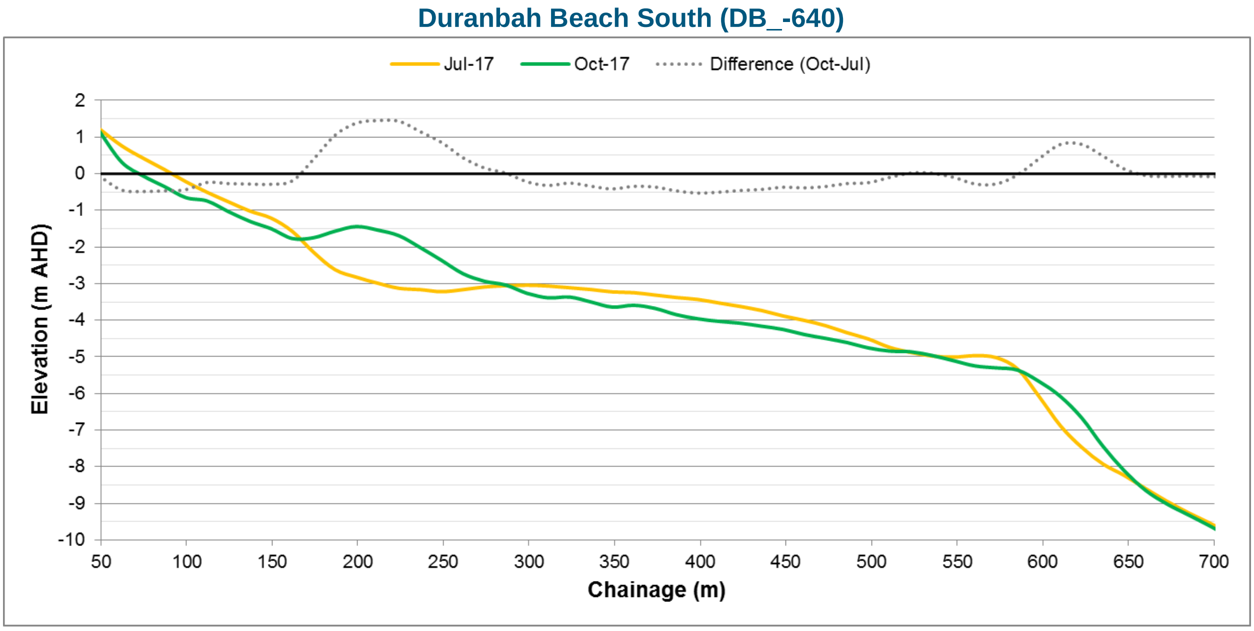
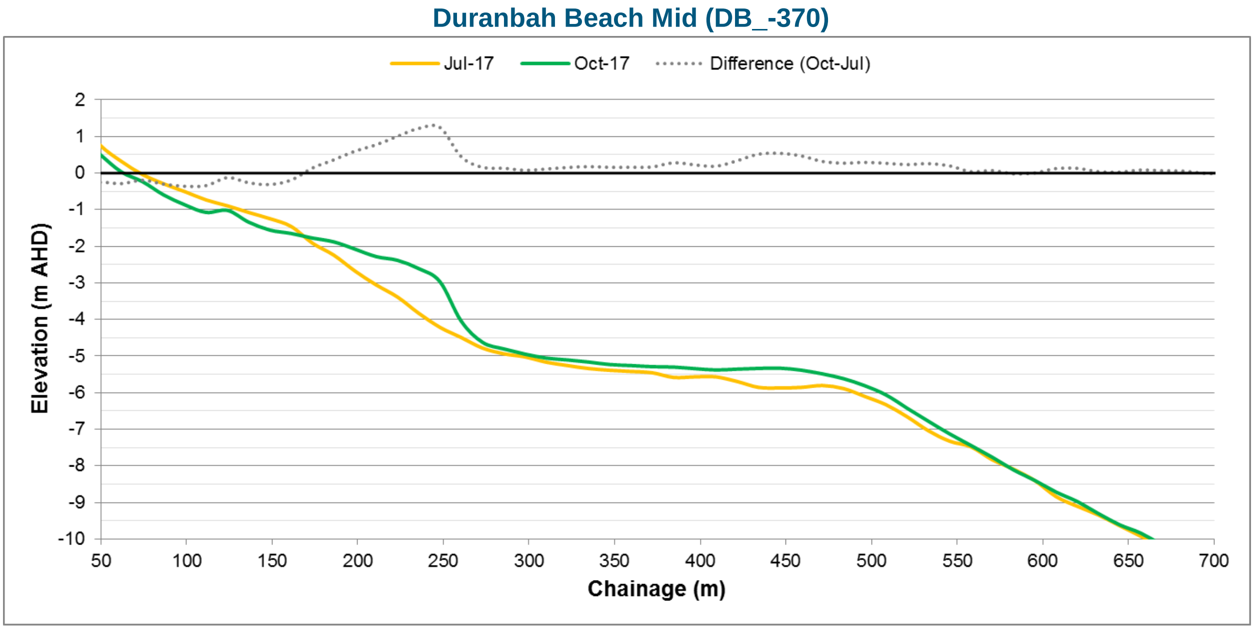
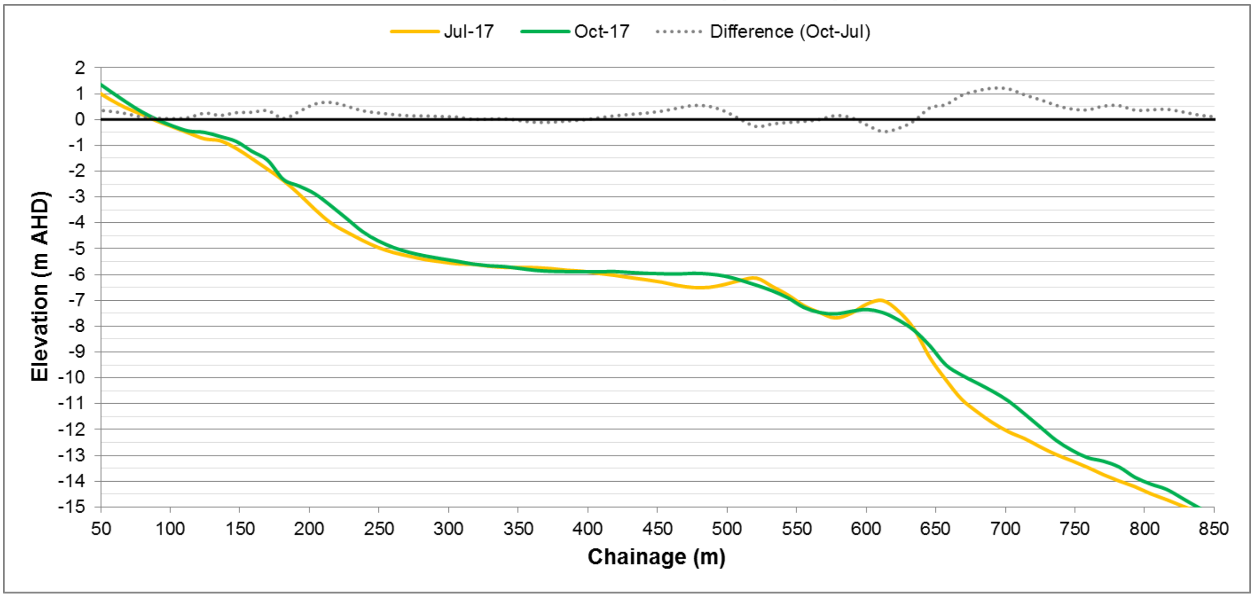
Appendix D – Bathymetric Profiles

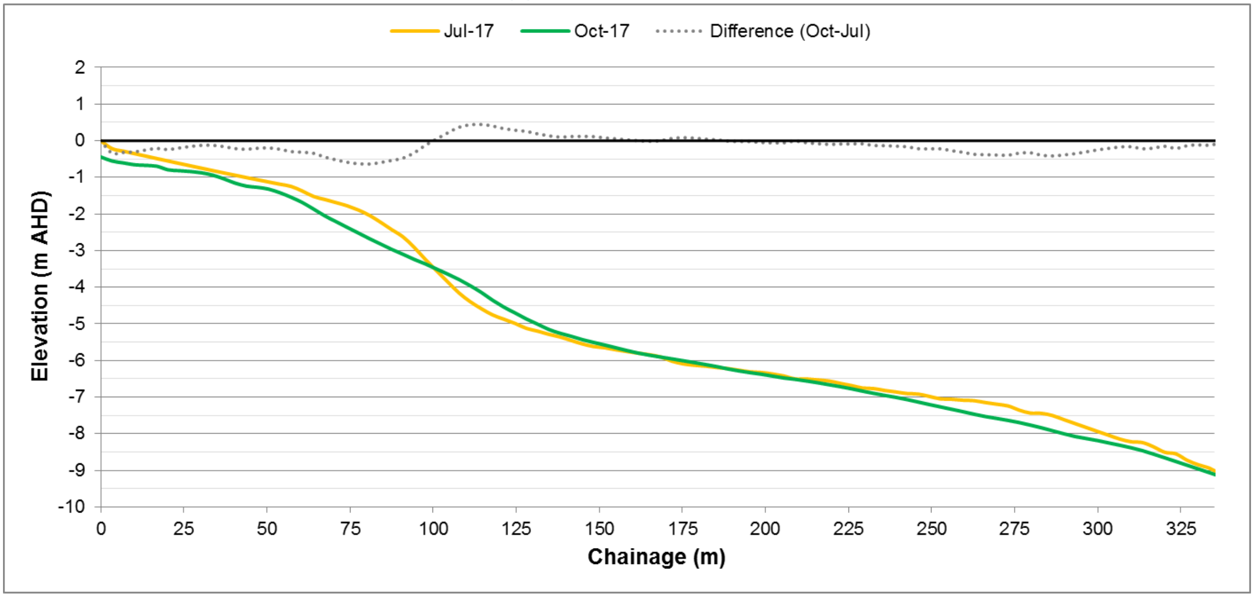




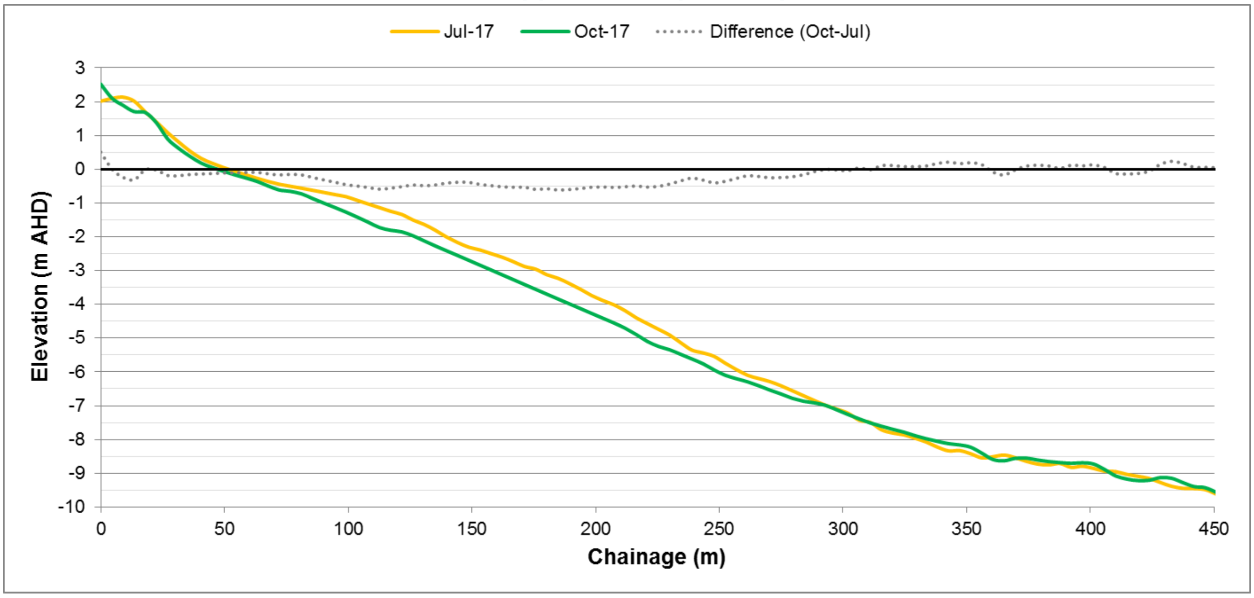
Duranbah Beach North (DB_-170)



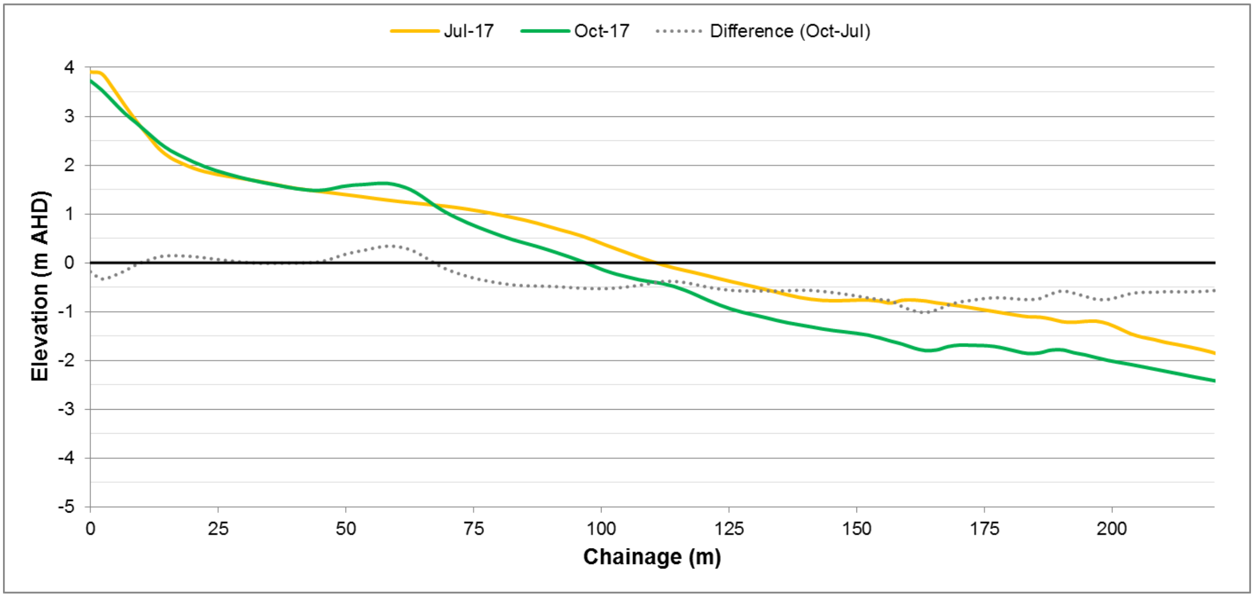
Froggies Beach (SRE_120)



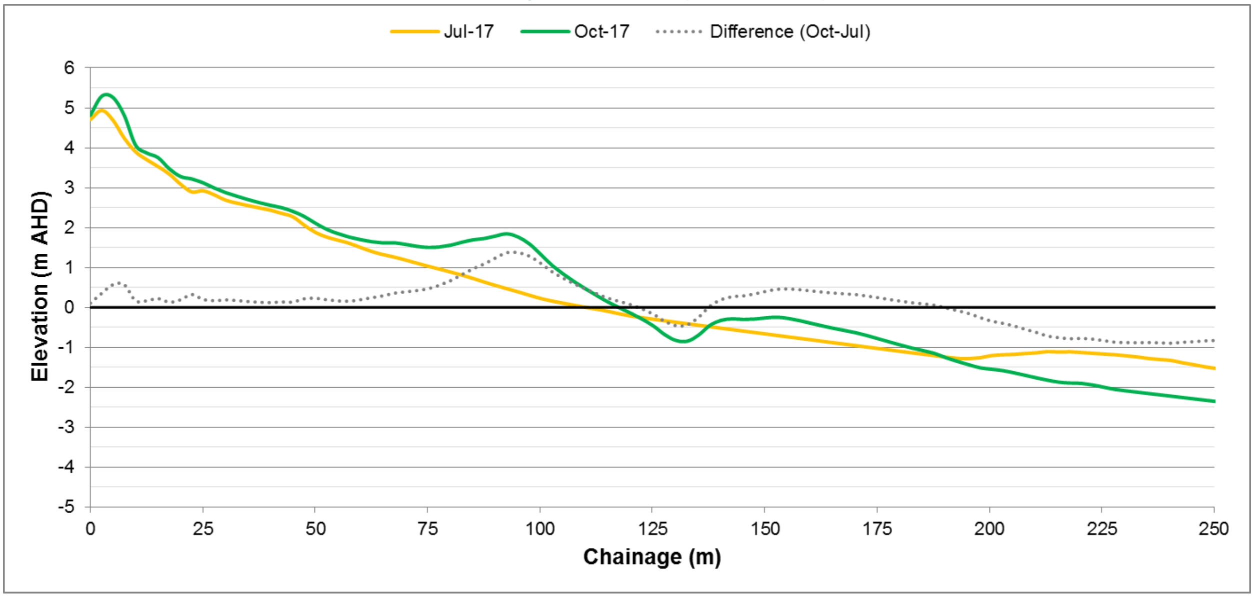
Snapper Rocks (RB_480)



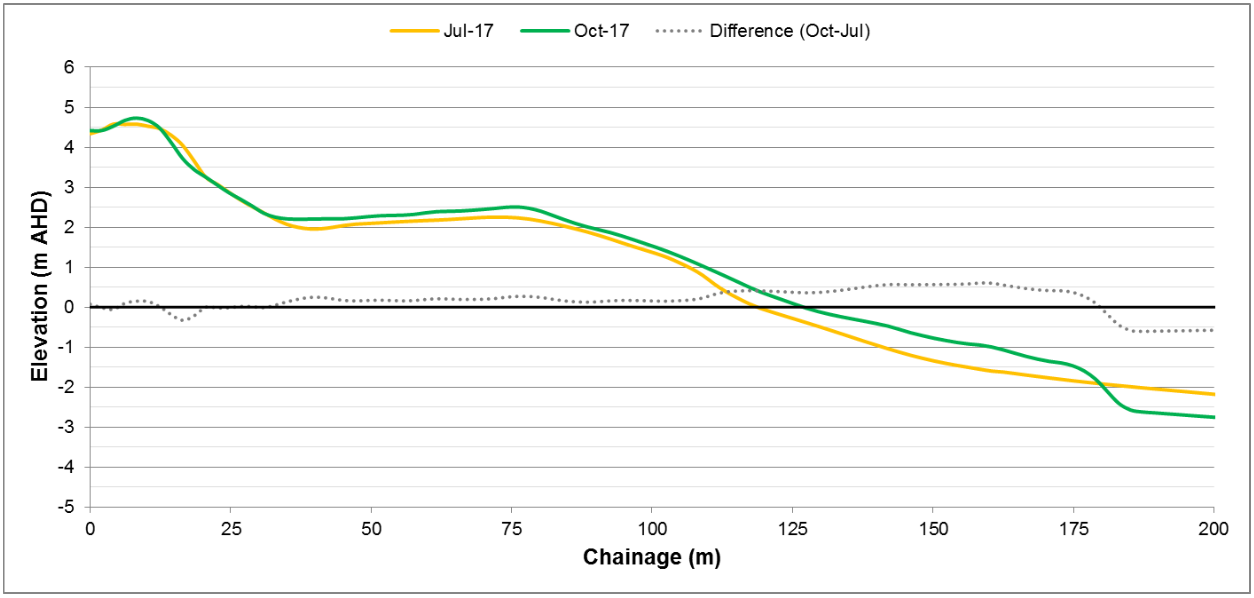
Rainbow Bay (RB_720)



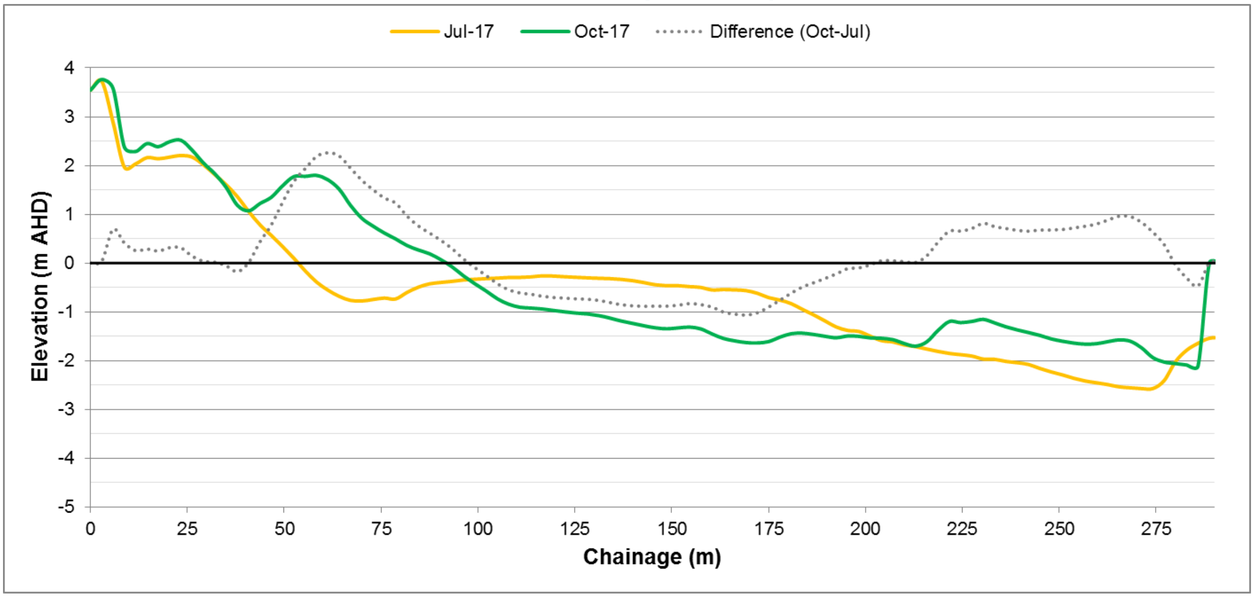
Coolangatta Beach (OOL_1200)



Kirra Groyne (OOL_1800)



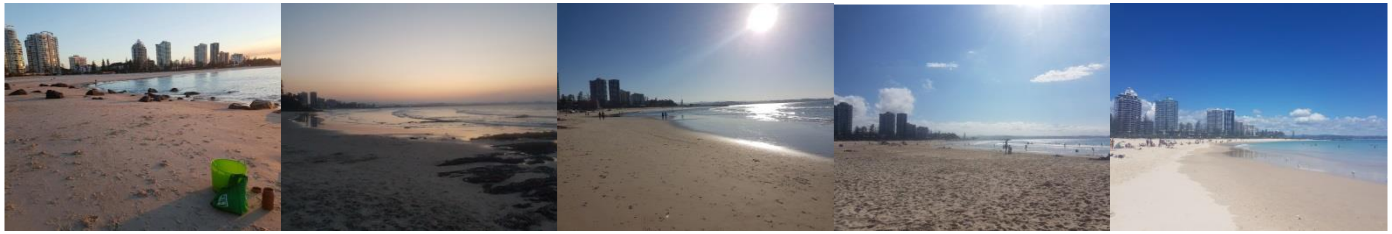
Kirra Beach (KIR_2220)



Appendix E – Beach Photographs

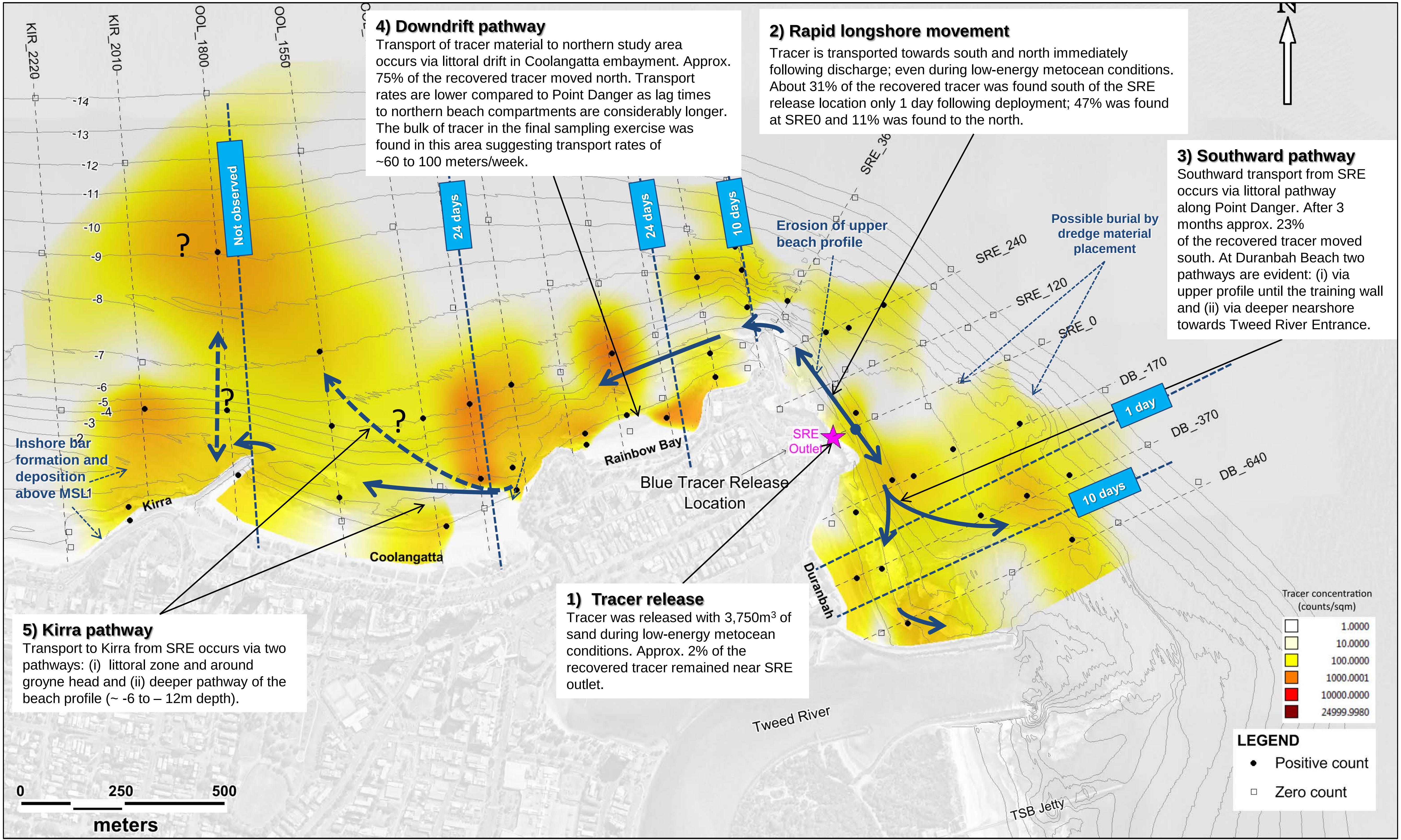
	Week1	Week 2	Week 4	Week 6	Week 10	Week 13
Duranbah						
Froggies						
Snapper Rocks						
Rainbow Bay						

Coolangatta



Kirra

Appendix F – Conceptual Sand Transport Model (Blue Tracer)



1) Tracer release

Tracer was released with 3,750m^3 of sand during low-energy metocean conditions. Approx. 2% of the recovered tracer remained near SRE outlet.

2) Rapid longshore movement

Tracer is transported towards south and north immediately following discharge; even during low-energy metocean conditions. About 31% of the recovered tracer was found south of the SRE release location only 1 day following deployment; 47% was found at SRE0 and 11% was found to the north.

3) Southward pathway

Southward transport from SRE occurs via littoral pathway along Point Danger. After 3 months approx. 23% of the recovered tracer moved south. At Duranbah Beach two pathways are evident: (i) via upper profile until the training wall and (ii) via deeper nearshore towards Tweed River Entrance.

4) Downdrift pathway

Transport of tracer material to northern study area occurs via littoral drift in Coolangatta embayment. Approx. 75% of the recovered tracer moved north. Transport rates are lower compared to Point Danger as lag times to northern beach compartments are considerably longer. The bulk of tracer in the final sampling exercise was found in this area suggesting transport rates of ~60 to 100 meters/week.

5) Kirra pathway

Transport to Kirra from SRE occurs via two pathways: (i) littoral zone and around groyne head and (ii) deeper pathway of the beach profile (~ -6 to – 12m depth).

Erosion of upper beach profile

Possible burial by dredge material placement

Inshore bar formation and deposition above MSL

Blue Tracer Release Location

PROJECT NO: PA1088 **PROJECT TITLE:** SRE Sand Tracing Study **CLIENT:** Tweed Sand Bypassing

Figure F1 – Conceptual Sand Transport Model (Blue Tracer)

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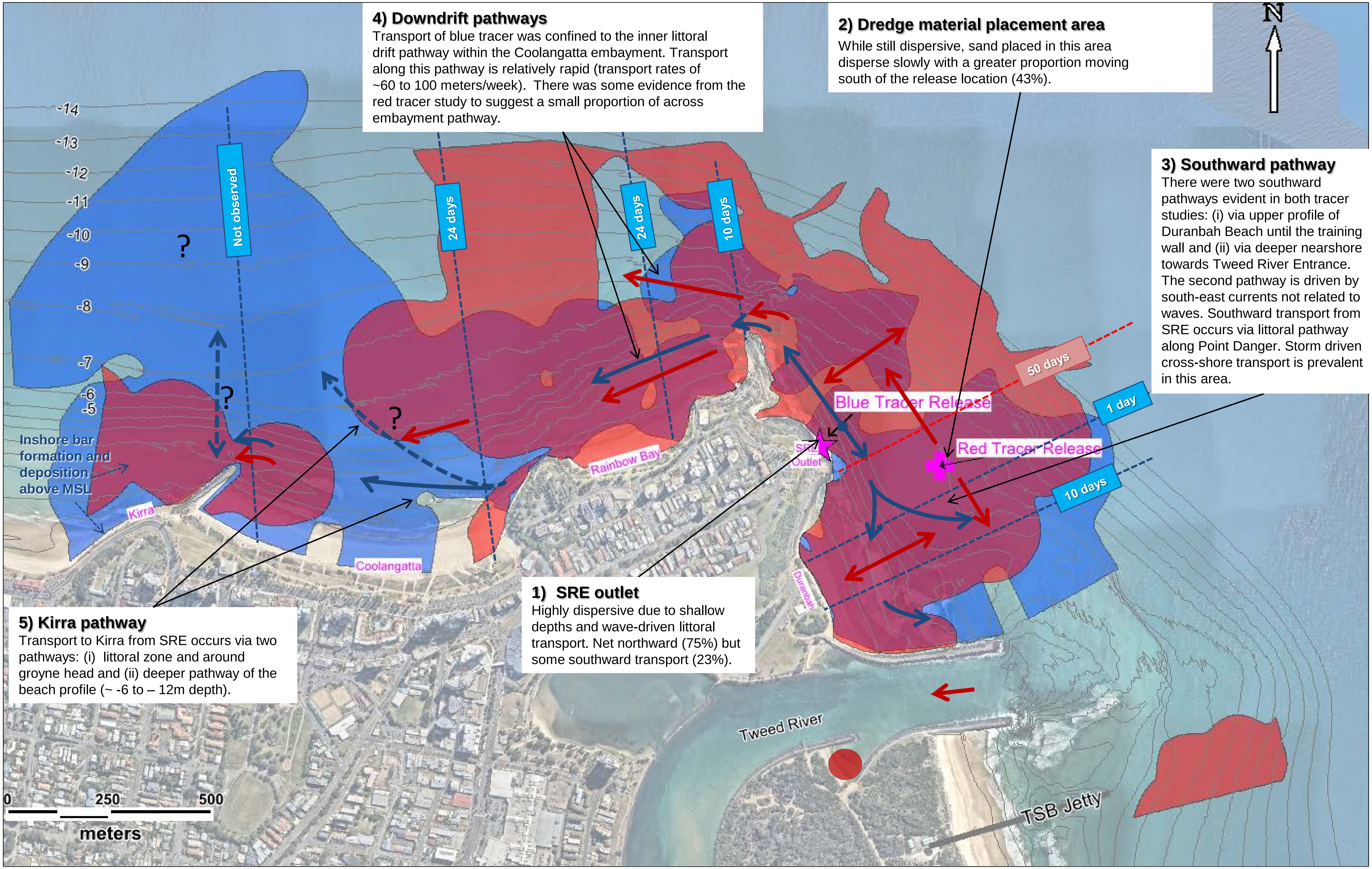
Appendix G – Conceptual Sand Transport Model (Red & Blue Tracers)



4) Downdrift pathways
Transport of blue tracer was confined to the inner littoral drift pathway within the Coolangatta embayment. Transport along this pathway is relatively rapid (transport rates of ~60 to 100 meters/week). There was some evidence from the red tracer study to suggest a small proportion of across embayment pathway.

2) Dredge material placement area
While still dispersive, sand placed in this area disperse slowly with a greater proportion moving south of the release location (43%).

3) Southward pathway
There were two southward pathways evident in both tracer studies: (i) via upper profile of Duranbah Beach until the training wall and (ii) via deeper nearshore towards Tweed River Entrance. The second pathway is driven by south-east currents not related to waves. Southward transport from SRE occurs via littoral pathway along Point Danger. Storm driven cross-shore transport is prevalent in this area.

1) SRE outlet
Highly dispersive due to shallow depths and wave-driven littoral transport. Net northward (75%) but some southward transport (23%).

5) Kirra pathway
Transport to Kirra from SRE occurs via two pathways: (i) littoral zone and around groyne head and (ii) deeper pathway of the beach profile (~ -6 to – 12m depth).

PROJECT NO: PA1088 PROJECT TITLE: SRE Sand Tracing Study CLIENT: Tweed Sand Bypassing

Figure G1 – Conceptual Sand Transport Model (Red & Blue Tracers)

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