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Turbid Plume Measurements – Port of Brisbane Pty Ltd. Dredgers ‘Brisbane’, ‘Amity’, ‘Ken-Harvey’ and ‘Alan M’

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Turbid Plume Measurements - Port of Brisbane Pty Ltd Dredgers 'Brisbane', 'Amity', 'Ken-Harvey' and 'Alan M'

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Title :	Turbid Plume Measurements - Port of Brisbane Pty Ltd Dredgers 'Brisbane', 'Amity', 'Ken-Harvey' and 'Alan M'
Author :	Craig Morgan, Jesper Nielsen.
Synopsis :	Summary of plume turbidity measurements about typical dredging operations by PBPL dredgers 'Brisbane', 'Amity', 'Ken Harvey' and the bed leveller 'Alan M' within the Port of Brisbane.

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EXECUTIVE SUMMARY

The Port of Brisbane Pty Ltd (PBPL) operates a fleet of three dredges and a bed leveller for capital and maintenance dredging works within the Brisbane Port limits. The fleet includes the trailer-suction hopper dredger (TSHD) *'Brisbane'*, the cutter-suction dredger (CSD) *'Amity'*, the clamshell bucket dredger *'Ken Harvey'* and the bed-levelling barge *'Alan M'*.

Dredging and bed levelling of sediments results in turbid plumes of suspended sediment. PBPL undertakes regular monitoring of each dredger and the bed leveller to provide information on the characteristics of a 'typical' plume of suspended sediment created during dredging operations. This information is used to guide the planning and management of dredging and bed levelling operations, particularly when working in locations where impacts to sensitive environmental receptors may be possible.

This report describes the 2011 investigation of plumes of suspended sediment created by the PBPL dredging vessels, with the objective of providing specific information on the characteristics of the turbid plumes.

The most distinctive difference between the turbid plumes created was between those resulting from sediments dredged within the lower Brisbane River estuary and those formed in northern Moreton Bay. The sediments from the Brisbane River estuary consisted of fine textured clays and silts which resulted in brown muddy turbid plumes following their disturbance by dredging. In contrast, sediments dredged by the *Brisbane* from the northern margin of Spitfire Channel in Moreton Bay consisted of sand. Disturbance of the sand resulted in a white, short-lived plume which settled quickly from the water column into the adjoining channel. The sediment plume at Spitfire Channel was therefore considered unlikely to have a potential impact to any sensitive environmental receptors (e.g seagrass meadows).

There were differences in the size and scale of the turbid plumes created by the different dredging vessels and the types of operation involving sediment disturbance. The dredging operations which created the largest and longest lasting turbid plumes involved the dumping of dredged material from the Brisbane River at the Mud Island DMPA by the dredger *Brisbane*. These plumes remained faintly visible at the water surface beyond the boundary of the Mud Island DMPA on both flood and ebb tides. The plumes covered distances of more than 2km. Although the plumes were evident beyond the Mud Island DMPA, impacts to potentially sensitive receptors in the Moreton Bay Marine Park were considered unlikely. This was because there are no known sensitive receptors in affected areas beyond the boundary of the Mud Island DMPA and because there is a past history (70+ years) of dredged sediment placement at the Mud Island DMPA.

Turbid plumes formed by the dredger *Brisbane* whilst dredging the Inner and Outer Bar Cuttings of the Brisbane River on the ebbing tide were formed over comparatively long distances (greater than 1km). The plumes remained visible up to approximately 1-1.5 hours after their formation. The plumes formed by these dredging activities were also considered unlikely to result in impacts to sensitive receptors in the Moreton Bay Marine Park, principally because there are no known sensitive receptors in the affected areas. The size and turbidity of plumes formed by the dredger *Brisbane* whilst dredging at the Inner Bar were small, compared with those created by container and bulk cargo vessel movements to and from the Port of Brisbane.

Turbid plumes formed by the *Amity*, *Ken Harvey* and bed levelling equipment *Alan M/Seahorse* were of a much smaller size at their dredging locations. The potential impacts to sensitive receptors at these sites were considered to be nil, because the plumes were small and there are no known sensitive receptors in the affected areas.

The features of the various dredging plant and the resulting plume characteristics measured at each of the monitoring locations in 2011 are summarised in Table E-1.

Table E- 1 Summary of PBPL Dredging Equipment and Turbid Plume Formation at the Various Dredging Locations

Dredger	*Brisbane*						*Amity*	*Ken Harvey*	*Alan M/Seahorse*
Dredger Type	Trailing Arm Suction Hopper Dredger						Cutter Suction Dredger	Clamshell Dredger	Bed Leveller
Dredging Location	Inner Bar	Outer Bar	Sand spit at Spitfire Channel	Swing Basin, BP Products	Mud Island DMPA		Port of Brisbane (Berth 12)	Colmslie, Entrance to Forgacs Dry Dock	Incitec and Pinkenba Wharves
Type of Operation	Maintenance Dredging	Maintenance Dredging	Maintenance Dredging	Maintenance Dredging	Dredged Material Placement	Dredged Material Placement	Capital Dredging	Maintenance Dredging	Maintenance Dredging
Plume Formation	Continuous, enhanced following hopper overflow	Continuous, enhanced following hopper overflow	Continuous, enhanced following hopper overflow	Continuous, enhanced following hopper overflow	Singular pulse	Singular pulse	Continuous	Intermittent pulses	Intermittent pulses
Tidal Condition	Ebb	Ebb	Flood	Ebb	Flood	Ebb	Ebb	Ebb	Ebb
Dredged Material (Sediment type)	Clay/Silt Mud	Clay/Silt Mud	Sand	Clay/Silt Mud	Clay/Silt Mud	Clay/Silt Mud	Mud surface, Sandy Clay below	Clay/Silt Mud	Clay/Silt Mud
Sediment Placement type	Hopper Discharge at DMPA		Pumped Discharge Onshore to FPE	Hopper Discharge at DMPA			Onshore Pumped Discharge	Barge transport to DMPA	Movement of material to insurance trenches
Background Turbidity (NTU)	7-8	3-4	0.2	8.5	4-5	3	5	26-30	5-7
Background Secchi Disc (m)	0.9-1.0	1.7	6.5-7.0	0.9	1.2-1.3	1.9-2.0	1.2	0.4	1.1-1.0
Intial Plume Dimensions near Surface (m) *	1200L x 30W	1000L x 30W	150L x 50W	150L x 30W	250L x 30W	250L x 30W	0 - 15L x 10W	20L x 20W	200L x 30W
Intial Plume Dimensions near Seabed (m) *	1200L x 50W	1200L x 50W	200L x 200W	150L x 50W	250L x 150W	250 x 150W	200L x 30W	30L x 25W	200L x 60W
Maximum Plume Turbidity (NTU)	65	140	10	105	110	190	40	130	110
Minimum Plume Secchi Disc (m)	0.1	<0.1	0.7	<0.1	<0.1	<0.1	1.1	0.1	0.2
Direction of Plume Travel	North and West	North and West	South and East	North	South and East	North and West	North east for 100m, then North West for 100m	West North West	East North East
Area affected by Plume	Brisbane River Entrance Channel and Shallow intertidal and sub-tidal areas of West Banks	Brisbane River Entrance Channel and Shallow sub-tidal areas of West Banks	Sand Spit and Spitfire Channel	Swing Basin	Mud Island DMPA and nearby adjoining areas	Mud Island DMPA and nearby adjoining areas	Inner Bar Reach	Localised area at entrance to Forgacs Dry Dock.	Localised area at Pinkenba wharf and up to 250m downstream.
Period of Plume visibility (hours)	1.5	1.5	0.75	1	>2.25	>2.25	N/A	N/A	0.3
Ultimate Extents of Plume (m) #	100-150 west	300-400m west	800	200	>2000	>2000	200	60	250
Potential Impact to Sensitive Receptors	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Nil	Nil	Nil
Reason	No known sensitive receptors in Entrance Channel or adjoining on West Banks	No known sensitive receptors in Entrance Channel or adjoining in shallow sub-tidal areas	Sediment Plume directed to Spitfire Channel	No known sensitive receptors in Swing Basin or adjoining in shallow intertidal areas	No known sensitive receptors in Mud Island DMPA or in adjoining affected sub-tidal areas	No known sensitive receptors in Mud Island DMPA or in adjoining affected sub-tidal areas	Very limited area of plume and no known sensitive receptors in affected area of Inner Bar Reach of the Brisbane River	Very limited area of plume and no known sensitive receptors in Entrance Channel to Forgacs Dry Dock	Limited area of plume and no known sensitive receptors downstream of Pinkenba wharf.

* recorded within 5 minutes of completion of discrete dredging or disposal event
# final detectable plume extent before degradation to background levels

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1 INTRODUCTION

1.1 Background

The Port of Brisbane Pty Ltd (PBPL) operates a fleet of three dredges and a bed leveller to undertake its capital and maintenance dredging programme within the Brisbane Port limits. The fleet includes the trailer-suction hopper dredger (TSHD) '*Brisbane*', the cutter-suction dredger (CSD) *'Amity'*, the clamshell bucket dredger *'Ken Harvey'* and the bed-levelling barge *'Alan M'*. All dredging and bed levelling is conducted within approved navigation channels, berths and swing basins. The resultant dredged material is either placed within the Port of Brisbane Future Port Expansion reclamation area or at the Mud Island Dredge Material Placement Area (subject to specific approval).

The creation of turbid plumes of suspended sediment is associated with the processes of dredging and bed levelling of marine sediments. Once disturbed by dredging activities, seabed sediments become entrained in the water column usually creating plumes of turbid water, which are visible from the water surface. The nature and extent of the plumes created depends on a range of factors including the type of dredge, the depth of dredging, the nature of the dredged material, the magnitude and direction of tidal currents, the surrounding bathymetry and the prevailing weather.

On a triennial basis, PBPL undertakes monitoring of each dredger and the bed leveller within its fleet to provide information on the characteristics of a 'typical' plume of suspended sediment created by the operation of the above mentioned fleet. This information is used to guide the planning and management of dredging and bed levelling operations, particularly when working in locations that are in close proximity to sensitive receptors[1].

PBPL commissioned BMT WBM to monitor the plumes of suspended sediment created by each dredger and the bed leveller while undertaking typical operations, with the objective of providing specific information on the characteristics of the plumes. The results of this investigation, which are documented in this report, will be used by PBPL to manage potential risks associated with plumes of suspended sediment generated by their dredging operations.

1.2 Study Objectives

The objectives of this study were to assess the nature and characteristics of the turbid plumes of suspended sediment generated by typical operation of the dredgers *Brisbane, Amity*, *Ken Harvey*, and the bed leveller *Alan M*. These objectives were achieved by the following means:

- Collecting measurements about the dredgers engaged in typical dredging or dredged material placement operations within the Port of Brisbane. For the dredger *Brisbane*, which is employed in most areas of the Port, plume measurements were collected across a range of sediment types at multiple dredging and sediment placement locations.

[1] Sensitive receptors are defined as marine plants or animals which may be affected by reduced light penetration or smothering resulting from sediment entrainment into the water column from dredging operations.

- Using a vessel mounted Acoustic Doppler Current Profiler[2] (ADCP) to record changes in the density of particles through the water column by measuring acoustic backscatter;
- Deploying drogues where applicable to guide the location of ADCP transects and to provide a visible surface indicator of the turbid plume paths;
- Interpreting the measured backscatter readings from the ADCP to determine the total suspended solids (TSS) concentrations, extents, lifetime and range of the plumes;
- Using a calibrated turbidity measuring instrument to measure water turbidity within and external to the dredge plumes. Collecting many turbidity profiles for use in the conversion of ADCP backscatter intensities to suspended solids concentrations and for additional assessment of the sediment plumes;
- Collecting water samples at various depths and over a wide range of TSS concentrations for use in the calibration of the ADCP backscatter intensities and assessment of the sediment plumes.
- The water samples were also used to determine the particle size distribution (PSD) of the suspended sediment;
- Using a Secchi disc to assist in quantifying visible surface turbid plumes;
- Collecting grab samples of the surface sediments where the dredgers were operating to assess the field texture and particle size distribution (PSD) of dredged sediment;
- Identifying the influence of other local factors (e.g. bathymetry, type of dredger etc.) on the suspended sediment concentrations within the vicinity of the dredgers; and
- Identifying any apparent effects of the turbid plumes on sensitive receptors.

1.3 Dredgers and Bed Levellers of PBPL

1.3.1 Overview

PBPL is responsible for the maintenance of 90km of navigational shipping channel, stretching from the northern tip of Bribie Island, across Moreton Bay, and into the Brisbane River. The dredging plant ensures safe, deep-water access to the port is maintained. Maintenance dredging between Fisherman Islands and the Hamilton Reach of the Brisbane River is also undertaken to enable safe passage of vessels visiting berths upstream.

A fleet of dredging vessels is required to manage the range of dredging situations within the Port. The flagship of the dredging fleet is the *Brisbane*, which is the largest dredger of its type based in Australia. The second largest vessel in the PBPL's fleet, the *Amity,* is a cutter suction dredger (CSD) presently engaged in long-term capital dredging for deepwater berth development and future port reclamation. The smallest dredging plant is the clamshell dredger *Ken Harvey,* whilst the small bed

[2] The principle of ADCP operation is that a pulse of sound is propagated through the water column and, if any material is in suspension, as the sound passes through that portion of the water, a percentage of the pulse will be backscattered. The intensity of the backscattered echo is used to estimate the suspended sediment concentration. This method offers the opportunity to remotely measure the suspended load in the water column with a resolution which is sufficient to characterise dynamic processes such as dredging or placement activities and to provide pictorial views of the suspended load. Characterisation of the dredging plumes is generally constructed by undertaking consecutive transects through the plumes formed during dredging.

leveller *Allan M* is employed to relocate material from confined areas, e.g. close to the wharf face, to locations where it can be readily dredged by a larger plant such as the *Brisbane*.

Monitoring of the PBPL dredgers was conducted over 6 days between the 15th May and the 7th June 2011 at the locations within the Port of Brisbane shown in Figure 1-1. The dredge monitoring programme followed a particularly wet summer in South East Queensland which resulted in significant siltation and maintenance dredging requirements within the lower Brisbane River and the Port of Brisbane. Sections 1.3.2 to 1.3.5 provide a brief summary of each of the dredgers and their operational characteristics at the time of plume monitoring.

Title:
Locality Plan

Figure: **1-1**

Rev: **A**

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

N

0 3.75 7.5km
Approx. Scale

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1.3.2 Dredger Brisbane

The *Brisbane* (refer to Figure 1-2), the largest vessel in PBPL's dredging fleet, is an 85m long ocean-going trailing arm suction hopper dredger (TSHD) which performs maintenance and capital dredging works within the Port of Brisbane for around three months of the year and contract maintenance dredging services for Central and North Queensland ports for the remainder.

The *Brisbane* is equipped with two trailing arm suction heads, on the port and starboard sides of the vessel, which are typically lowered and dragged along the seafloor, simultaneously dredging the bed sediments either side of the vessel as it progresses forward. The drag heads are lifted clear of the seabed when moving astern. To efficiently fill the hopper (volume 2,900 m^3) with dredged material, the vessel is usually operated in an overflowing mode whereby the dredged sediments are concentrated within the hopper over time. A telescoping weir within the centre of the hopper can be elevated to maximise the retention of dredged material before discharge from the hopper occurs. Excess water and suspended sediments are ultimately discharged from the hopper via the weir to the underside of the keel, approximately 5 metres below the water line.

Depending upon the nature of sediments to be dredged, dredging to effectively fill the dredge hopper generally lasts between 1 and 1.5 hours, typically without any overflow from the hopper occurring in the first 15-20 minutes. Subsequently, a dredging overflow plume of turbid water is usually obvious as the overflow water and suspended sediments discharged from the underside of the keel are entrained to the water surface by the action of the vessel's propellers operating near the stern of the vessel as it moves ahead. This results in an obvious surface plume of dredged sediment astern of the *Brisbane* for the remainder of the dredging duration.

Following cessation of dredging the *Brisbane* typically delivers its load of material to a designated spoil ground. Within the Moreton Bay Marine Park the spoil ground sanctioned for use by PBPL[3] is the Mud Island Dredged Material Placement Area (DMPA). On arrival at the spoil ground the dredger typically slows to a speed of a few knots and the dredged sediment loaded within the hopper is deposited over the required placement area by opening a series of 5 valves set within the bottom of the hopper, allowing for gravitational settlement of dredged material from the vessel through the water column to the seafloor. Alternatively the dredged material can be pumped ashore from the hopper for settlement within bunded reclamation areas, for example at the Port Of Brisbane Future Port Expansion Area.

Monitoring of the turbid plumes about the *Brisbane* took place whilst the vessel was performing the following duties:

- Maintenance dredging at the Brisbane River Inner Bar Cutting (15th May and 7th June 2011);
- Maintenance dredging at the Brisbane River Outer Bar Cutting (7th June 2011);
- Maintenance dredging at the Port of Brisbane Swing Basin (15th May 2011);

[3] Mud Island Dredged Material Placement Area has been sanctioned for use by PBPL by the QLD Department of Environment and Resource Management.

- Maintenance dredging at Spitfire Channel in Northern Moreton Bay on a flooding tide (21st May 2011);
- Placement of dredged material at the Mud Island DMPA on an ebbing tide (31st May 2011);
- Placement of dredged material at the Mud Island DMPA on a flooding tide (7th June 2011).

Monitoring of the turbid plumes created by dredging in the lower Brisbane River Estuary and Bar Cutting was generally undertaken on the ebbing tide so as to provide the best opportunity to review the impact of the turbid plume characteristics as they might be experienced down-current at potentially sensitive receptor sites in Moreton Bay. Monitoring of the turbid plumes created by dredged material placement activities at the Mud Island Dredged Material Placement Area were undertaken on both the flooding and ebb tides so as to provide information on the spatial extent of the plume and the potential for containment of plumes within the spoil ground.

Figure 1-2 TSHD *Brisbane* lowering her starboard suction head at Spitfire Channel (21st May 2011)

1.3.3 Dredger *Amity*

The *Amity*, the second largest vessel in the PBPL's fleet is a cutter suction dredger (CSD) presently engaged in long-term capital dredging[4] of mud, sand and gravel shoals at the mouth of the Brisbane River for deepwater berth development and future port reclamation. The completed dredging works will ultimately result in the major extension of berth pockets and approaches at the seaward end of the Port of Brisbane and the reclamation of adjoining impounded areas for future port development purposes. The water depth over shoal areas adjoining the Future Port Expansion area in the vicinity of Berth 12, *Amity*'s location of operation during this monitoring program, is approximately 1.2-1.5m

[4] Capital dredging refers to developmental dredging of an area not previously dredged or not previously dredged to the design depth.

below datum with a design dredging depth of 16m below datum being created by the *Amity* within the newly formed berth areas.

The *Amity* is equipped with a large cutter suction head deployed from the bow with pilotage near the bow, stores and accommodation amidships and large dredging and booster pumps and anchoring spuds positioned aft. It has a continuous dredged material handling capacity of approximately 750m^3/hour. Dredged sediments are delivered directly to the adjoining future port reclamation area *via* a 650mm diameter-floating pipeline. Once discharged to the impounded area, the dredged sediments are allowed to settle via a network of wet storages with the excess water ultimately being discharged to Moreton Bay at the seaward extremity of the Future Port Expansion Area.

The *Amity* (refer to Figure 1-3) is positioned by stern spuds and manoeuvres over the dredging area using port and starboard side anchors to swing in arcs up to 30m wide across the dredging area. At the time of monitoring the dredger was positioned with its head facing upstream in approximately 10-12m of water and was working to locally increase the depth to design specifications of approximately 16m below datum. This was achieved by manoeuvring the cutter suction head side to side resulting in a series of submarine dredging faces each approximately 2m deep stepping down to the design depth. Turbidity plumes at the dredging site are created by the cutter head as it cuts into the dredging face.

Monitoring of the *Amity* took place on the ebbing tide whilst the vessel was undertaking:

- Capital dredging and associated reclamation at Berth 12 adjacent to the Port of Brisbane Future Port Expansion Area (31st May 2011)

Figure 1-3 The *Amity* engaged in capital dredging at the Port of Brisbane (31st May 2011)

1.3.4 Dredger *Ken Harvey*

The *Ken Harvey* is a clamshell bucket dredger used for dredging berths and approaches where its small size enables it to operate in confined areas. It consists of a small barge equipped with a bow-mounted crane and clamshell grab with aft accommodation and hydraulic and electrical power packs. It is pushed to the dredging location using a small tug and manoeuvres over the dredging area using a series of port and starboard side anchors as well as head and stern anchors. The *Ken Harvey* (refer to Figure 1-4) has a material handling capacity of approximately 50-80m^3/hour, lifting material from the bed with its 3.25m^3 clamshell bucket and loading into a bottom-dump or split-hull hopper barge moored alongside. Once fully loaded the barge is pushed by tug to the Mud Island DMPA whilst a second barge is pushed into place so that dredging is a more or less continuous process. Turbid plumes are created by the clamshell as it bites into the bed sediments and the bucket is closed, and as the bucket is lifted through the water column. As it is lifted above the water surface a considerable amount of turbid water also spills from the closed bucket back to the water surface.

Monitoring of the *Ken Harvey* took place whilst the *Ken Harvey* was undertaking maintenance dredging at the approaches to the Forgacs dry dock at (16^{th} May 2011).

Figure 1-4 The *Ken Harvey* undertaking maintenance dredging at the approaches to the Forgacs dry dock at Colmslie (16^{th} May 2011)

1.3.5 Bed Leveller *Alan M*

The bed leveller *Alan M* was the smallest item of dredging plant monitored. The *Alan M* (refer to Figure 1-5) consists of a 12m long barge equipped with a stern-mounted blade, which is used to grade and level the bed sediments adjoining existing piles and wharf areas. It is pushed and positioned using the small tug *Seahorse*. The blade is similar in shape and function to that found on conventional earthmoving equipment such as a road grader. The depth and angle of the blade is controlled from the wheelhouse of the *Seahorse*. The bed levelling unit, whilst operating in fine silt and mud, has a dredged material movement capacity of approximately 100-150m^3/hour.

The *Alan M* and *Seahorse* work together to grade the berth face areas such that the blade is lowered, angled and pushed forward and along the face of the wharf into the prevailing tidal currents. In plan view, the bed levelling process follows a number of consecutive 'C' shaped dredging cycles to remove the accumulated sediments from the quayline of a berth. The lower section of the 'C' represents the travel path moving into the berth where the bed levelling blade is lowered to the correct depth, the middle section of the 'C' represents the distance along the quayline from which the sediment is graded and the upper section of the 'C' represents the departure from the quayline where the material accumulated against the blade is typically moved offshore into an over-dredged pocket, awaiting future dredging by larger dredging plant. Turbidity plumes are created as the levelling blade is moving sediments along the sea floor causing resuspension of the sediments in the water column.

Monitoring of the *Alan M* took place whilst it was undertaking:

- Bed levelling at Incitec South Wharf (1st June 2011); and
- Bed levelling at Pinkenba Wharf (1st June 2011).

Figure 1-5 The bed levelling barge *Allan M* and tug *Seahorse* working at Pinkenba Wharf (1st June 2011)

2 METHODOLOGY

2.1 Overview

Monitoring the operations of the different dredgers and bed leveller took place over a range of locations each with a potentially unique set of sediment types, hydrodynamic conditions and background levels of suspended sediment. Furthermore the range in dredge types, sizes, capacities and means of handling dredged material were sufficiently varied so that each operation was unique and an individual chapter has been prepared for the analysis of the plumes of suspended sediment resulting from operation of each dredger – refer to Chapters 3 to 11.

The means of collecting and analysing the data for each of the nine operations were similar with the field team adapting and improvising where necessary to suit the conditions for the specific dredging or bed levelling operation. Sections 2.2 and 2.3 provide details on how the data was collected and analysed whilst chapters 3 to 11 describe those variations adopted for the individual dredging operations.

In general, the measurement of turbid plume characteristics down-current of the dredging plant was compared with the background measurement of water turbidity immediately up-current of the dredger or the placement area. Alternatively, background measurements of turbidity and ACDP backscatter were collected prior to the arrival of mobile dredging plant such as the *Brisbane* or the *Allan M* and these measurements were then compared with those obtained during the dredging or placement activities. The direction of movement of the turbid plume was identified by drogue tracking allied with ADCP backscatter intensities evident in either cross or long sectional transects through the plumes. Water quality (turbidity) profiling, water sampling, Secchi disc transparency measurements and ADCP transects through the plumes at regular intervals after their formation or at distances downstream of their formation were used to describe the spatial and temporal characteristics of the turbid plumes. Water and sediment sampling and analysis procedures for TSS were undertaken in accordance with the Department of Environment and Resource Management (2010) Monitoring and Sampling Manual Version 2 - Environmental Protection Water Policy 2009.

2.2 Survey Logistics

Prior to each of the monitoring dates, the masters of the dredgers *Brisbane*, *Amity, Ken Harvey and Alan M* were briefed by PBPL environmental personnel on the proposed suspended sediment measurement exercises and were requested to execute dredging operations following standard procedures and work methods. With the exception of plume measurements at the Swing Basin, PBPL environmental personnel were responsible for the selection of typical dredging areas for monitoring the dredge plumes from the various dredgers.

Turbid plume measurements were undertaken from the 6m BMT WBM survey vessel *Resolution II*, which was able to communicate and co-ordinate measurement and sampling activities with the dredgers *via* mobile telephone or VHF marine radio. Where possible, BMT WBM survey personnel met with the respective dredge masters in person prior to starting measurements to discuss the planned monitoring operations and the specific characteristics of the dredger or bed leveller.

2.3 Monitoring Plumes of Suspended Sediment

2.3.1 Drogue Deployments

Drogues were used for the co-ordination of suspended sediment plume measurements in this study. Deployed within a turbid plume drogues provided a visual indicator of the plume path over time which assisted the planning of progressive measurements (such as ADCP backscatter transects, turbidity profiles, Secchi disc transparency measurements and the collection of water samples) in areas of highest sediment concentrations. This was particularly important when the near surface turbidity levels decreased with time after plume formation.

The drogue devised by BMT WBM shown in Figure 2-1 consisted of a sub-surface vane deployed at a depth consistent with the plume being tracked, a surface float and a marker flag with a light for night-time visibility. The drag force of water currents acting on the submerged vane exceeded the wind drag on the drogue mast and hence its path was generally representative of the movement of turbid plumes. In instances where collision of the drogue with dredgers and/or other vessels was possible, a small spar drogue consisting of a 2m long brightly coloured PVC tube weighted at one end was substituted. The spar drogue was, however, not as effective as the primary drogue, being more susceptible to wind interference since it was positioned higher in the water column.

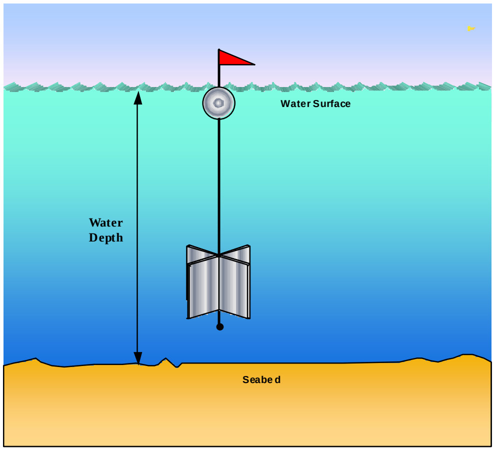

Figure 2-1 Typical BMT WBM drogue configuration

Figure 2-2 Drogue deployed at Mud Island DMPA (7th June 2011)

2.3.2 Sediment Grab Samples

Grab samples of sediment from the sea bed were collected to describe the texture of the sediments being dredged. At all dredging areas surface sediment samples were collected using a small Van Veen grab (gape of $0.028m^2$) which provided a basis for a field description of the sediment texture. The sediment samples were analysed by Trilab Laboratory at Newmarket for sediment particle size using Australian Standard sieve sizes from 2.36mm down to 75 micron.

In most instances, the laboratory analysis of sediment particle size by sieving the samples provided a limited insight over and above the field texture assessment since the percentage of fines in all samples except those at Spitfire Channel constituted over 90% of the sample.

2.3.3 Secchi Disk Surface Water Clarity Measurements

A 30 cm diameter Secchi disc with graduated 0.5m line markings was used to measure the transparency of surface water within and external to the turbid dredge plumes. The disc with alternating black and white quadrant markings was lowered into the water column until the disc vanishing point was found and this depth measurement was recorded as the surface water clarity for the profiling location. The Secchi disc visibility measurements provided a useful comparative check on the validity of near surface turbidity measurements.

2.3.4 Water Samples and Turbidity Measurements

Water samples were collected from all dredging and placement plumes using a 12 VDC Jabsco pump sampler. Its 18mm diameter water intake was attached to the body of a YSI Model 6600 submersible water quality (turbidity) profiling sonde[5] connected via a 30m cable to a YSI Model 650MDS multi-parameter surface display and data logging unit. Time tagged turbidity profile measurements at the YSI sonde were recorded every 2 seconds on the 650 MDS handset. At any moment in time, plume turbidity measurements were related with water sampled at a particular depth horizon as well as the vessel's position (via dGPS) and the ADCP's backscatter intensity in the plume recorded in the ADCP software WINRIVER II running on a laptop computer aboard *Resolution II*.

The water samples were collected in 1L polyethylene bottles and were subsequently analysed in the laboratory for Total Suspended Solids (TSS) concentrations. Selected water samples representative of those from each dredging area with highest suspended solids concentrations were submitted for further laboratory analysis of the size of suspended sediment particles using laser diffraction methods. A total of 56 water samples were delivered to the Queensland Health Forensic and Scientific Services Nutrients Laboratory at Coopers Plains for TSS analysis. Following TSS analysis, seven samples selected on the basis of their high TSS results were directed to *Microanalysis Australia* at Victoria Park, WA for analysis of the particle size of the suspended material.

To convert ADCP backscatter to a recognised measure of water turbidity such as TSS concentration it was necessary to develop an empirical relationship between TSS in the collected water samples and water turbidity measured by the YSI Model 6600 water quality instrument. The most accurate and efficient means for conversion of ADCP backscatter to TSS was to use the extensive turbidity

[5] The instrument's turbidity sensor was two-point calibrated before use in distilled water (0.0NTU) and in a AMCO 100NTU polymer bead solution.

data set (measured in Nephelometric Turbidity Units, NTU) compiled during plume profiling as the basis for conversion.

The TSS concentrations in mg/L were paired with the corresponding turbidity NTU readings. The relationship between turbidity and TSS should be close to linear with the gradient dependent on the nature of the suspended sediments. The specific relationship derived based upon the analysis of all collected samples (n=56) from Moreton Bay and the lower Brisbane River is shown in Figure 2-3.

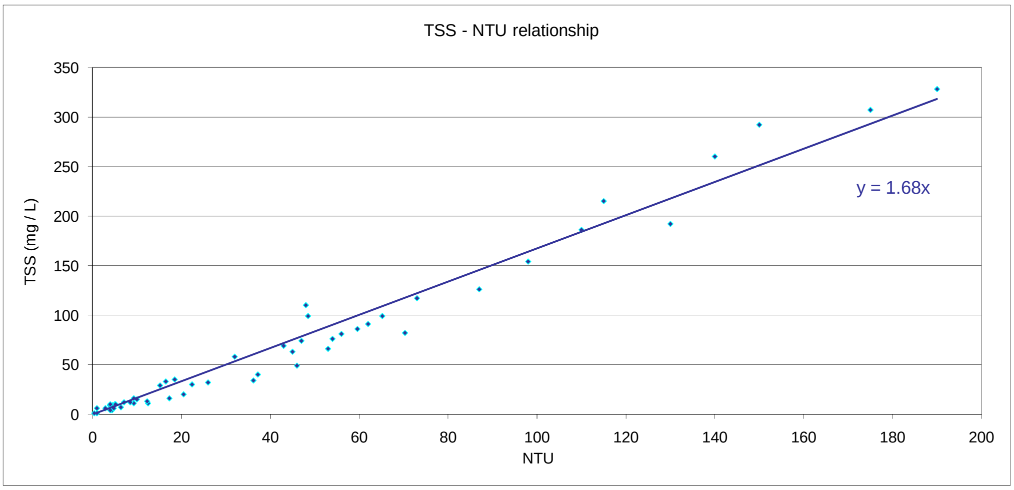

Figure 2-3 Relationship between Turbidity (NTU) and TSS (mg/L) – All Data

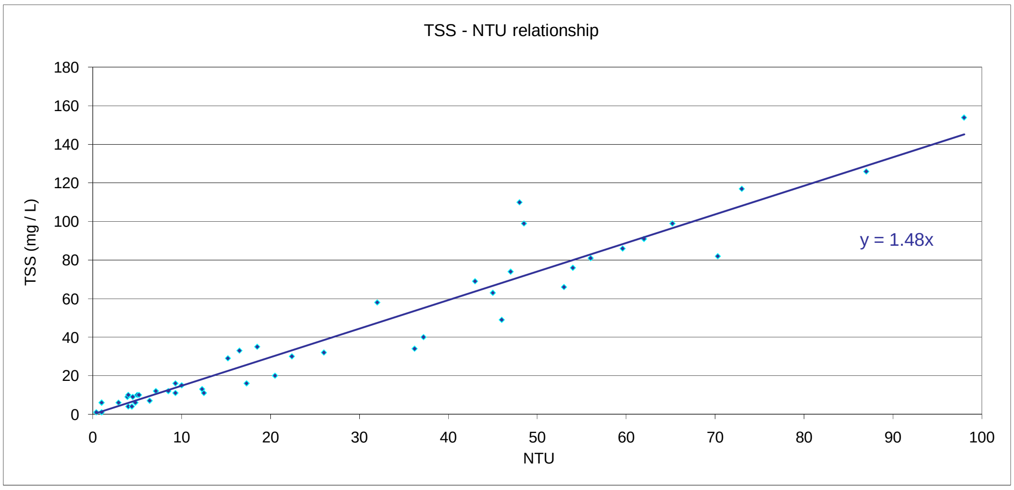

Figure 2-4 Relationship between Turbidity and TSS, where turbidity < 100NTU

Figure 2-4 shows the refined linear relationship between turbidity and the corresponding water sample TSS concentrations at lower turbidities. The relationship for lower turbidity measurements was derived to compensate for the slight over-prediction of TSS concentrations for waters between 15NTU and 100NTU evident when using the overall relationship. All turbidity profiling measurements obtained using the YSI Model 6600 Sonde were converted to TSS concentrations using these two relationships, based upon the laboratory based TSS concentrations.

The conversion of the ADCP backscatter readings to TSS was undertaken as outlined in section 2.3.5 below.

2.3.5 ADCP Transects

Acoustic Doppler Current Profilers (ADCPs), as the name suggests, were designed and primarily used for the collection of current velocity (speed and direction) data. They function by emitting sound waves at a given frequency and listening for the frequency shift of returning signals reflected (backscattered) by particles throughout the water column. The velocity of the particles and hence the current speed and direction is determined by the discrepancy between the frequencies of the emitted and reflected signals. The intensity of the reflected sound waves gives an indication of the concentration of the suspended particles, so an ADCP, once properly calibrated, can become a robust tool for determining the concentration of suspended sediments throughout the water column.

As a means of collecting TSS data an ADCP offers several advantages over other traditional methods. Although the accuracy of an ADCP's TSS concentrations is unlikely to equal that of laboratory analysis of collected water samples, the TSS concentrations can be obtained from the entire water column virtually instantaneously. Discrete water sampling or turbidity profiling cannot provide such detailed spatial resolution of measurements through the water column. When the ADCP is vessel mounted it can record multiple transects through the plumes of suspended sediment indicating both spatial and temporal changes in the plume density. Hence, after careful conversion of backscatter intensities to TSS, an ADCP can provide in a single measurement campaign an unparalleled insight into the nature of plumes generated by dredging or bed levelling equipment. An example of the ADCP's ability to illustrate the nature of dredge plumes is shown in Figure 2-5. It shows the residual turbid plume from the dredger *Brisbane* overflowing during dredging of the Inner Bar Cutting western toeline at the mouth of the Brisbane River.

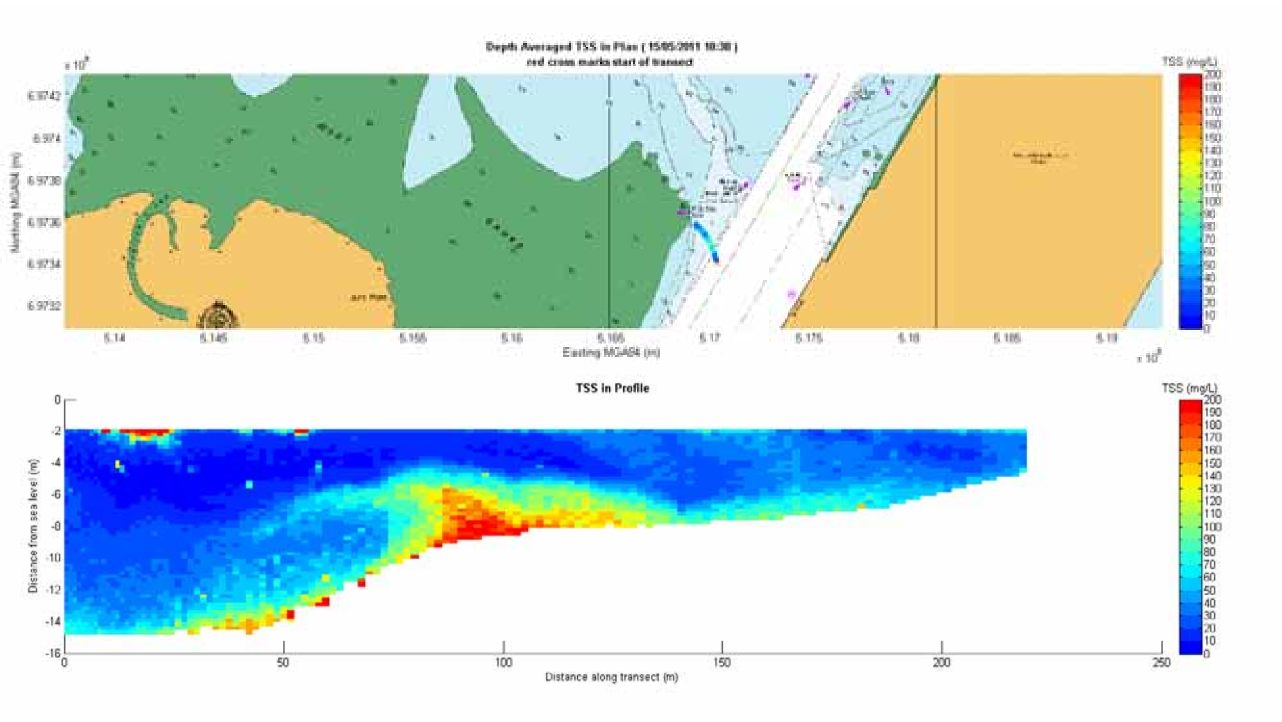

Figure 2-5 Example of an ADCP's ability to illustrate turbid dredge plumes

TSS data spanning the range of concentrations (resulting from conversion of the turbidity profile measurements over the full range of water depths) was used to convert the ADCP backscatter readings to TSS values.

The TSS data from the turbidity profiles was paired to the corresponding ADCP backscatter readings using the time and depth information associated with both data sets. The process of selection of various coefficients used to convert the ADCP's backscatter signals into TSS concentrations was fine tuned using the software package SEDIVIEW. SEDIVIEW provides the user with a graphical interface especially useful in the data conversion (backscatter intensity to TSS) and calibration and verification processes.

In accordance with the SEDIVIEW manual, independent calibrations of the ADCP backscatter readings were undertaken for each day of the dredge plume data collection campaign as the backscatter intensities were sensitive to the set-up of the ADCP. In a manner similar to the turbidity profiling instrument, the ADCP backscatter intensities vary with the nature and characteristics of suspended sediment at each location. The coefficients used in the calibration of the ADCP backscatter readings were consistent between almost all measurement sites except for those identified for the dredger *Brisbane* whilst it was operational at Spitfire Channel in northern Moreton Bay, which differed from other locations. When calibrating the ADCP backscatter intensity to TSS it was important to recognise potential sources of error which could have resulted in underestimates or overestimates in TSS concentrations, particularly those at shallow or deep water depths.

For example, fine air bubbles entrained in the water column by a dredger's (or tug's) propellers reflect the ADCP's emitted sound waves in a similar manner to suspended sediment and this can lead to overestimates in the TSS concentrations where air bubbles are present (usually in the upper part of the water column). In such instances corresponding independent measurements of turbidity through the water column and the collection of water samples for TSS analysis complimented the use of the ADCP since they were not affected by the presence of air bubbles and were reviewed to discriminate overestimates within the raw ADCP data. As an example, the raw ADCP plots of TSS suggested that that the surface turbid plumes created by the tug *Seahorse* during bed levelling operations shown in Figure 2-6 had a surface TSS in excess of 200mg/L. However the corresponding turbidity measurements and water samples revealed the surface plumes to have TSS concentrations no greater than 100 mg/L.

A reasonable calibration (ADCP backscatter intensity to TSS) was ultimately achieved for all days of the data collection campaign, through careful comparison and scrutiny of each comparative data set (ADCP backscatter, turbidity, TSS based upon laboratory analysis of water samples). However, depending upon the type of dredging plant some transects still include potential contamination of the upper water column TSS signal by entrained air bubbles. These are indicated where presented in the report.

Other potential error sources included the difficulty of getting exactly comparative measurements between the ADCP and the turbidity profiling instrument due to high spatial and temporal variability of the near field turbid plumes. Although every effort was made to ensure that accurate locations were achieved for collection of the samples in time and space, often the initial turbid plume conditions were sufficiently variable such that external effects such as the prevailing wind, currents or vessel wash acting upon the research vessel would result in its departure from the targeted plume centroid.

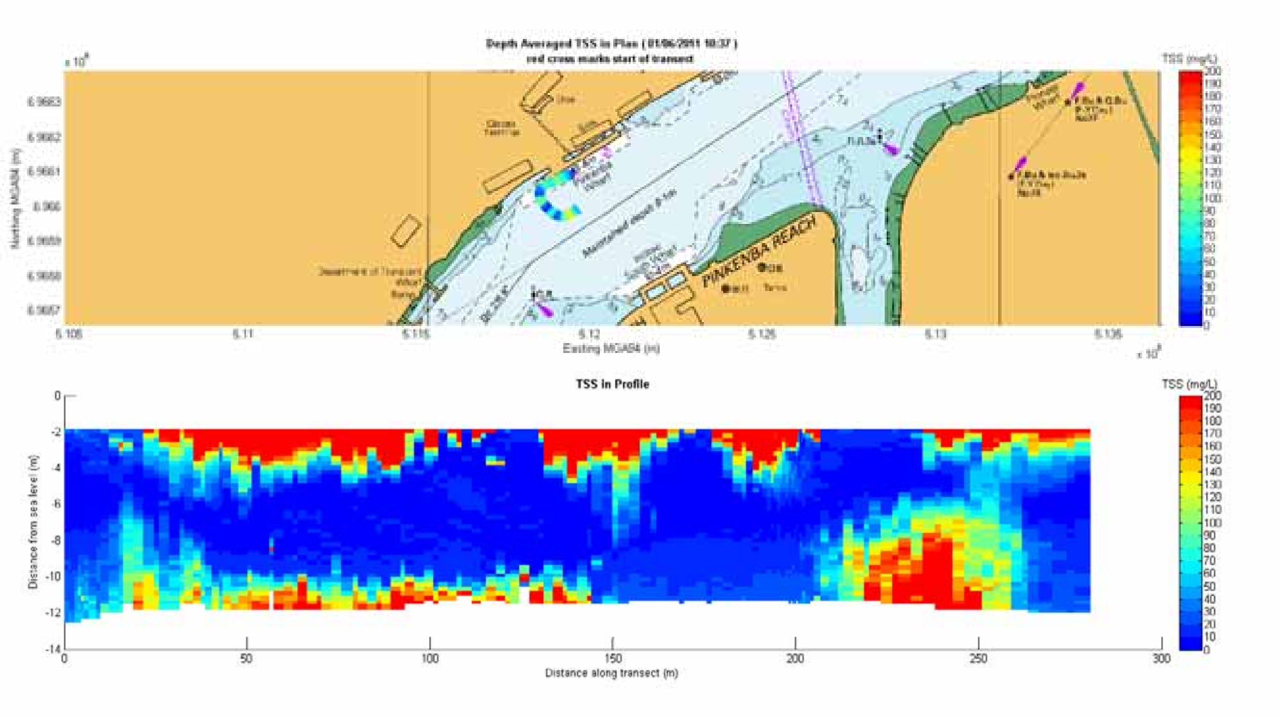

Figure 2-6 Example of air bubbles inducing overestimates in raw surface TSS concentrations recorded by the ADCP. (Surface plumes from the *Alan M* and *Seahorse* were actually less than 100 mg/L according to the measured turbidity and TSS derived from water sample analyses)

For the purposes of concise reporting, a limit of 3 ADCP TSS transects were shown depicting the turbid plumes for each type and location of dredging or placement presented within the report. The three figures were selected to best illustrate the range of plume conditions during the monitoring period. Appendices A to I contain the full suite of ADCP TSS transects recorded over the six days of plume measurements.

In some instances where multiple plumes were recorded at a study location, the ADCP TSS plots shown within the report may not follow a time history sequence, but were selected to show salient features of plume development.

3 DREDGER 'BRISBANE' AT INNER BAR CUTTING

3.1 Observations and TSS Plots

Table 3-1 shows a schedule of operations and a summary of observations for the monitoring of the dredger *Brisbane* at the Inner Bar Cutting on the morning of 15th May 2011. Figure 3-1 illustrates the *Brisbane* undertaking maintenance dredging in the Inner Bar Cutting during turbid plume measurements.

On the 15th May 2011, the *Brisbane* dredged the western toe-line of the Inner Bar Reach of the Brisbane River between the Inner Bar Beacon and Luggage Point with both suction heads operational. Dredging was undertaken whilst slowly proceeding into Port, stemming the ebbing tide. The dredger undertook dredging on two occasions punctuated by sediment placement at the Mud Island Dredged Material Placement Area. On the first dredging occasion there was a period of approximately 15-20 minutes of dredging before the start of overflow from the dredge hopper. Efforts to gather ADCP data on the first dredging run between 07:30 and 08:50 were hampered by problems with the ADCP operating software and also by surrounding vessel traffic.

Measurements of plume dimensions and turbidity were conducted during the second dredging event between 09:50 and 11:05. Background turbidity levels in the channel were typically 7-8NTU with corresponding Secchi disc measurements of approximately 0.9-1.0m. The shallow water overlying West Banks was visibly more turbid with background water turbidities being approximately 18-20NTU, with a corresponding Secchi disc measurement of 0.4m. The shallow water exposed the seabed sediments on West Banks to the effects of wind waves, tidal currents and vessel wash to a greater extent than elsewhere about the channel.

The surface turbid plume created by the *Brisbane* was linear along the channel alignment estimated as being approximately 1200m in length at the completion of dredging and between 30m and 50m in width, depending upon the time after plume formation. Turbidities of up to 65NTU were measured in the centre of the dredge plume, immediately after passage of the dredger. Surface turbidities (in the uppermost 2-3m of the water column) approximately 100-150m astern of the dredger (estimated 2-3 minutes after passage of the dredger) were, however, more typically 20-25NTU with levels above approximately 40NTU being measured occasionally. The surface plume from dredging was able to be observed visually for a period of up to approximately 45 minutes after dredging and was evident using the ADCP for a period in excess of 1 hour.

ADCP transects shown in Figure 3-2 to Figure 3-4 illustrate the turbid plume TSS concentrations recorded about the *Brisbane* whilst dredging at the Inner Bar Cutting on the 15th May 2011. Appendix A provides a compilation of all ADCP TSS transects undertaken about dredger *Brisbane* whilst dredging the Inner Bar Reach on the ebbing tide on the 15th May and also on the 7th June 2011[6].

[6] Surface plumes recorded immediately astern of the *Brisbane* usually have entrained air bubbles in the upper section of the water column, which result in a local overestimation of the TSS concentration. Unfortunately, this is an unavoidable aspect of the ADCP plume measurement methodology and should be kept in mind when reviewing the ADCP TSS plots for the dredger *Brisbane*.

Figure 3-2 shows a cross sectional ADCP TSS transect through the stern wake of the dredger (shortly after passage of the dredger), showing the typical turbid plume development after hopper overflow. It shows a plume consisting of sediments lost from the dredge hopper and settling from the vessel hull as well as sediments disturbed by each of the suction heads located either side of the dredger track.

Figure 3-3 shows a similar cross sectional transect recorded approximately 5 minutes later, which shows the further settlement of suspended sediments within the plume and the gradual progression of settled material into the deep areas of the channel.

Figure 3-4 shows the movement of the turbid plume into the shallows adjoining West Banks. The ADCP transects and current measurements through the overflow plume suggested that the surface turbid plume was quickly advected north and west to the shallow turbid water covering West Banks at the mouth of the Brisbane River. This limited the capacity to track and measure the surface plume where it blended with the higher background turbidity water overlying the banks, since the water depths were less than 1m in most instances.

The pattern of water and plume movement of the surface dredge plume evident from the ADCP was confirmed by drogue tracking. Due to the constant vessel traffic using the navigation channel, a small spar drogue was deployed only after the surface plume had moved to the edge of the channel, approximately 5 minutes after overflow. The first drogue deployment indicated that the surface waters were quickly moved onto West Banks, adjoining the entrance channel. A second drogue deployment approximately 30 minutes after overflow confirmed the consistent north-westerly pattern of surface plume movement. Limited sampling of the bed sediments on West Banks did not indicate the presence of any seagrass in the vicinity of the turbid plume measurements.

The surface dredge plume moved independently of the disturbed sediments closer to the seabed. The subsurface plume tended to slide downslope into deeper water towards the centre of the channel alignment and was then advected in a north easterly direction along the channel alignment on the ebbing tide.

It was a point of interest that the size and turbidity of plumes formed by the dredger *Brisbane* whilst dredging at the Inner Bar on the 15th May 2011 were small, compared with those simultaneously created by container and bulk cargo vessel (and associated tug) movements to and from the Port of Brisbane. These plumes were formed by the propulsion systems of the vessels and their attendant tugs, suspending the fine muddy bed sediments in the Inner Bar Reach whilst manoeuvring to and from the nearby berths.

Table 3-1 Schedule of Operations, Dredger *Brisbane* at Inner Bar Cutting: 15th May 2011

Time	Event	Comments
07:14	Predicted high water of 2.1m.	Predicted ebb tide range at the Brisbane bar of 1.8m. Cool clear morning west to south westerly winds at 12 knots.
09:30	Sample background conditions within channel at Inner Bar Beacon.	Secchi disk: 1m, turbidity 6-8NTU in channel.
09:47	*Brisbane* begins dredging into Port.	Dredging of western toe-line of channel
10:05	Dredge hopper overflow begins.	Dredge master phones to notify us of overflow, turbid brown plumes evident at water surface astern of dredger. Secchi disc: 0.15m within plume. Turbidity typically 15-25NTU in plume.
10:30	Large container ship pulls out from berth assisted by tugs.	Large sediment plumes generated by passing tugs and ship, much larger and visibly more turbid than *Brisbane's* dredging plume.
11:00	Final plume measurement at Inner Bar Cutting	Max turbidity of 65NTU at 11.8 m depth
11:05	Collect grab sample of dredged sediment	Dark grey fine mud with detectible traces of very fine sand.
11:15	Head to BP products wharf for further plume measurements.	
13:44	Predicted Low water of 0.3m	

Figure 3-1 Surface dredging plume generated by the *Brisbane* at the Inner Bar Cutting (15th May 2011)

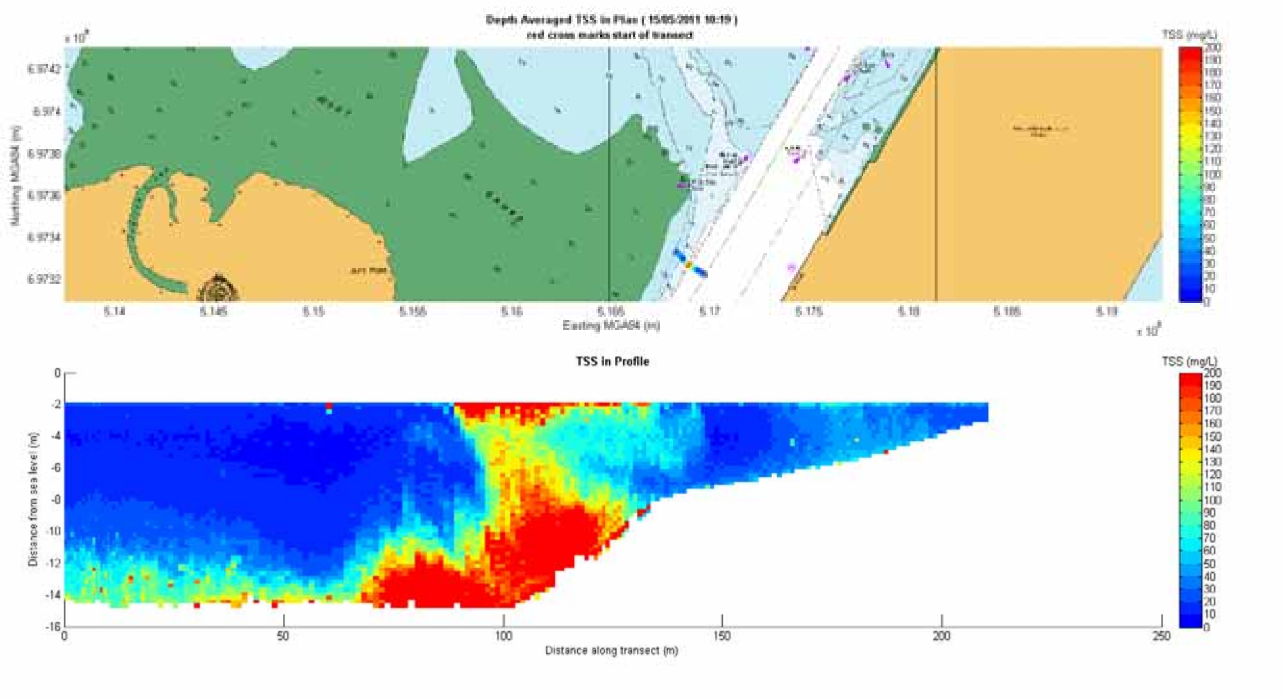

Figure 3-2 ***Brisbane*** **at Inner Bar, transect 4**

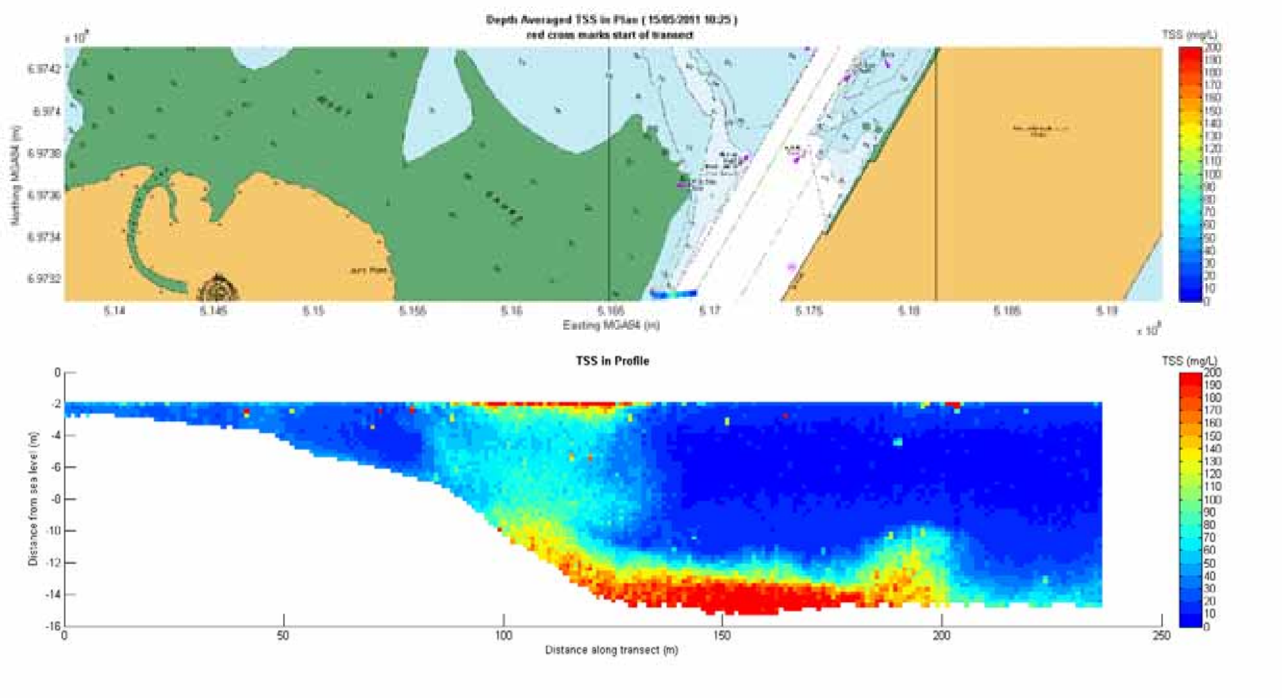

Figure 3-3 ***Brisbane*** **at Inner Bar, transect 5**

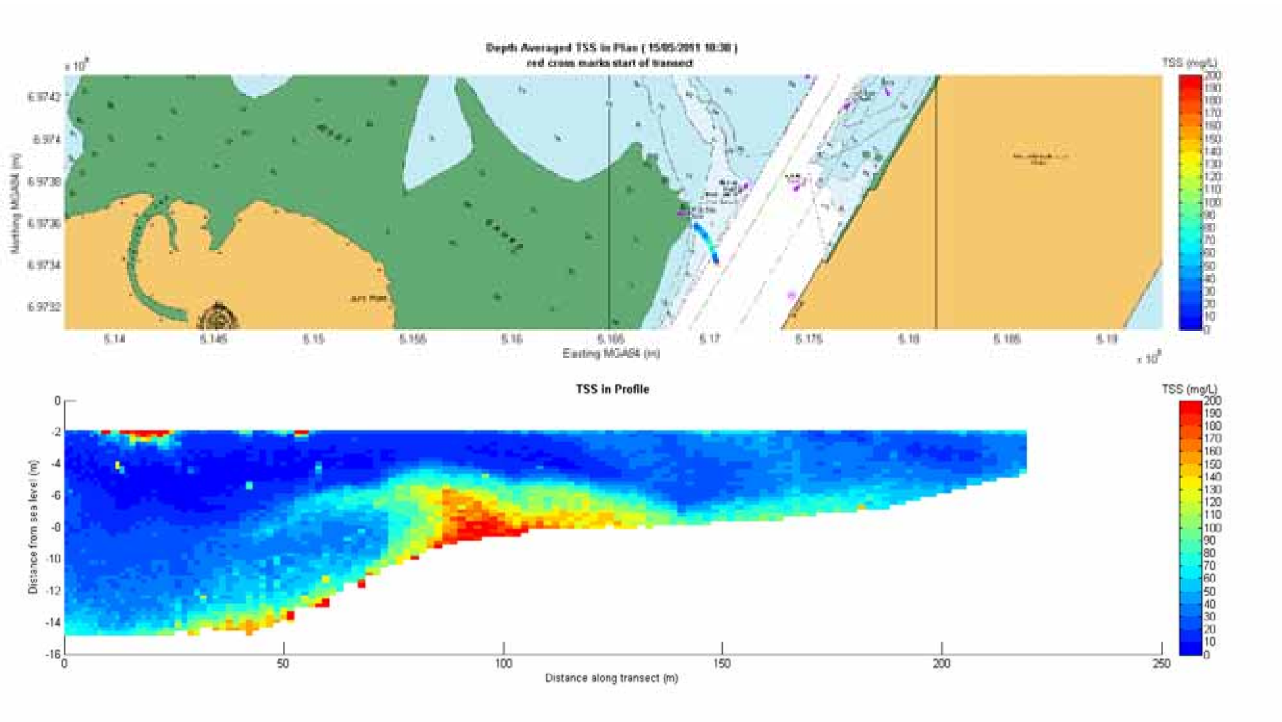

Figure 3-4 ***Brisbane* at Inner Bar, transect 7**

3.2 Sediment Samples

3.2.1 Particle Size Distribution of Suspended Sediment

The particle size of suspended material in the dredge plume from the *Brisbane* working at the Inner Bar consisted mainly of very fine silts and clays as shown in Figure 3-5. Together these very fine particles constituted over 90% of the material in suspension captured in a water sample collected at a depth of 11m in the centre of the plume formed astern of the dredger.

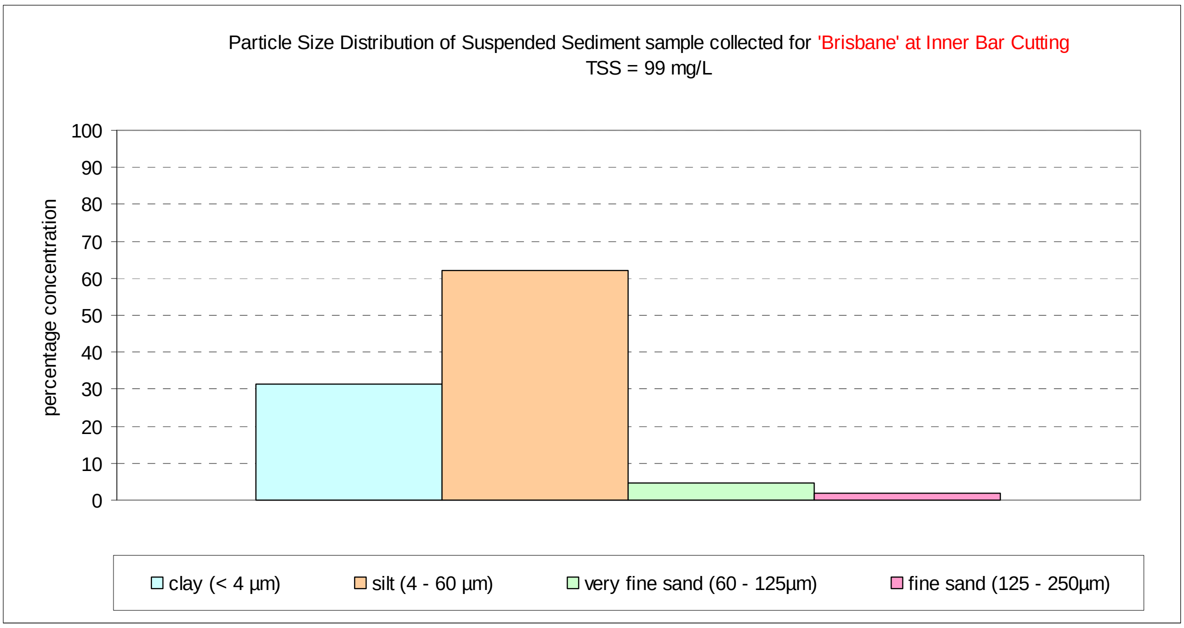

Figure 3-5 **PSD of Suspended Sediment for *Brisbane* at Inner Bar Cutting**

3.2.2 Grain Size Analysis of Grab Sample

The particle size analysis of a sediment sample obtained from the dredging area on the western toe-line of the Inner Bar Reach on the 15th May 2011 is shown in Figure 3-6. The graph illustrates the percentage of material passing through each of the Australian Standard Sieve sizes[7], from 2.36mm, 1.18mm, 0.60mm, 0.425mm, 0.300mm, 0.150mm, to the smallest at 0.075mm. Most bed sediments sampled in this study consisted mainly of very fine clay and silts, so often the percentage of material to be dredged which passed through the smallest sieve size (0.075mm or 75µm) was in excess of 90% of the sampled material. Figure 3-6 shows that approximately 65% of the sampled bed material from the Inner Bar was fine grained clays and silts smaller than 75µm; with approximately 20% consisting of very fine sand (less than 150µm) and 10% of fine sand (less than 300 µm).

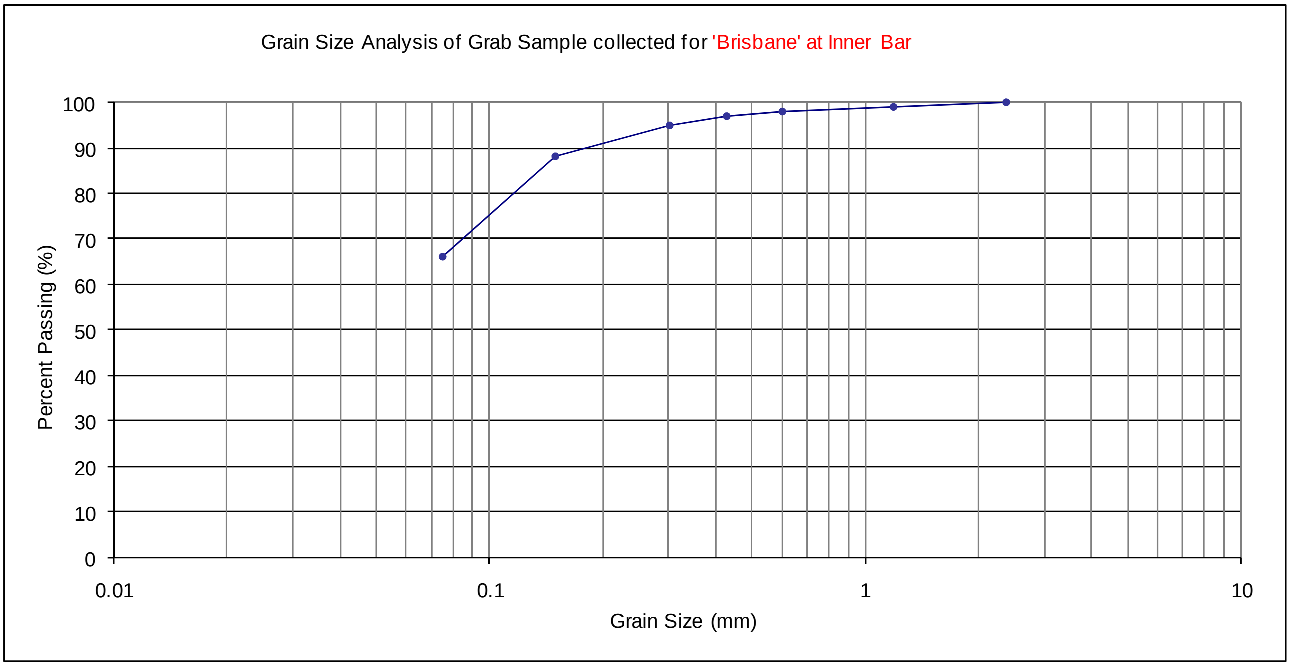

Figure 3-6 Grain Size Analysis of sediment grab sample for *Brisbane* at Inner Bar Cutting

[7] Standard sieve aperture sizes for use in soil particle size grading for engineering purposes.

3.3 Discussion

Sediment plumes generated by the *Brisbane* undertaking maintenance dredging in the Inner Bar Cutting were approximately 1200m in length and approximately 30-50m in width. As shown in the ADCP transects there were generally two plumes, one surface and one nearer the seabed. The surface plumes were advected with the ebbing tide north and west into the shallow water adjoining West Banks and broadened in this shallow area. The deeper plumes appeared to hug the western channel slope, with some material settling and falling towards the channel centreline whilst being advected in a north easterly direction along the navigation channel alignment.

The surface plumes were visible within seconds of hopper overflow as advised by the master of the *Brisbane*. Quickly evolving plumes of suspended sediment and the apparent 'boiling' of the water immediately astern of the *Brisbane* revealed that although the hopper sediments were released at keel level (approximately 6 metres below the water surface), these were readily entrained in the turbulence generated by the *Brisbane's* propulsion system and lifted to the water surface. The levels of TSS in the surface plumes as indicated by the ADCP are likely overestimates due to tiny air bubbles entrained by the *Brisbane's* propellers. Turbidity profiles and TSS analysis of collected water samples from the plume suggest the actual TSS concentration near the water surface normally less than 150 mg/L.

The ADCP transects show in detail the formation of surface plumes associated with the discharge of dredged material from the hopper as well as the settlement of this material toward the seabed. Additionally, the disturbance of the seabed sediments by the suction drag heads is also evident for example in Transect 3, Figure 3-2. The settlement of the near bed component of the turbid plumes towards the centreline of the channel is evident in Figure 3-3 and Figure 3-4.

The near bed plumes were generated by the combination of movement of the suction heads across the seafloor with continuing input from the settlement of material released above from the dredge hopper. A typical near bed plume was that depicted in Figure 3-3. Those plumes generated at the bed which were advecting with the ebbing tide are depicted in Figure 3-4. According to the turbidity profiles and TSS analyses, the concentrations in the near bed plumes were unlikely to exceed 300mg/L.

Approximately 1 hour after the start of dredging, the surface plume was no longer visible from *Resolution II*, though the last vestiges of the surface plume were still evident in the shallow waters adjacent to the West Banks.

The particle size distribution of suspended sediments within the turbid plume (based on laboratory analysis of one of the water samples collected whilst monitoring the *Brisbane* at the Inner Bar Cutting) comprised very fine textured sediments. The size range of the supended sediment was similar to measurements from the other dredge monitoring locations (excluding those at Spitfire channel), with approximately 30% clays, 60 % silts and the remainder consisting of very fine to fine sands.

Although sieve analysis of the collected bed sample from the Inner Bar Cutting did not provide concise information on the texture of the fines, the consistency of the sediment was similar to other locations in the dredge plume monitoring programme, except Spitfire Channel. Its field classification was a dark grey mud consisting of silts and clays with traces of very fine sand. The particle size analysis undertaken by sieving indicated that approximately 65% of the sediment sample consisted of very fine silts and clays less than 75µm in diameter. The remainder consisted mainly of very fine and fine sand (approximately 30%).

The size and turbidity of plumes formed by the dredger *Brisbane* whilst dredging at the Inner Bar on the 15th May 2011 were small, compared with those created by container and bulk cargo vessel movements to and from the Port of Brisbane.

4 DREDGER 'BRISBANE' AT OUTER BAR CUTTING

4.1 Observations and TSS Plots

Table 4-1 shows a schedule of operations and a summary of observations for the monitoring of the dredger *Brisbane* at the Outer Bar Cutting on the afternoon of 7th June 2011 during an ebb tide.

ADCP TSS transects shown in Figure 4-1 to Figure 4-3 illustrate the turbid plume TSS concentrations recorded astern of the *Brisbane* whilst dredging into Port on the ebbing tide at the western toe-line of the Outer Bar Cutting on the 7th June 2011. Figure 4-1 illustrates a cross section of the turbid plume characteristics after hopper overflow, showing settlement of dredged material through the water column as well as disturbance of the bed sediments by the suction heads. Figure 4-2 shows the advection and dispersion of the turbid plume some 10 minutes later into the shallow water on the western side of the channel. The plume was much reduced in its turbidity approximately 50 minutes after plume formation as shown in Figure 4-3.

The *Brisbane* dredged the western channel toe line of the Outer Bar Cutting in the vicinity of the Coffee Pots (Entrance beacons 11 and 12) with both suction heads operational. Dredging was initially undertaken enroute into Port and then again heading to sea, covering the same area. Between the two passes there was a pause in dredging whilst a ship, *Golden Kimi* steamed to sea. There was the usual period of approximately 15 minutes of dredging before the start of the overflow from the dredge hopper. A complete sequence of ADCP TSS plots recorded at the Outer Bar is shown in Appendix B.

The surface and near bed plumes were distinguishable immediately following the path of the dredger but as time passed the plumes became a little more uniform through the water column with the near surface part of the plume being advected out of the channel onto the shallower channel surrounds to the north and west. Later, after the seaward passage of the dredger, the ADCP transects showed two sediment plumes, one which was advected westwards towards the shallow channel surrounds and a residual deeper plume which remained in the channel.

The amount of vessel traffic in the channel on this afternoon limited the opportunity for the deployment of any drogues in the dredge plume. Since the dredge plumes displayed uniformity along their length, the turbid plume monitoring was in this instance undertaken without the use of a drogue.

Background turbidity levels in the channel prior to dredging were approximately 3-4NTU with corresponding Secchi disc measurements of approximately 1.7 metres.

Turbidities of up to 140NTU were recorded in the centre of the dredge plume, shortly (2-3 minutes) after passage of the dredger, with surface turbidities approximately 100m astern of the dredger as high as 90NTU. The initial dredge plumes created by the *Brisbane* were linear along the channel alignment spanning approximately 1000m in length and 30m in width. As time passed, the near bed plume spread along the western edge of the channel floor whilst a part of the plume was advected westward up onto the surrounding shallows extending as far as 300-400m from the western edge of the channel.

Table 4-1 Schedule of Operations, Dredger *Brisbane* at Outer Bar Cutting: 7th June 2011

Time	Event	Comments
Earlier	Monitor *Brisbane* at Inner Bar briefly and then monitor dredged material placement activities at Mud Island twice on the flooding tide	
13:24	High water – 1.8m	Calm winds, overcast sky and heavy shipping traffic in channel.
14:35	Measure background turbidity levels in Entrance Channel.	Turbidity 3.5NTU, Secchi disc 1.7 – 1.8 m
14:40	*Brisbane* moves to Outer Bar Cutting for dredging into Port.	
14:50	Begin turbid plume monitoring	Surface plumes with up to 90NTU recorded and Secchi disc readings as low as 0.05m in plume.
15:20	Waiting for *Golden Kimi* to pass through channel.	Noticeable sediment plume generated from *Golden Kimi's* propellers
15:40	*Brisbane* dredges heading to sea	New plume created, near bed plume stays within channel, surface plume advected with ebbing tide.
15:45	Resume turbid plume measurements	
16:11	Collect grab sample of bed sediment	Dark grey mud with discernable traces of fine sand
17:00	Final transect	No visible plume at water surface.
19:16	Low water – 0.6m	

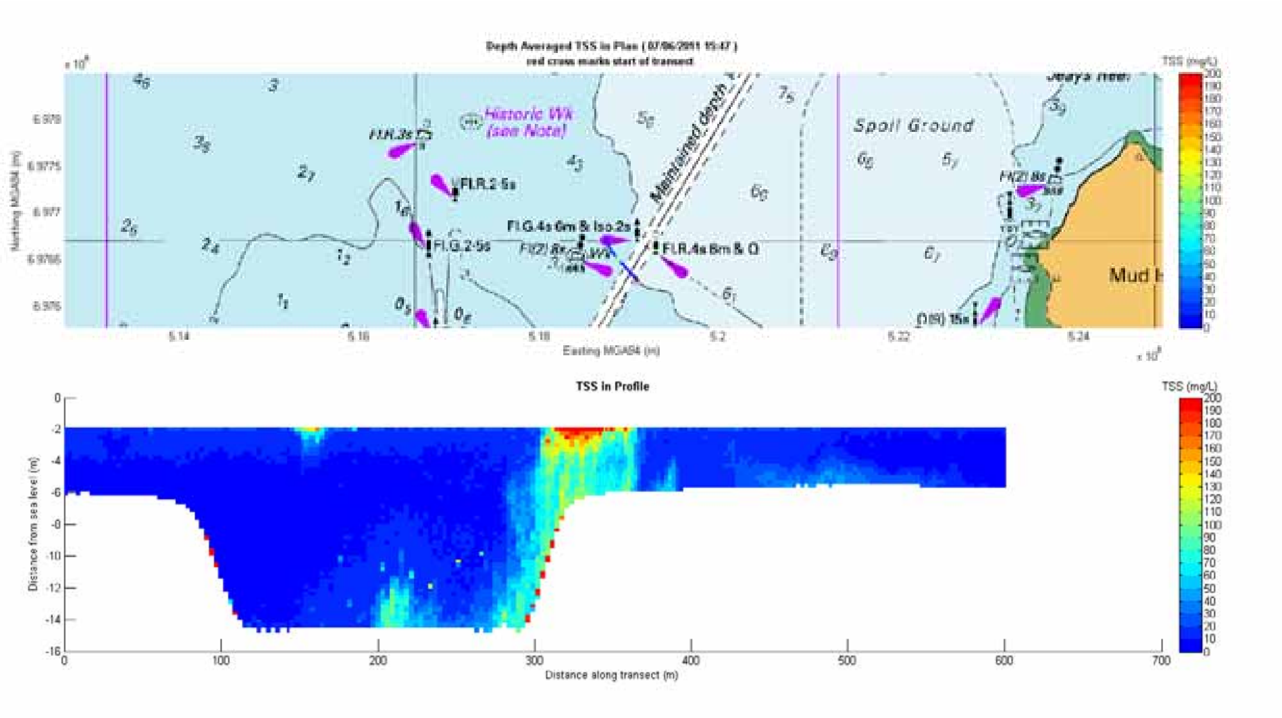

Figure 4-1 *Brisbane* at Outer Bar, transect 7

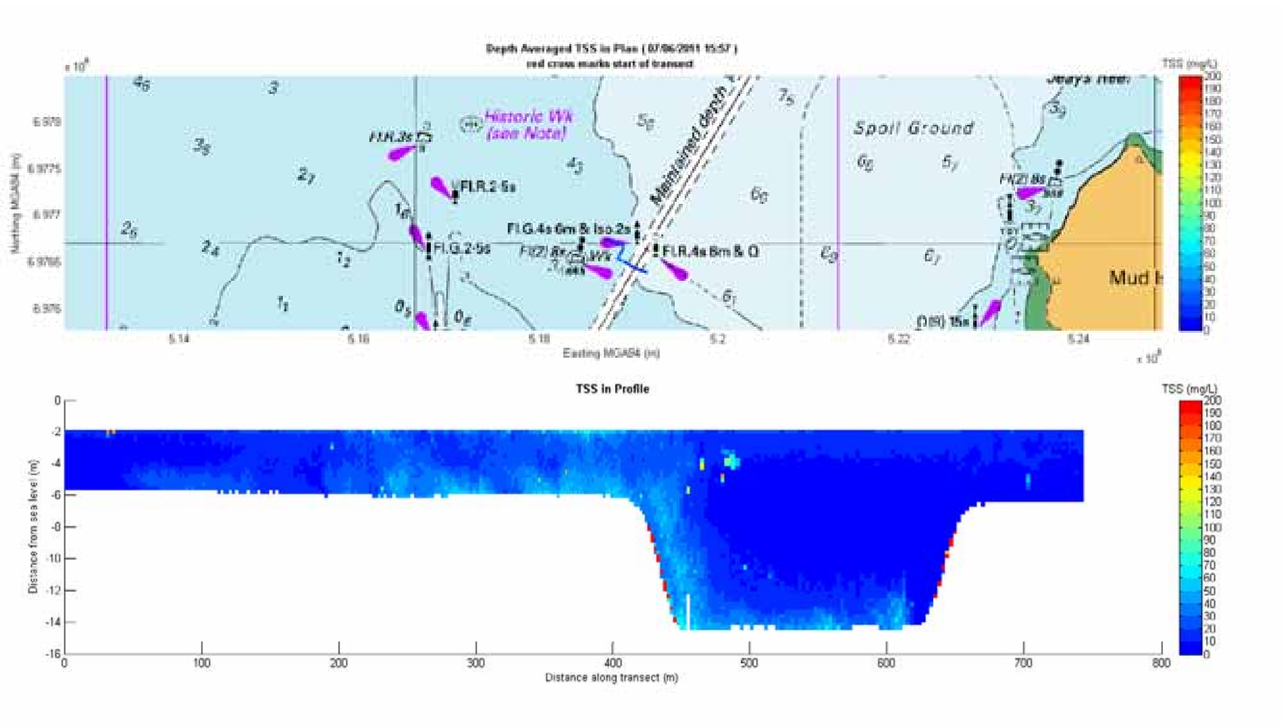

Figure 4-2 ***Brisbane* at Outer Bar, transect 8**

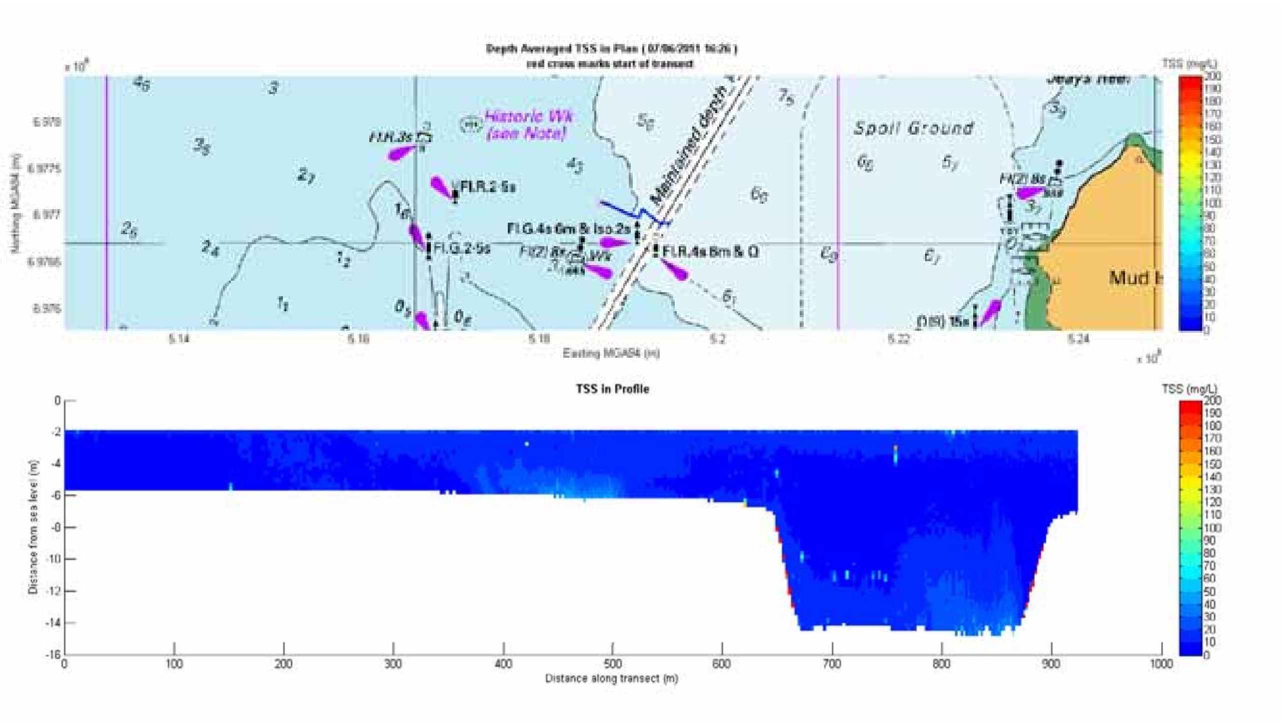

Figure 4-3 ***Brisbane* at Outer Bar, transect 10**

4.2 Sediment Samples

4.2.1 Particle Size Distribution of Suspended Sediment

The particle size of suspended material in the dredge plume from the *Brisbane* working at the Outer Bar consisted mainly of very fine silts and clays as shown in Figure 4-4. These fine particles constituted approximately 90% of the material in suspension captured in a water sample collected at a depth of 11m in the centre of the plume formed astern of the dredger.

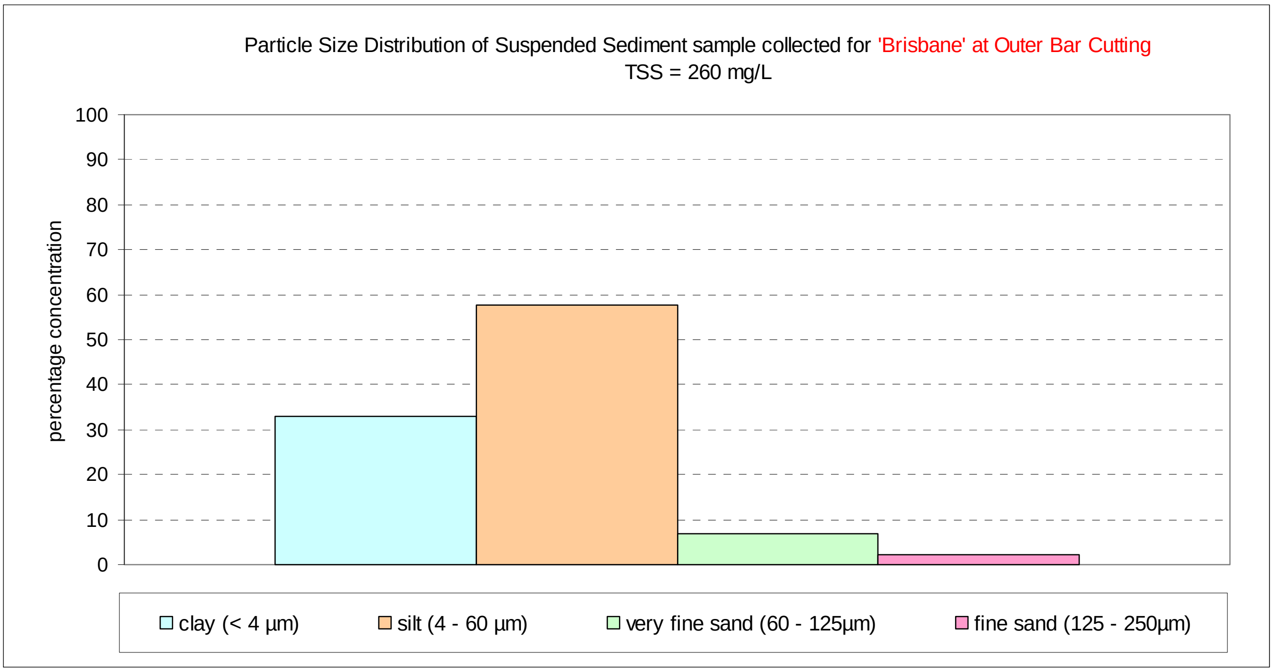

Figure 4-4 PSD of Suspended Sediment for *Brisbane* at Outer Bar Cutting

4.2.2 Grain Size Analysis of Grab Sample

Figure 4-5 shows the particle size analysis of a collected sediment sample from the western toe-line of the Outer Bar Cutting. The sampled material almost wholly consisted of very fine clay and silt particles (approximately 90% of the sample) with approximately 10% very fine and fine sands.

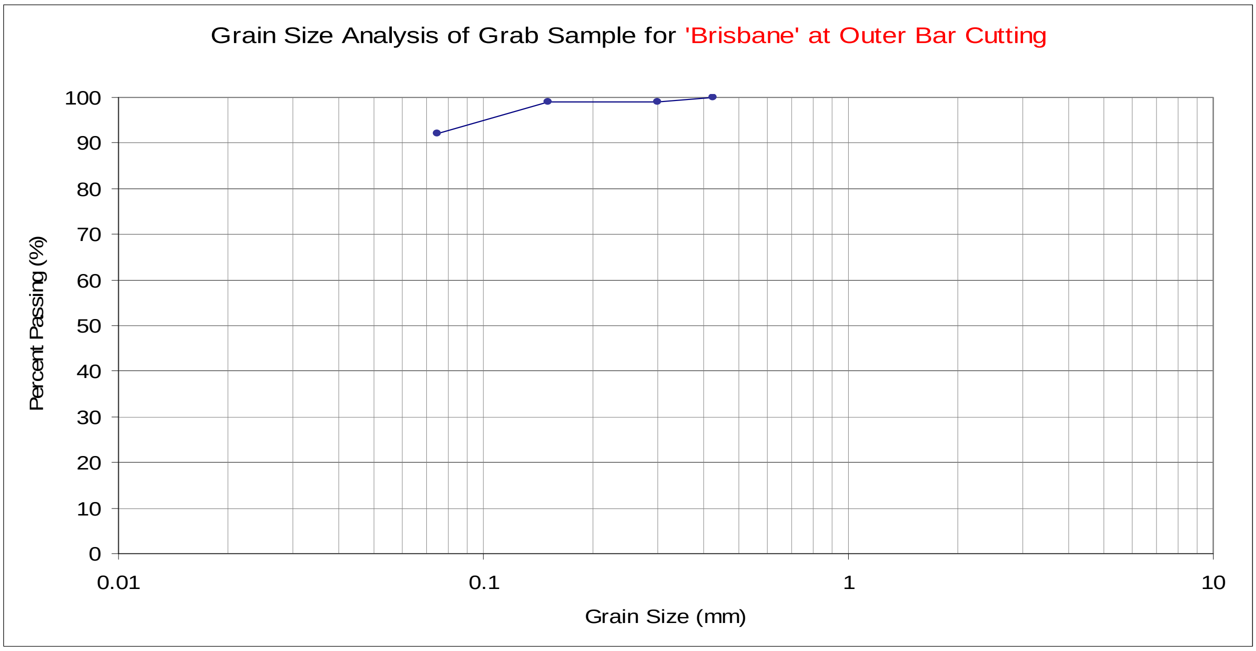

Figure 4-5 Grain Size Analysis of Sediment Grab Sample for *Brisbane* at Outer Bar Cutting

4.3 Discussion

Sediment plumes created by the *Brisbane* whilst undertaking maintenance dredging in the Outer Bar Cutting were similar to those formed at the Inner Bar Cutting. Similarly, they were approximately 1000m in length, following the dredge track and were approximately 30-50m in width near the water surface shortly after their formation. There were generally two plumes formed within the water column after the passage of the dredger, one at the water surface and one nearer the seabed. With time, the distinction between the surface and near bed plumes reduced and consisted of a surface plume, more or less uniform in profile, being advected across the western bed slope of the entrance channel and into shallower water beyond the channel alignment. The near bed plume, originally located near the western toe-line of the channel, spread further eastward, ultimately settling over the width of the entrance channel seafloor.

The surface plumes were visible within seconds of overflow from the dredge hopper. The levels of TSS in these surface plumes as indicated by the ADCP were overestimates due to tiny air bubbles caused by the *Brisbane's* propellers. The actual TSS concentrations at or near the water surface were normally less than 150 mg/L, based upon the turbidity profiling measurements and the analysis of collected water samples. The surface turbid plumes remained visible to the naked eye for a period of approximately 45- 50 minutes after their formation.

The near bed plumes were generated by the suction heads moving across the seafloor as well as sediments settling from above following their release from the dredge hopper. The initial form of the near-bed plume is shown in Figure 4-1 generated at the western toe line of the channel. Figure 4-1 and Figure 4-2 show the sediment being advected to the west beyond the channel alignment with the ebbing tide. Figure 4-2 and Figure 4-3 show the near bed plume settling across the channel floor.

Based upon turbidity profiling measurements and water sample analyses, the TSS concentrations in the near bed plumes were unlikely to exceed 300 mg/L.

The particle size distribution for suspended sediments in one of the water samples collected in the dredge plume created by the *Brisbane* at the Outer Bar Cutting was similar to the results from the Inner Bar Cutting with approximately 60% silts, 30% clays with the remaining 10% consisting of very fine to fine sands.

The particle size of sediment being dredged at the Outer Bar Cutting was also similar to the Inner Bar Cutting consisting of a dark grey mud of silts and clays with traces of very fine sand. In this instance, approximately 90% of the sample consisted of fine clays and silts less than 75microns, with the remainder (less than 10%) consisting of very fine and fine sand.

5 DREDGER 'BRISBANE' AT SPITFIRE CHANNEL

5.1 Observations and TSS Plots

Table 5-1 provides a schedule of operations and a summary of observations for the monitoring of the dredger *Brisbane* at Spitfire Channel on the flooding tide during the morning of 21st June 2011.

The drogue track illustrated in Figure 5-1 shows the path of dredge plume movement was in a south easterly direction on the morning flooding tide of the 21st May 2011. The elapsed times indicate the time after plume formation associated with the last dredging activity at site.

ADCP Transects shown in Appendix C illustrate the background and turbid plume TSS concentrations recorded about the *Brisbane* whilst dredging on the flooding tide at Spitfire Channel on the 21st May 2011. Figure 5-2 shows the cross sectional profile through the final dredging plume as it was tracked down-current from its point of formation using the ADCP, allied with the surface drogue. Figure 5-3 and Figure 5-4 show similar cross sectional profiles through the plume at consecutively later stages of plume advection and settlement.

The *Brisbane* dredged the sand spit near beacon NW12 which shelves southwards towards the western end of the Spitfire Channel, closest to Bribie Island. Dredging was undertaken with both suction heads down whilst progressing across the sand spit for approximately 150 – 200m before lifting the drag heads, going astern, and then repeating the process. Due to the limited area of the sand spit to be dredged and the intermittent pattern of dredging, hopper overflow did not commence until approximately 40 minutes into the dredging operation.

The turbid plumes were mainly categorised as subsurface with the highest concentrations, around 10NTU, found at depths of approximately 10m and below. White plumes of sandy sediments at concentrations higher than background turbidity levels were visually discernable at and well below the water surface, attributed to the very low background turbidity levels at the dredging site.

A drogue, described in Section 2.3.1, was deployed in the centre of the last plume left by the dredger following completion of its dredging operations. The drogue greatly assisted in the successful monitoring of the downstream movement of the plume. Since the turbid plume material consisted largely of sand it rapidly disappeared from the water surface and was not able to be visually identified after approximately 25 minutes. The ADCP transects demonstrated highest TSS concentrations at the drogue's position up until the plume was no longer distinguishable above background levels approximately 45-50 minutes after deployment and almost 800 metres from the drogue's deployment location.

A grab sample of surface sediments from the dredging location comprised mainly clean white sand with a small amount of shell material.

Table 5-1 Schedule of Operations, Dredger *Brisbane* at Spitfire Channel: 21st May 2011

Time	Event	Comments
06:47	Low water – 0.6m	Waves to 1m, rain with light to moderate southerly winds.
09:50	Measurement of background turbidity levels	Turbidity 0.2NTU, Secchi disc 6-7m
10:10	*Brisbane* begins dredging	
10:15	Monitoring turbid plumes created by *Brisbane*	Plume turbidities not exceeding 10NTU, visible surface plumes over 250m in width distinguishable by eye above background levels but rarely exceeding 2-3NTU.
11:15	Drogue deployed	Drogue deployed in the centre of the last plume left by *Brisbane* before it departs for Future Port Reclamation area at the Port of Brisbane.
11:20	Transects of plume passing drogue	Drogue was critical for providing a visual point of reference for monitoring the dredge plumes.
12:10	Drogue retrieved	Plume no longer discernable. ADCP is more capable of detecting and measuring plume turbidity than the profiling turbidity measuring instrument when turbidity is less than 1NTU.
12:15	Grab sample of bed sediments	White mixture of sands with shell fragments and a live yabby (*Callianassa australiensis*)
12:14	High water - 1.7m	Wind and weather conditions easing.

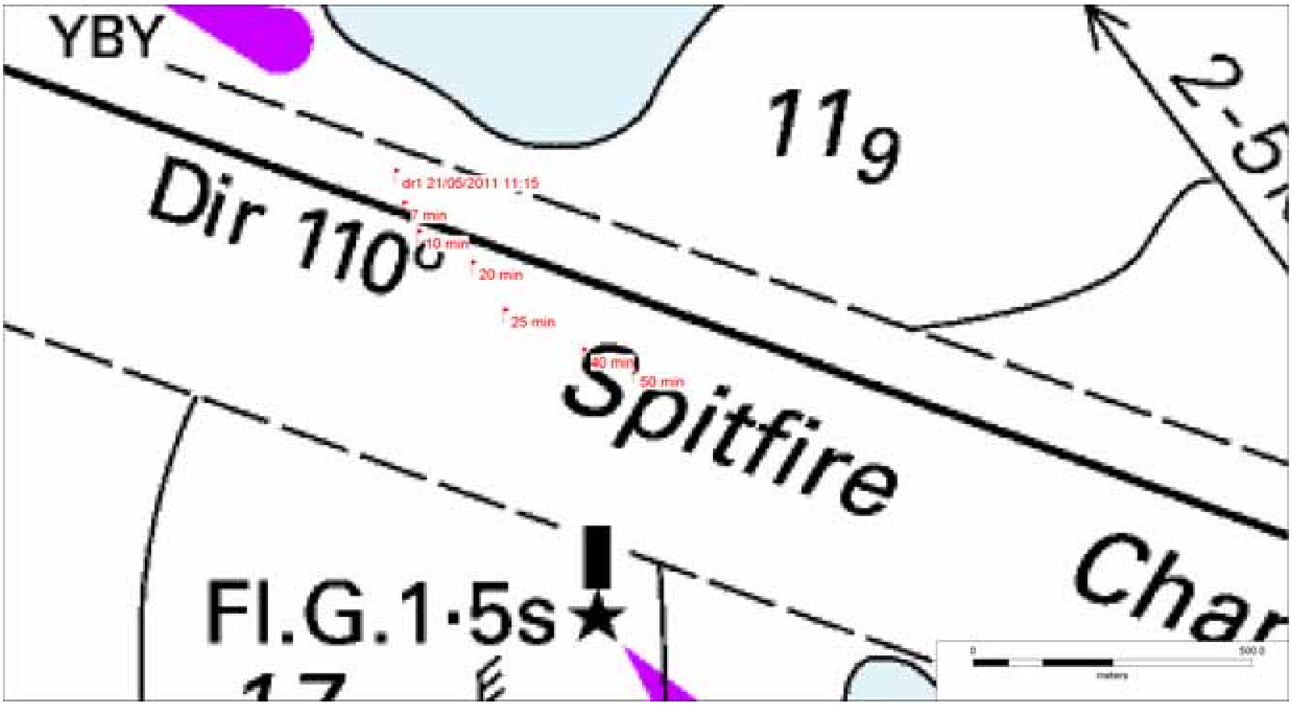

Figure 5-1 Drogue Track for *Brisbane* at Spitfire Channel

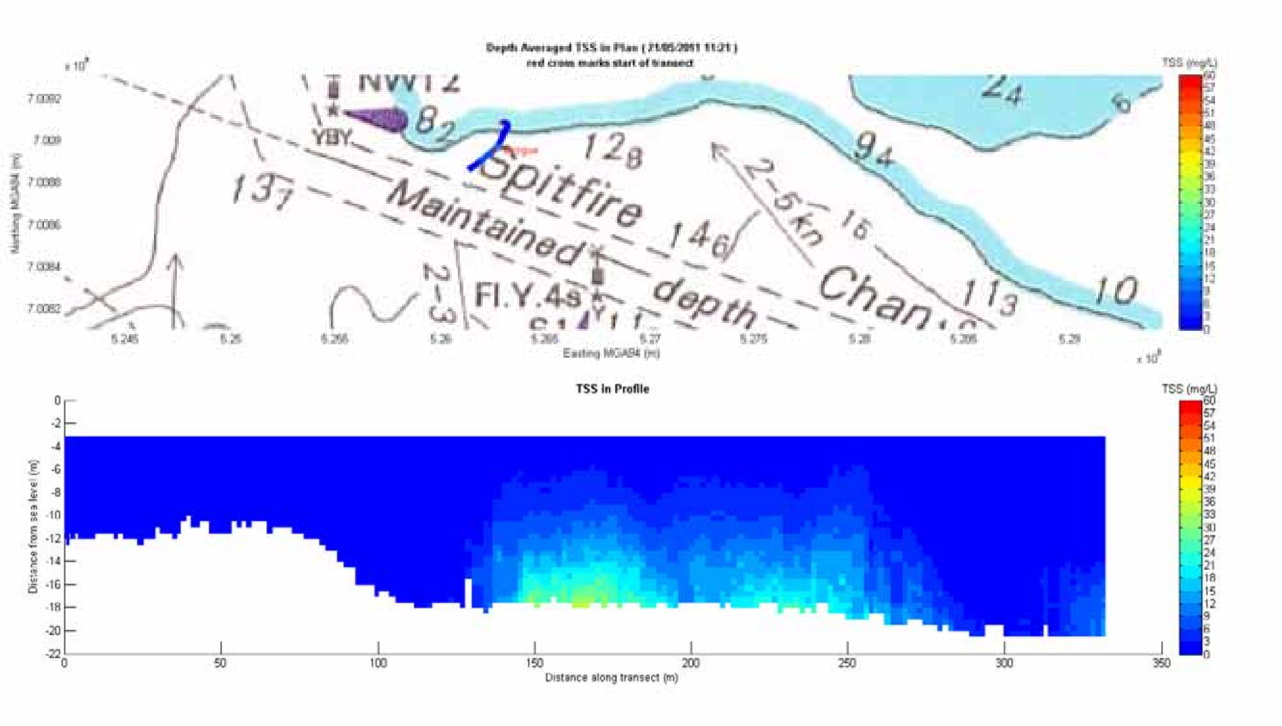

Figure 5-2 ***Brisbane* at Spitfire Channel, Transect 7**

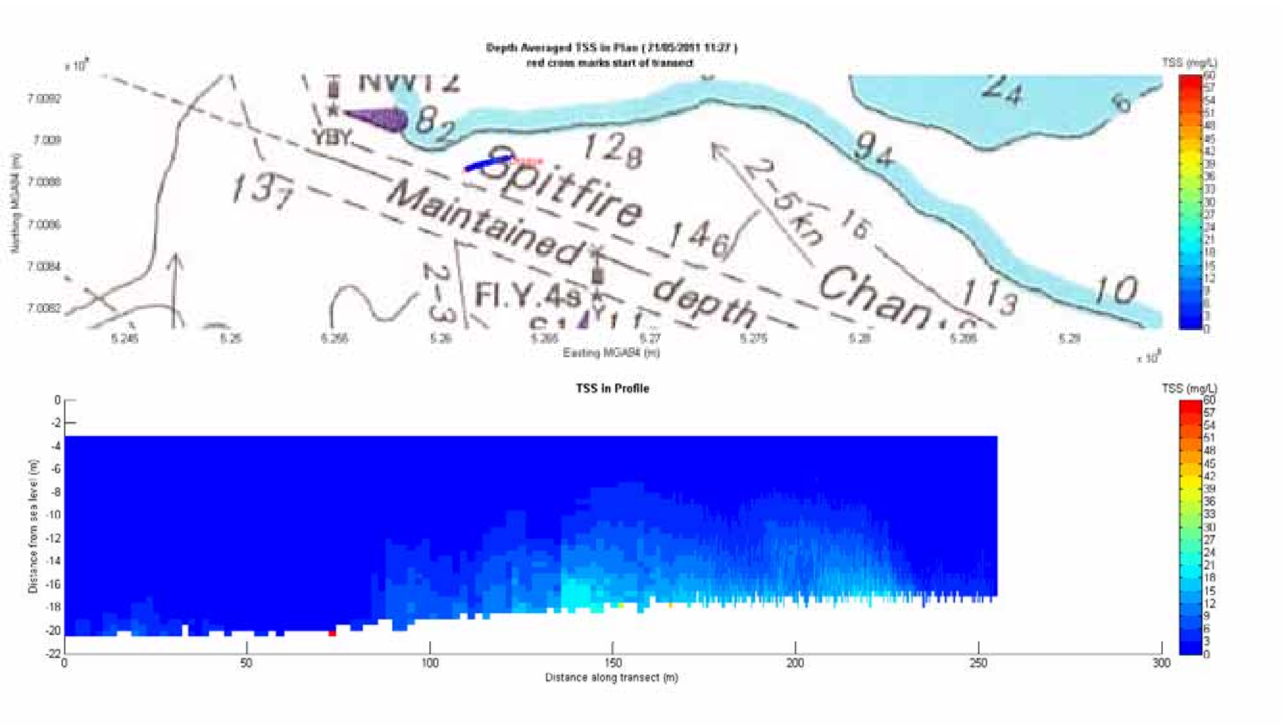

Figure 5-3 ***Brisbane* at Spitfire Channel, Transect 8**

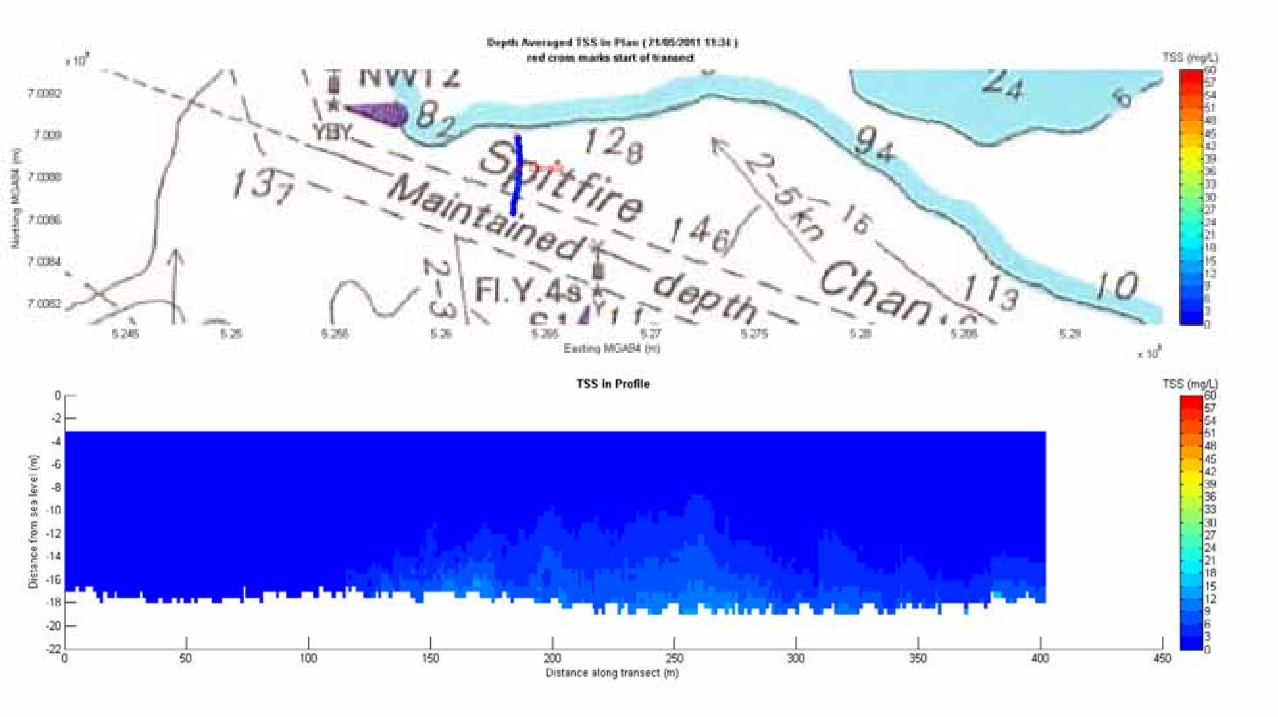

Figure 5-4 *Brisbane* at Spitfire Channel, Transect 9

5.2 Sediment Samples

5.2.1 Particle Size Distribution of Suspended Sediment

The particle size of suspended material in the dredge plume sample collected from Spitfire Channel was unlike any other dredging location and consisted mainly of fine silts and also medium sands as shown in Figure 5-5. The silt particles constituted approximately 55% of the material in suspension, whilst the medium and coarse sand material accounted for approximately 28% of sediment collected in a water sample at a depth of 11m in the centre of the plume formed astern of the dredger.

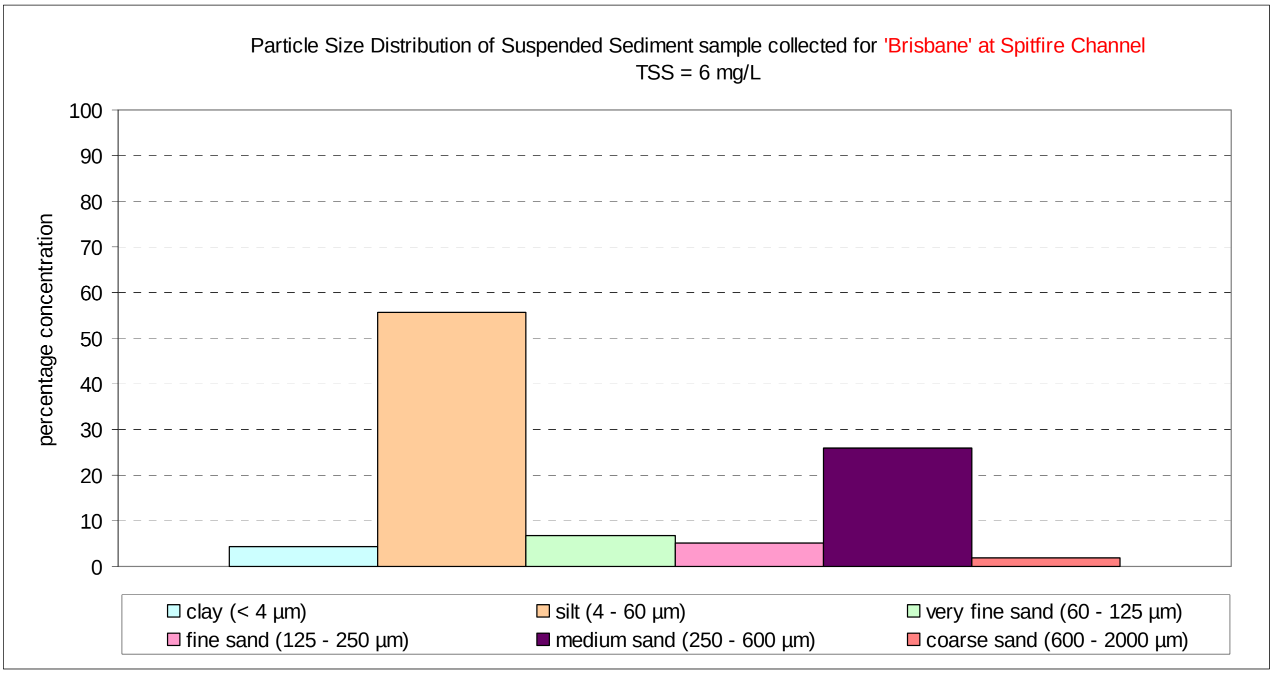

Figure 5-5 PSD of Suspended Sediment for *Brisbane* at Spitfire Channel

5.2.2 Grain Size Analysis of Grab Sample

Figure 5-6 shows the texture of a sediment sample collected from the dredging location on the sand spit at Spitfire Channel. Greater than 90% of the sampled material consisted of fine and medium sand particles with less than 3% silt.

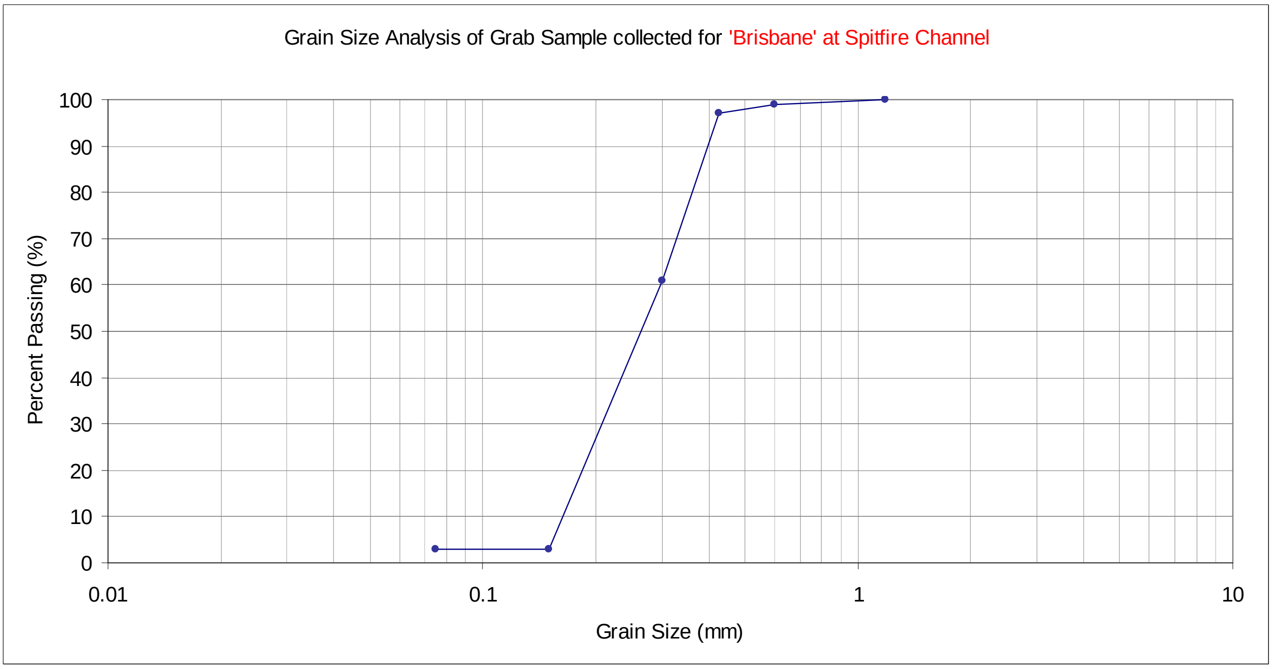

Figure 5-6 Grain Size Analysis of a Sediment Grab Sample for *Brisbane* at Spitfire Channel

5.3 Discussion

Sediment plumes generated by the *Brisbane* undertaking maintenance dredging at Spitfire Channel were approximately 150 to 200 metres in length and of a similar width, due to the intermittent nature of the dredging operation across the sand spit. Even in the near-field, the dredge plume as shown in Figure 5-2 was sub-surface in nature with the suspended sediment concentrations progressively increasing with depth.

The lack of a distinct surface plume was attributed to the nature of the sediments being dredged. The almost complete absence of fine textured clay or silt sediments in the dredged material resulted in minimal loss of fines from the hopper overflow. The hopper overflow was primarily clean sea water occasionally mixed with sand when the vessel was moved suddenly by the prevailing sea conditions. The dredged sandy sediments from the Spitfire Channel settled quickly instead of remaining entrained in the water column. The reduced formation of surface plumes may also have been influenced by a somewhat slower vessel speed required to dredge the small area of the sand spit, such that a lower level of propulsion turbulence was acting on the hopper overflow. However, the sediment particle size analysis demonstrated that there was a very low percentage of fine sediments at Spitfire Channel to entrain in a surface plume and it was evident from the ADCP transects that the predominant sand particles dredged at this site settled much faster than the fine silt and clay particles present in the hopper overflow at other locations.

Figure 5-2 depicts a typical dredge plume from the *Brisbane* whilst operating at Spitfire Channel. It shows a sediment concentration gradient with higher concentrations tending towards the seabed. TSS concentrations within the near-field dredge plume were unlikely to have exceeded 40 mg/L, with these concentrations found only very near the seabed. This estimate was somewhat higher than indicated by turbidity profiling measurements, though the turbidity measurements were limited to a maximum depth of approximately 12m by the length of the available submersible hose required for pumped water samples. It was estimated that the near-bed plume occupied an area of approximately 200 metres in length and width, with TSS concentrations up to 40mg/L whilst the dredger was operational at the sand spit.

The drogue was particularly useful when conducting the ADCP transects at Spitfire Channel since the plume was not visible from the water surface for more than 20-25 minutes after dredging. However, the drogue provided a clear indication of the movement of the plume well after this time until no plume was evident. Using the ADCP, the dredge plume was discernable above background levels up to 45-50 minutes after the cessation of dredging, having drifted approximately 800m in a south easterly direction along the channel from where it was formed.

The particle size distribution of suspended sediment in a water sample collected from the centre of the dredge plume at Spitfire Channel was inconsistent with the results from other dredging locations. The sample contained approximately 55% silts and over 40% sand ranging from very fine to coarse sand categories. Only 3% of the suspended material was within the clay sized fraction. The water sample from Spitfire Channel on which the suspended solids were analysed had a low TSS concentration of only 6 mg/L, compared to samples from other dredging locations where TSS concentrations were of the order of 100 mg/L or more. This reinforced the idea that turbid plume formation was much reduced at Spitfire Channel because of the comparatively coarse sandy texture of seabed sediments.

The grain size analysis of a sediment sample from the dredging area at Spitfire Channel yielded less than 5% fine silts and clays with the remainder (>95%) consisting of very fine to coarse sands. The field classification of the same sediment sample was medium sand with a small percentage of shell fragments.

6 DREDGER 'BRISBANE' DUMPING ON EBB TIDE

6.1 Observations and TSS Plots

Table 6-1 provides a schedule of operations and a summary of observations for the monitoring of the *Brisbane* during sediment placement on the ebbing tide at the Mud Island DMPA on the 31st May 2011.

The drogue track illustrated in Figure 6-1 shows the path of dredge plume movement from the point of dredged material placement. Plume movement was in a north westerly direction on the afternoon ebbing tide of the 31st May 2011. The elapsed times shown in Figure 6-1 indicate the time after plume formation associated with sediment placement at the site.

Figure 6-2 shows the pattern of sediment suspension in the water column shortly after dumping of dredged material. It indicates there was a broad area in which the mass descent of material released from the dredge hopper was settling to the seafloor. Following its impact with the seabed there was a frontal surge of material which spread radially across the seafloor in all directions from the initial area of impact (Figure 6-2). Figure 6-3 suggests that the dredged material carried in the frontal surge mixed with the lower water column and then settled when the initial frontal velocity had reduced. Figure 6-4 shows there was a plume of residual fine material which was advected with the ebbing tide over considerable distances down-current from the initial point of sediment placement.

The Mud Island DMPA covers an extensive area of approximately 10km^2 to the west and south west of Mud Island in central Moreton Bay (refer to Figure 6-1) with water depths ranging between approximately 6 and 10m below datum. Placement of sediments on the ebbing tide involved the *Brisbane* steaming to an approved part of the Placement Area to release its load of maintenance dredging material obtained from the lower reaches of the Brisbane River. Placement of the dredged material is a relatively quick process (compared to dredging) typically requiring less than 5-10 minutes to empty the hopper before the dredger resumes steaming to its next dredging site. The process of placement is usually conducted in the form of a 'U' shaped bend with the dredger progressing forward at slow speed, whilst slowly turning back towards the Port entrance channel. To track the dredged material placement plume, a drogue was deployed into the plume at the site of the release. ADCP cross and long sectional transects were then collected as the turbid plume dispersed and advected with the ebbing tide.

Immediately following the placement of dredged material by the *Brisbane*, a plume of highly turbid water was visible astern of the dredger. It was also evident that a front of turbid water quickly developed along the sea floor in all directions from the point of release. The front was advected most strongly in the direction of the ebbing tidal currents, which was towards the northwest. The frontal edge of the plume was recorded at distances of up to 500m from the plume centroid some 1-2 hours after placement. The turbid plume was still slightly visible and detectible above background levels, using the ADCP approximately $2^{1/2}$ hours after dumping, at which time the plume width and length exceeded 2km.

Background turbidity levels over the DMPA were approximately 3NTU, with corresponding Secchi disc measurements of approximately 1.9-2.0m, prior to release.

Initial turbidities of up to 190NTU were measured in the centre of the placement plume at depth and up to 100NTU near the water surface. Within 30 minutes, the turbidities within the placement plume had reduced to less than 20NTU.

Table 6-1 Schedule of Operations, Dredger *Brisbane* Dumping on Ebb Tide: 31st May 2011

Time	Event	Comments
08:09	High water - 1.8m	
11:30	Conclude monitoring of *Amity*	Depart from Berth 12 to the Mud Island DMPA.
12:10	Measure background conditions at Mud Island DMPA	Turbidity 3NTU, Secchi disc visibility 2m.
12:25	*Brisbane* begins sediment placement.	*Brisbane* follows a broad 'U' turn to release sediment from the hopper.
12:30	Drogue deployed	Astern of *Brisbane*
12:35	Monitoring of placement plume	Cross sectional transects through the plume, passing the drogue. Initial plume turbidities up to 190NTU at 8.2m depth and 100NTU at the water surface. Secchi disc visibility reduced to 0.1m.
14:23	Low water – 0.4m	
15:15	Drogue retrieved	Plume no longer detectible

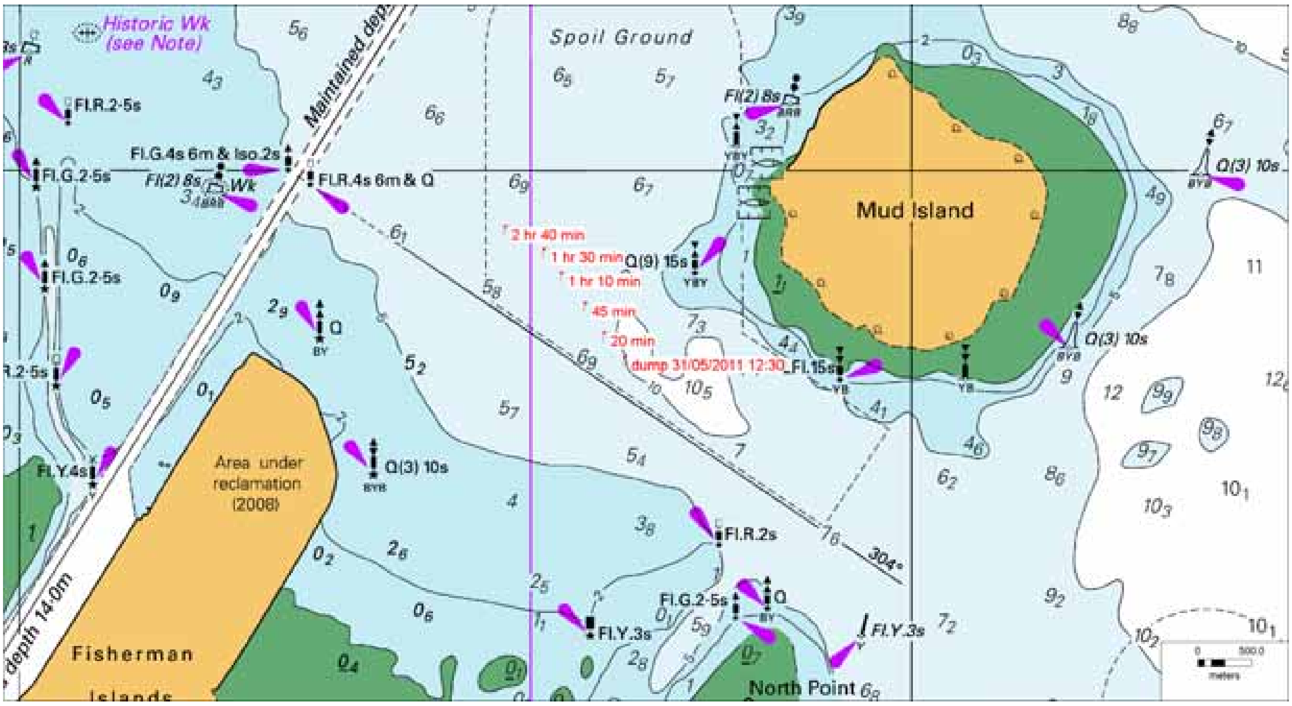

Figure 6-1 Drogue Track for *Brisbane* Dumping on Ebb Tide

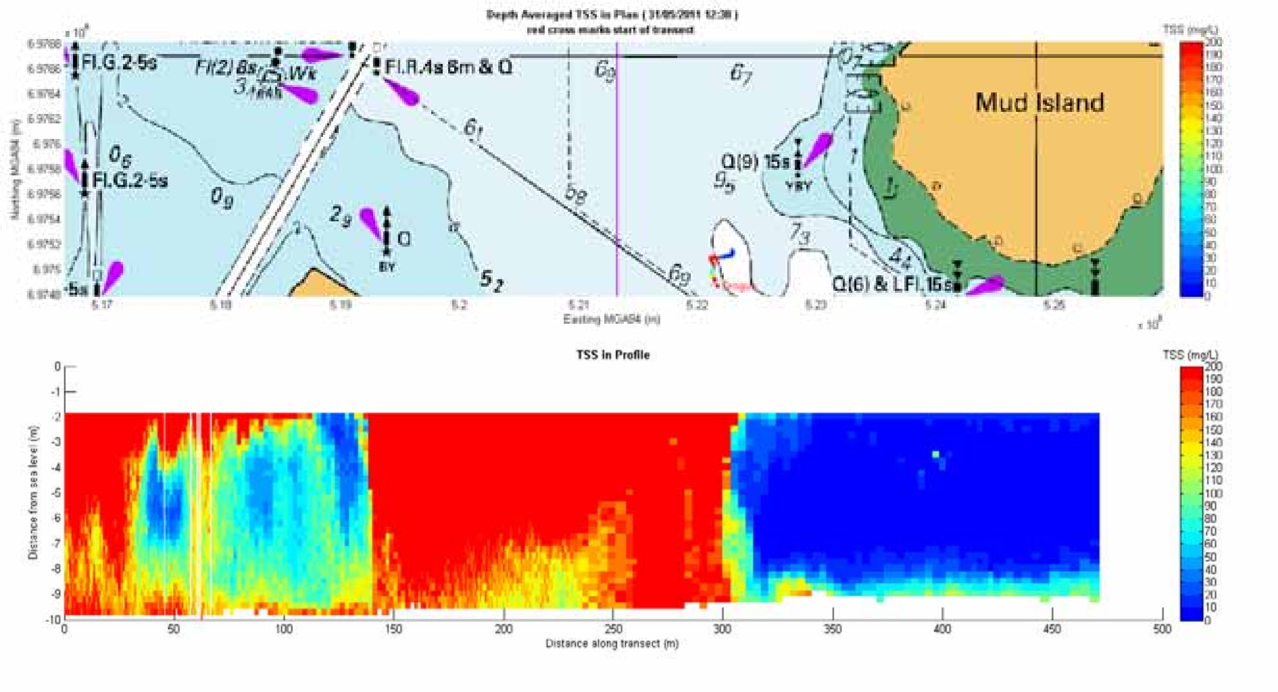

Figure 6-2 *Brisbane* **Dumping on Ebb Tide, transect 1**

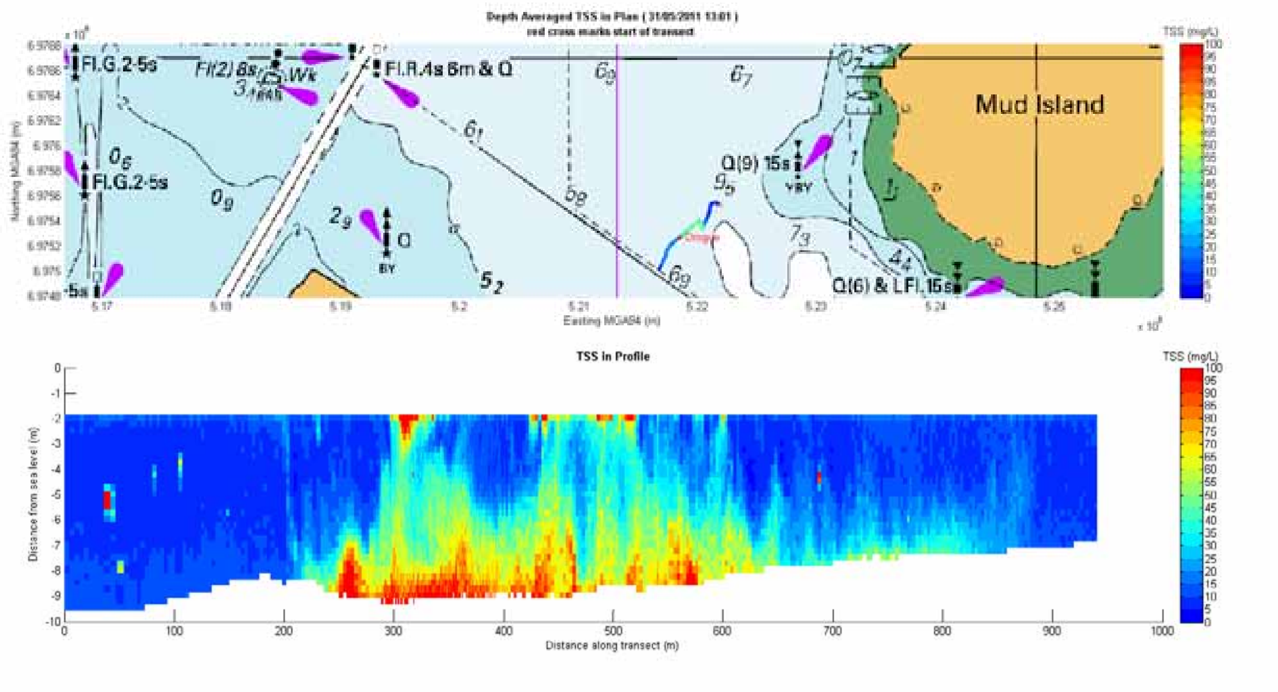

Figure 6-3 *Brisbane* **Dumping on Ebb Tide, transect 2**

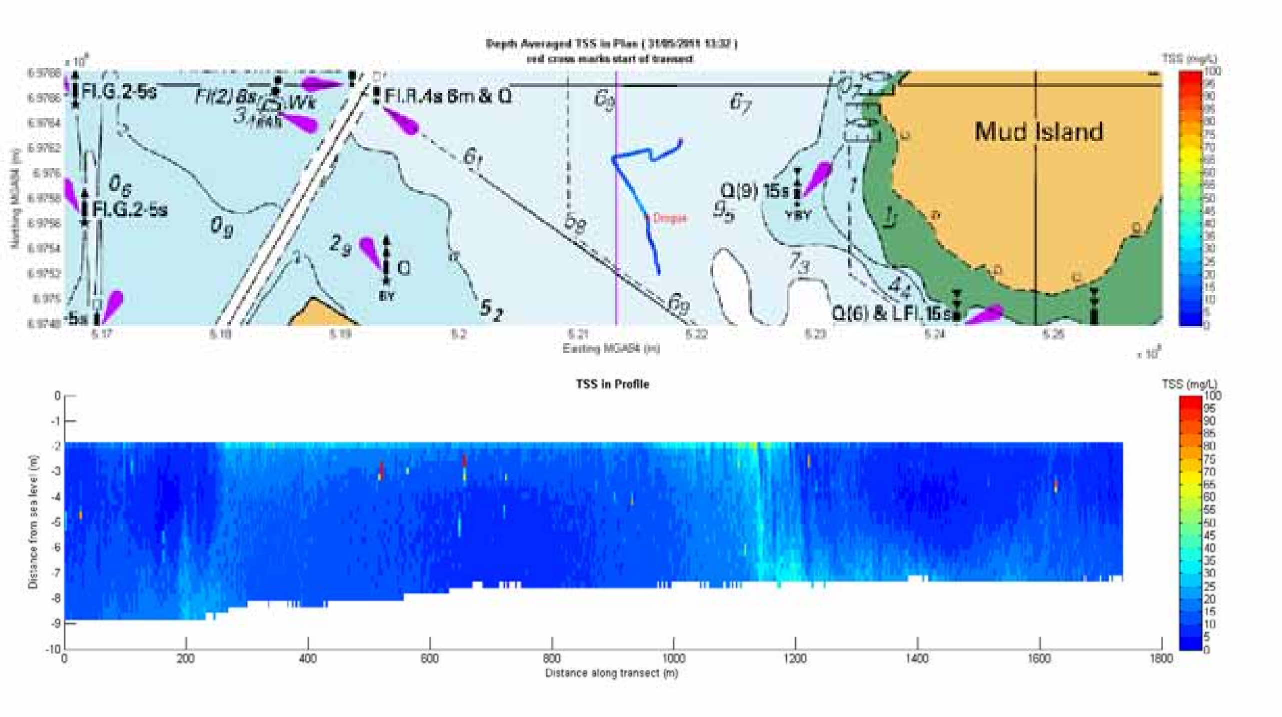

Figure 6-4 ***Brisbane* Dumping on Ebb Tide, transect 3**

6.2 Discussion

Initial sediment plumes generated by the dredger *Brisbane* whilst dumping sediment over the Mud Island DMPA were 150-200m long following the 'U' shaped vessel track adopted by the dredger whilst it cleared the hopper. The initial surface plume width was approximately 30m, though this rapidly changed as a series of subsurface turbid plume fronts rolled across the seafloor and then became visible at the water surface some 60-80m either side of the vessel path. By the time the dredge plumes were scarcely detectible, some $2^{1/2}$ hours after placement, the plume dimensions were elongated to approximately 2 kilometres in length and width.

The levels of TSS in the initial surface plume transects indicated by the ADCP are likely overestimates due to tiny air bubbles caused by the *Brisbane's* propellers. Based upon the turbidity profiles and analysis of water samples within the initial plume, created within 5 minutes of sediment dumping, the TSS concentrations within the near surface plume were normally less than 150 mg/L.

Figure 6-2 and Figure 6-3 show the sequence of plume front development and dispersion which ensued following sediment placement. Initially, there was a broad area of mass descent of material released from the dredge hopper which quickly descended to the seafloor. This was immediately followed by a front of turbid water which radiated in all directions across the seafloor away from the plume centroid for distances of up to several hundred metres. TSS concentrations exceeding 200 mg/L near the seafloor were evident in the early ADCP transects through the plume (refer to Figure 6-2). After the material carried in the frontal surge mixed with the lower section of the water column, much of the initial suspended sediment plume settled within 30 minutes of placement (Figure 6-3).

The placement plume moved with the ebbing tide across the DMPA covering 2 kilometres in approximately 2 hours 40 minutes on the ebbing tide, before it became indistinguishable from background turbidity. Part of the placement plume drifted beyond the western boundary of the Mud Island DMPA on the ebbing tide. The TSS concentration of the plume was by this stage quite low, being of the order of 5-10mg/L, a level which is likely to be exceeded frequently during naturally occurring stronger wind or current conditions. (No seagrass meadows are known to exist in the near vicinity of the western boundary of the Mud Island DMPA. At these low TSS concentrations it is unlikely that the plume turbidities would have affected any potentially sensitive receptors such as seagrasses).

The particle size distribution (PSD) of suspended material within the dumping plume sample was consistent with the other dredging operations within the lower Brisbane River estuary, with a high percentage of very fine material consisting of approximately 60% silts, and 35% clays with the remaining 5% consisting of very fine to fine sands.

7 DREDGER 'BRISBANE' DUMPING ON FLOOD TIDE

7.1 Observations and TSS Plots

Table 7-1 provides a brief schedule of operations and a summary of observations for the monitoring of the dredger *Brisbane* whilst dumping dredged material at the Mud Island DMPA on the 7th June 2011 on a flooding tide.

Three placement plumes were monitored during the flooding tide over the morning and early afternoon of the 7th June 2011 at the Mud Island DMPA. The drogue tracks showing the path of dredge plume movement from the release location for the first two plumes are illustrated in Figure 7-1 and Figure 7-2. Only the initial plume extents were recorded from the third dumping event. Plume movement on the flooding tide was in a southerly (plume 1) and south easterly (plume 2) direction on the 7th June 2011. The elapsed times indicate the time after plume formation associated with sediment dumping at the site.

Figure 7-3 shows a small section through the third dumping plume which was recorded soon after the release of sediment on the flooding tide. It shows the mass descent of material at the placement site and the rapid development of a frontal surge of dredged material which spread rapidly across the seafloor following its impact with the seabed. The frontal surge appeared to carry material not directly deposited upon impact out to distances of several hundred metres within minutes of placement. Figure 7-4 shows the settlement of suspended material within plume 1, approximately 10 minutes after dumping by dredger *Brisbane*. Although the extents of the visible surface plume were intersected in this transect, the extents of the frontal surge of material close to the seabed were not reached. Other figures showing the sequence of dumping plumes on the flooding tide on the 7th June, shown in Appendix E, suggest that the frontal surge can result in near-bed turbid plumes of suspended sediment radiating out to distances of 400-500m within 10 minutes of sediment placement. Figure 7-5 illustrates dumping plume 1, approximately 2 hours 10min after deposition; which indicates the presence of fine suspended material between the water surface and the seabed adjacent to and just beyond the southern boundary of the Mud Island DMPA.

Background turbidity levels over the Mud Island DMPA were 4-5NTU with Secchi disc measurements of approximately 1.2-1.3m.

Three dumping plumes were monitored on the flooding tide. On each occasion a drogue was deployed into the plumes of dumped sediment and cross sectional and long sectional ADCP transects were recorded through the plume as the sediments settled, and were dispersed and advected with the flooding tide.

In a manner similar to the dumping plume which formed on the ebbing tide, a front of turbid water radiated across the sea floor in all directions up to 500m from the plume centroid in the ADCP transects collected soon after each placement event. Turbidities of up to 110NTU (Secchi disc <0.1m) were recorded in the centre of the plumes. In each instance, plume turbidity remained over 30NTU in the centre of the surface plume for almost an hour.

The turbidity levels in the plumes were still detectible above background levels after approximately 2 hours with the plume dimensions exceeding 2 kilometres. Turbidities measured within the residual plumes varied from 10-12NTU at the water surface to 25-50NTU close to the seabed at this time.

Table 7-1 Schedule of Operations, *Brisbane* Dumping on Flood Tide: 7th June 2011

Time	Event	Comments Field Condition
07:39	Low water – 0.6m	
08:25	Measure background conditions at the Mud Island DMPA	Turbidity 4-5NTU, Secchi disc visibility of 1.2 -1.3m. Flooding tide
08:30	*Brisbane* begins sediment dumping on Mud Island DMPA	Brisbane follows a broad 'U' turn to release sediment from dredge hopper
08:32	Deploy Drogue	Astern of *Brisbane*
08:35	Monitoring of Placement Plume 1	Cross sectional transects through the plume, passing the drogue.
11:02	*Brisbane* begins sediment dumping on Mud Island DMPA	Redeploy drogue astern of *Brisbane*.
11:05	Monitoring of dumping Plume 2	Cross sectional transects through the plume, passing the drogue.
13:24	High water - 1.8m	
13:43	Collect ADCP measurement of 3rd dumping plume	Slack water

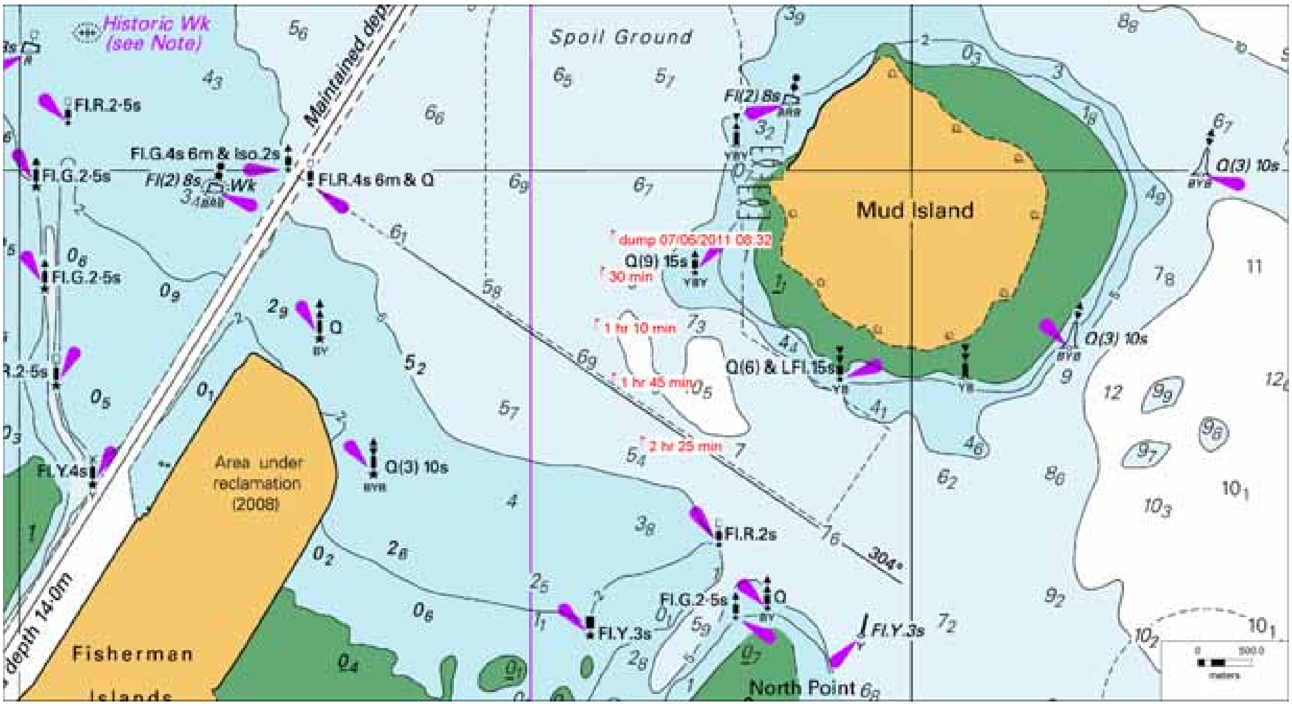

Figure 7-1 Drogue Track for *Brisbane* Dumping on Flood Tide, Plume1

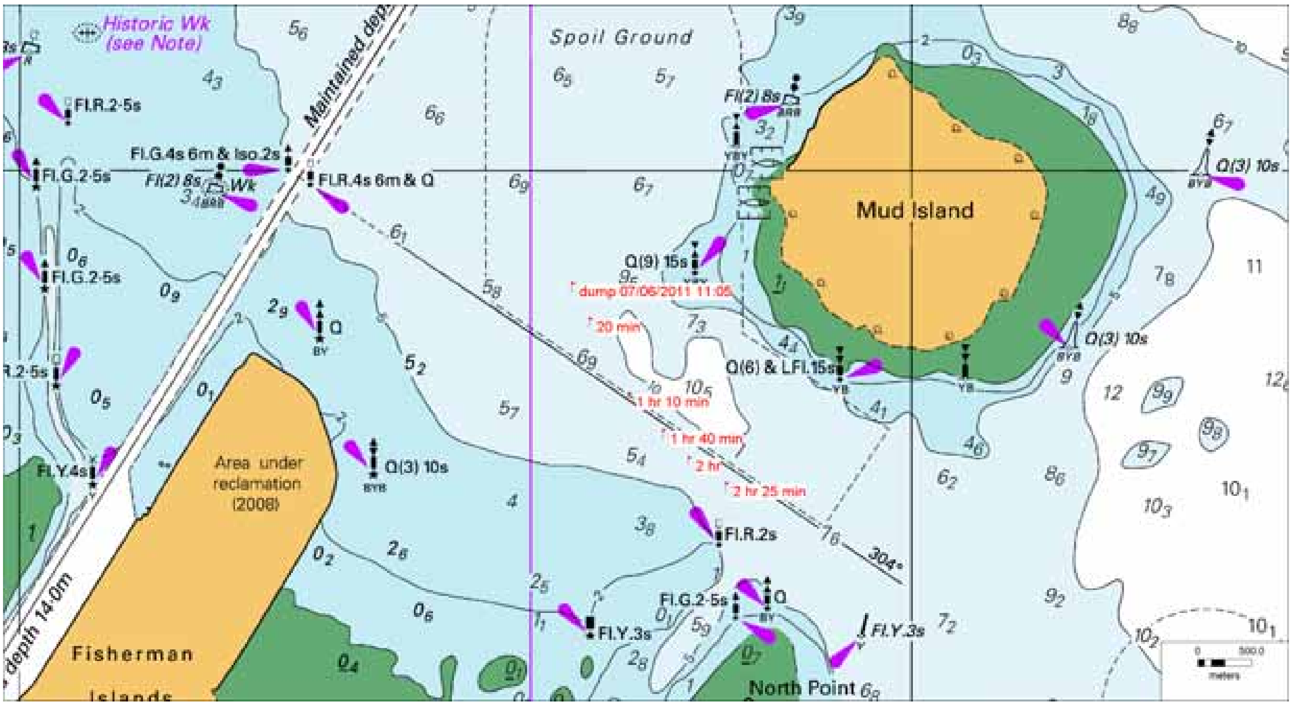

Figure 7-2 Drogue Track for *Brisbane* Dumping on Flood Tide, Plume 2

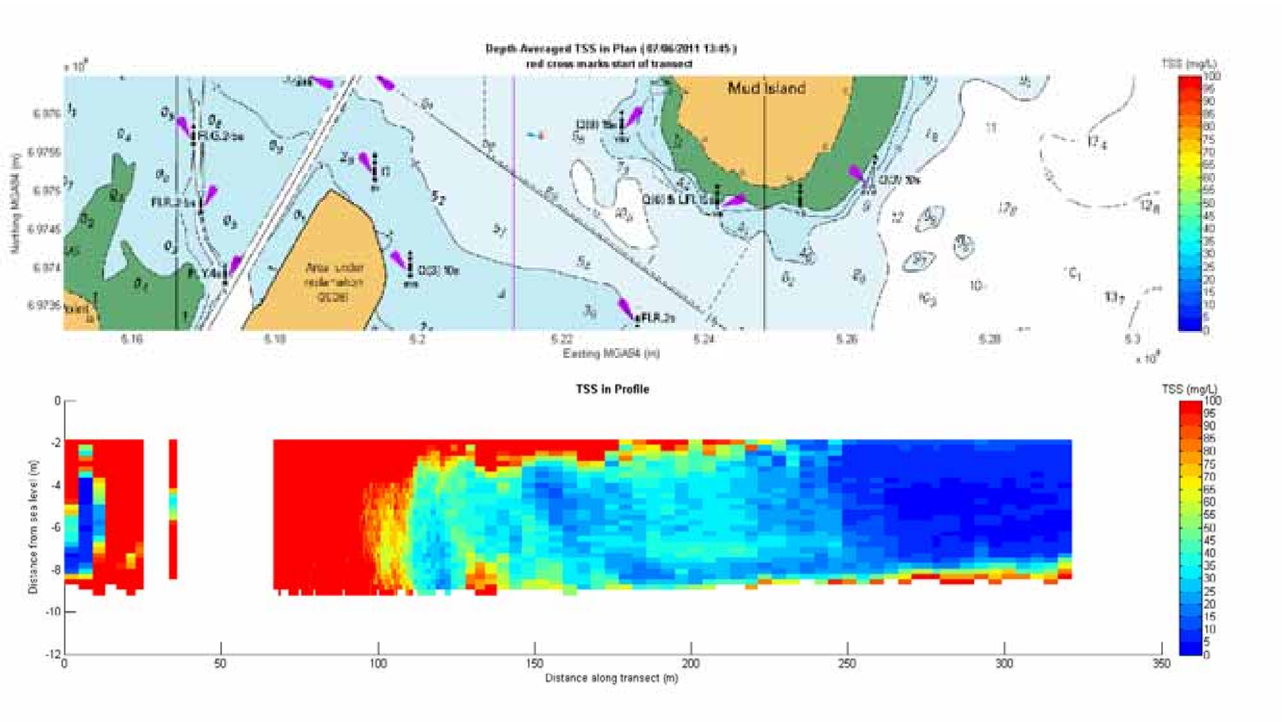

Figure 7-3 ***Brisbane*** **Dumping on Flood Tide, transect 1c**

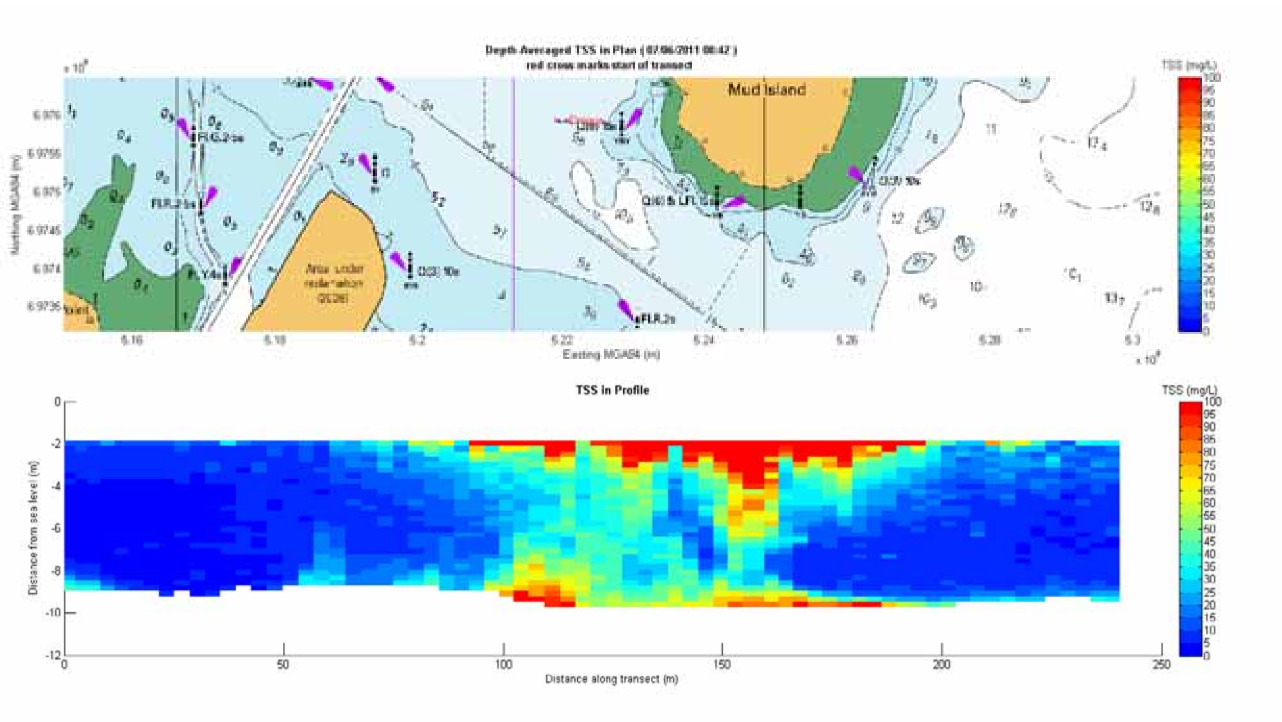

Figure 7-4 ***Brisbane*** **Dumping on Flood Tide, transect 2**

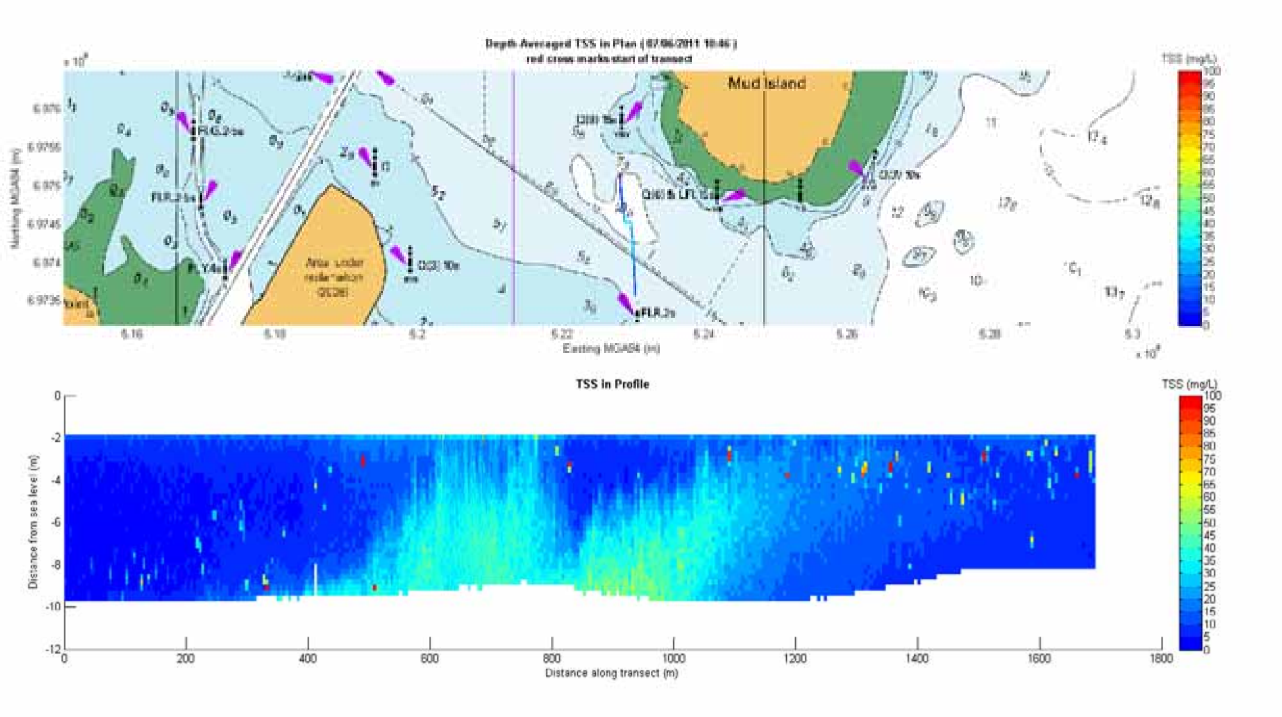

Figure 7-5 ***Brisbane*** **Dumping on Flood Tide, transect 8**

7.2 Sediment Samples

7.2.1 Particle Size Distribution of Suspended Sediment

Figure 7-6 illustrates the particle size range of sediments suspended in the centre of the placement plume, based upon analysis of a water sample collected shortly after sediment placement at depth of 9m during the flood tide of 7th June 2011.

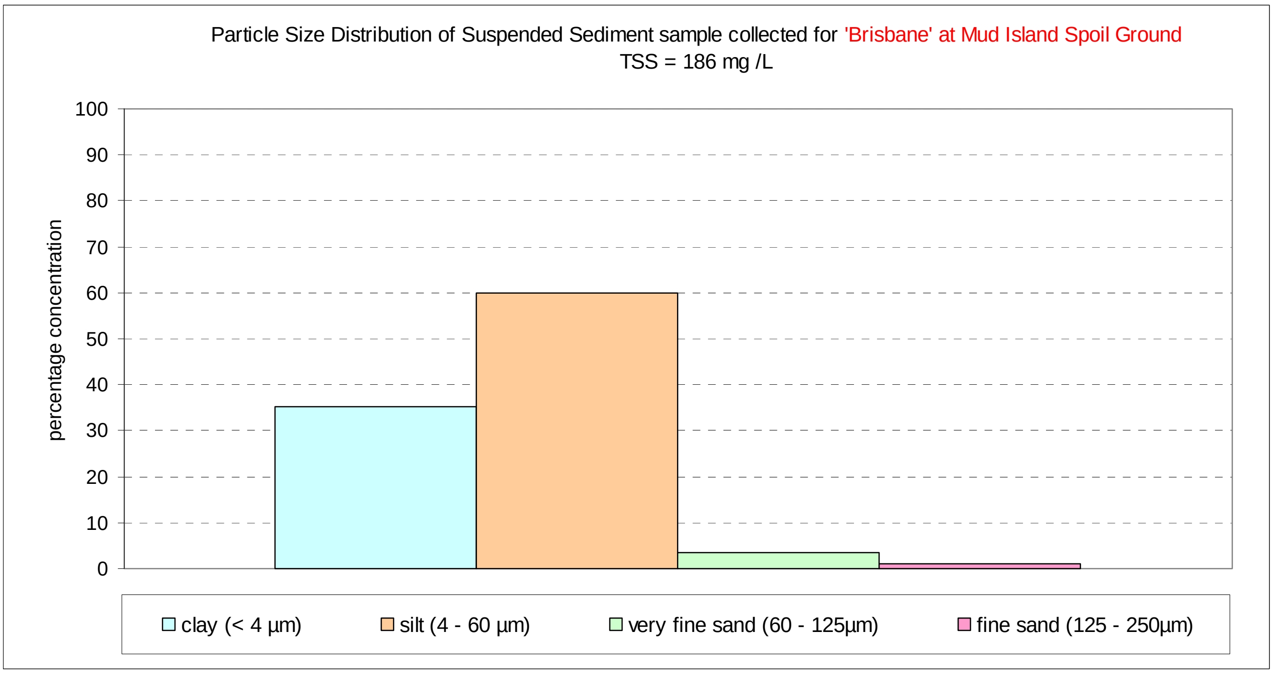

Figure 7-6 PSD of Suspended Sediment for *Brisbane* at Mud Island Spoil Ground, Flooding Tide

7.3 Discussion

The turbid placement plumes at the Mud Island DMPA measured during the flooding tide on the 7th June 2011 indicate advection across the Spoil Ground in a south to south easterly direction towards the channel between Mud and St Helena Islands. Similar to the ebb tide placement plume, it was evident that the surface and sub-surface component of the plumes formed by sediment placement were advected up to several hundred metres beyond the southern and eastern boundary of the Mud Island DMPA. In each instance, the bulk of the placed material was contained within the boundaries of the Mud Island DMPA, though the last vestiges of these plumes were still visible from the water surface 2- $2^{1/2}$ hours after their formation.

8 DREDGER 'BRISBANE' SWING BASIN

8.1 Observations and TSS Plots

Table 8-1 provides a schedule of operations and a summary of observations for the monitoring of the dredger *Brisbane* at the Swing Basin adjoining the BP products wharf on the 15th May 2011.

Figure 8-1 to 8-3 demonstrate the sequence of plume development about the dredger *Brisbane* whilst it was dredging the berth face and approaches to the BP products wharf at the Swing Basin on the ebbing tide during the afternoon of the 15th May 2011. Figure 8-1 shows the initial plume formed by dredging of the berth approach toeline. Figure 8-2 illustrates a transect through the dredging plume approximately 10 minutes later, a little further offshore. Figure 8-3 shows further plume development, following several dredging passes of the berth approach toeline.

Dredging appeared to be mainly undertaken with only one dredge suction head operational, probably due to the shallow water depths at this location. Appendix F shows all of the ADCP TSS transects recorded through the dredge plume formed at the Swing Basin on the ebb tide.

Table 8-1 Schedule of Operations, *Brisbane* at Swing Basin: 15th May 2011

Time	Event	Comments Field Condition
07:14	High water – 2.1m	Predicted ebb tide range at the Brisbane bar of 1.8m Brisk morning west to south westerly winds at 12 knots
09:00 – 11:05	Monitoring *Brisbane* at Inner Bar Cutting	
11:35	Sample of background conditions at Swing Basin	Secchi disc: 0.9m, Turbidity 8.5NTU
11:45	*Brisbane* begins dredging.	Only one suction head lowered.
12:25	Overflow commences	Notified of overflow by dredge master
12:30	Monitoring of sediment plumes	Plumes only visible intermittently from the surface Secchi disks between 0.1 to 0.3m and turbidity between 56 – 105NTU in localised plumes adjacent to dredger.
13:10	Final ADCP transect	
13:15	Collect grab sample of bed sediments	Dark grey fines with detectible traces of very fine sand
13:44	Low water – 0.3m	

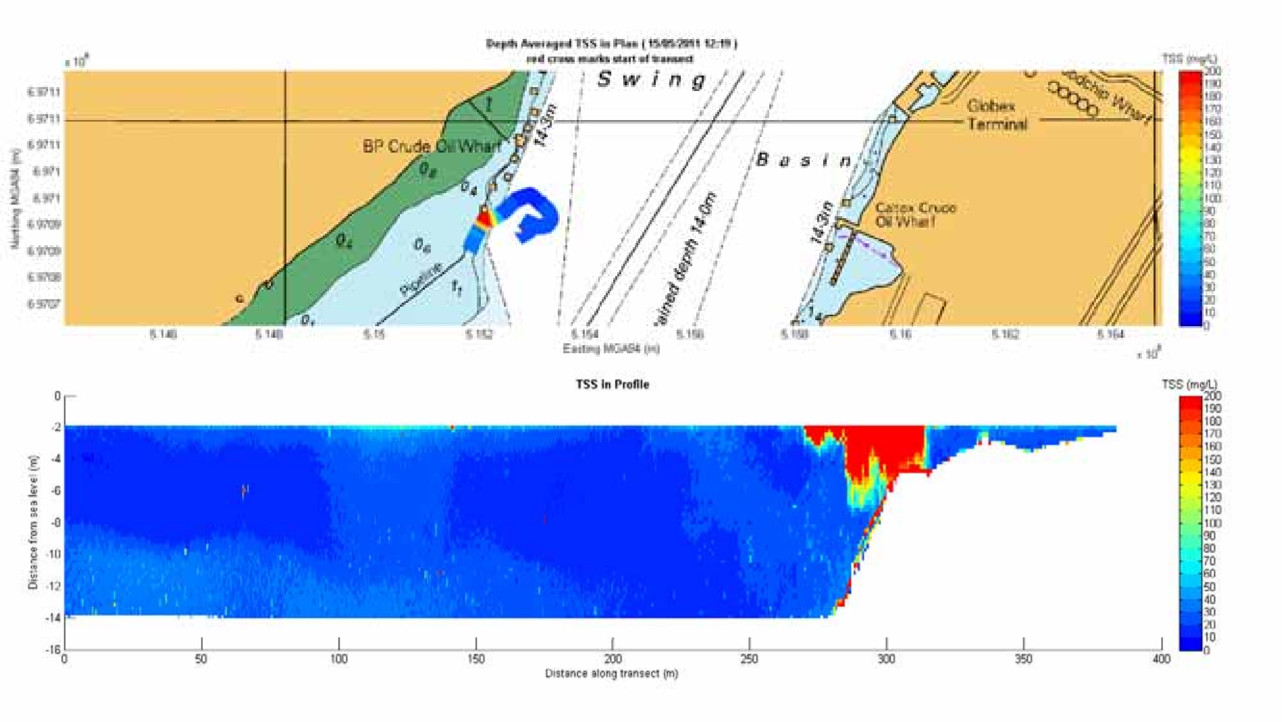

Figure 8-1 *Brisbane* at Swing Basin, Transect 1

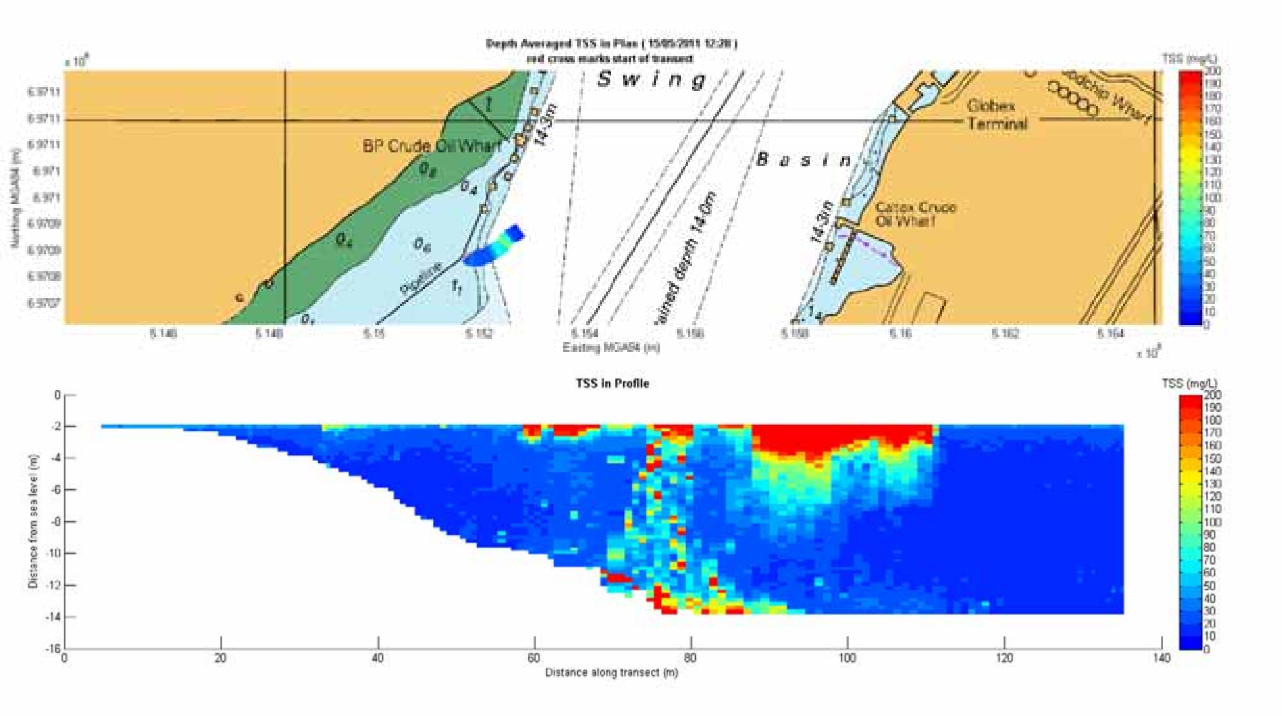

Figure 8-2 *Brisbane* at Swing Basin, Transect 2

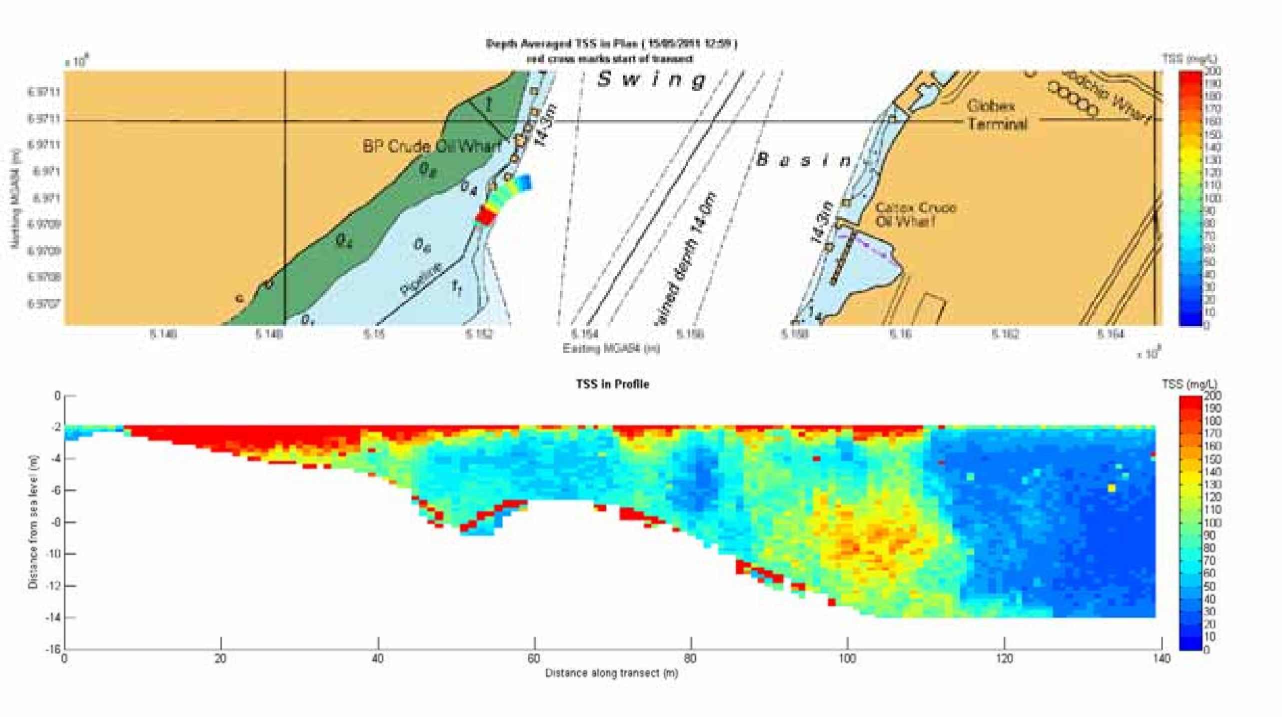

Figure 8-3 *Brisbane* at Swing Basin, Transect 5

8.2 Sediment Samples

Figure 8-4 shows the particle size analysis for a sediment sample collected from the Swing Basin, near the BP products wharf on the 15th May 2011. The sample was comprised of fine textured black mud, consisting almost entirely of clay and silt fractions below 75µm.

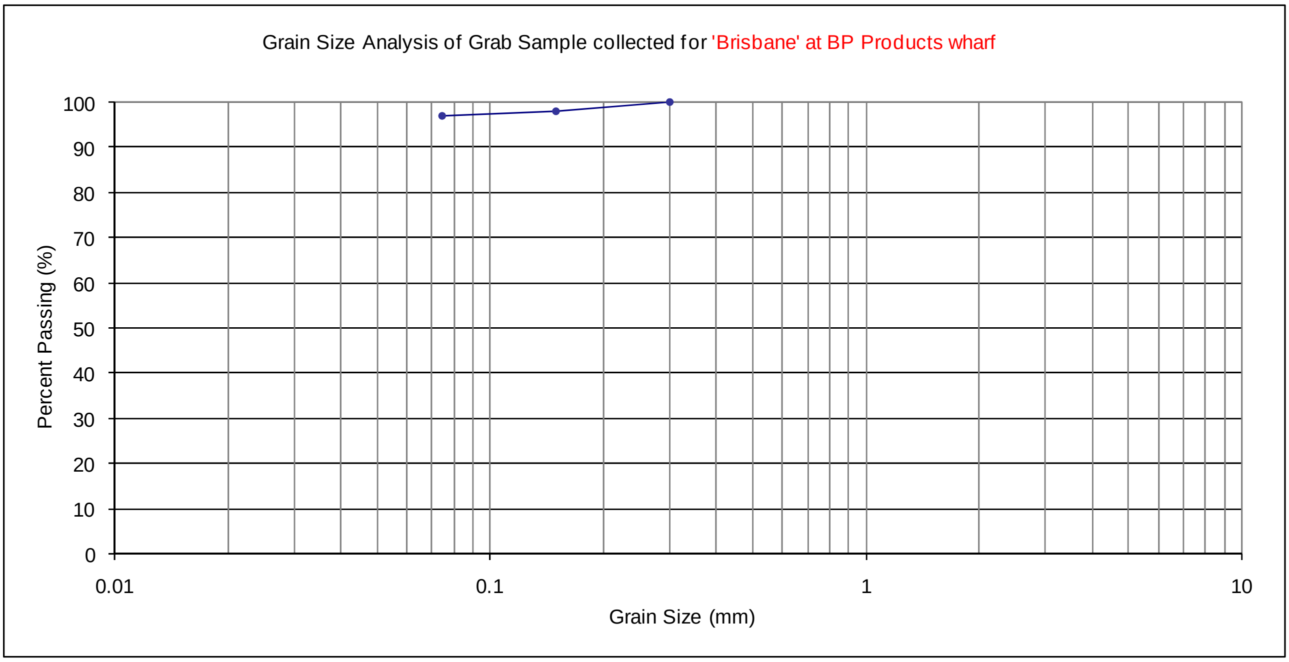

Figure 8-4 Grain Size Analysis for *Brisbane* at Swing Basin

8.3 Discussion

Given that dredge plume turbidity measurements earlier in the morning of the 15th May 2011 at the Inner Bar Reach were limited and affected by vessel traffic and problems with the ADCP operating software, BMT WBM undertook a further series of measurements and turbidity profiles in the Swing Basin adjoining the BP products wharf, just upstream of Luggage Point. The dredging operation here required the dredger to travel at reduced speeds backwards and forwards along the berth face and along the upstream toeline of the departure channel area leading from the berth. Some very high turbidities were measured in the dredge plume at this location, due to the proximity to the dredger (only ten metres away at times) and also the effective movement of fine sediments resulting from both the hopper overflow and the comparatively shallow waters adjoining the dredging area. The shallow waters and shallow surface bed sediments were considerably disturbed by the propeller thrust of the operating dredger.

The high plume turbidity concentrations also permitted the collection of an important set of high TSS concentration water samples for corroboration of the ADCP backscatter with laboratory analysis of collected water samples for TSS. The background turbidity was also considerably higher at this location, being 15-20NTU, with the highest dredge plume turbidities being up to approximately 170NTU close to the bed. Surface plume turbidities were lower, being 40-50NTU within 50-60m of the dredger.

The areal extent of the surface dredging plume was quite limited, being some 50-100m wide and at times up to 200 metres long depending upon the length of the dredge track to the berth toeline. The turbid dredge plumes created during the dredging process on the ebbing tide were otherwise usually confined to the immediate berth area and the shallow waters landward of the berth area.

9 DREDGER 'AMITY'

9.1 Observations and TSS Plots

The schedule of operations and a summary of observations whilst monitoring the *Amity* at the Port of Brisbane (Fishermans Island) on the 31st May 2011 is shown in Table 9-1. Appendix G shows all of the ADCP TSS plots recorded on the day.

The *Amity* is a stationary dredger with turbid plumes being formed almost continuously via the dredging action of the cutter suction as it is guided back and forth across the seafloor by the dredge operator. Figure 9-1 and Figure 9-2 illustrate the formation of the turbid plume close to the seafloor. Figure 9-3 shows the low turbid plume concentrations further away from the dredger.

The conditions for monitoring of turbid plumes created by the *Amity* were, in contrast to other measurement locations, favourable for the following reasons. Interference from other vessels or their plumes did not occur, the background turbidity was low, weather conditions were fair and the *Amity* was more or less stationary with no propeller to create air bubbles resulting in interference with ADCP backscatter measurements. Measuring the turbid plume from the dredger was, however, difficult because of the orientation of the dredger with respect to the ebb tide. Since the dredger alignment was almost parallel with the ebb tide current, which set in a north easterly direction along the alignment of the Inner Bar Reach, the plume created by dredging at the seafloor was largely obscured by the dredging plant and equipment moored above.

For this reason, the majority of ADCP transects passed close to the *Amity,* usually starting and finishing in areas with background turbidity levels. The deployment of a drogue to indicate current or plume movements was not undertaken mainly because of the likely stranding or entanglement of the drogue in the shallow water or in the dredging discharge pipeline approximately 100-150m downstream of the dredger. Also, because the dredging plume was formed at the seafloor, there was concern that a drogue would not accurately represent the movement of the turbid dredge plume. The ADCP plume measurements demonstrated this concern was valid.

The dredging plumes created by the *Amity* were generated at the cutter suction head, positioned on the seafloor approximately 10-16 m below datum. There was little to no evidence of a surface plume and plume tracking was undertaken using the ADCP. Secchi disc measurements at the water surface in the area downstream of the operational dredger were constant at 1.1-1.2m and turbidity at the water surface rarely exceeded 5NTU, consistent with the background levels measured 50m upstream of the dredger. Near-bed turbidity measurements collected adjacent to the cutter head (approximately 15-20m downstream), rarely exceeded 40NTU with the constantly generated plumes being carried by the ebbing tide almost 200m, close to the seabed, before becoming no longer detectible. Turbid plumes generated by the *Amity* rarely exceeded 50m in breadth.

Table 9-1 Schedule of Operations, *Amity* at Port of Brisbane (Fishermans Island): 31st May 2011

Time	Event	Comments
08:09	High water - 1.8m	Expected tidal range at Brisbane bar 1.4m, Fine day with noticeable haze over Brisbane City
09:00	Collect grab sample	Dark grey fines with discernable traces of fine sand
09:20	Board *Amity* and meet with dredge master and crew.	Dredged material is sandy clay unlike the surface sediments, cutter head 12 – 14m below waterline, friendly – coffee and biscuits offered
10:00	Measurement of background conditions on an ebbing tide	Secchi disc: 1.2m, Turbidity: 4-5NTU
10:10	Begin measurements of plume	Collect water samples, turbidity & ADCP backscatter measurements. Secchi disc 1.2m, turbidity: max generally under 20NTU near bed, Plume not visible from water surface.
11:00	Measurement of background turbidity levels	Background turbidity levels remain constant. Secchi disc: 1.2m, Turbidity: 4-5NTU
11:10	Continue ADCP measurements of plume	Plumes found subsurface and downstream of cutter head Secchi disk:1.2m, Typical plume turbidity 10 – 20NTU
11:30	Last sample	
11:35	Depart for Mud Island DMPA	To record the *Brisbane* placing dredged material on the ebb tide.
14:23	Low water - 0.4m	

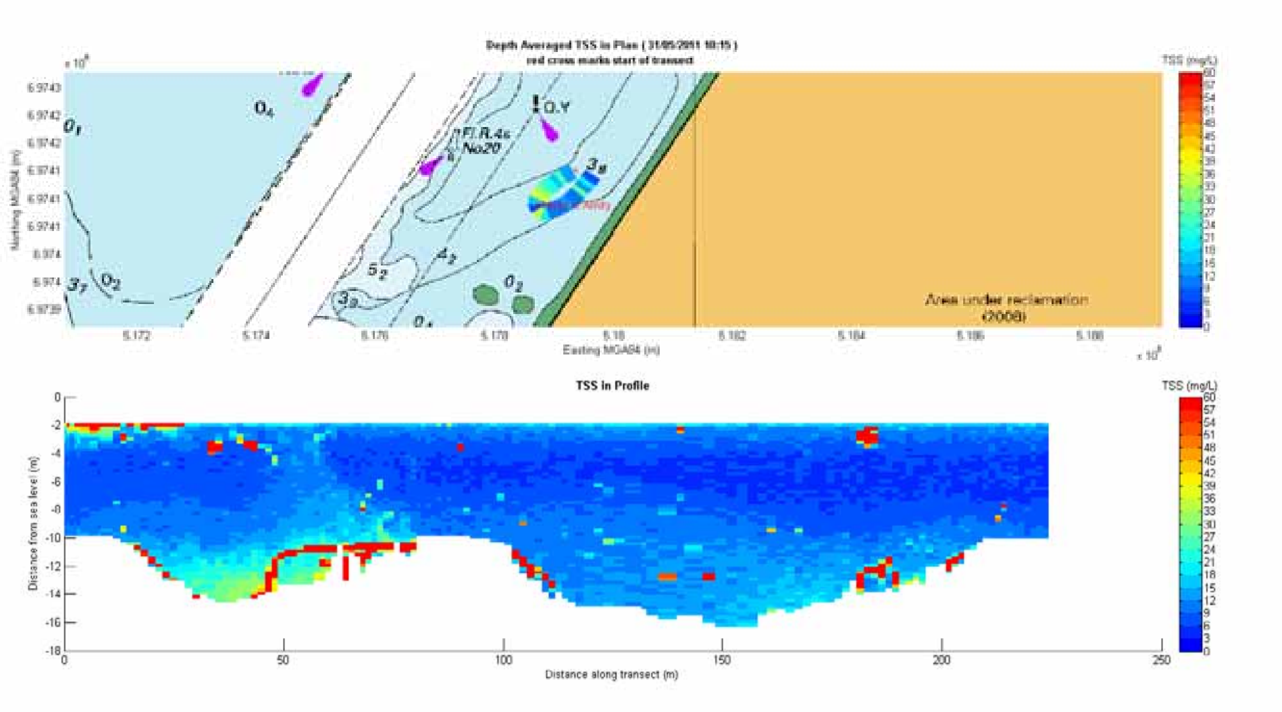

Figure 9-1 *Amity* at Fishermans Island, transect 4

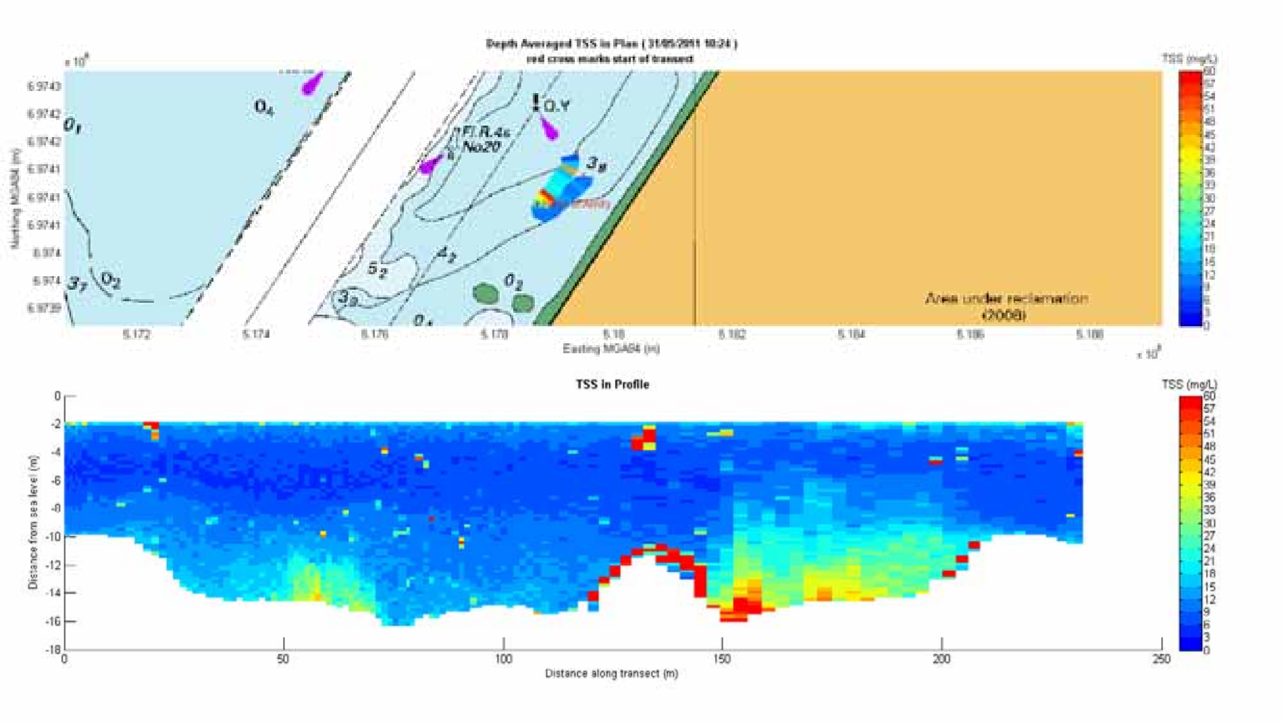

Figure 9-2 ***Amity*** **at Fishermans Island, transect 6**

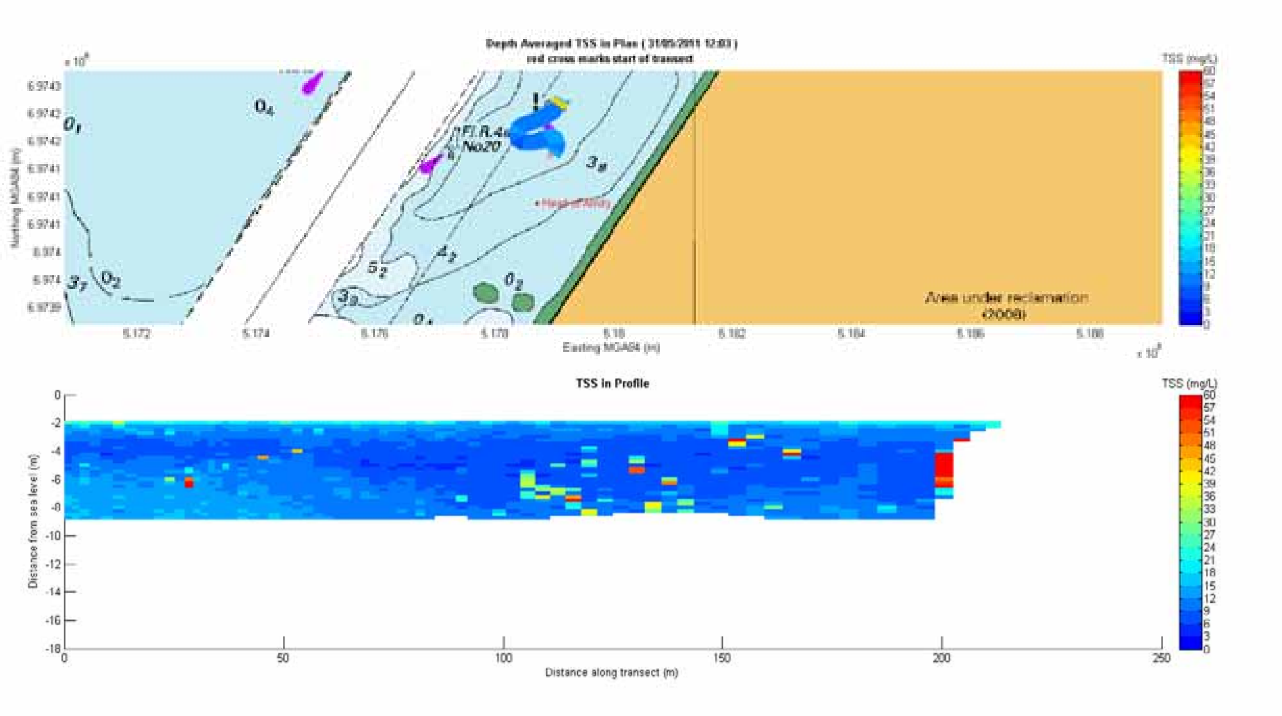

Figure 9-3 ***Amity*** **at Fishermans Island, transect 18**

9.2 Sediment Samples

9.2.1 Particle Size Distribution of Suspended Sediment

The particle size of suspended material in the dredge plume from the *Amity* working at Berth 12 at the Port of Brisbane consisted mainly of very fine silts and clays as shown in Figure 9-4. Together these very fine particles constituted over 95% of the material in suspension in a water sample collected at a depth of 8m in the centre of the plume formed adjacent to the dredger.

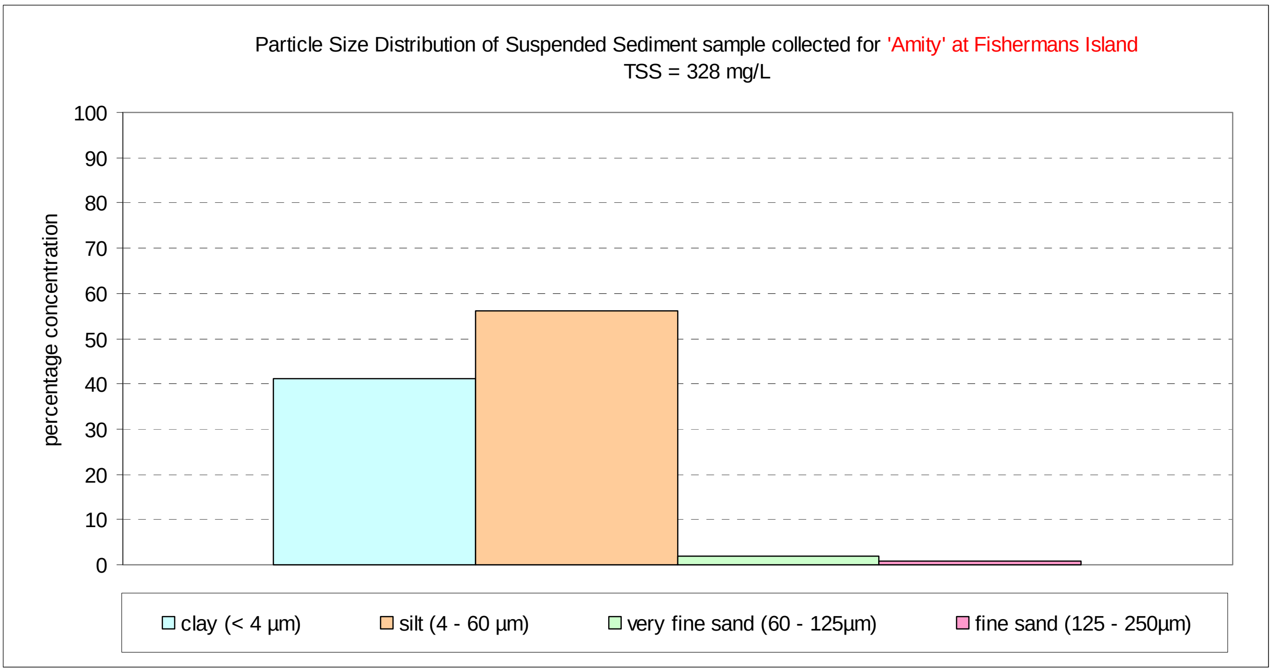

Figure 9-4 PSD of Suspended Sediments for *Amity* at Fishermans Island

9.2.2 Grain Size Analysis of Grab Sample

Figure 9-5 shows the particle size analysis of a collected sediment sample from the dredging area at Berth 12, approximately 30m upstream of the dredger. The sampled material consisted primarily of very fine clay and silt particles (approximately 95% of the sample) with approximately 5% very fine and fine sands.

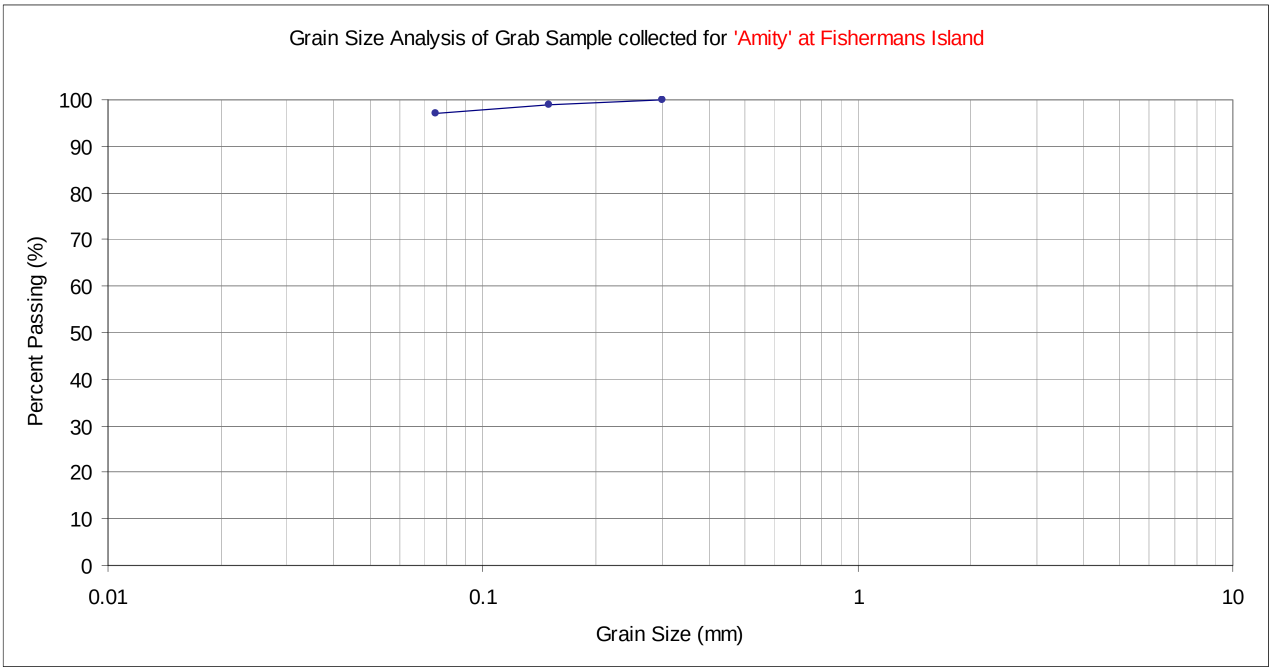

Figure 9-5 Grain Size Analysis of Dredged Sediment for *Amity* at Fishermans Island

9.3 Discussion

Sediment plumes generated by the *Amity* were subsurface plumes carried downstream by the ebbing tide. The dredge plume was quite limited in its spatial extent (refer to Figure 9-1 and Figure 9-2). Sediment concentrations rarely exceeded 50 mg/L in the near field and were no longer detectible above background levels at distances beyond 200m from the cutter head. Turbid plumes were created by sediment entrained in the water column 10-16m below the water surface, where the dredge cutter head was operational. During the period of monitoring, the dredge plume was generally not visible at the water surface. Figure 9-1 shows the appearance of a small near-surface plume, though this was not evident from the vessel. The reason for this may have been the difference between the actual water surface and first ADCP measurement depth cell (bin), which was almost 1.5m below the water surface.

The ADCP TSS plots show that the turbid plume created at the seafloor was initially advected approximately 100-150m down-current on the ebbing tide in a north easterly direction parallel with the Inner Bar Reach of the Brisbane River to the point where there was a abrupt change in the seabed slope, created by previous dredging of the shallow banks, seaward of the dredger. Rather than being carried up this steep slope by the prevailing currents, the ADCP indicated that the plume remained close to the seabed. The plume was then diverted across the base of the wall slope, in a north westerly direction for a further 50-60m towards the centreline of the Inner Bar Cutting where it was indistinguishable from the background turbidity. The turbid plume created by the dredger on the ebbing tide did not impact any known sensitive receptors within the estimated 200m travel distance from the dredger.

Figure 9-3 shows a localised increase in turbidity associated with the fretting of the sediments from the exposed face of the dredged wall, downstream of *Amity*. This fretting was in response to locally increased ebb tide velocities as the water depth reduced in a seaward direction acting upon the exposed wall sediments.

The particle size distribution (PSD) of suspended material within a plume sample from the *Amity* was consistent with the other dredging operations in the lower Brisbane River estuary consisting of approximately 40% clays and 60% silts with minimal concentrations of very fine and fine sands.

According to the *Amity's* dredge master, the underlying sediments being dredged at Berth 12 were primarily sandy clays, unlike the muddy surface material sampled using the grab sampler. The muddy surface sediments collected were similar in texture to other sampling locations collected within the Lower Brisbane River estuary and were consistent with recently deposited material from the January 2011 flood event in the Brisbane River.

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10 DREDGER 'KEN HARVEY'

10.1 Observations and TSS Plots

Table 10-1 provides a schedule of operations and a summary of observations for the monitoring of the *Ken Harvey* at the Forgacs Dry Dock at Colmslie in the Hamilton Reach of the Brisbane River on the 16th May 2011.

As illustrated in Figure 1-4, the *Ken Harvey* is a stationary item of dredging plant, which was dredging the entry channel to the Forgacs Dry Dock at Colmslie, approximately 25-30m in front of the closed dry dock gate. The measurement of turbid plumes about the *Ken Harvey* was complicated by the combination of the local bathymetry and multiple anchor and wire rope mooring lines positioned about the dredger to secure the vessel and dumb barge at the dredging location.

The local bathymetry consisted of a shelving shallow rocky bank located on the riverine side of the entry channel to the dry dock. The bank extended westwards, perpendicular to the dry dock gate. The dry dock entry channel being dredged by *Ken Harvey* in front of the gate was deep compared with the surrounding area, being some 8-10m below datum. As a consequence, although the ebb tide current was measured at approximately 0.35-0.4m/s within the adjacent Hamilton Reach of the Brisbane River, the ebb tide current at the dredging location was almost zero, since there was a stagnation point in the velocity profile immediately ahead of the dry dock gate on the ebbing tide. The low water velocity in front of the dry dock gate in combination with the adjacent shelving rocky bank limited the opportunity for formation of a turbid plume and its advection for any significant distance downstream on the ebbing tide. The shoal area adjoining the dry dock entry channel effectively contained the turbid dredge plume to the area upstream of the dry dock gates. So although the tide was ebbing (moving downstream), turbid plume movement from the *Ken Harvey* actually moved very slowly in an upstream direction, following the locally deeper water depths available in the entry channel to the dry dock.

Figure 10-1 shows the ADCP TSS transect travelling towards the dry dock dredging location from a location offshore, showing localised confinement of the turbid dredged plume to the area adjacent to the dry dock. Figure 10-2 illustrates transects around the stern of the dredger and dumb barge, showing no turbid plume movement past the shallow rocky bank on the ebb tide. Figure 10-3 shows the ADCP TSS transect approximately 60m upstream (though down-current) of dredging. It shows the last traces of the plume which are close to the riverbed. Appendix H presents all of the ADCP TSS transects recorded about the *Ken Harvey* on the ebb tide of 16th May 2011.

The background water turbidity in the Brisbane River about the *Ken Harvey* was highest of any of the dredging locations in the monitoring programme, with typical turbidity measurements of 26-30NTU and corresponding Secchi disc measurements of approximately 0.4m, approximately 100-150m upstream of the dredger. From the muddy appearance of the water at this location there still appeared to be quite a considerable catchment input of freshwater flow to the Brisbane River. The ADCP TSS transects were run from the Brisbane River to as close to the operating clamshell as was practicable (and safe) given the proximity of the anchors, barges and mooring lines about the vessel. The transects were run quite close to the moored vessels (*Ken Harvey* and dumb barge) so that the turbid plume could be identified and it wasn't until several different tracks had been trialled that it became evident that the turbid plume was in fact slowly moving upstream on the ebbing tide.

In this instance, no drogues were deployed for fear of snagging the various anchor cables used to secure *Ken Harvey* at the dredging location.

Typical plume turbidities were between 50 and 90NTU near the water surface close to the dredger (within 10m) with corresponding Secchi disc measurements as low as 0.1-0.2m. Maximum turbidity measured within the plume was 130NTU, near the water surface, approximately 8m from the dredger.

Table 10-1 Schedule of Operations, *Ken Harvey* at Forgacs Dry Dock: 16th May 2011

Time	Event	Comments
08:08	High water - 2.1m	Expected tidal range at Brisbane Bar of 1.8m, Calm and sunny.
08:30	Moor next to *Ken Harvey*, meet with dredge operators	
08:55	Begin measurements of background conditions	Brown river water, Secchi disc: 0.4m Turbidity: 30NTU
09:00	Begin measurements of sediment plumes	Plumes detectible adjacent to dredge clamshell
09:25	Dredging stops	Barge full and awaiting replacement
10:50	Dredging recommences	New barge arrives, the tug *Turtle* is used to manoeuvre new barge to site.
10:55	Continue monitoring	Secchi disk reduced to 0.1m, 8m from dredge, turbidity reading of 50-90NTU in plume.
12:55	Stopped dredging	Washing off barge
13:20	Sediment grab sample collected	Sample consists of dark grey mud with a trace of very fine sand.
14:29	Low water – 0.3m	

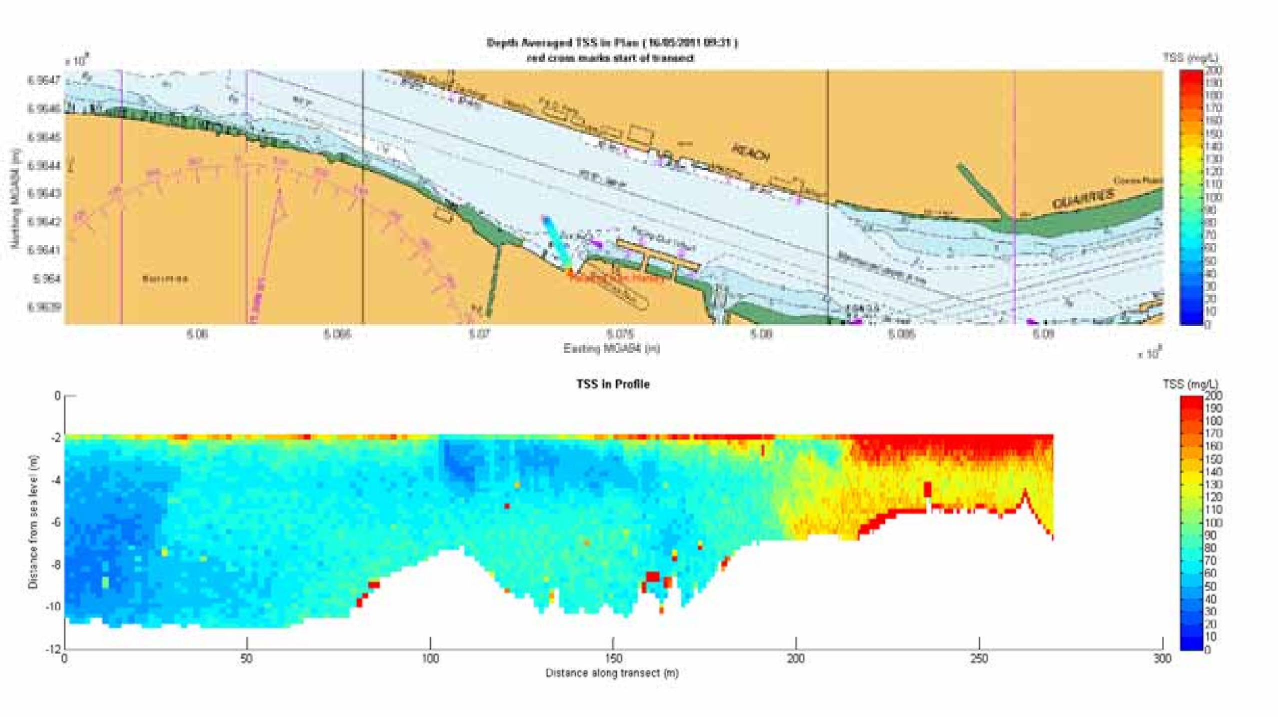

Figure 10-1 ***Ken Harvey*** **at Forgacs, transect 2**

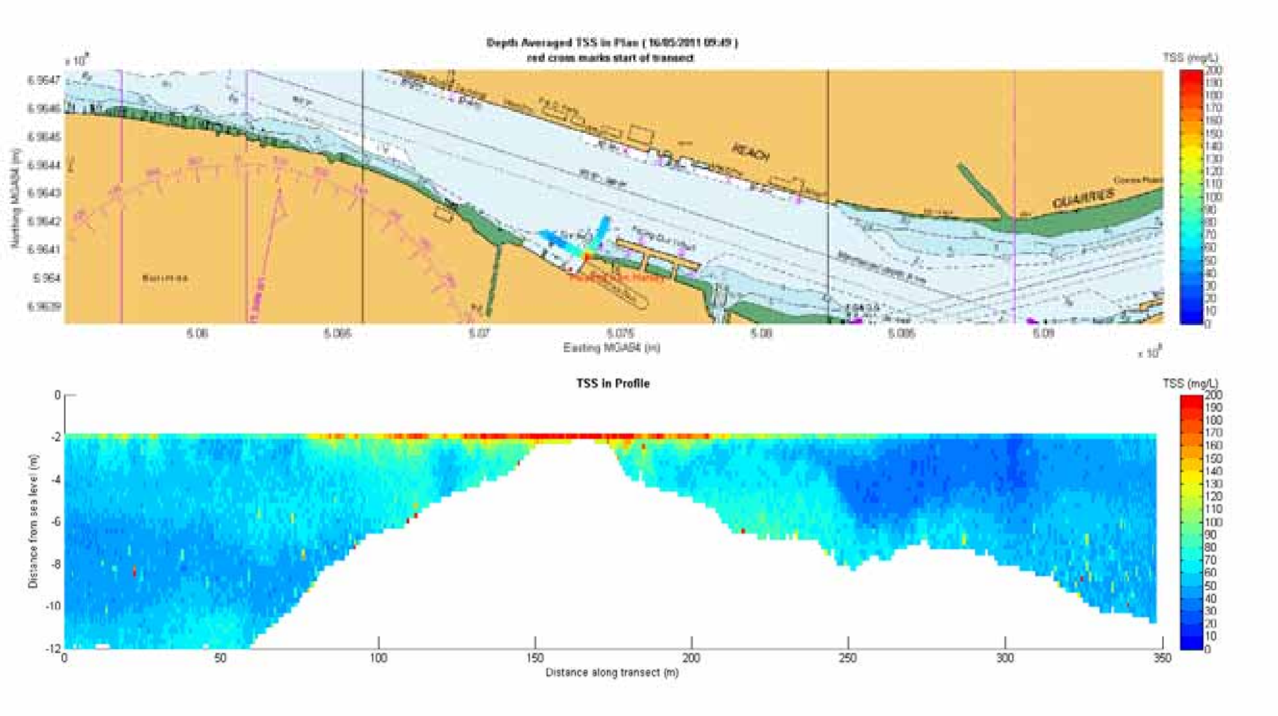

Figure 10-2 ***Ken Harvey*** **at Forgacs, transect 3**

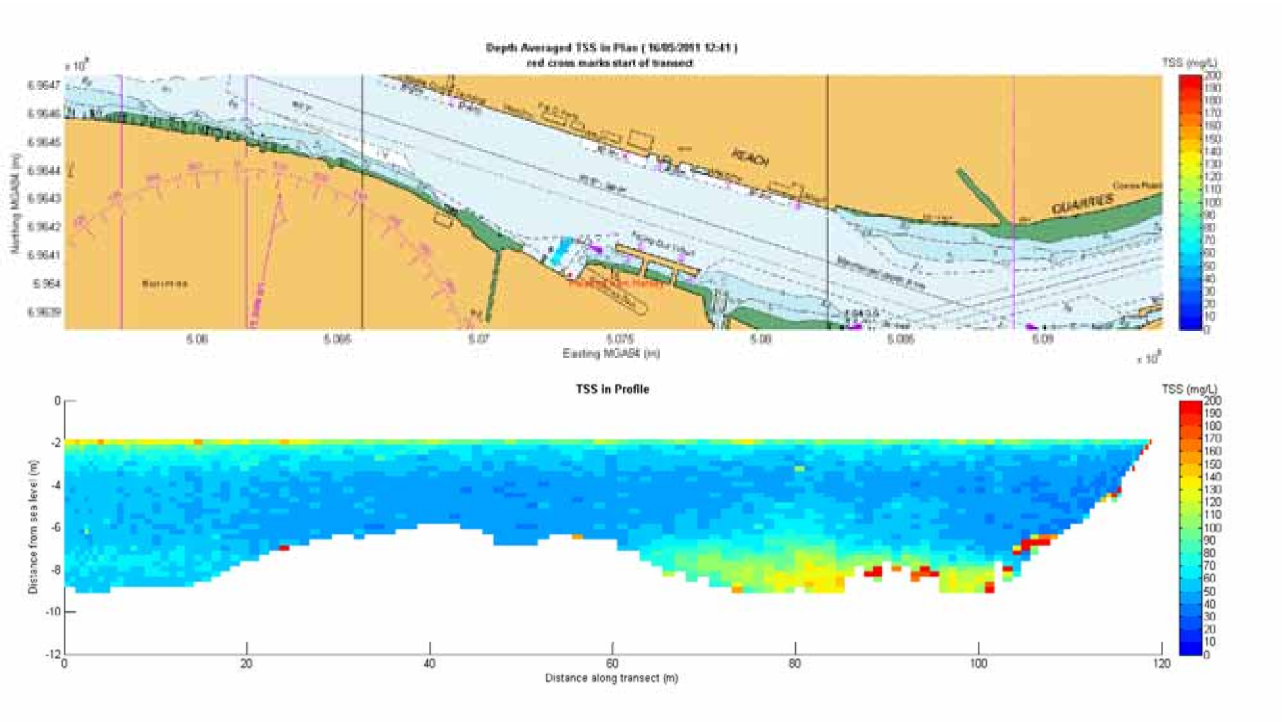

Figure 10-3 *Ken Harvey* at Forgacs, transect 12

10.2 Sediment Samples

10.2.1 Particle Size Distribution of Suspended Sediment

The particle size of suspended material in the dredge plume from the *Ken Harvey* working at the Forgacs dry dock consisted mainly of very fine silts and clays as shown in Figure 10-4. Together these very fine particles constituted over 90% of the material in suspension captured in a water sample collected at a depth of 3m adjacent to the dredger.

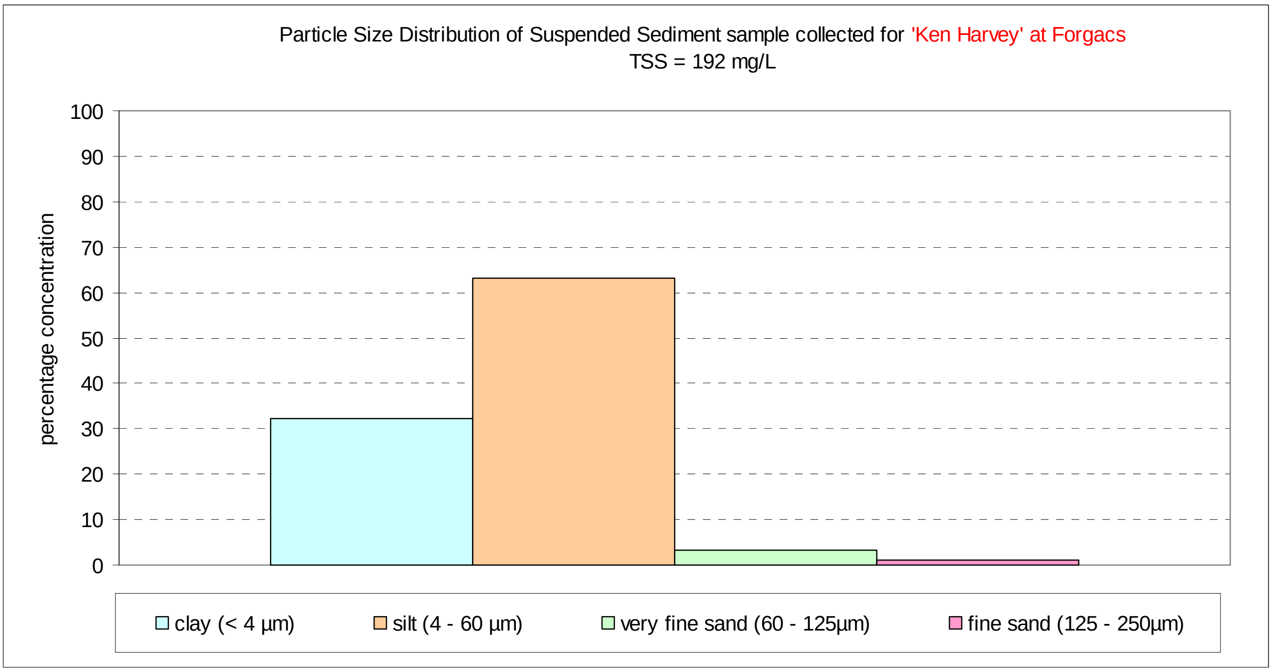

Figure 10-4 PSD of Suspended Sediment for *Ken Harvey* at Forgacs Dry Dock, Colmslie

10.3 Discussion

Sediment plumes generated by the *Ken Harvey* were localised and of a small scale, being apparent near the riverbed no further than approximately 60m from the operational dredger.

The turbid plumes were generated in pulses by the lowering, grabbing and lifting of the clamshell with dredged sediments through the water column and any spillage whilst the dredged material was lifted and dropped into the waiting dumb barge. The ADCP TSS transects and turbidity profiles all showed suspended sediment levels in the plume exceeding 150mg/L and reaching 200mg/L in close proximity (within 20-25m) of the dredger (refer to Figure 10-1).

The turbid plume was evident above background concentrations at a distance of approximately 50-60m upstream of the dredger, near the riverbed as shown in Figure 10-3. The very slow movement of the plume upstream on the ebbing tide was in part likely due to protective shallow bathymetry on the riverine edge of the dry dock entry channel which provided protection from higher ebb tide velocities further offshore, possibly with a very small residual upstream recirculation velocity. Probably of equal importance were the localised deeper waters of the entry channel which allowed the plume sediments to settle under gravity. The high ADCP TSS concentrations evident in Figure 10-2 in the very shallow water near the shallow rocky shoal were not part of the plume generated by the *Ken Harvey* but resulted from re-suspension of sediment in shallow areas due to passing vessel wash.

The particle size distribution (PSD) of suspended sediments in a water sample collected from the turbid plume about *Ken Harvey* consisted almost entirely of very fine clay and silt material.

Laboratory analysis of the sediment grab sample collected adjacent to the Ken Harvey was not undertaken due to its inadvertent loss at the laboratory. Field classification of the sediment sample texture was a dark grey mud of silt and clays with traces of very fine sand - similar to the other dredging locations in the Brisbane River estuary.

11 BED LEVELLER 'ALAN M' AND 'SEAHORSE'

11.1 Observations and TSS Plots

Table 11-1 shows a schedule of operations and a summary of observations for the monitoring of the *Alan M* at the Incitec and Pinkenba wharfs on the 1st June 2011.

Appendix I illustrates the recorded ADCP TSS plots for the bed leveller *Alan M* and *Seahorse*. Figure 11-1 illustrates an ADCP TSS transect recorded whilst following 20-30m astern of the bed levelling vessels at Pinkenba wharf. The bed leveller resulted in the formation of visible surface plumes astern of *Seahorse*, though surface TSS concentrations shown in Figure 11-1 were overestimated because of the presence of fine bubbles in the stern wake of the *Seahorse*. Figure 11-2 and Figure 11-3 show the ADCP TSS concentrations in the plumes formed by bed levelling approximately 100m and 200m downstream of the bed levelling area respectively.

Recording the near field plumes generated by the fast moving *Alan M* and *Seahorse* was unlike the monitoring required for the *Amity* or *Ken Harvey*. The *Alan M* was pushed by tug *Seahorse* at a speed of between 2 and 4 knots during the bed levelling process. Once the combined vessels (barge and tug) were located at the bed levelling position (and the bed levelling blade was lowered to the correct level), the sediment was then moved quite quickly away from the berth. Each bed levelling cycle (start to finish) required approximately 5 minutes, so it was difficult to complete the required near-field plume measurements before the next bed levelling cycle was already underway. To do so, the survey vessel *Resolution II* followed astern of *Alan M* on its 'C' shaped track, (refer to Section 1.3.5), and then quickly cleared the area just before the bed levelling unit returned to the measurement area on its next levelling operation. Turbid plume measurements using the ADCP TSS transects alone were able to be recorded on every second bed levelling operation. However, when turbidity profiling measurements and water sample collection were also required, these measurements could only be collected at a frequency of every third or fourth bed levelling operation.

No drogues were deployed because of the likelihood of interference with the bed levelling craft or other vessels using the main navigation channel. In order to determine the effects of the ebb tide upon plume settlement and dispersion, shore-normal ADCP transects were conducted, moving further downstream until the plumes were no longer detectible, (Figure 11-2 and Figure 11-3).

The surface plumes were clearly visible behind the *Seahorse* when the bed levelling blade was positioned on the seafloor. The plumes were accompanied by highly energetic eddies, surfacing at speeds up to 1m/s, and these were associated with the turbulence generated by the *Seahorse's* propulsion units. Small air bubbles could be seen in the surface plumes and these were responsible for overestimates in the ADCP measurements of TSS. The surface plumes generated by the bed leveller were quick to disperse and were no longer evident 5-10 minutes after their formation.

Typical background water turbidity readings on the ebbing tide at Pinkenba wharf area were 5-7NTU with Secchi disc visibility of 0.8-0.9m. Typical surface turbidity concentrations in the near field plumes rarely exceeded 25NTU and those close to the seabed exceeded 100NTU. The surface plumes were dispersed to background turbidities within 100-150m downstream of the dredging area. The nearbed plumes were still evident at distances up to 200m from their point of formation. Neither surface nor near-bed turbid plumes were evident at a distance of 250m downstream of the bed leveller.

Table 11-1 Schedule of Operations, *Alan M* and *Seahorse* at Incitec and Pinkenba Wharfs: 1st June 2011.

Time	Event	Comments
08:48	High water - 1.8m	Expected tidal range at Brisbane bar of 1.4m, overcast conditions
09:30	Liaise with dredge master	
09:45	Take background readings	Turbidity: 5NTU, Secchi disk: 0.9m
09:45	Begin measurements at Incitec South wharf.	ADCP and turbidity profiling measurements allied with TSS water sample collection. Turbidity:32NTU, Secchi disk: 0.2m typical for surface plume, Turbidity 115NTU in the near-bed plume.
10:00	*Alan M* moves to Pinkenba wharf	Making way for *Brisbane* to dredge near Incitec South wharf
10:10	Continue measurements now at Pinkenba Wharf	Transects following tug *Seahorse* closely to detect maximum concentrations. Transects downstream to determine the extent of the plume's movement. Intense short lived plumes of mud and air bubbles generated by tugs propellers. Plumes downstream not detectible at 250m and only just detectible with ADCP at 170m downstream.
11:30	Final ADCP transect	
11:35	Dredging operations complete	Dredge master awaits survey vessel
11:40	Collect sediment grab sample	Dark grey mud of fines with traces of very fine sand.
15:00	Low water – 0.4m	

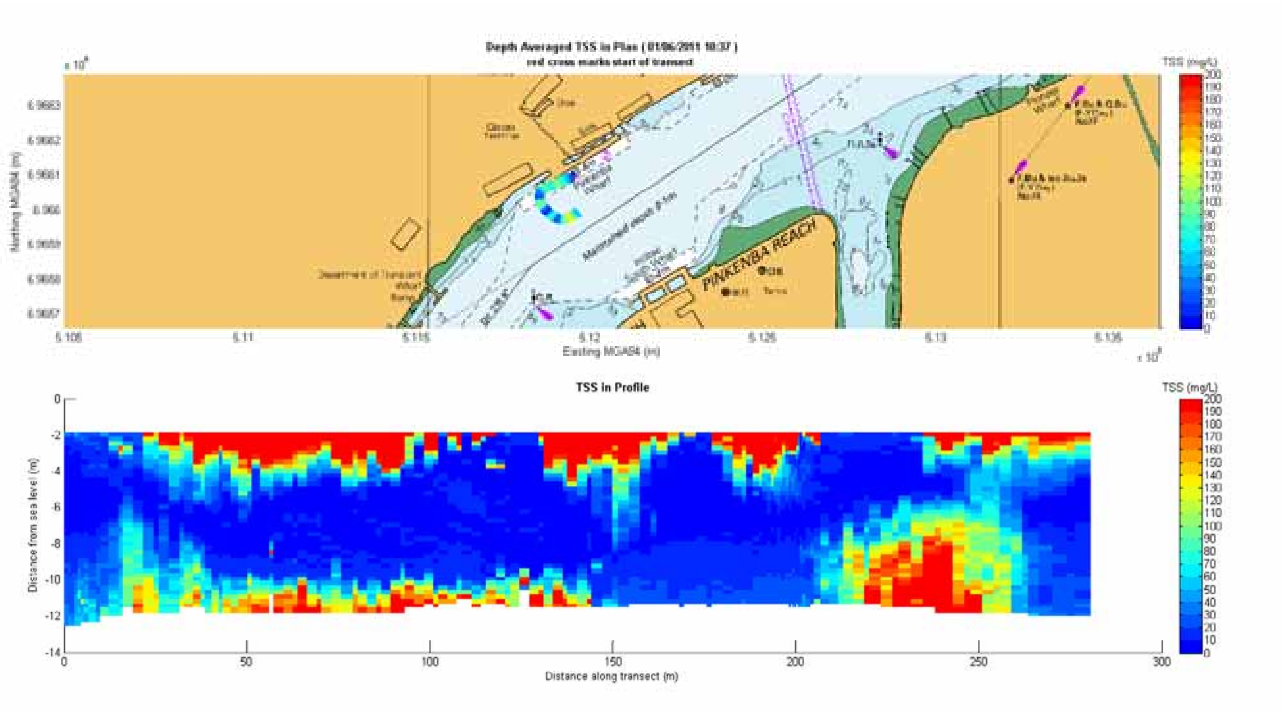

Figure 11-1 *Alan M* at Pinkenba Wharf, transect 2

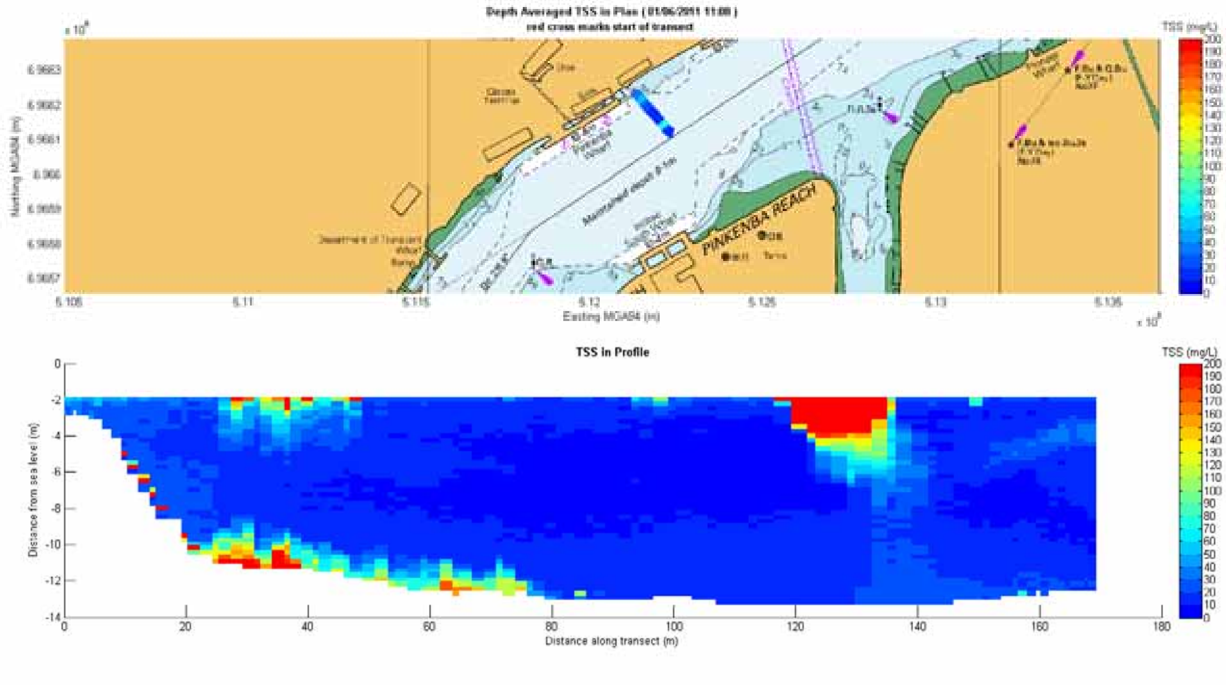

Figure 11-2 *Alan M* **at Pinkenba Wharf, transect 6**

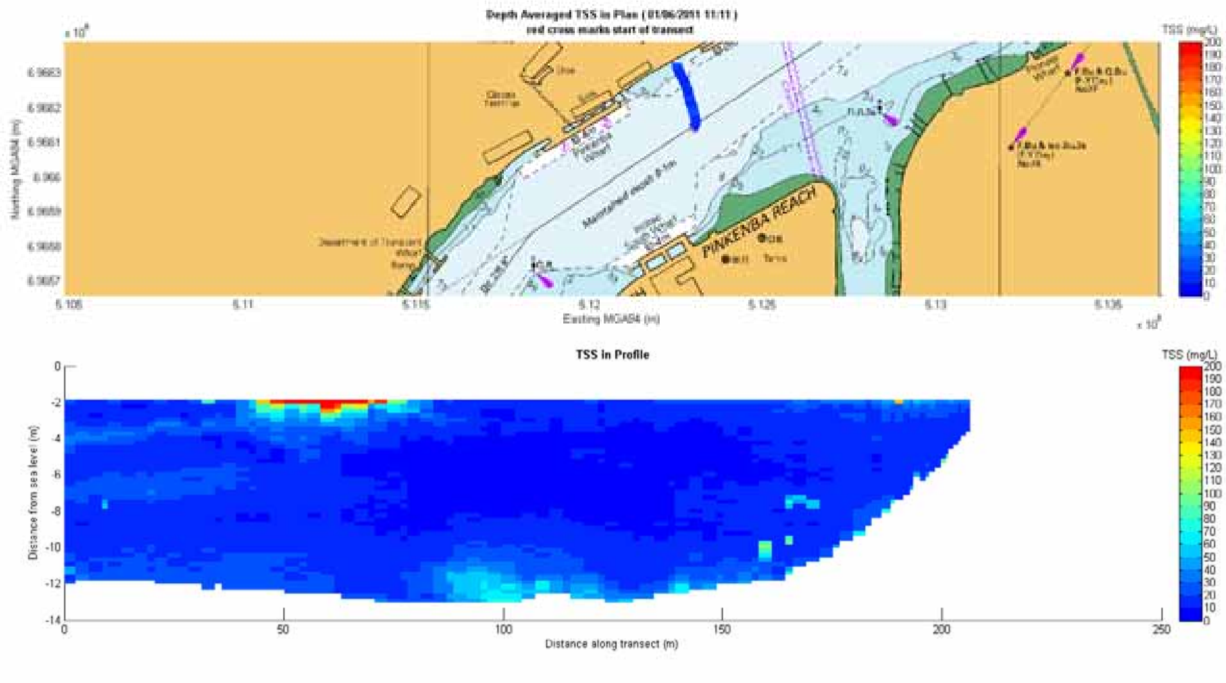

Figure 11-3 *Alan M* **at Pinkenba Wharf, transect 7**

11.2 Sediment Samples

11.2.1 Particle Size Distribution of Suspended Sediment

The particle size of suspended material in the dredge plume from the bed Leveller *Allan M and Seahorse* working at the Incitec wharf consisted mainly of very fine silts and clays as shown in Figure 11-4. Together, these very fine particles constituted over 90% of the material in suspension in a water sample collected at a depth of 11m astern of the bed leveller.

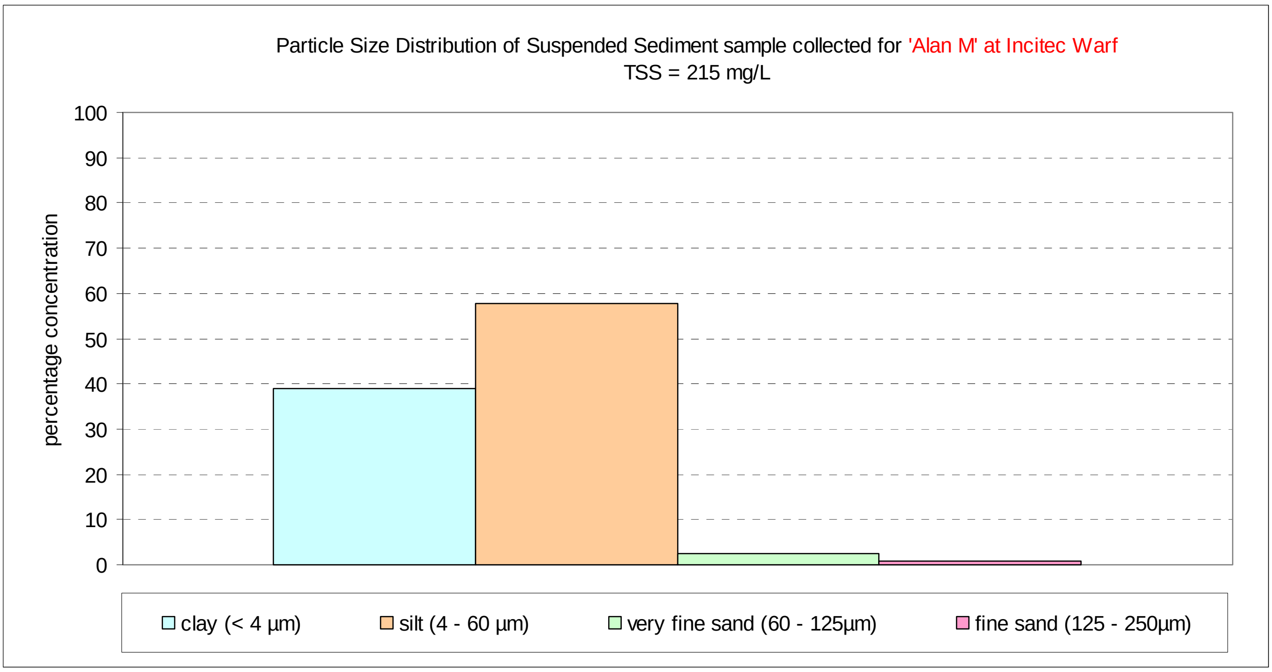

Figure 11-4 PSD of Suspended Sediments for *Alan M* at Incitec Wharf

11.2.2 Grain Size Analysis of Grab Sample

The particle size analysis of a sediment sample obtained from the bed levelling area at Pinkenba wharf on the 1st June 2011 is shown in Figure 11-5. The bed sediments collected consisted almost wholly of very fine clay and silts, with 99% of the sampled material passing through the smallest 75µm diameter mesh.

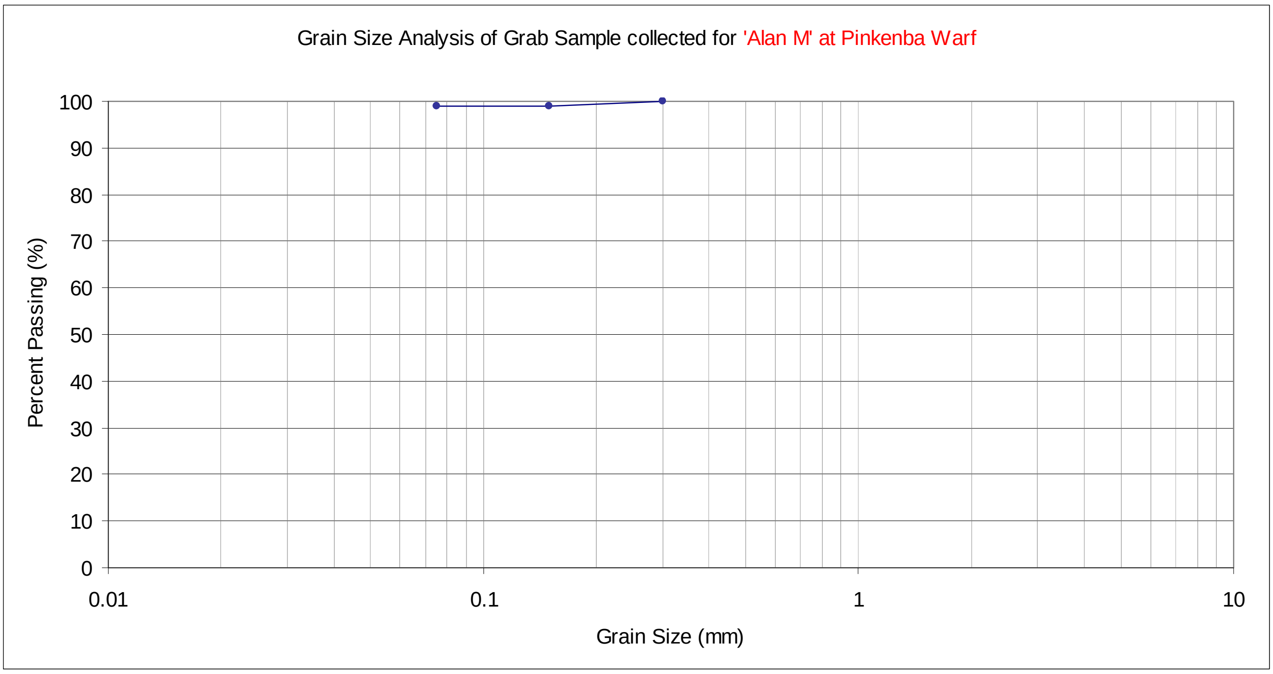

Figure 11-5 Grain Size Analysis for *Alan M* at Pinkenba Wharf

11.3 Discussion

Sediment plumes generated by the *Alan M* and *Seahorse* were characterised by clearly visible plumes at the water surface and plumes of considerably higher TSS concentrations near the seabed. At the water surface, the estimated plume length was typically 120-150m and followed the length of the vessel track, from where the bed levelling blade was lowered to the seafloor and used to push sediments off the face of the berth area. Newly formed surface plumes had a width of approximately 15-20m at the water surface and appeared to have been formed by the action of bed sediments rising over the bed levelling blade. The plumes were entrained into the water column above the blade and were ultimately raised to the water surface by the tug's propulsion units. The surface plumes remained visible for up to 5 to 10 minutes and approximately100-150m downstream of their point of formation. Based upon the turbidity profiles and laboratory analysis of collected water samples, the surface plume TSS concentrations were of the order 30 to 40 mg/L, (not 200mg/L as indicated by the ADCP TSS transects).

The near bed plumes were generated by the blade of the bed leveller *Alan M* pushing through the sediment. Initially, the near bed plumes consisted of high concentrations of suspended sediment with the ADCP TSS, turbidity profiling measurements and collected water samples all indicating TSS concentrations up to 200 mg/L. The near bed plumes were evident in the ADCP transects up to 200m downstream of the bed levelling operations. The plumes were not evident 250m downstream of bed levelling operations on the ebbing tide.

The particle size distribution (PSD) of suspended solids within a water sample collected from the turbid plume astern of the *Alan M and Seahorse* consisted almost entirely of very fine textured clay and silt particles. This result was consistent with the size analysis of surface sediment collected from the Pinkenba wharf berth, which was fine textured mud containing almost exclusively clay and silt sized particles.

APPENDIX A: DREDGER 'BRISBANE' AT INNER BAR CUTTING

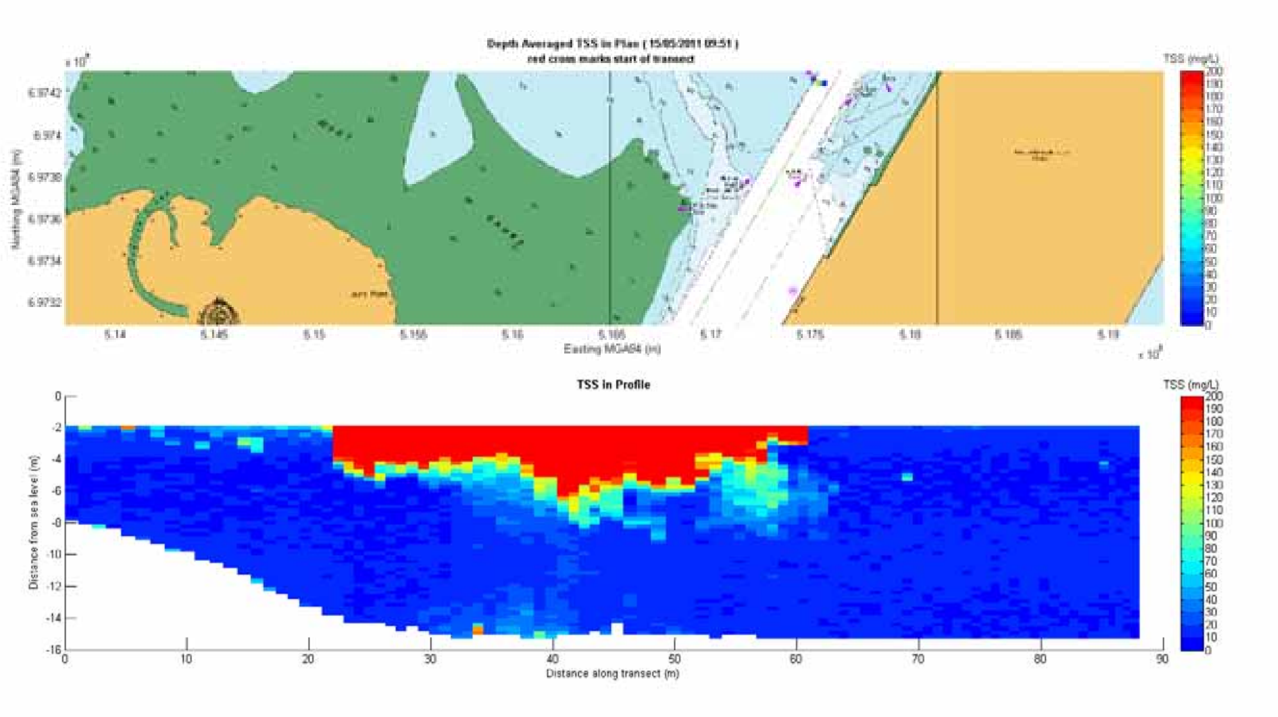

Figure A- 1 ***Brisbane*** **at Inner Bar, transect 1 (Astern of dredger prior to hopper overflow)**

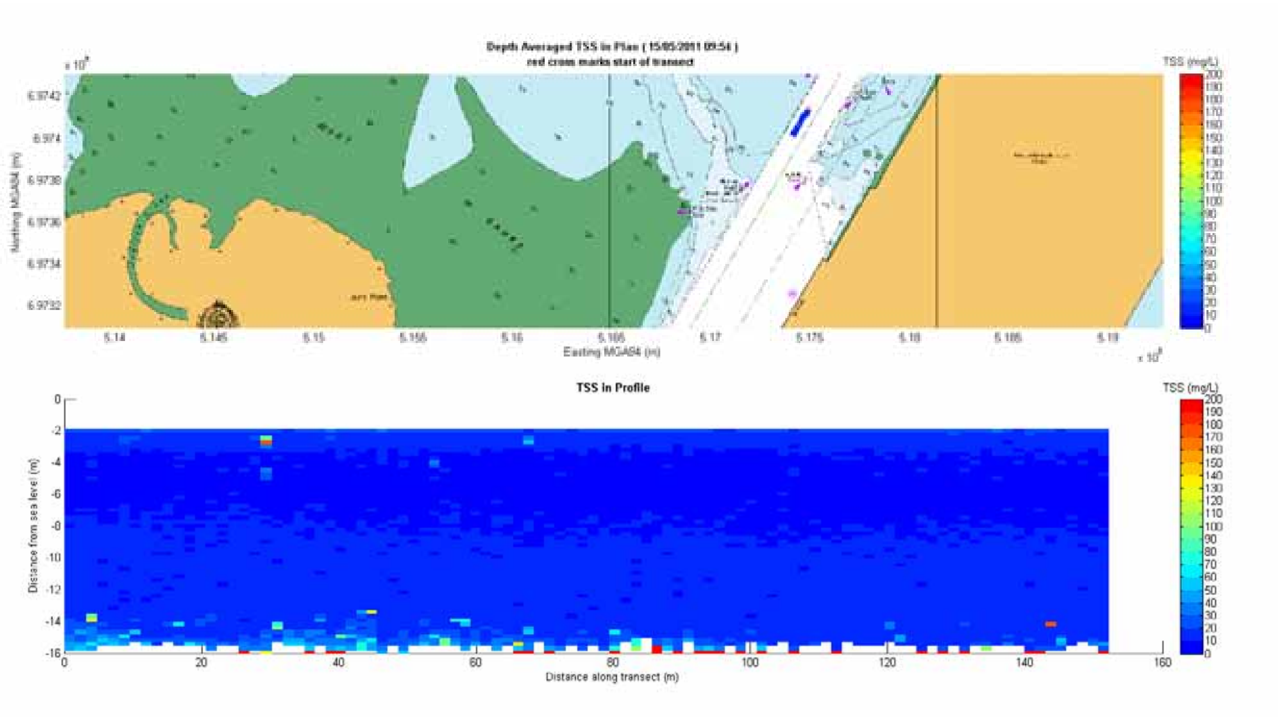

Figure A- 2 Brisbane at Inner Bar, transect 2

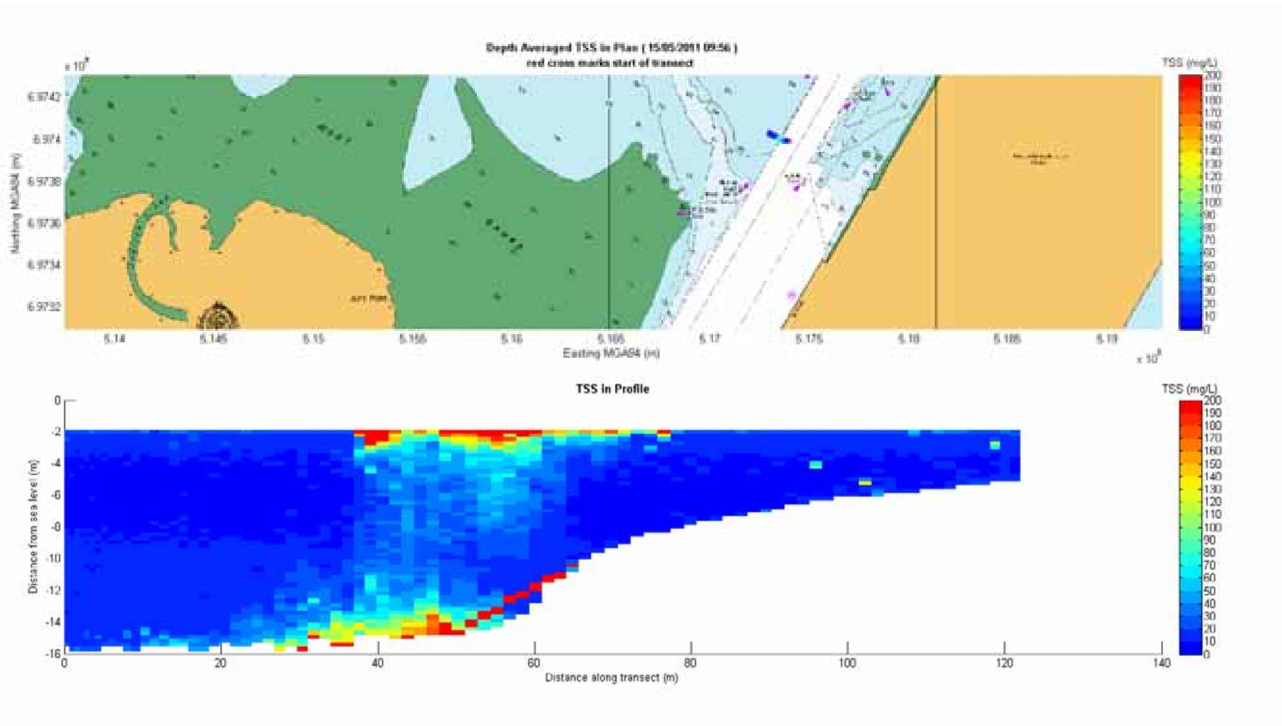

Figure A- 3 ***Brisbane*** **at Inner Bar, transect 3**

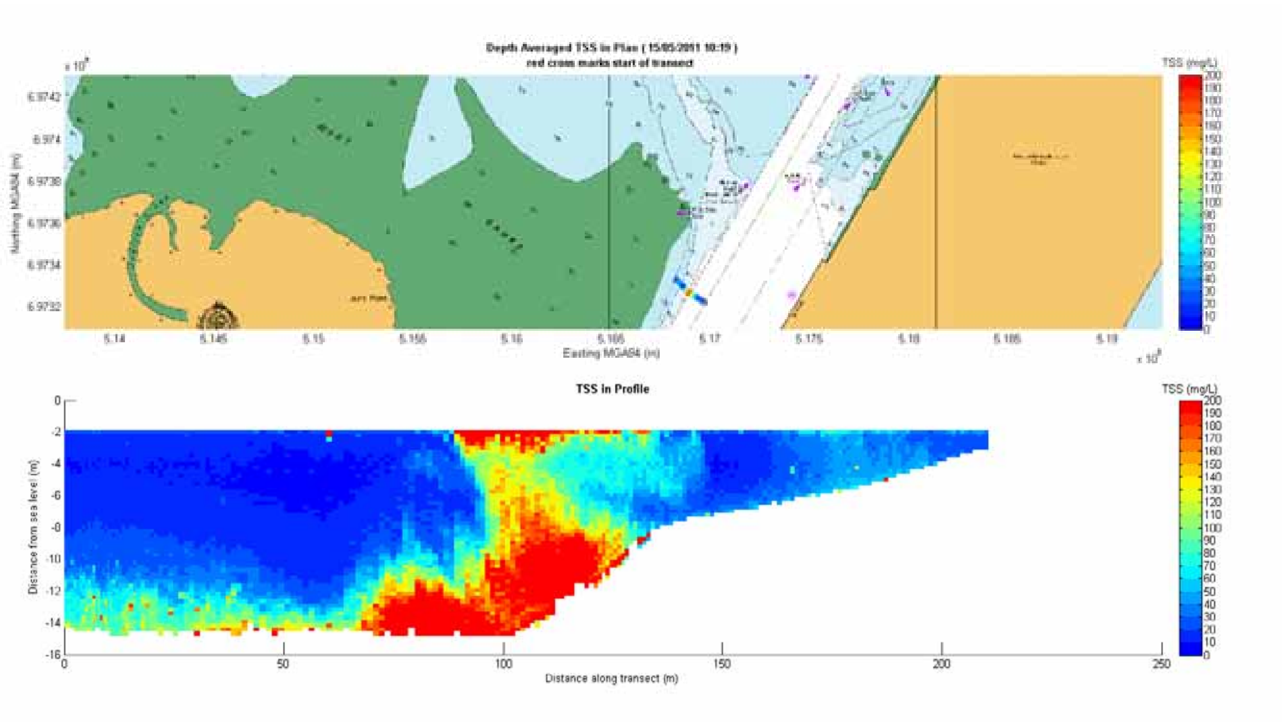

Figure A- 4 ***Brisbane*** **at Inner Bar, transect 4**

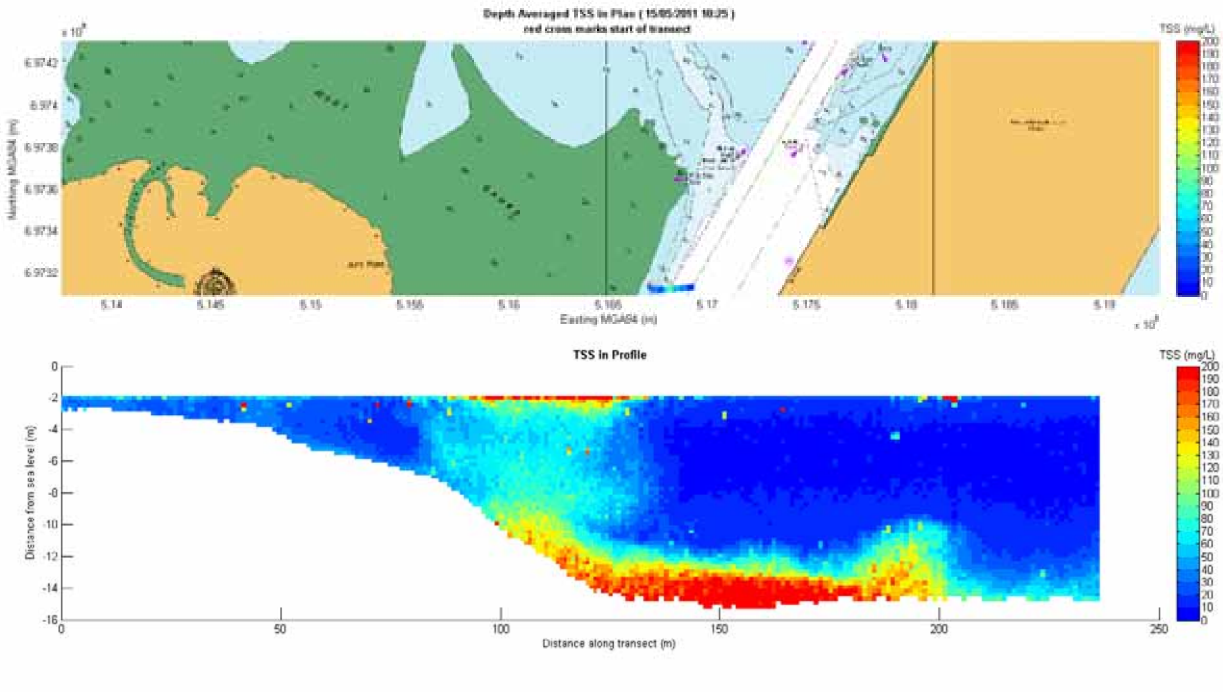

Figure A- 5 Brisbane at Inner Bar, transect 5

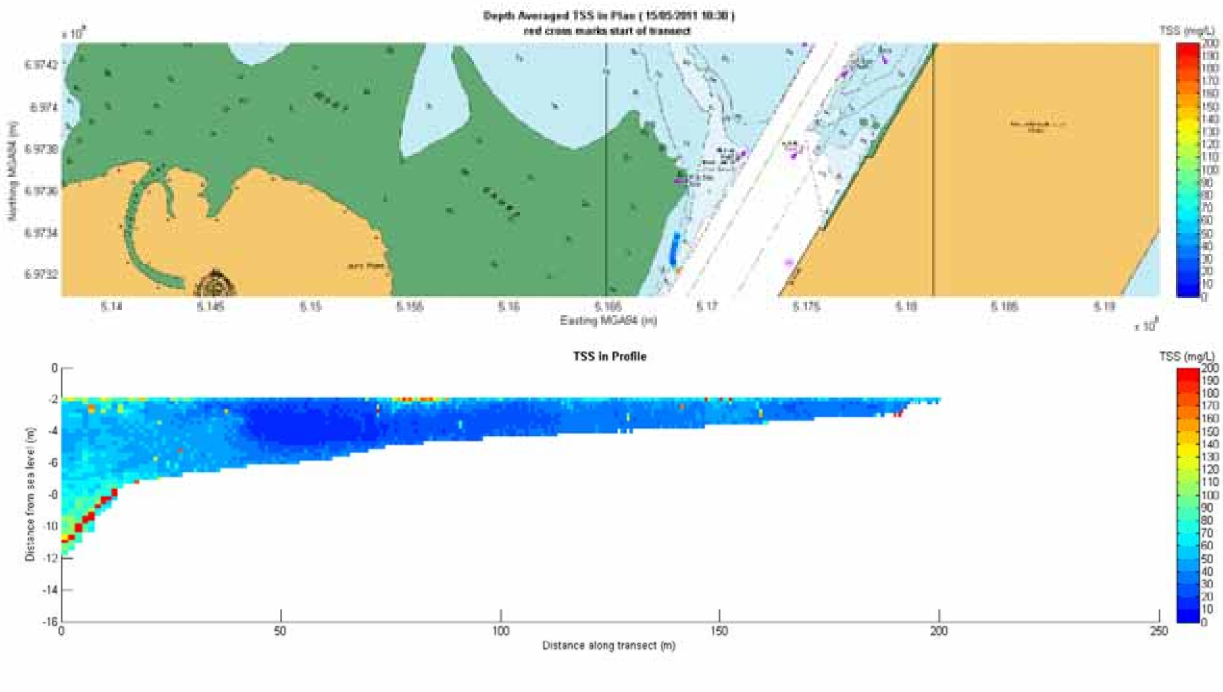

Figure A- 6 *Brisbane* at Inner Bar, transect 6

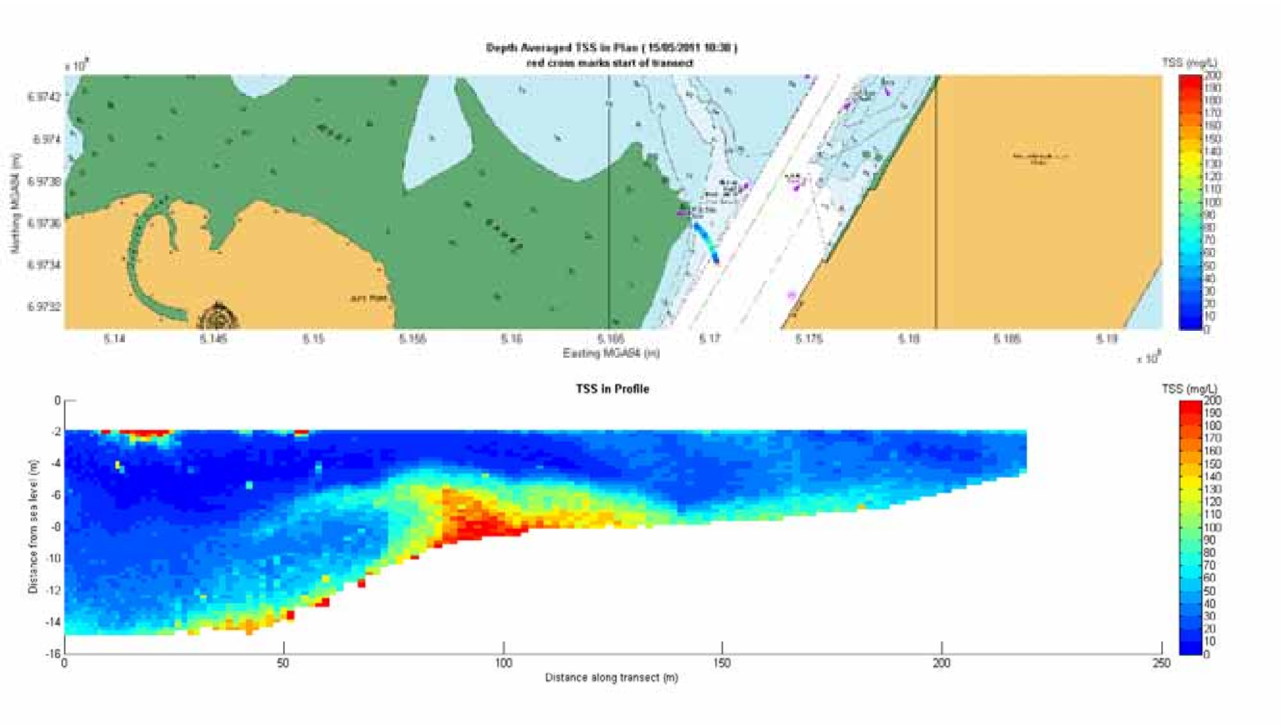

Figure A- 7 *Brisbane* at Inner Bar, transect 7

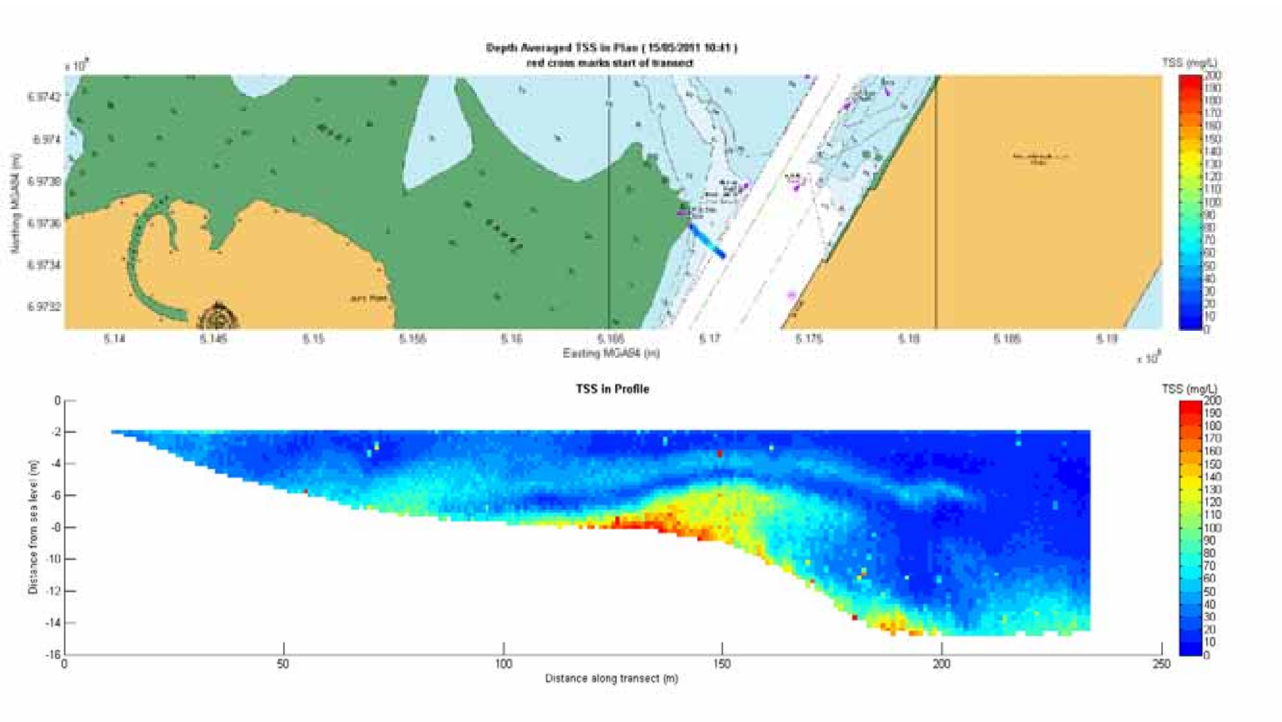

Figure A- 8 *Brisbane* at Inner Bar, transect 8

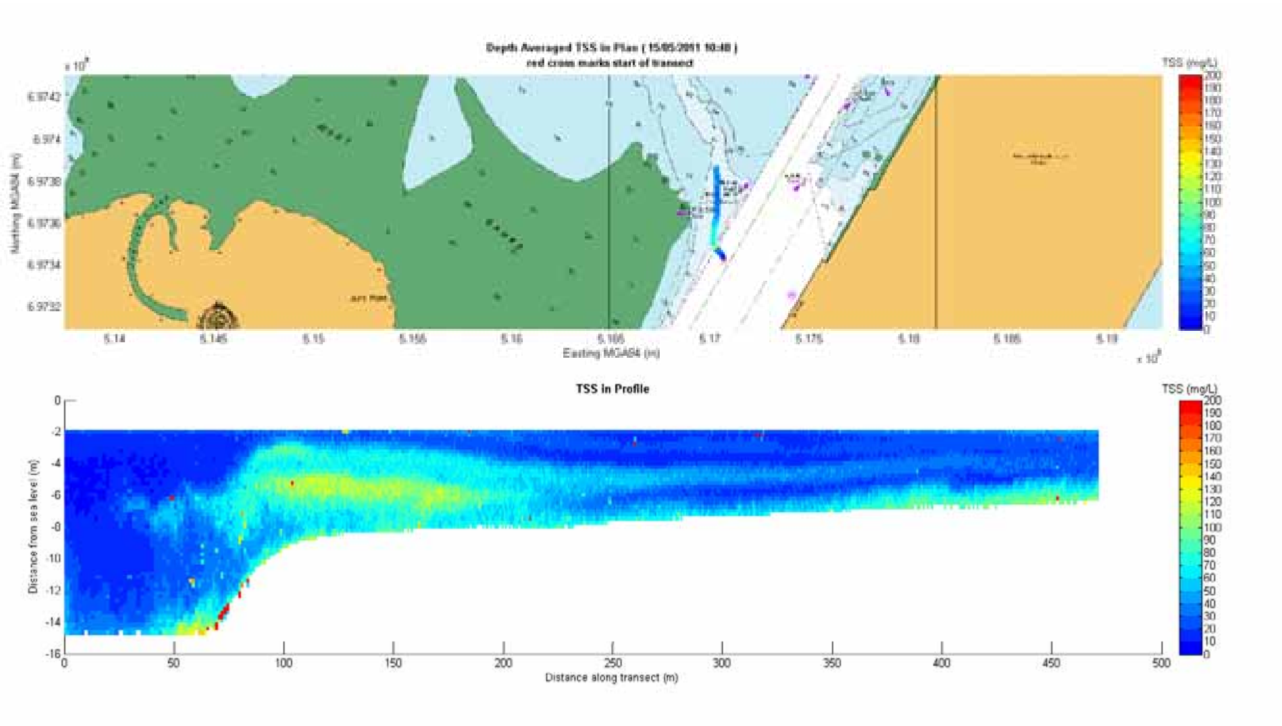

Figure A- 9 *Brisbane* at Inner Bar, transect 9

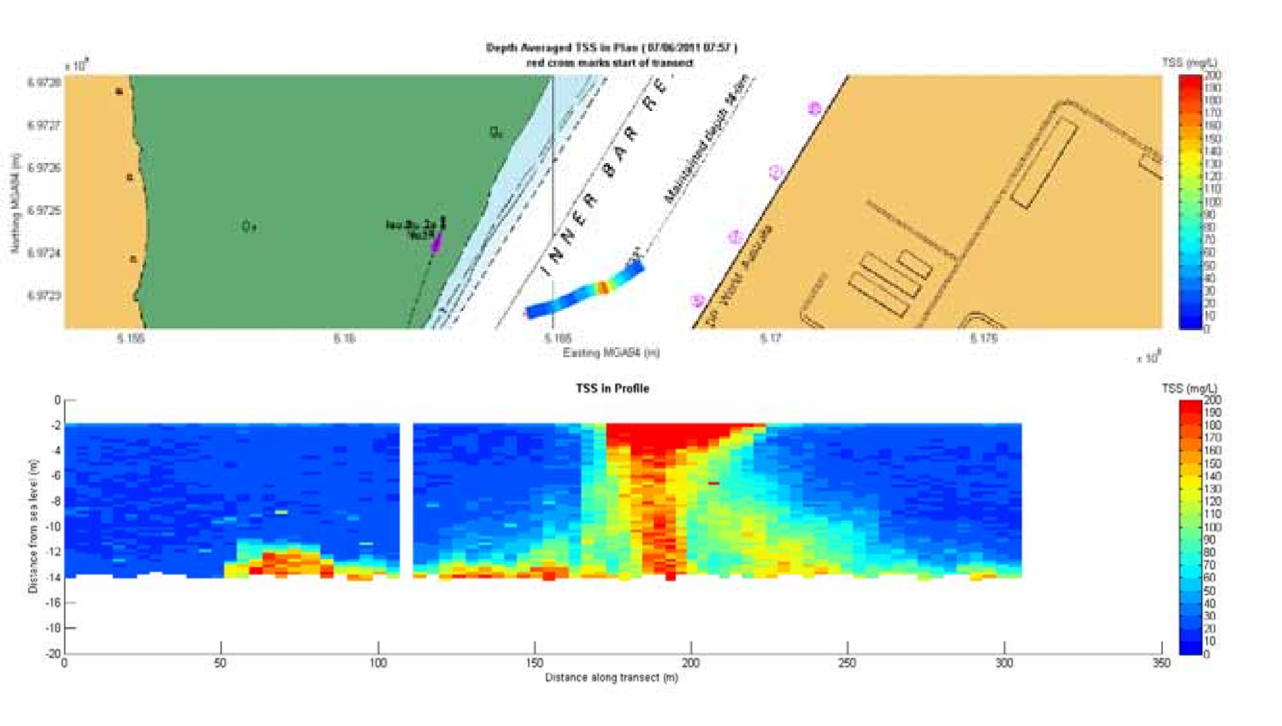

Figure A- 10 *Brisbane* at Inner Bar, transect 1b

APPENDIX B: DREDGER 'BRISBANE' AT OUTER BAR CUTTING

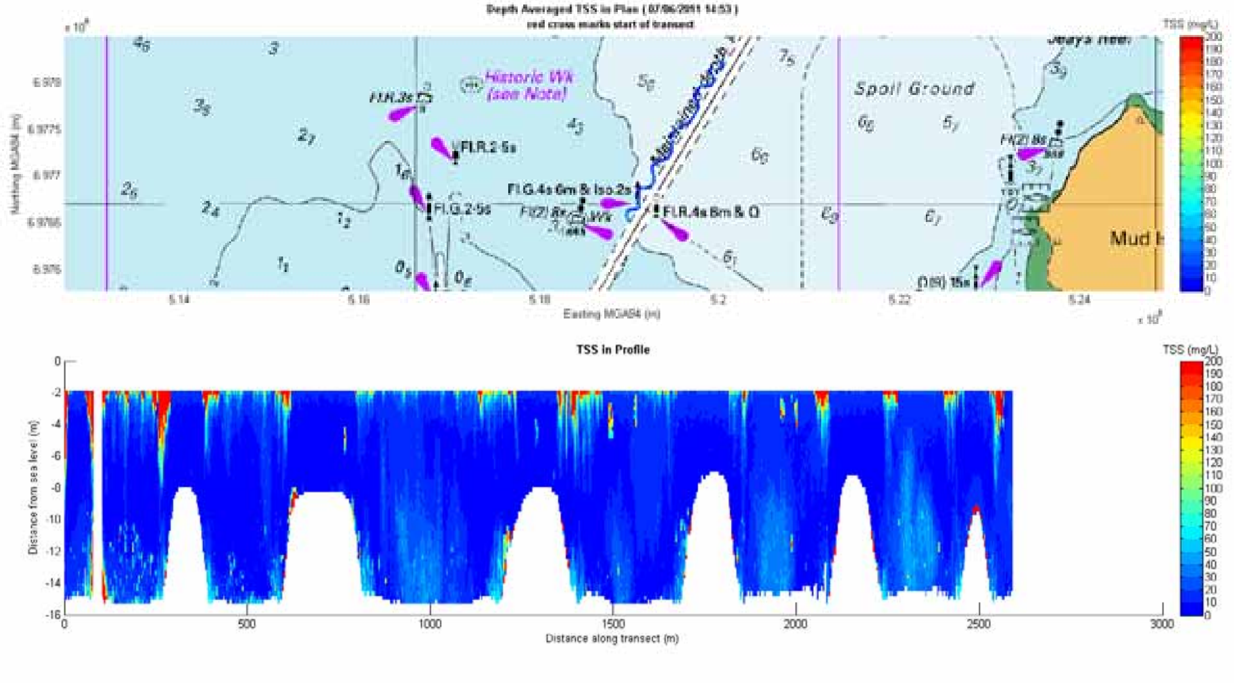

Figure B- 1 ***Brisbane*** **at Outer Bar, transect 1 (prior to hopper overflow)**

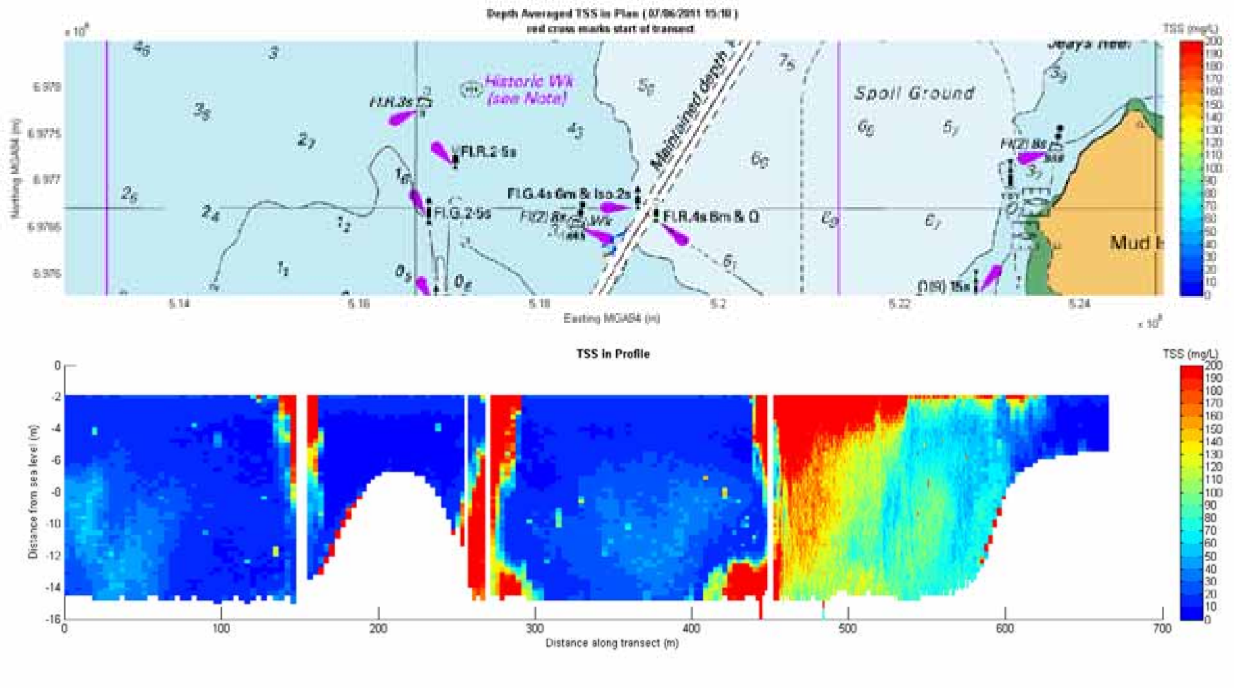

Figure B- 2 ***Brisbane*** **at Outer Bar, transect 2**

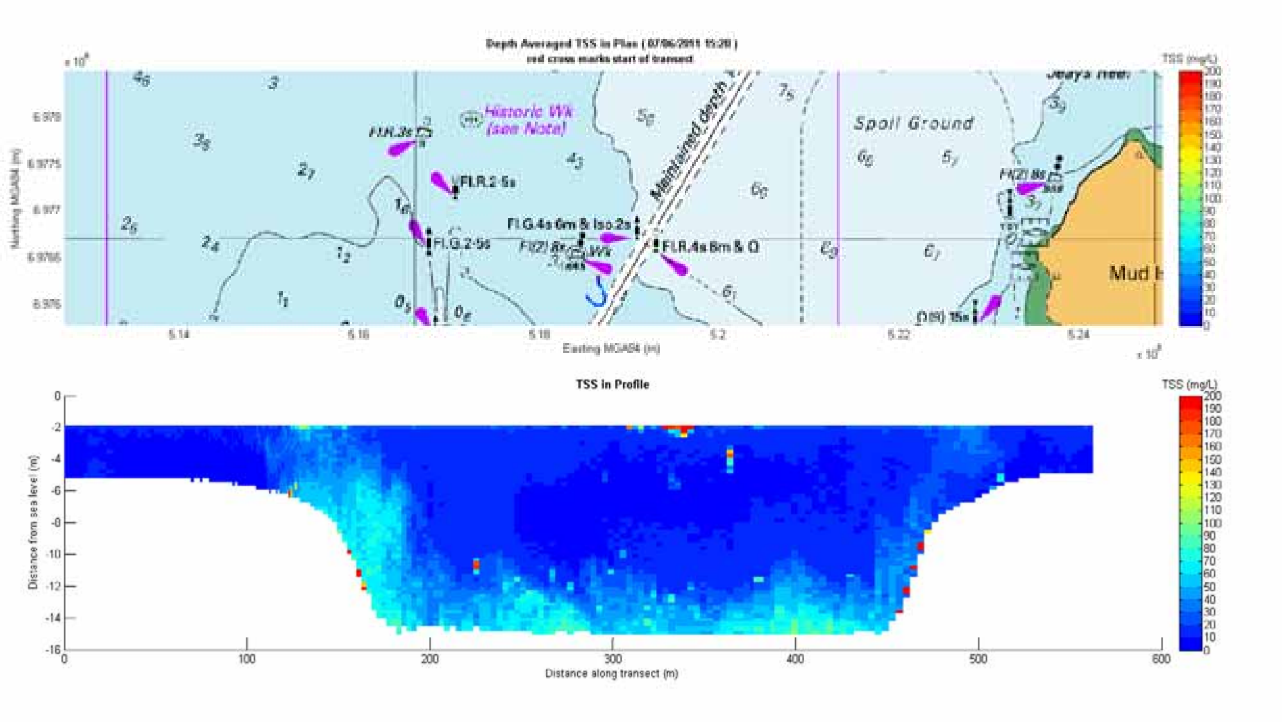

Figure B- 3 *Brisbane* at Outer Bar, transect 3

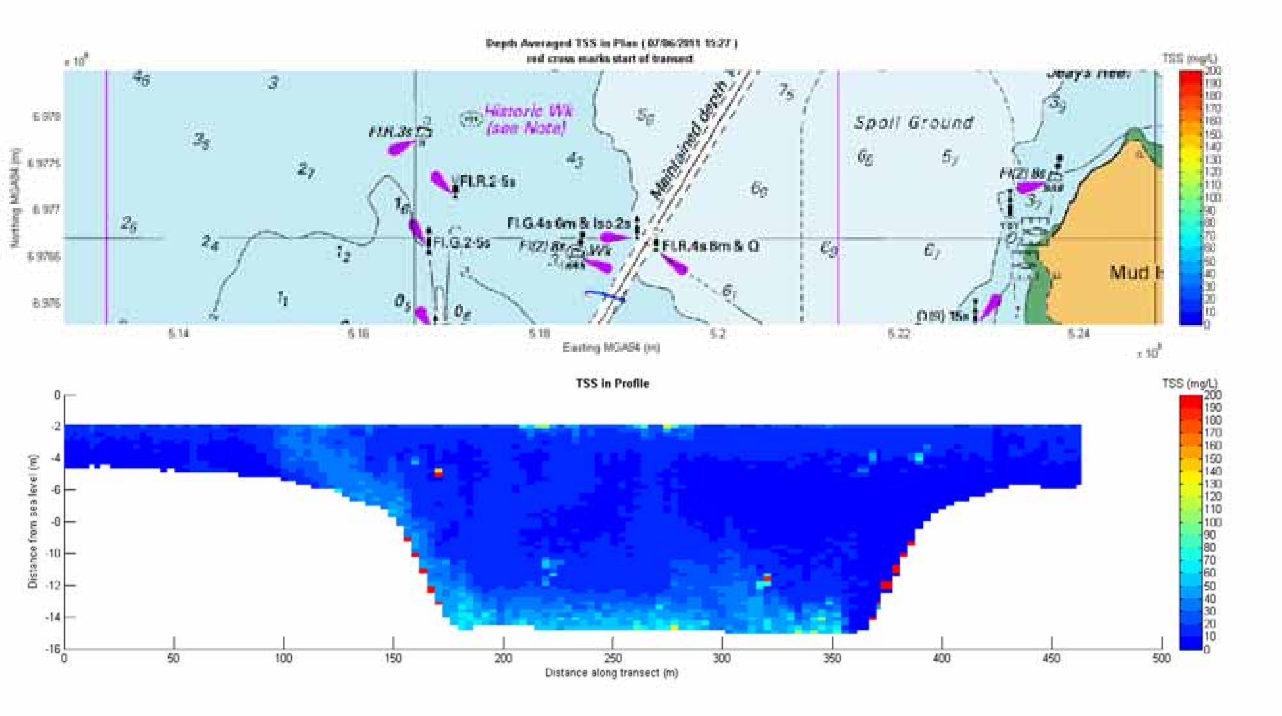

Figure B- 4 *Brisbane* at Outer Bar, transect 4

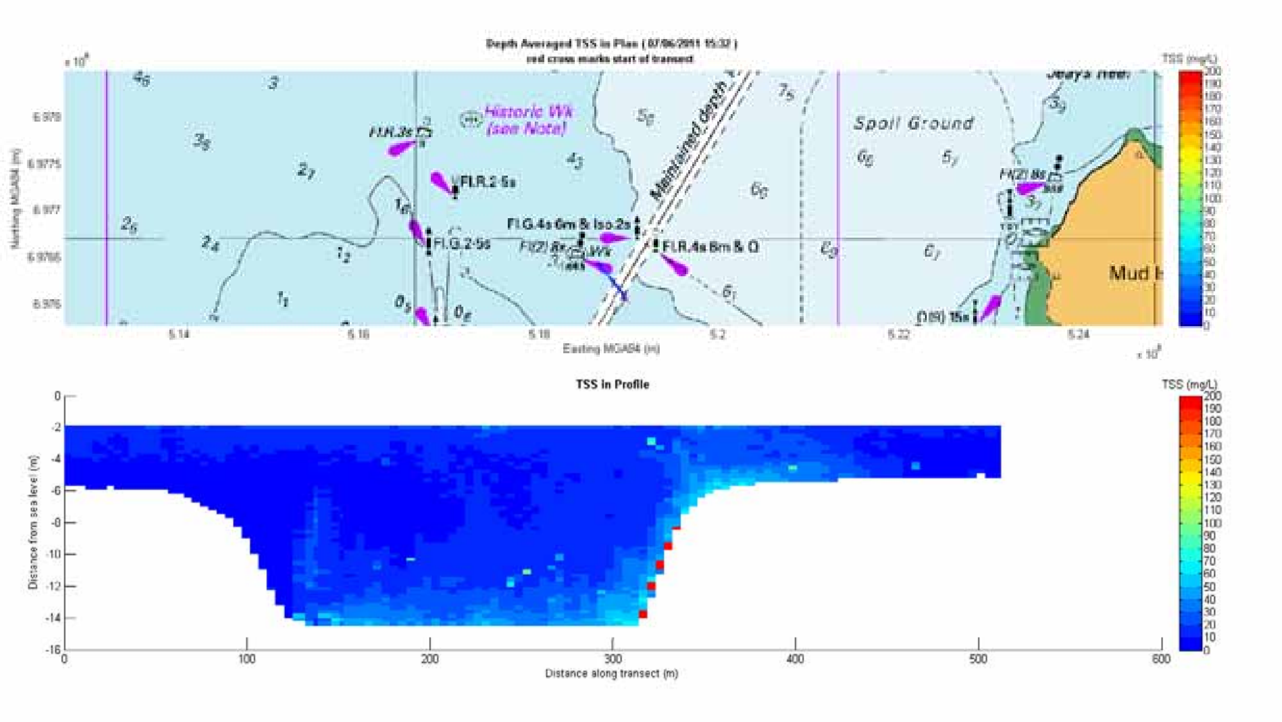

Figure B- 5 *Brisbane* at Outer Bar, transect 5

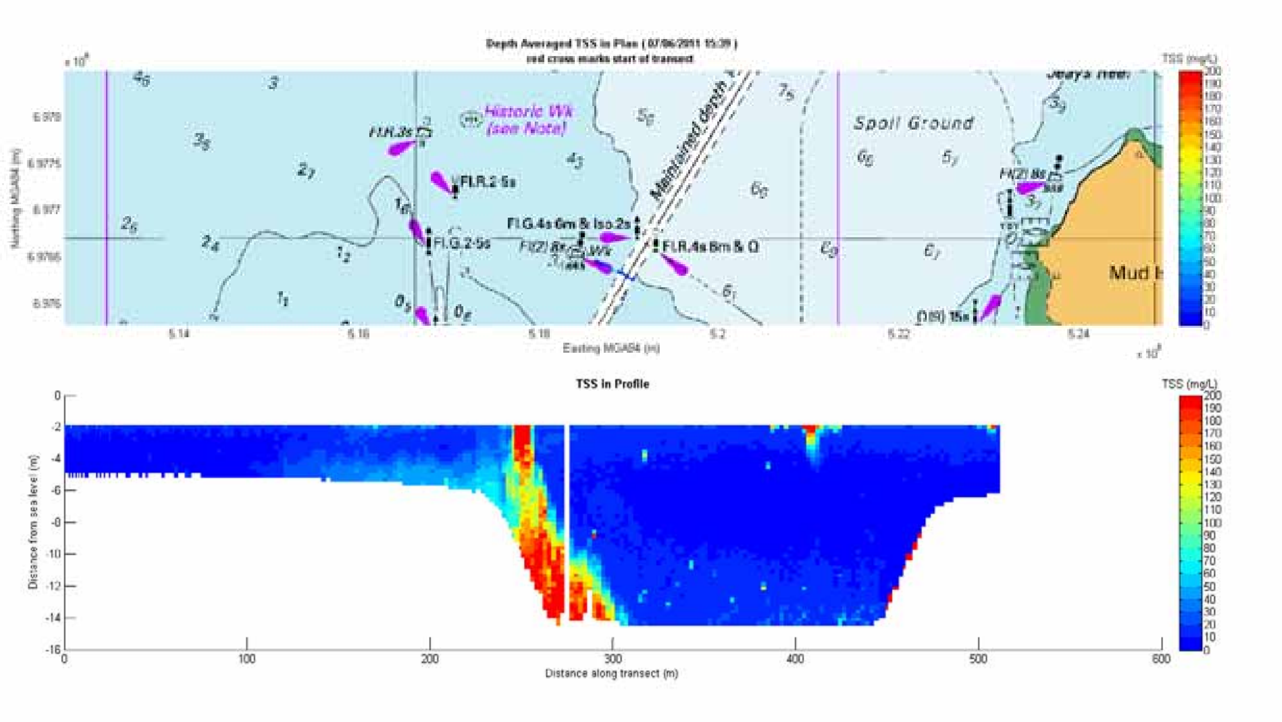

Figure B- 6 *Brisbane* at Outer Bar, transect 6

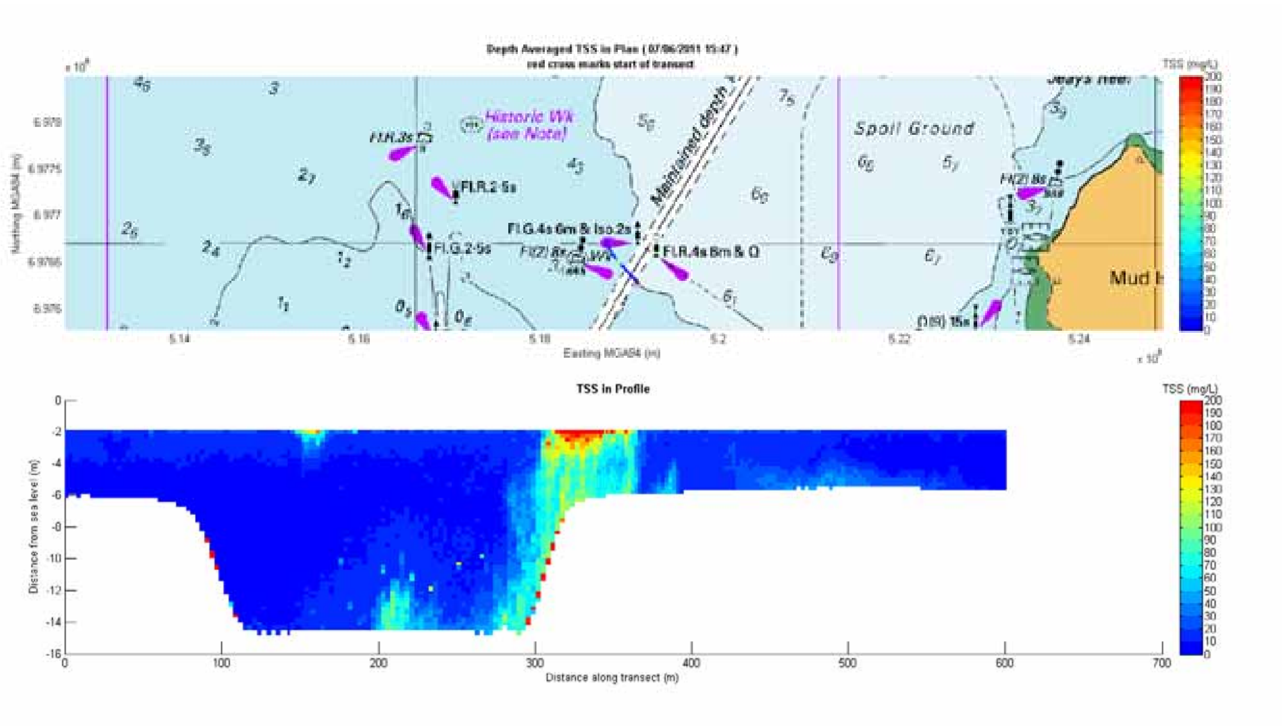

Figure B- 7 *Brisbane* at Outer Bar, transect 7

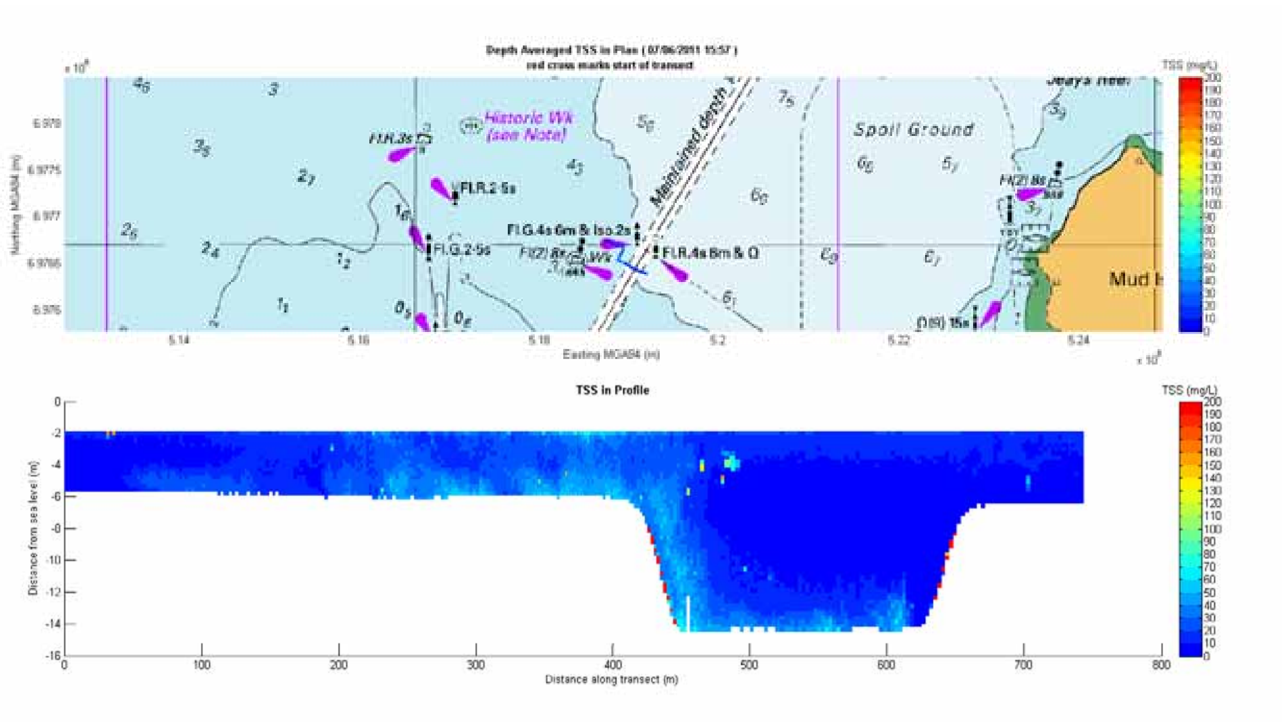

Figure B- 8 *Brisbane* at Outer Bar, transect 8

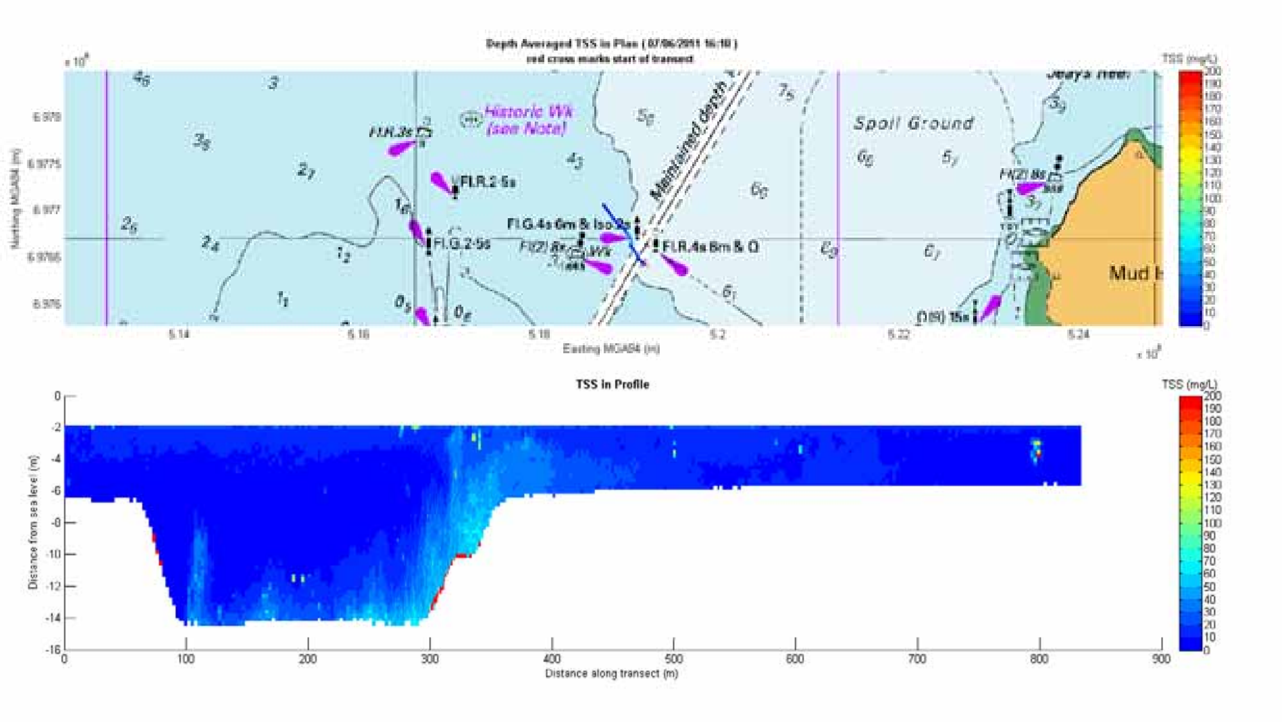

Figure B- 9 *Brisbane* at Outer Bar, transect 9

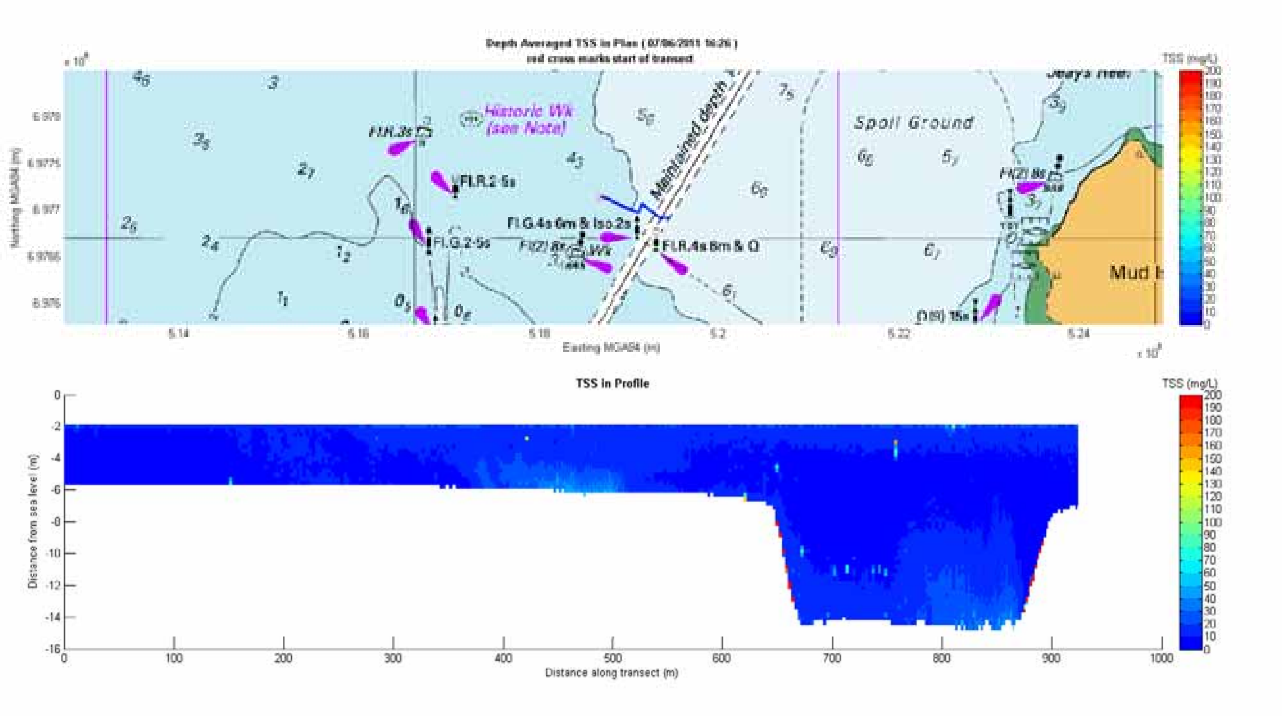

Figure B- 10 *Brisbane* at Outer Bar, transect 10

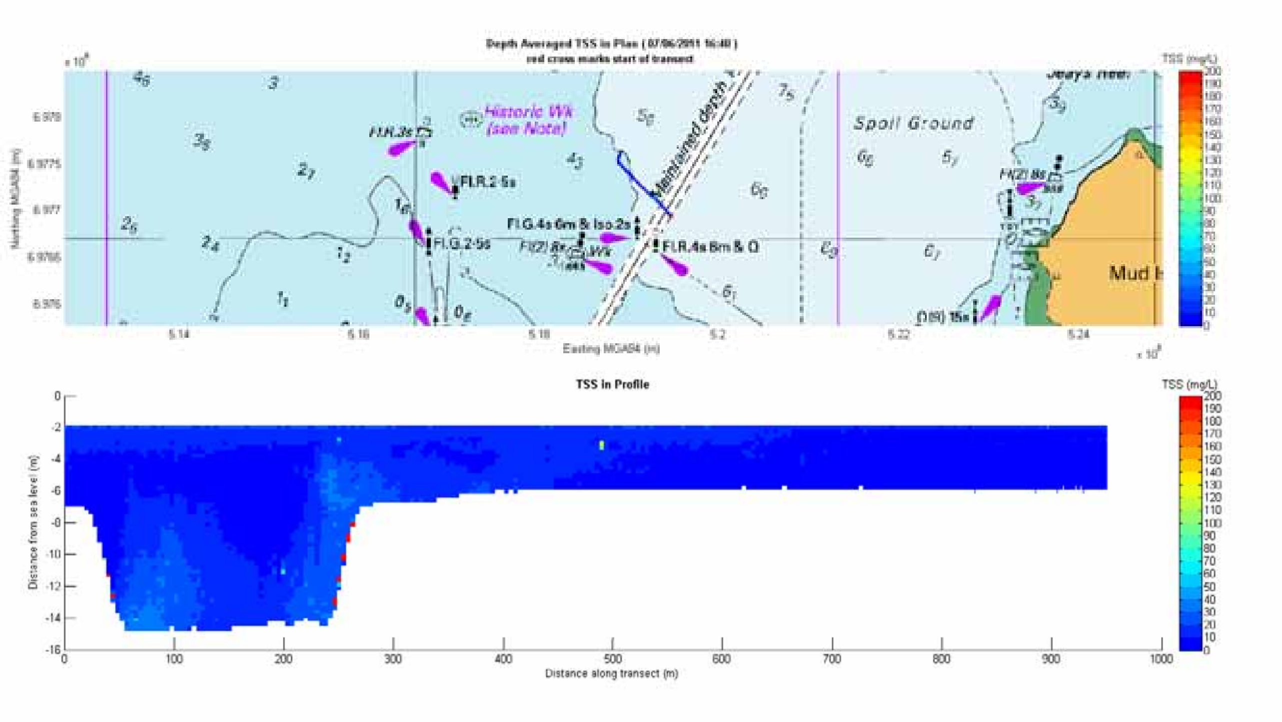

Figure B- 11 *Brisbane* at Outer Bar, transect 11

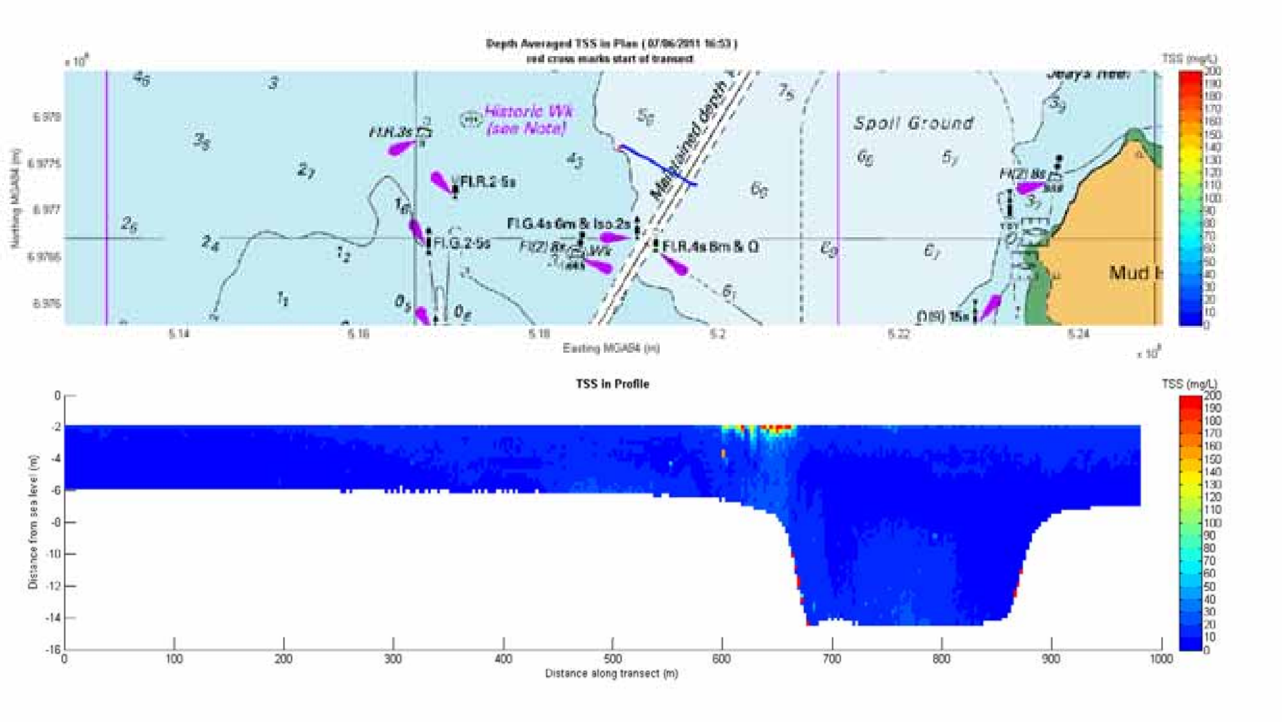

Figure B- 12 *Brisbane* at Outer Bar, transect 12

APPENDIX C: DREDGER 'BRISBANE' AT SPITFIRE CHANNEL

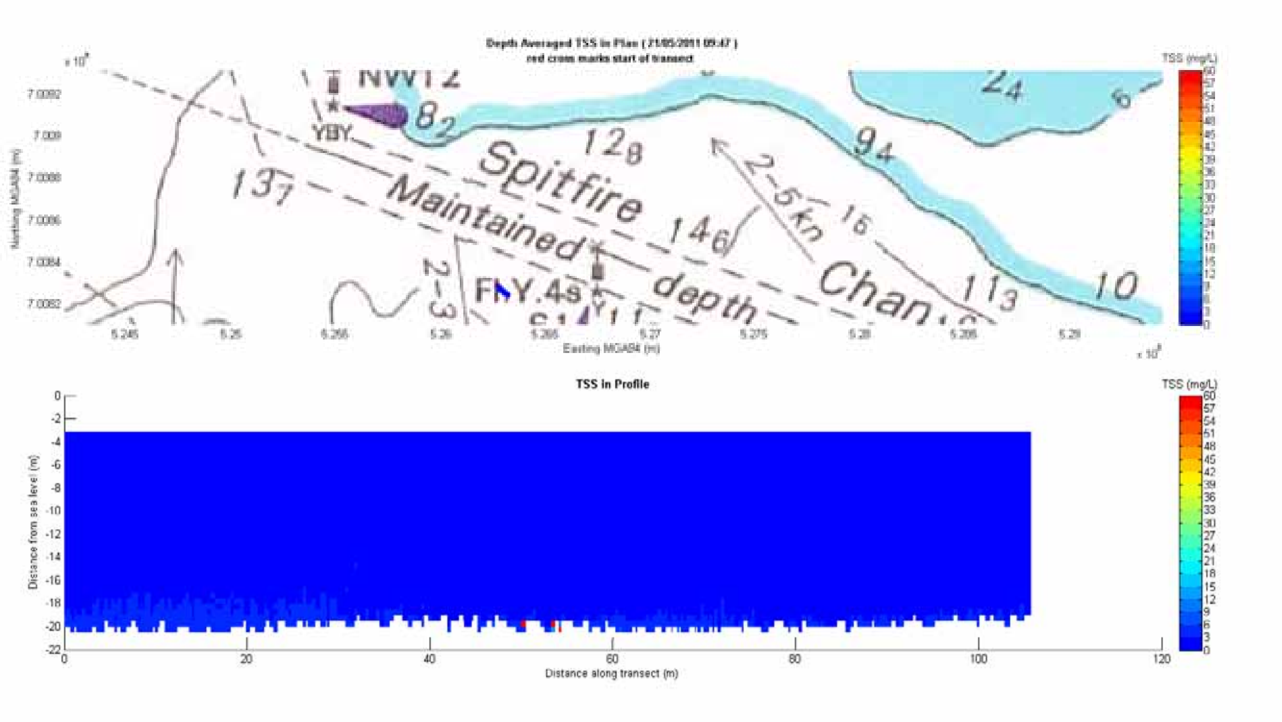

Figure C- 1 *Brisbane* at Spitfire Channel, Transect 1

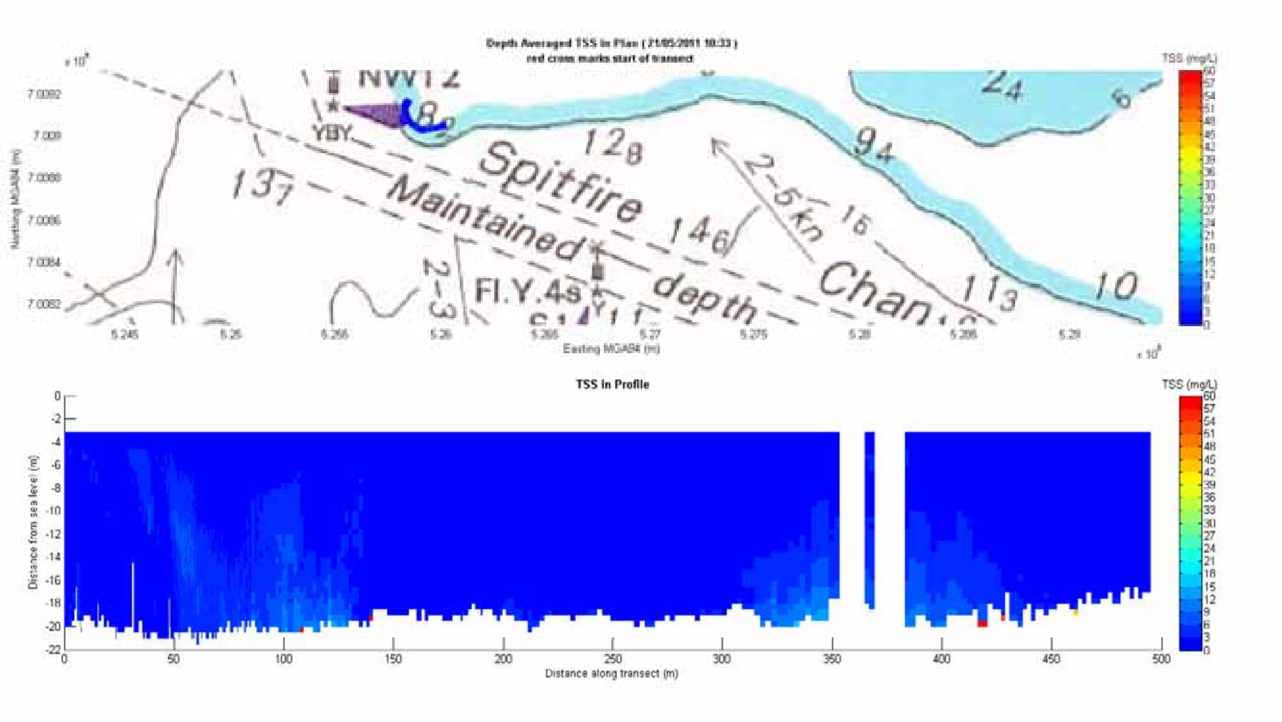

Figure C- 2 *Brisbane* at Spitfire Channel, Transect 2

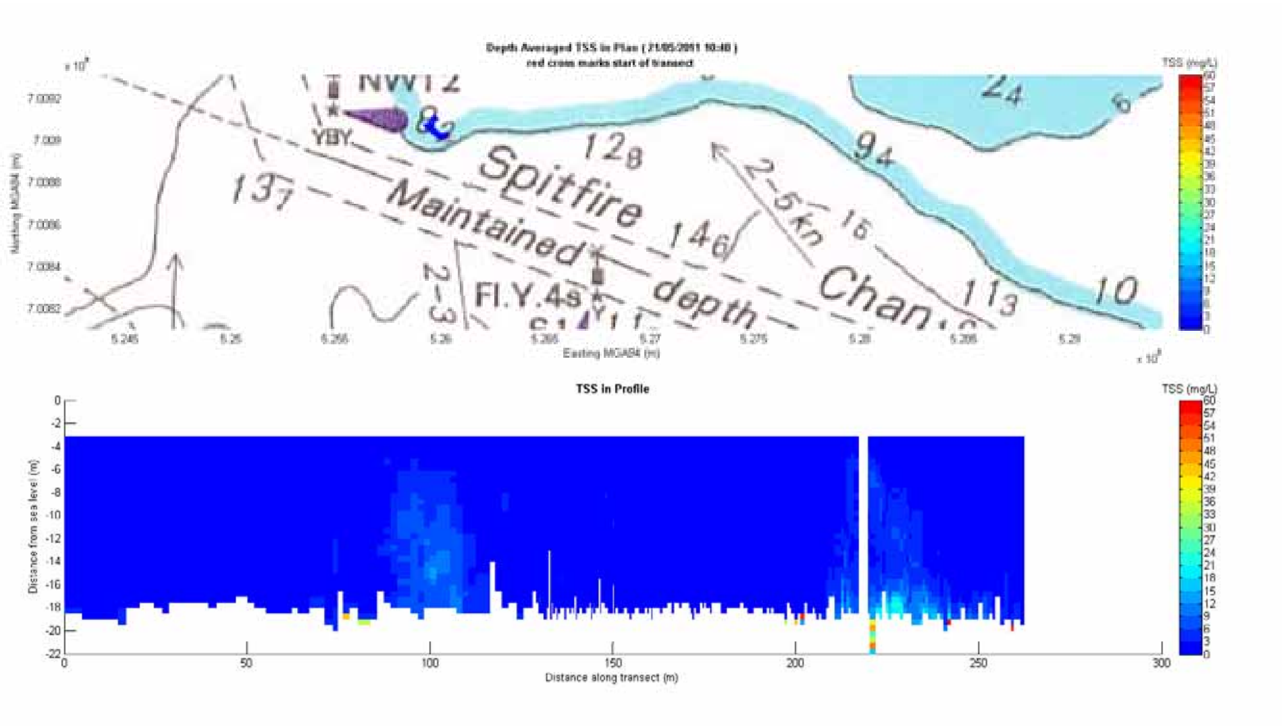

Figure C- 3 *Brisbane* at Spitfire Channel, Transect 3

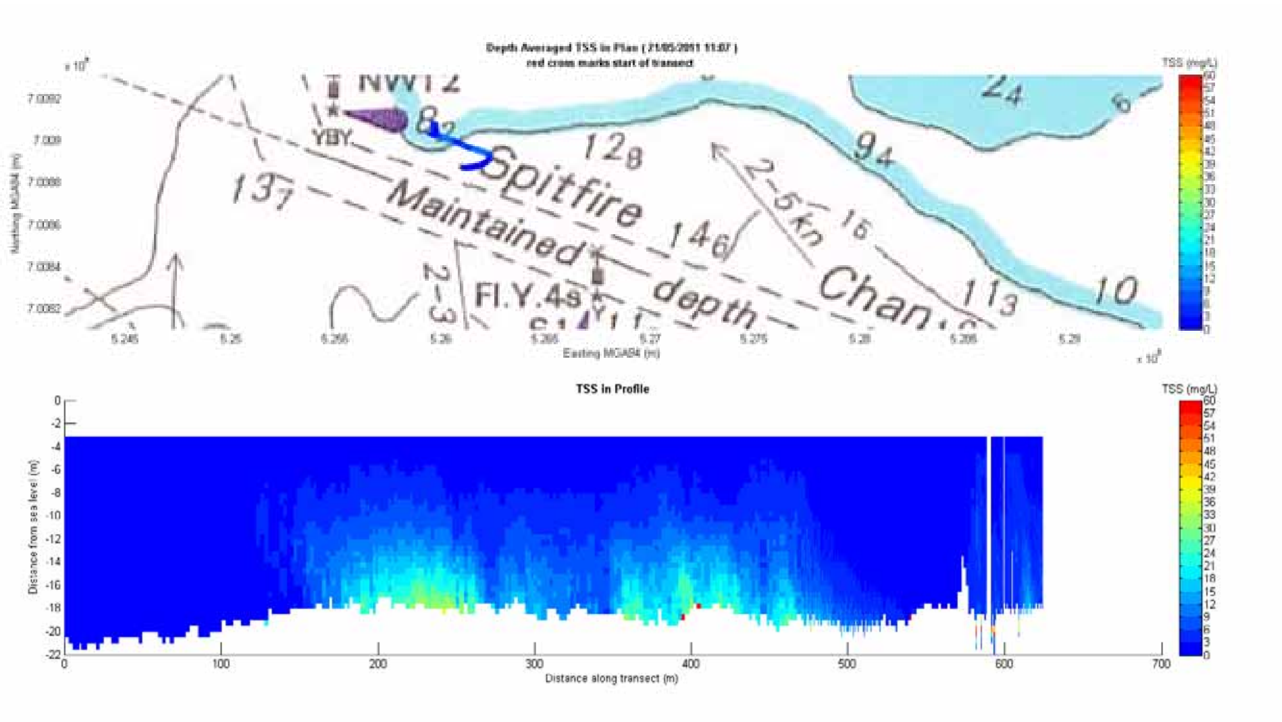

Figure C- 4 *Brisbane* at Spitfire Channel, Transect 4

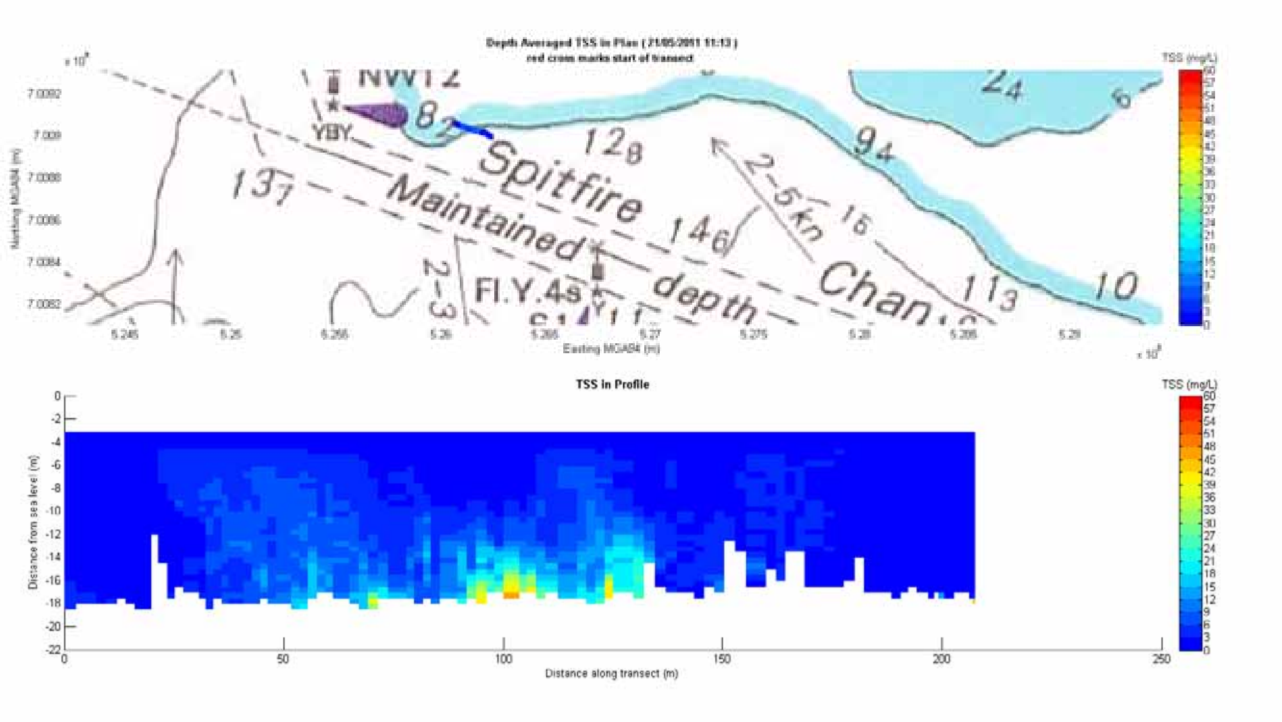

Figure C- 5 *Brisbane* at Spitfire Channel, Transect 5

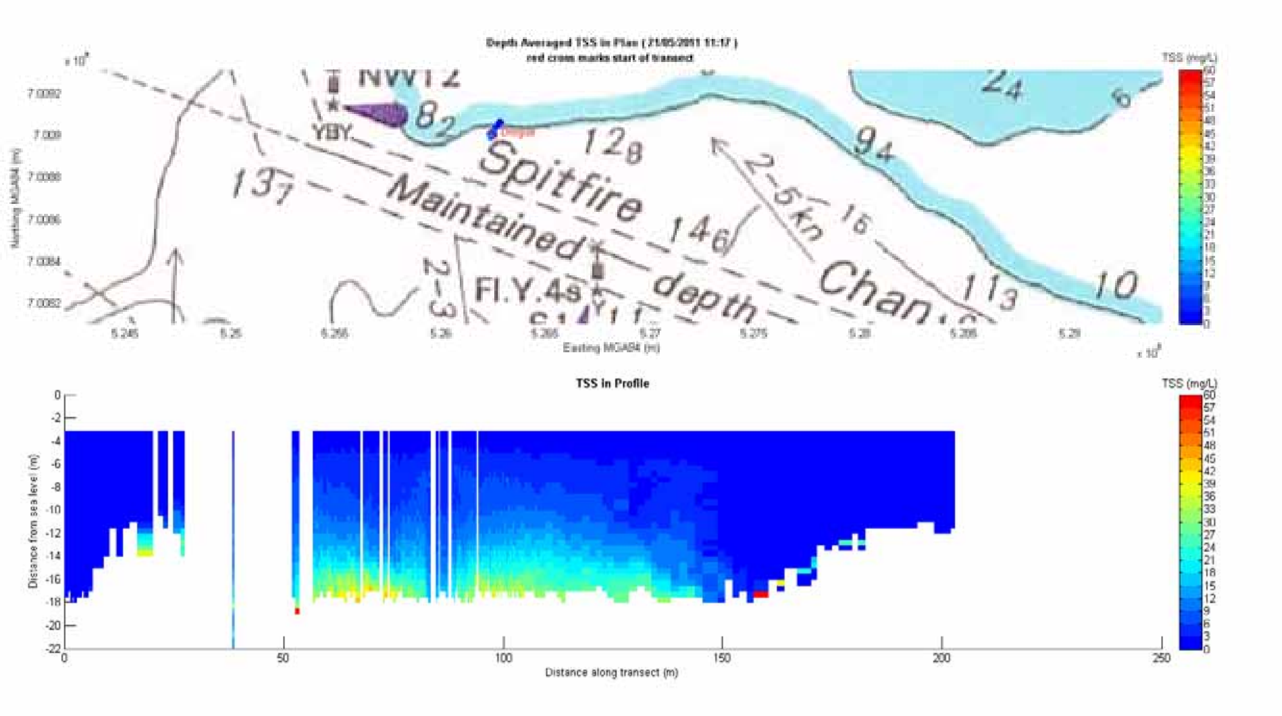

Figure C- 6 *Brisbane* at Spitfire Channel, Transect 6

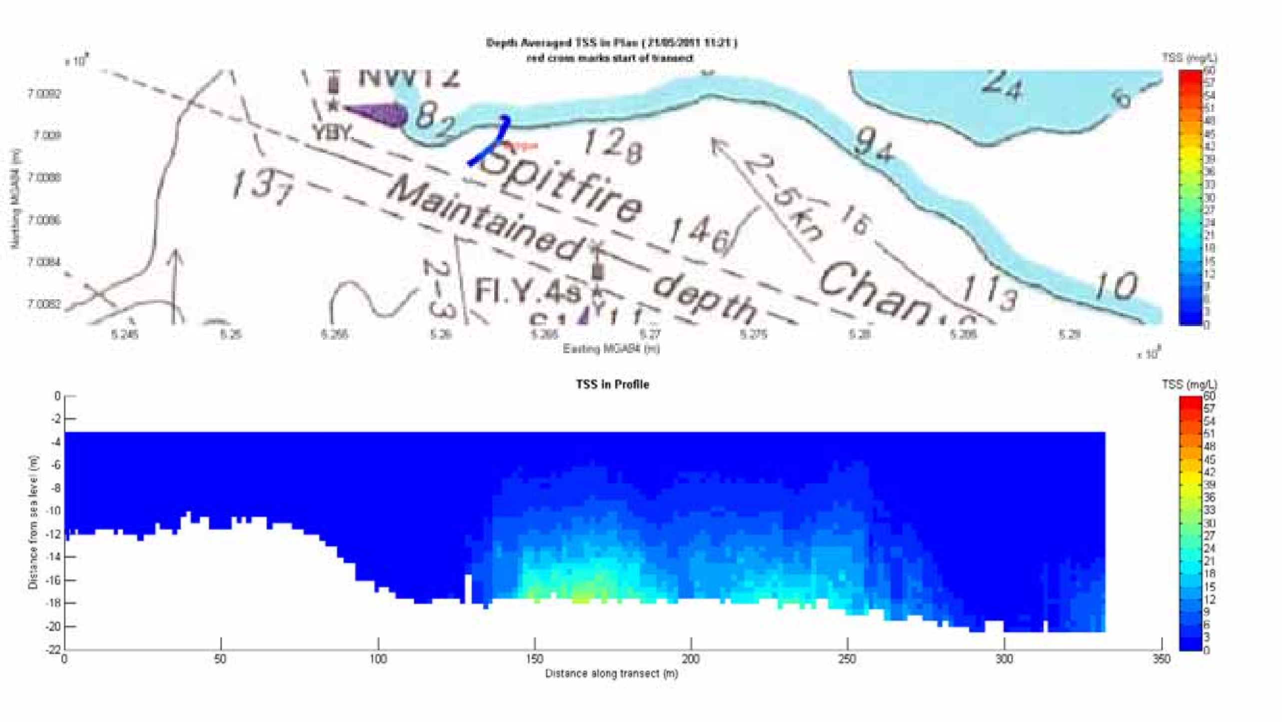

Figure C- 7 *Brisbane* at Spitfire Channel, Transect 7

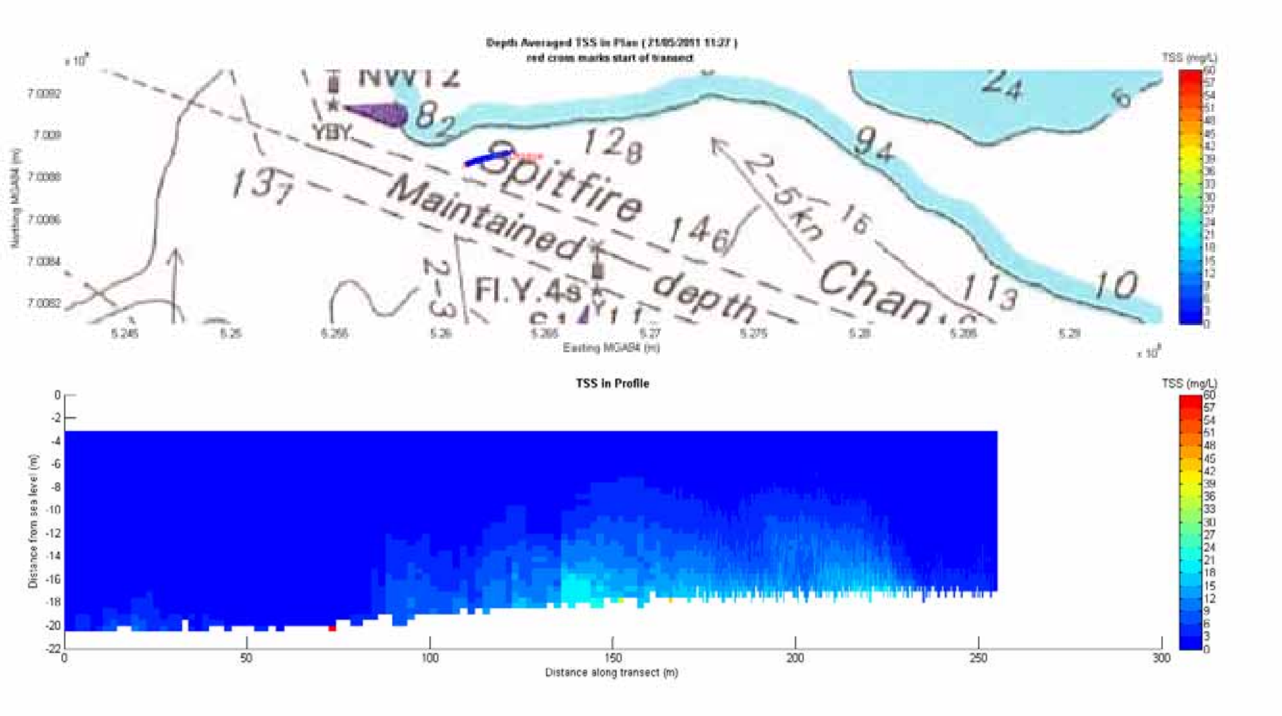

Figure C- 8 *Brisbane* at Spitfire Channel, Transect 8

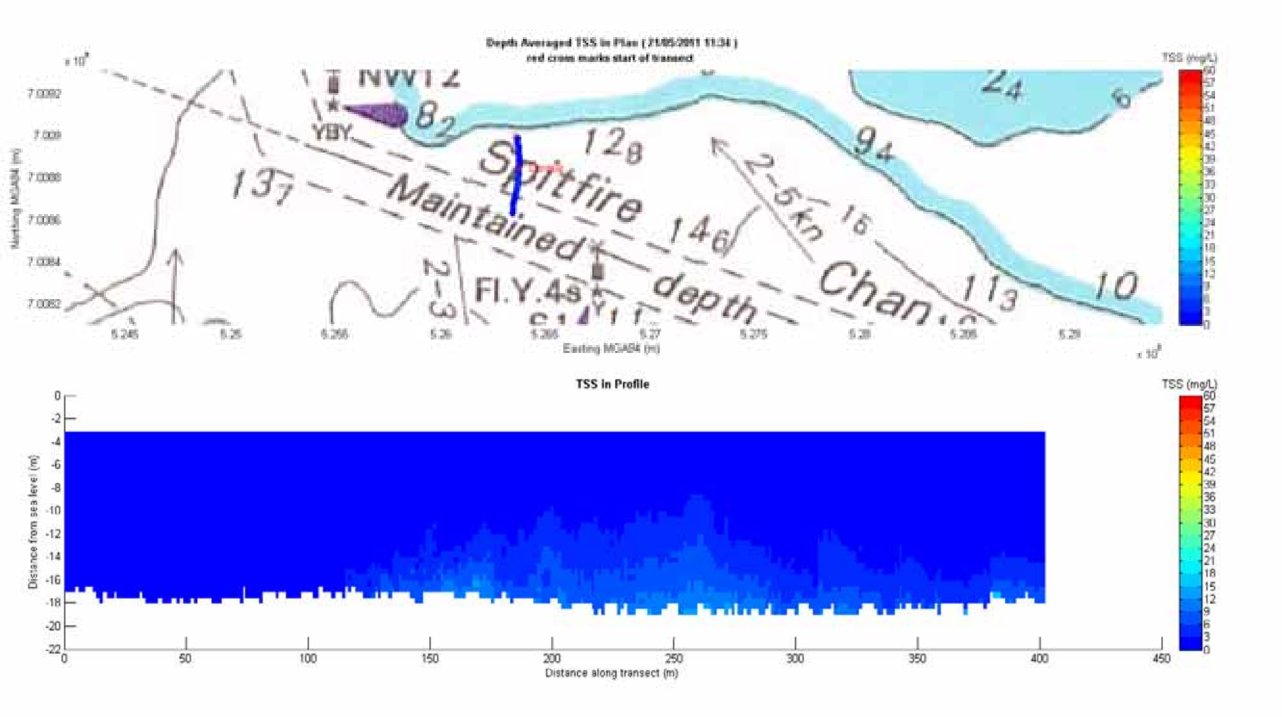

Figure C- 9 *Brisbane* at Spitfire Channel, Transect 9

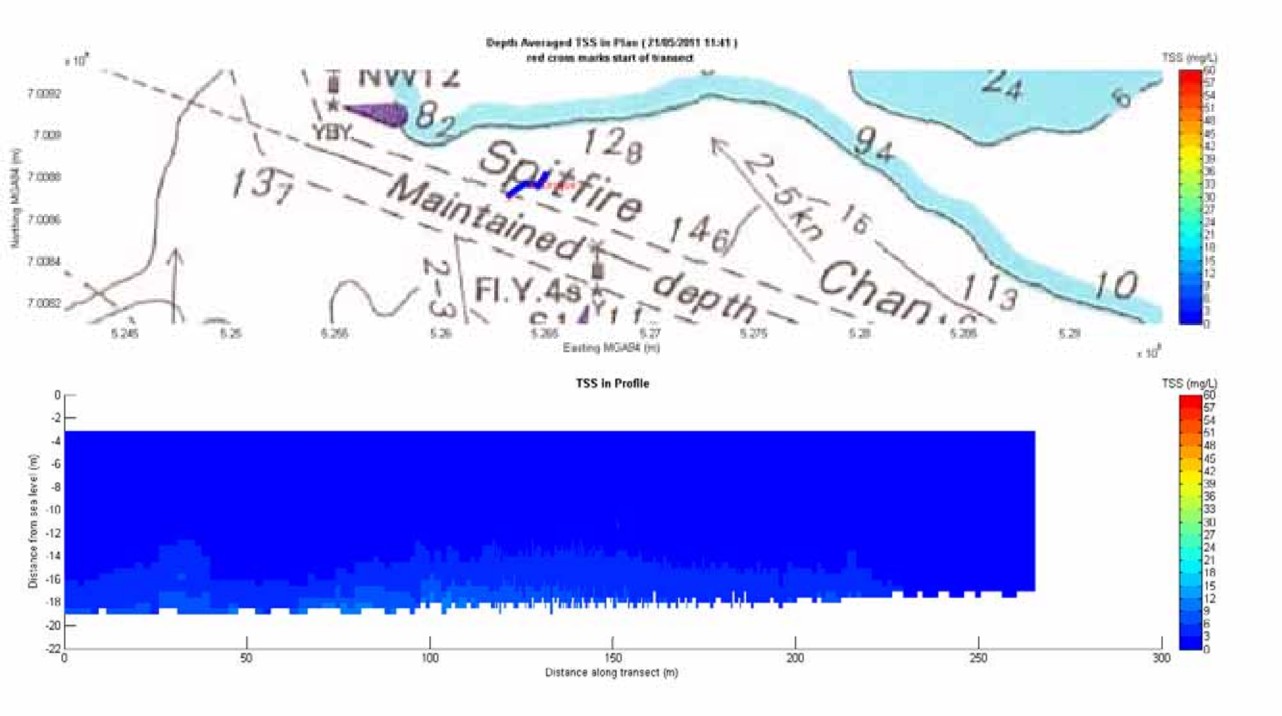

Figure C- 10 *Brisbane* at Spitfire Channel, Transect 10

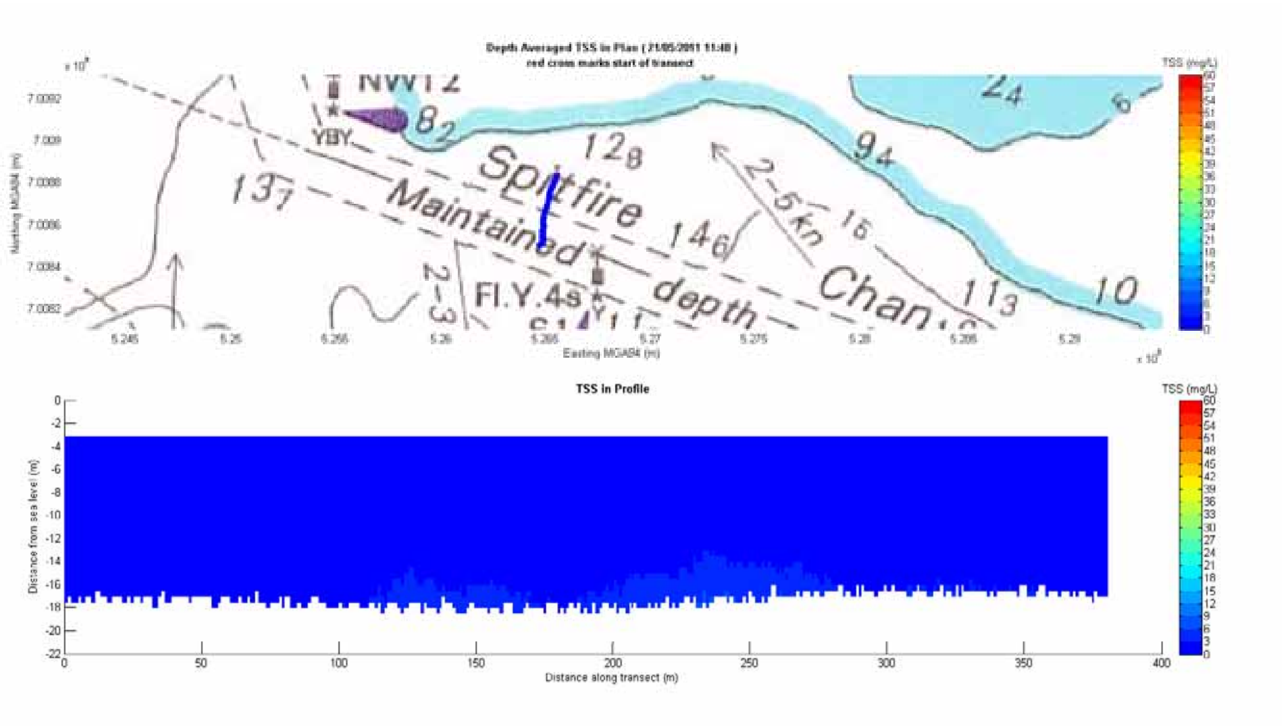

Figure C- 11 *Brisbane* at Spitfire Channel, Transect 11

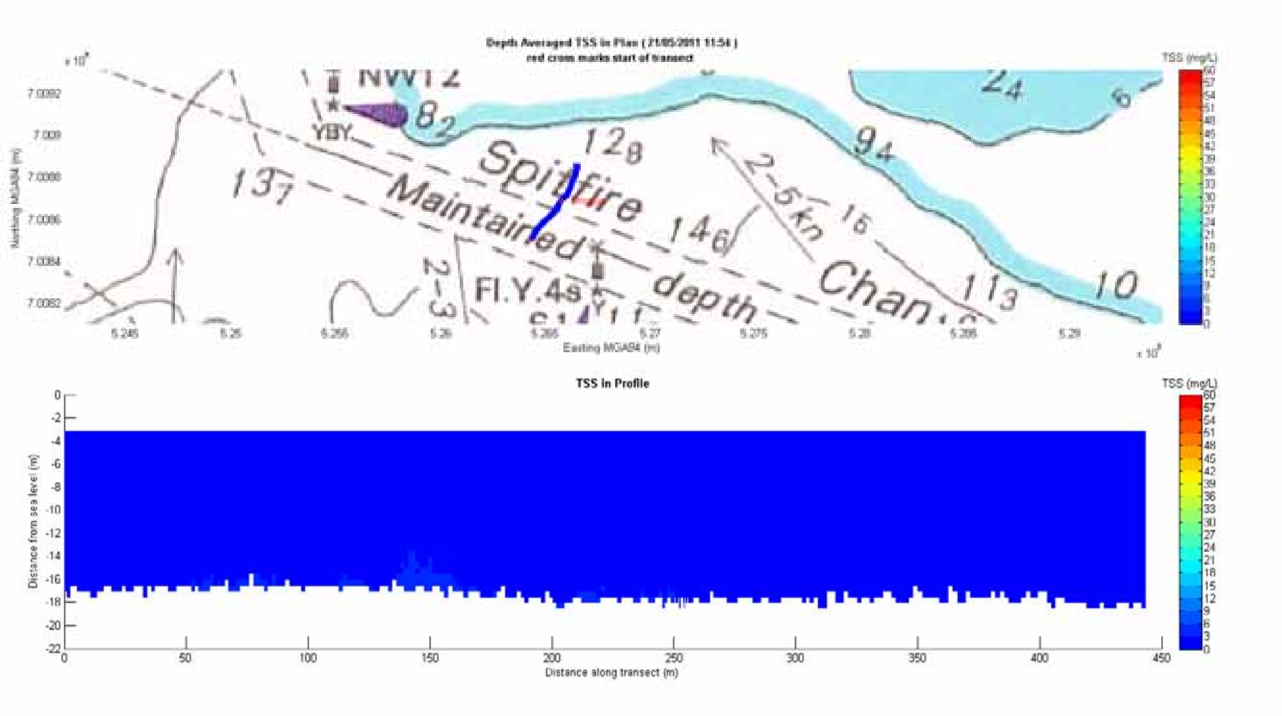

Figure C- 12 *Brisbane* at Spitfire Channel, Transect 12

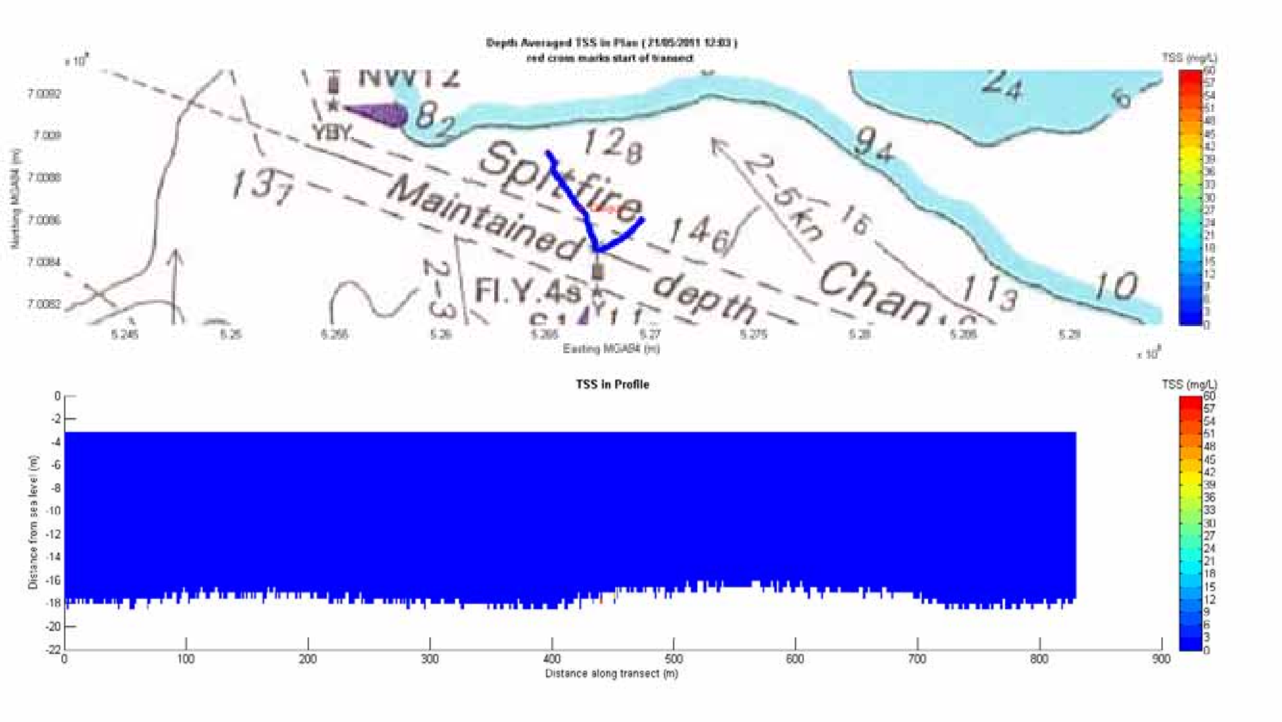

Figure C- 13 *Brisbane* at Spitfire Channel, Transect 13

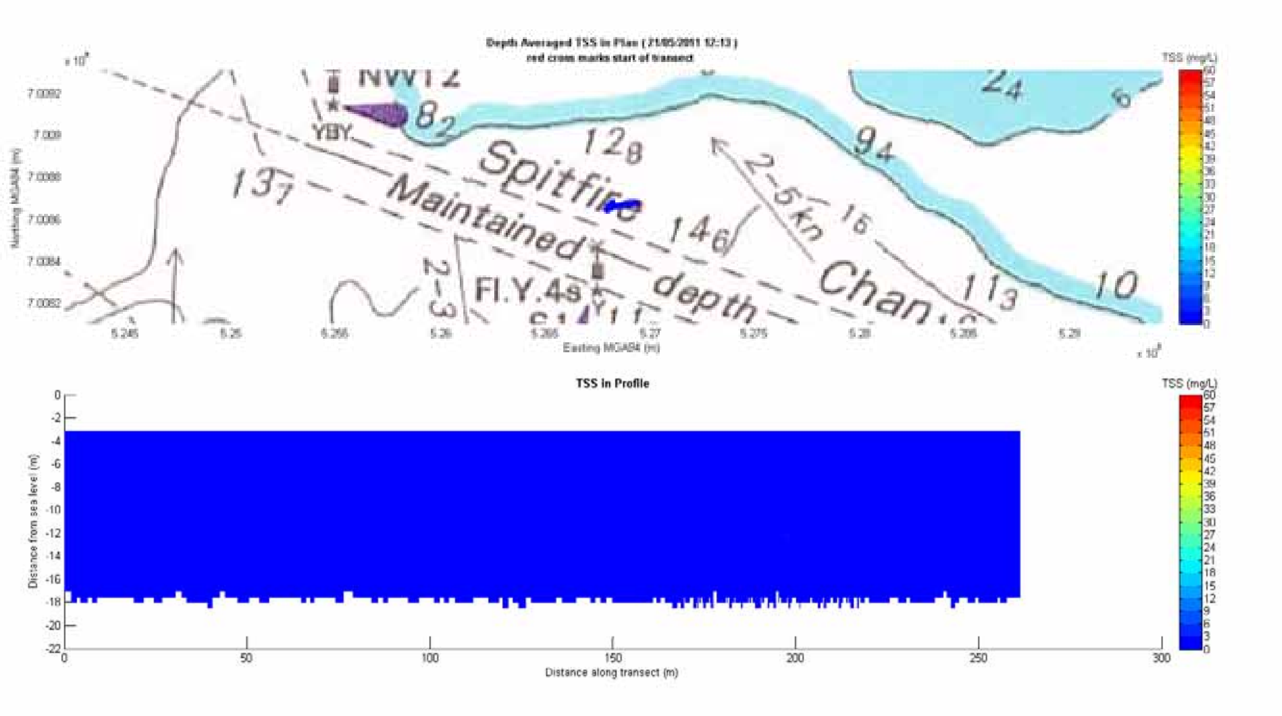

Figure C- 14 *Brisbane* at Spitfire Channel, Transect 14

APPENDIX D: DREDGER 'BRISBANE' DUMPING ON EBB TIDE

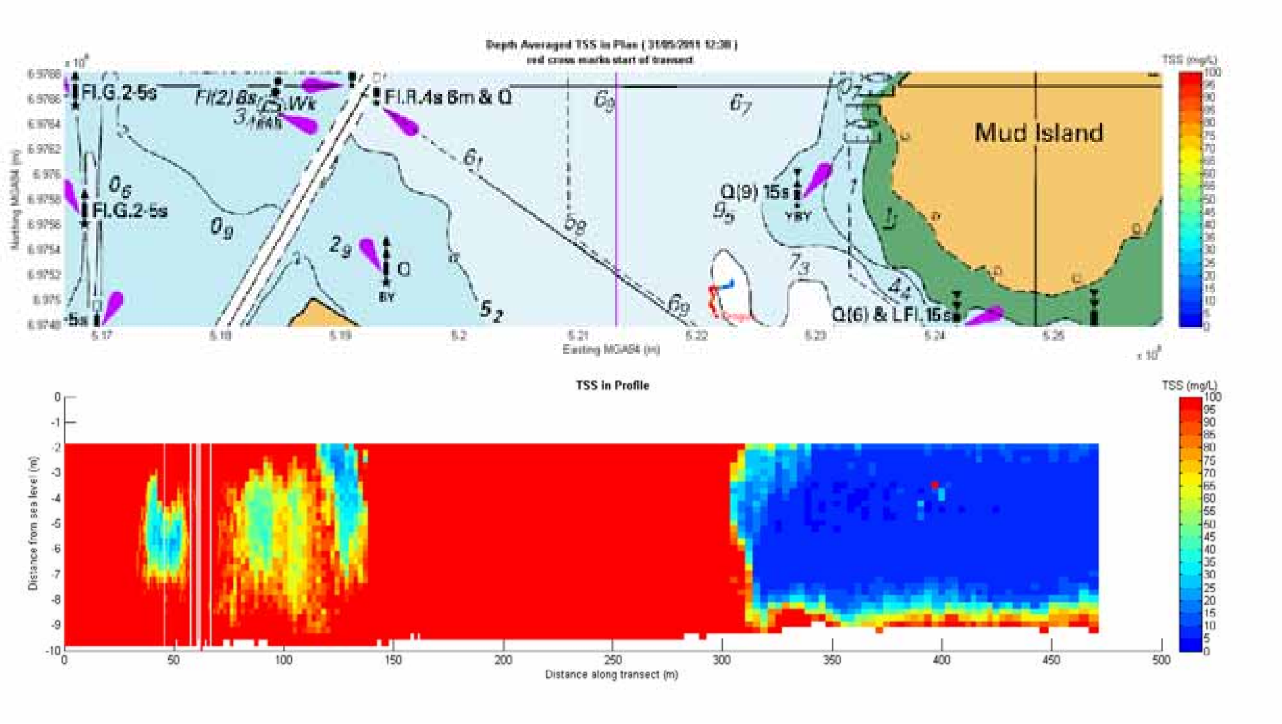

Figure D- 1 *Brisbane* Dumping on Ebb Tide, transect 1

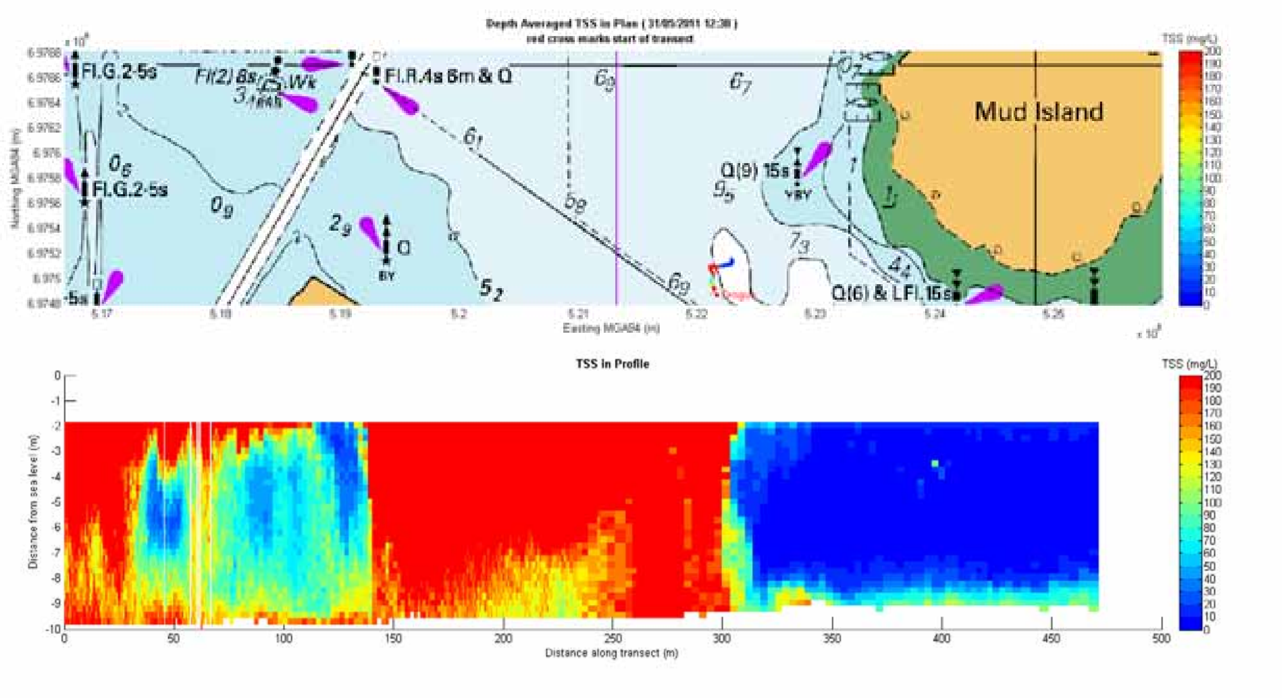

Figure D- 2 *Brisbane* Dumping on Ebb Tide, transect 1 (different scaling)

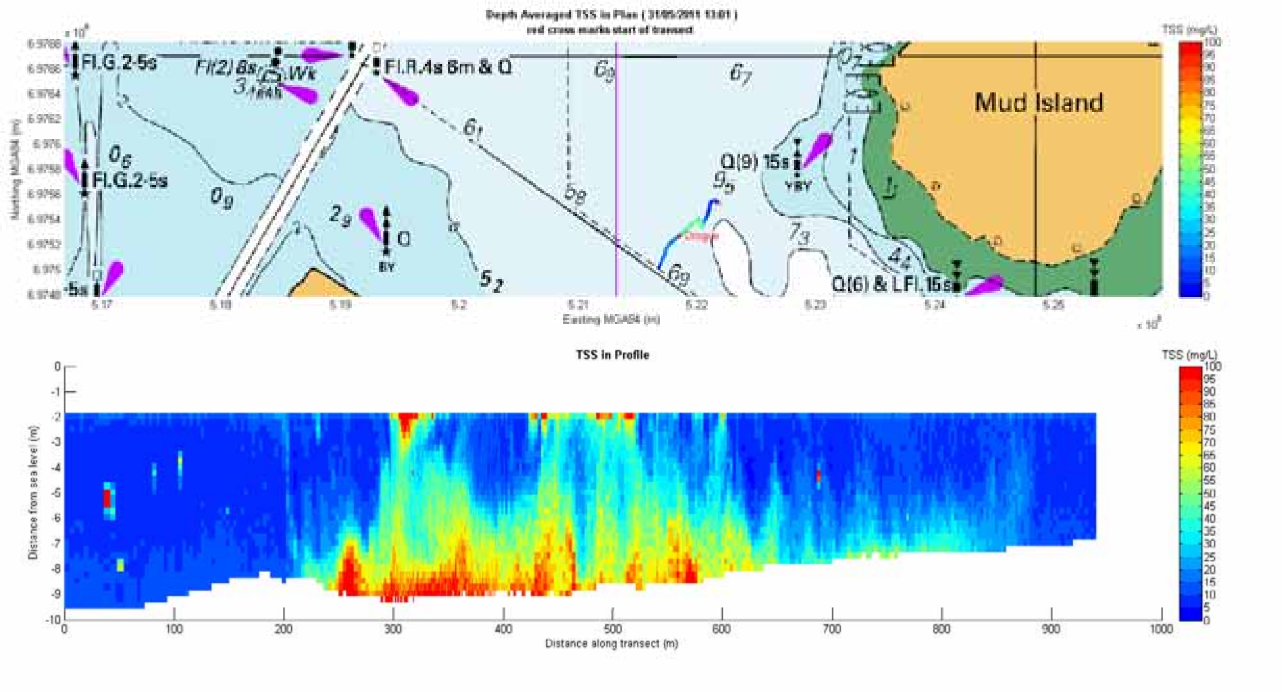

Figure D- 3 ***Brisbane*** **Dumping on Ebb Tide, transect 2**

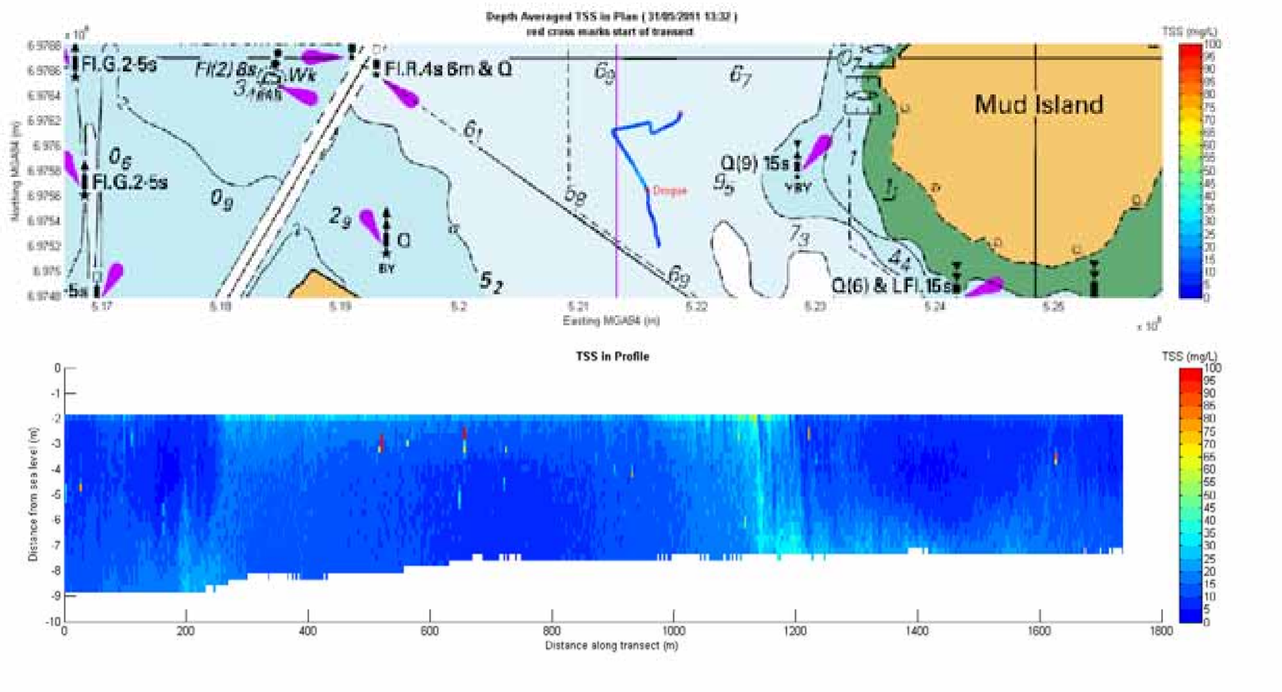

Figure D- 4 ***Brisbane*** **Dumping on Ebb Tide, transect 3**

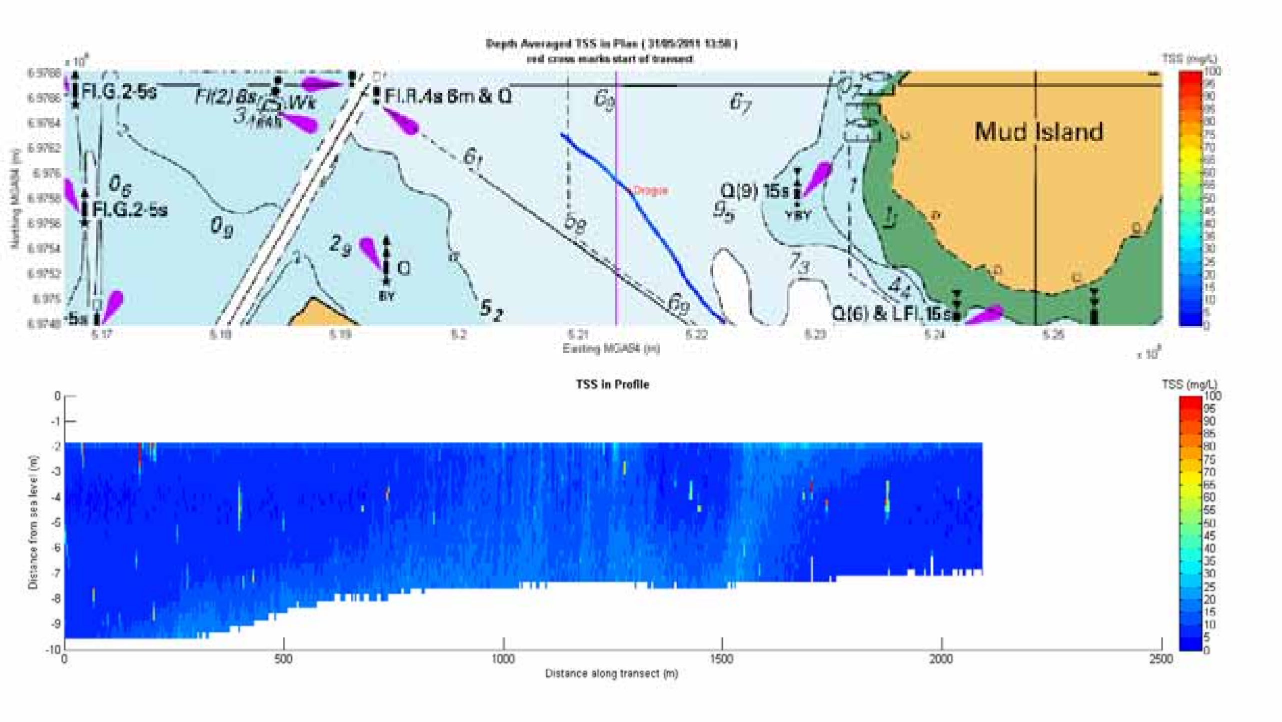

Figure D- 5 ***Brisbane*** **Dumping on Ebb Tide, transect 4**

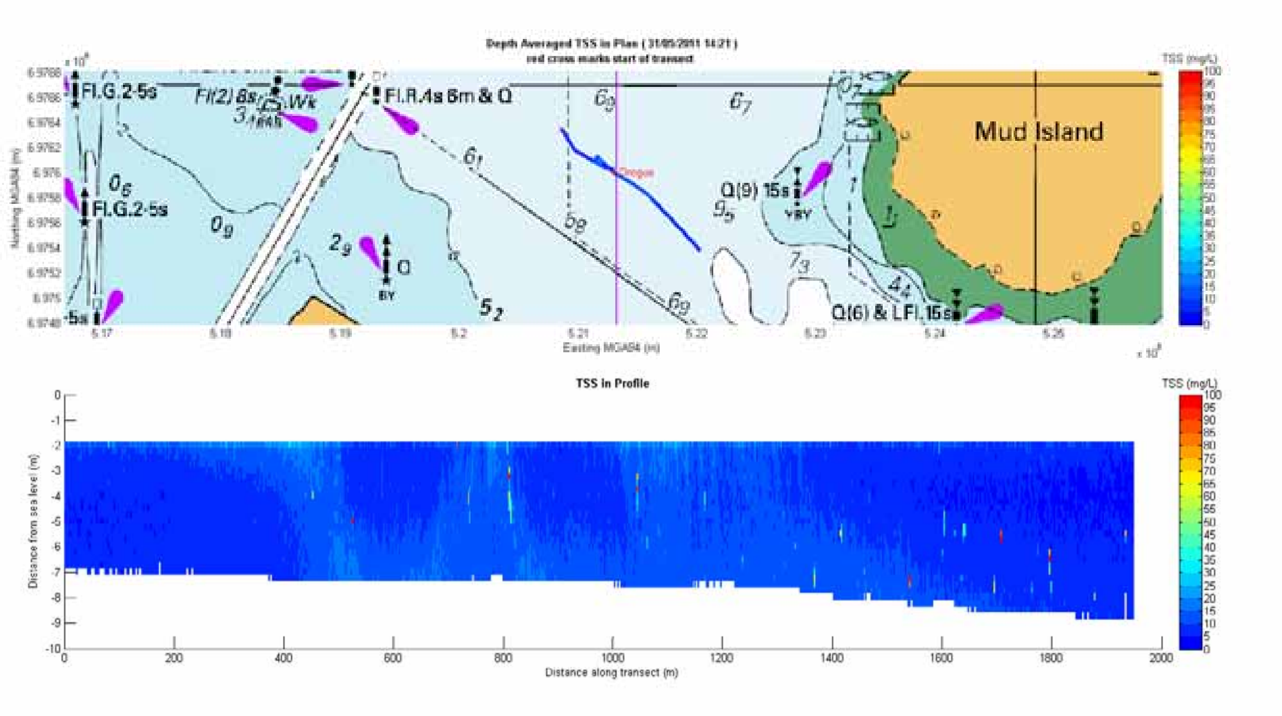

Figure D- 6 ***Brisbane*** **Dumping on Ebb Tide, transect 5**

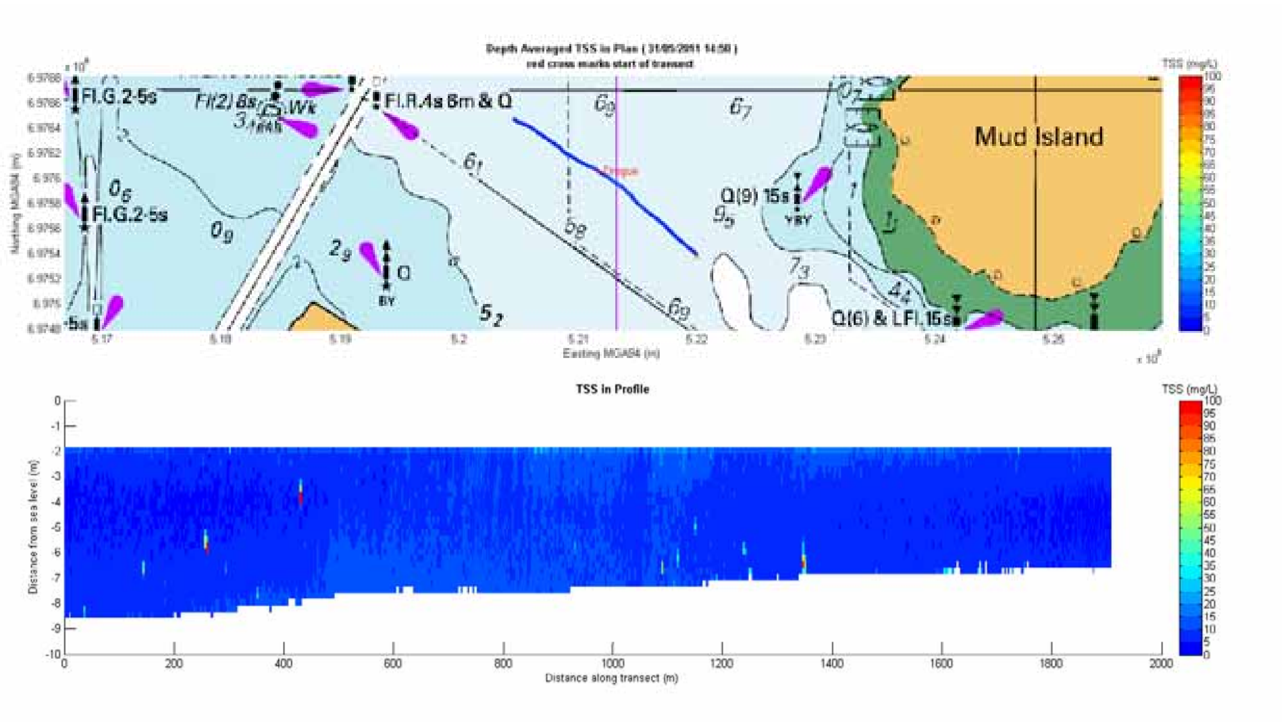

Figure D- 7 ***Brisbane*** **Dumping on Ebb Tide, transect 6**

APPENDIX E: DREDGER 'BRISBANE' DUMPING ON FLOOD TIDE

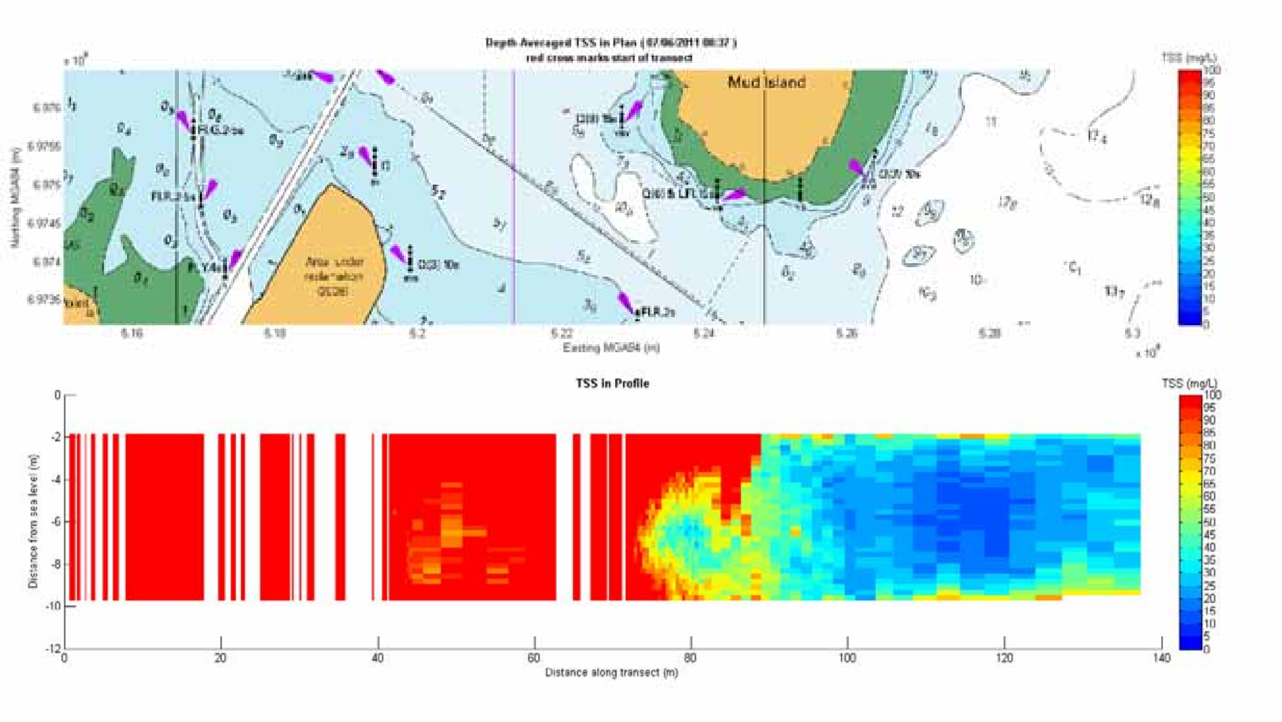

Figure E- 1 *Brisbane* Dumping on Flood Tide, transect 1

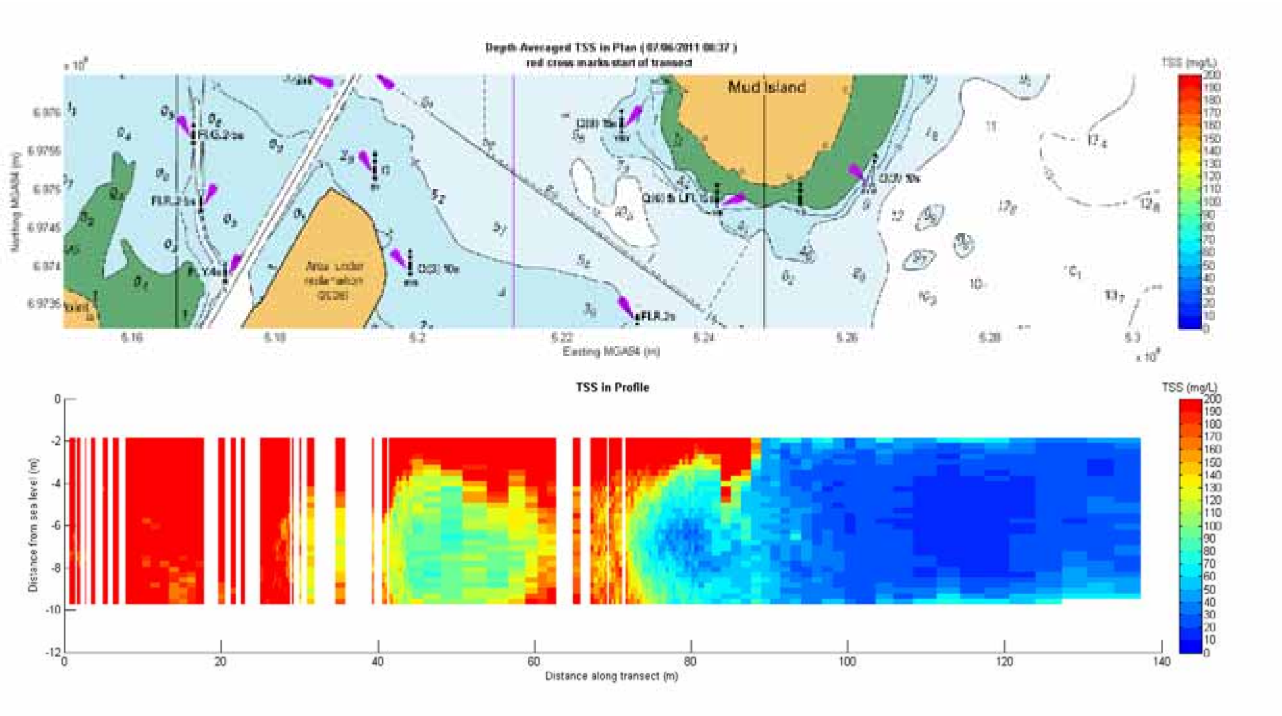

Figure E- 2 Brisbane Dumping on Flood Tide, transect 1 (different scaling)

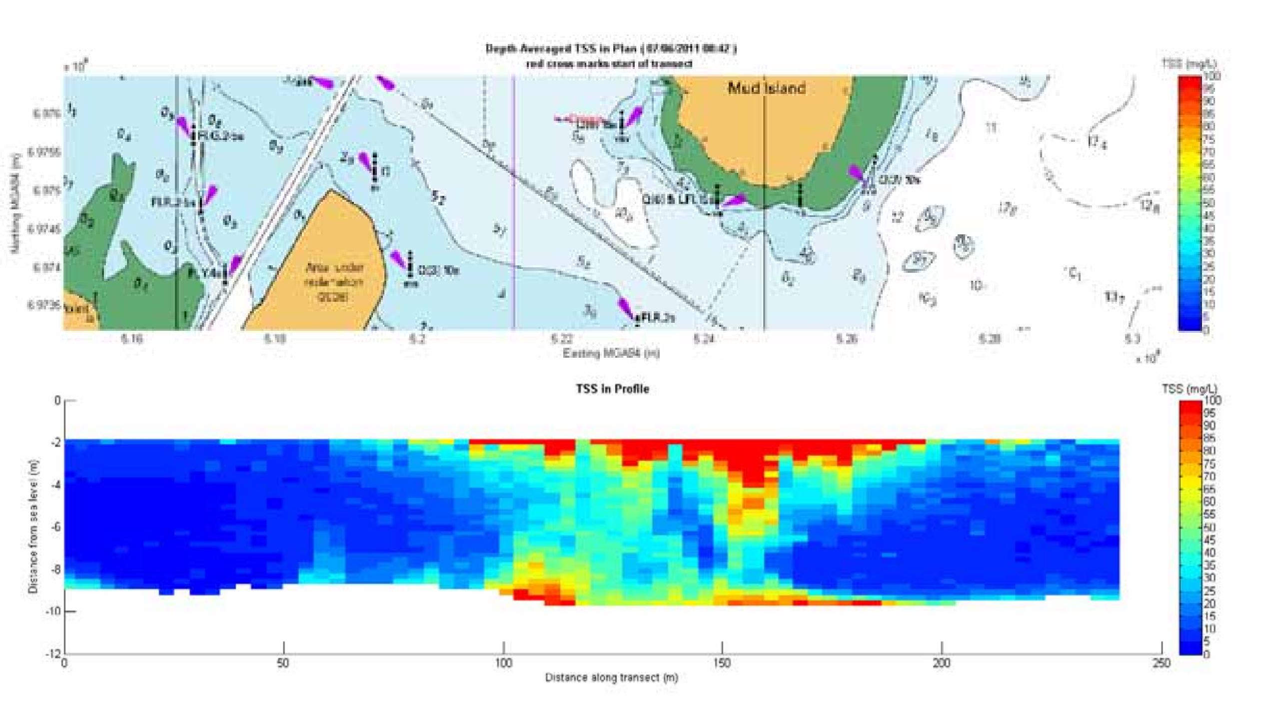

Figure E- 3 *Brisbane* Dumping on Flood Tide, transect 2

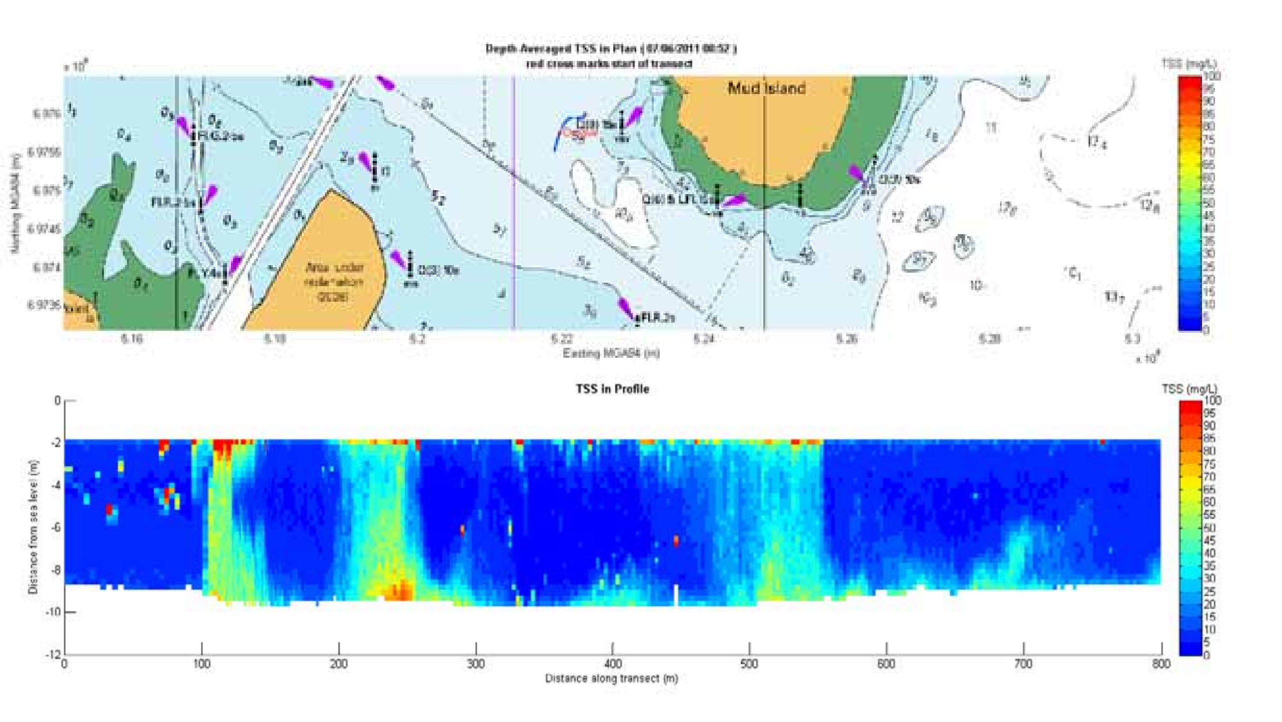

Figure E- 4 *Brisbane* Dumping on Flood Tide, transect 3

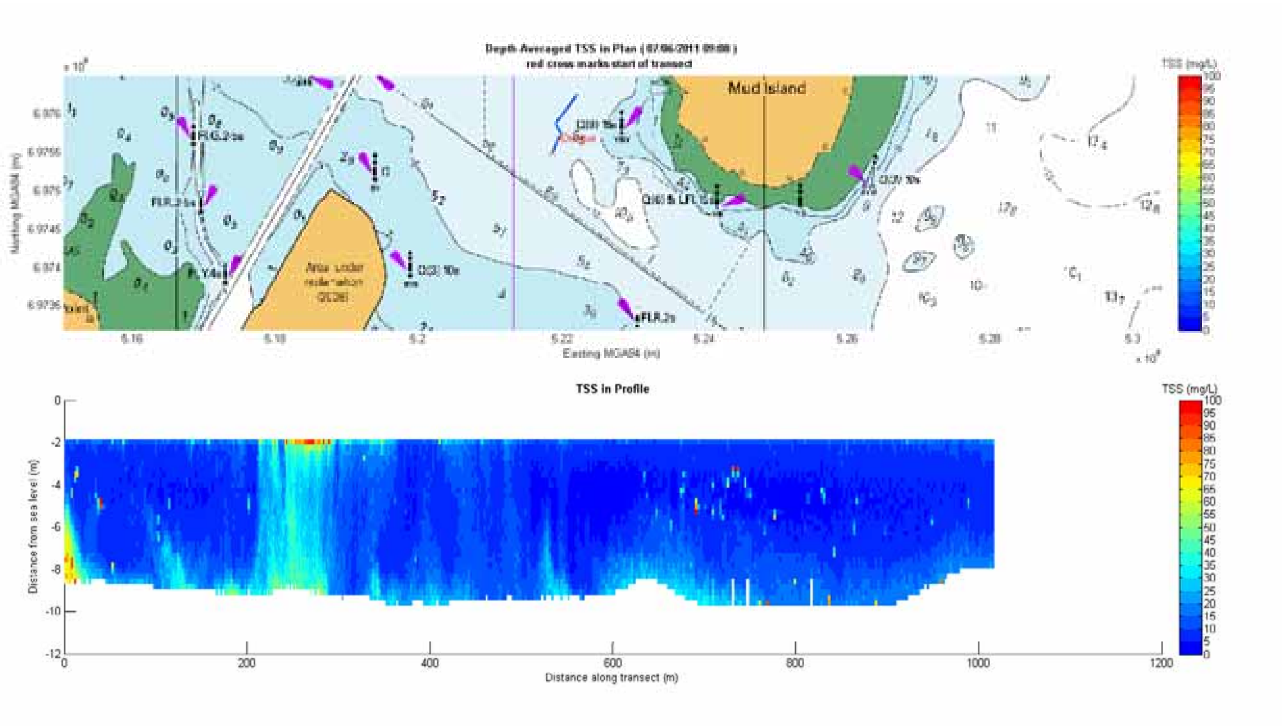

Figure E- 5 *Brisbane* Dumping on Flood Tide, transect 4

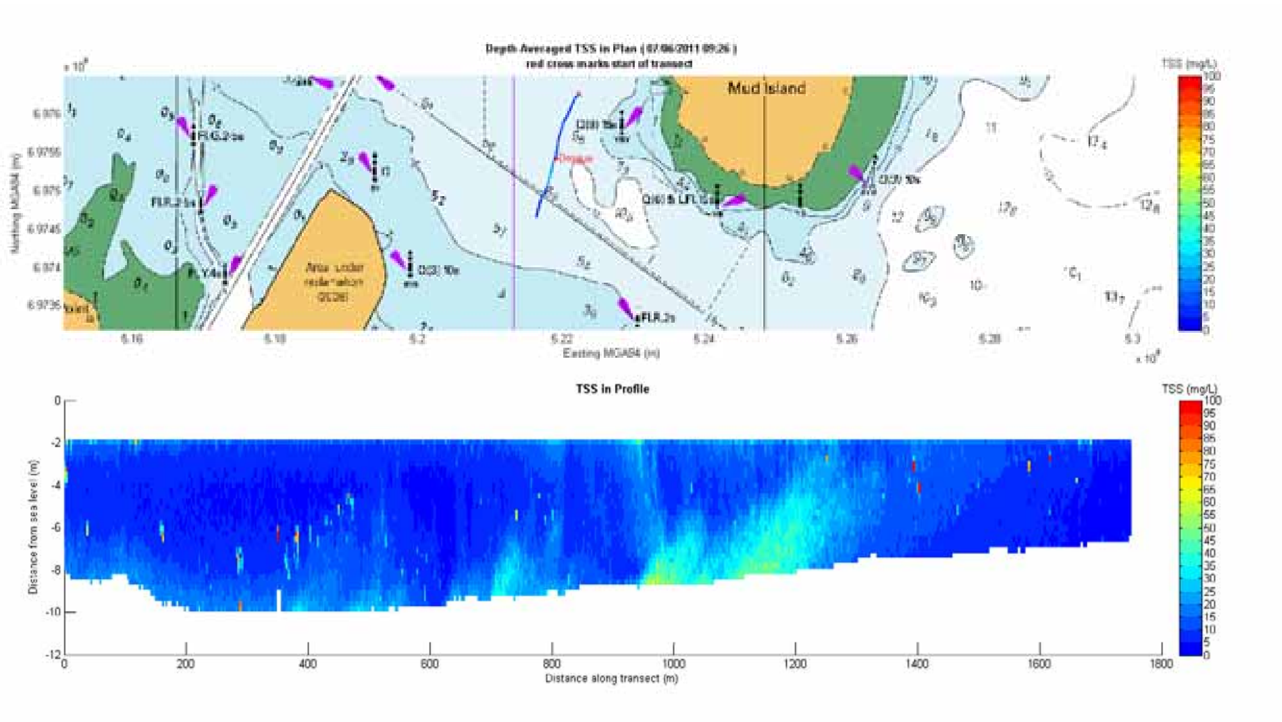

Figure E- 6 *Brisbane* Dumping on Flood Tide, transect 5

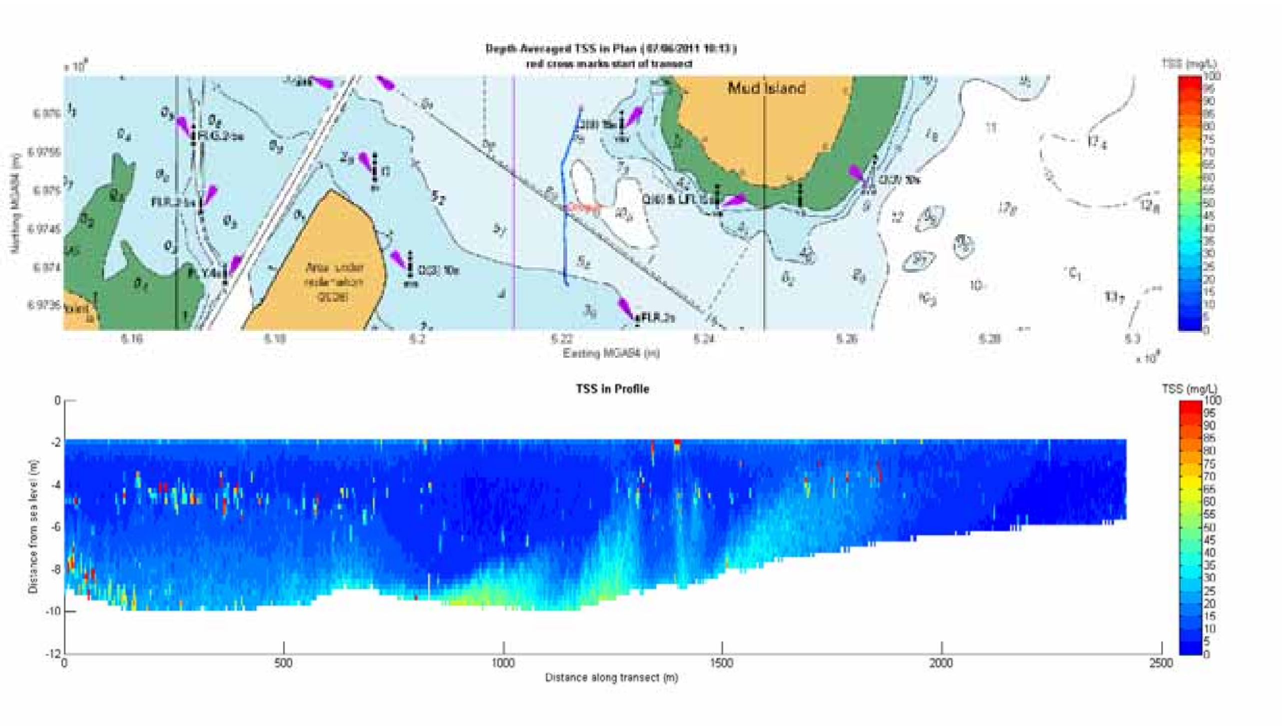

Figure E- 7 ***Brisbane*** **Dumping on Flood Tide, transect 6**

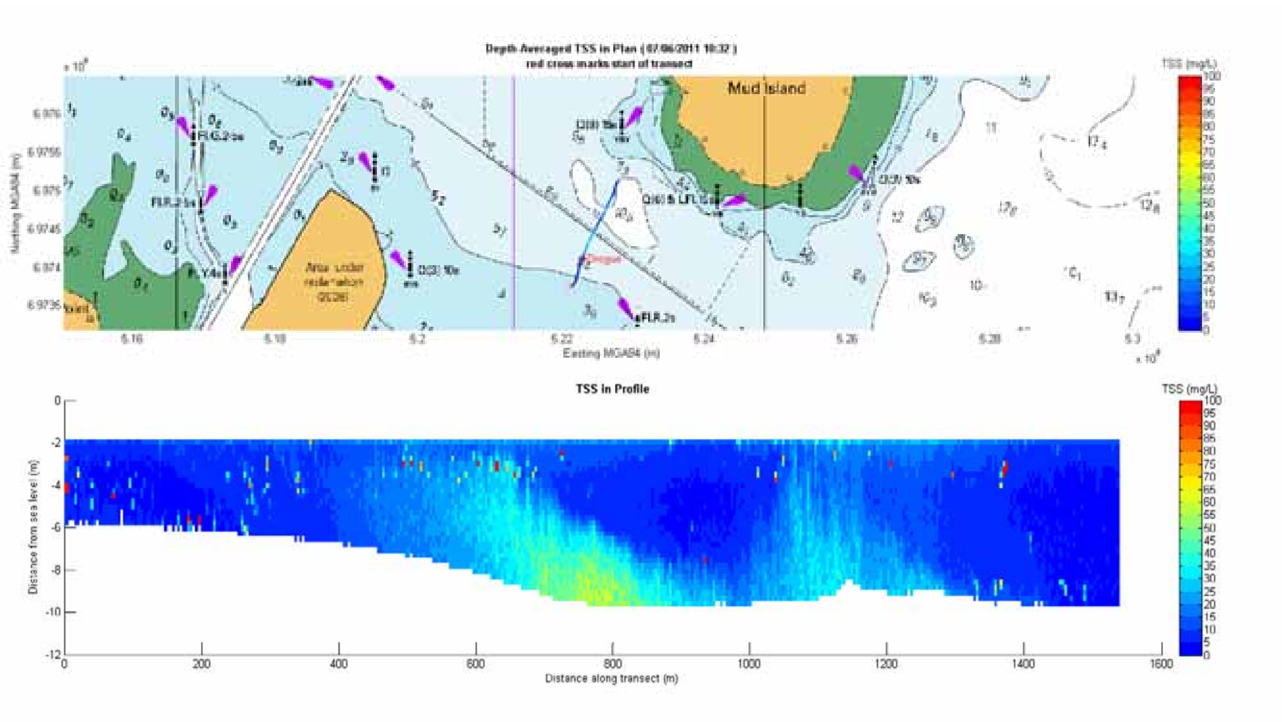

Figure E- 8 ***Brisbane*** **Dumping on Flood Tide, transect 7**

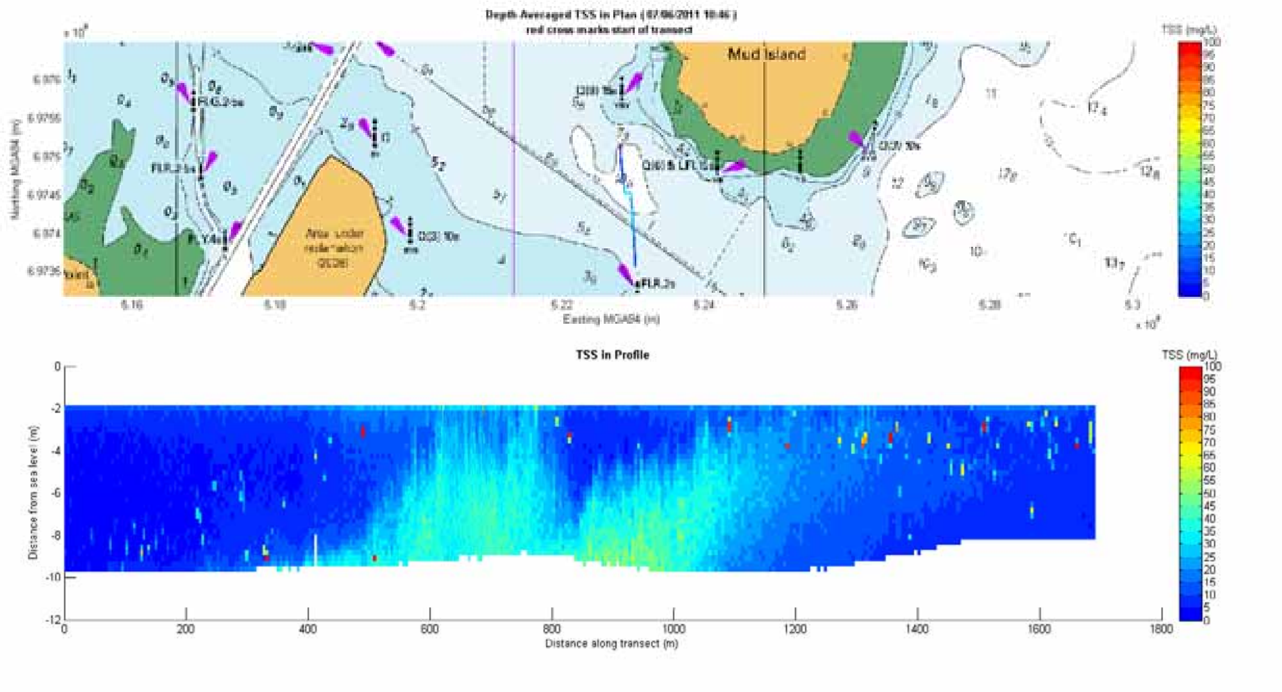

Figure E- 9 ***Brisbane*** **Dumping on Flood Tide, transect 8**

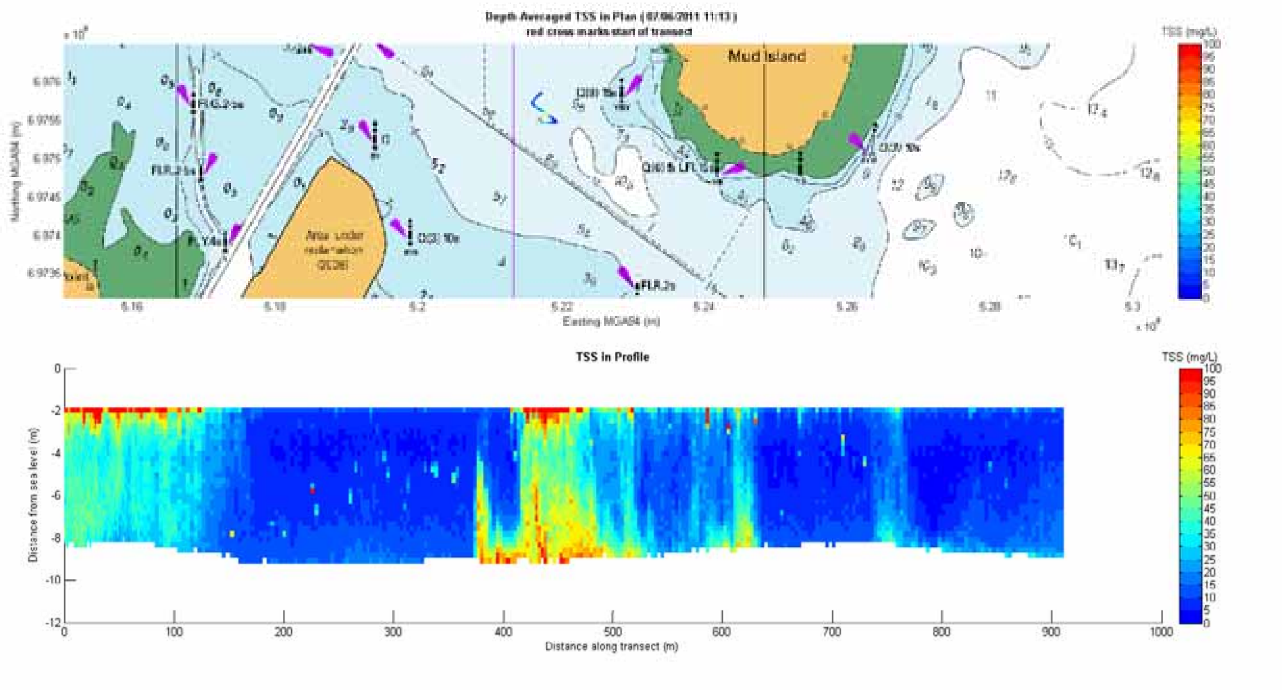

Figure E- 10 ***Brisbane*** **Dumping on Flood Tide, transect 1b**

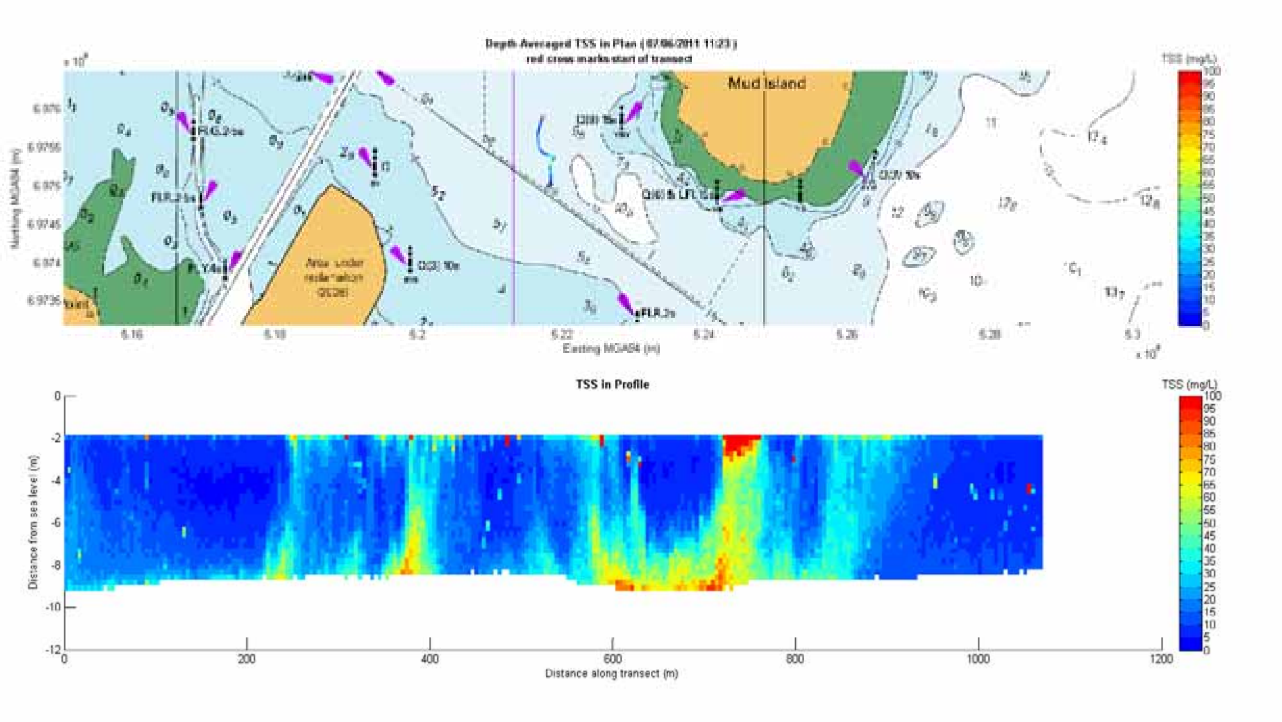

Figure E- 11 *Brisbane* Dumping on Flood Tide, transect 2b

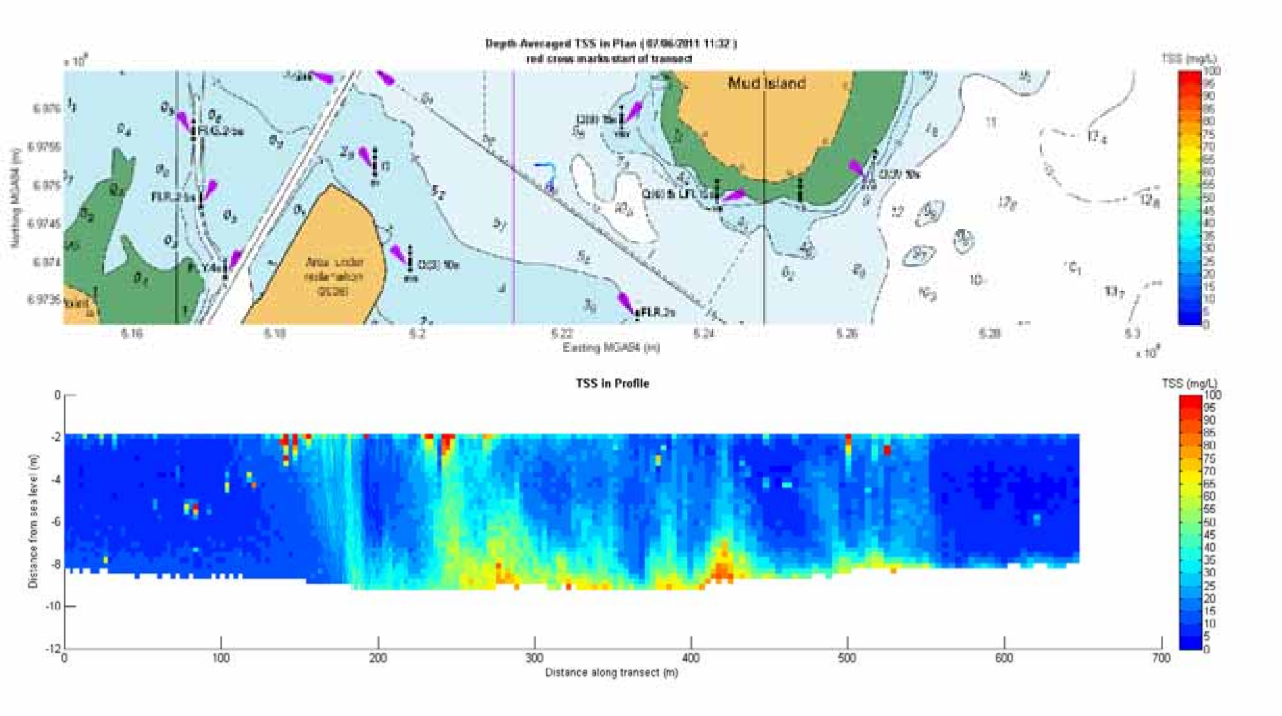

Figure E- 12 *Brisbane* Dumping on Flood Tide, transect 3b

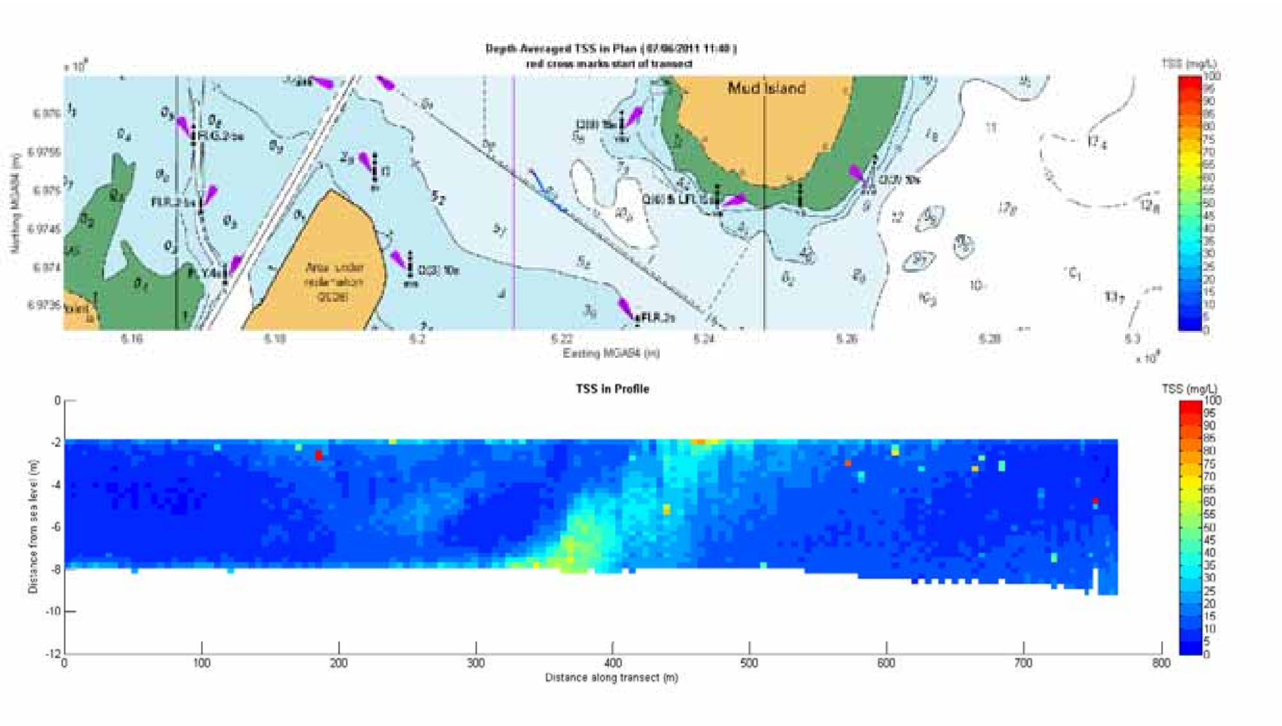

Figure E- 13 *Brisbane* Dumping on Flood Tide, transect 4b

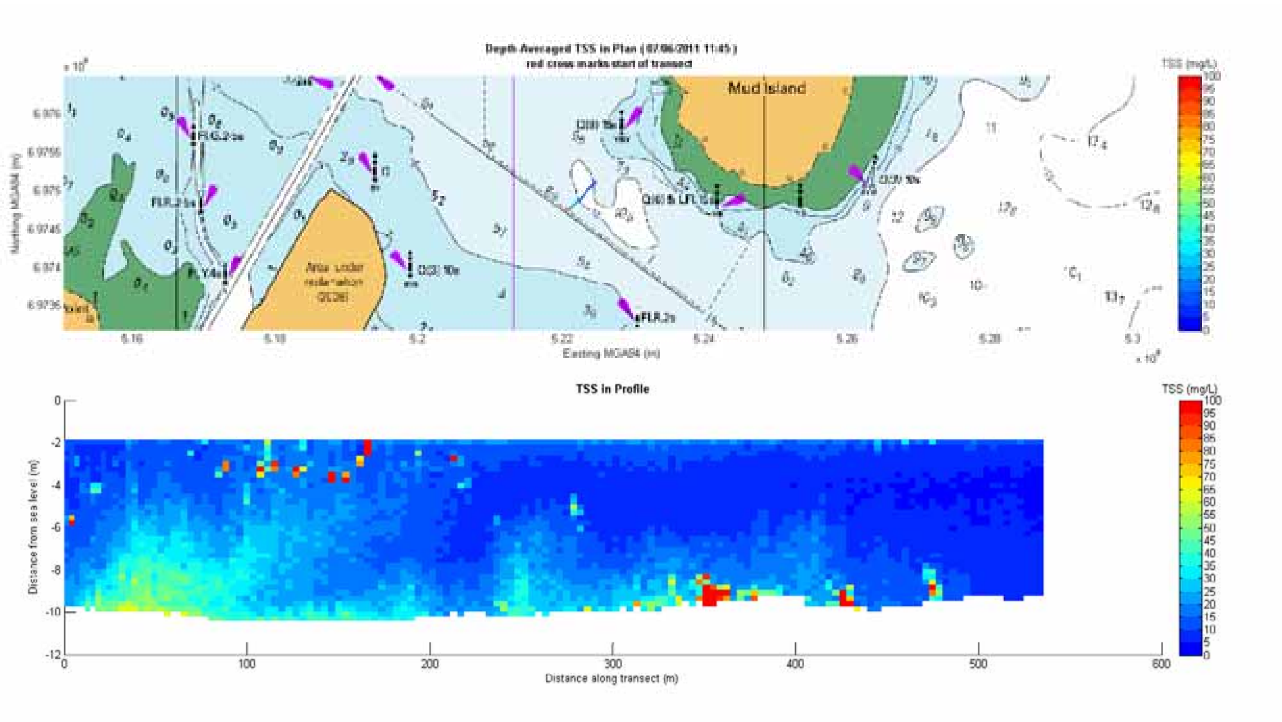

Figure E- 14 *Brisbane* Dumping on Flood Tide, transect 5b

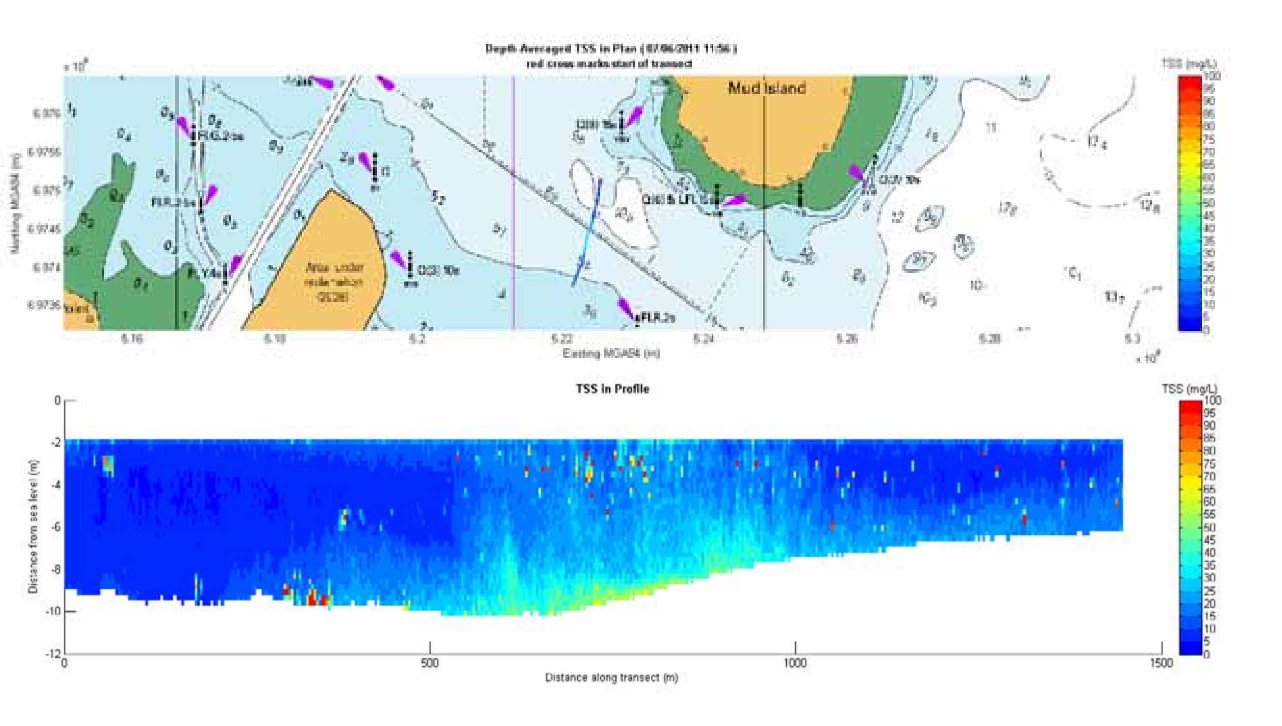

Figure E- 15 *Brisbane* Dumping on Flood Tide, transect 6b

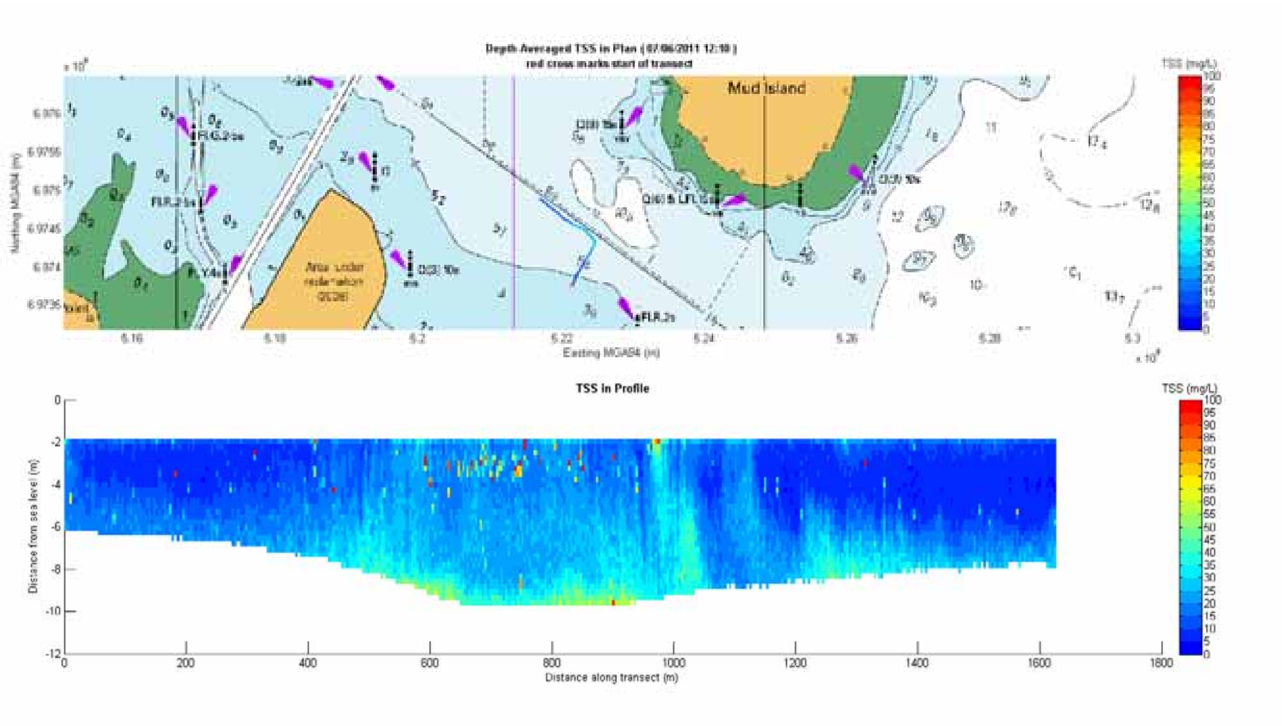

Figure E- 16 *Brisbane* Dumping on Flood Tide, transect 7b

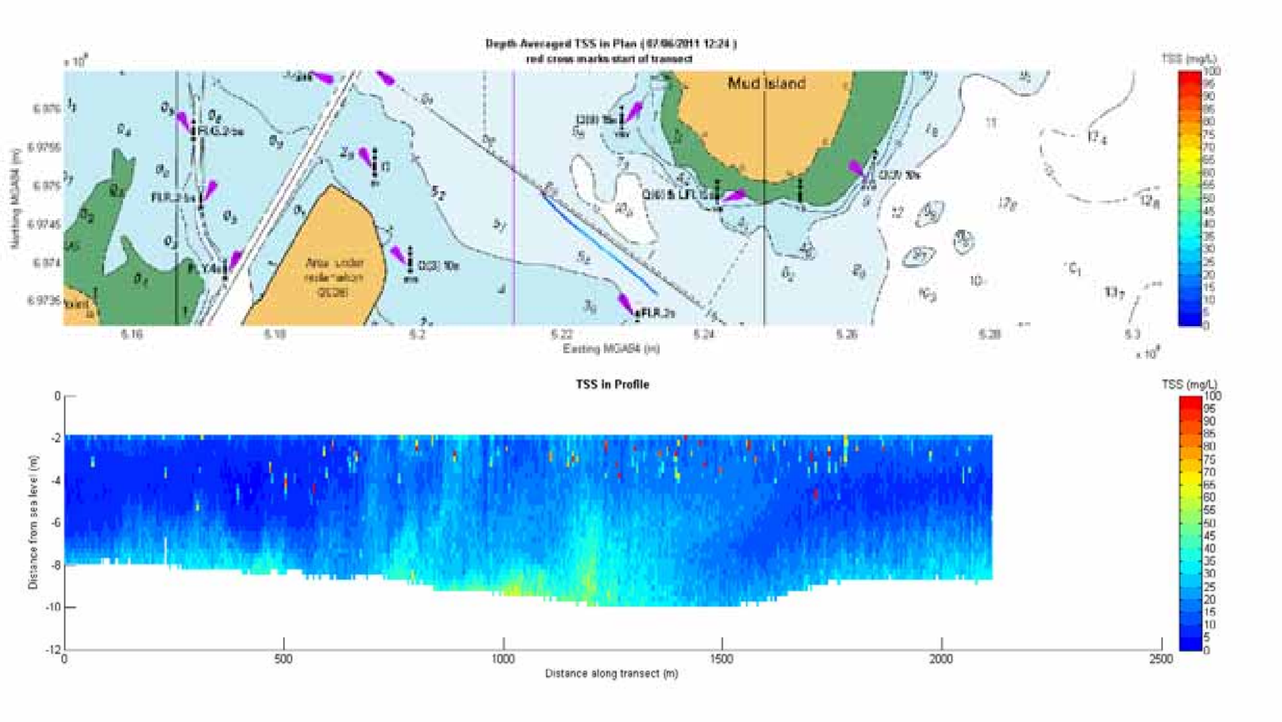

Figure E- 17 *Brisbane* Dumping on Flood Tide, transect 8b

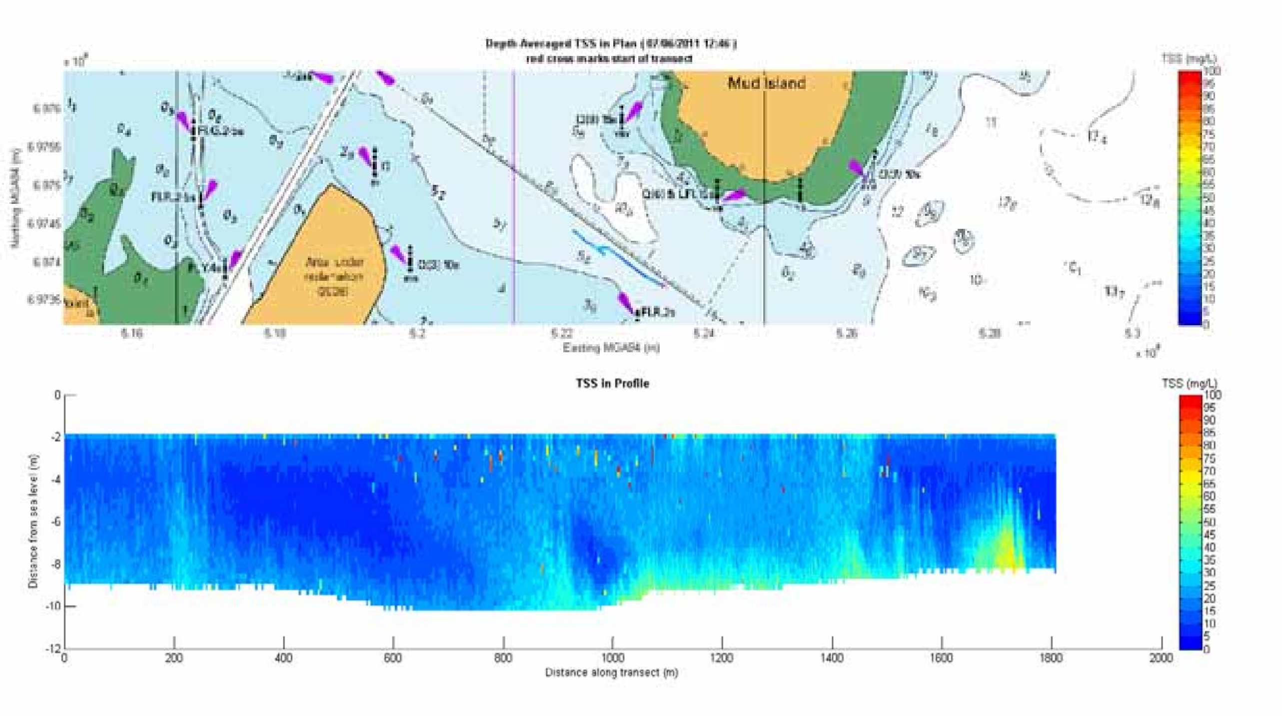

Figure E- 18 *Brisbane* Dumping on Flood Tide, transect 9b

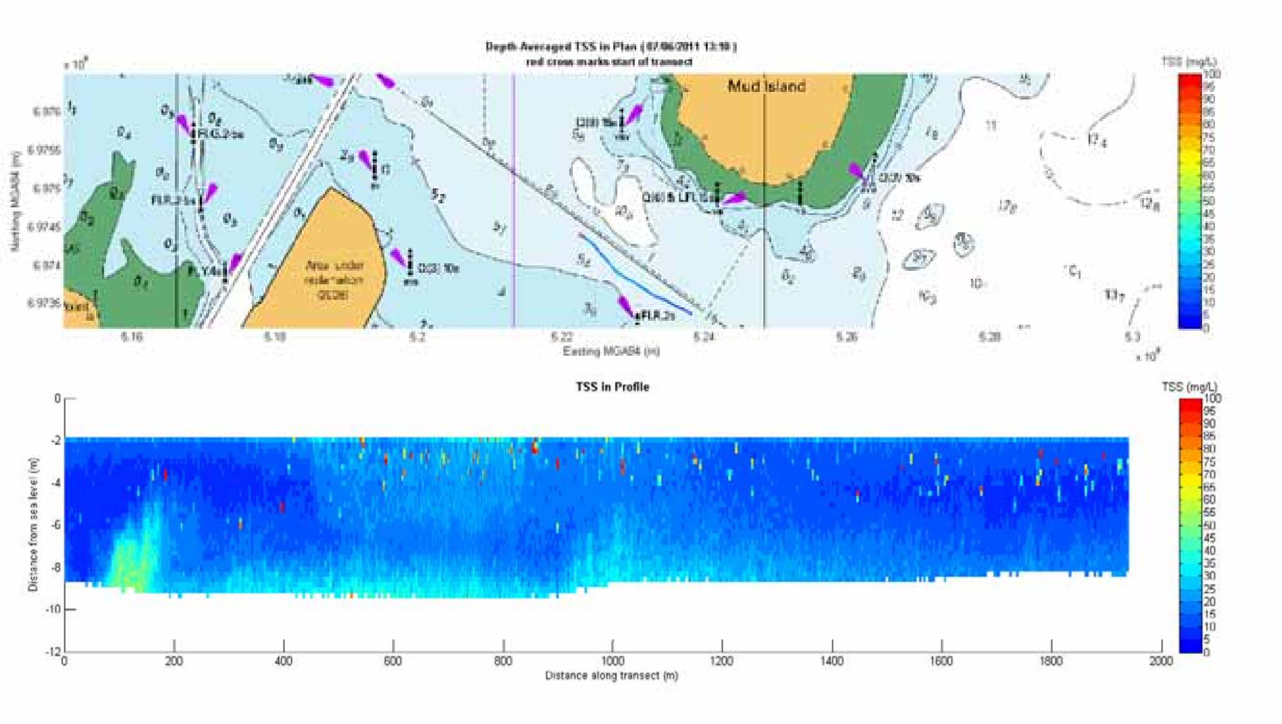

Figure E- 19 *Brisbane* Dumping on Flood Tide, transect 10b

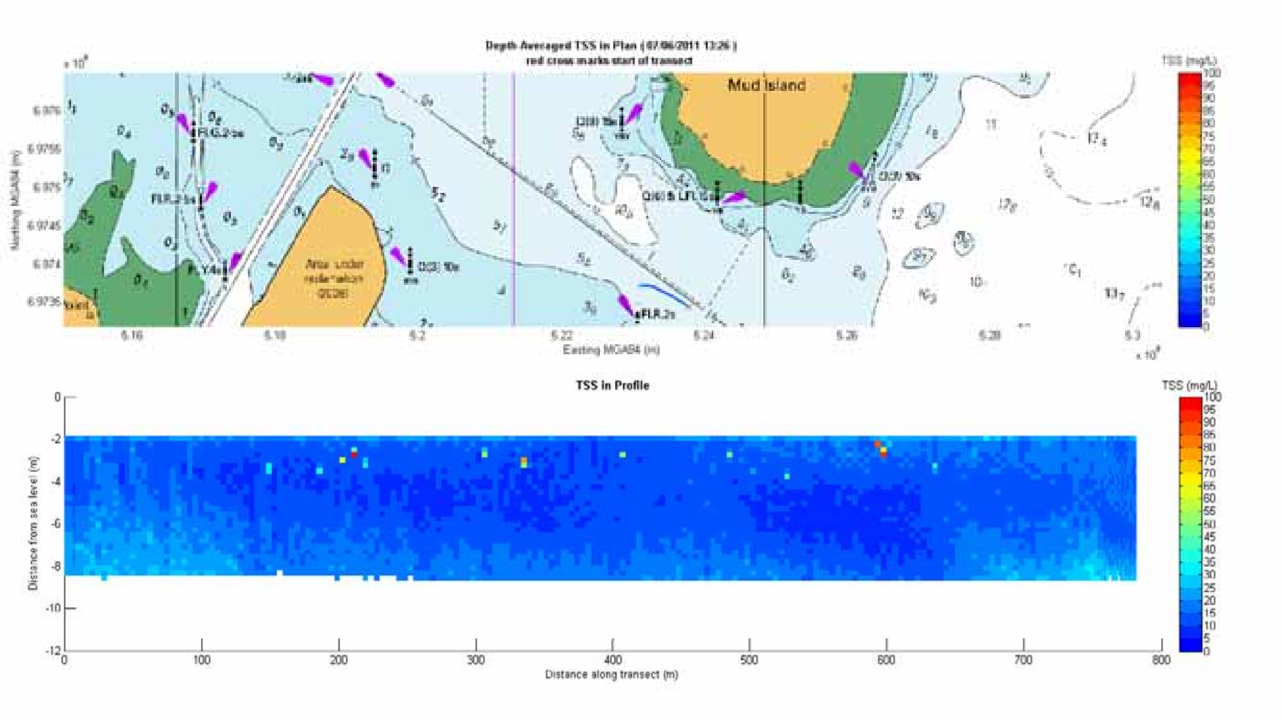

Figure E- 20 *Brisbane* Dumping on Flood Tide, transect 11b

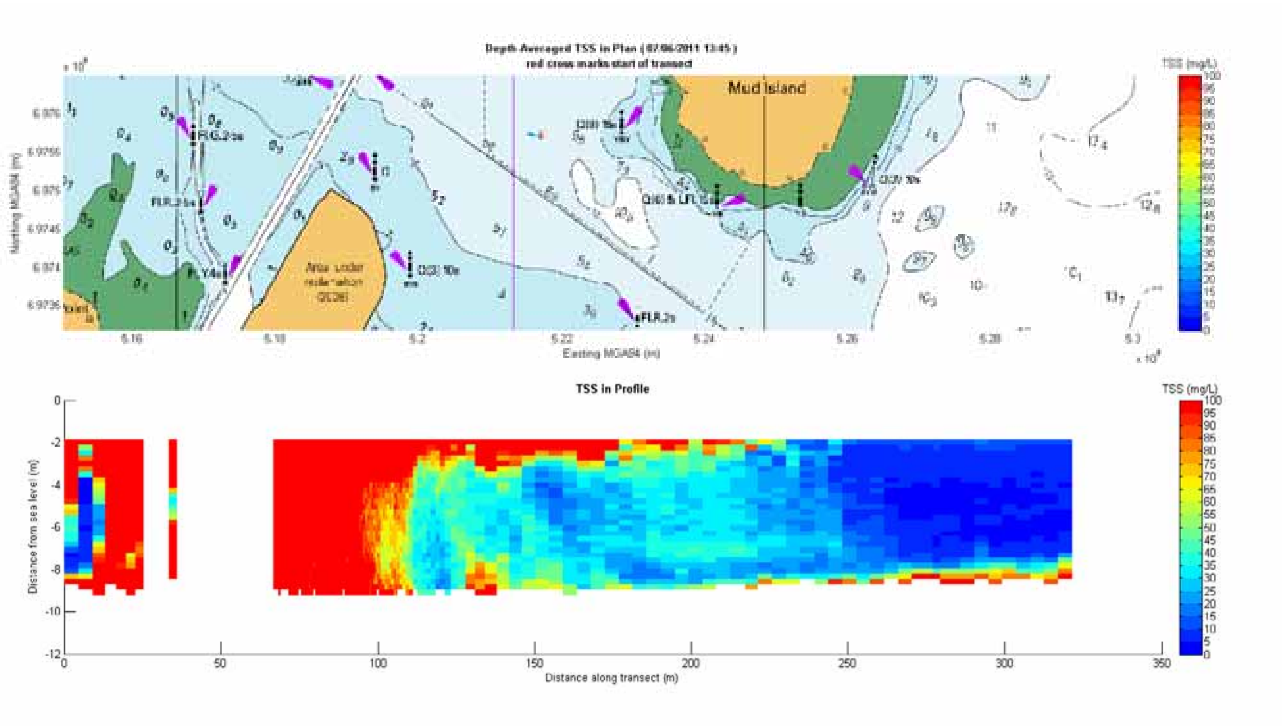

Figure E- 21 *Brisbane* Dumping on Flood Tide, transect 1c

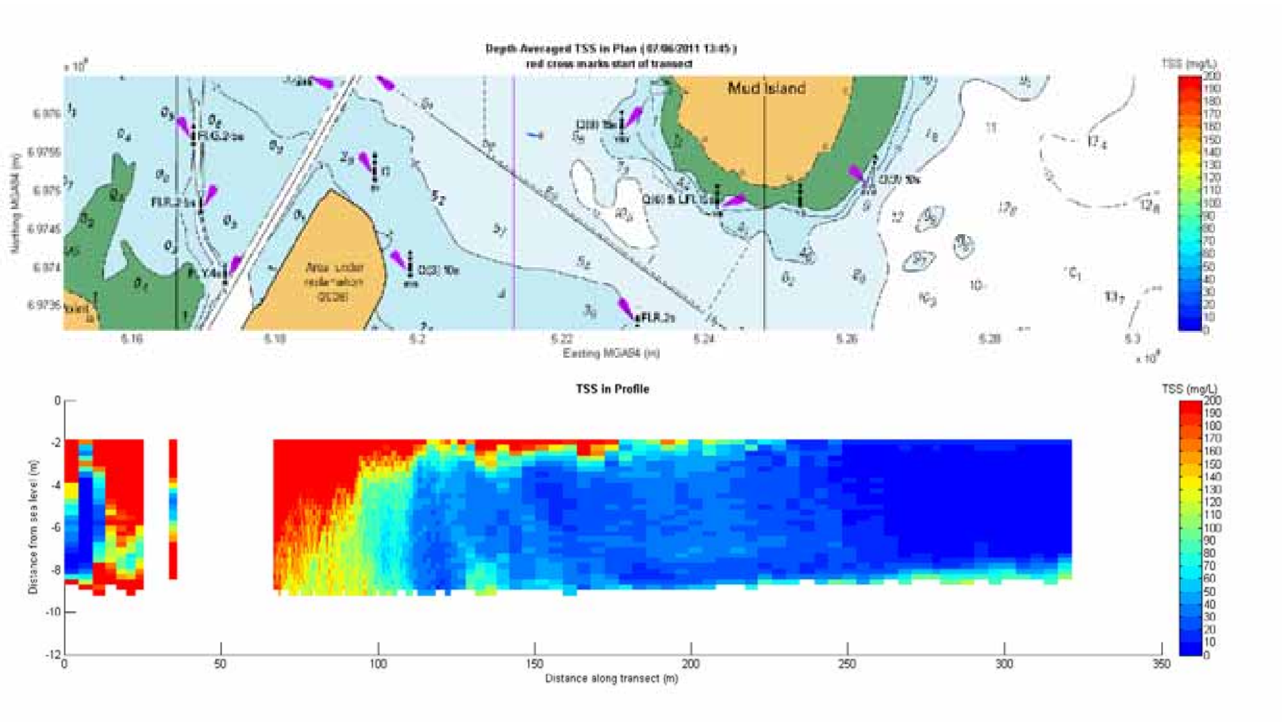

Figure E- 22 *Brisbane* Dumping on Flood Tide, transect 2c

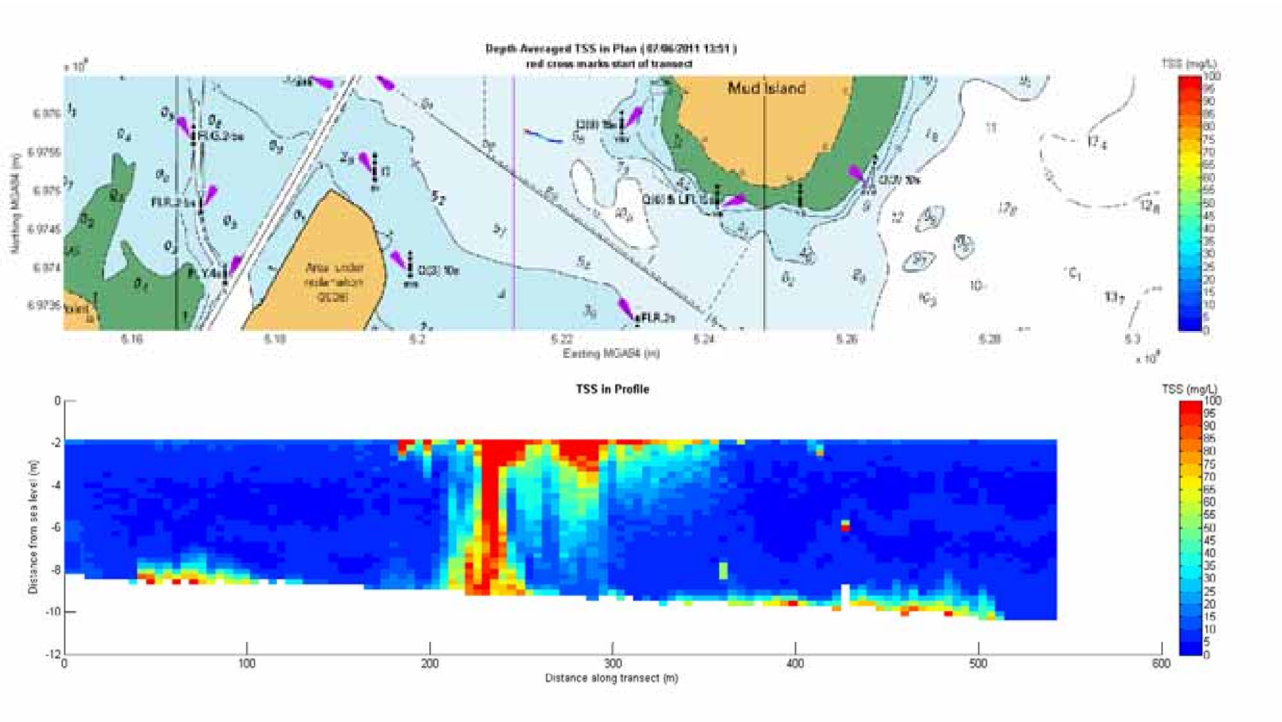

Figure E- 23 *Brisbane* Dumping on Flood Tide, transect 3c

APPENDIX F: DREDGER 'BRISBANE' SWING BASIN

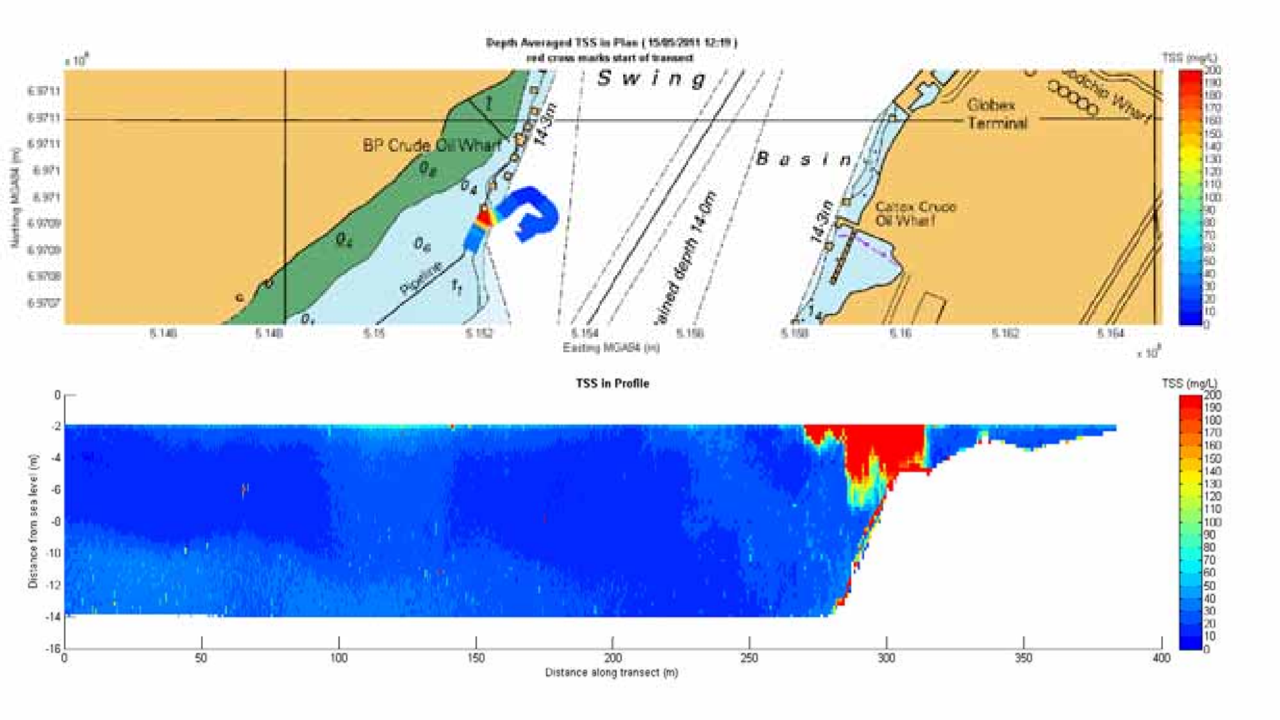

Figure F- 1 ***Brisbane*** **at Swing Basin, Transect 1**

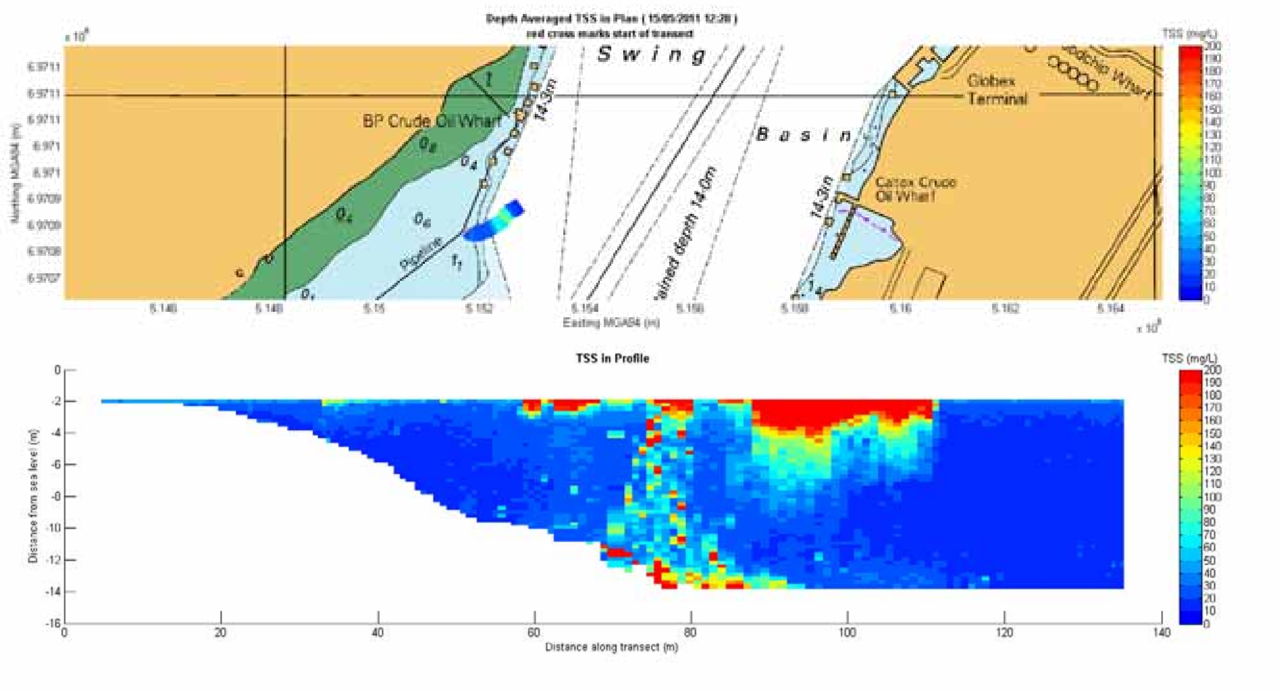

Figure F- 2 ***Brisbane*** **at Swing Basin, Transect 2**

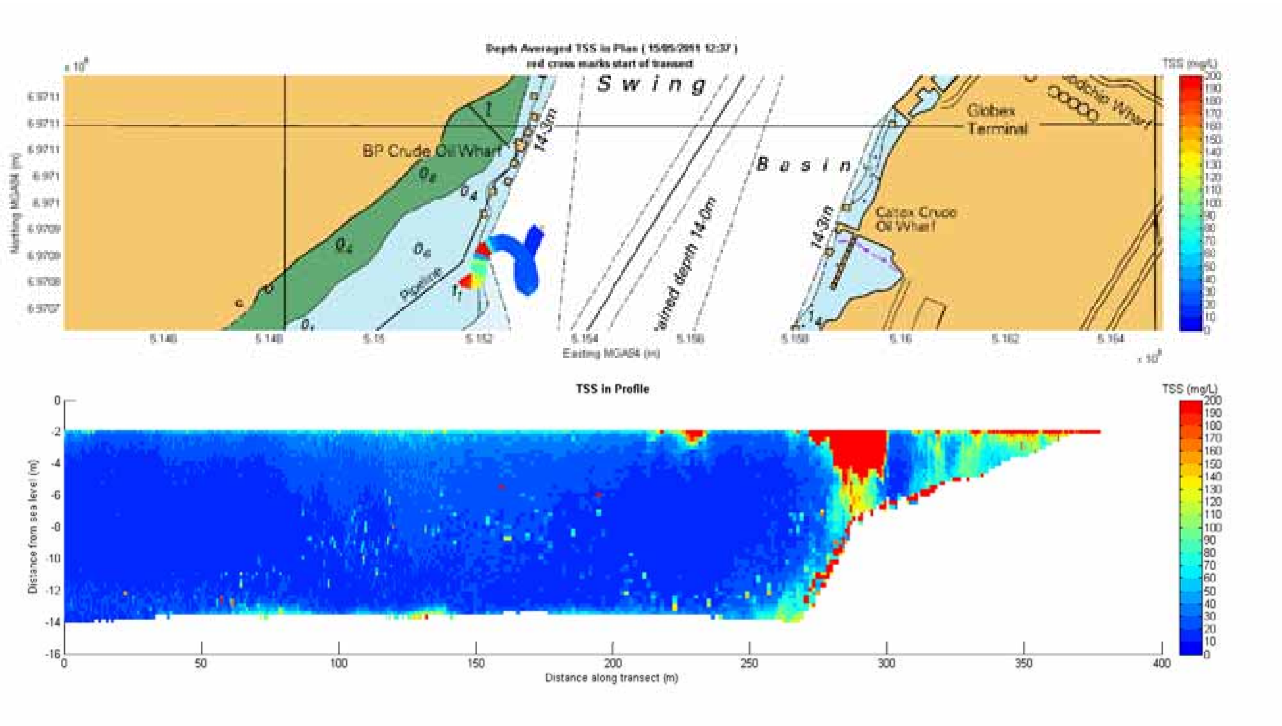

Figure F- 3 *Brisbane* at Swing Basin, Transect 3

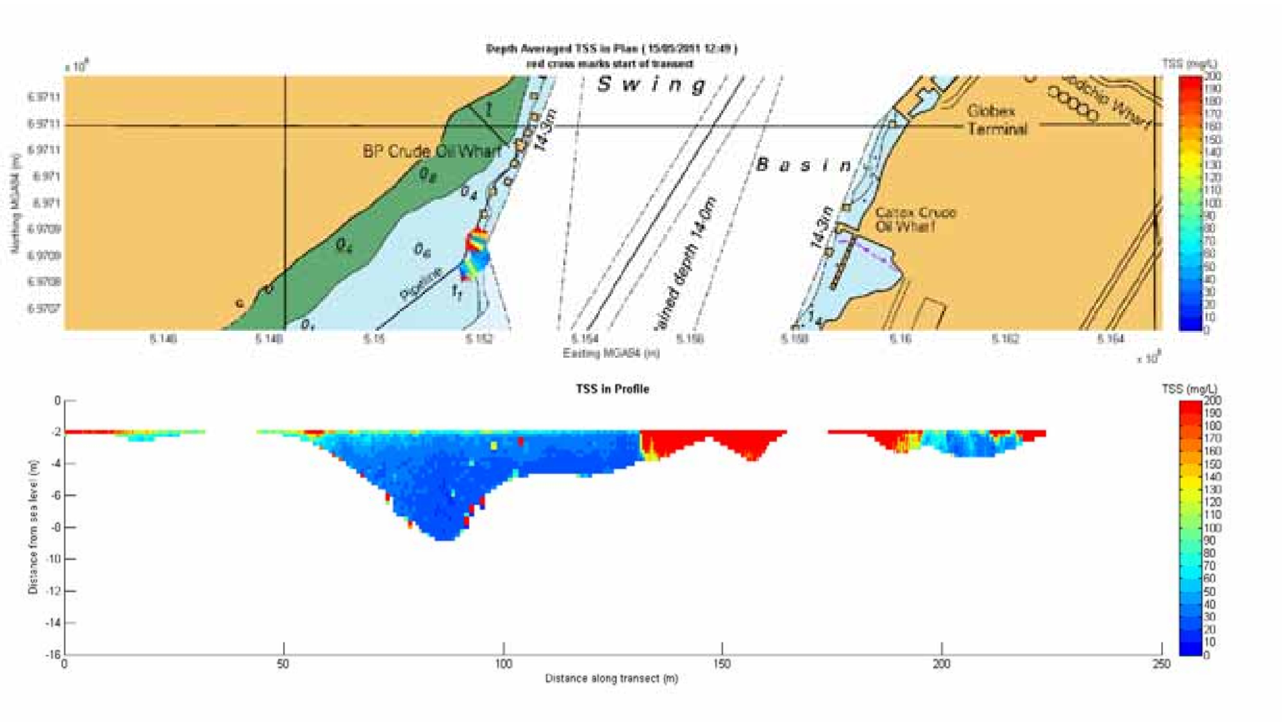

Figure F- 4 *Brisbane* at Swing Basin, Transect 4

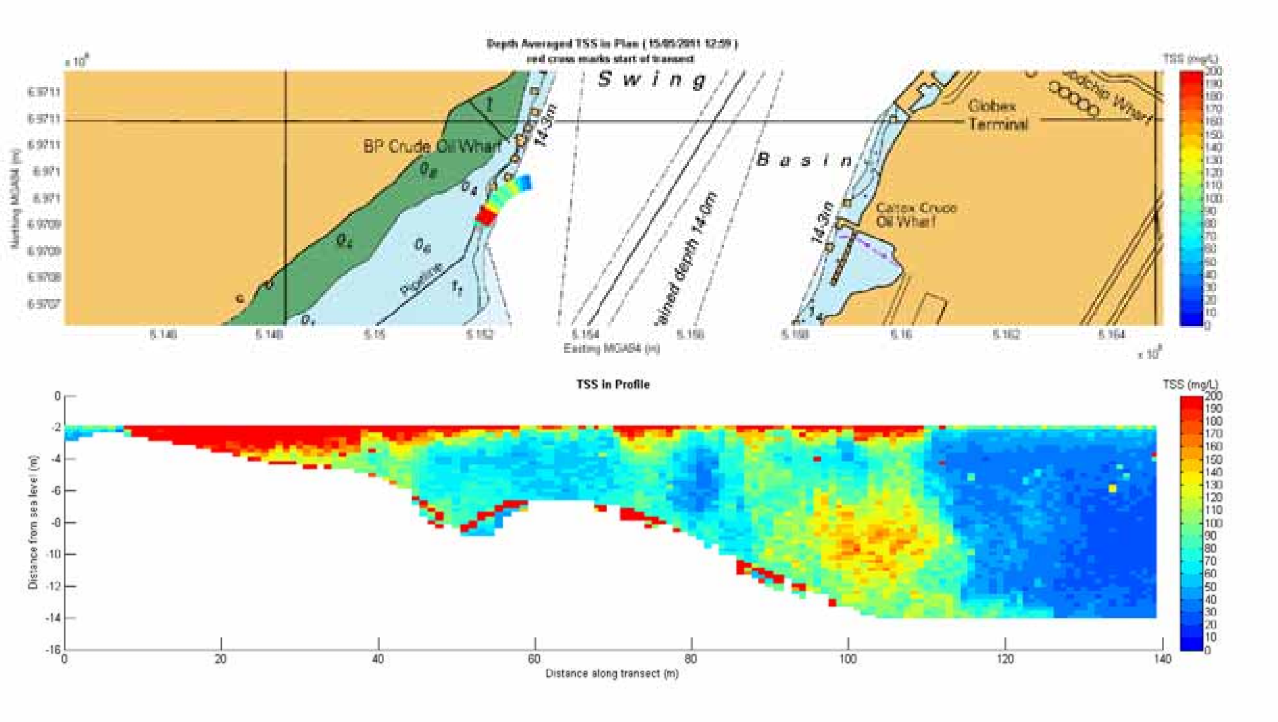

Figure F- 5 *Brisbane* at Swing Basin, Transect 5

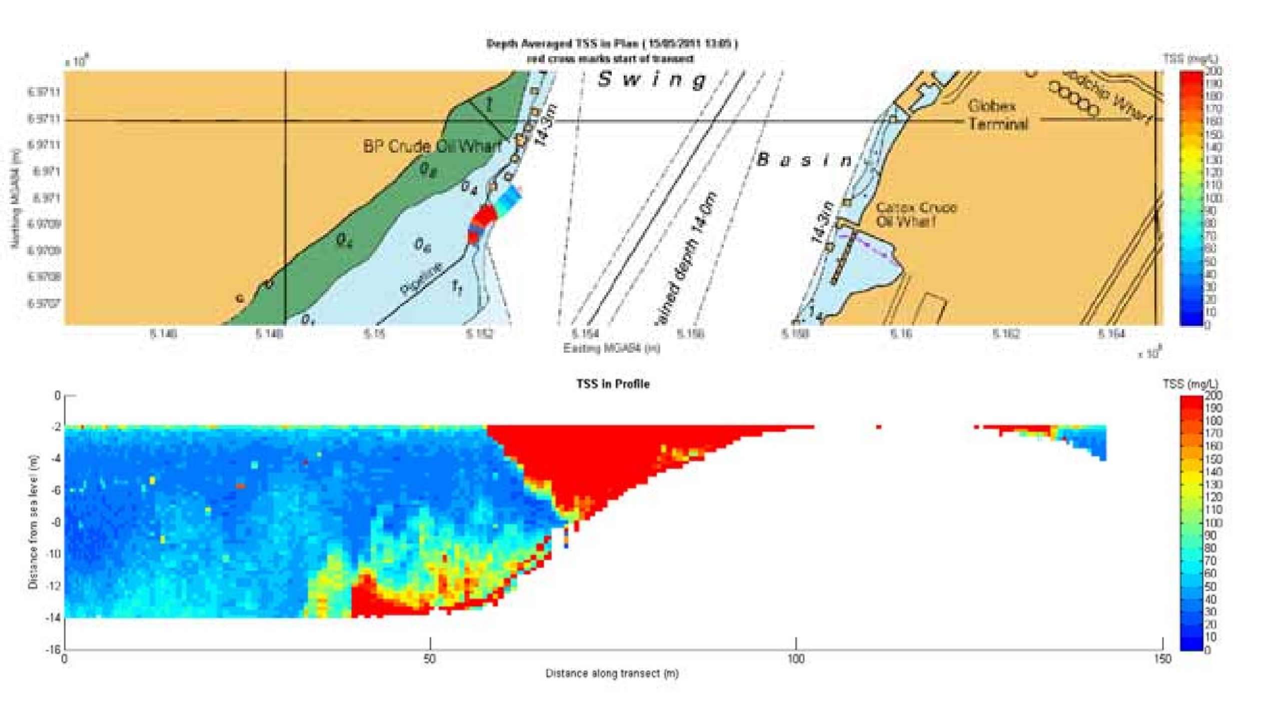

Figure F- 6 *Brisbane* at Swing Basin, Transect 6

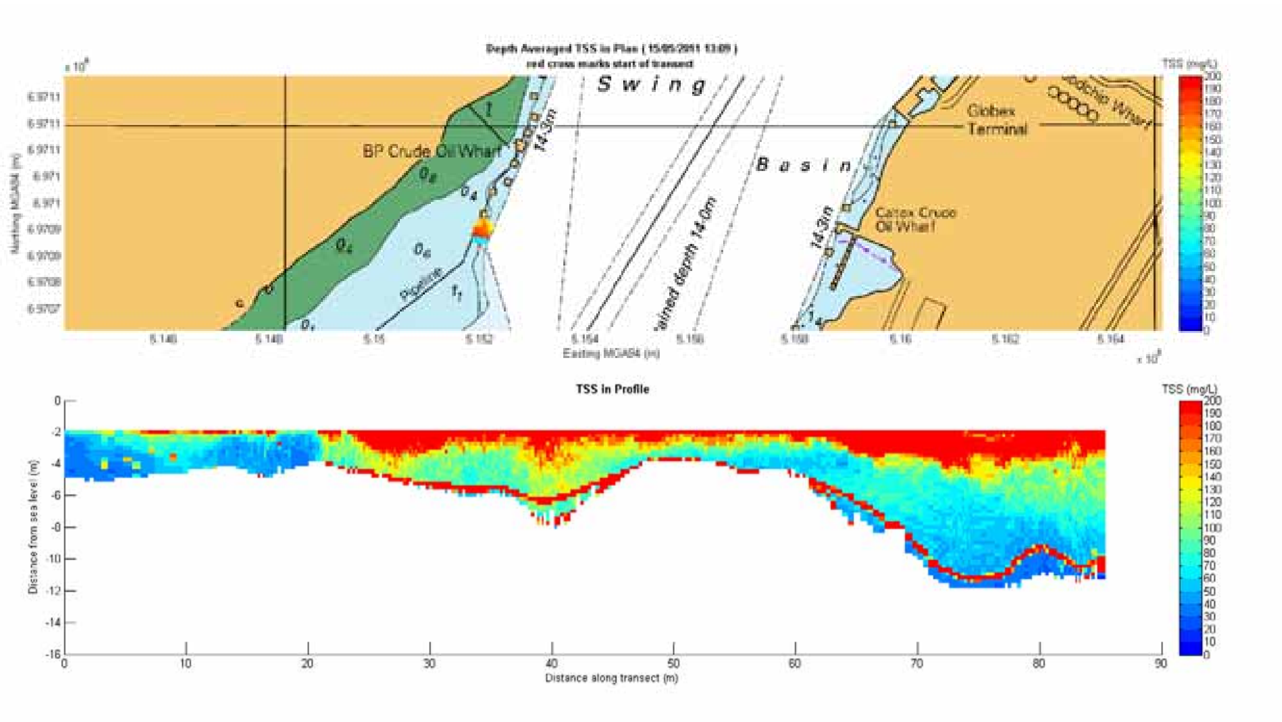

Figure F- 7 *Brisbane* at Swing Basin, Transect 7

APPENDIX G: DREDGER 'AMITY'

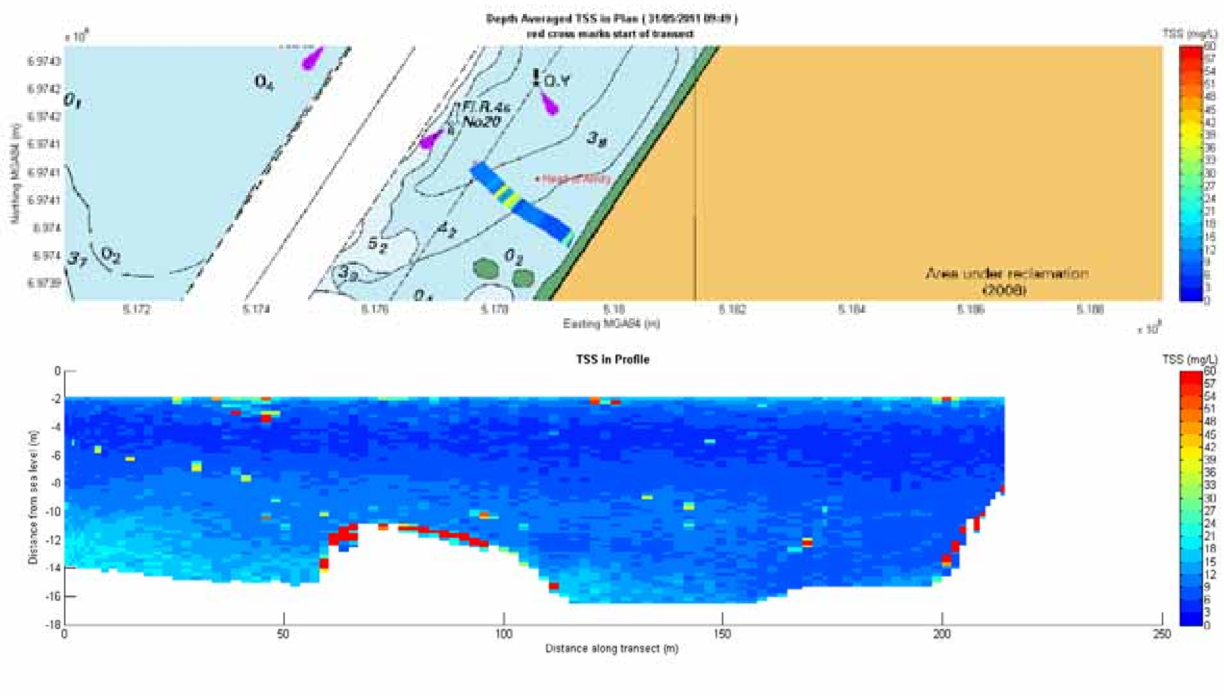

Figure G- 1 *Amity* at Fishermans Island, transect 1

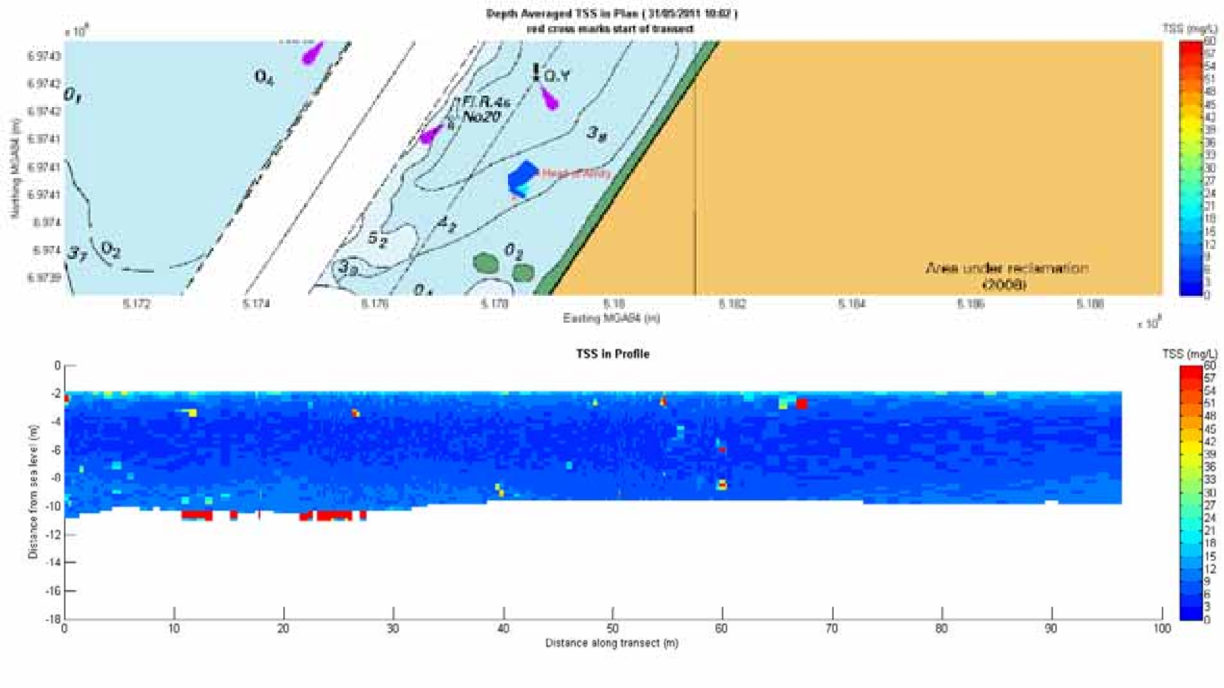

Figure G- 2 *Amity* at Fishermans Island, transect 2

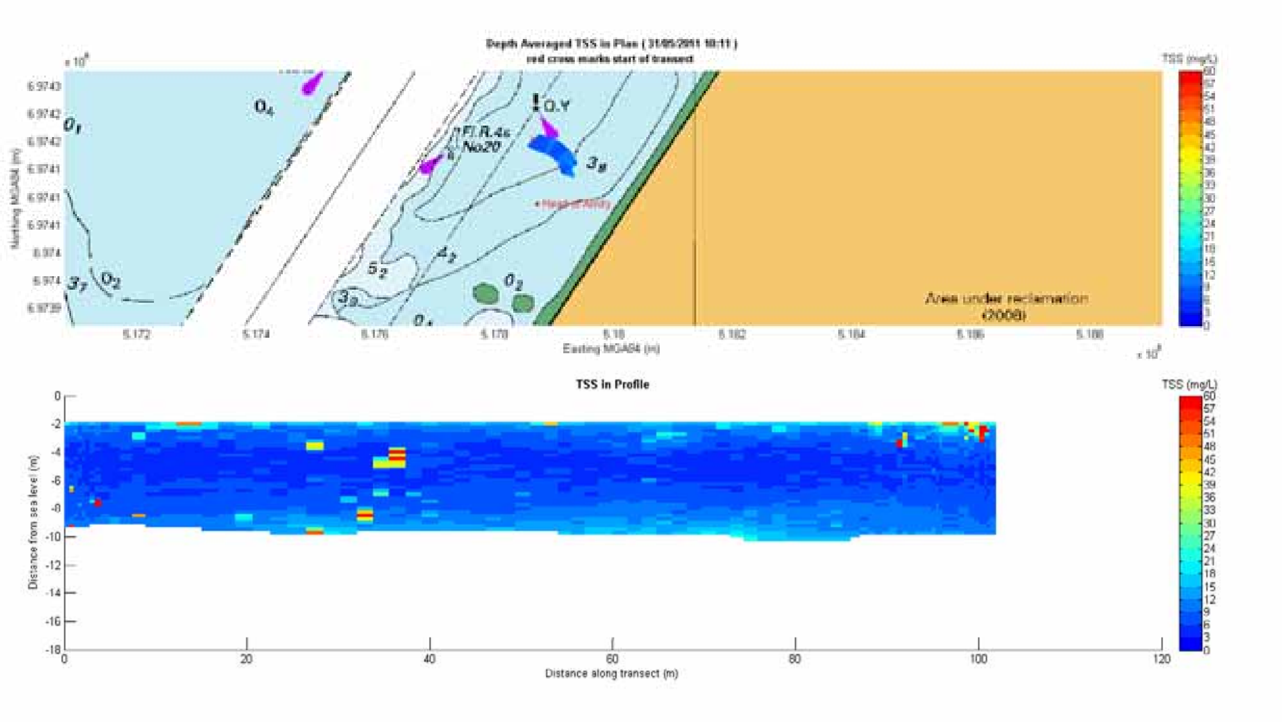

Figure G- 3 *Amity* at Fishermans Island, transect 3

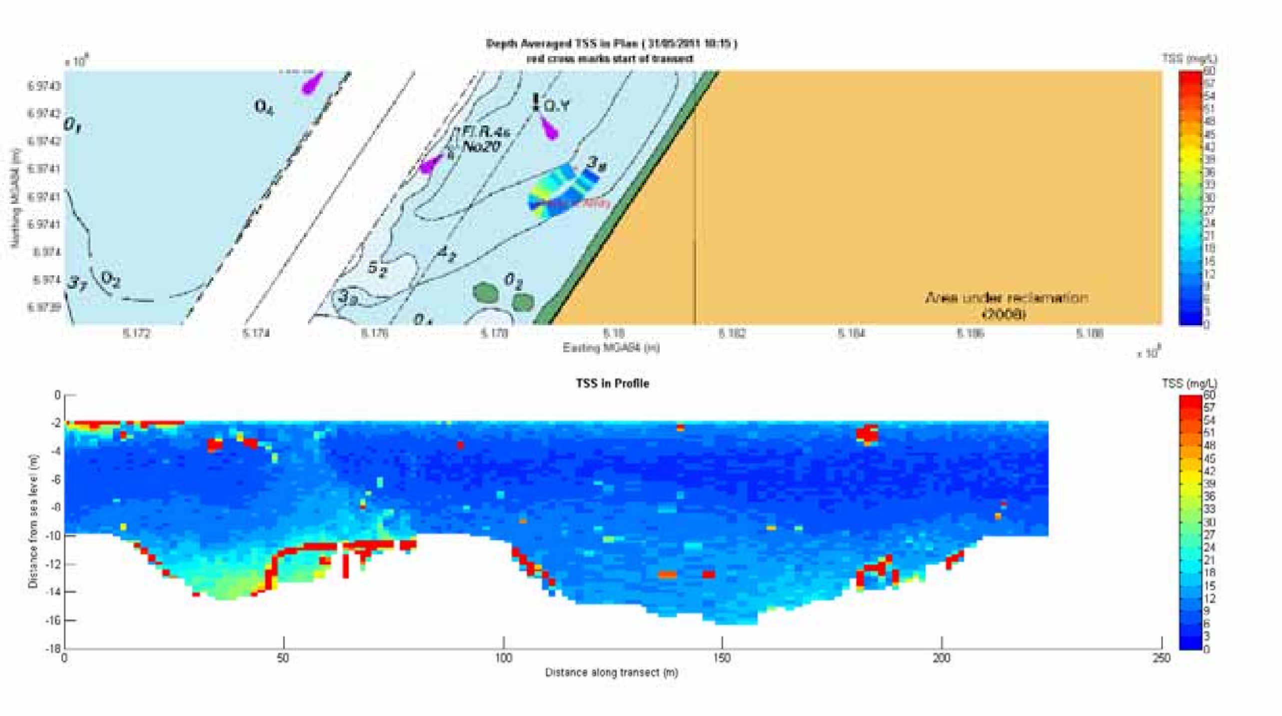

Figure G- 4 *Amity* at Fishermans Island, transect 4

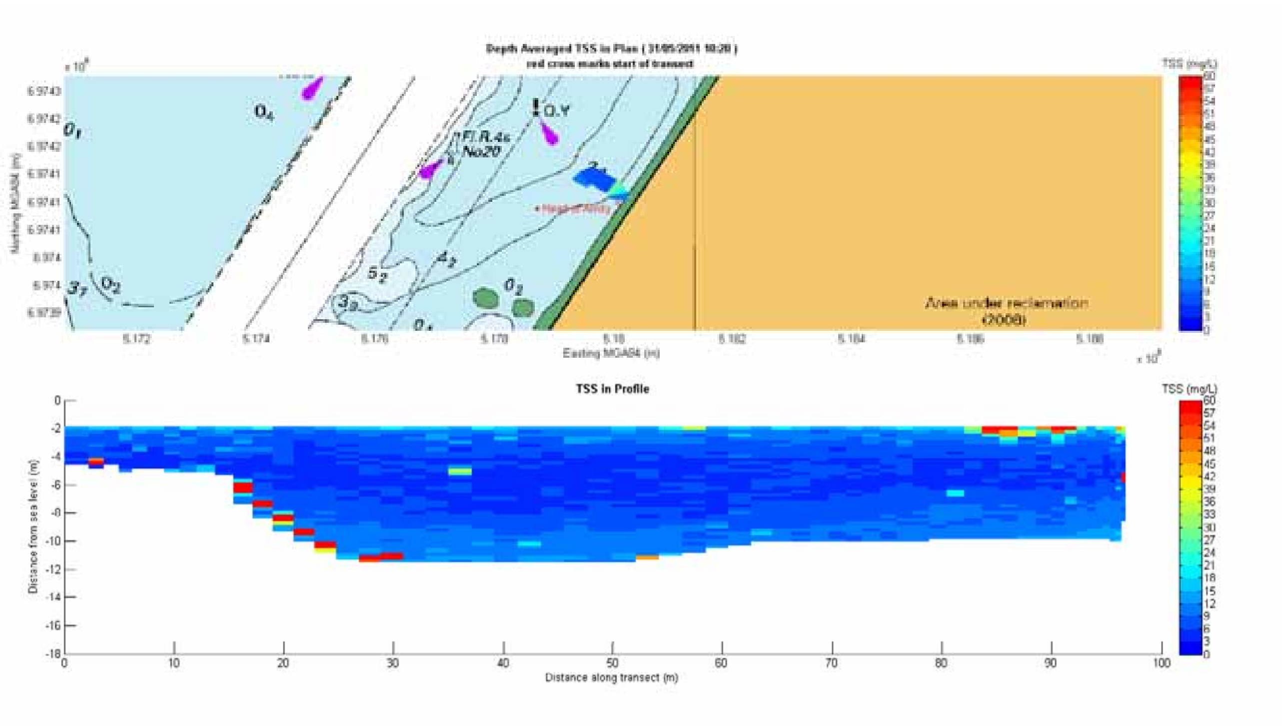

Figure G- 5 ***Amity*** **at Fishermans Island, transect 5**

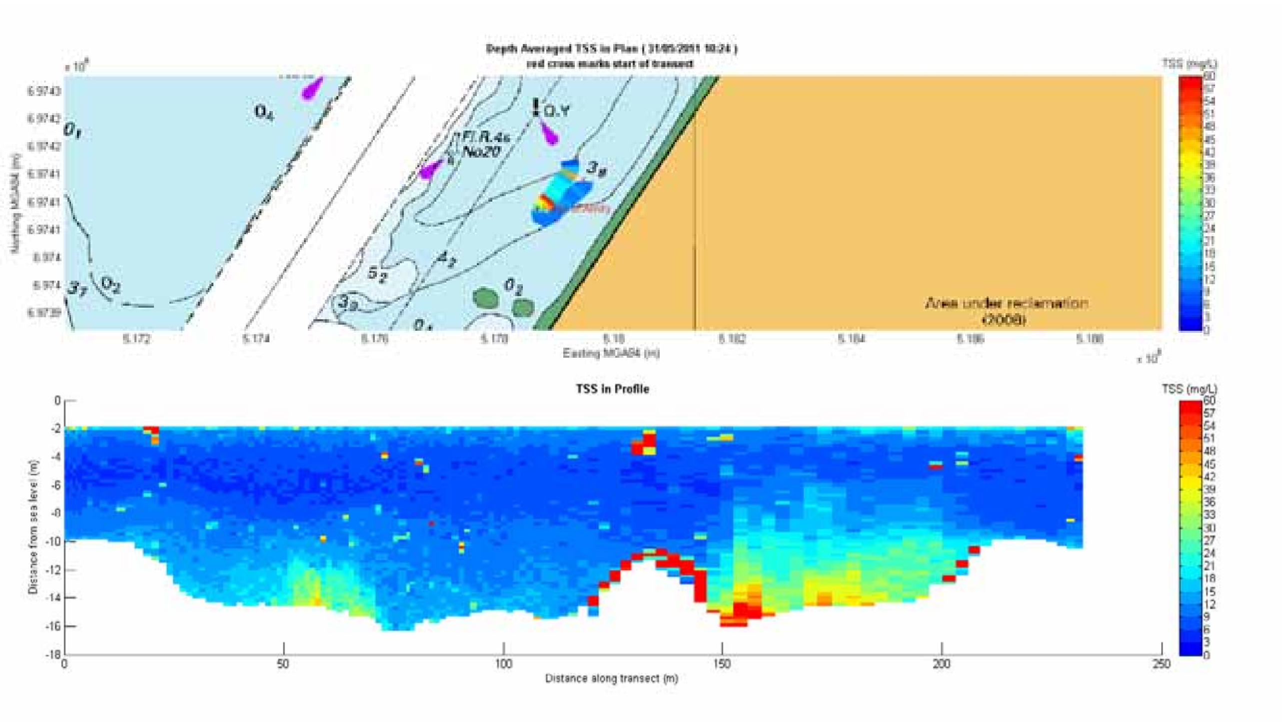

Figure G- 6 ***Amity*** **at Fishermans Island, transect 6**

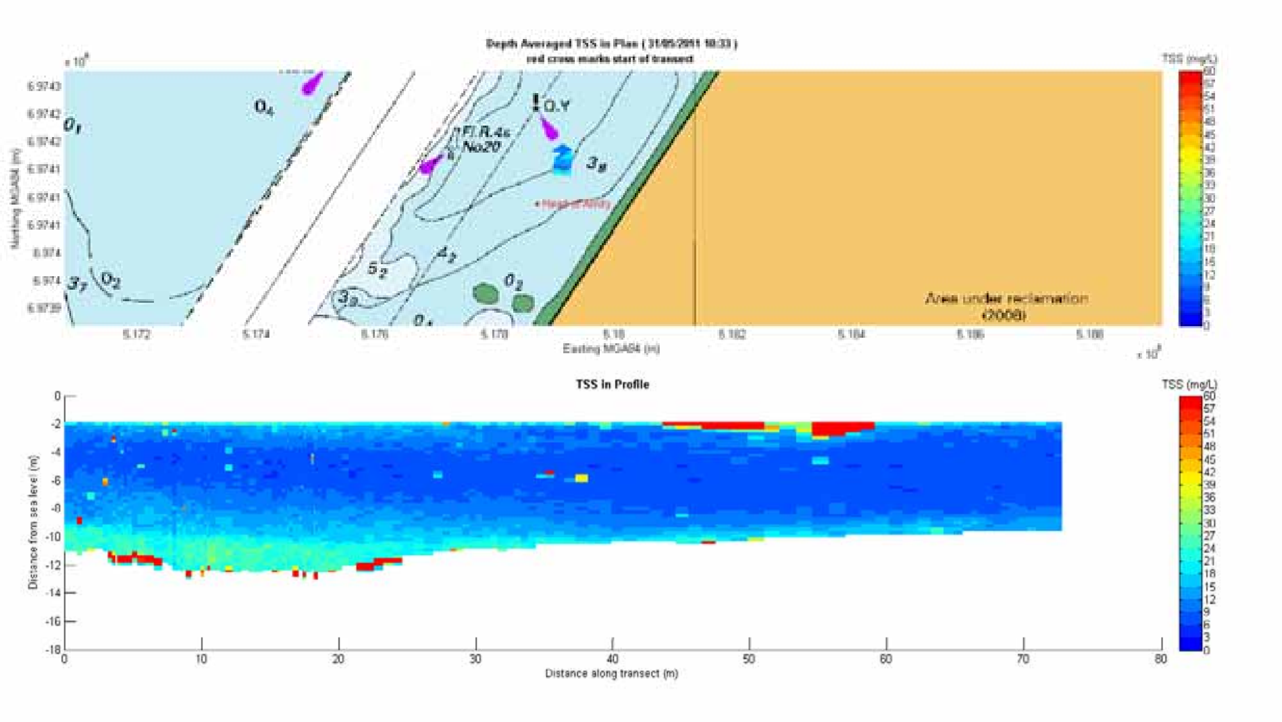

Figure G- 7 *Amity* at Fishermans Island, transect 7

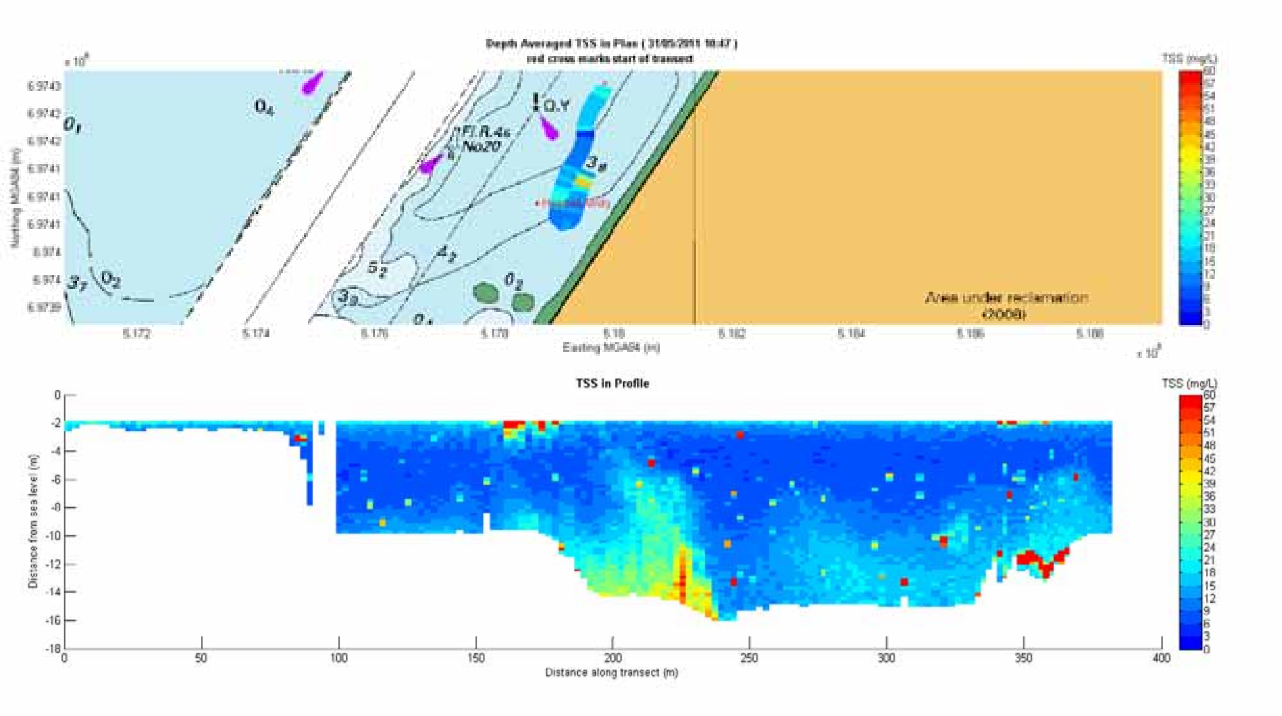

Figure G- 8 *Amity* at Fishermans Island, transect 8

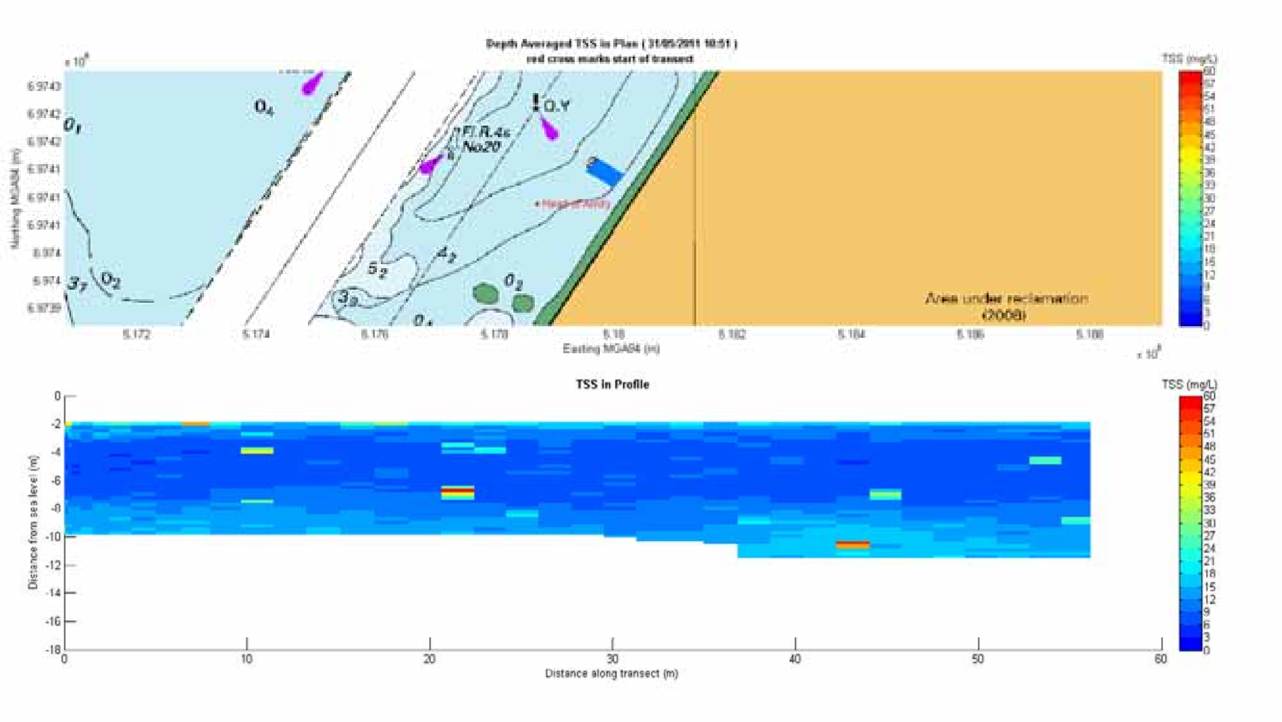

Figure G- 9 *Amity* at Fishermans Island, transect 9

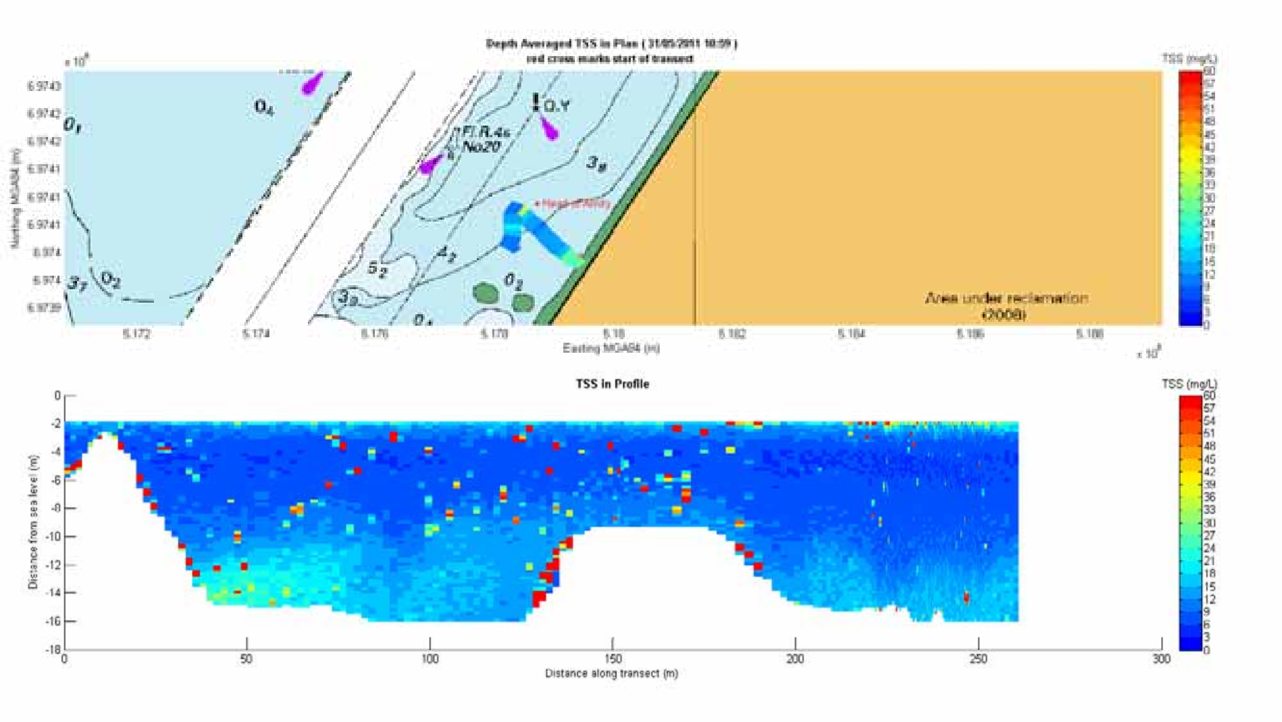

Figure G- 10 *Amity* at Fishermans Island, transect 10

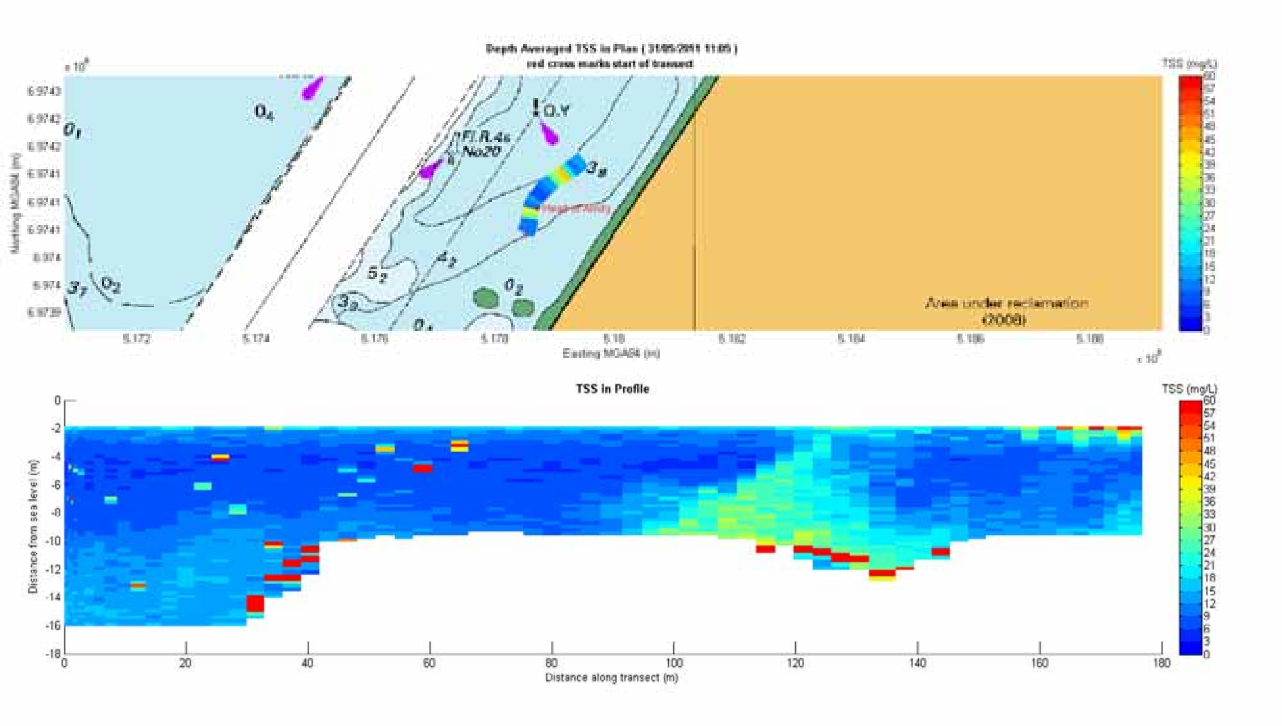

Figure G- 11 *Amity* at Fishermans Island, transect 11

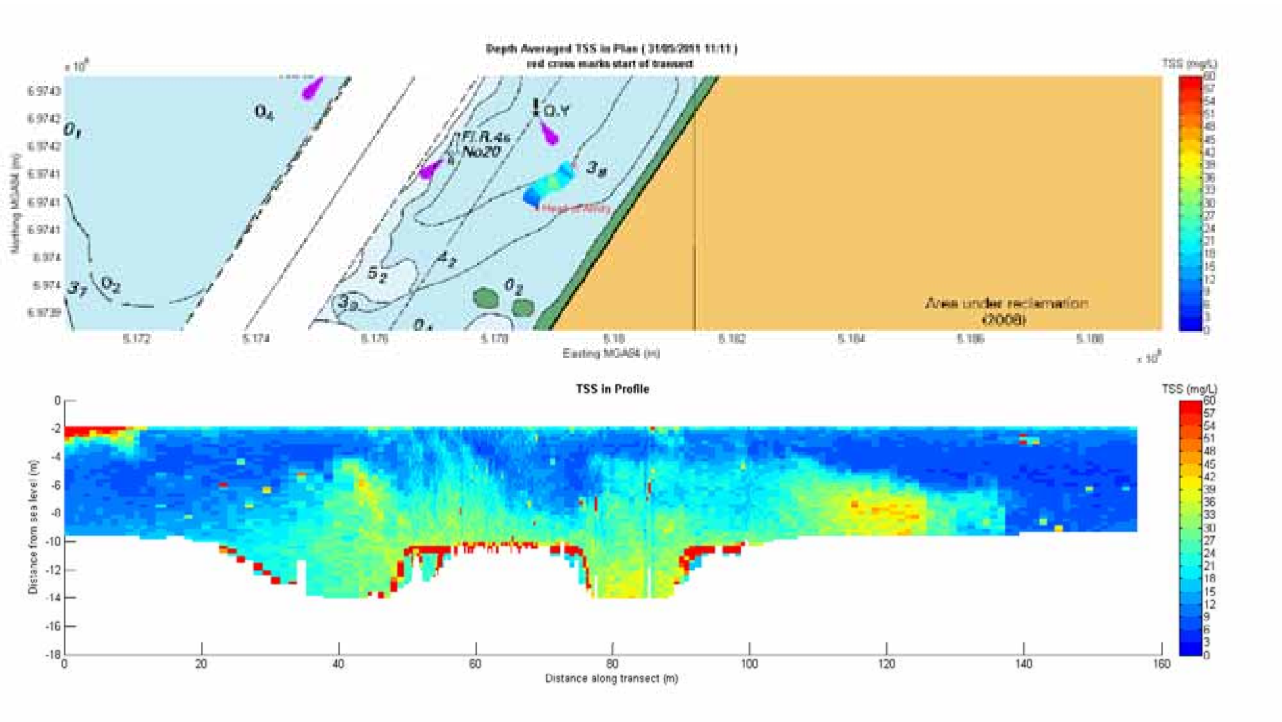

Figure G- 12 *Amity* at Fishermans Island, transect 12

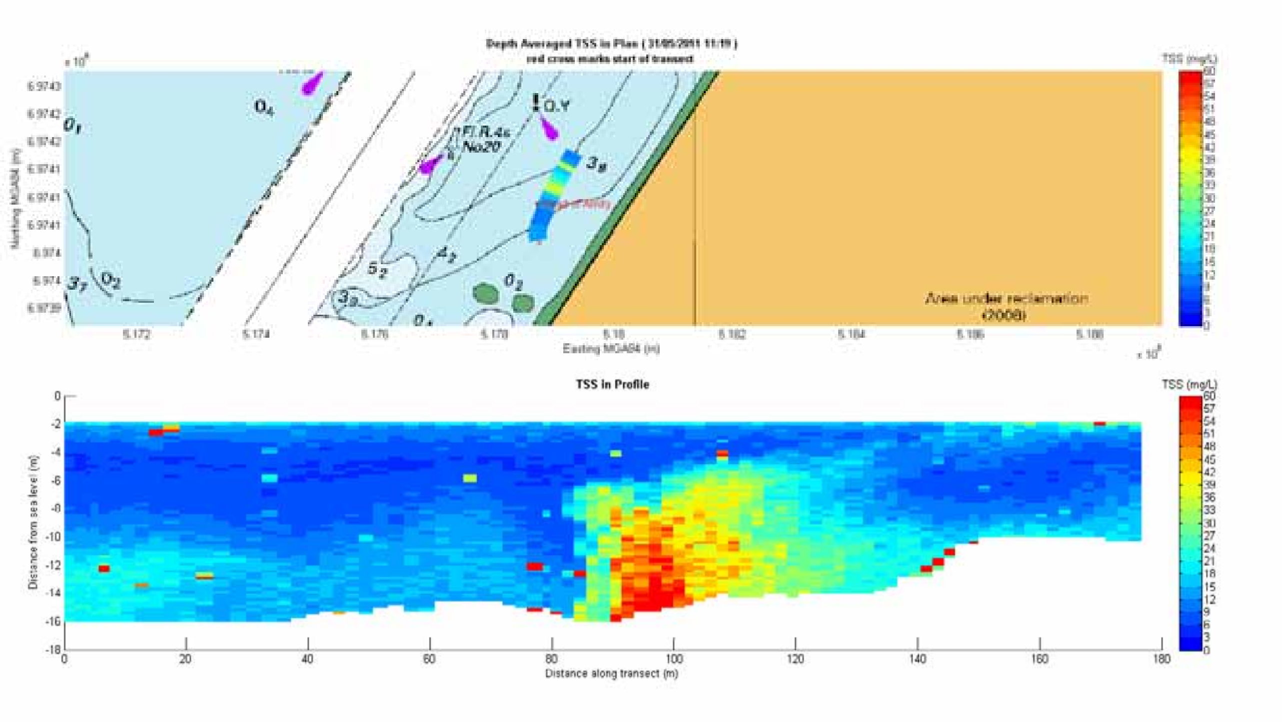

Figure G- 13 *Amity* at Fishermans Island, transect 13

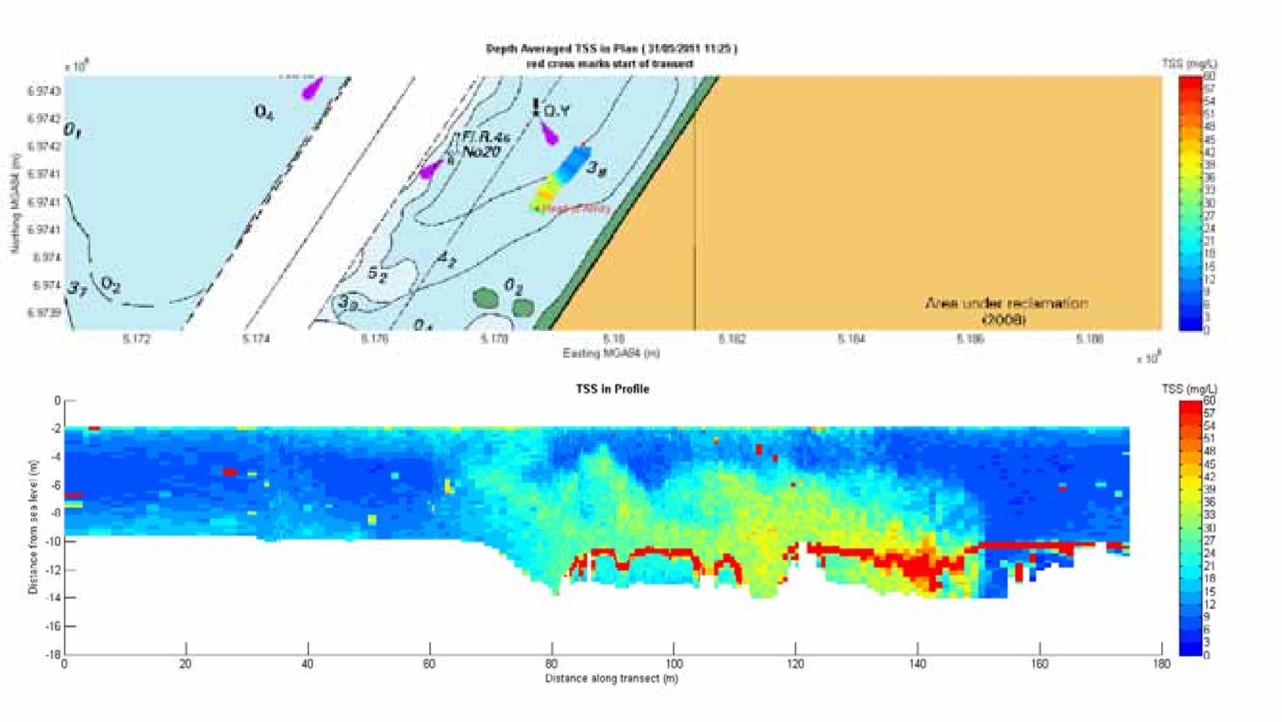

Figure G- 14 *Amity* at Fishermans Island, transect 14

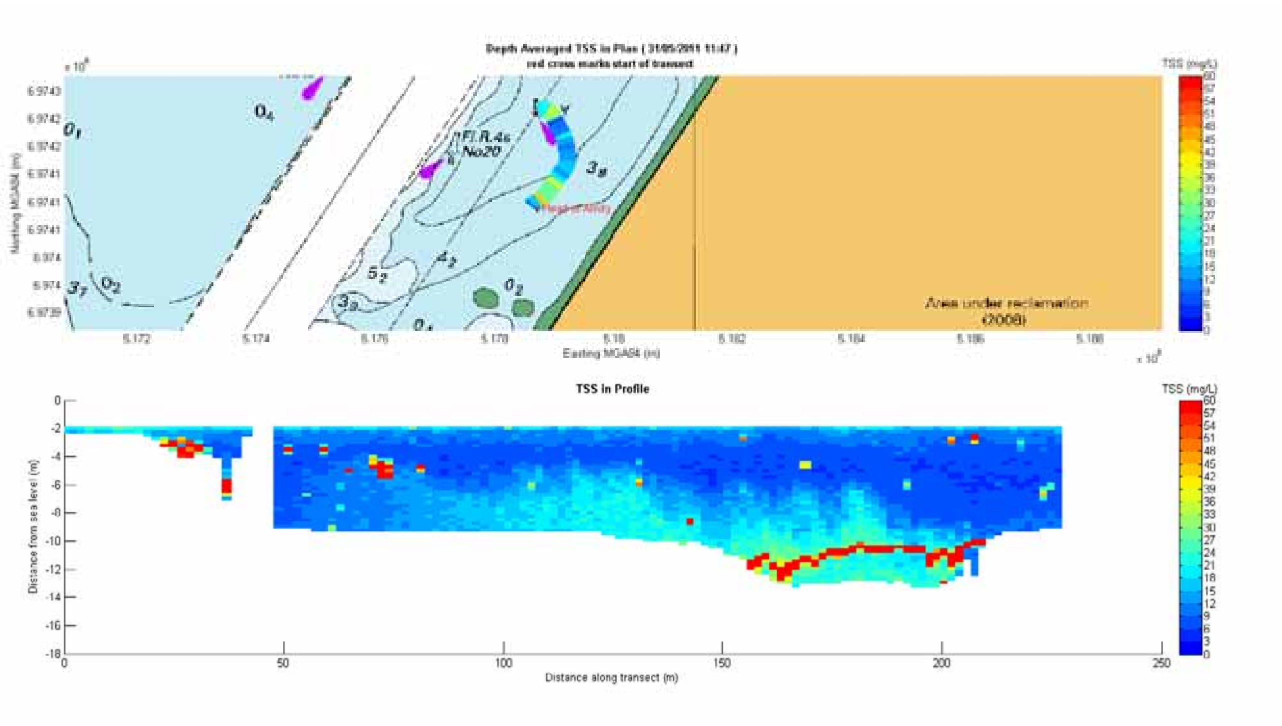

Figure G- 15 *Amity* at Fishermans Island, transect 15

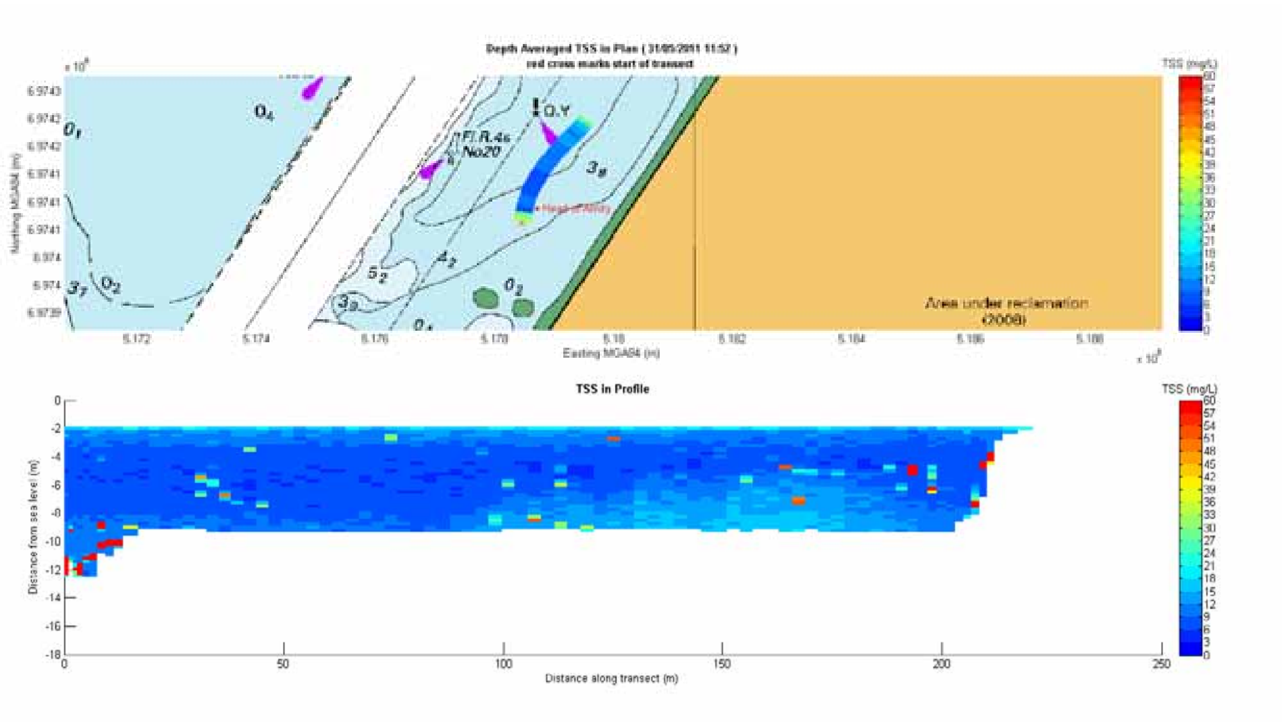

Figure G- 16 *Amity* at Fishermans Island, transect 16

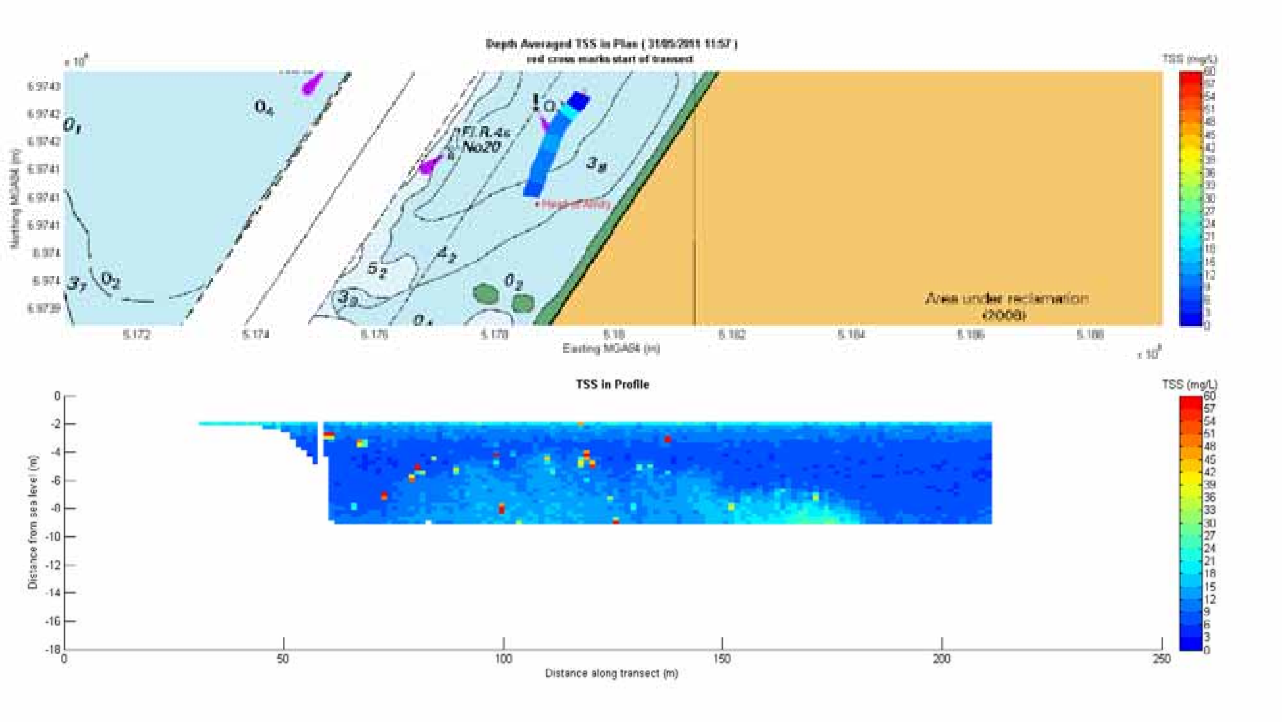

Figure G- 17 *Amity* at Fishermans Island, transect 17

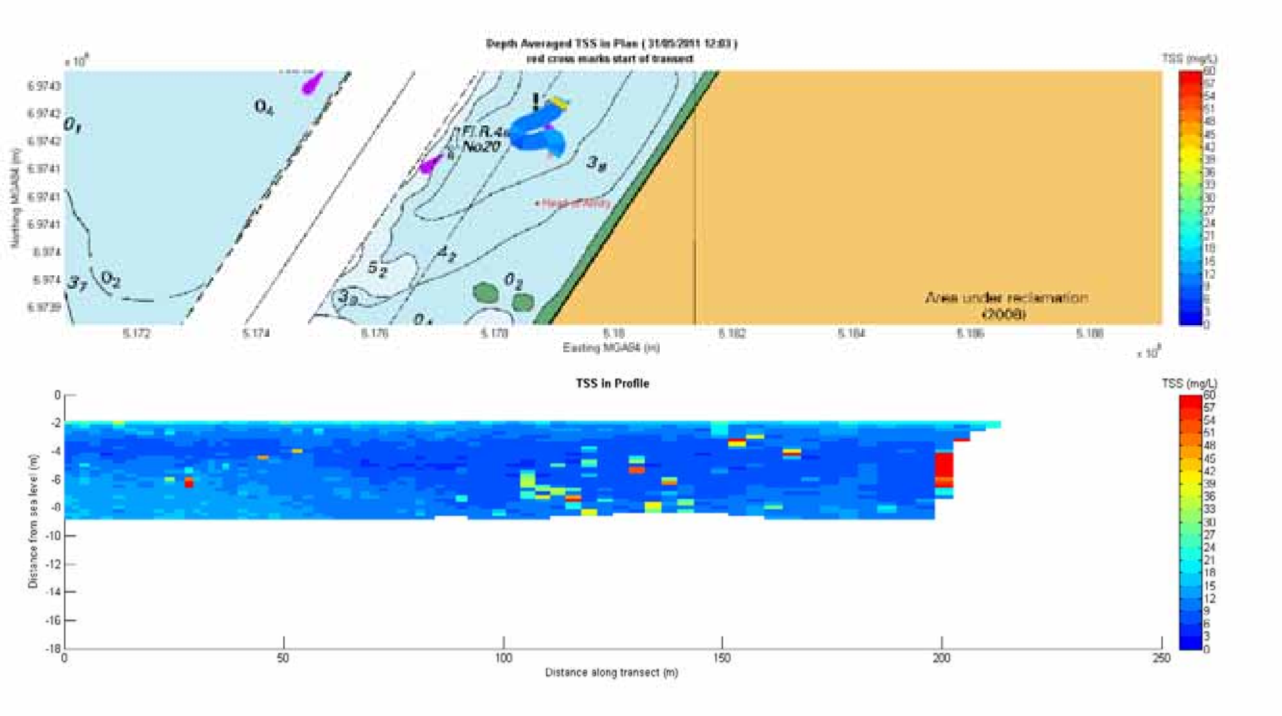

Figure G- 18 *Amity* at Fishermans Island, transect 18

APPENDIX H: DREDGER ‘KEN HARVEY’

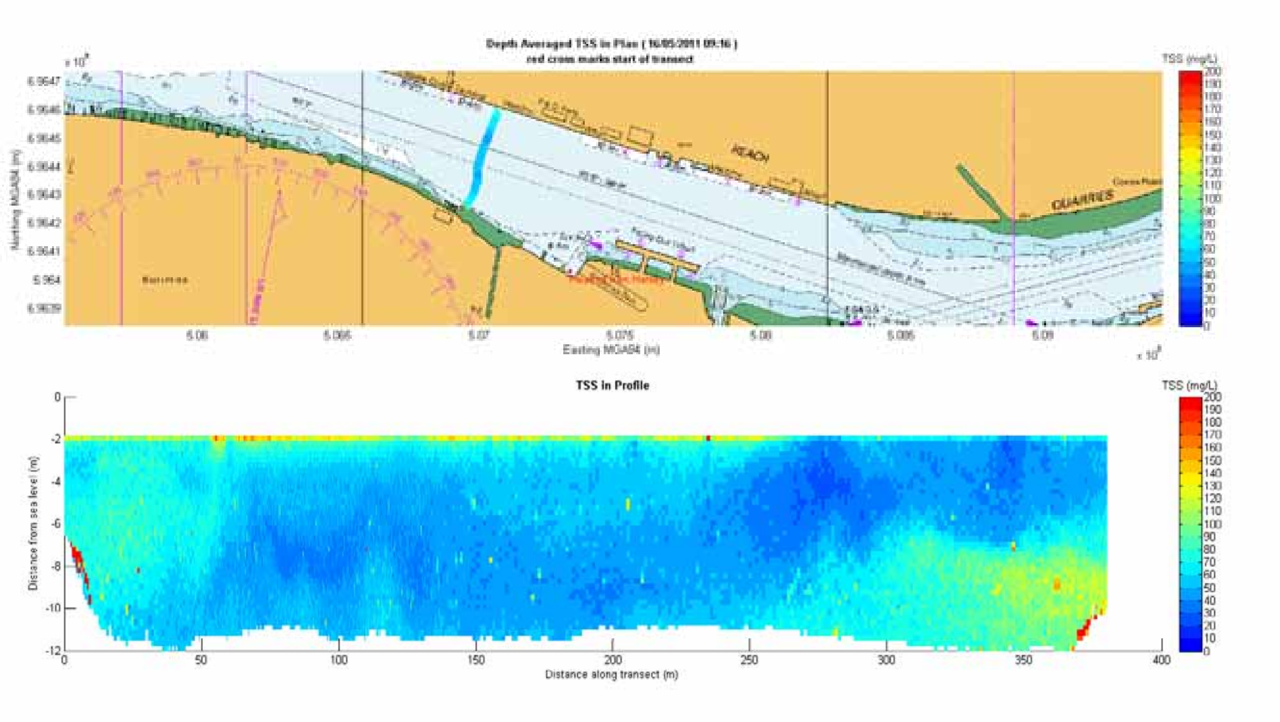

Figure H- 1 *Ken Harvey* at Forgacs, transect 1

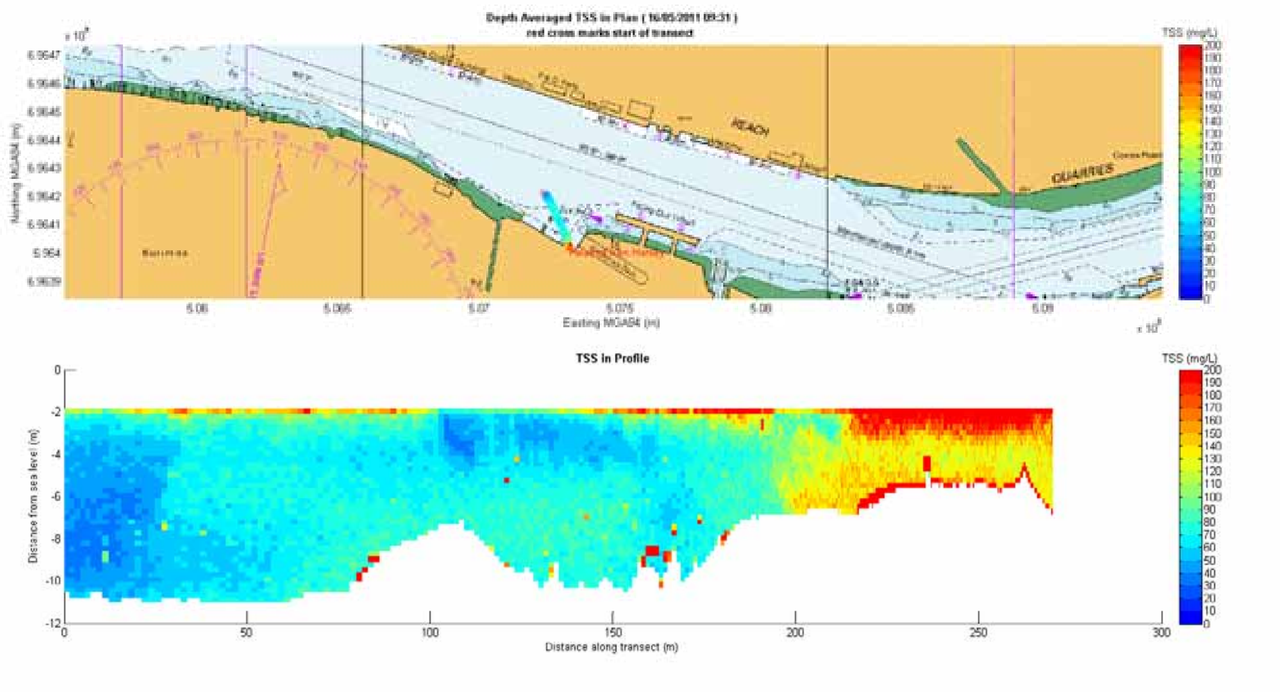

Figure H- 2 *Ken Harvey* at Forgacs, transect 2

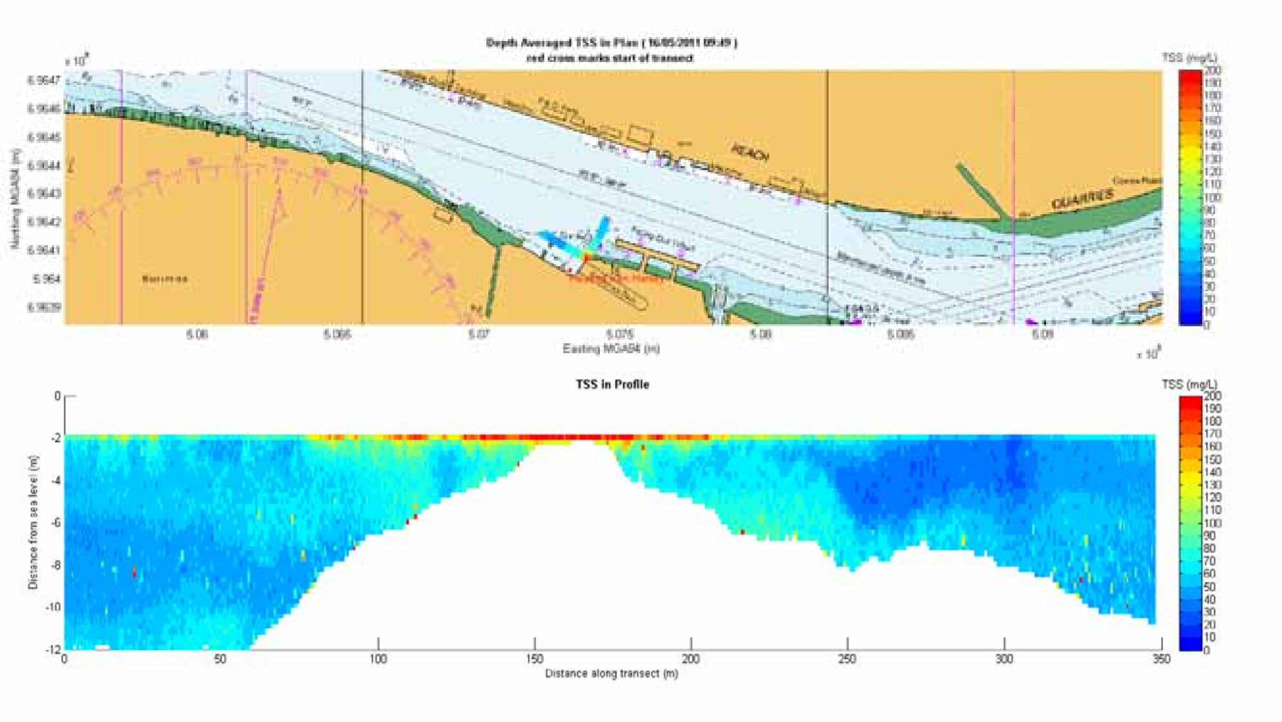

Figure H- 3 *Ken Harvey* at Forgacs, transect 3

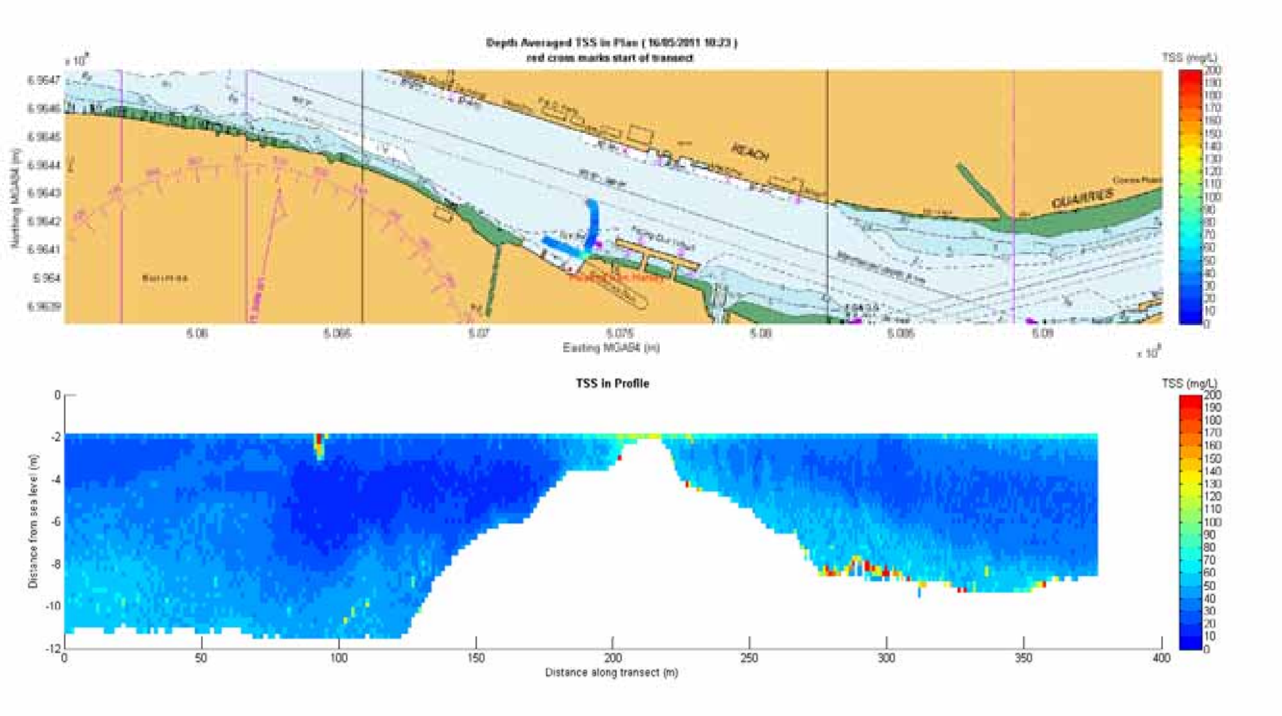

Figure H- 4 *Ken Harvey* at Forgacs, transect 4

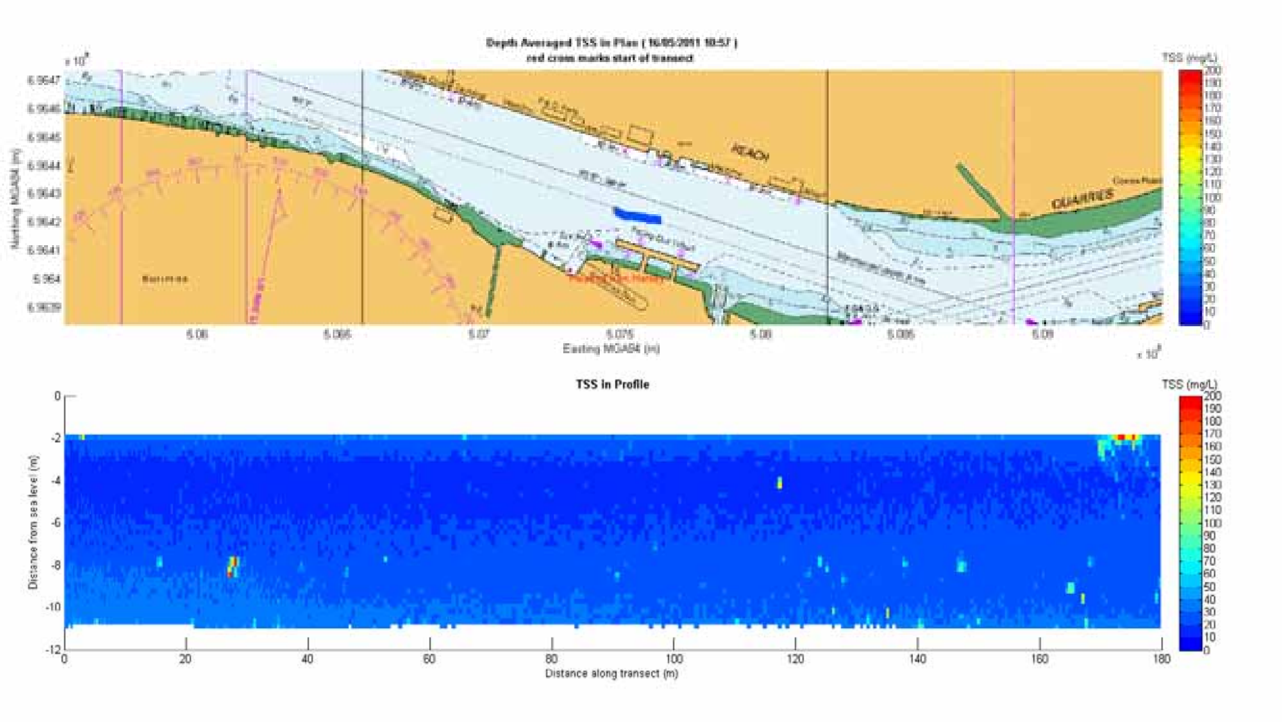

Figure H- 5 *Ken Harvey* at Forgacs, transect 5

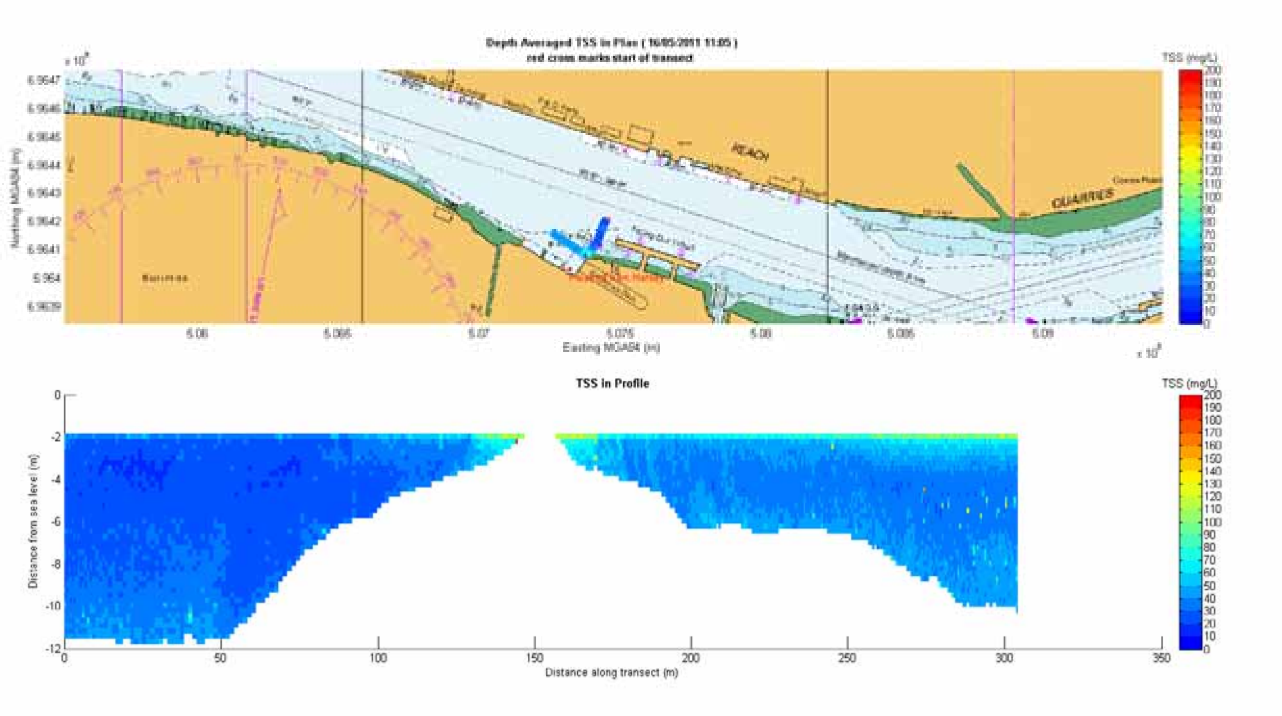

Figure H- 6 *Ken Harvey* at Forgacs, transect 6

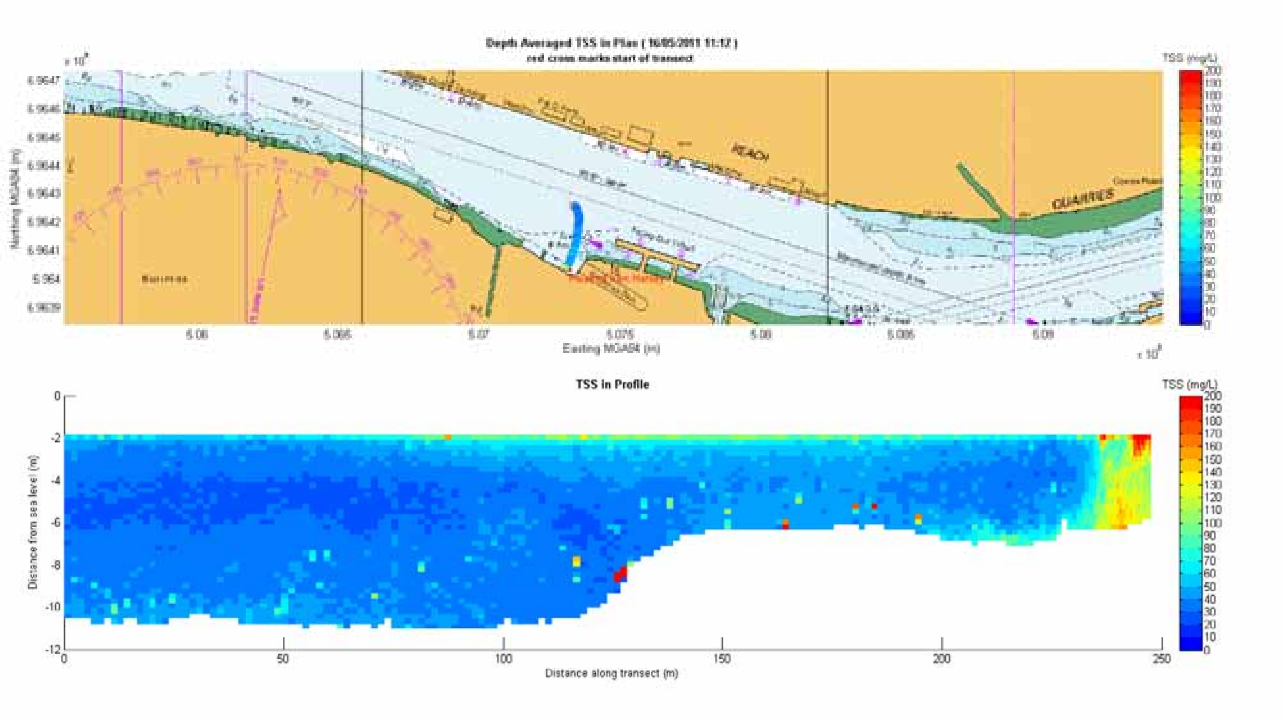

Figure H- 7 ***Ken Harvey*** **at Forgacs, transect 7**

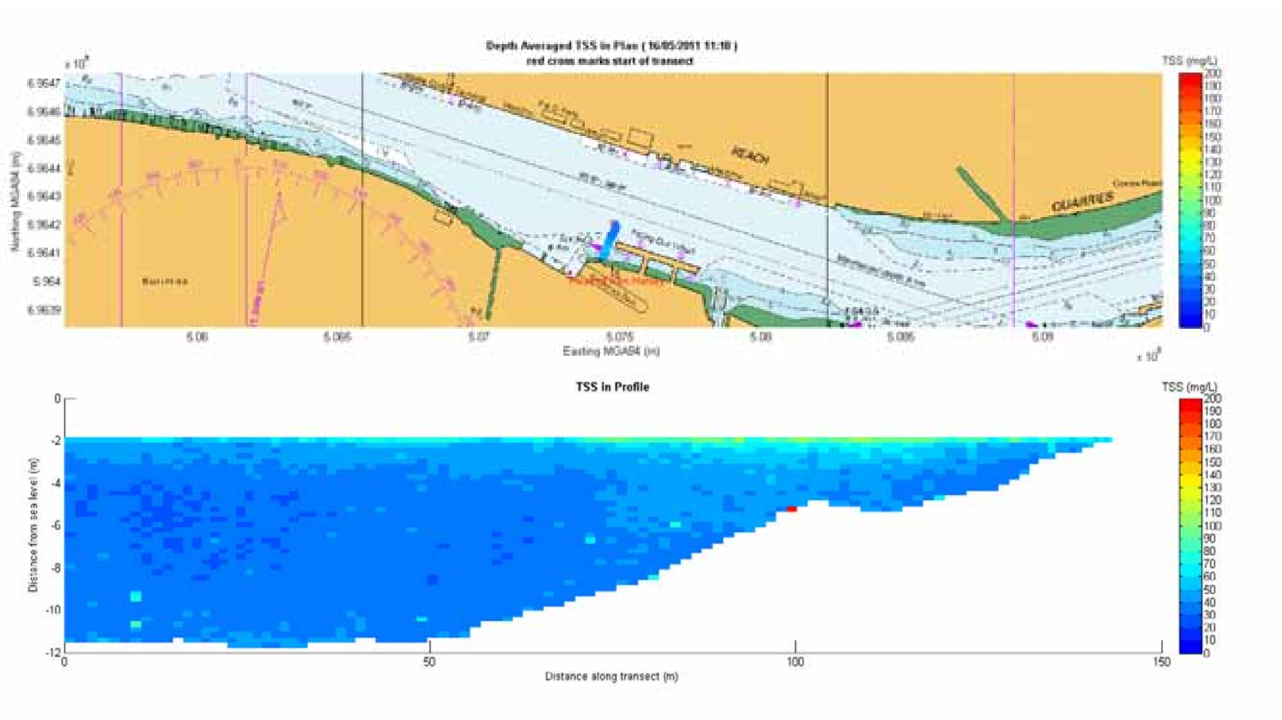

Figure H- 8 ***Ken Harvey*** **at Forgacs, transect 8**

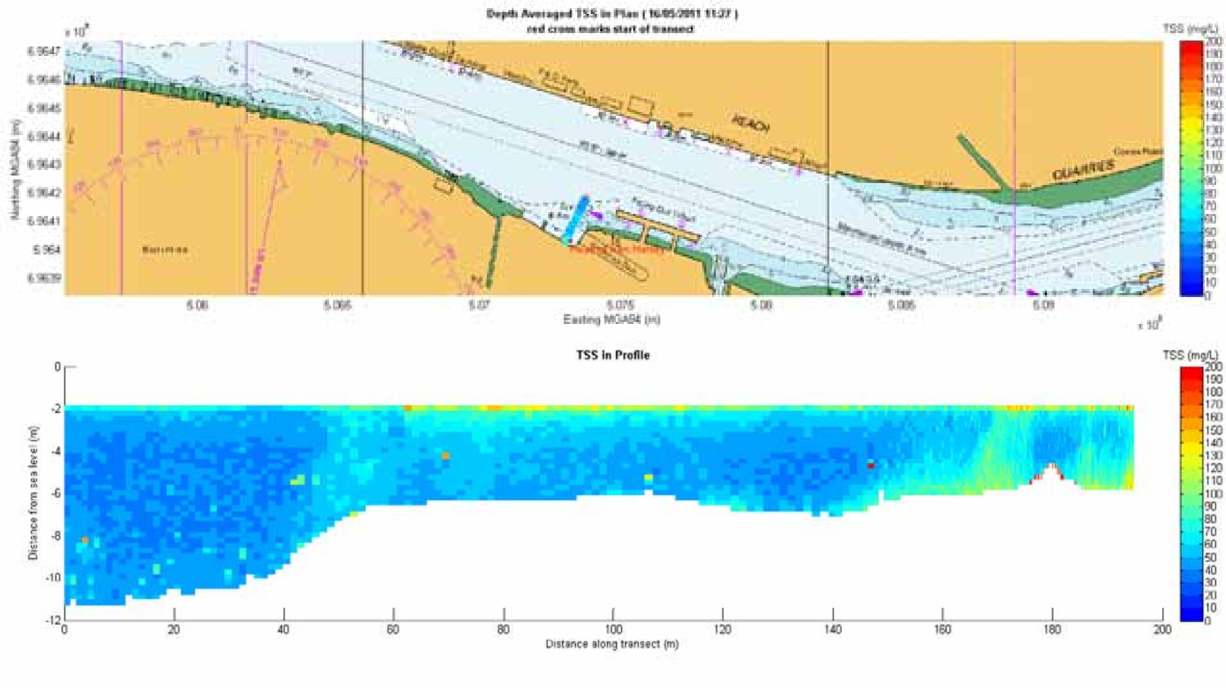

Figure H- 9 ***Ken Harvey* at Forgacs, transect 9**

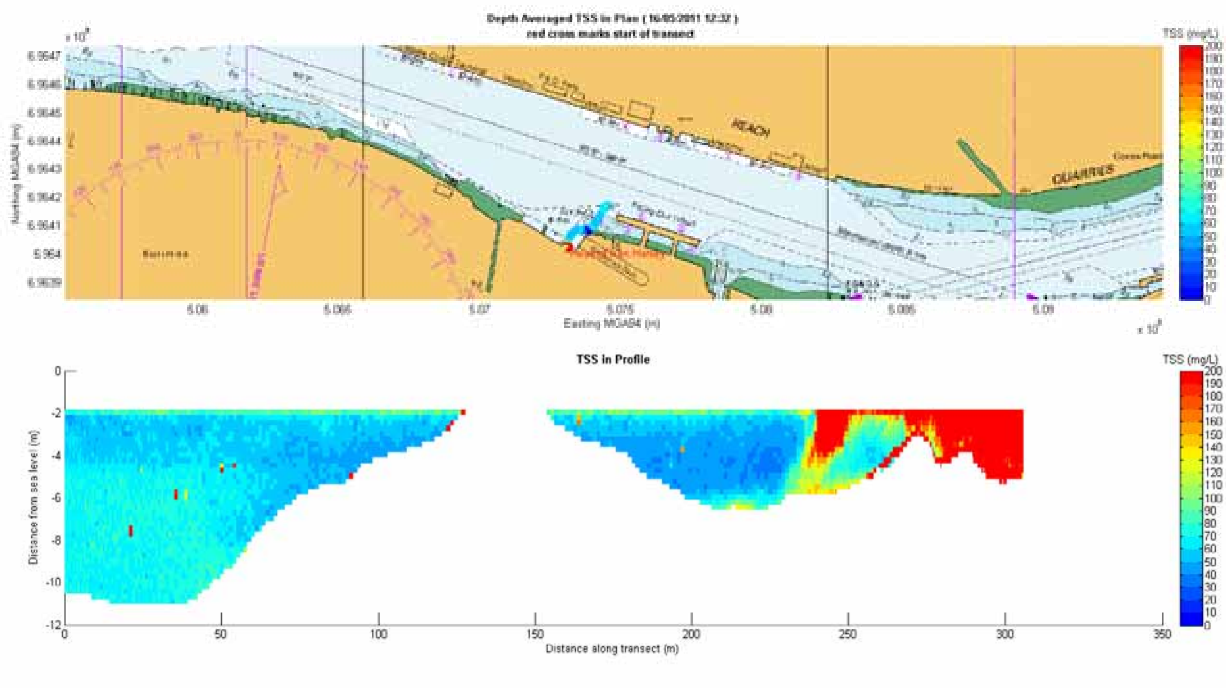

Figure H- 10 ***Ken Harvey* at Forgacs, transect 10**

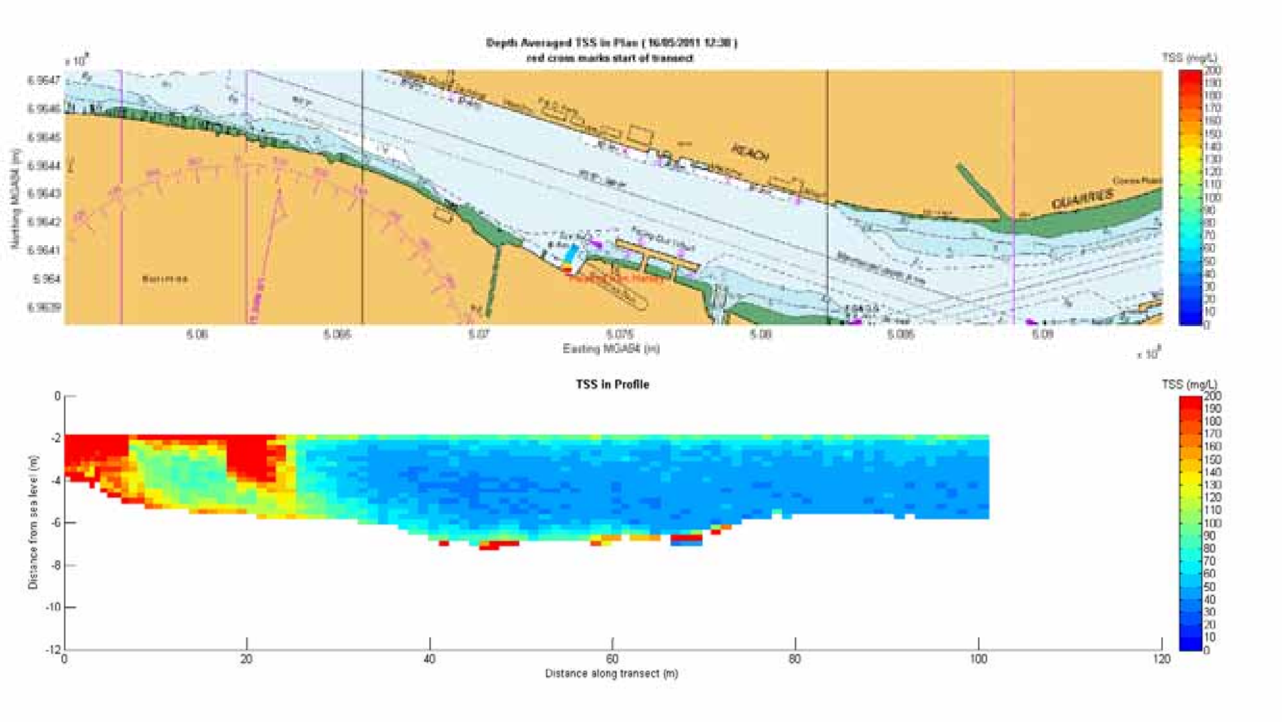

Figure H- 11 *Ken Harvey* at Forgacs, transect 11

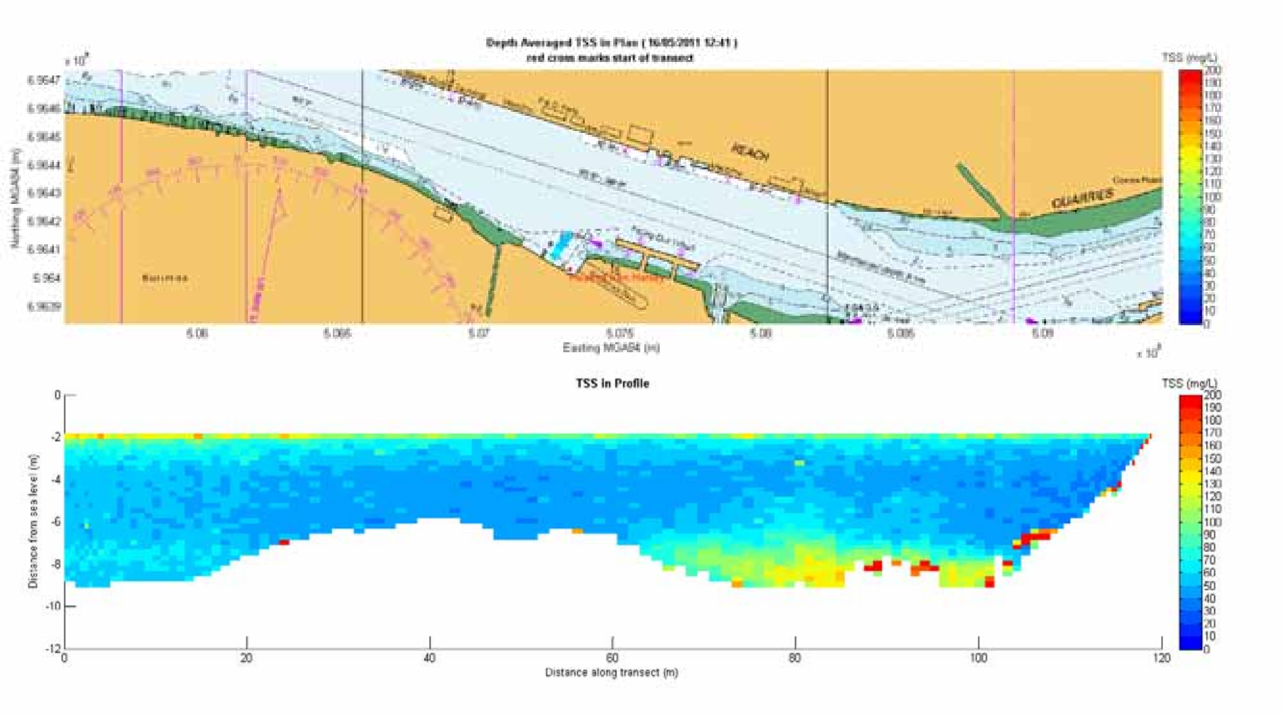

Figure H- 12 *Ken Harvey* at Forgacs, transect 12

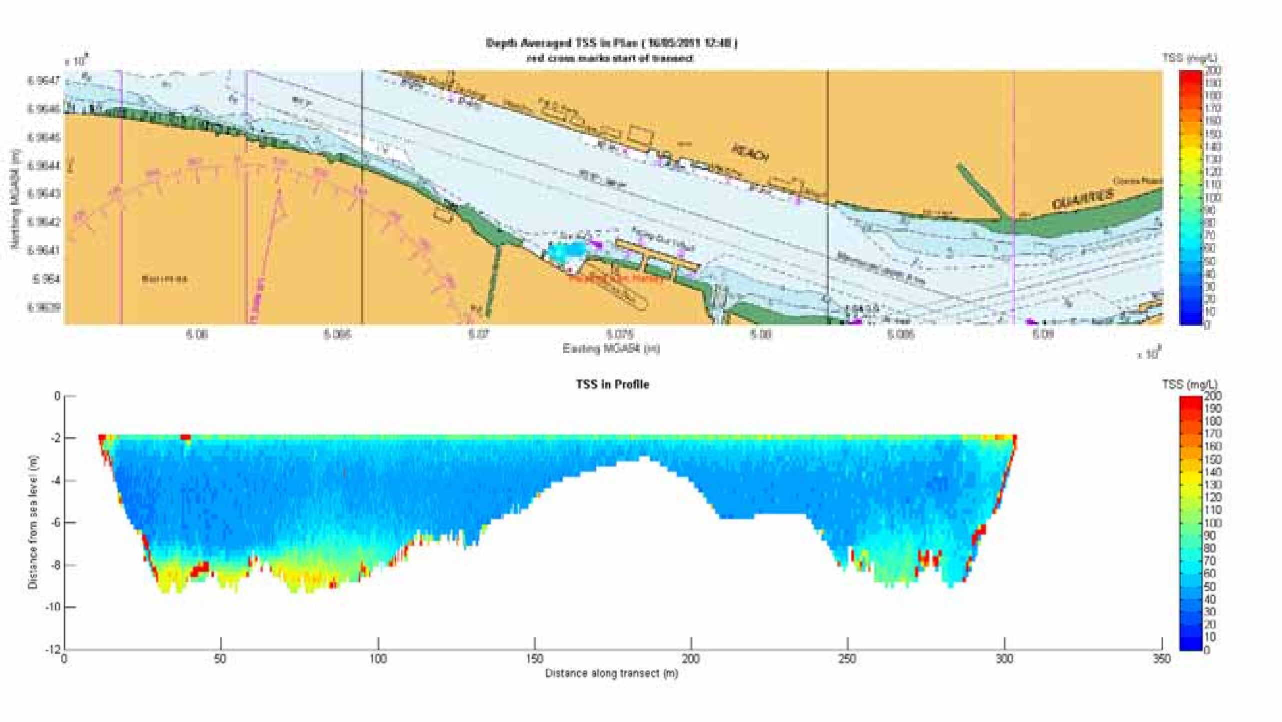

Figure H- 13 *Ken Harvey* at Forgacs, transect 13

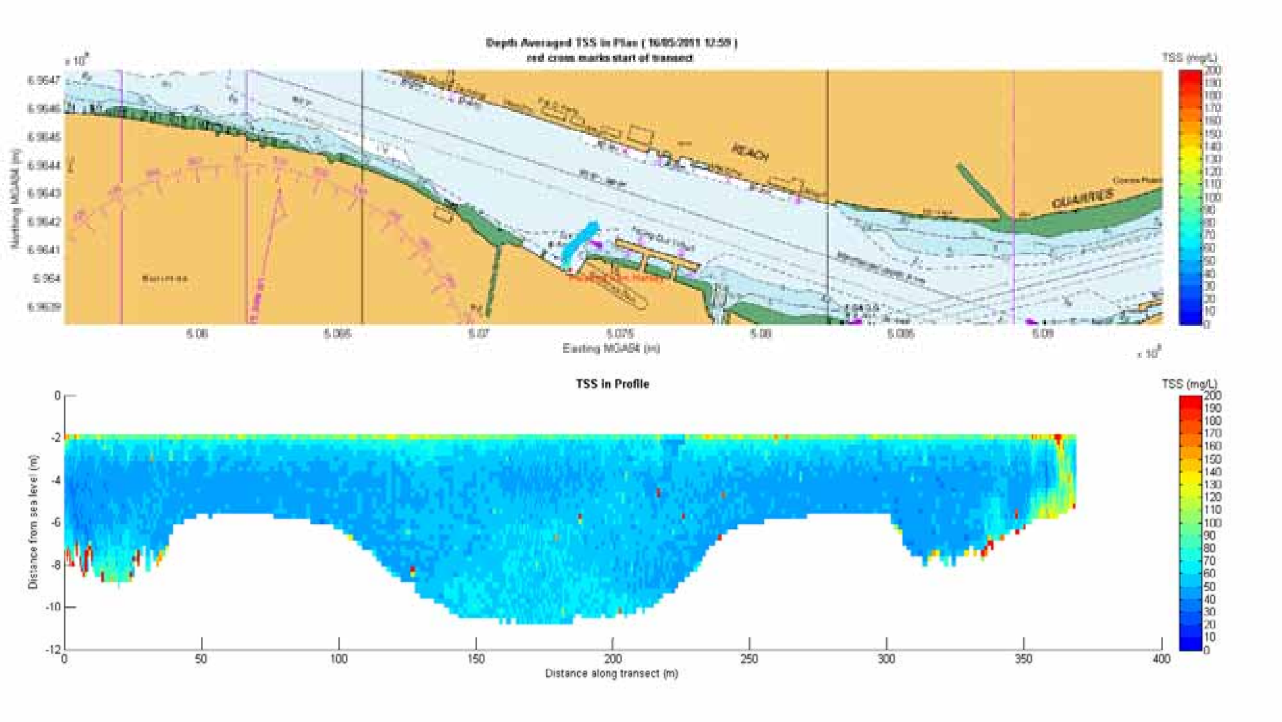

Figure H- 14 *Ken Harvey* at Forgacs, transect 14

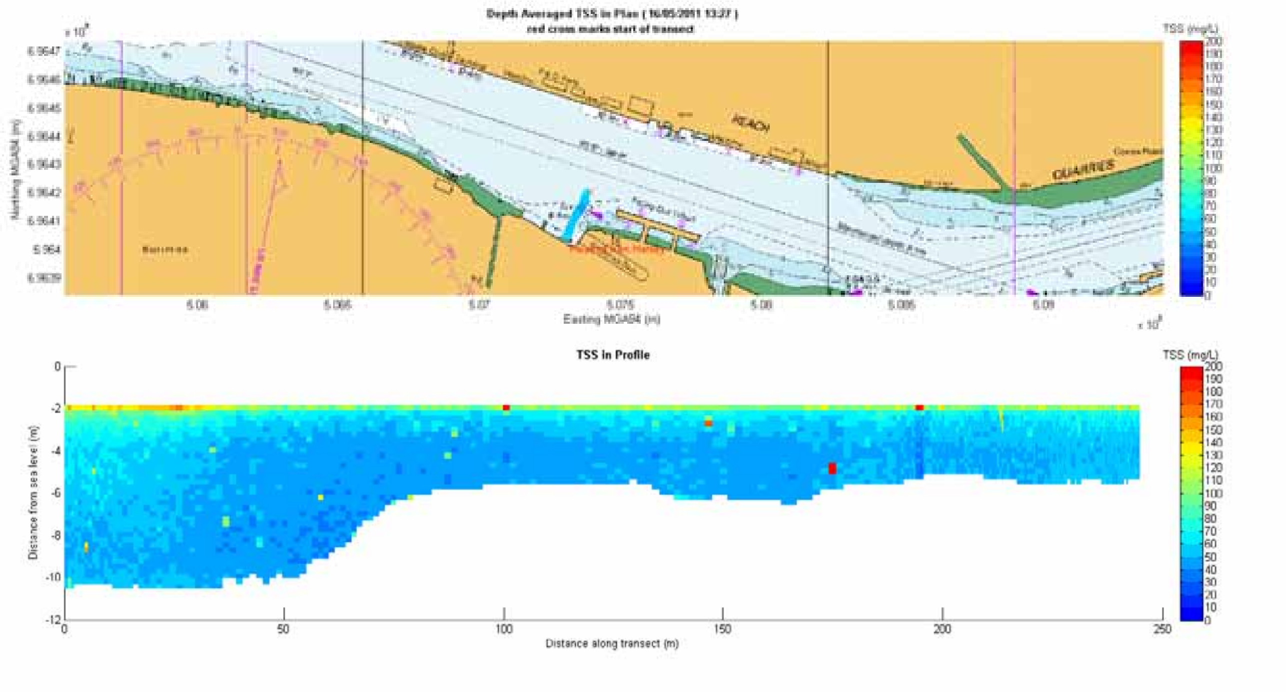

Figure H- 15 *Ken Harvey* at Forgacs, transect 15

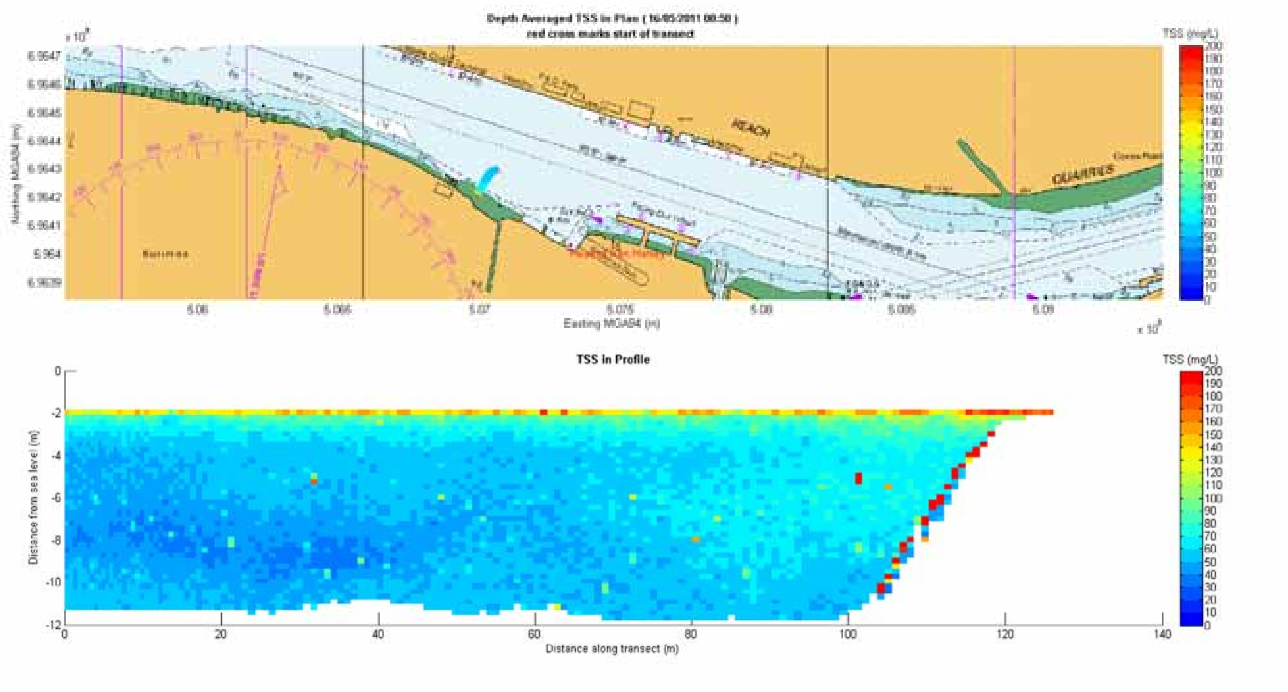

Figure H- 16 *Ken Harvey* at Forgacs, transect 16

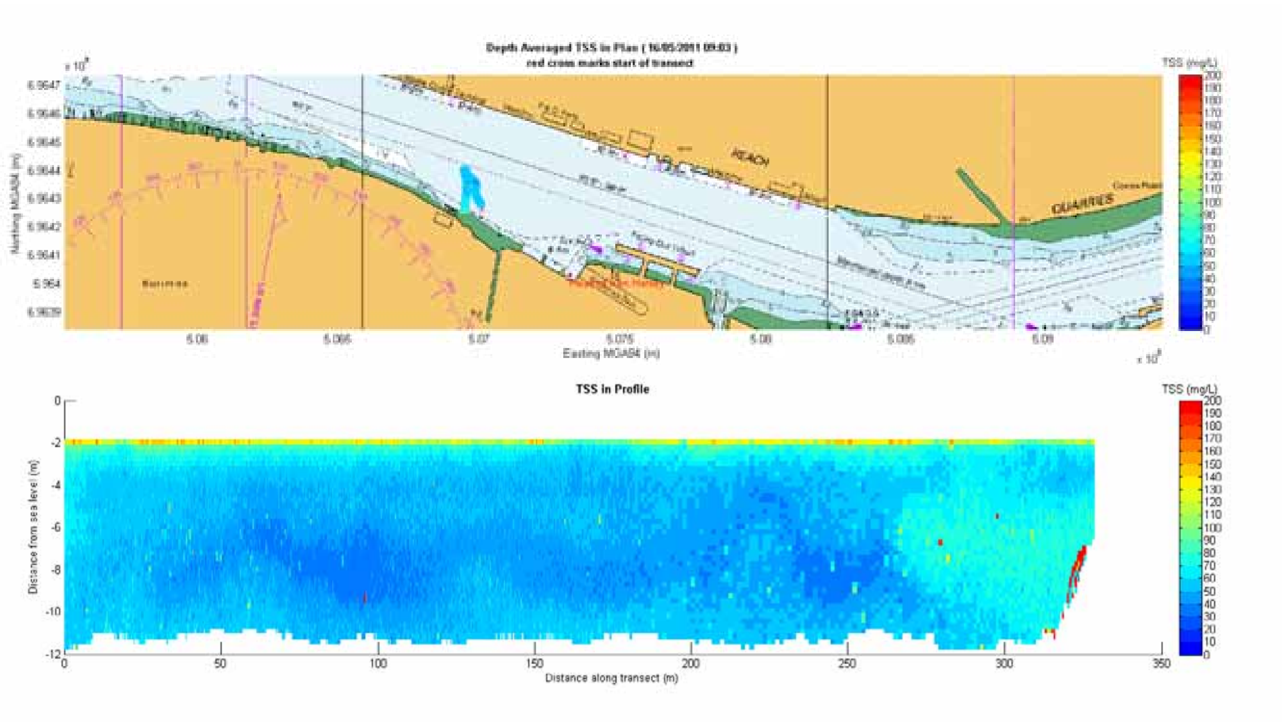

Figure H- 17 *Ken Harvey* at Forgacs, transect 17

APPENDIX I: BED LEVELLER 'ALAN M'

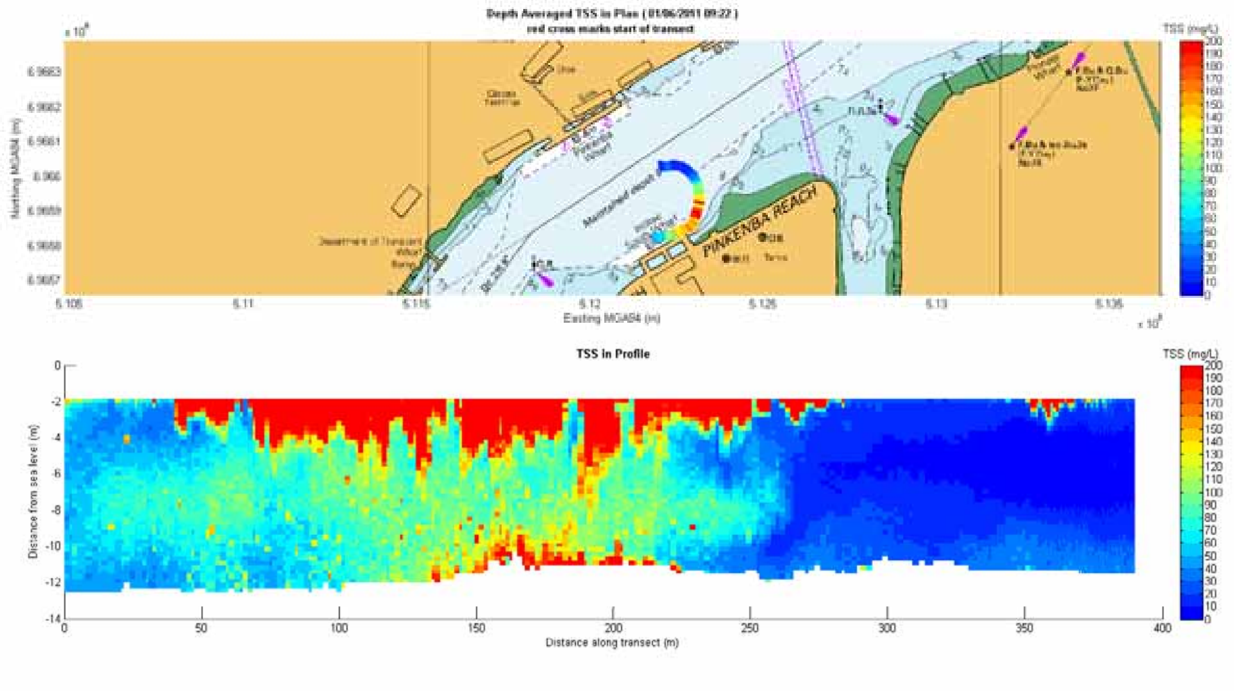

Figure I- 1 ***Alan M*** **at Incitec Wharf, transect 1**

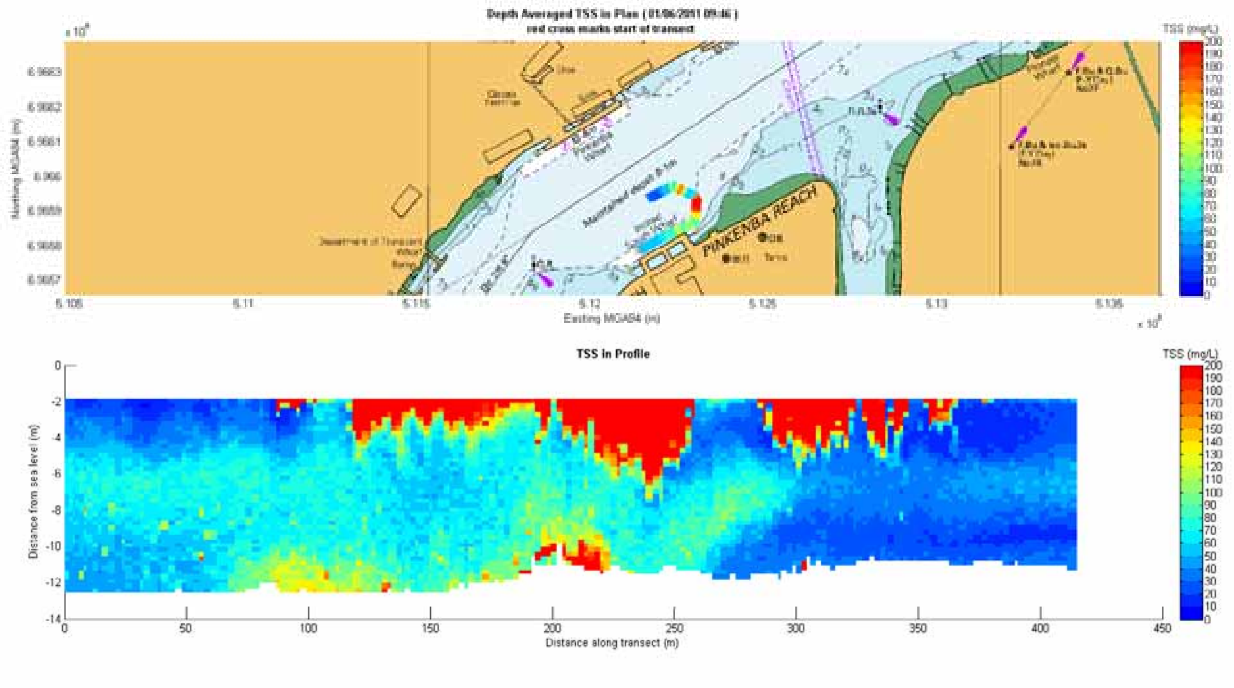

Figure I- 2 ***Alan M*** **at Incitec Wharf, transect 2**

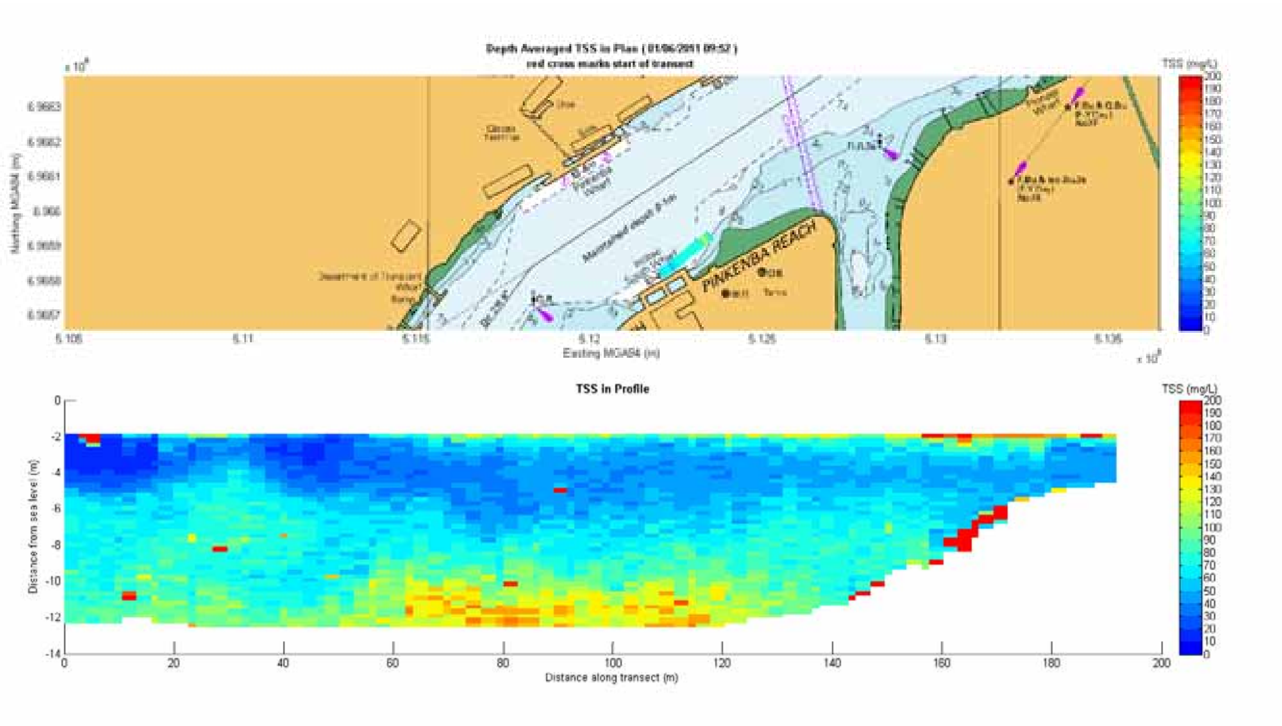

Figure I- 3 ***Alan M*** **at Incitec Wharf, transect 3**

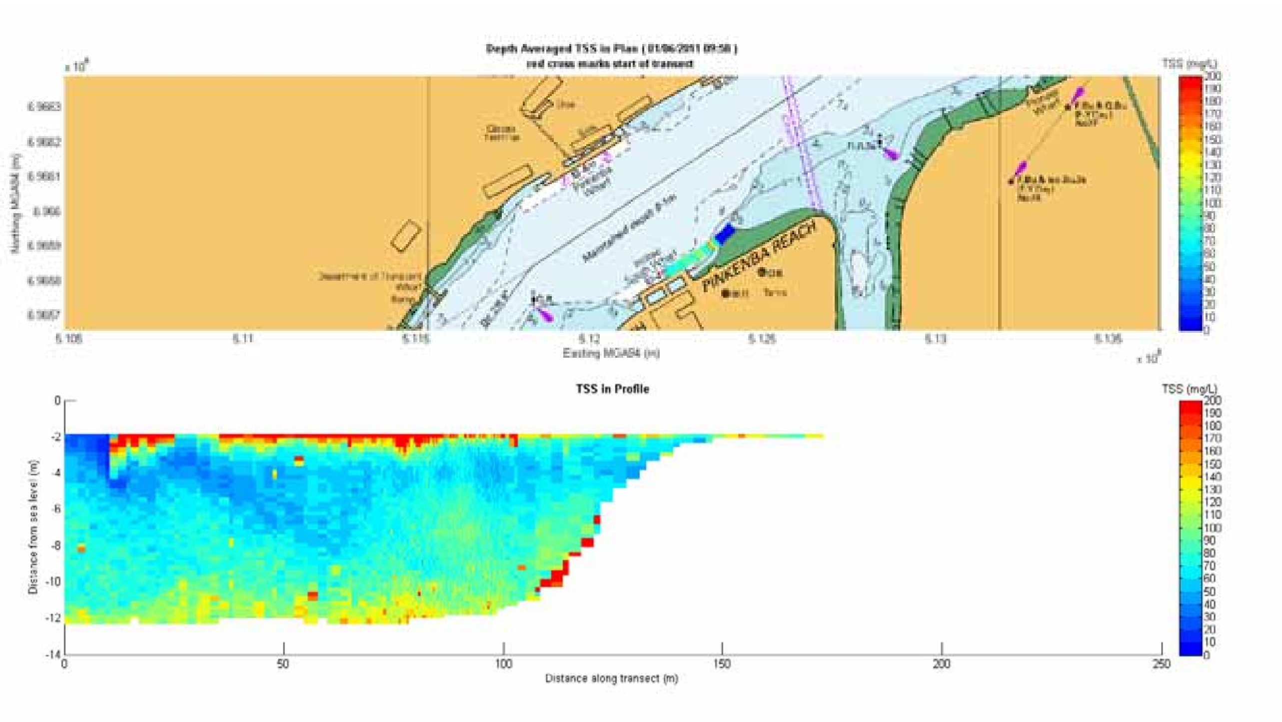

Figure I- 4 ***Alan M*** **at Incitec Wharf, transect 4**

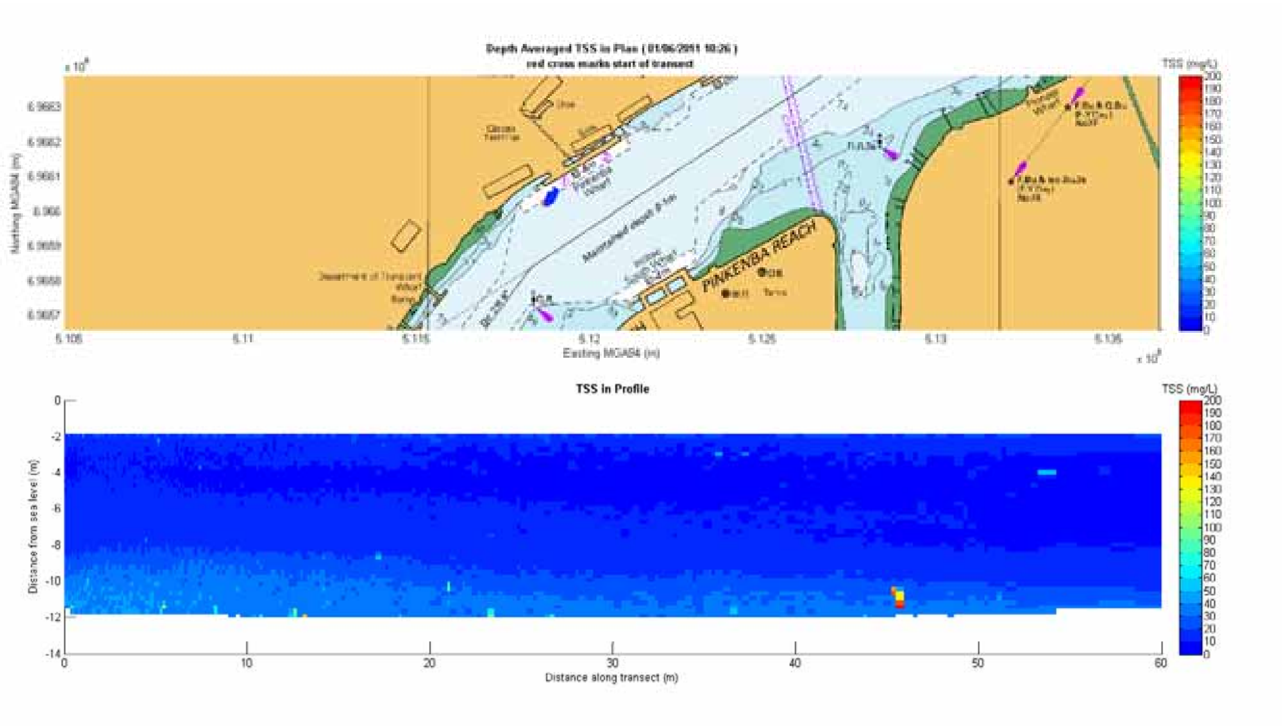

Figure I- 5 *Alan M* **at Pinkenba Wharf, transect 1**

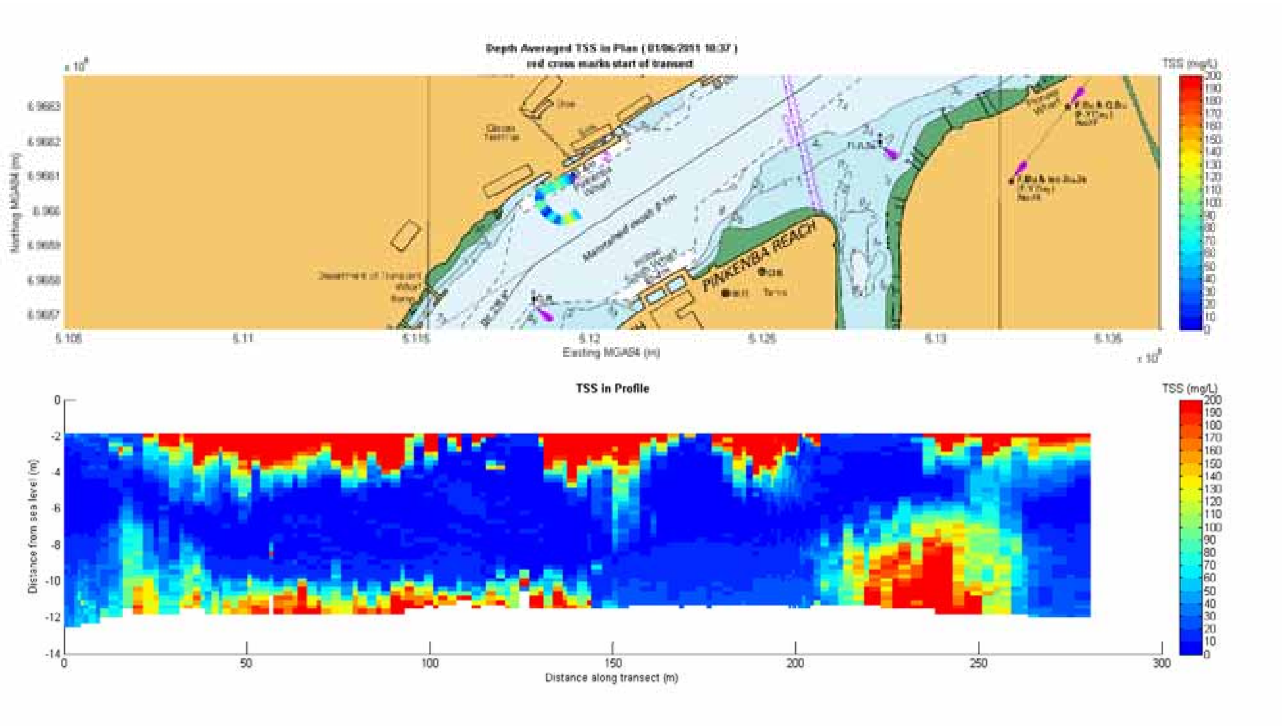

Figure I- 6 *Alan M* **at Pinkenba Wharf, transect 2**

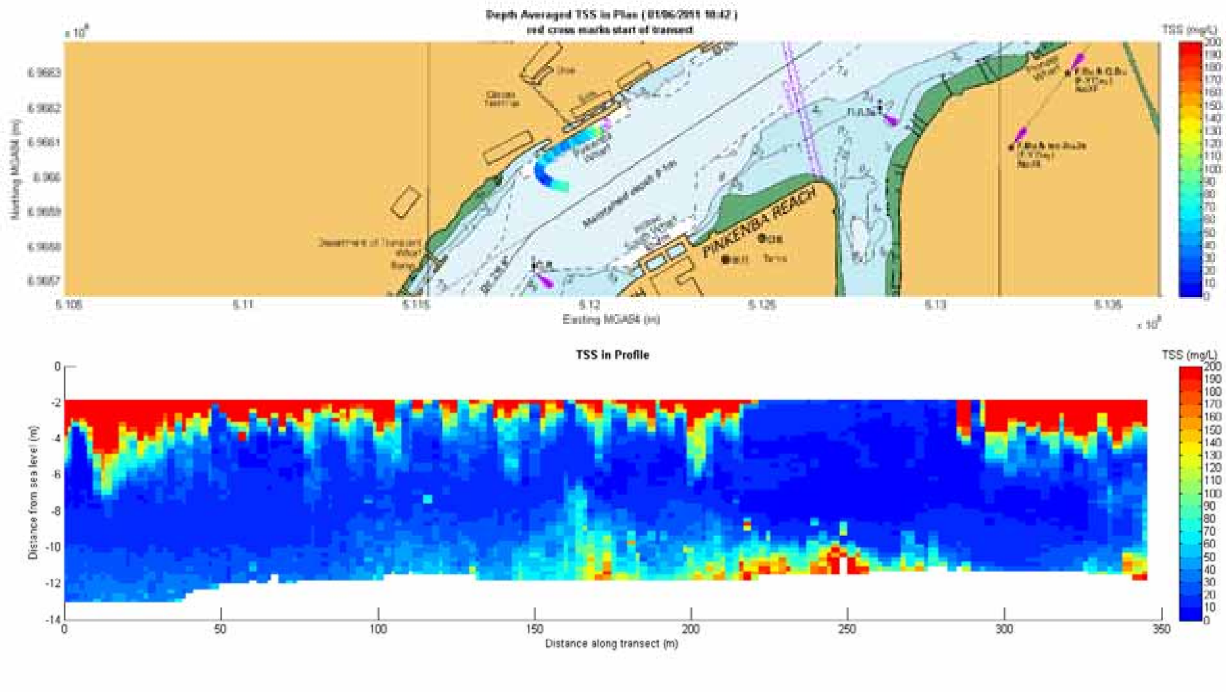

Figure I- 7 *Alan M* at Pinkenba Wharf, transect 3

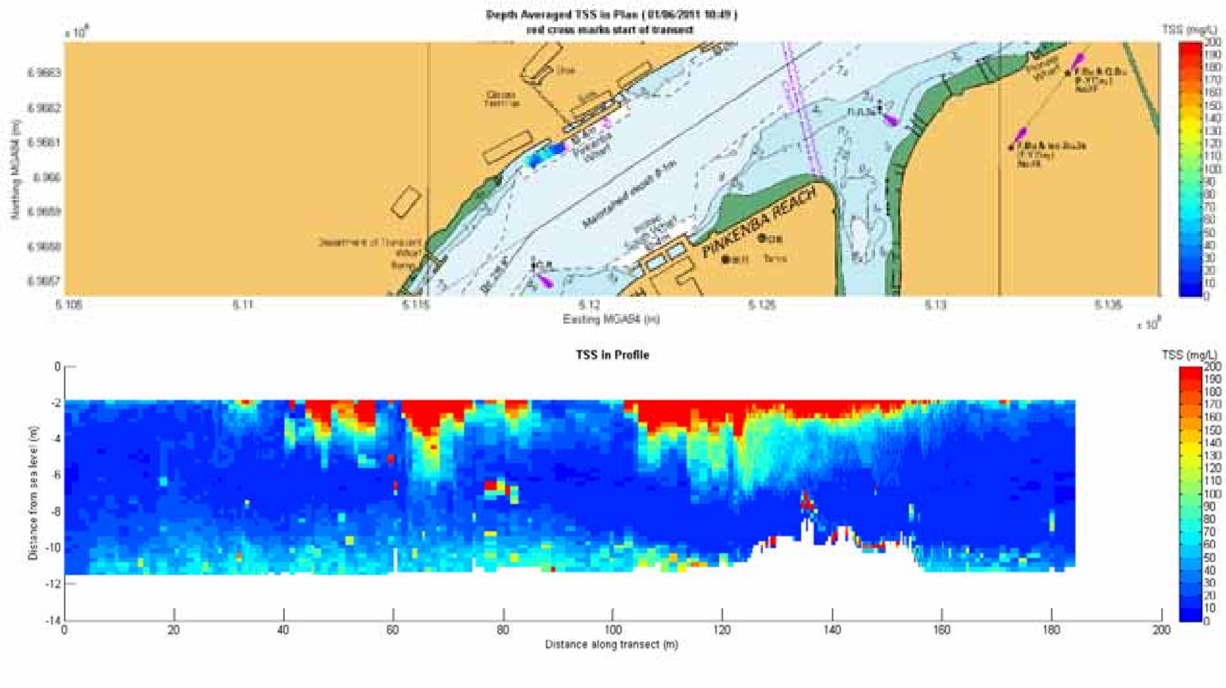

Figure I- 8 *Alan M* at Pinkenba Wharf, transect 4

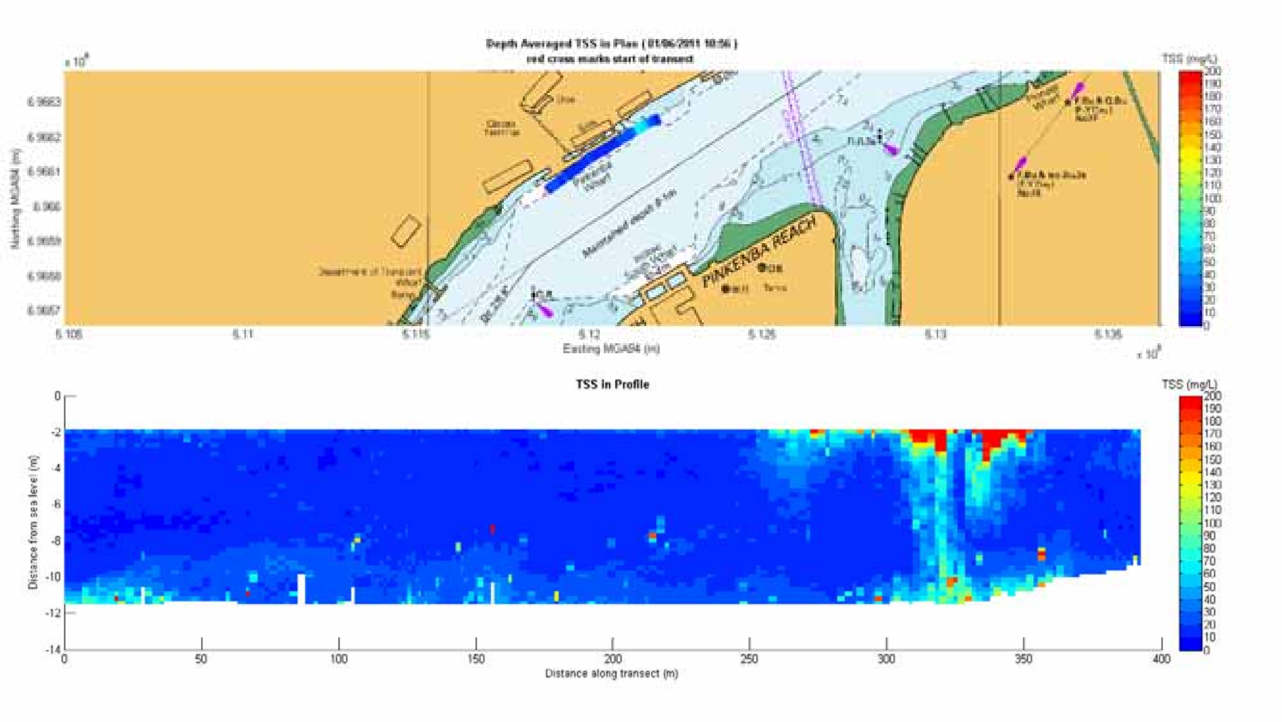

Figure I- 9 ***Alan M*** **at Pinkenba Wharf, transect 5**

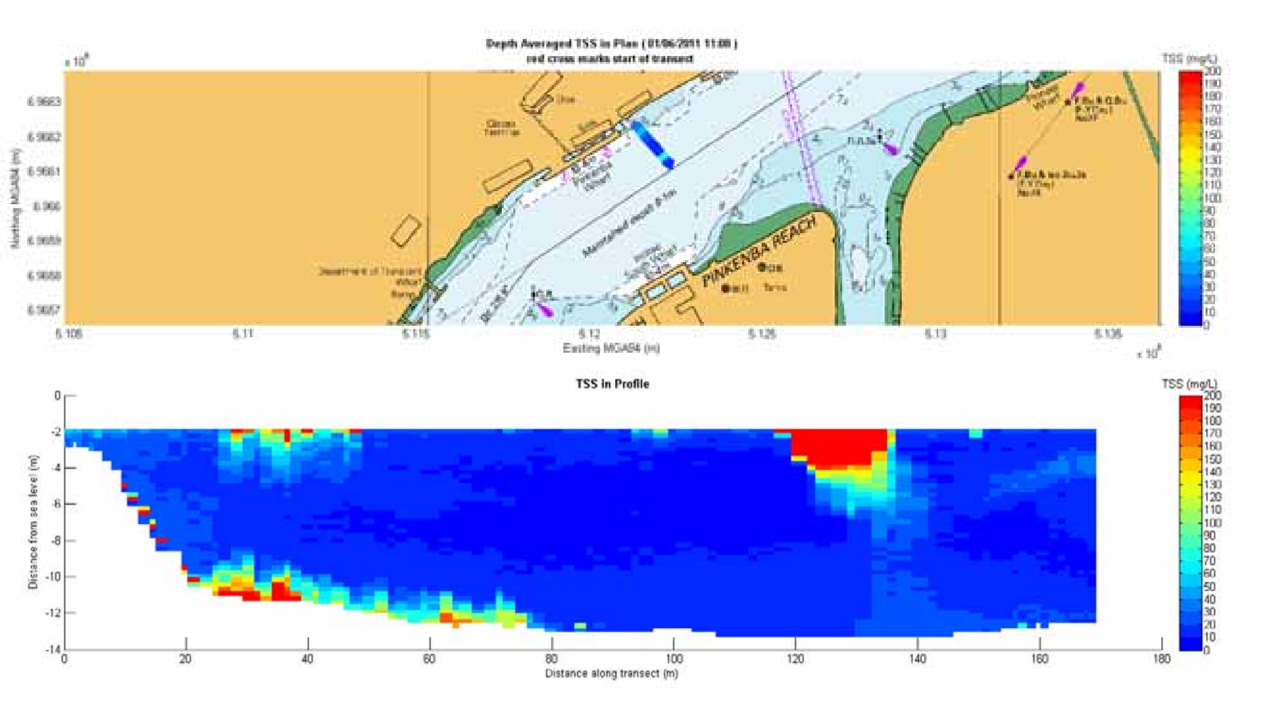

Figure I- 10 ***Alan M*** **at Pinkenba Wharf, transect 6**

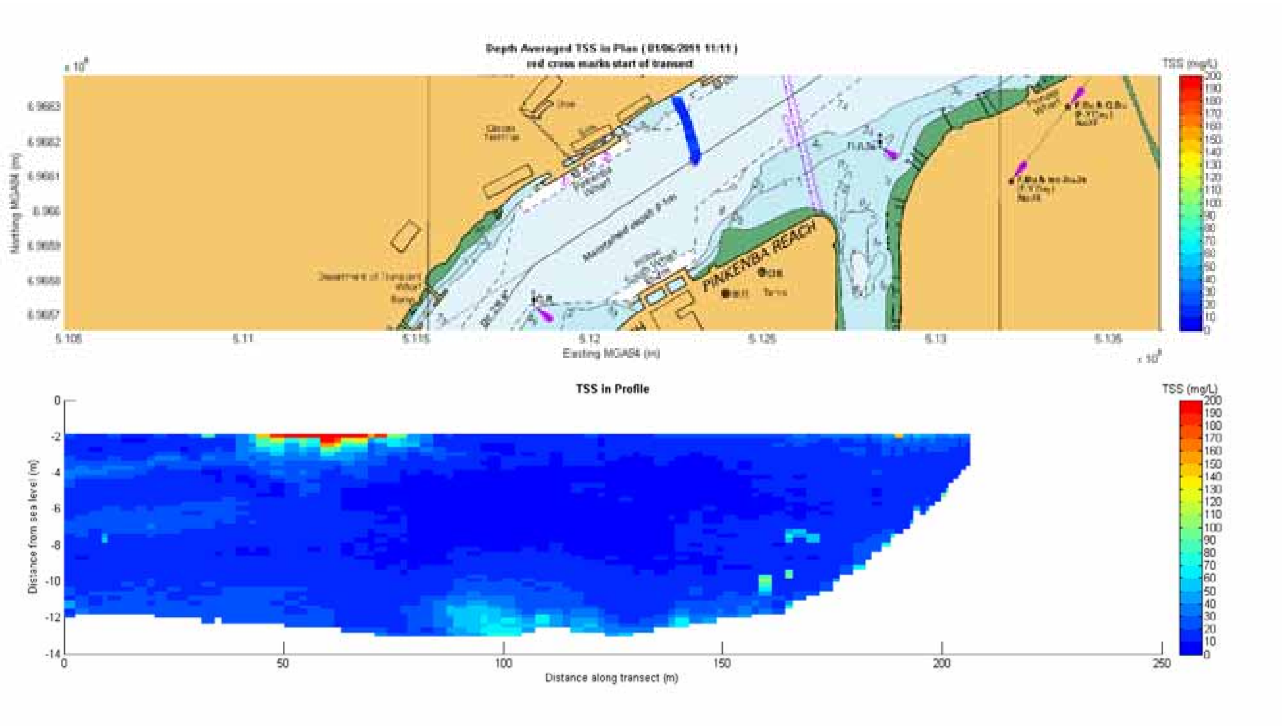

Figure I- 11 *Alan M* at Pinkenba Wharf, transect 7

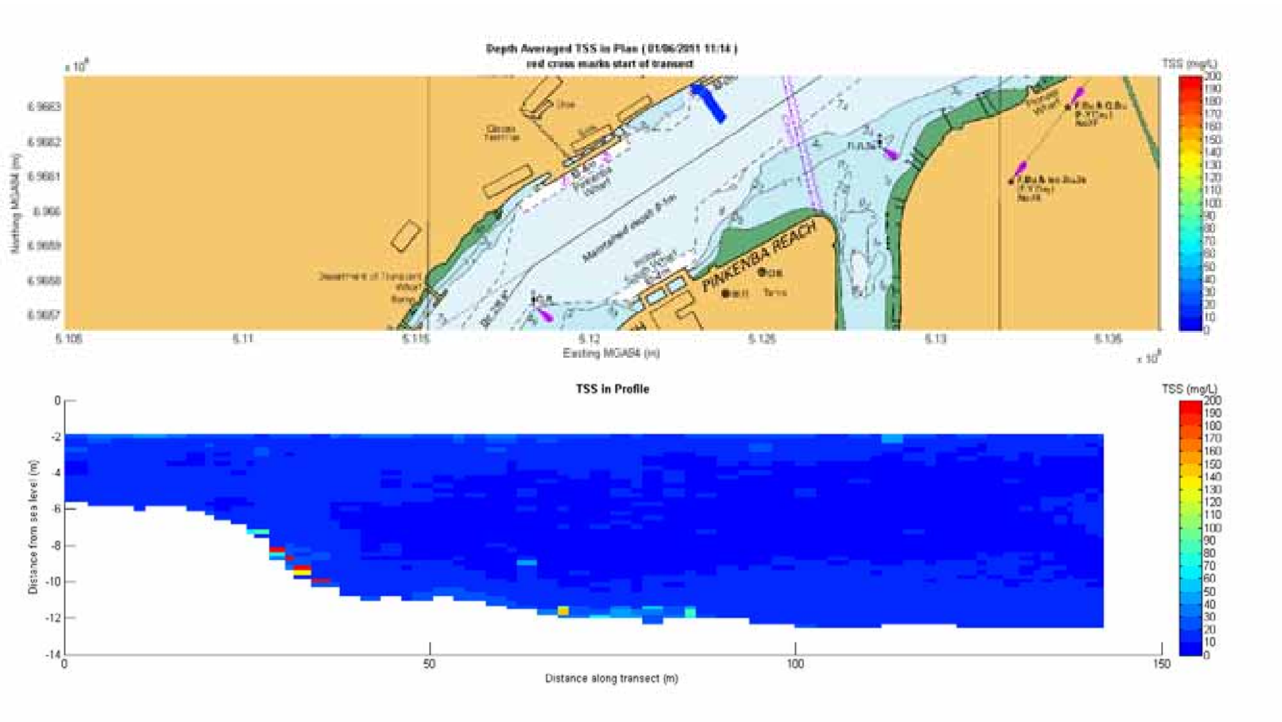

Figure I- 12 *Alan M* at Pinkenba Wharf, transect 8

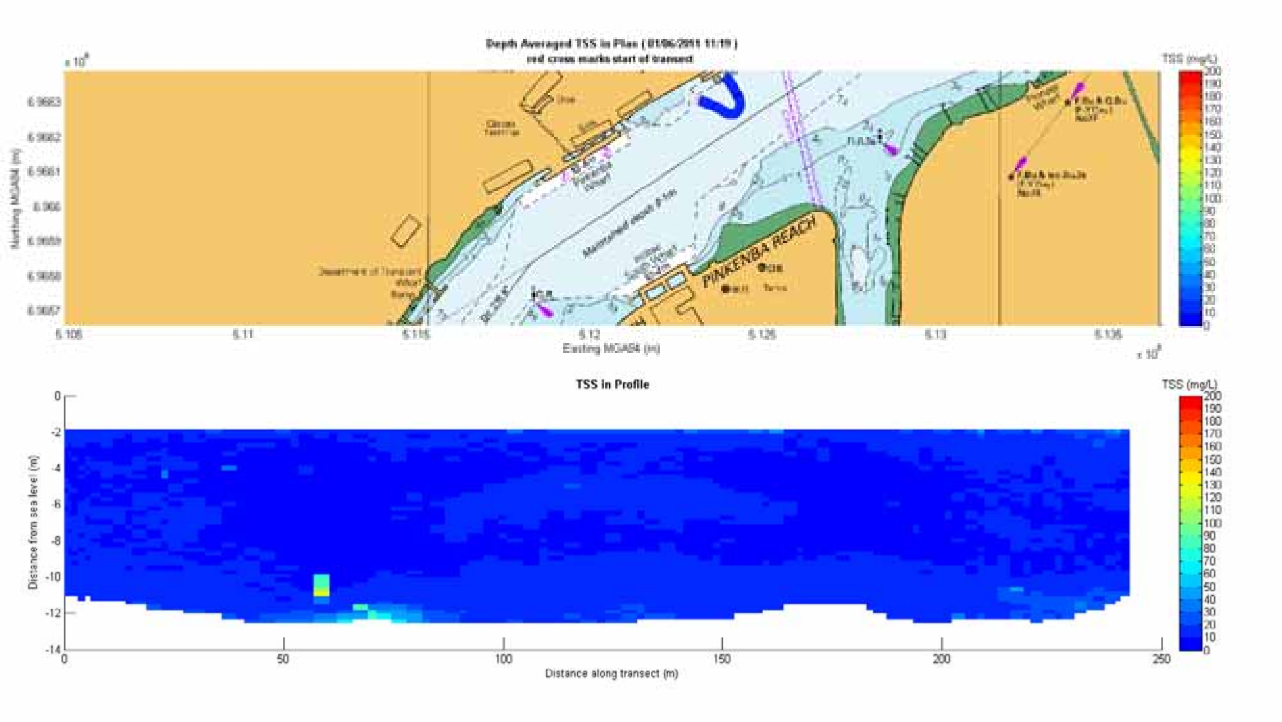

Figure I- 13 ***Alan M*** **at Pinkenba Wharf, transect 9**

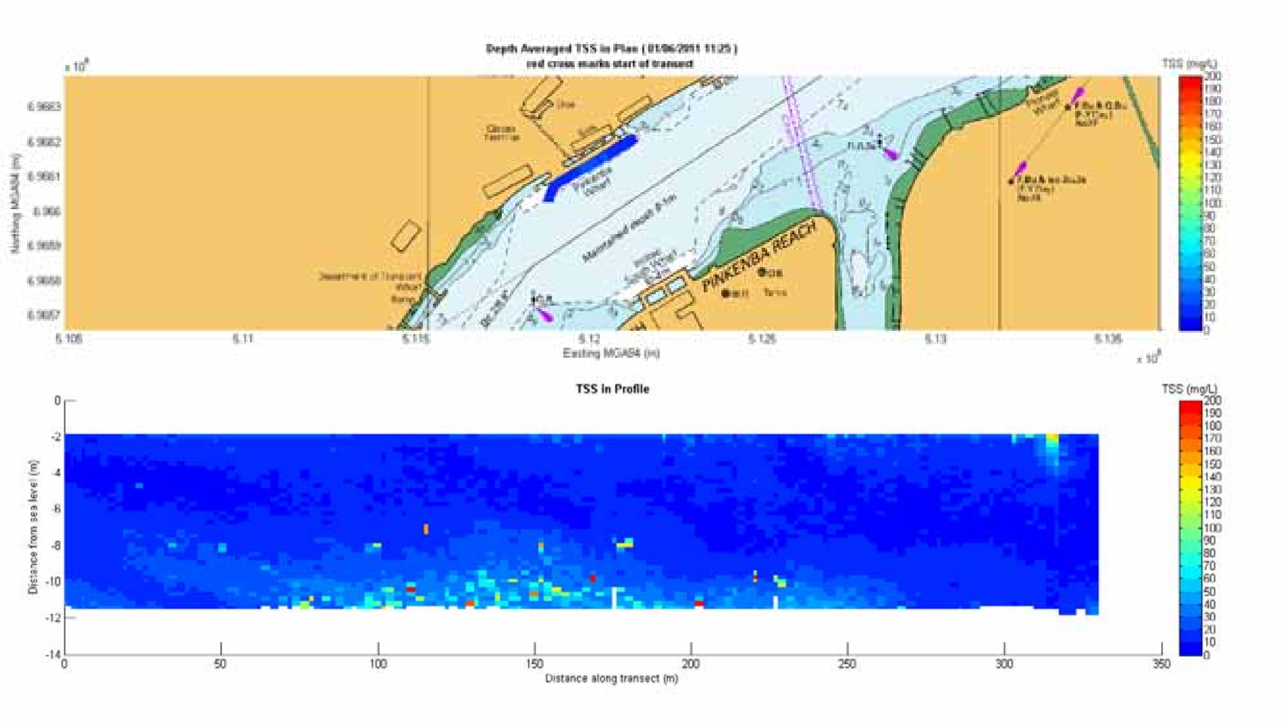

Figure I- 14 ***Alan M*** **at Pinkenba Wharf, transect 10**

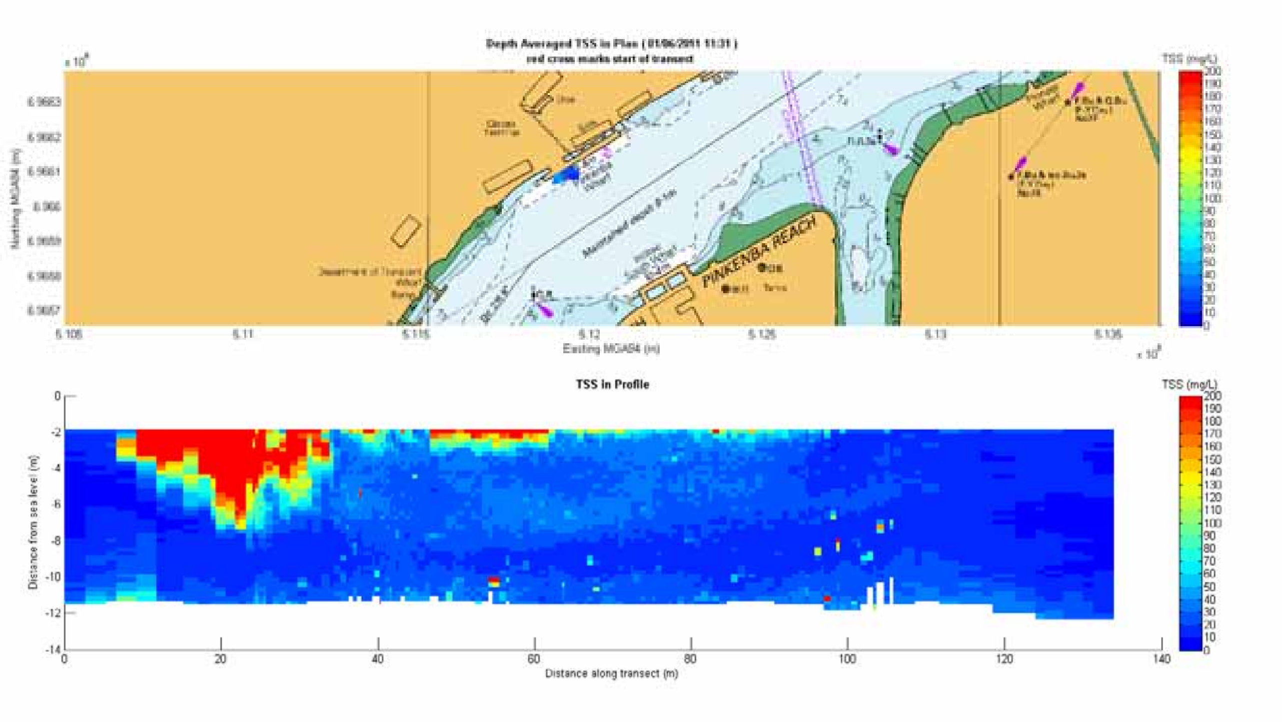

Figure I- 15 ***Alan M*** **at Pinkenba Wharf, transect 11**

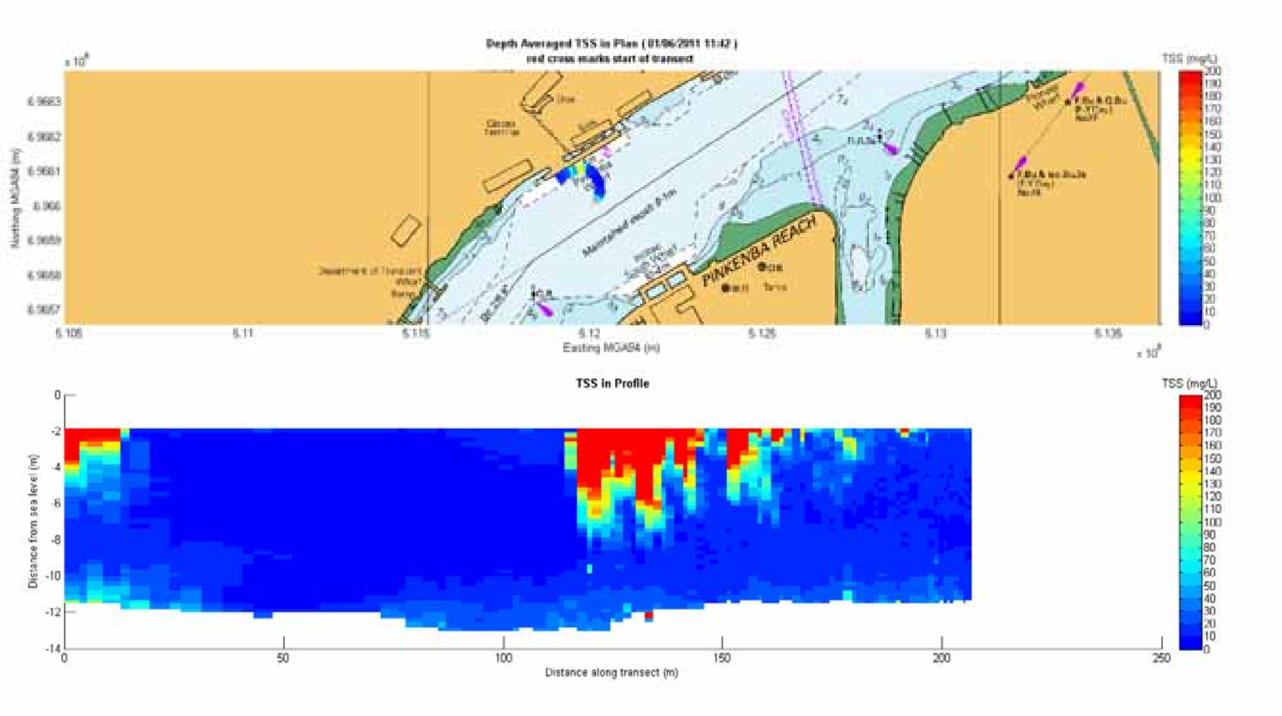

Figure I- 16 ***Alan M*** **at Pinkenba Wharf, transect 12**

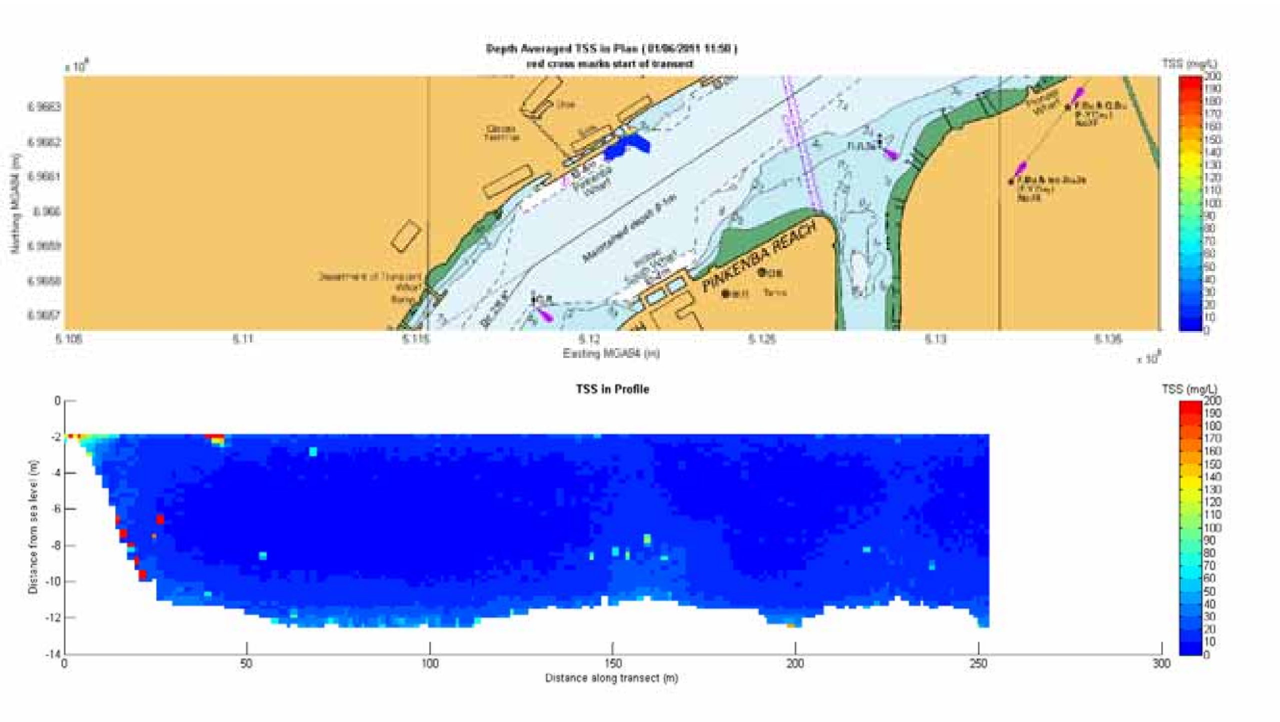

Figure I- 17 ***Alan M*** **at Pinkenba Wharf, transect 13**

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