PORT OF **WEIPA**

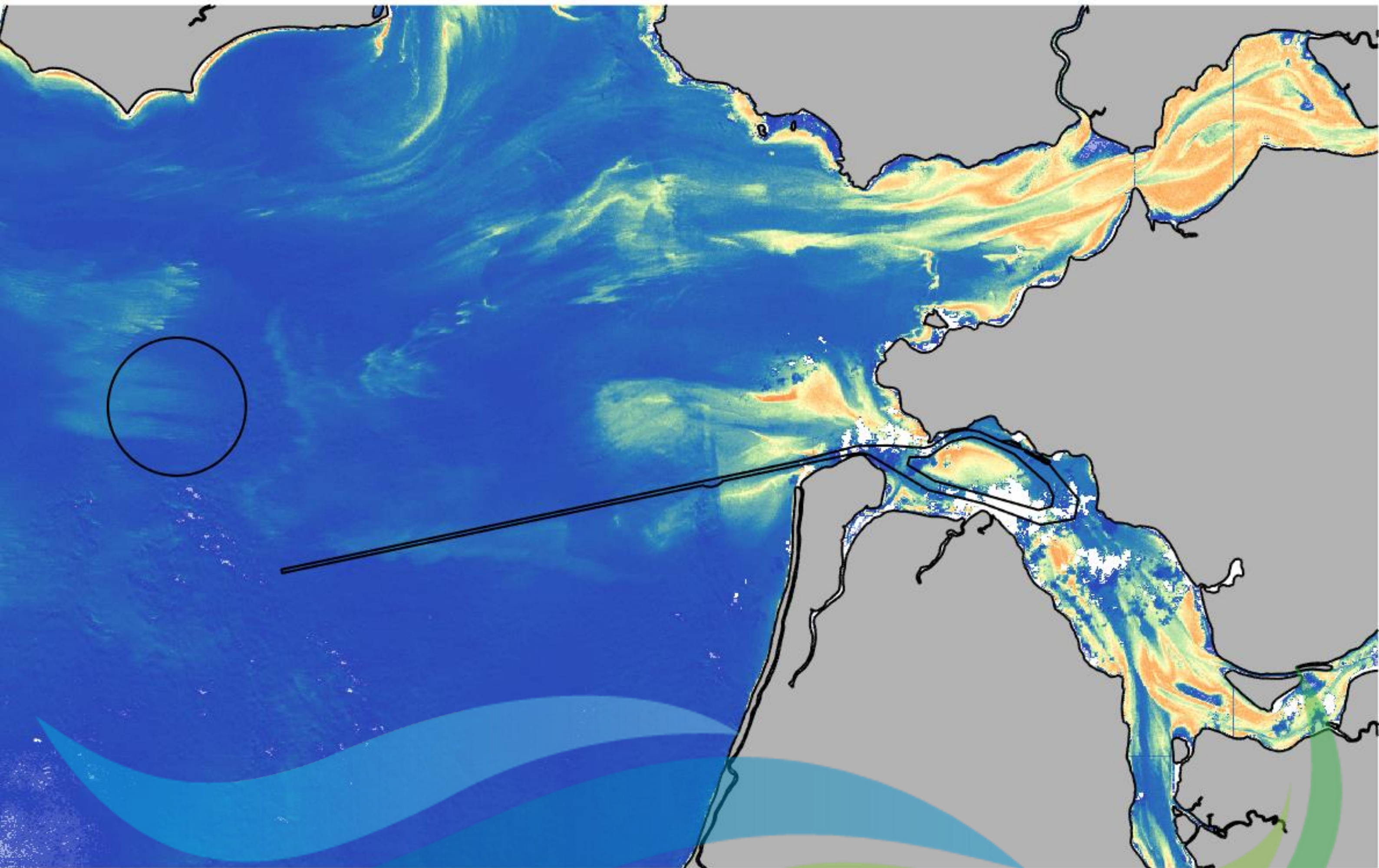
SUMMARY

2021 Turbidity Monitoring

Port of Weipa, 2021 Maintenance Dredging

Summary of Turbidity Monitoring

Report No. P042_R02v02



Technical Report
September 2021

PORT & COASTAL SOLUTIONS

Port of Weipa, 2021 Maintenance Dredging

Summary of Turbidity Monitoring

Report No. P042_R02v02

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North Queensland Bulk Ports Corporation Ltd

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Executive Summary

North Queensland Bulk Ports Corporation (NQBP) commissioned Port and Coastal Solutions Pty Ltd (PCS) to undertake work to support the 2021 maintenance dredging program at the Port of Weipa. This included the following:

1) to analyse the turbidity and metocean conditions over the duration of the dredge program, including 14 days pre- and post-dredging;
2) to assess the relative contribution of the maintenance dredging and placement activities on the natural turbidity at the measurement sites;
3) to better understand the spatial extent of any plumes resulting from the maintenance dredging and placement activities based on satellite-derived turbidity data; and
4) provide a technical report which presents and interprets both the in-situ benthic turbidity data and satellite-derived turbidity data collected over the entire pre-, during and post-dredging periods.

The 2021 maintenance dredging program was undertaken by the TSHD Brisbane and involved the relocation of approximately 320,000 m^3 of sediment from the dredged areas of the Port to the Albatross Bay Dredge Material Placement Area (DMPA). Following the 2020 maintenance dredging program the DMPA was moved to the west, by the distance of its radius (1.1 nautical miles), to provide additional capacity for the future. The data showed that during the dredging program the turbidity around the Port of Weipa was generally driven by the natural conditions (predominantly the astronomical tide), with higher turbidity occurring during periods of larger range spring tides. The key findings from the turbidity data analysis are detailed below:

- based on the measured in-situ benthic turbidity data the turbidity during the pre-, during and post-dredging periods of the 2021 maintenance dredging program appears to have been predominantly controlled by the metocean conditions;
- the exceedance analysis of the in-situ measured benthic turbidity data shows increased duration exceedances over the dredging period of the 2021 maintenance dredging program at WQ4. However, based on the available information this is not expected to be a result of the dredging activity but rather a change in the natural turbidity at this site (i.e. it is now naturally more turbid) since the turbidity threshold was defined. Based on this it is suggested that the benthic turbidity data at WQ4 are reviewed and the reason for the change in natural turbidity is investigated. Based on the findings of this the benthic turbidity threshold should be redefined at WQ4 to ensure it is representative of the natural turbidity which occurs at the site. The turbidity during the dredging period was well within the range of natural variability at WQ1 and WQ2;
- as expected, the dredging and placement activities associated with the Port of Weipa 2021 maintenance dredging program were found to result in visible plumes. Plumes were observed close to the dredger when dredging, adjacent to the South Channel, in the Approach Channel of the Inner Harbour and within the Albatross Bay DMPA. The size and concentration of the plumes was variable:
  - the largest plume was up to 6 km in length and 1 km in width with a concentration of around 15 mg/l, occurring adjacent to the South Channel due to ongoing dredging in the area during a period of neap tides. Satellite imagery indicated that this plume persisted for several days (although it is possible that natural processes and laden tankers in transit in the South Channel could also have contributed to this plume). A similar plume was also identified during a period of spring tides, although this plume was more elongate as a result of the faster spring tidal currents and was found to be due to natural processes as no dredging or bed levelling was undertaken in the South Channel at the time;
  - plumes in the Inner Harbour were approximately 1 to 2 km in length by 200 m in width with concentrations of up to around 15 mg/l; and

  - plumes in the DMPA from the placement of dredged sediment were typically less than 0.5 km in extent following placement on neap tides and less than 2 km in extent on spring tides and only persisted for short durations (of the order of hours). The observed plumes were consistent with placement by the TSHD Brisbane during previous annual maintenance dredging programs prior to the Albatross Bay DMPA being moved.
- all of the plumes resulting from maintenance dredging (including those from both dredging and placement) were found to remain close to where they were created. This shows that little net residual transport occurs in the region, this was also noted during the 2019 and 2020 maintenance dredging programs and as part of the Port of Weipa Sustainable Sediment Management assessment (PCS, 2019b, 2020b and 2020c). Based on this, it can be assumed that the majority of the sediment suspended by the maintenance dredging is subsequently redeposited close to where it was either dredged or placed;
- the Port of Weipa 2021 maintenance dredging program did not influence the regional turbidity in the area. The dredging only influenced the local turbidity close to where dredging was undertaken in the Port and in the Albatross Bay DMPA. Natural variations in turbidity driven by the tide and wave conditions over the monitoring period were larger than the variations in turbidity due to the maintenance dredging; and
- due to high levels of cloud cover following the completion of the 2021 maintenance dredge program, it was not possible to determine how quickly the turbidity returned to natural conditions. However, based on information from the 2020 maintenance dredge program (PCS, 2020b), and imagery available four days post dredging, it is expected that the turbidity had returned to natural conditions within one to four days with no remaining areas with elevated turbidity due to the maintenance dredging and placement activities.

1. Introduction

North Queensland Bulk Ports Corporation (NQBP) commissioned Port and Coastal Solutions Pty Ltd (PCS) to undertake work to support the 2021 maintenance dredging program at the Port of Weipa. This included the following:

- source satellite imagery for the Port of Weipa region and process the imagery to output satellite-derived turbidity to show the spatial distribution of turbidity over the duration of the dredging program plus 14 days pre- and post-dredging;
- obtain metocean data for the Weipa region over the whole pre-, during and post-dredging period to help interpret the satellite-derived turbidity data;
- provide a pre-dredging technical note prior to the dredging commencing which presents the satellite-derived turbidity data and metocean conditions. The note will provide an overview of the natural turbidity and the relative influence of different drivers (e.g. waves and tidal currents) during the pre-dredging period;
- provide a during dredging technical note between day 10 and day 14 of the maintenance dredging. The note will present results from the satellite-derived turbidity monitoring over this initial dredging period and discuss the potential impacts of the dredging on the turbidity in the region; and
- provide a post dredging technical report following completion of the maintenance dredging and the post monitoring period. This note will present both the satellite derived turbidity and in-situ benthic turbidity data for the pre-, during and post-dredge periods and discuss the metocean conditions, the associated natural variability in turbidity and potential impacts of the maintenance dredging to turbidity in the region.

Following completion of the 2021 maintenance dredging program and the 14 day post-dredging period, this technical report presents and discusses the metocean and turbidity data collected.

1.1. Project Overview

The Port of Weipa is located in the Gulf of Carpentaria, on the north-west coast of the Cape York Peninsula in Northern Queensland (Figure 1). The Port is within Albatross Bay, a large embayment, with the wharves and berths located in the Embley River (Figure 1 and Figure 2).

In the 2020/21 financial year, the Port of Weipa handled approximately 16 million tonnes of commodities, including bauxite, fuel, cattle and general cargo. Rio Tinto Alcan (RTA) currently operates most of the port facilities for the export of bauxite (aluminium ore) from the nearby RTA mine.

The layout of the Port of Weipa is shown in Figure 1. The Port consists of:

- a main shipping channel in Albatross Bay called South Channel; and
- an Inner Harbour, which is within the Embley River and consists of four shipping berths (Lorim Point East and West, Humbug Wharf and Evans Landing) and the Approach and Departure Channels (Figure 2).

The Port has approximately 622 hectares of channels, swing basins and berths where depths are maintained by maintenance dredging. NQBP currently has a 10-year Sea Dumping Permit for the Port of Weipa which allows for an average of 1,200,000 m^3 of sediment to be removed by maintenance dredging per annum, although this includes a contingency for events such as cyclones and so is not realised on an annual basis.

Since 2002 maintenance dredging at the Port of Weipa has been undertaken annually by the Trailing Suction Hopper Dredger (TSHD) Brisbane, with volumes ranging from approximately 300,000 m^3 to 2,400,000 m^3. The sediment, which has historically been removed by maintenance dredging, has been relocated to the offshore Dredge Material Placement Area (DMPA) located in Albatross Bay (Figure 1). Following the 2020 maintenance dredging program the DMPA was moved to the west, by the distance of its radius (1.1 nautical miles), to provide additional capacity for the future.

Based on detailed bathymetric analysis by PCS (2018a) it was found that the annual sedimentation at the Port was highly variable depending on the wave conditions which occurred during the wet season, with the occurrence of Tropical Cyclones (TCs) in the region being a key driver for larger waves and increased sedimentation. The analysis also found that the majority of the sedimentation occurred in the South Channel, with limited sedimentation occurring in the Inner Harbour region (see Figure 3 for locations).

There were no TCs during the 2020/21 wet season, with only three wave events having a peak in significant wave height of more than 1.5 m. As a result, the sedimentation was much lower than that which occurred in 2018/19 (when there were three TCs and a prolonged tropical low), being broadly similar to the 2019/20 dredge volume. The 2021 maintenance dredging program commenced on the 26th April 2021 at 07:52 and was completed at 04:00 on 18th May 2021. During the program approximately 320,000 m^3 was relocated to the recently moved Albatross Bay DMPA by the TSHD Brisbane.

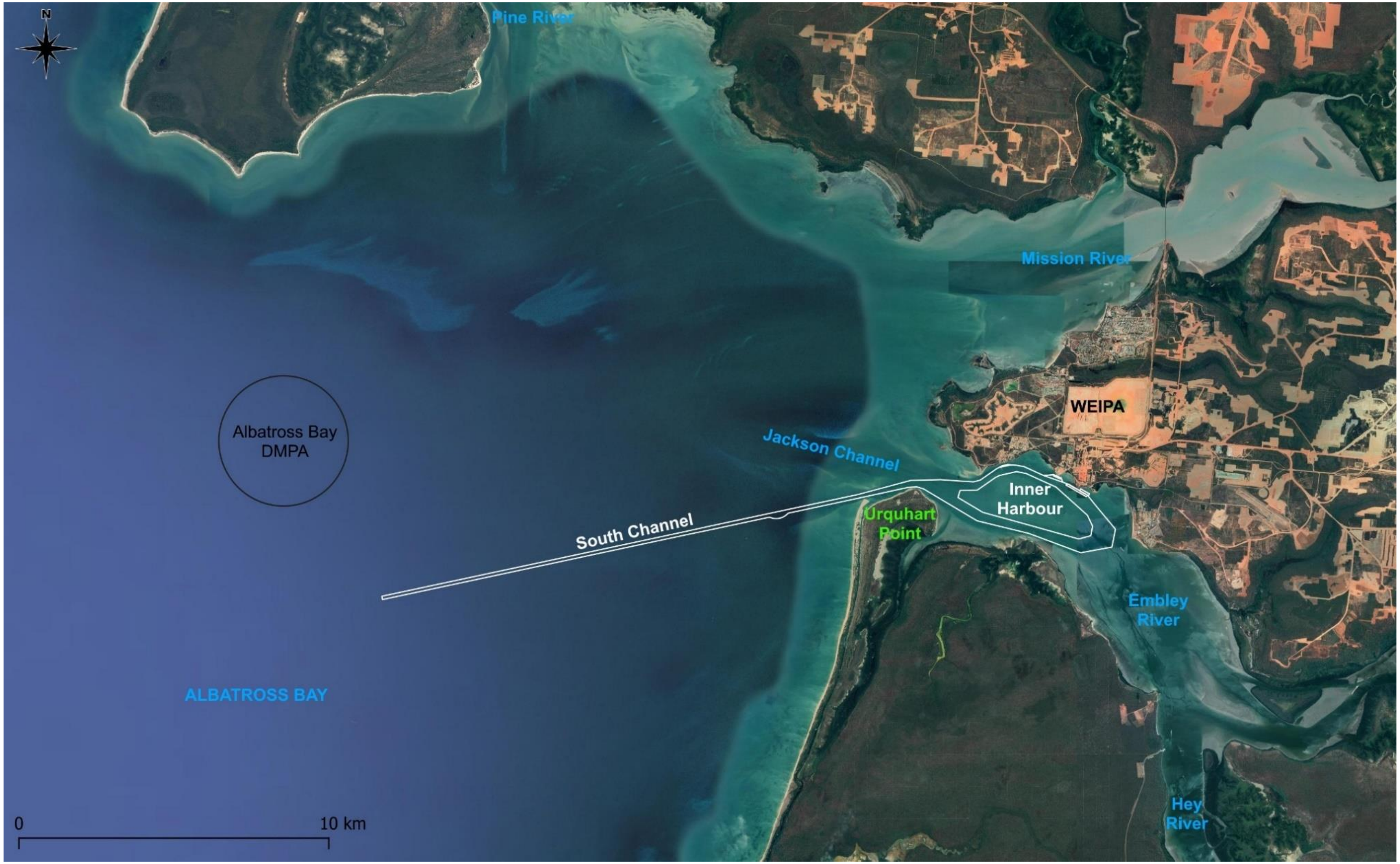


Figure 1. Layout of the Port of Weipa.

Figure 2. **Close up of the Port of Weipa Inner Harbour area.**

1.2. Report Structure

The report herein is set out as follows:

- a summary of the dredge program is provided in **Section 2**;
- details of the turbidity monitoring undertaken are provided in **Section 3**;
- analysis of the in-situ turbidity and satellite-derived data is presented in **Section 4**; and
- a summary of the findings is detailed in **Section 5**.

Unless stated otherwise, levels are reported to Chart Datum (CD). Zero metres CD is equal to the Lowest Astronomical Tide (LAT) at the Port of Weipa. Volumes presented throughout are in-situ cubic metres.

2. Dredge Program

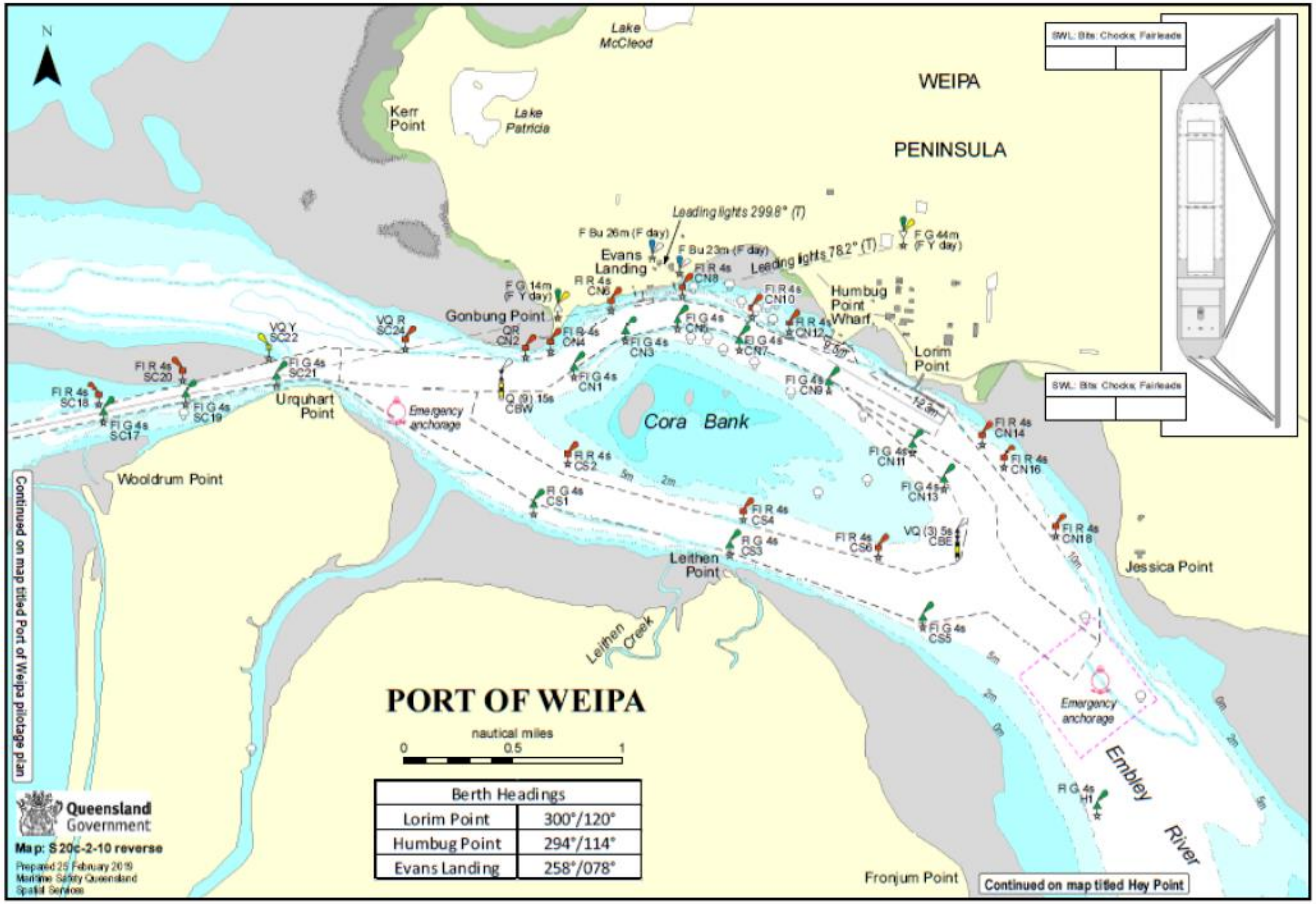
The Port of Weipa 2021 maintenance dredging program commenced on the 26th April 2021 at 07:52 Australian Eastern Standard Time (AEST) and was completed on the 18th May 2021 at 04:00 AEST. Over this 22 day period a total of 174 dredge loads were relocated to the recently moved Albatross Bay DMPA (see Section 1.1 for further details), with an average of 8 loads per day. The majority of the maintenance dredging undertaken as part of the 2021 program was focused in the South Channel, with close to 90% of the dredge loads from this area. It is important to note that the maintenance dredging requirement within the South Channel was not uniform, with approximately 40% of the sediment removed from between SC10 and SC14 which represents approximately 20% of the total length of the South Channel (3.75 km of the total 17.5 km length of the channel).

The following loads were dredged from the different port areas:

- Eight loads from South Channel, SC2 to SC6 (Figure 3): six loads of silt and two mixed loads of sand and silt were dredged from the offshore section of the South Channel with dredging in this area undertaken on the 5th, 12th and 14th May 2021;
- 40 loads from South Channel, SC6 to SC10 (Figure 3): 29 loads of silt and 11 mixed loads of sand and silt were dredged from this section of the South Channel with dredging in this area undertaken on the 26th to 29th April 2021 and on the 3rd to 5th, 7th to 13th and 15th May 2021;
- 63 loads from South Channel, SC10 to SC14 (Figure 3): 51 loads of silt and 12 mixed loads of sand and silt were dredged from this section of the South Channel with dredging in this area undertaken every day between the 27th April and the 17th May 2021 except the 8th and 12th May 2021;
- 26 loads from South Channel, SC14 to SC18 (Figure 3): 26 loads of silt were dredged between beacons SC14 and SC18 of the South Channel (with 24 of these between SC14 and SC16). Dredging in this area was undertaken on approximately two thirds of the days between the 29th April and the 16th May 2021;
- 19.5 loads from South Channel, SC18 to Urquhart Point (Figure 3): Fifteen and a half loads of sand, two loads of silt and two loads of mixed sand and silt were dredged from this section of the South Channel. Dredging in these areas was undertaken on the 26th and 30th April, 1st, 2nd, 4th to 10th, 12th and 15th to 16th May 2021; and
- 18 loads from Inner Harbour, CN3 to CN5, CS3 to CS5, South Toe, Approaches to Humbug Wharf, East Cora Bank, Lorim Point Wharf and SC24 to CN2 (Figure 4) :10.5 loads of mixed sand and silt were dredged from the Inner Harbour. A further five loads of silt and 2.5 loads of sand were also removed from this area. Dredging within the Inner Harbour areas was undertaken on the 27th to 28th April, 1st, 4th to 6th, 8th to 10th, 14th and 17th May 2021.

All of the dredged sediment was placed at the Albatross Bay DMPA, with the location of the placements within the DMPA being rotated between the five separate regions of the DMPA to ensure an even distribution over the DMPA.

Figure 3. Location of the Port of Weipa ambient monitoring sites (WQ1, WQ2 and WQ4), DES waverider buoy (WRB) and South Channel (beacons SC2 – SC24).



Source: MSQ, 2019.

Figure 4. Location of the Port of Weipa and beacons within the Inner Harbour.

2.1. Metocean Conditions

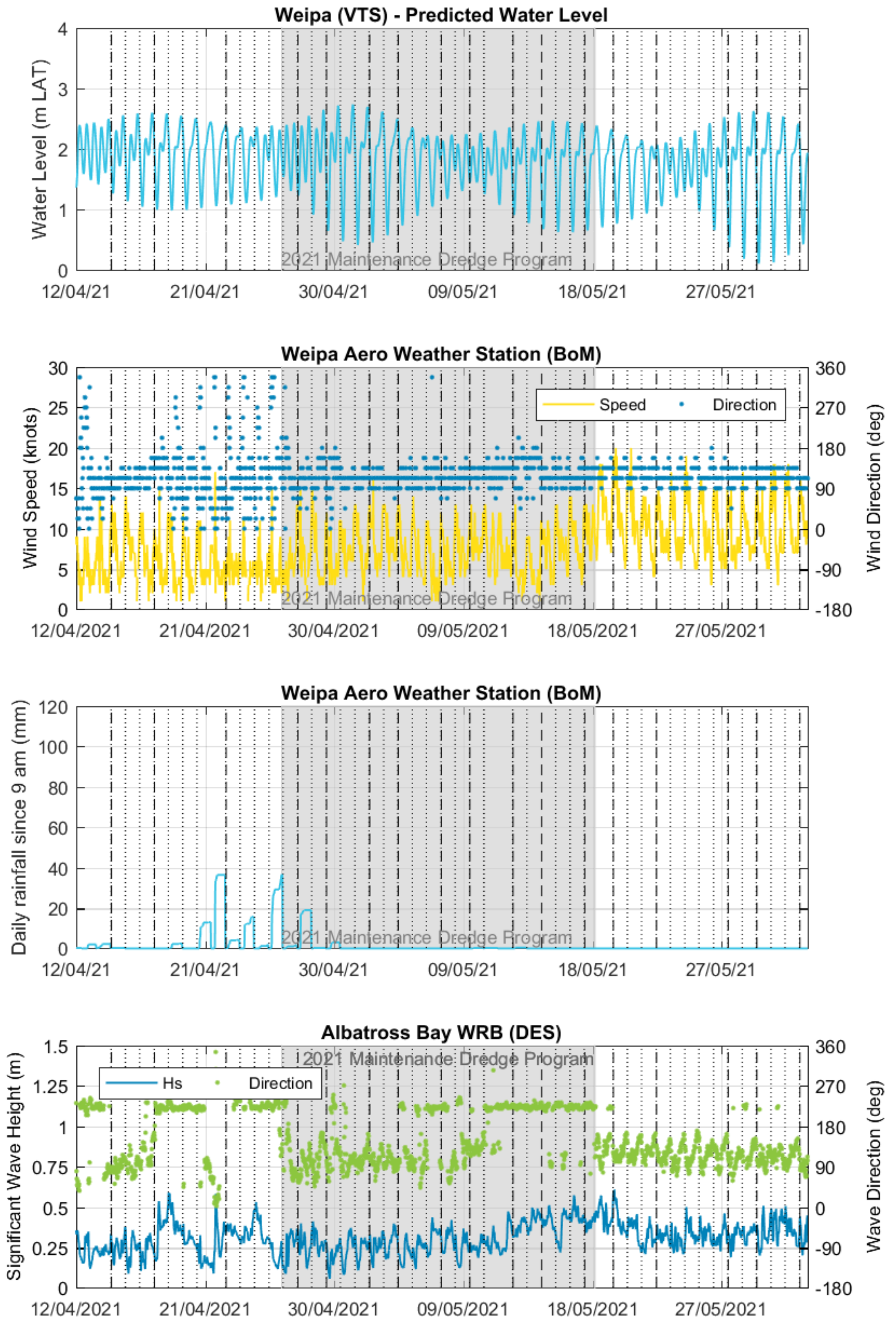
To provide an understanding of the metocean conditions over the pre-, during and post dredging periods, the following data have been sourced:

- Water Level: the predicted water level for the Port of Weipa (provided by the Bureau of Meteorology (BoM));
- Wind and Rain: measured wind and rainfall at the BoM Weipa Aero weather station (ID 027045); and
- Waves: measured wave conditions at the Albatross Bay waverider buoy (WRB) (Figure 3) (provided by the Department of Environment and Science (DES)).

The metocean conditions over the entire monitoring period are shown in Figure 5, with shading indicating the period of maintenance dredging. The dashed and dotted lines indicate when satellite images were captured (refer to Section 4.2). The figure shows the following:

- the metocean conditions are fairly consistent and can be considered to represent calm dry season conditions;
- the winds are consistent over the pre-dredge and dredge period, with peak speeds during the day of 10 to 15 knots and lighter winds overnight. Wind directions are typically from the east to south-east (i.e. from the coast at Weipa) throughout the period. During the post dredge period wind speeds increase with peaks of up to 20 knots occurring during the day;
- moderate rainfall occurred during the pre-dredge period and during the first three days of the dredge. The rainfall during this period was relatively high for the time of year, with two days when the daily rainfall was just under 40 mm. For reference, the median rainfall at Weipa is 75 mm and 7 mm in April and May, respectively and with 7 days and 2 days per month experiencing more than 1 mm daily rainfall;
- the wave conditions over the pre-dredge period were typically from the south-east (i.e. generated by an offshore wind), with significant wave heights (H_s) generally less than 0.5 m. There were two occasions over the pre-dredge period when the H_s reached 0.5 m, the first was waves from the north which were locally generated during a period with high rainfall when the wind speed exceeded 15 knots and the wind was from the north-west and the second was due to longer period waves from the south when local winds were relatively calm; and
- at the start of the maintenance dredging program the waves were generated by the local offshore winds (so that they travelled away from the Weipa shoreline) and were relatively small (H_s of less than 0.4 m). During the last week of the dredge the waves were from the southwest indicating that they were generated by offshore swell conditions, while wave heights during this period were slightly increased, they remained relatively small, being less than 0.6 m throughout. Following the completion of the dredging the wave direction switched back to locally generated waves due to offshore winds, with the waves travelling away from the Weipa shoreline.

Overall, the monitoring period is considered to be relatively calm in terms of wave conditions, although some localised resuspension of fine-grained sediment in shallow areas of Albatross Bay could have occurred during the pre-dredging period and towards the end of the dredging when the H_s was around 0.5 m.



Note: Dashed lines indicate times when satellite images were obtained and analysed, grey shaded area shows 2021 maintenance dredge program.

Figure 5. Metocean conditions at Weipa over the monitoring period, with water level (upper), winds (upper middle), rainfall (lower middle) and waves (lower).

3. Turbidity Monitoring

As part of the ongoing ambient water quality monitoring which NQBP have setup, benthic turbidity data have been collected by James Cook University (JCU) since January 2018 at monitoring sites around the Port of Weipa. The instruments measure near bed turbidity in Nephelometric Turbidity Unit equivalent (NTUe)[1]. There were originally two sites in Albatross Bay (WQ2 and WQ5), but one of these sites (WQ5) was decommissioned in July 2018 and there are currently two sites (WQ1 and WQ4) in the Inner Harbour (Figure 3).

The instruments were serviced a couple of weeks before the 2021 maintenance dredging program began and retrieved for data downloaded approximately two months after completion of the dredging program. Data up to the end of June 2021 were provided by JCU. During in-house quality checks it was determined that data collected at WQ2 for the post-dredge period was erroneous (with no correlation between the measured benthic turbidity and metocean drivers, turbidity at the other monitoring sites or satellite derived TSM during this period) and these readings were therefore removed from the dataset ahead of analysis.

Details of the benthic turbidity data available at the monitoring sites are provided in Table 1. The table also notes the data return for each site over the 2021 maintenance dredging monitoring period, which includes 14 days pre-dredging, 22 days during dredging and 14 days post dredging (50 days in total). The data return at two of the sites was high, being 100% at WQ1 and 97% at WQ4. However, due to the removal of erroneous data from the post-dredge period at WQ2, the data return at this site was notably lower (70%).

Table 1. Summary of ambient water quality monitoring data available for this assessment.

Location	Approx. Depth (m MSL)	Total Benthic Data Period	Data Return for 2021 Dredging Period
WQ1	5 m	19/01/18 to 30/06/21	100%
WQ2	4 m	16/03/18 to 30/06/21	70%
WQ4	4 m	19/01/18 to 30/06/21	97%

3.1. Previous Analysis

Benthic turbidity data from the ongoing ambient monitoring were analysed by PCS (2019a and 2020a) to understand the natural variability in turbidity at the three monitoring sites. The analysis undertaken prior to the 2019 maintenance dredging program suggested that the 95th percentile turbidity for the dry season period could be used as a representative benthic turbidity threshold for the 2019 maintenance dredging program. The subsequent more detailed analysis undertaken as part of the Environmental Thresholds component of the Port of Weipa Sustainable Sediment Management (SSM) Project recommended that the 90th percentile turbidity should be adopted as a turbidity intensity threshold as it approximately correlates with published benthic Photosynthetically Active Radiation (PAR) thresholds for the species of seagrass which are present in the Weipa region. Both of these turbidity intensity thresholds were considered during the 2020 maintenance dredge program to calculate the duration of time the thresholds were exceeded so that the assessment could be related to both previous studies. For consistency with the 2020 maintenance dredge program, both intensity thresholds were also considered for the 2021 program.

[1] The international turbidity standard ISO7027 defines turbidity readings in NTU for 90 degree backscatter, while the JCU instrumentation uses 180 degree backscatter. In recognition of this fact, the units are reported as NTU equivalent (NTUe).

The 90th and 95th percentile turbidity intensity thresholds for the dry season period at the three ambient water quality monitoring sites which have been adopted for this assessment are shown in Table 2.

Table 2. Dry season benthic turbidity thresholds derived by PCS (2019a and 2020a).

Location	90th Percentile Turbidity Threshold (NTUe)	95th Percentile Turbidity Threshold (NTUe)
WQ1	17	21
WQ2	15	25
WQ4	18	28

4. Data Analysis

This section presents in-situ turbidity data and satellite-derived turbidity data to provide an understanding of the variability in turbidity in the Weipa region and to determine the potential impact of the maintenance dredging activity on water quality in the region.

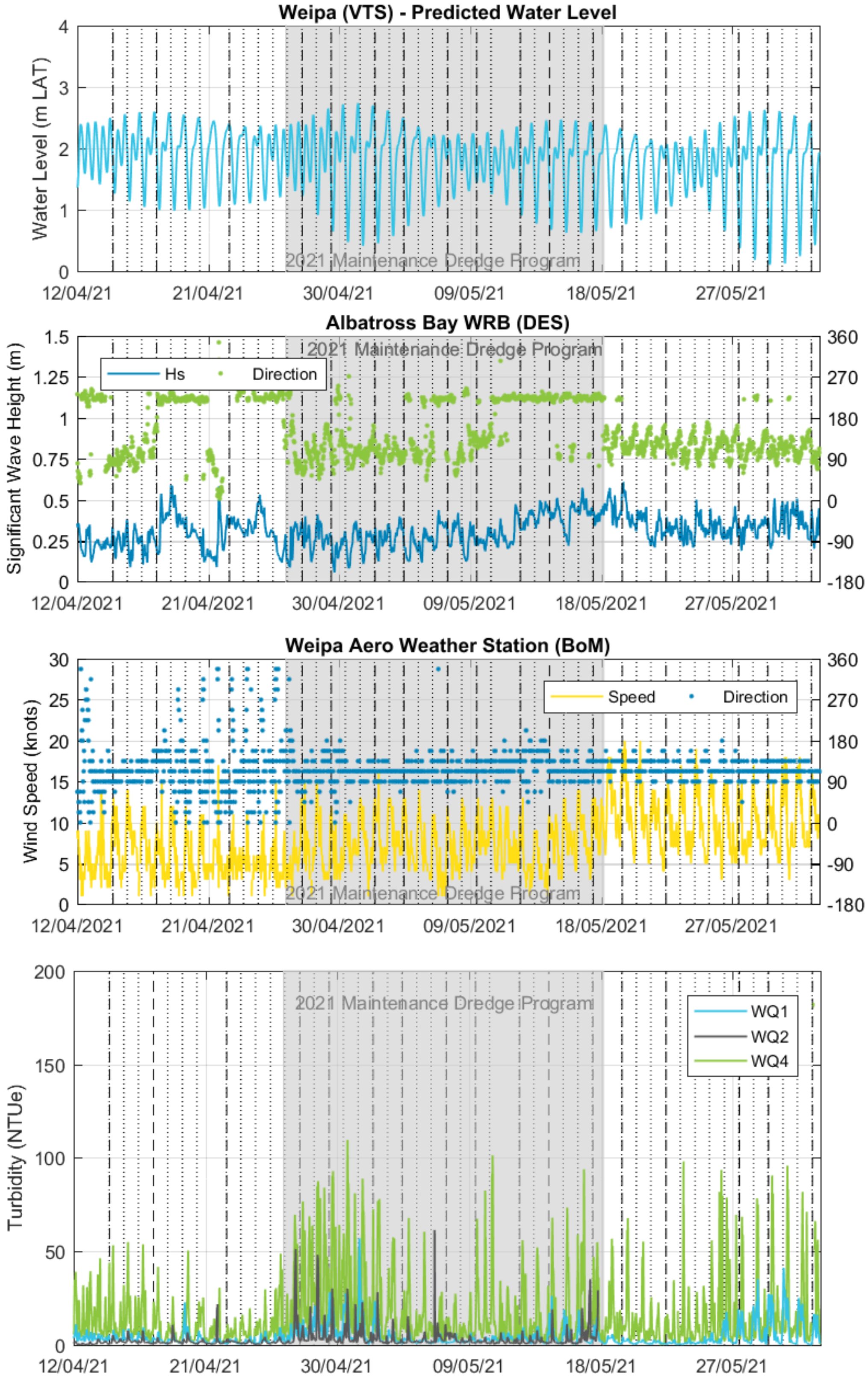
4.1. In-situ Turbidity Analysis

The measured benthic turbidity data at the three monitoring sites, along with the predicted water level for the Port of Weipa (calculated by BoM) and the measured wave conditions in Albatross Bay (from the DES WRB in Albatross Bay) are shown in Figure 6, while individual plots for each monitoring site are shown in Figure 7. The figure shows that there is a clear tidal signal in the turbidity data at WQ1 and at WQ2 (during the pre- and during dredge periods when data was available), with increased turbidity correlating with the larger tidal range over the spring tides.

The turbidity data at WQ4 has regular peaks in turbidity throughout most of the monitoring period. These peaks exceed 50 NTUe, with the magnitude of the peaks not directly corresponding to the metocean conditions or the turbidity measurements at WQ1 (the other Inner Harbour site). In particular, high turbidity peaks occur during neap tide periods, coinciding with the flood tide. A similar pattern was also observed at WQ4 during the 2019 and 2020 maintenance dredging programs. The monitoring site at WQ4 was selected to be in proximity to existing seagrass beds in the area to provide local water quality data which can be correlated with seagrass survey data. The turbidity data was found to have been noticeably higher since May 2019 when the site location was moved by around 350 to the south-east (PCS, 2019b), although it was subsequently moved back but the higher turbidity persisted. The reason for the higher turbidity at WQ4 since May 2019 is unknown, although it appears to be a localised process which influences the benthic turbidity measurements at this location. Based on the most recent measurements during the 2021 maintenance dredging program it appears that this localised process is continuing to result in elevated turbidity at WQ4.

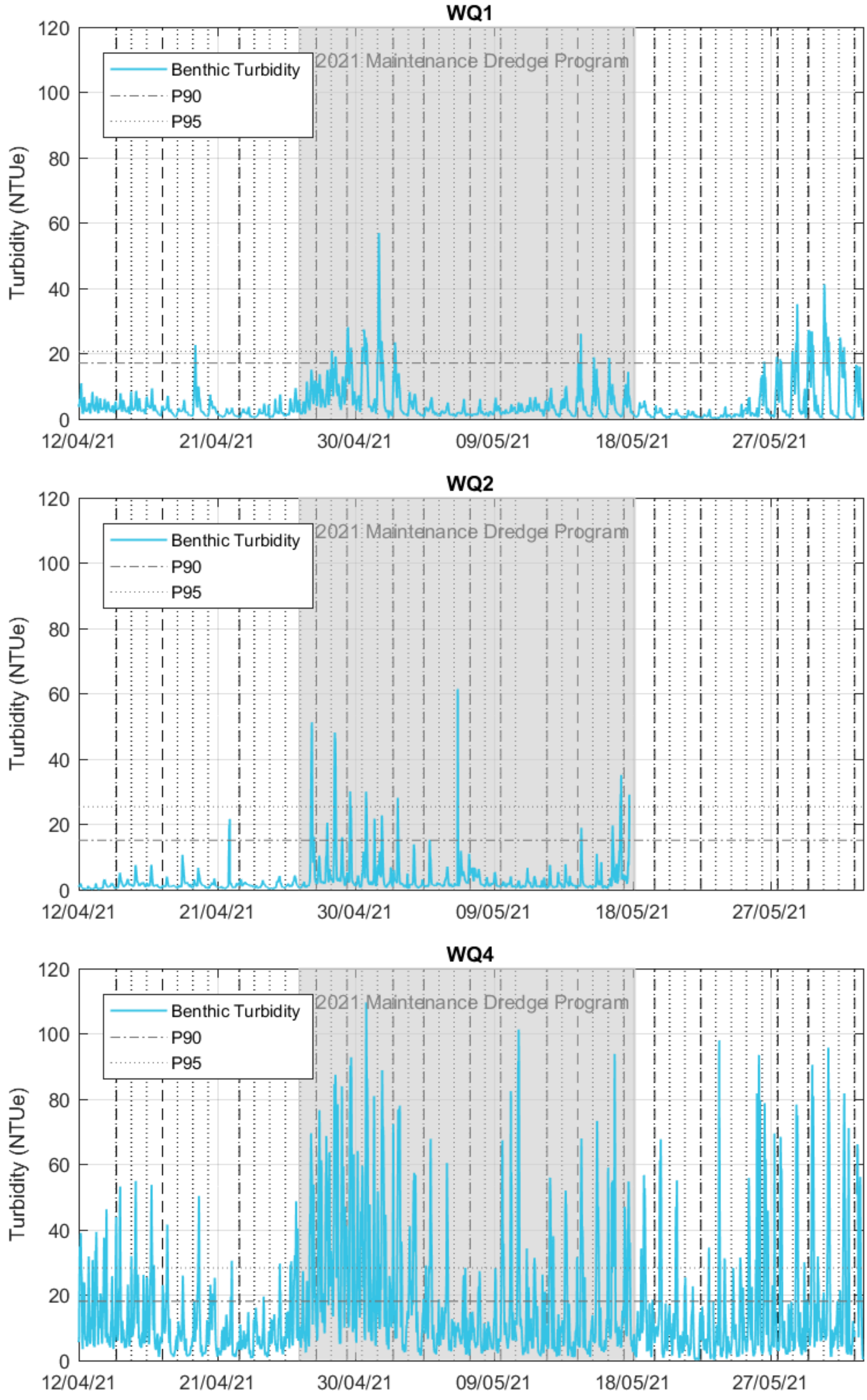
Based on the benthic turbidity data at WQ1 it appears that the turbidity during the pre-, during and post dredging periods of the 2021 maintenance dredging program was predominantly controlled by the metocean conditions. This is also true of WQ2 for the pre and during dredge periods when data were available. In general, the benthic turbidity data at WQ4 also shows comparable timing and magnitude of peaks in turbidity over the entire monitoring period providing further evidence that the turbidity was predominantly controlled by natural processes. The exception to this is at the start of the dredge period (over the first seven days) when the turbidity was slightly elevated. This could be a result of the higher rainfall prior to this period, a localised natural process or a result of increased turbidity associated with dredging. This is discussed in more detail in Section 4.1.1.

To further assess any potential increase in turbidity at the sites due to maintenance dredging the duration of time the benthic turbidity intensity thresholds detailed in Table 2 were exceeded is analysed in the following section.



Note: Dashed lines indicate periods when satellite images were obtained and analysed, grey shaded area shows dredge period.

Figure 6. Metocean and turbidity conditions at Weipa over the monitoring period, with water level (upper), waves (upper middle), winds (lower middle) and turbidity at the three monitoring sites (lower).



Note: Vertical dashed lines indicate periods when satellite images were obtained and analysed, grey shaded area shows dredge period.

Figure 7. Measured turbidity data at the three Weipa monitoring sites over the monitoring period, with WQ1 (upper), WQ2 (middle) and WQ4 (lower).

4.1.1. Exceedance

The duration of time that both the 90th and 95th percentile benthic turbidity intensity thresholds were exceeded at the three monitoring sites was calculated over 14 days pre-dredging, the 22 days during dredging and 14 days post dredging for the 2021 maintenance dredging program (Table 3). For reference, statistics on the wave conditions over the same periods are provided in Table 4. The wave statistics show that there were not any significant variations in wave conditions throughout the dredge monitoring period. The exceedance results show similar patterns in the benthic duration exceedances at WQ1 and WQ2 for the pre- and during dredging periods. At WQ1 the lowest benthic duration exceedances occurred over the pre- and post-dredging periods and the highest exceedance occurred during the dredging period. At WQ2 the pre- and during-dredge exceedances were similar to those at WQ1. At WQ4 the duration exceedance over the dredging period was significantly higher than at WQ1 and WQ2 (around 7 to 9 times higher). The reason the duration exceedance was significantly higher at WQ4 was because the turbidity intensity thresholds at WQ4 did not consider the elevated turbidity at the site post May 2019 (this period was excluded from the analysis) as it was assumed that the turbidity would become lower again once the site was moved back to its original position.

The benthic turbidity thresholds were previously defined using the 90th and 95th percentile of the measured turbidity data during the dry season. As a result, the thresholds would typically be expected to be exceeded for 10% and 5% of time, which over the 22 day dredge program would equal 53 hours and 26 hours respectively (and approximately two thirds of this for the 14 day pre- and post-dredging periods). Based on this, the results presented in Table 3 show that the duration exceedances were well below average over the pre-dredging period and slightly below average over the dredging period at both WQ1 and WQ2. For the post dredge period the duration exceedance at WQ1 remained well below average (With no reliable data available at WQ2). However, at WQ4 the duration of exceedance did reach the average duration threshold during dredging and during the pre and post dredge periods. As previously noted this is a result of the ongoing elevated natural turbidity which has occurred at the site since May 2019 not corresponding to the benthic turbidity intensity thresholds at the site which were based on data pre May 2019. This is further shown as the duration of exceedance reached the threshold during all three periods indicating that the reason for the exceedance is due to the natural conditions at the site as opposed to a significant increase in turbidity at the site due to the maintenance dredging.

To further assess whether the turbidity over the 2021 maintenance dredging program monitoring period remained within the natural range, the duration exceedance of the 90th percentile turbidity has been compared to the duration thresholds (scaled to the 22 day dredge duration) suggested by PCS (2020a). These thresholds were suggested as possible adaptive management thresholds which could be adopted sequentially to minimise the risk of any impacts to sensitive receptors. The average duration of 53 hours was only exceeded at WQ4 where the 90th percentile[2] and maximum durations[3] were both also exceeded. The time series of turbidity at WQ4 indicates that the turbidity is highest during the early part of the dredge (between the 27th April and the 1st May 2021), coinciding with spring tides. The dredge logs indicate that the majority of dredging in this region was undertaken in the second week of the maintenance dredge program (between the 4th and 9th of May) and it is therefore unlikely that the elevated turbidity at the start of the dredge program is related to the dredging. As previously noted, elevated turbidity at WQ4 occurred throughout the monitoring (pre-, during and post dredging), showing that the natural turbidity at the site is high. Elevated turbidity was also noted at WQ4 during the 2019 and 2020 maintenance dredging, with a significant increase in the natural turbidity at the site noted since May 2019 (PCS, 2019b). This was thought to be related to a localised process due to the location of the

[2] This was 97 hours, 123 hours and 109 hours for a 20 day dredge at WQ, WQ2 and WQ4, respectively during the dry season.

[3] This was 133 hours, 238 hours and 173 hours for a 20 day dredge at WQ, WQ2 and WQ4, respectively during the dry season.

instrument having been moved between deployments, but the elevated benthic turbidity at WQ4 has persisted since this time. As a result, it is suggested that the benthic turbidity data at WQ4 are reviewed and the reason for the elevated turbidity since May 2019 is investigated. Based on the findings of this the benthic turbidity threshold should be redefined to ensure it is representative of the natural turbidity which occurs at the site.

At WQ1 and WQ2 where the average duration was not exceeded, the turbidity during the dredging period was well within the range of natural variability and as such no adaptive monitoring would have been implemented should real time monitoring have been undertaken at these sites.

Table 3. Duration of exceedance of the previously derived benthic turbidity intensity thresholds over the Port of Weipa 2021 maintenance dredging program.

Location	14 days Pre-Dredging (hrs)		22 days During Dredging (hrs)		14 days Post-Dredging (hrs)	
	90th %ile	95th %ile	90th %ile	95th %ile	90th %ile	95th %ile
WQ1	1.2	0.7	26.8	13.7	26	16
WQ2	0.8	0	23.8	10.5	-[1]	-[1]
WQ4	66.0	23.7	182.7	125.2	80.2	54.7

[1] no reliable benthic turbidity data were available at WQ2 during the post-dredging period.

Table 4. Measured significant wave height at the Albatross Bay WRB statistics over the Port of Weipa 2021 maintenance dredging program.

Statistic	Pre-Dredging	During Dredging	Post-Dredging	Entire Period
Median H_s (m)	0.28	0.29	0.34	0.31
90th percentile H_s (m)	0.41	0.43	0.45	0.43
95th percentile H_s (m)	0.47	0.46	0.49	0.47
Maximum H_s (m)	0.59	0.57	0.61	0.61
Hours H_s > 0.5 m	9.0	5.0	14.5	28.5

4.2. Satellite-Derived Data

Satellite-derived turbidity data are a valuable resource which can provide a reliable spatial overview of the variability in turbidity over a large area (Fearns et al., 2017). Analysis of repeat images can be used to assist in understanding how spatial variations in turbidity change over time.

To better understand the spatial extent of both the natural turbidity in the Weipa region and any plumes resulting from the maintenance dredging activity (including from the placement of dredged sediment at the Albatross Bay DMPA), satellite imagery was used. High-resolution imagery from the Sentinel-2 (10 m) and Landsat-8 (30 m) sensors and low-resolution imagery (approximately 300 m) from the Sentinel-3 sensor were sourced over the 2021 maintenance dredge monitoring period.

In the Weipa region the repeat satellite coverage is high for the Sentinel-3 sensor (images captured 11 out of every 14 days) relatively high for the Sentinel-2 sensor (images captured every 2 to 3 days) and low for the Landsat-8 sensor (one image captured every 16 days). The reason the temporal coverage is relatively high for the Sentinel-2 sensor is because the area is partially covered by two separate satellite tracks, which means the entire region is not covered for each image (the Inner Harbour is only captured in every second image). The satellite data are restricted by cloud cover, and so imagery can only be used when there is little to no cloud cover in the areas of interest.

The available imagery was post processed to calculate the satellite-derived turbidity based on the approach of Brockmann et al. (2016). This approach provides an estimate of total suspended matter (TSM) and has been validated in various studies (Kyryliuk and Kratzer, 2019). An assessment of the accuracy of the satellite derived TSM against the in-situ near bed turbidity data is provided in section 4.2.1. Irrespective of local calibration, the spatial variability shown by the images provides a reliable indication of how the turbidity varies in the region and allows areas with higher turbidity to be identified.

Throughout the dredge period PCS provided NQBP with TSM from satellite imagery available from all three satellite sensors to provide as much near real-time information about the natural turbidity and any plumes due to the maintenance dredging as possible. From the daily updates provided during the dredging it was noted that the plumes from the maintenance dredging were relatively small and localised and as such they can be difficult to identify from the lower resolution Sentinel-3 imagery. Based on that, the technical note provided during dredging focussed on satellite imagery from the Sentinel-2 sensor (PCS, 2021). This post dredging report also focusses on imagery from the Sentine-2 sensor, but where high quality clear images from Sentinel 3 and Landsat 8 are available these are also included.

Over the pre-, during and post-dredging monitoring periods a total of 15 high resolution satellite images were captured by the Sentinel-2 sensor. As a result of high cloud cover during some of the satellite passes two of the images were unusable, further the Inner Harbour region was only covered by seven of the Sentinel-2 images (two of which were unusable due to high cloud cover). In addition, there were three Landsat-8 images and 43 Sentinel-3 images (of which 23 are presented here) captured during the monitoring period.

Details of the satellite images analysed as part of this assessment are provided in Table 5 for the pre-dredging monitoring period, Table 6 during dredging and Table 7 for the post-dredging monitoring period. Images presented are detailed in black text while other images are detailed in grey.

Table 5. Available satellite images for the pre-dredging monitoring period.

Date and Time	Satellite Name	Details
14/04/2021 10:20	Sentinel-3	Port area free from cloud. Image not included (higher resolution from Landsat 8 available).
14/04/2021 10:47	Sentinel-2	Good clear image free of clouds.
15/04/2021 09:57	Sentinel-3	Good clear image free of clouds.
16/04/2021 09:57	Sentinel-3	Good clear image free of clouds.
17/04/2021 10:57	Sentinel-2	Good clear image free of clouds, image excludes Inner Harbour area.
18/04/2021 10:16	Sentinel-3	Good clear image free of clouds.
19/04/2021 09:53	Sentinel-3	High level of cloud cover.
20/04/2021 10:06	Sentinel-3	Patchy cloud obscuring image.
22/04/2021 10:15	Sentinel-3	Patchy cloud obscuring image.
22/04/2021 10:57	Sentinel-2	Port area generally free from cloud, image excludes Inner Harbour area.
23/04/2021 09:49	Sentinel-3	Port area mostly free from cloud, some patchy cloud along coastal areas.
24/04/2021 10:39	Landsat-8	Good clear image free from cloud.
24/04/2021 10:02	Sentinel-3	Port area free from cloud. Image not included (higher resolution from Landsat 8 available).
26/04/2021 10:12	Sentinel-3	High level of cloud cover.

Table 6. Available satellite images during dredging.

Date and Time	Satellite Name	Details
27/04/2021 10:22	Sentinel-3	Patchy cloud obscuring image.
27/04/2021 10:57	Sentinel-2	Full cloud cover.
28/04/2021 09:59	Sentinel-3	Full cloud cover.
29/04/2021 10:31	Sentinel-3	Good clear image, with some high level cloud. Image not included (higher resolution from Sentinel 2 available).
29/04/2021 10:47	Sentinel-2	Generally clear with some cloud cover over the Inner Harbour region. The TSHD Brisbane was delayed at this time (between 08:24 and 15:10) with the most recent activity being placement of sand and silt at the DMPA between 05:55 and 06:18.
30/04/2021 10:08	Sentinel-3	Good clear image, with some high level cloud. At this time the TSHD Brisbane was dredging silt (load 33) from SC14 to SC16, with dredging starting at 09:42 and continuing until 10:27.
01/05/2021 10:18	Sentinel-3	Good clear image, with some high level cloud. At this time the TSHD Brisbane was steaming between Lorim Point and the DMPA having finished dredging load 40 at 08:44.
02/05/2021 09:55	Sentinel-3	Good clear image free of clouds. At this time the TSHD Brisbane was steaming between SC16 and the DMPA having finished dredging load 48 at 09:23.
02/05/2021 10:57	Sentinel-2	Patchy cloud over the offshore area, image excludes Inner Harbour area. At this time the TSHD Brisbane was steaming between away from the DMPA having placed silt at the DMPA between 10:22 and 10:35.
03/05/2021 10:27	Sentinel-3	Good clear image free of clouds. At this time the TSHD Brisbane was discharging load 57 (silt from SC10 to S12) at the DMPA (10:24 to 10:34).
04/05/2021 10:05	Sentinel-3	Good clear image free of clouds. At this time the TSHD Brisbane was dredging load 67 (sand and silt from CS3 to CS5) with dredging having started at 09:19 and finishing at 10:13.
04/05/2021 10:47	Sentinel-2	Good clear image free of clouds. At this time the TSHD Brisbane was steaming to the DMPA to place load 67.
05/05/2021 10:17	Sentinel-3	Good clear image free of clouds. At this time the TSHD Brisbane was steaming away from the DMPA having placed load 75 (silt from SC2 to SC4) at 9:36 to 9:43.
06/05/2021 09:51	Sentinel-3	Good clear image free of clouds. At this time the TSHD Brisbane was steaming away from the DMPA having placed load 82 (silt from SC14 to SC16) at 8:19 to 8:28.
07/05/2021 10:23	Sentinel-3	Good clear image free of clouds. At this time the TSHD Brisbane was steaming away from the DMPA having placed load 91 (silt from SC8 to SC10) at 09:44 to 09:51.

Date and Time	Satellite Name	Details
07/05/2021 10:57	Sentinel-2	Good clear image free of clouds, image excludes Inner Harbour area. At this time the TSHD Brisbane was dredging load 92 (silt from SC10 to SC12), with dredging having started at 10:46.
08/05/2021 10:00	Sentinel-3	Good clear image free of clouds. At this time the TSHD was in transit to the DMPA having finished dredging load 98 (sand and silt from CN5) at 9:10.
09/05/2021 10:14	Sentinel-3	Moderate cloud cover offshore.
09/05/2021 10:47	Sentinel-2	Patchy clouds over offshore area. At this time the TSHD was in transit to the DMPA having finished dredging load 105 (sand and silt from CS3 to CS5) at 09:22.
10/05/2021 09:48	Sentinel-3	Full cloud cover.
10/05/2021 10:39	Landsat-8	Moderate cloud cover offshore. At this time the TSHD Brisbane was dredging load 115 (at Lorim Point), with dredging having started at 10:10.
12/05/2021 09:57	Sentinel-3	Moderate cloud cover over Inner Harbour area.
12/05/2021 10:57	Sentinel-2	Patchy clouds over offshore area, image excludes Inner Harbour area. At this time the TSHD Brisbane was dredging load 133 (silt and sand from SC4 to SC6), with dredging having started at 10:50.
13/05/2021 10:10	Sentinel-3	Good clear image free of clouds. The TSHD Brisbane was delayed at this time (07:45 to 15:13).
14/05/2021 10:47	Sentinel-2	Good clear image free of clouds. At this time the TSHD was in transit from the DMPA having placed load 146 (silt from SC14 to SC16) at 08:57 to 09:05.
15/05/2021 10:16	Sentinel-3	Good clear image free of clouds. At this time the TSHD Brisbane was dredging load 156 (sand from SC17 to SC21) having started at 08:55.
16/05/2021 09:53	Sentinel-3	Good clear image free of clouds. At this time the TSHD Brisbane was placing load 163 (silt from SC12 to SC14) at the DMPA (09:43 to 09:57).
17/05/2021 10:07	Sentinel-3	Good clear image free of clouds. At this time the TSHD Brisbane was in transit from the DMPA having placed load 171 (silt from SC12 to SC14) at 09:31 to 09:43.
17/05/2021 10:57	Sentinel-2	Good clear image free of clouds, image excludes Inner Harbour area. At this time the TSHD Brisbane was still in transit after placing load 171.

Table 7. Available satellite images for the post-dredging monitoring period.

Date and Time	Satellite Name	Details
19/05/2021 10:16	Sentinel-3	High levels of cloud cover.
19/05/2021 10:47	Sentinel-2	High levels of cloud cover.
20/05/2021 09:49	Sentinel-3	Moderate cloud cover, image excludes Inner Harbour area.
21/05/2021 10:02	Sentinel-3	Some clouds obscuring parts of image.
22/05/2021 10:57	Sentinel-2	Moderate cloud cover, image excludes Inner Harbour area.
23/05/2021 10:12	Sentinel-3	Good clear image free of clouds.
24/05/2021 10:22	Sentinel-3	High levels of cloud cover.
25/05/2021 09:59	Sentinel-3	Good clear image free from clouds.
26/05/2021 10:31	Sentinel-3	Good clear image free from clouds. Image not included (higher resolution from Landsat-8 available).
26/05/2021 10:39	Landsat-8	Good clear image free from clouds.
27/05/2021 10:08	Sentinel-3	Patchy cloud obscuring image.
27/05/2021 10:57	Sentinel-2	Good clear image free of clouds, image excludes Inner Harbour area.
28/05/2021 10:18	Sentinel-3	Good clear image free of clouds.
29/05/2021 09:55	Sentinel-3	Good clear image free of clouds.
30/05/2021 10:27	Sentinel-3	Good clear image free of clouds.
31/05/2021 10:04	Sentinel-3	Good clear image free of clouds.
01/06/2021 10:17	Sentinel-3	Good clear image free from clouds. Image not included (higher resolution from Sentinel-2 available).
01/06/2021 10:57	Sentinel-2	Patchy cloud cover, image excludes Inner Harbour area.
02/06/2021 09:52	Sentinel-3	High levels of cloud cover.

4.2.1. Data Validation

To provide an understanding of the accuracy of the values from the satellite-derived TSM data, a validation process has been undertaken. Over the 50 day monitoring period associated with the 2021 maintenance dredging program satellite derived TSM data (in mg/l) have been compared with the in-situ benthic suspended sediment concentration (SSC) data (in mg/l) derived based on the turbidity data measured by the JCU loggers at WQ1 and WQ2. Data from WQ4 was not included to avoid skewing the analysis (since the logger was found to be affected by localised near-bed processes causing high turbidity during some stages of the tide which are not evident in the satellite derived TSM). The in-situ SSC data were calculated by JCU by applying site specific turbidity to SSC correlations which were developed based on previous measurements and processed water samples. Data were only compared when measurements from both methods were available at the site at the same time. This meant that the number of comparative data points available for the correlation varied between the two sites, with the most data at WQ2 as all satellite images covered this area, while only every other image covered the Inner Harbour area. Only data collected at WQ2 before the 19th May 2021 were included, since data collected at the logger after this time were erroneous. The satellite imagery shows additional evidence that the data over the post dredge period were erroneous as the imagery showed no notable increases in turbidity at WQ2 (while the erroneous data showed consistent peaks in turbidity of more than 100 NTU).

The correlation between the satellite derived TSM data from Sentinel-2 and the in-situ benthic logger SSC data over the 2021 maintenance dredging monitoring period is shown in Figure 8. The correlation shows the following:

- the satellite derived TSM and in-situ SSC values are typically low, for the most part being less than 10 mg/l;
- there is a good degree of correlation between the satellite derived TSM and in-situ SSC data (with an r^2 of 0.86) indicating that the satellite derived TSM from Sentinel-2 can be used to provide a reliable representation of the benthic in-situ measured SSC data at the WQ1 and WQ2 monitoring sites; and
- the fact that it is possible to develop a fit to the data which is close to a 1:1 fit suggests that the concentrations close to the bed can be considered to be representative of the depth-averaged concentrations through the water column (which is what the satellite measures). This is not surprising given the relatively shallow depth at the measurement sites (between 4 and 5 m below MSL).

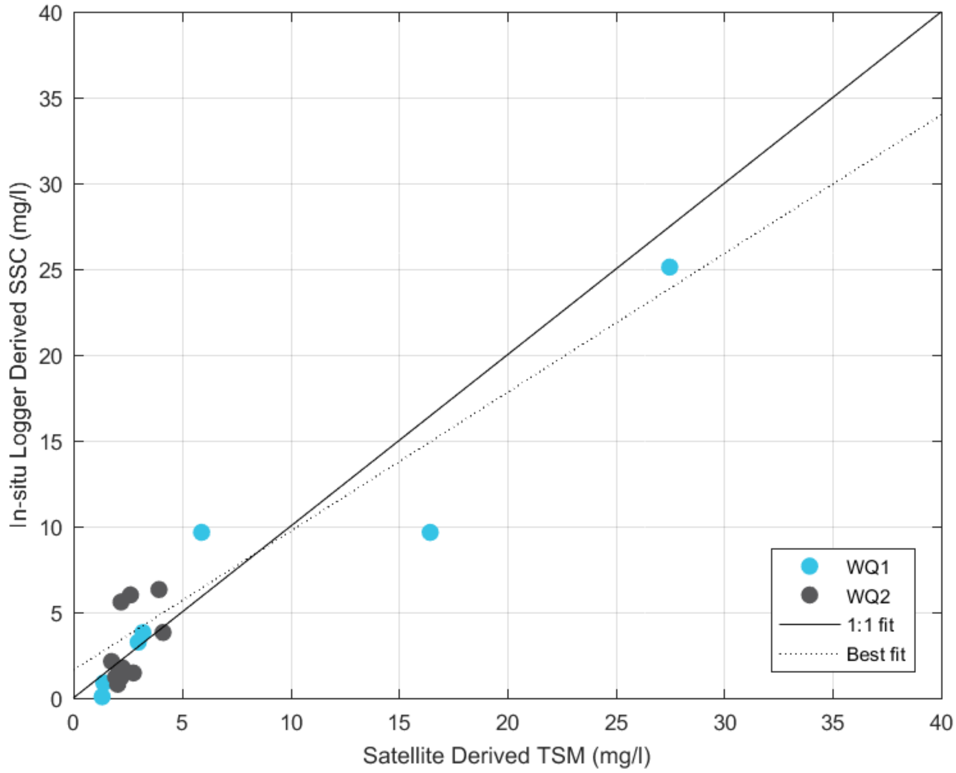


Figure 8. Correlation between satellite derived TSM from Sentinel-2 and in-situ logger derived SSC over the 2021 maintenance dredge monitoring period.

As a further check, comparisons of satellite derived TSM from the different satellite platforms was undertaken using images captured at similar times. Images from Sentinel-2 and Sentinel-3 on the 14th April 2021 and the 7th May 2021 are compared in Figure 9 and Figure 10 and images from Landsat-8 and Sentinel-3 on the 24th April 2021 are compared in Figure 11. Satellite derived turbidity from the Sentinel-3 platform was validated ahead of undertaking this comparison[4]. In general, the agreement between the three satellite platforms is good with all three showing broadly similar values and patterns. However, the Sentinel-3 turbidity close to land is higher than that from the higher resolution platforms. This is an artefact of the coarser resolution of the Sentinel-3 sensor (with cells partially covered by dry land or very shallow areas where the seabed is visible returning an artificially higher TSM value). In addition, during periods of higher turbidity the TSM derived from the Sentinel-3 platform is elevated relative to the TSM derived from the Sentinel-2 platform. The validated TSM derived from the Sentinel-2 platform is considered to provide the most reliable indication of the in-situ SSC and as a result of this along with the high spatial resolution of the Sentinel-2 imagery (10 m) it is suggested that imagery from this sensor should be the preferred imagery for any future adaptive management associated with maintenance dredging.

[4] Sentinel-3 images provided in the daily updates had not been validated and showed turbidity values that were higher than those shown here.

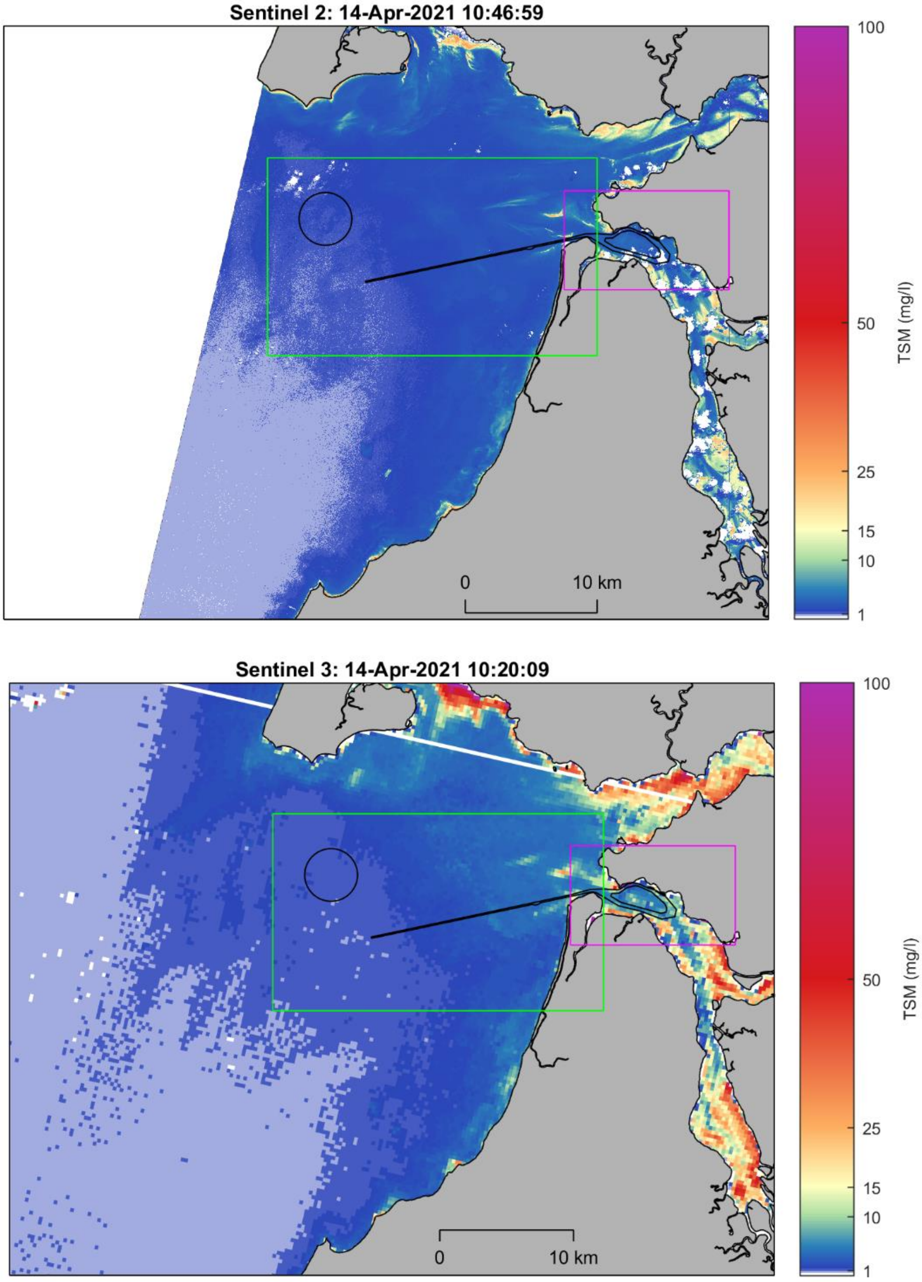


Figure 9. Comparison of Sentinel 2 and Sentinel 3 satellite derived turbidity on the 14th April 2021.

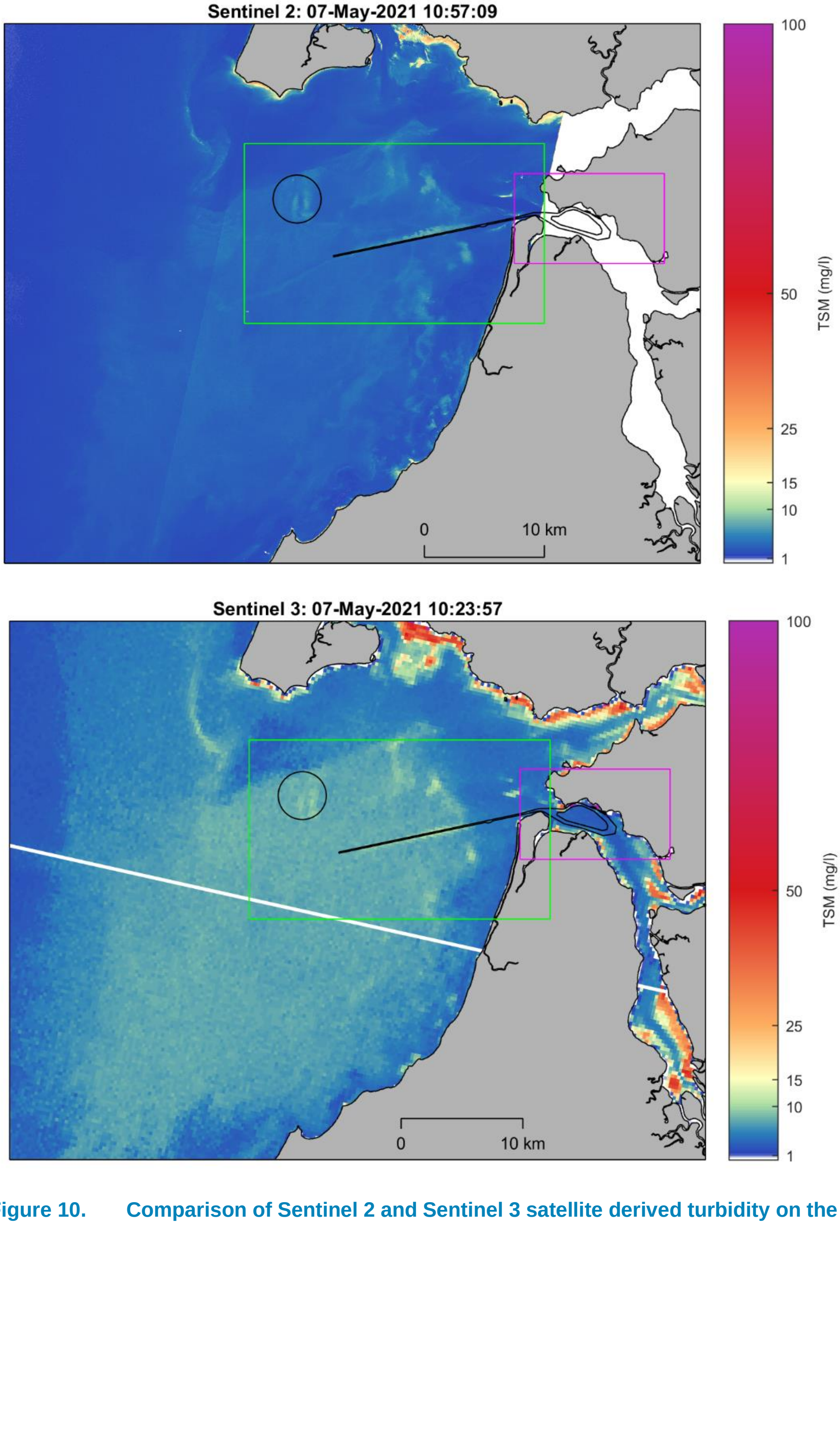


Figure 10. Comparison of Sentinel 2 and Sentinel 3 satellite derived turbidity on the 7th May 2021.

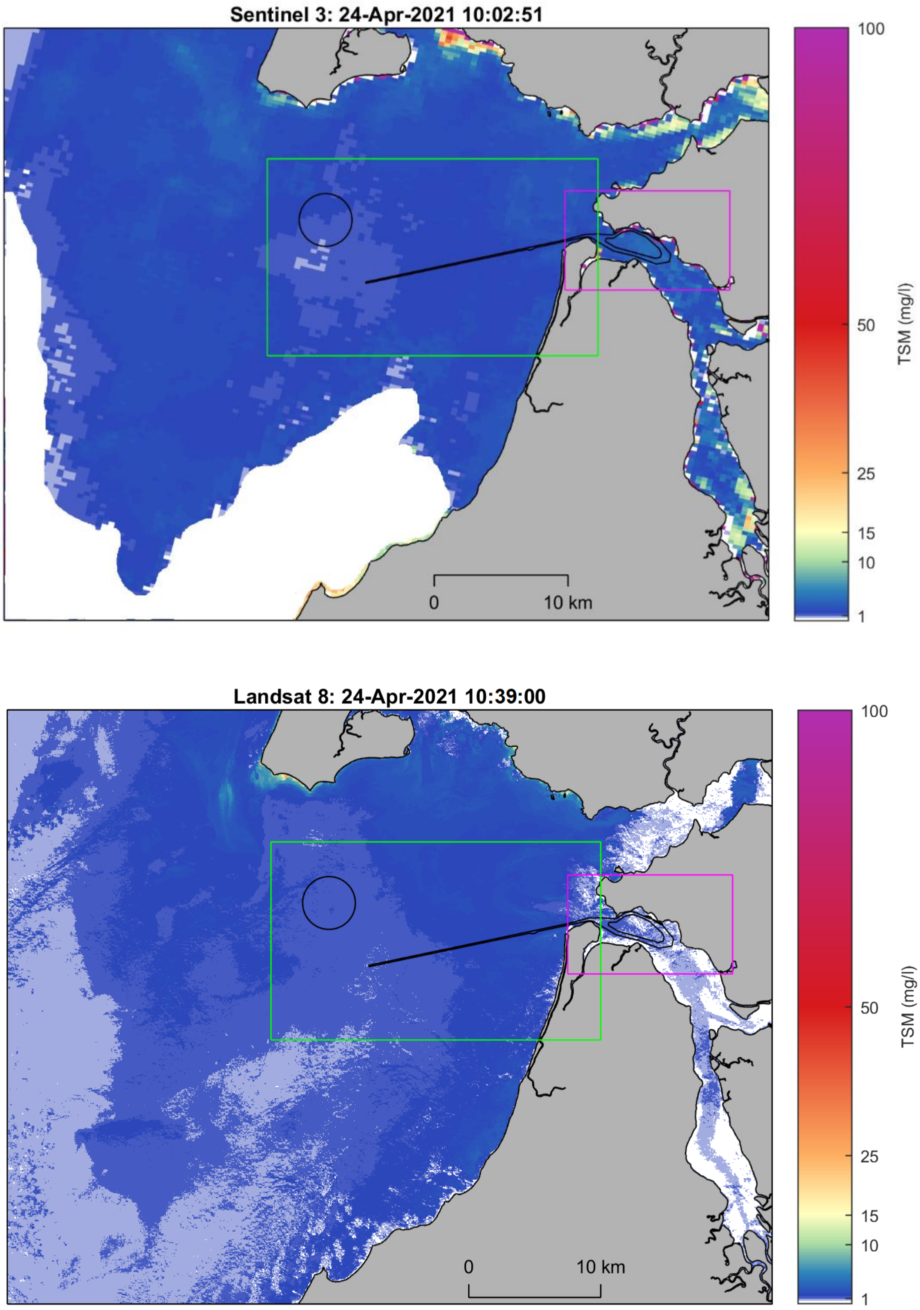


Figure 11. Comparison of Sentinel 3 and Landsat-8 satellite derived turbidity on the 24th April 2021.

4.2.2. Turbidity Analysis

To provide an understanding of natural turbidity levels within the study area and to identify the extent of potential increases in turbidity due to the 2021 maintenance dredging program, the turbidity analysis was undertaken at three different spatial scales, namely:

- regional (Albatross Bay region);
- local (Port of Weipa); and
- dredge vessel (in close proximity to the TSHD Brisbane).

4.2.2.1. Regional Scale

To provide an understanding of how the turbidity in Albatross Bay varied over the 2021 Maintenance Dredging Program, plots of the satellite-derived TSM in the Albatross Bay region for the usable satellite images are shown in Figure 12 to Figure 51. The plots show the following:

- Pre-Dredging: the pre-dredging images (Figure 12 to Figure 19) show that TSM throughout the majority of Albatross Bay was relatively low (less than 10 mg/l, equivalent to approximately 7 NTU), which corresponds to the calm metocean conditions over this period. While not captured by these images, pre-dredge images from the 2020 maintenance dredge (PCS, 2020b) showed that areas with elevated TSM of 10 to over 25 mg/l can naturally occur throughout Albatross Bay and in the adjacent estuaries, with the potential for localised areas of elevated TSM in the region of the South Channel and Albatross Bay DMPA during periods of enhanced tidal flows and/or wave activity;
- During Dredging: Higher TSM of more than 15 mg/l (approximately 11 NTU) did occur in the shallow areas of Albatross Bay and in the adjacent estuaries in the images captured during the dredge period (Figure 20 to Figure 41). For example, elevated TSM was widely visible in the shallow areas of the estuaries on the 29th April 2021 (Figure 20). The TSHD Brisbane was not operating at the time this image was captured (with placement at the DMPA having occurred four hours before the time of the image and with dredging at SC6 to SC8 having finished more than five hours before the time of the image). This image was captured on the ebb stage of a large spring tide and it is therefore likely that tidal flows naturally resuspended sediments across the shallower areas during this period.

  The imagery has also shown plumes with TSM of up to 15 mg/l (approximately 11 NTU) and spatial extents of kilometres around the South Channel and DMPA most notable towards the end of the dredge period. Based on the spatial extent of the plumes, the metocean conditions and dredge activity the plumes are considered to be predominantly due to natural processes.

  Despite the validation of the Sentinel-3 TSM, it is apparent that during times of elevated TSM, the TSM from the Sentinel-3 is high relative to that from the Sentinel-2 and Landsat-8 sensors (for example on the 17th May 2021 the offshore TSM from the Sentinel-2 sensor (Figure 41) was less than 10 mg/l, while from Sentinel-3 (Figure 40) it was more than 15 mg/l). Despite this difference, the patterns of TSM are consistent between the different sensors; and
- Post-Dredging: the post dredging images (Figure 42 to Figure 51) show that TSM in Albatross Bay did not change significantly during the first week of the post dredge period, generally remaining low throughout much of Albatross Bay. Some localised plumes are present in the DMPA on the high resolution images on the 26th and 27th May 2021 (Figure 45 and Figure 46), however taking account of the tidal state at the time of image capture (late ebb to low water) and the time since the last load was placed at the DMPA (more than one week) it is considered unlikely that these are a result of sediment placement activities at the DMPA. As the tidal ranges increase to spring tides approximately ten days post dredge, the TSM in Albatross Bay and the Inner Harbour also increased with values of more than 25 mg/l at the Harbour Entrance (and in the Estuaries) (Figure 47 to Figure 50), with natural processes dominating the observed TSM.

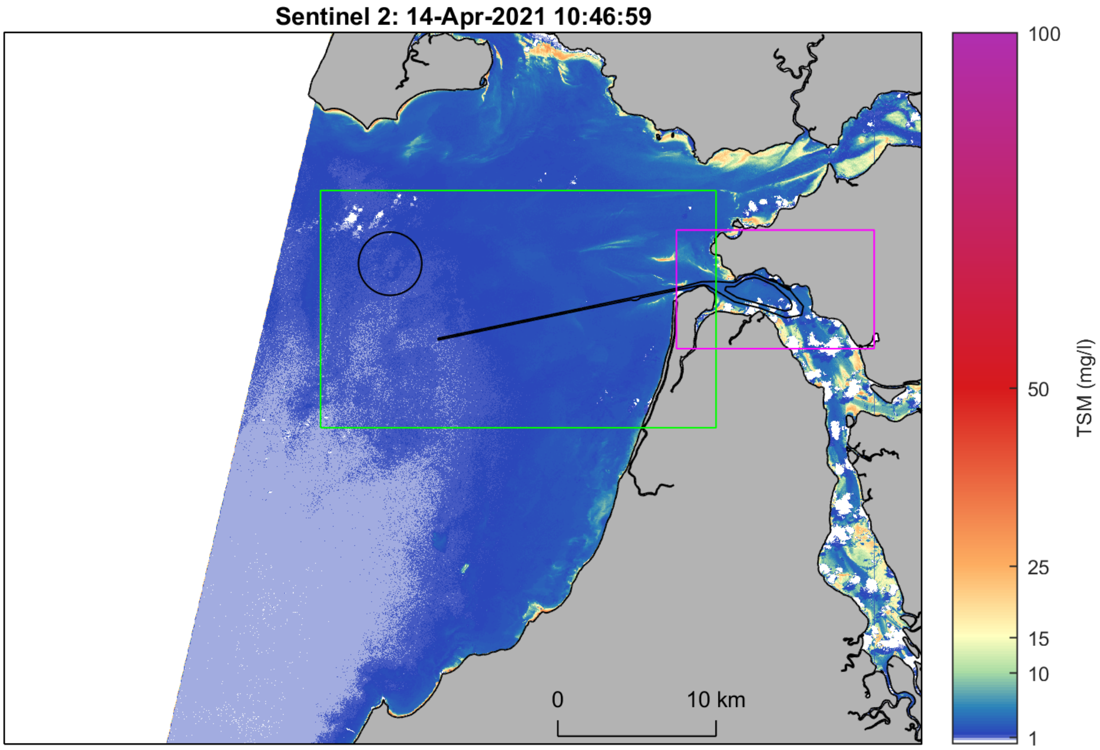


Figure 12. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 14/04/2021 at 10:57 AEST (pre-dredging).

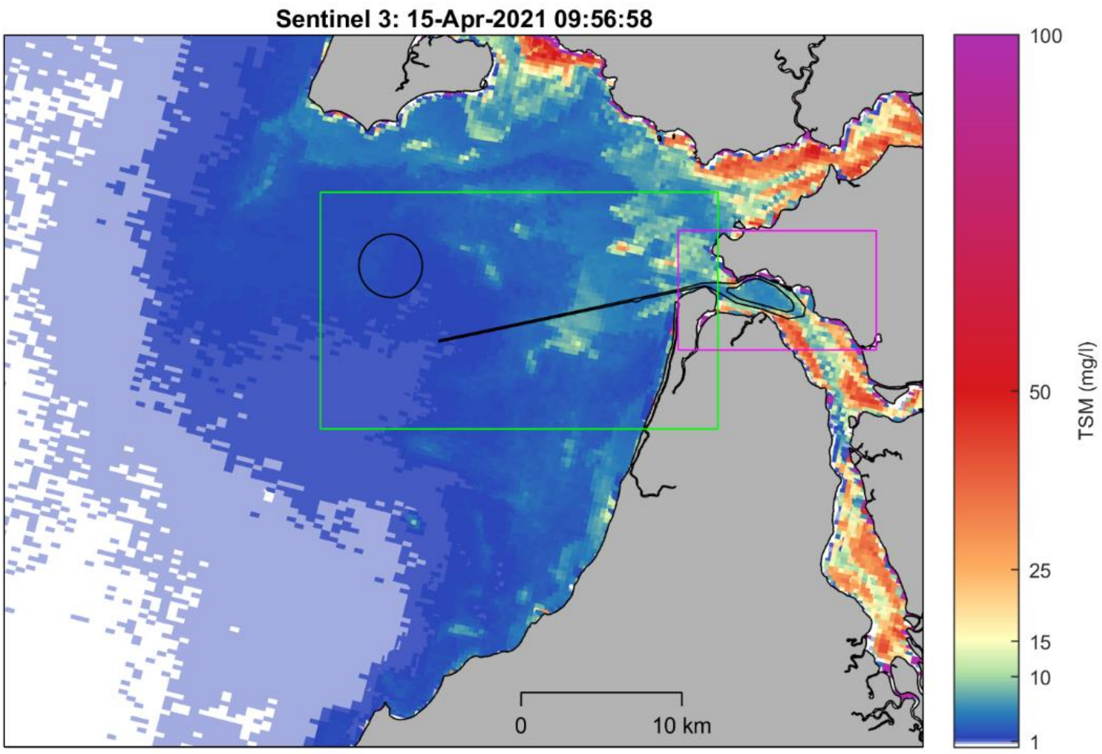


Figure 13. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 15/04/2021 at 09:56 AEST (pre-dredging).

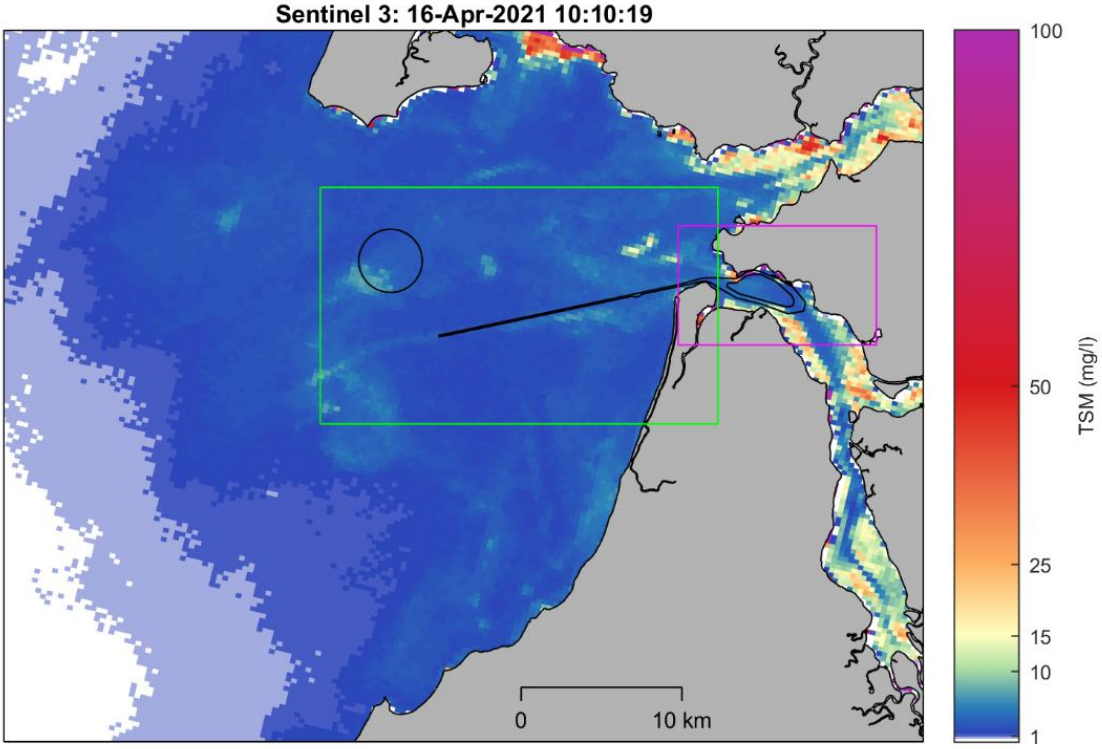


Figure 14. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 16/04/2021 at 10:10 AEST (pre-dredging).

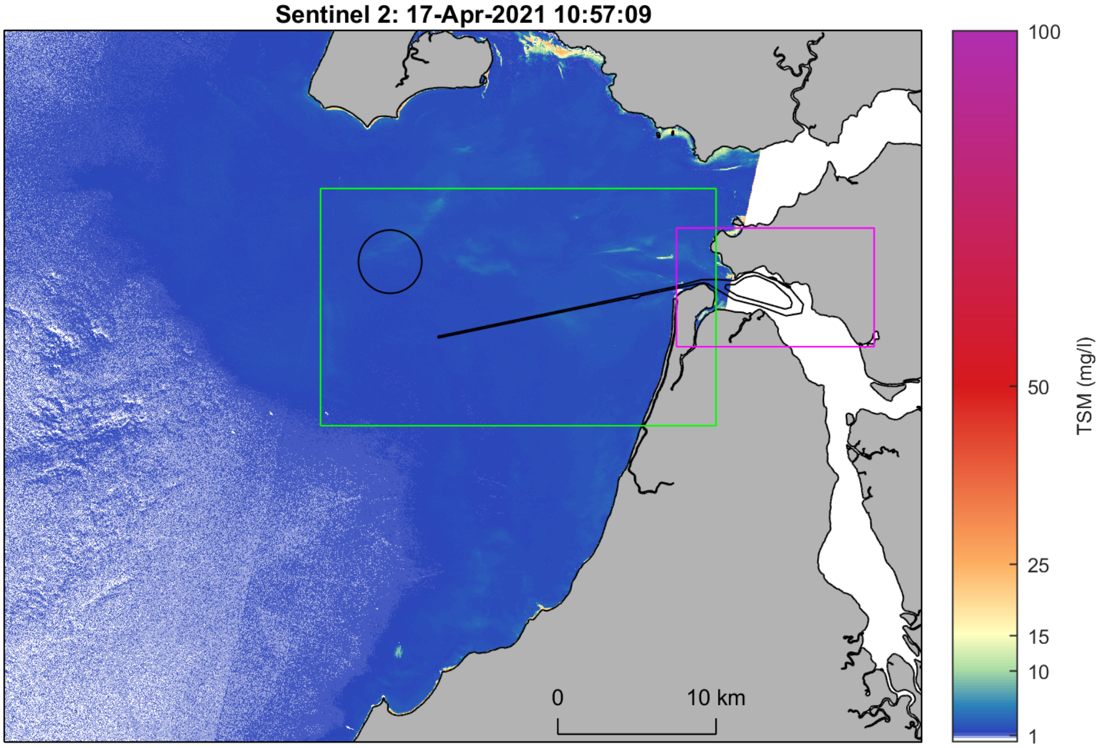


Figure 15. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 17/04/2021 at 10:57 AEST (pre-dredging).

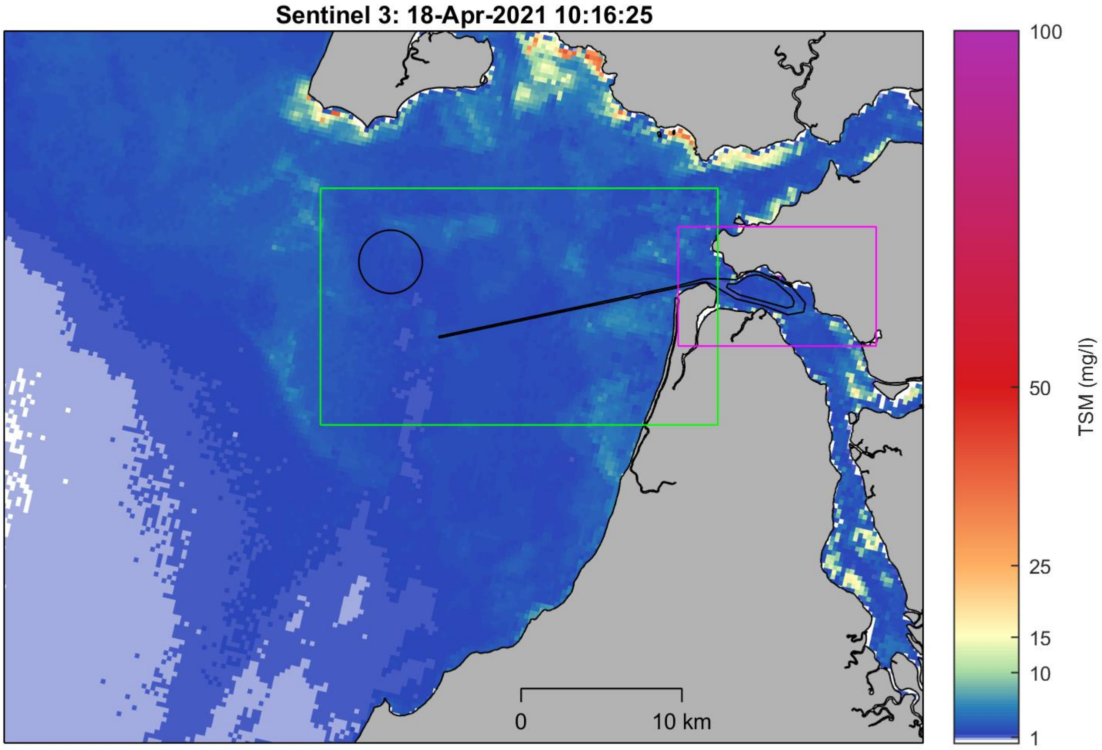
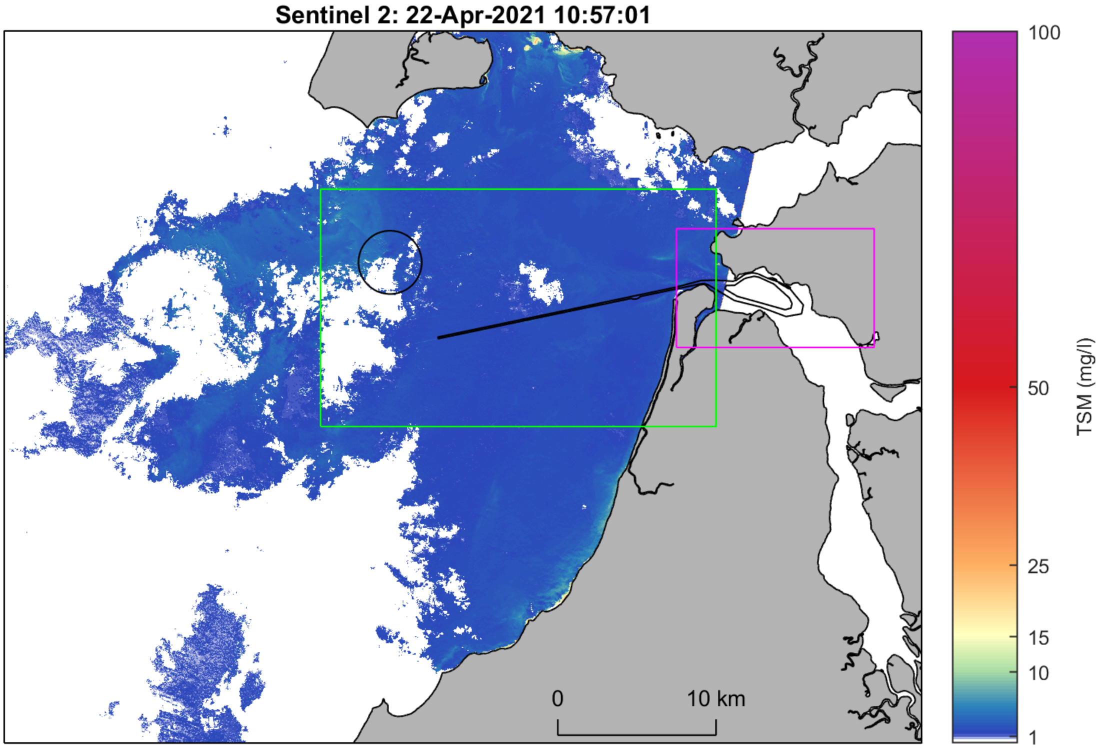


Figure 16. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 18/04/2021 at 10:16 AEST (pre-dredging).



Note: the white areas represent cloud cover.

Figure 17. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 22/04/2021 at 10:57 AEST (pre-dredging).

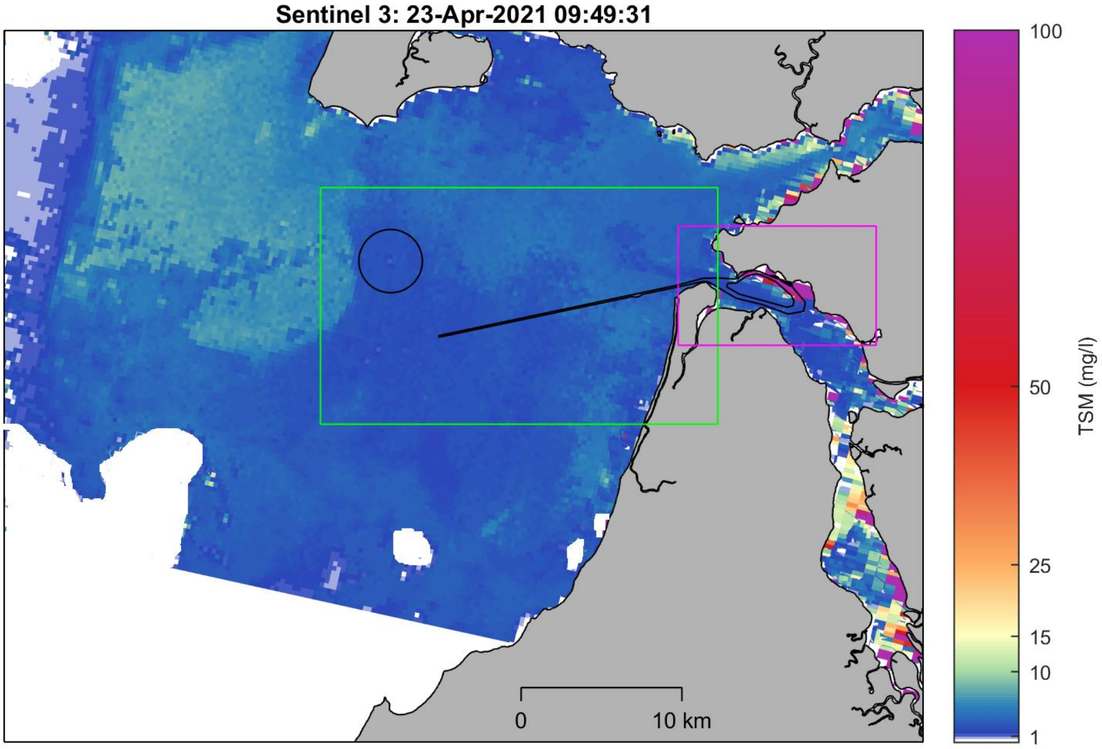


Figure 18. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 23/04/2021 at 09:49 AEST (pre-dredging).

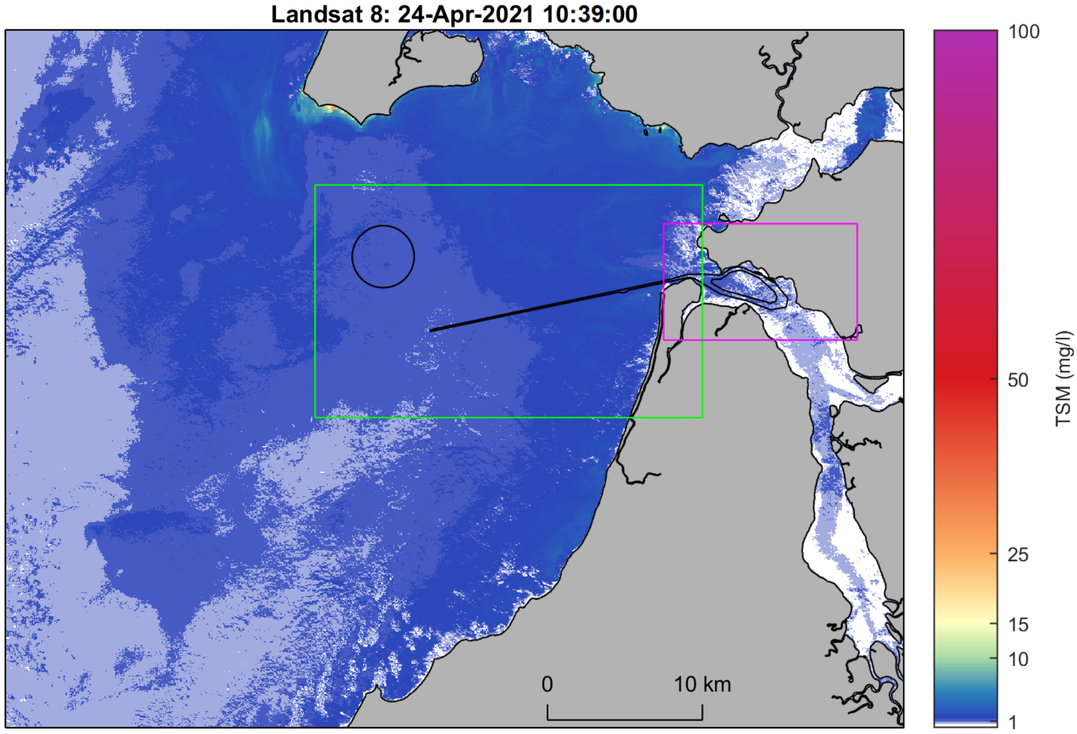


Figure 19. Satellite-derived turbidity from the Landsat-8 sensor for Albatross Bay on 24/04/2021 at 10:39 AEST (pre-dredging).

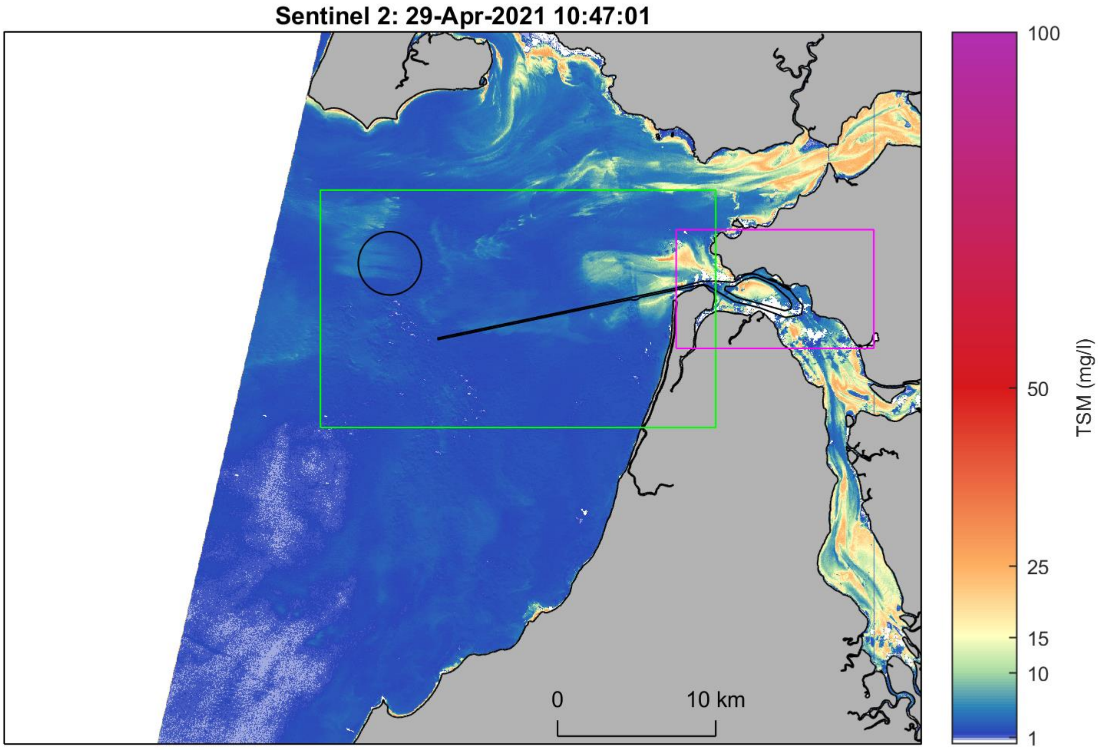


Figure 20. **Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 29/04/2021 at 10:47 AEST (dredging).**

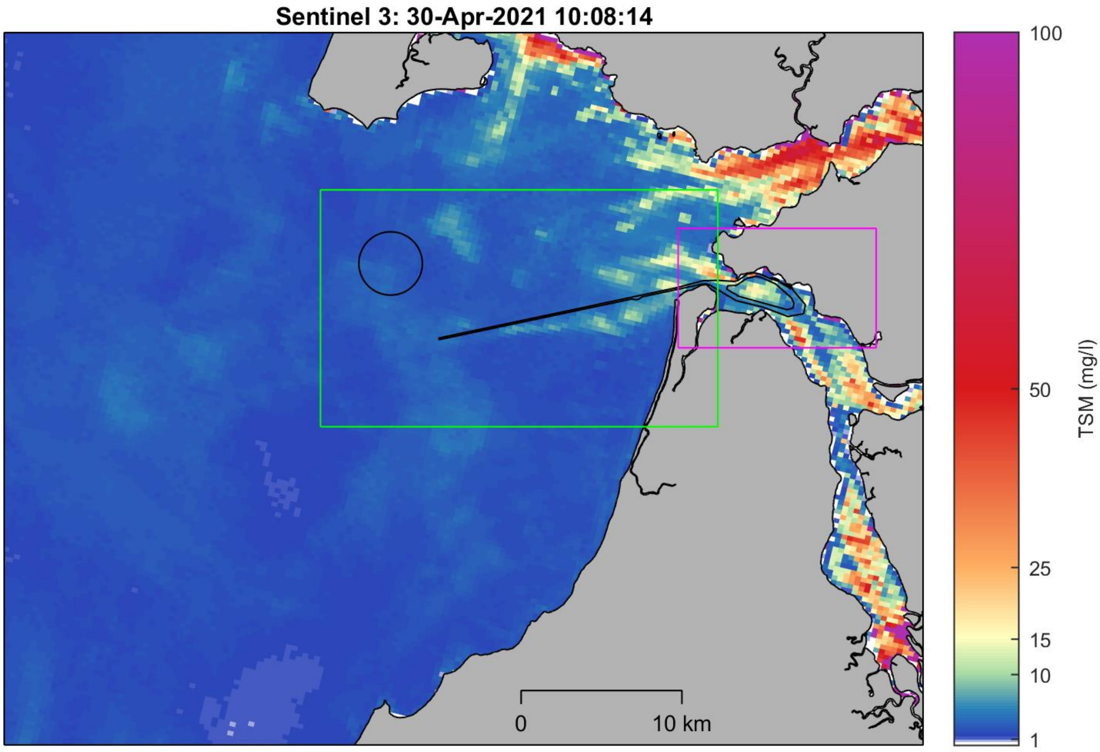


Figure 21. **Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 30/04/2021 at 10:08 AEST (dredging).**

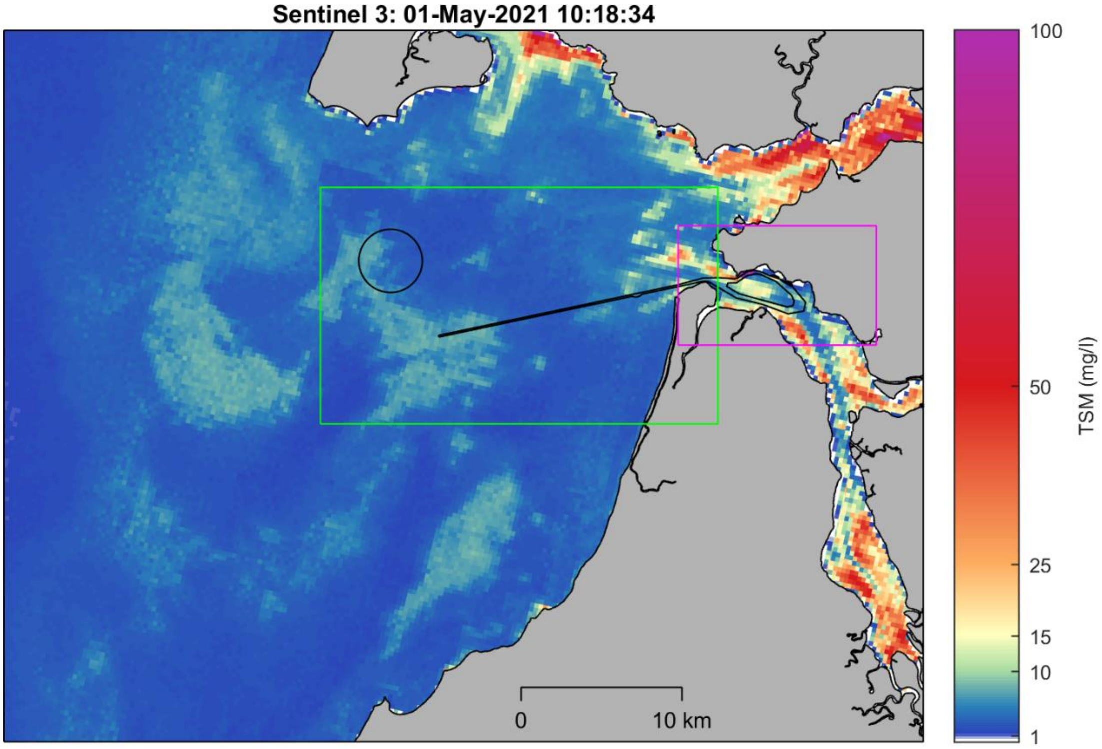


Figure 22. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 01/05/2021 at 10:18 AEST (dredging).

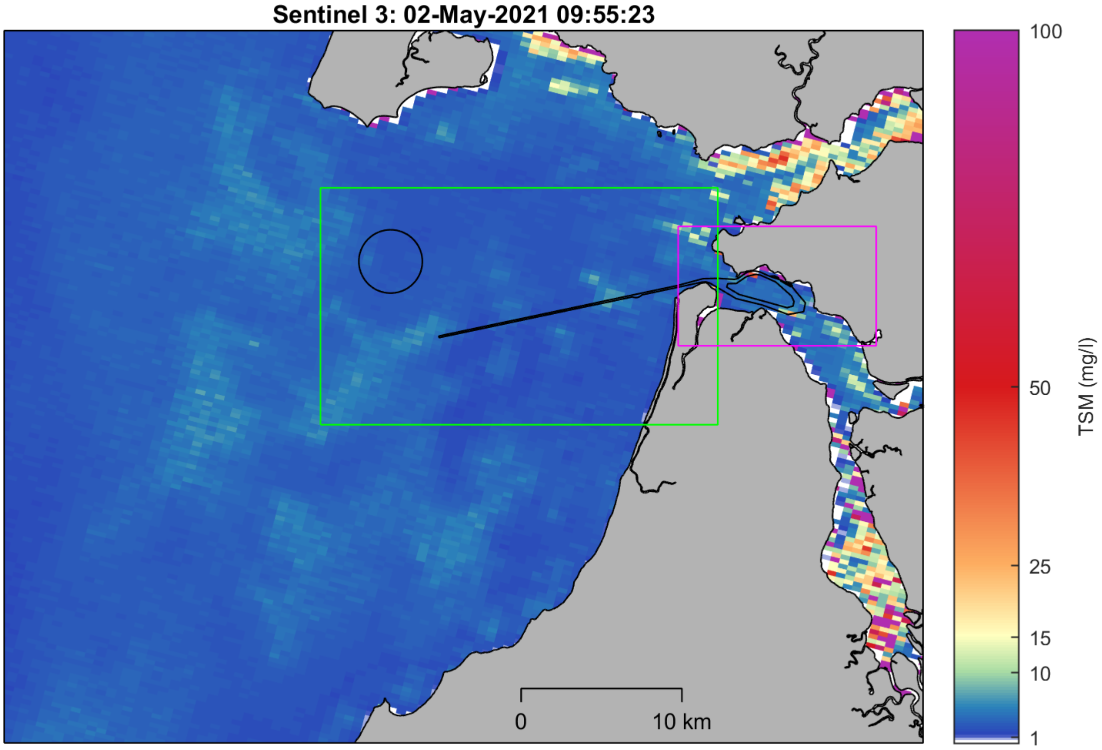


Figure 23. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 02/05/2021 at 9:55 AEST (dredging).

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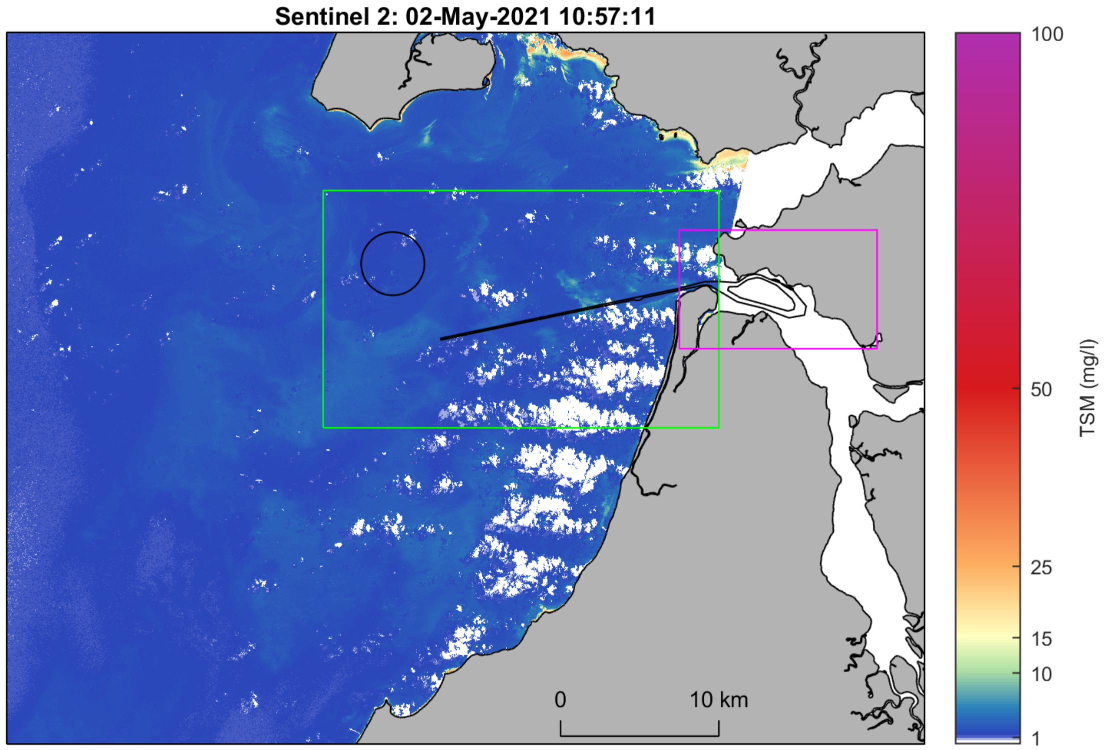


Figure 24. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 02/05/2021 at 10:57 AEST (dredging).

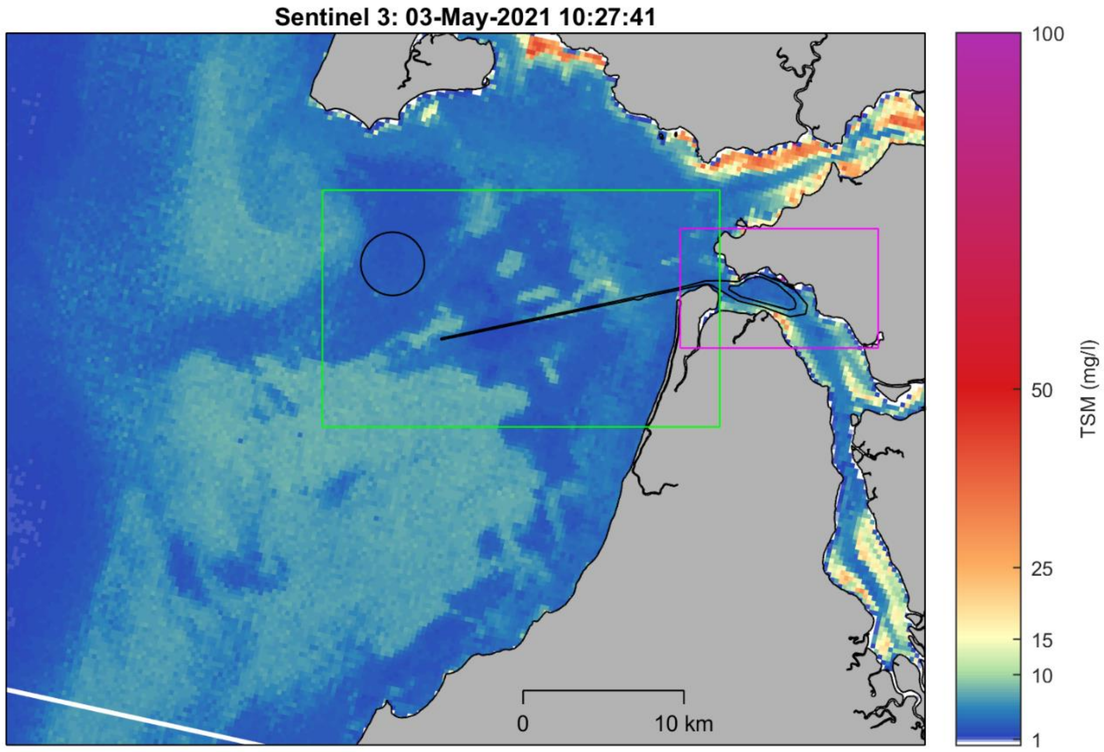


Figure 25. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 03/05/2021 at 10:27 AEST (dredging).

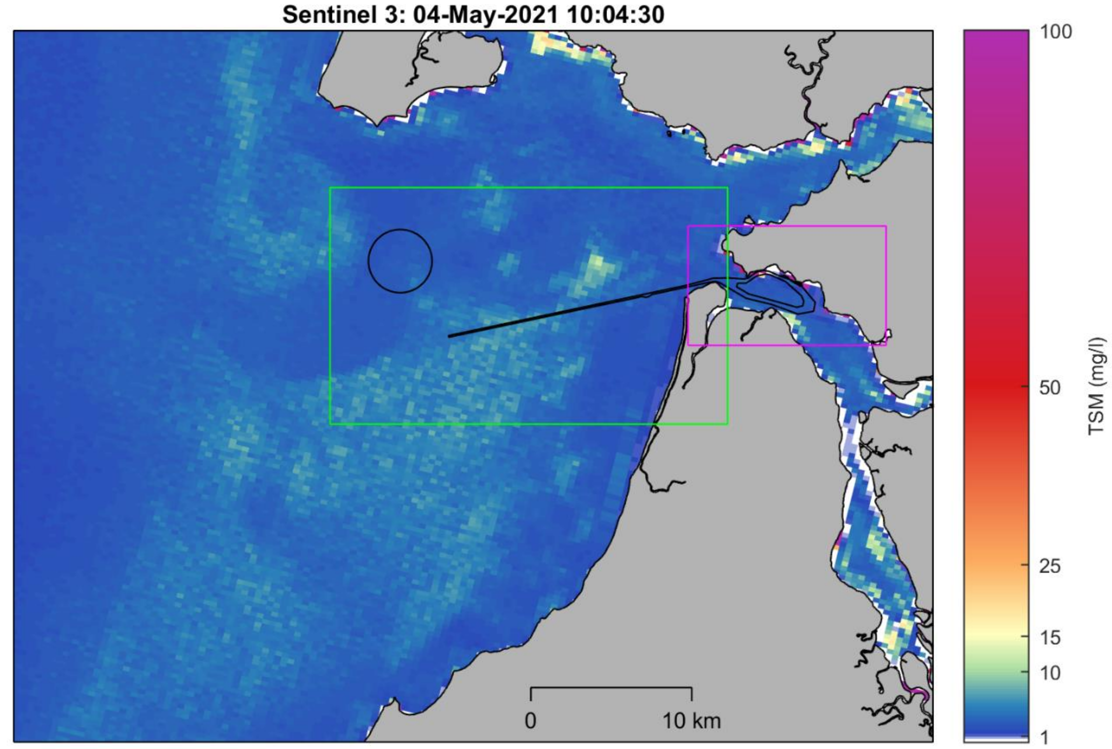


Figure 26. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 04/05/2021 at 10:05 AEST (dredging).

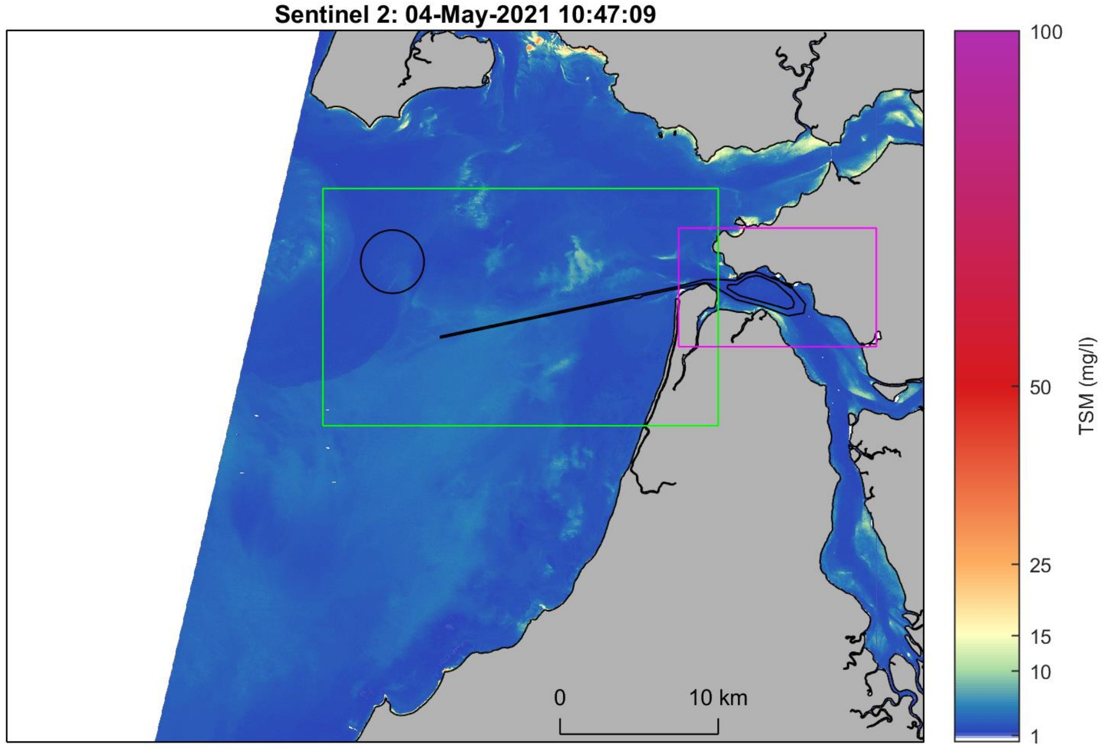


Figure 27. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 04/05/2021 at 10:47 AEST (dredging).

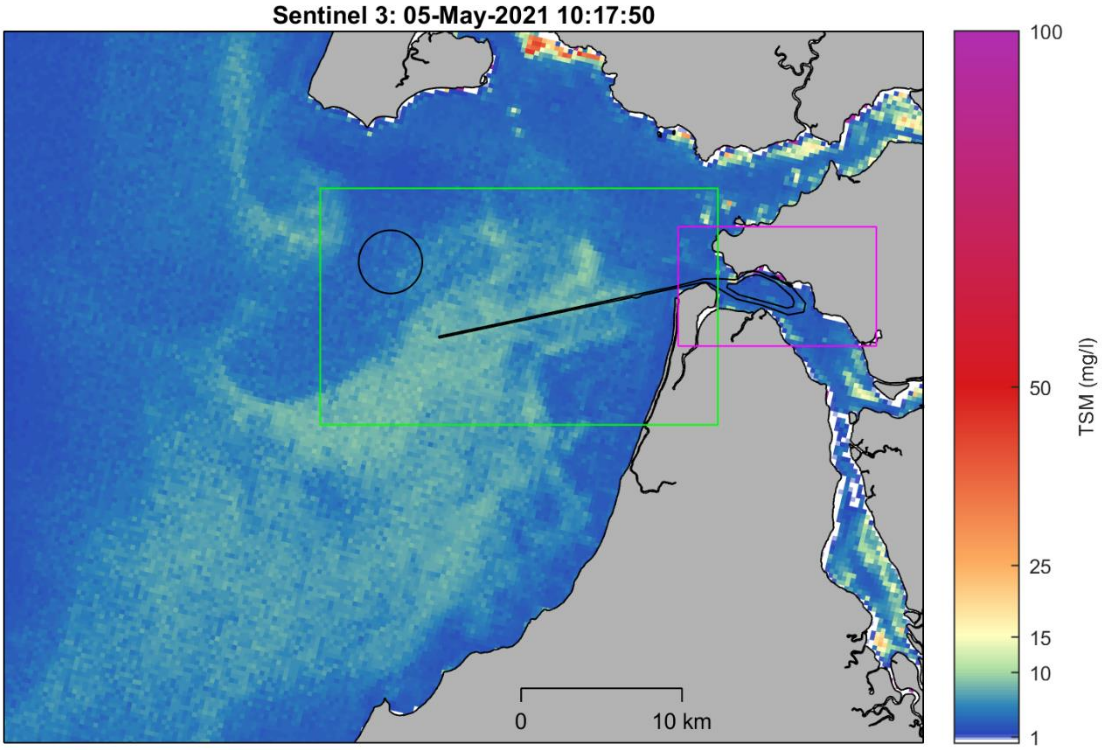


Figure 28. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 05/05/2021 at 10:17 AEST (dredging).

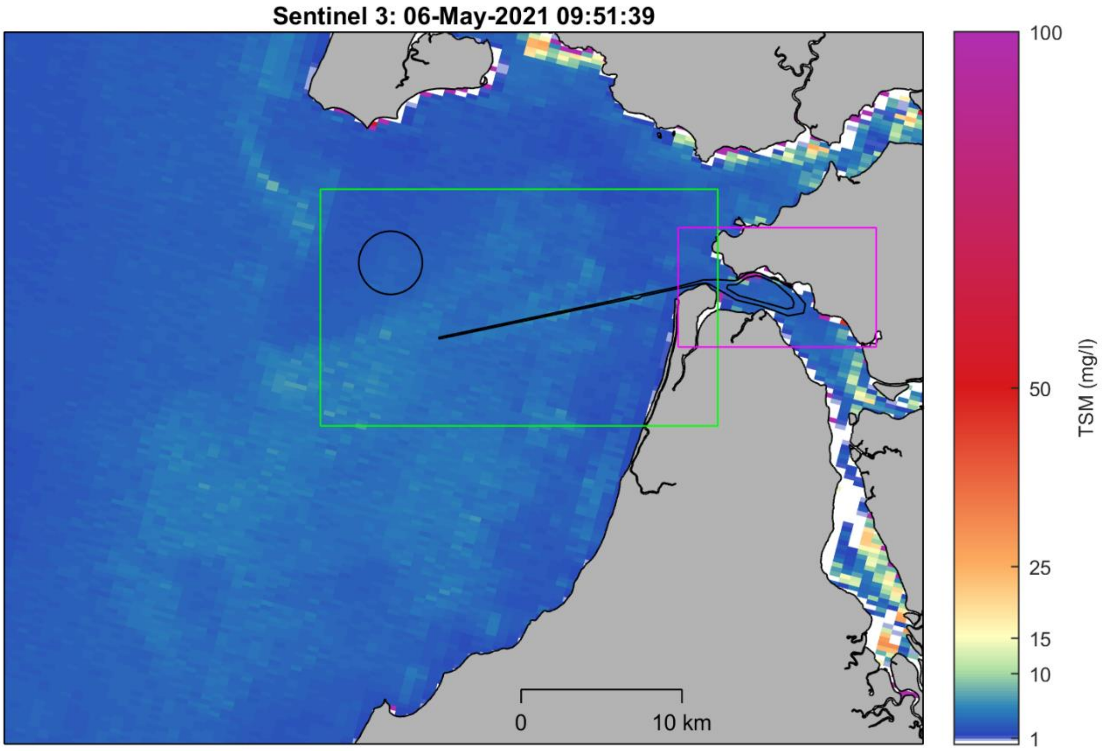


Figure 29. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 06/05/2021 at 9:51 AEST (dredging).

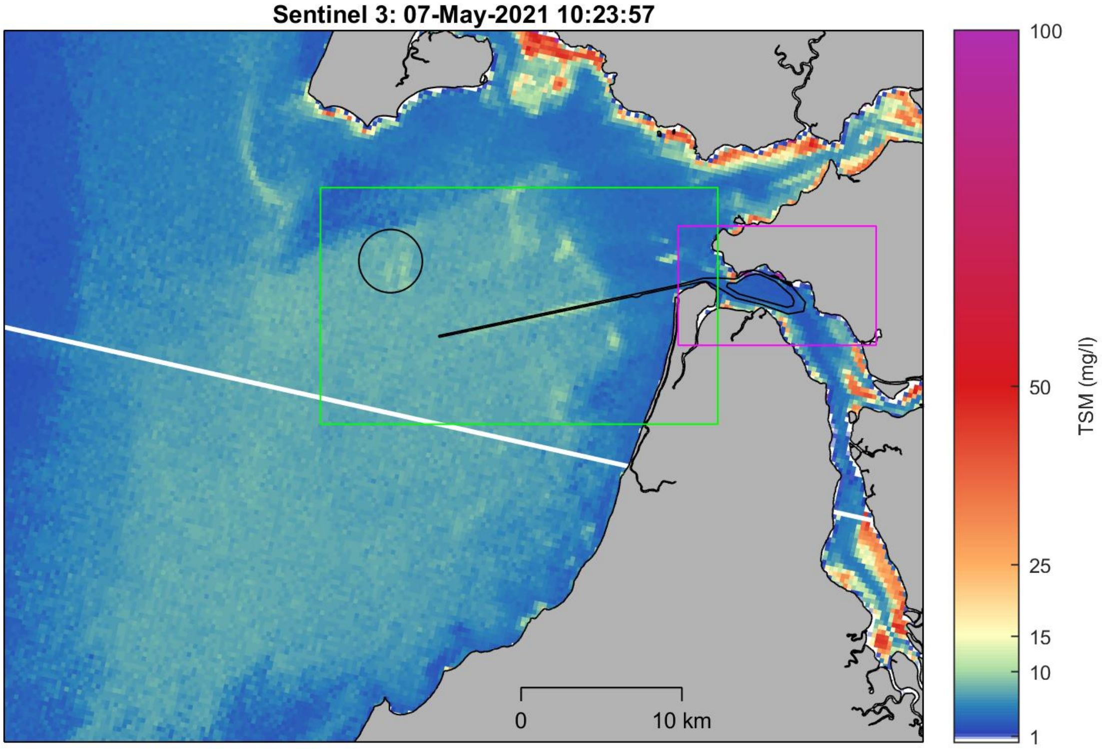


Figure 30. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 07/05/2021 at 10:23 AEST (dredging).

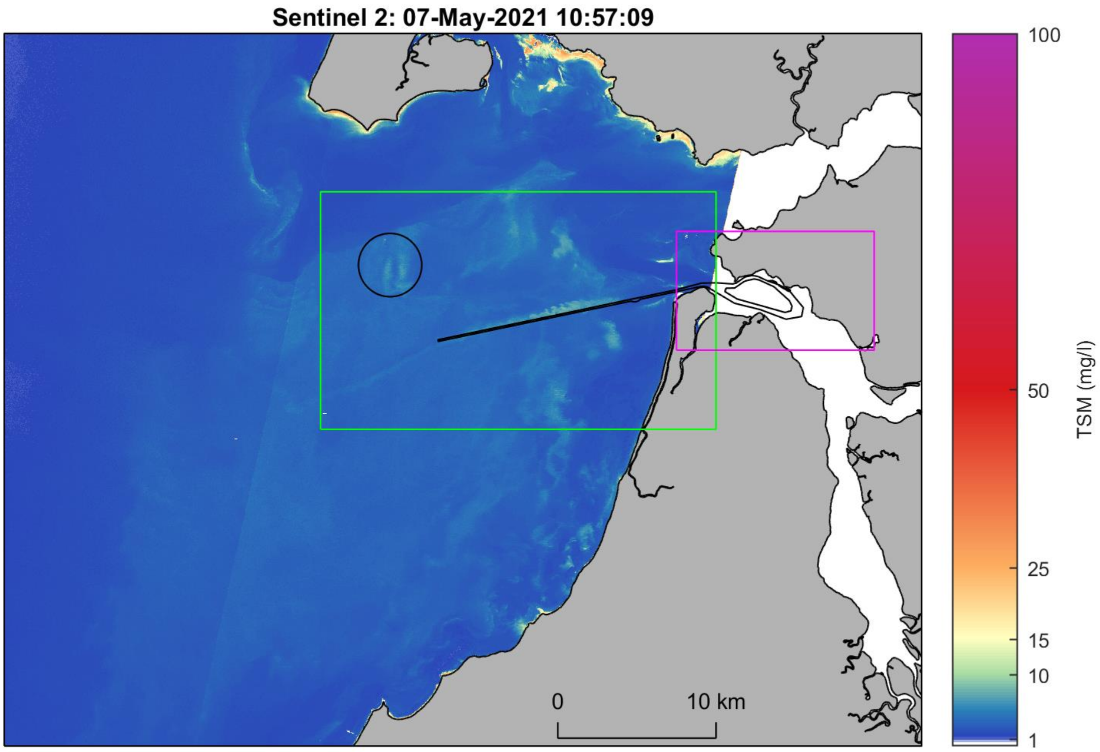


Figure 31. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 07/05/2021 at 10:57 AEST (dredging).

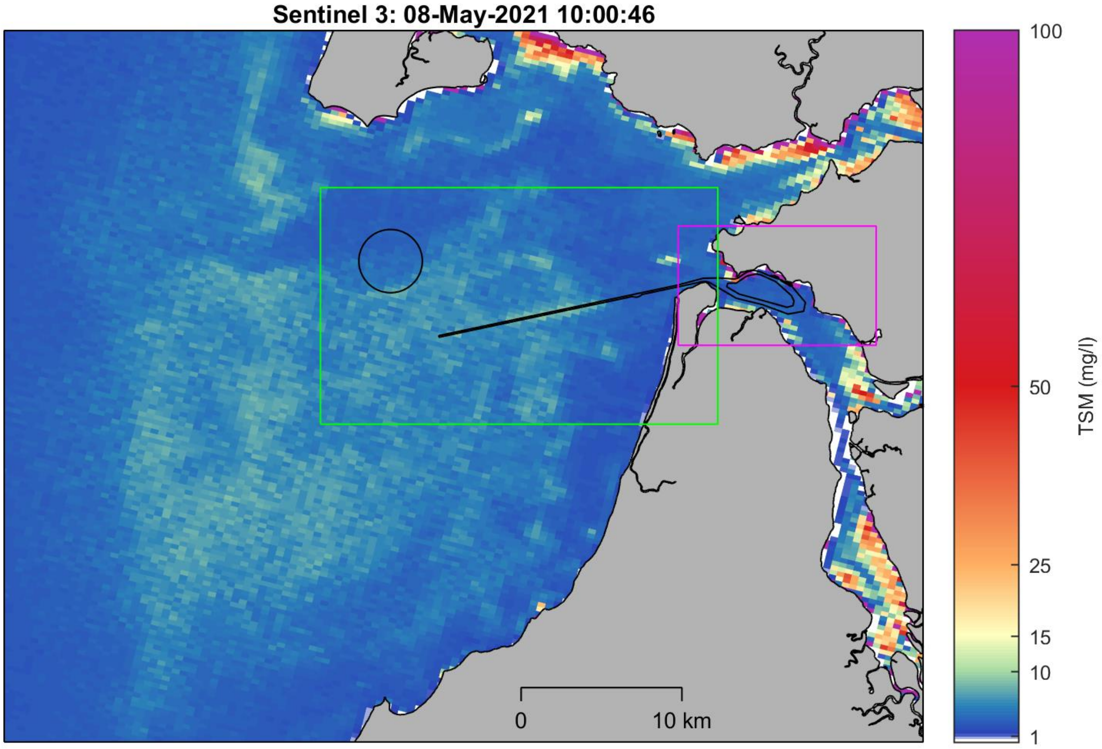


Figure 32. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 08/05/2021 at 10:00 AEST (dredging).

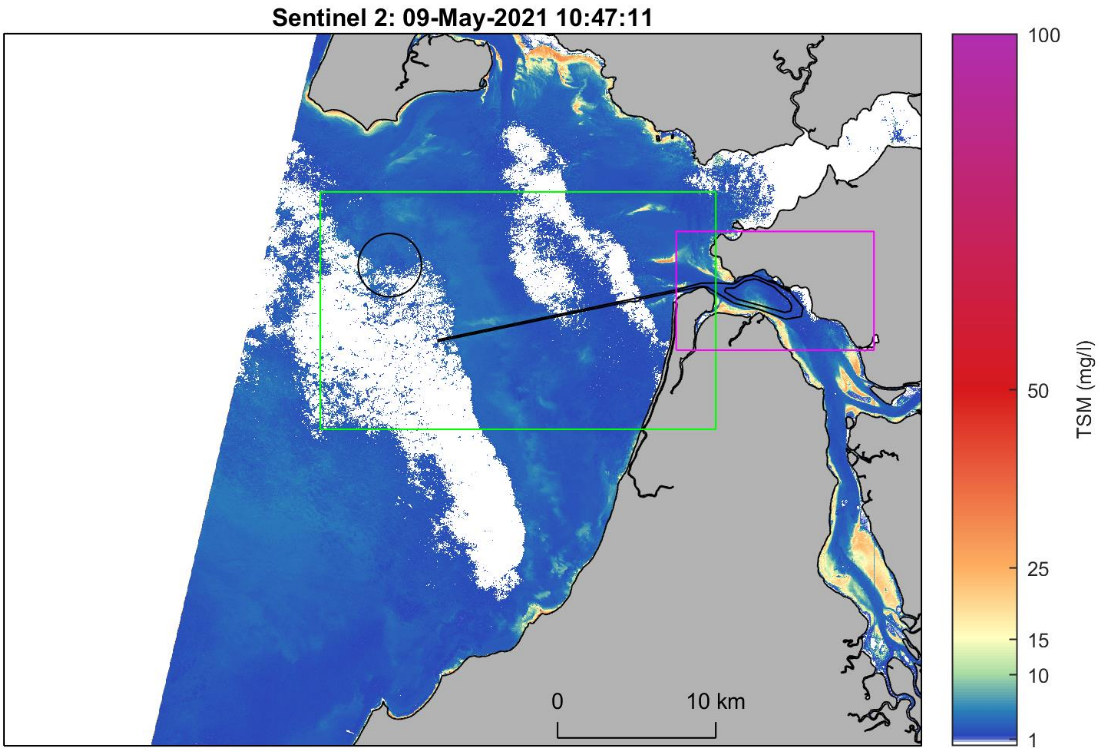


Figure 33. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 09/05/2021 at 10:47 AEST (dredging).

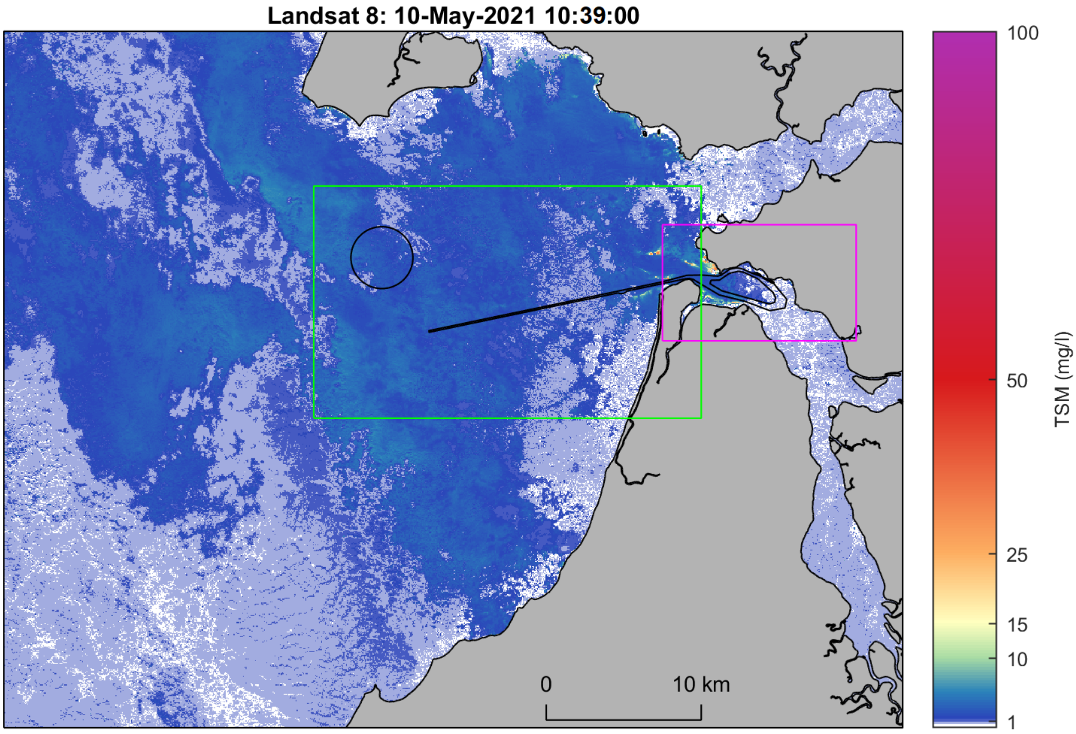


Figure 34. **Satellite-derived turbidity from the Landsat 8 sensor for Albatross Bay on 10/05/2021 at 10:39 AEST (dredging).**

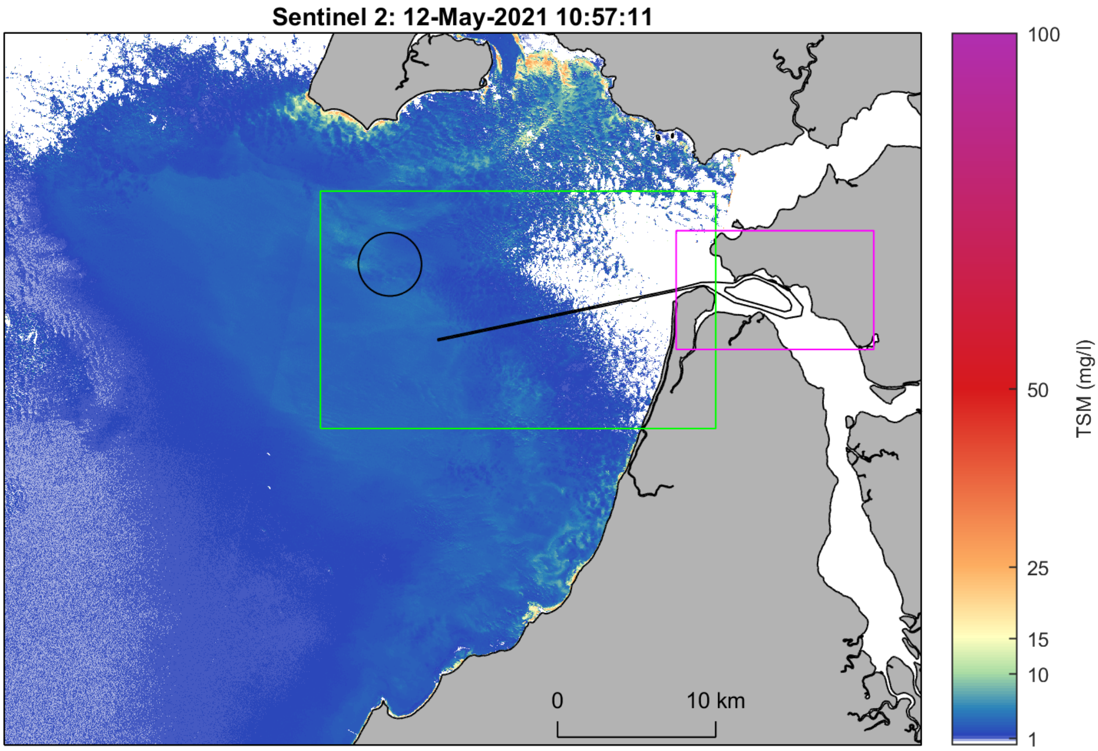


Figure 35. **Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 12/05/2021 at 10:57 AEST (dredging).**

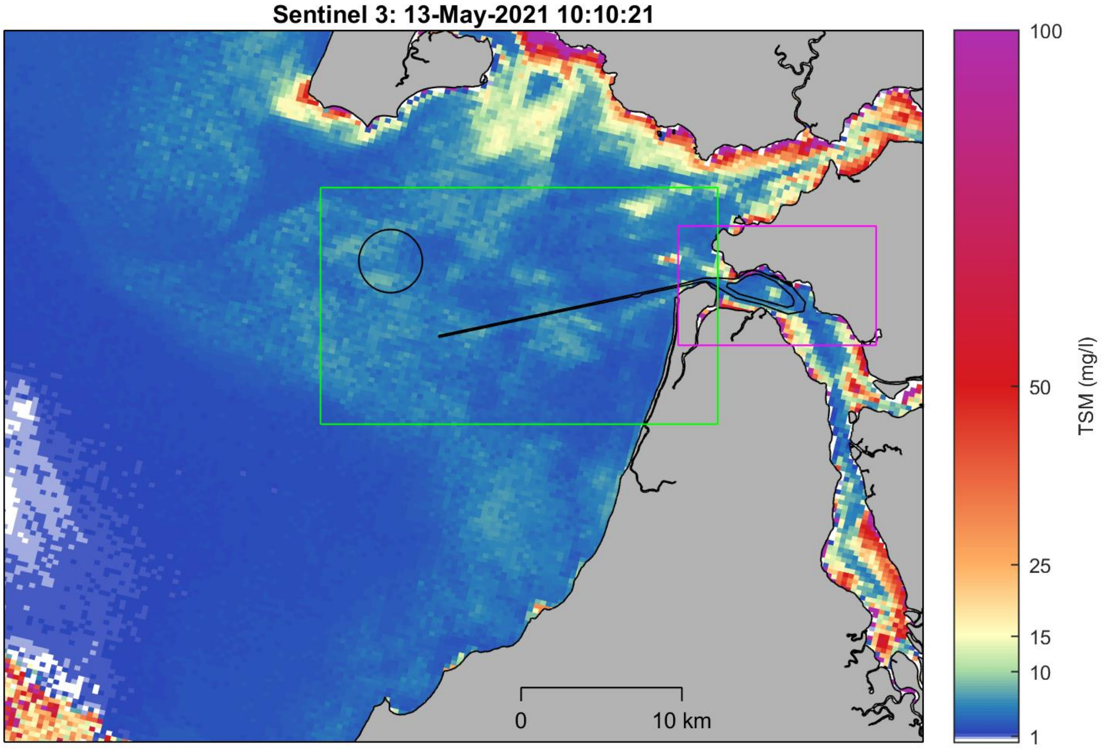


Figure 36. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 13/05/2021 at 10:10 AEST (dredging).

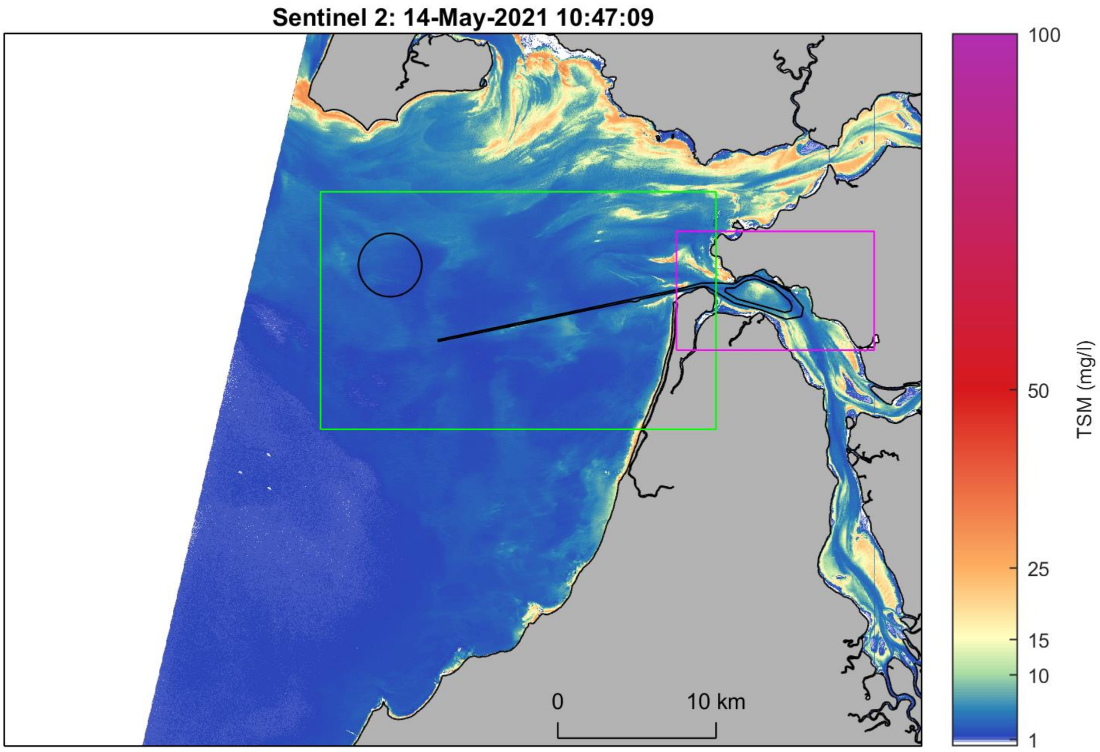


Figure 37. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 14/05/2021 at 10:47 AEST (dredging).

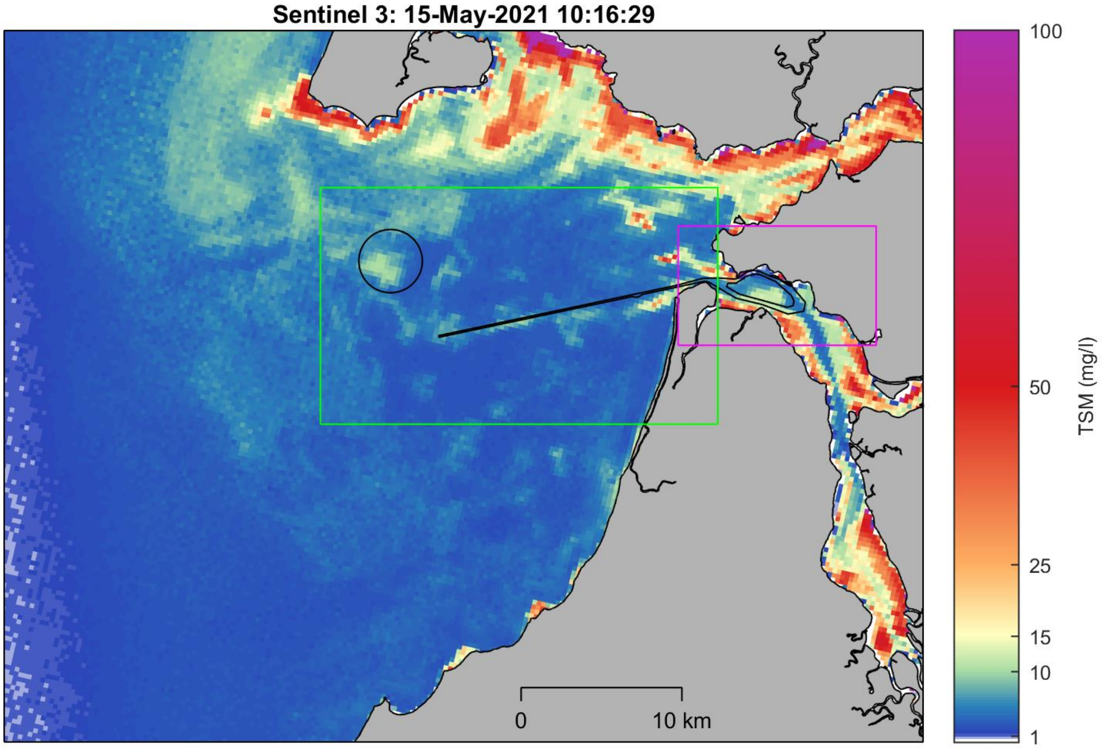


Figure 38. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 15/05/2021 at 10:16 AEST (dredging).

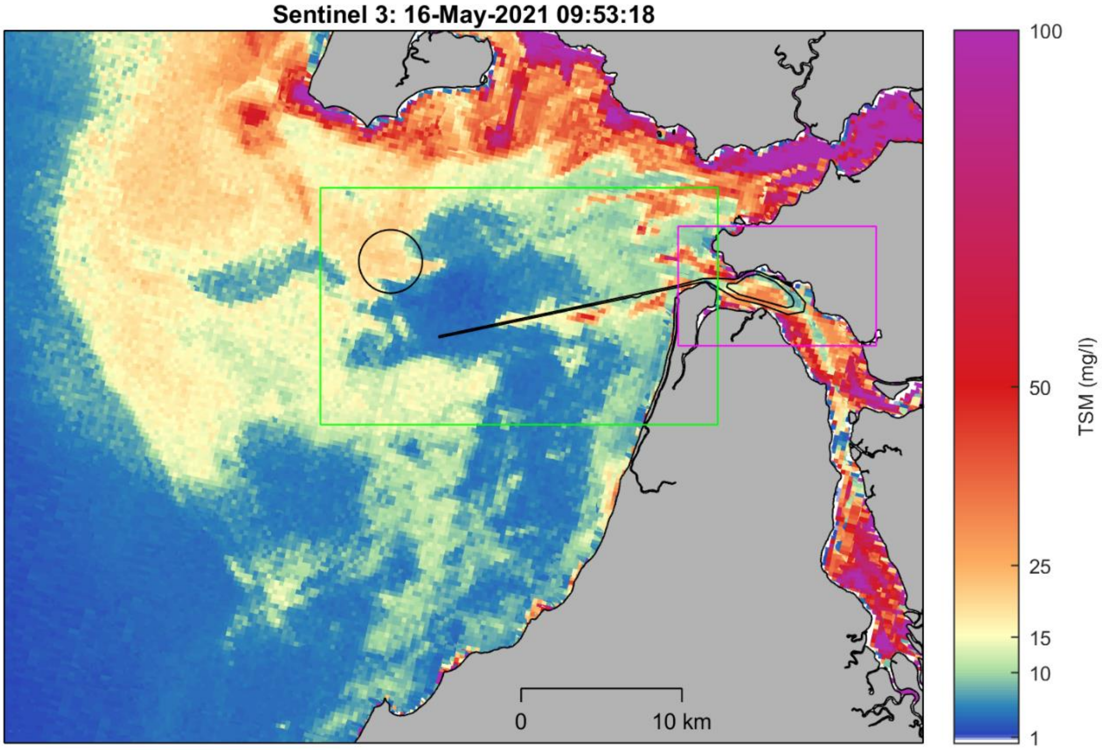


Figure 39. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 16/05/2021 at 9:53 AEST (dredging).

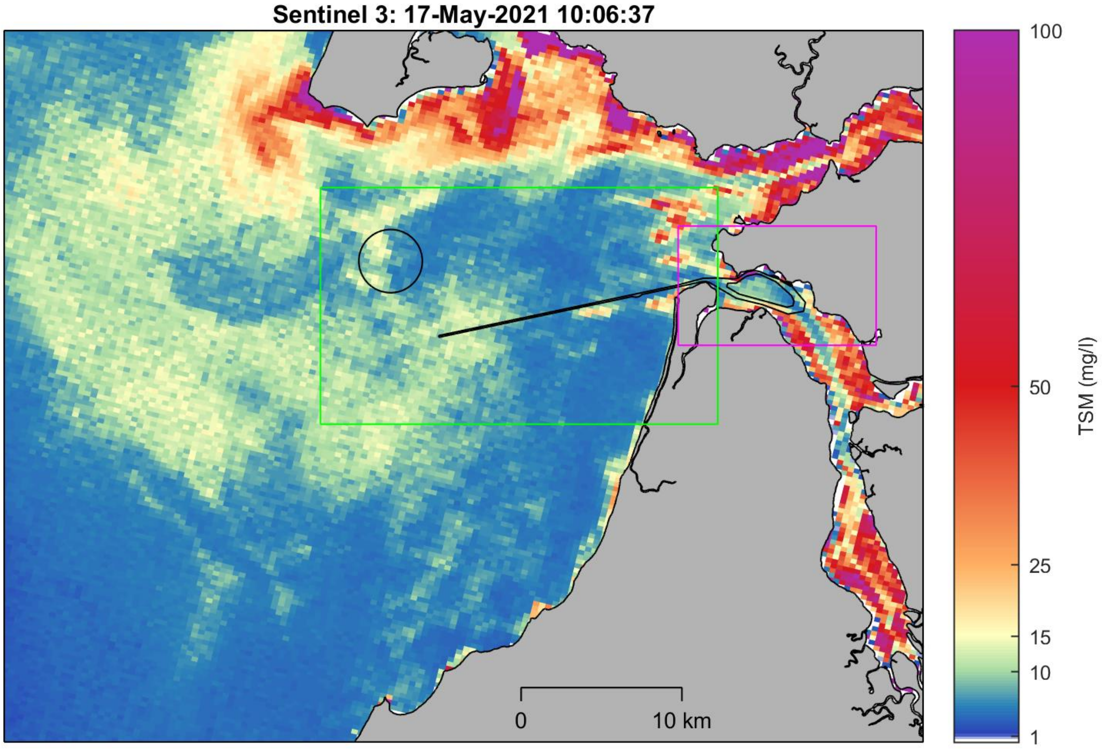


Figure 40. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 17/05/2021 at 10:07 AEST (dredging).

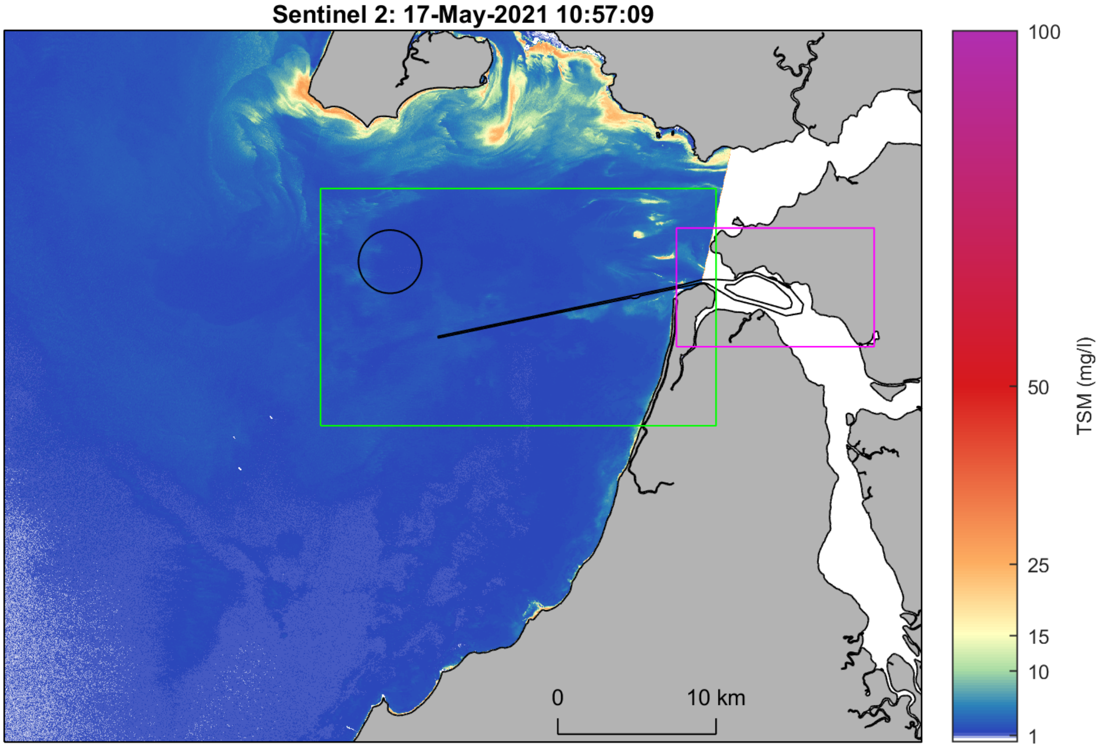


Figure 41. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 17/05/2021 at 10:57 AEST (dredging).

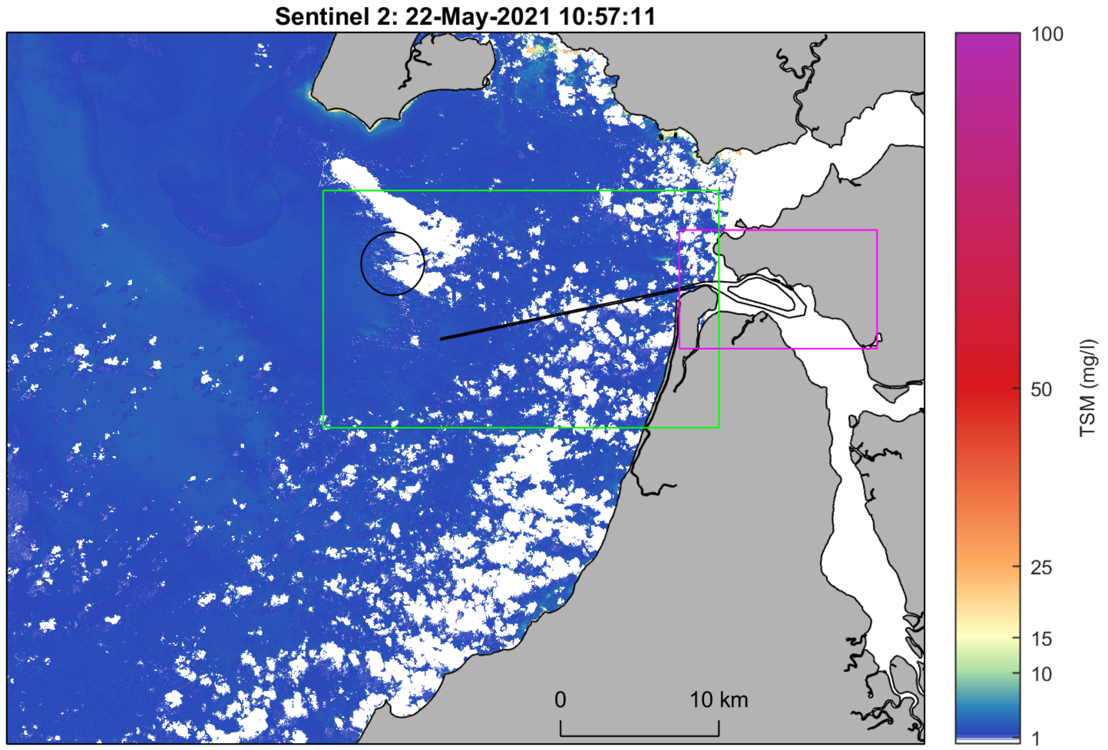


Figure 42. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 22/05/2021 at 10:57 AEST (post-dredging).

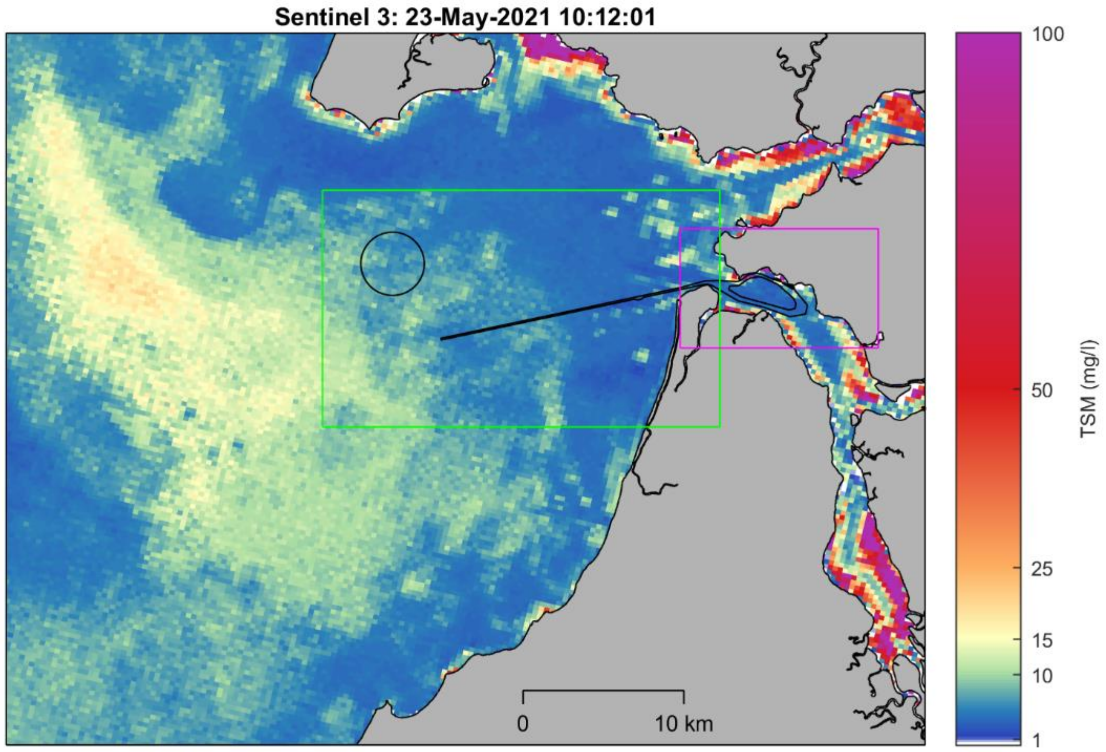


Figure 43. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 23/05/2021 at 10:12 AEST (post-dredging).

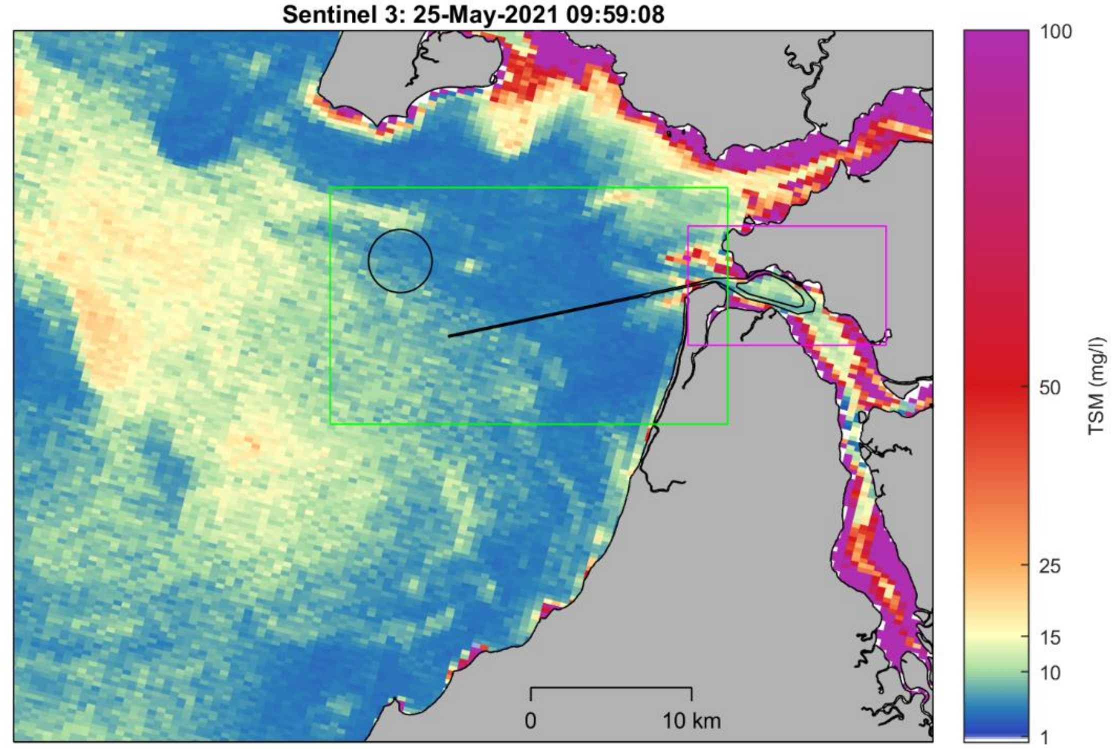


Figure 44. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 25/05/2021 at 9:59 AEST (post-dredging).

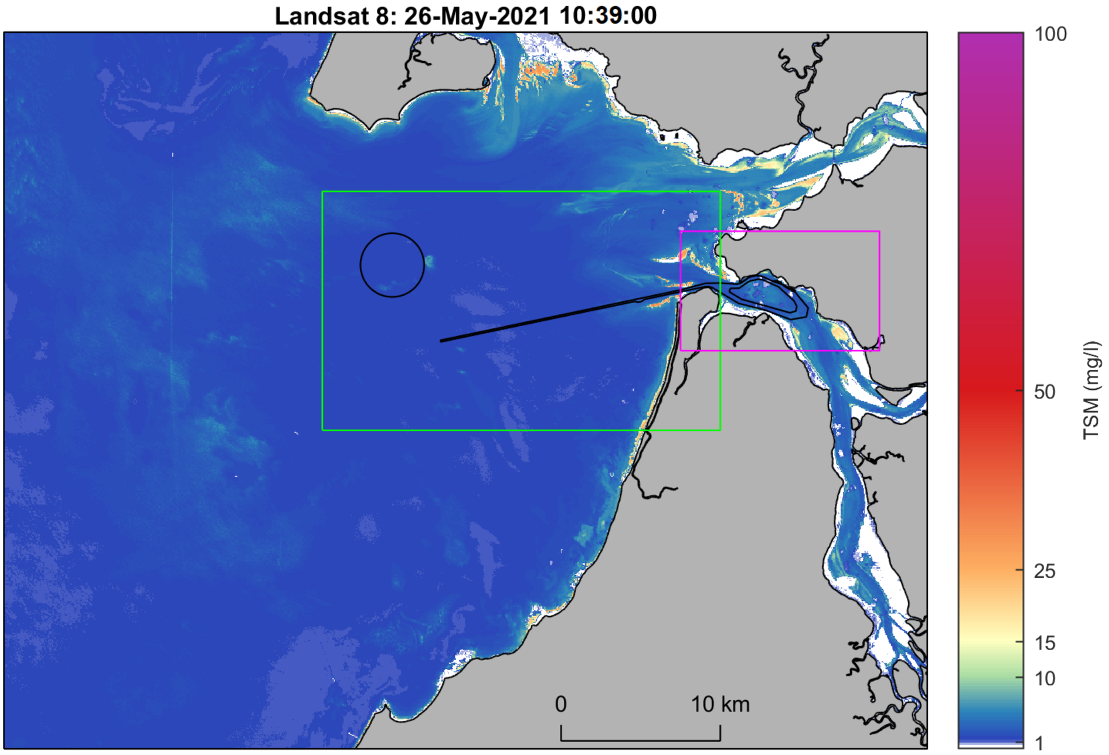


Figure 45. Satellite-derived turbidity from the Landsat 8 sensor for Albatross Bay on 26/05/2021 at 10:39 AEST (post-dredging).

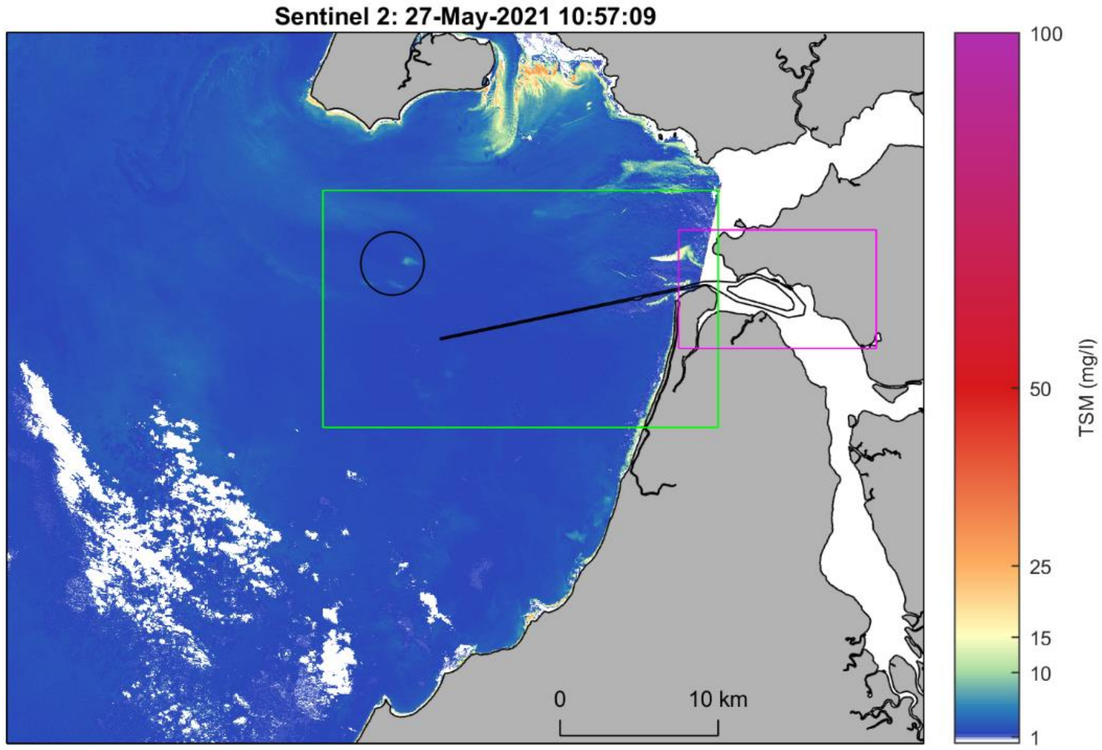


Figure 46. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 27/05/2021 at 10:57 AEST (post-dredging).

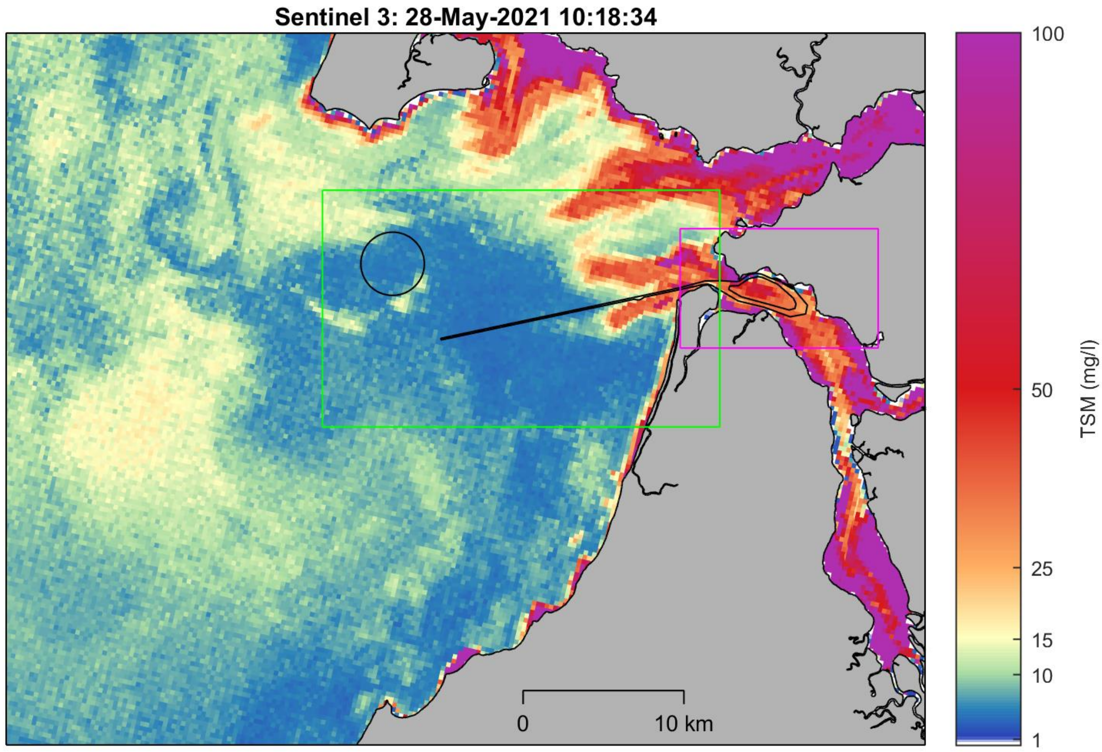


Figure 47. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 28/05/2021 at 10:19 AEST (post-dredging).

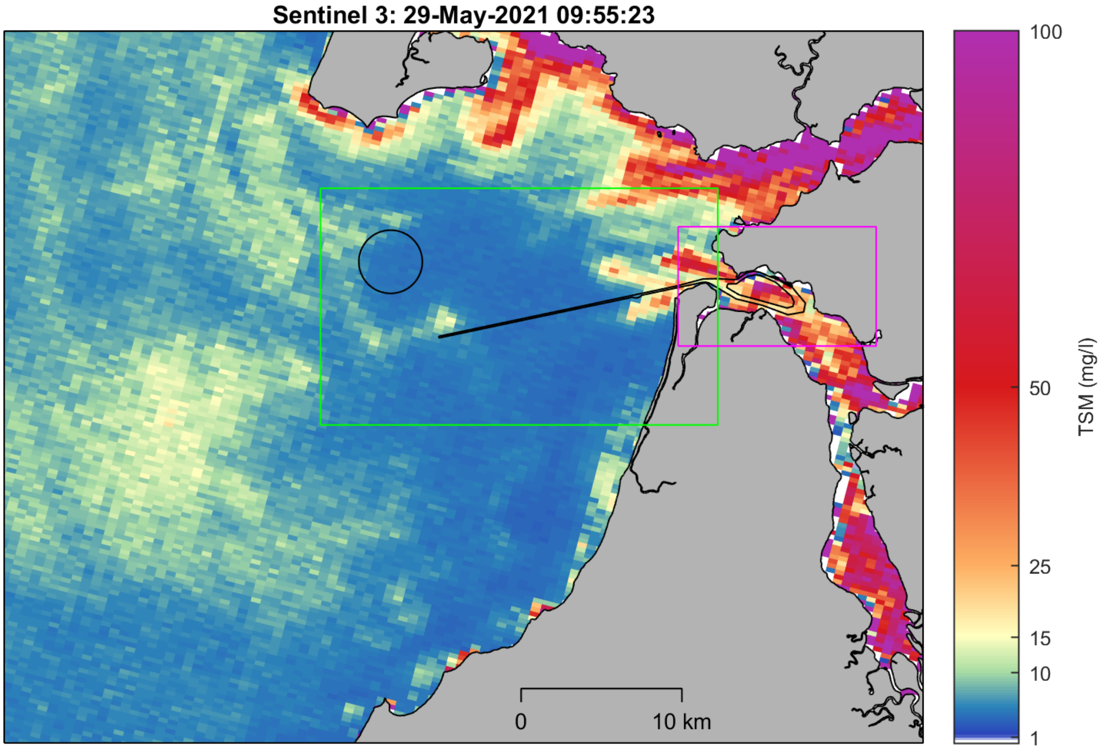


Figure 48. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 29/05/2021 at 09:55 AEST (post-dredging).

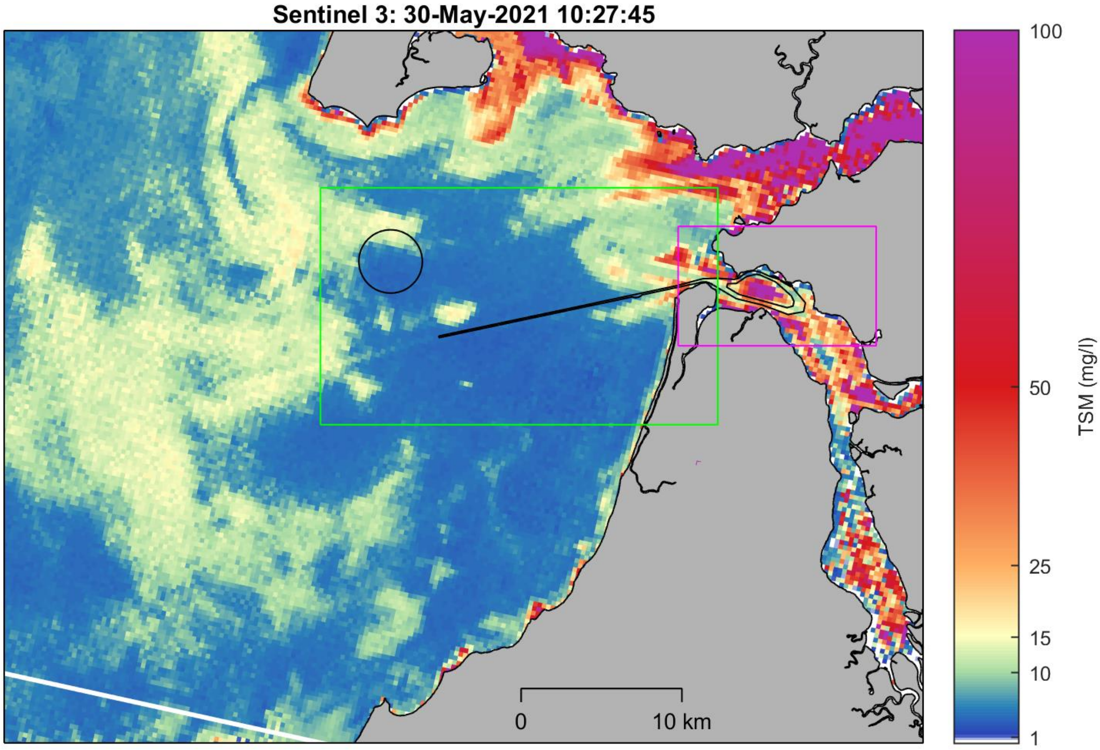


Figure 49. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 30/05/2021 at 10:28 AEST (post-dredging).

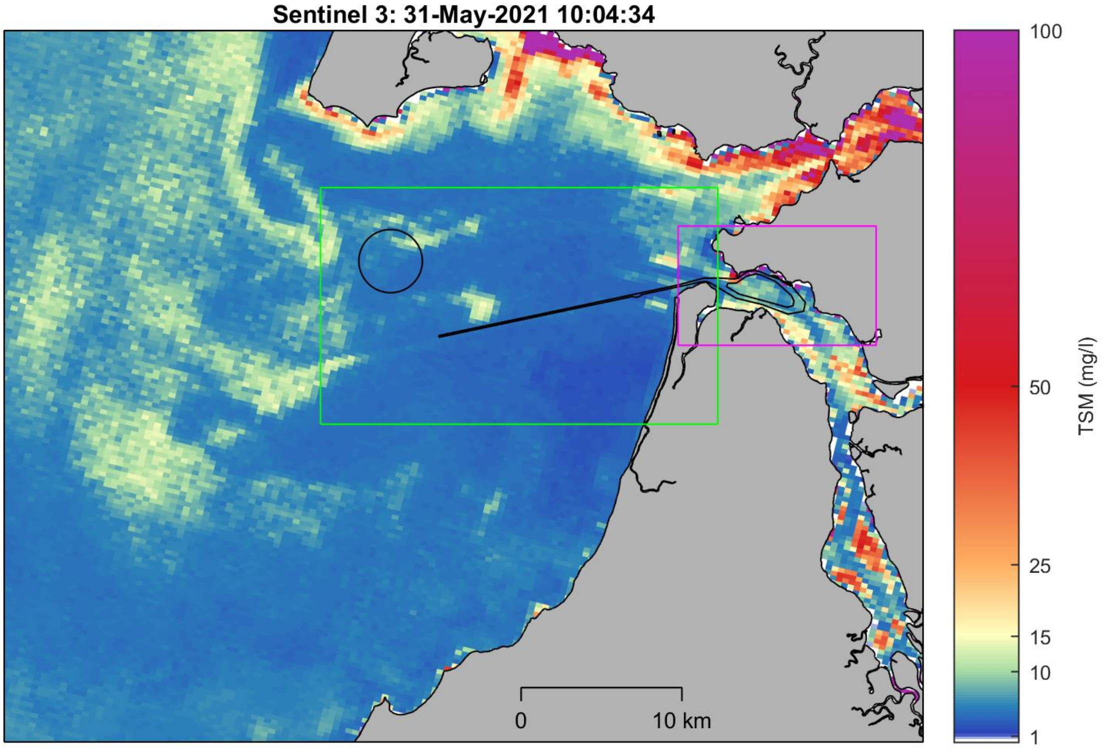


Figure 50. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 31/05/2021 at 10:05 AEST (post-dredging).

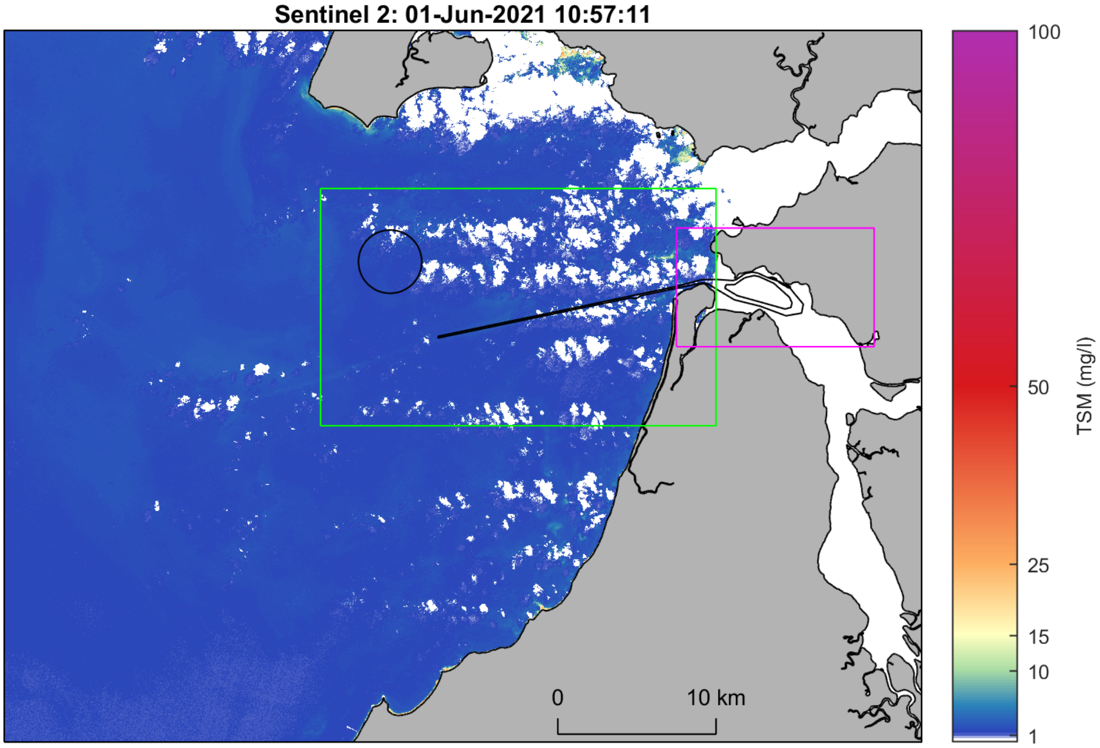


Figure 51. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 01/06/2021 at 10:57 AEST (post-dredging).

4.2.2.2. Local Scale

To show how the local turbidity around the Port of Weipa varied over the 2021 Maintenance Dredging program, plots of the satellite-derived TSM covering the South Channel and Albatross Bay DMPA and the Inner Harbour area are shown for the pre-, during and post-dredging periods in Figure 55 to Figure 86. The plots show the following:

- Pre-Dredging: the imagery from the pre-dredging period shows generally low TSM (less than 10 mg/l equivalent to approximately 7 NTU) across the South Channel and DMPA (Figure 55 to Figure 59). The Sentinel-3 image from the 23rd April 2021 shows high values along the shallow coastal areas in the Inner Harbour area, but it is likely that the sensor is detecting either the bed or is influenced by the patchy cloud along the coast, rather than a sediment plume. As noted with respect to the regional scale plots, the images from the 2020 pre-dredge period exhibited greater natural variability in TSM than presented here for the 2021 pre-dredge period (PCS, 2020b);
- During Dredging: the available images during the maintenance dredging program show localised plumes adjacent to the South Channel (mainly between SC8 and SC14), which could be residual plumes related to the maintenance dredging and bed levelling activity. The TSM of the plumes is around 15 mg/l based on Sentinel-2 imagery (and up to 25 mg/l based on Sentinel-3 imagery) and the extent is around 6 km length and 1 km width. Localised plumes were also evident in the Approach Channel of the Inner Harbour due to dredging and bed levelling (up to 15 mg/l, only identified by the higher resolution Sentinel-2 imagery) and within the Albatross Bay DMPA due to recent placement of sediment within the DMPA (with concentrations of around 10 mg/l). The plumes in the DMPA were typically 500 m or less in length and only remained detectable for a short period (of the order of hours). The plumes identified resulting from dredging and placement activity remained close to where the placement or dredging activity occurred, showing that very little residual transport of the plumes away from where they were generated occurs.

  Further details of the observed plumes are provided below:

  - 2nd May 2021 (Figure 64): there was a plume of approximately 300 m by 200 m with a peak TSM of 10 mg/l (approximately 7 NTU) in the DMPA (background TSM of around 1 mg/l). A load of predominantly silt dredged from SC14 to SC16 in the South Channel was placed at the DMPA approximately 20 minutes before the image was captured. There is no evidence of any other plumes in the DMPA in the image, meaning that any plume resulting from the previous load of silt from the South Channel placed at the DMPA three hours before the image was captured was no longer visible;
  - 4th May 2021 (Figure 67): there was a low concentration plume approximately 2 to 3 mg/l (1 to 2 NTU) above background TSM over an area of approximately 2 km length by 200 m width in the Approach Channel of the Inner Harbour. The plume was not detected by the Sentinel-3 image (taken approximately 45 minutes before the Sentinel-2 image) on the 4th May 2021 (Figure 66), most likely due to the small elevations above background. Dredging of mixed silt and sand had finished in this area approximately 35 minutes prior to the Sentinel-2 satellite image being captured. This shows that the plume resulting from the dredging remained detectable for more than 30 minutes after the dredging finished but, based on the TSM relative to background it is likely that the plume will not have remained detectable for much longer. The plume extends to the location of the WQ4 in-situ logger. The time series of turbidity at the logger confirms that this plume is unlikely to remain detectable after the time of the Sentinel-2 image with natural increases in turbidity associated with tidal variations expected to make the small scale plume more difficult to identify;
  - 7th May 2021 (Figure 71): there was a low concentration plume within the South Channel between SC8 and SC14 with TSM of up to 15 mg/l (approximately 10 NTU) with a spatial extent of approximately 6 km by 1 km. The TSHD Brisbane is visible within the plume indicating that the plume was generated by the maintenance

dredging activity in the area. The image was captured approximately ten minutes after the start of the current dredge cycle, with dredging continuing at this location for another twenty minutes after the time of the image. The magnitude and intensity of the plume could therefore have increased slightly over time. The Sentinel-3 image from the 8th May also shows elevated TSM in this region, although dredging in this area had not occurred for more than four hours prior to image capture. Similarly, the Sentinel-2 image from the 9th May shows elevated TSM along the South Channel but sightly further to the west (between SC4 to SC6), although no dredging had been undertaken there for at least four hours before image capture. It is uncertain whether the elevated TSM in this region is from a low concentration plume remaining from dredging over previous hours or days, or a result of propeller wash from the transit of a laden tanker or natural processes. Either way, the neap tidal conditions result in limited tidal mixing and dispersion of any generated plumes. The image from the 10th of May (Figure 74) does not show any clear plume in this region indicating it has dispersed.

The Sentinel 2 image from the 7th May 2021 also shows a small localised plume of up to 10 mg/l (approximately 7 NTU) with a spatial extent of approximately 400 m by 200 m within the DMPA from the placement of sediment in the DMPA from the previous dredge cycle (which occurred approximately one hour before the time of the image);

- 9th May 2021 (Figure 73): there was a plume with concentrations of around 15 mg/l in the Approach Channel of the Inner Harbour, approximately 1 km by 200 m in extent. The TSHD Brisbane had been dredging in this region approximately one and a half hours before the time of the image and the Pacific Titan had also been undertaking bed levelling in the Inner Harbour that morning and it is therefore likely that this plume is a result of dredging activity;
- 12th May 2021 (Figure 75): there is a clear line of elevated TSM from the propeller wash of the laden TSHD Brisbane sailing to the DMPA from SC4 (Where the dredger left the South Channel) and a small localised plume in the DMPA from the recent placement of sediment. The TSM for both plumes are around 5 mg/l above the adjacent background levels;
- 14th May 2021 (Figure 77): there is a low concentration plume (up to 15 mg/l) in the South Channel between SC8 and SC6, extending over an area approximately 2 km in length and 100 m in width. The TSHD Brisbane had not been operating in the region of the South Channel that day and the Pacific Titan was undertaking bed levelling in the Inner Harbour. The low resolution images from the 15th and 16th May 2021 (Figure 78 and Figure 79) also show a slight elevation in turbidity in this region (up to 20 mg/l). However, these images also show other areas of elevated TSM away from the dredge channels. Based on the available information and the dredge activity it is likely that the low concentration plume is due to spring tidal currents as opposed to dredging or bed levelling.

  The Sentinel 2 image from the 14th May 2021 also shows a low concentration plume (less than 10 mg/l) in the DMPA. This plume is only just visible indicating that the plume from the most recent placement (which was 1 hour 40 minutes before the time of image capture) has for the most part dispersed and/or settled out; and
- 17th May 2021 (Figure 80 and Figure 81) there is a localised area immediately to the south of the South Channel between SC10 and SC14 where the TSM is elevated to around 15 mg/l (from the Sentinel-2 image, the Sentinel-3 image shows slightly high values of around 25 mg/l). The TSHD finished dredging this area of the channel 1 hour and 20 minutes before this image was captured. This was the fifth consecutive load to be dredged from that region of the South Channel and it is therefore likely that this area of increased turbidity is a result of the maintenance dredging activity. There is also a small plume of less than 10 mg/l in the southwestern part of the DMPA, which is likely to be from the last placement at the DMPA which occurred approximately an hour and a half before the image was captured.

- Post-Dredging: the first usable post dredging image is more than four days after the last dredge load was placed at the Albatross Bay DMPA (image from the 22nd May 2021 shown in Figure 82), with high levels of cloud cover obscuring images in the days after the completion of the dredge. The image on the 22nd May is also partially obscured by cloud cover and it is not possible to identify any plumes still present which could be a result of maintenance dredge activity. As noted in Section 4.2.2.1, the high resolution imagery from the 26th May and 27th May (Figure 85 and Figure 86) show small plumes (around 500 m in extent at concentrations of around 10 mg/l) in and around the DMPA but taking account of tidal state at the time of the images (close to low water) and the time since the completion of the dredge it is likely that these are a result of natural processes.

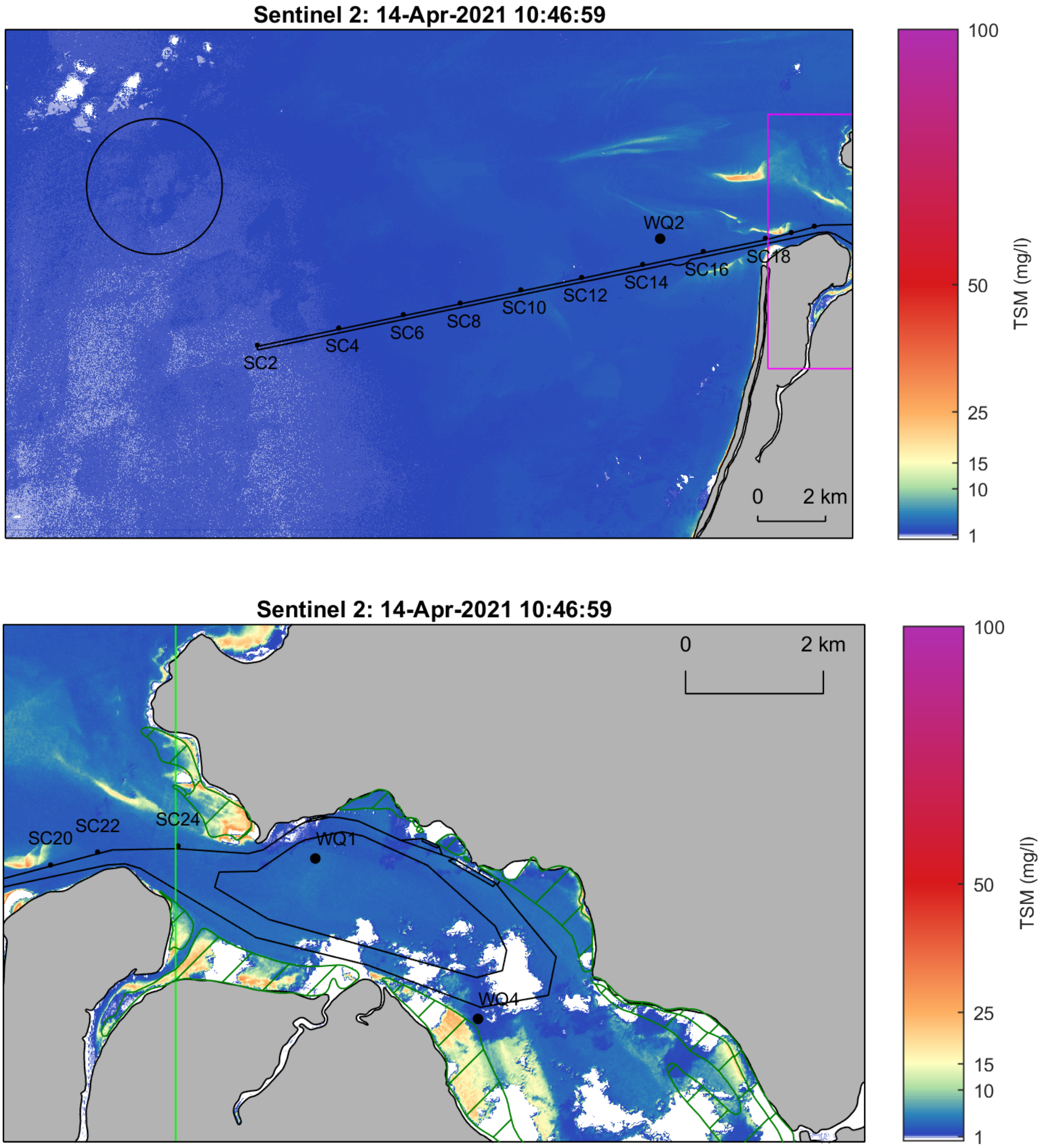


Figure 52. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 14/04/2021 at 10:47 AEST (pre-dredging).

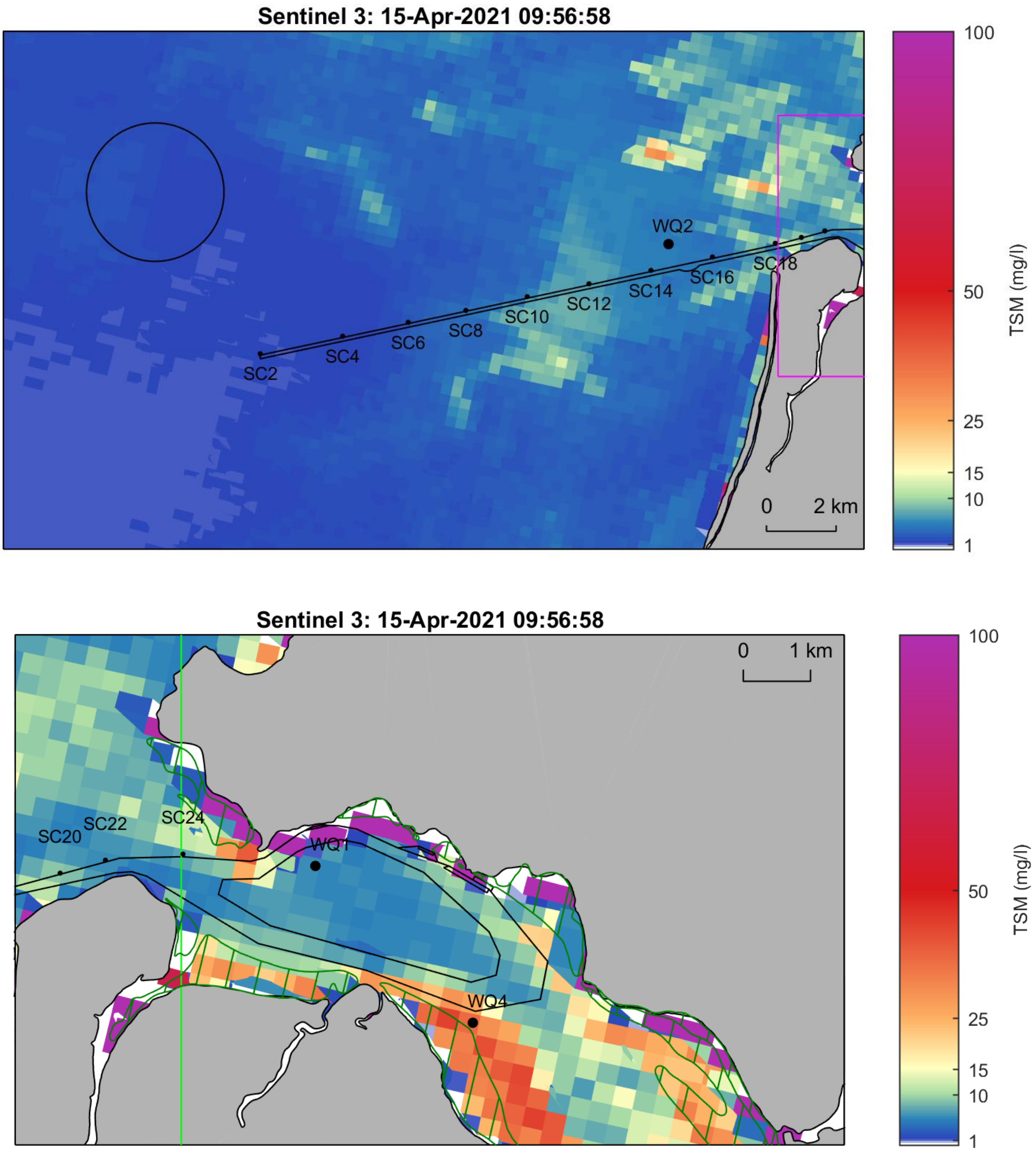


Figure 53. **Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 15/04/2021 at 09:57 AEST (pre-dredging).**

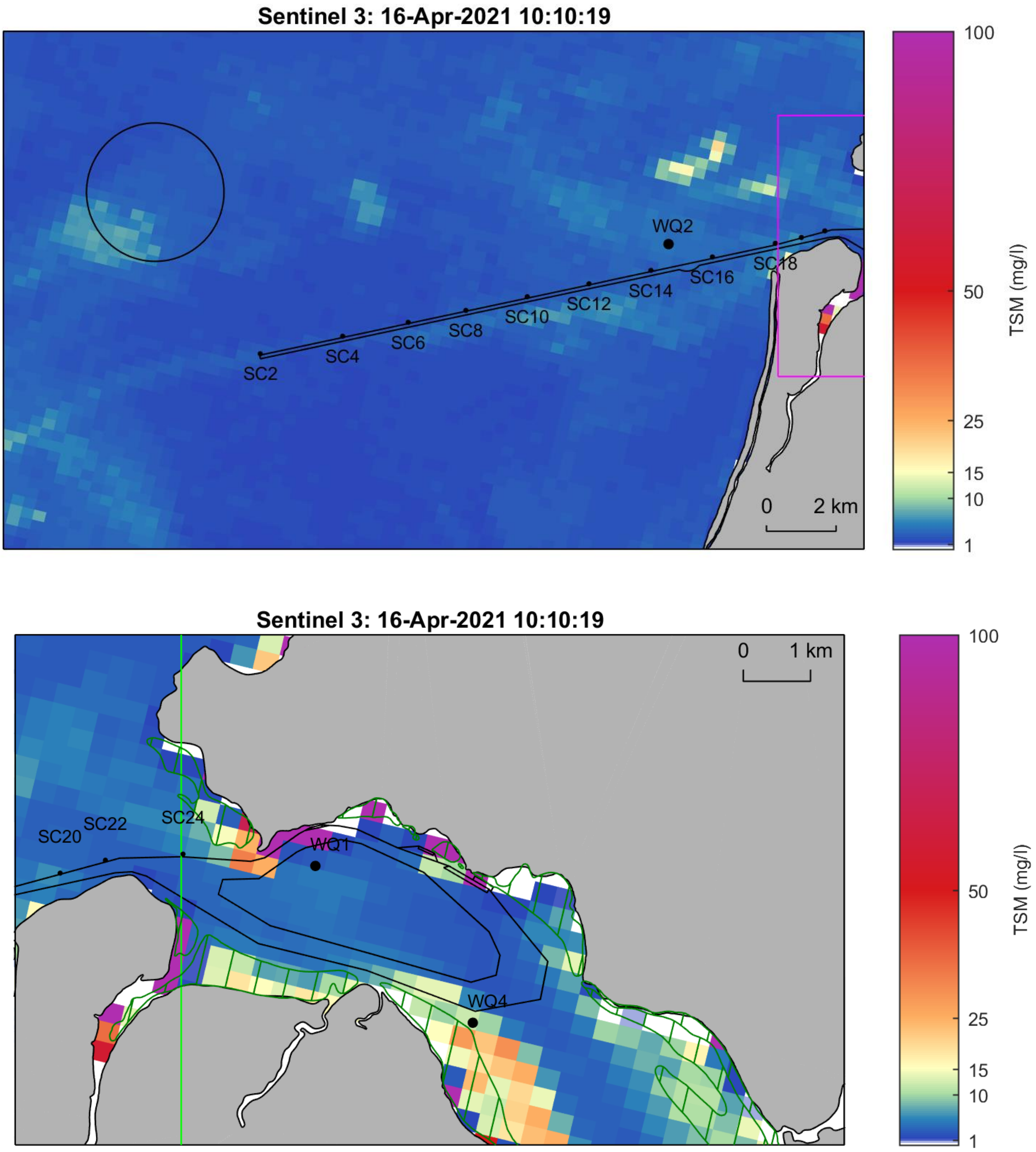


Figure 54. **Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 16/04/2021 at 10:10 AEST (pre-dredging).**

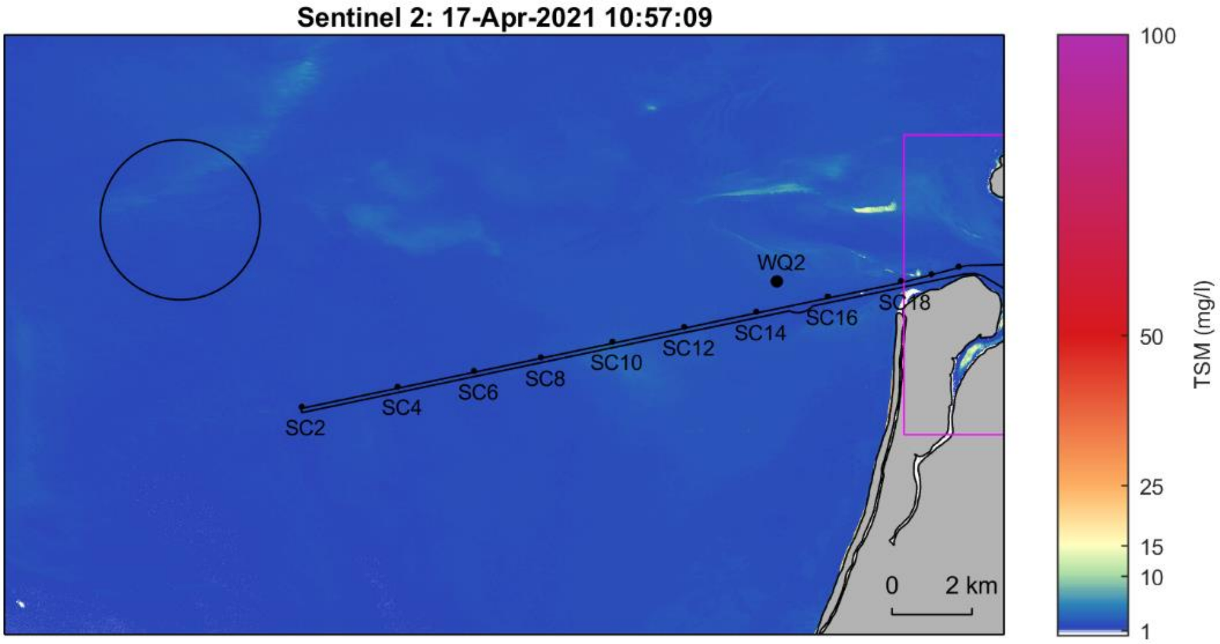


Figure 55. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 17/04/2021 at 10:57 AEST (pre-dredging). *Image does not cover Inner Harbour.*

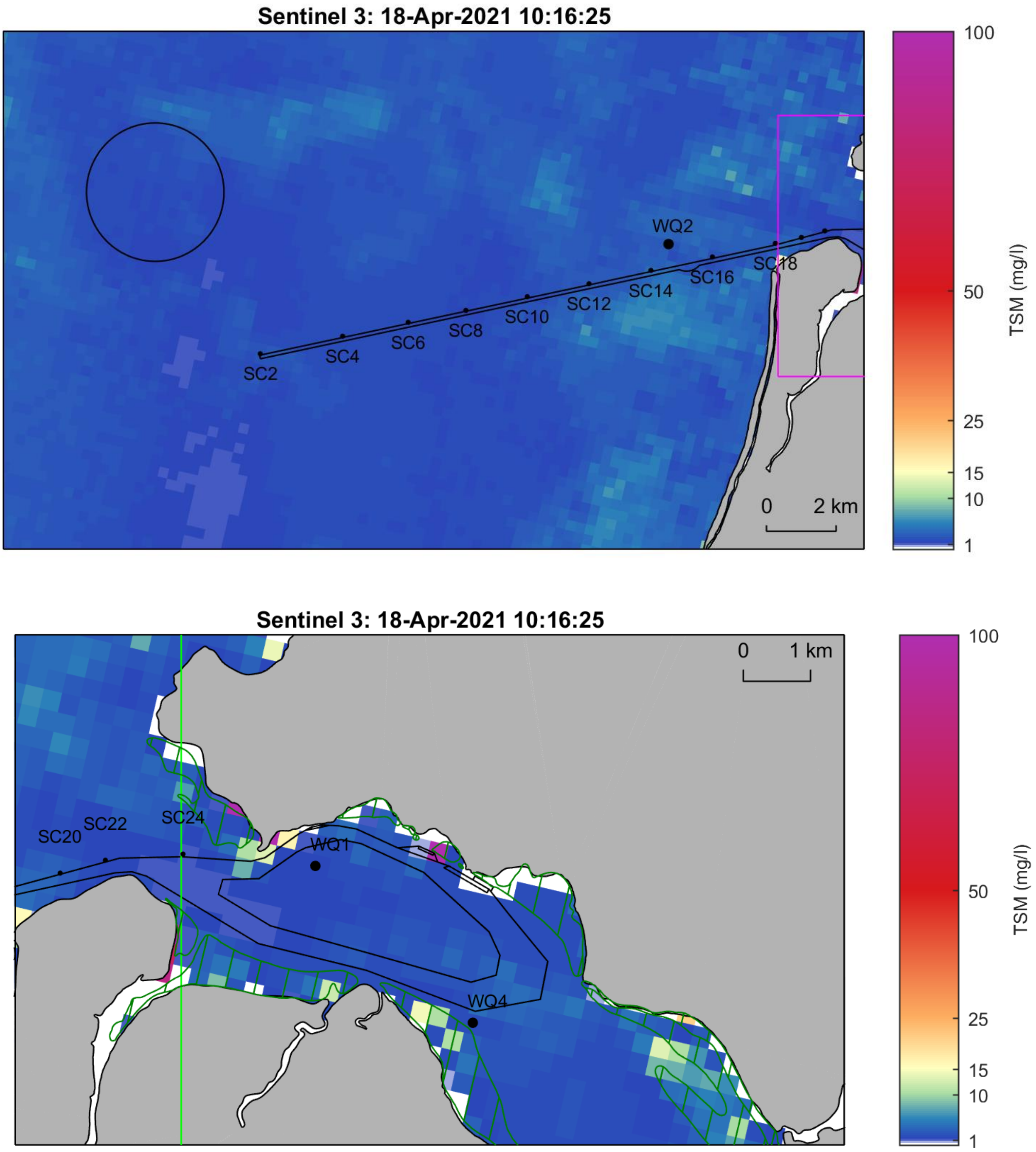
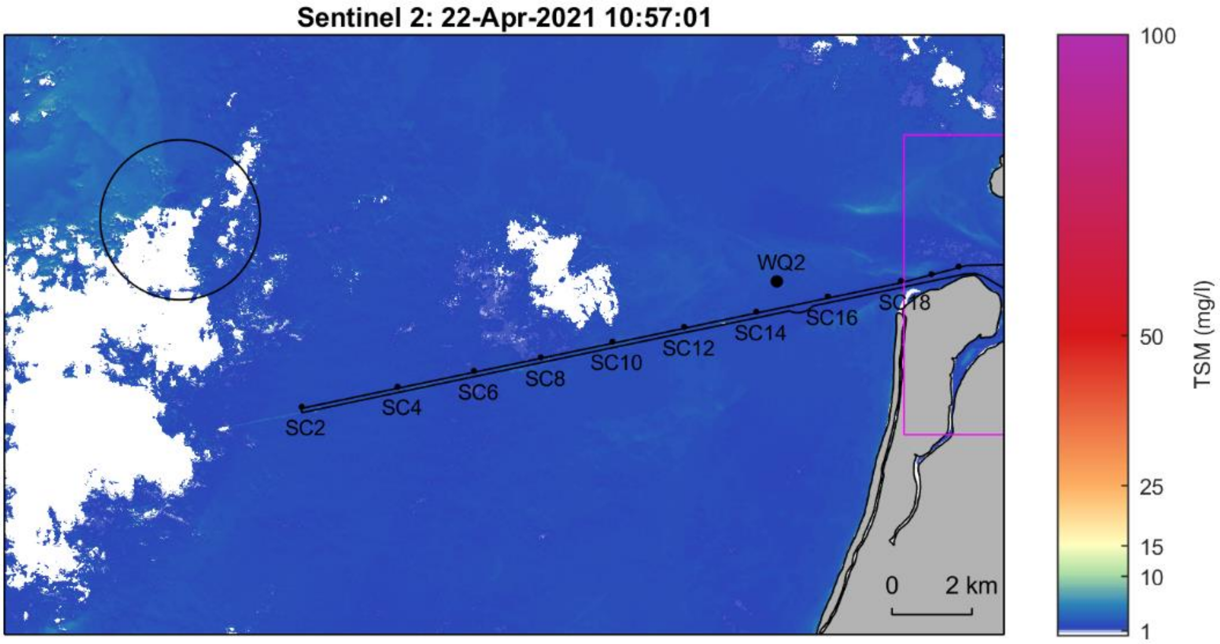


Figure 56. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 18/04/2021 at 10:16 AEST (pre-dredging).



Note: the white areas represent cloud cover.

Figure 57. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 22/04/2021 at 10:57 AEST (pre-dredging). *Image does not cover Inner Harbour.*

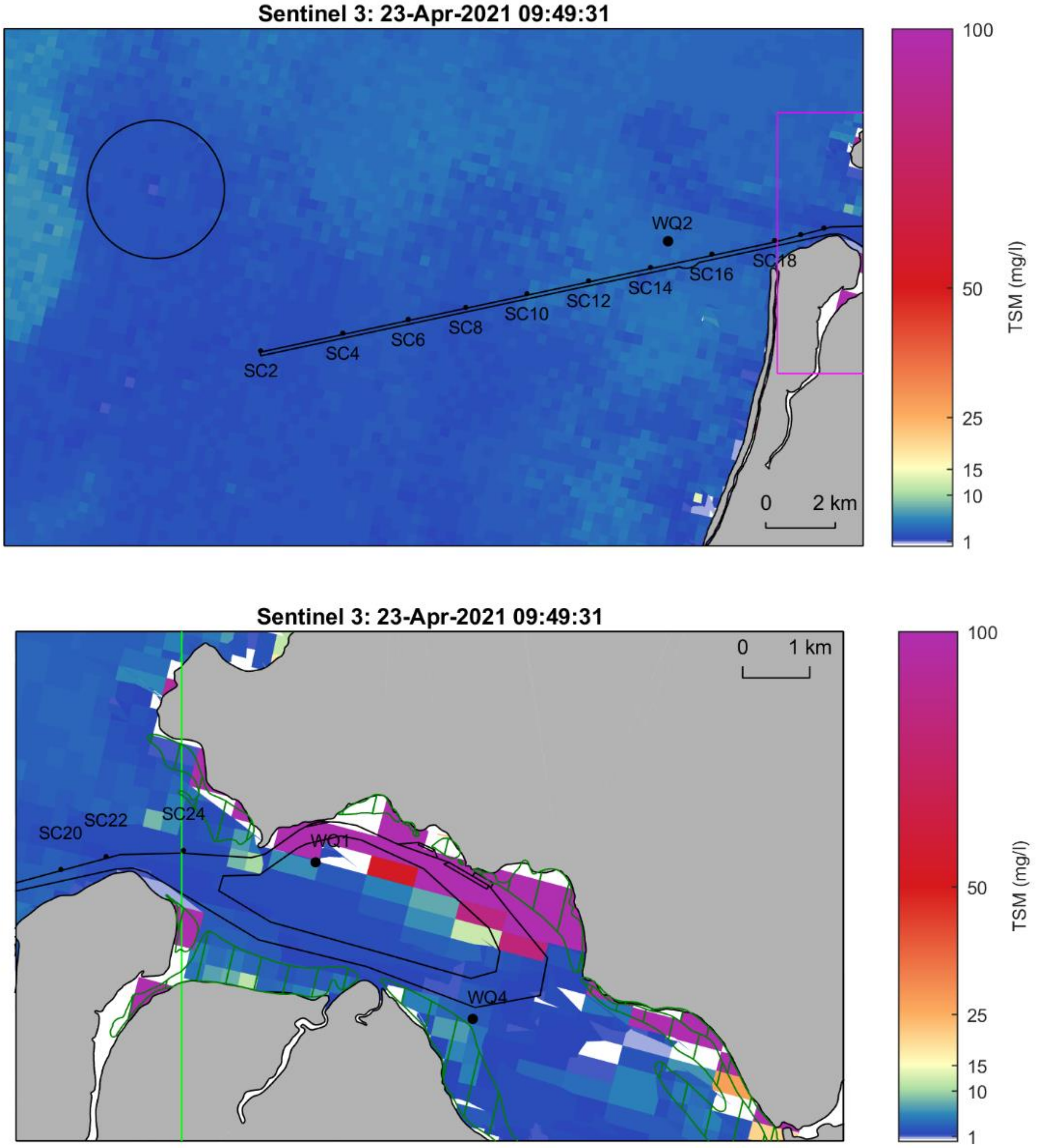


Figure 58. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 23/04/2021 at 09:49 AEST (pre-dredging).

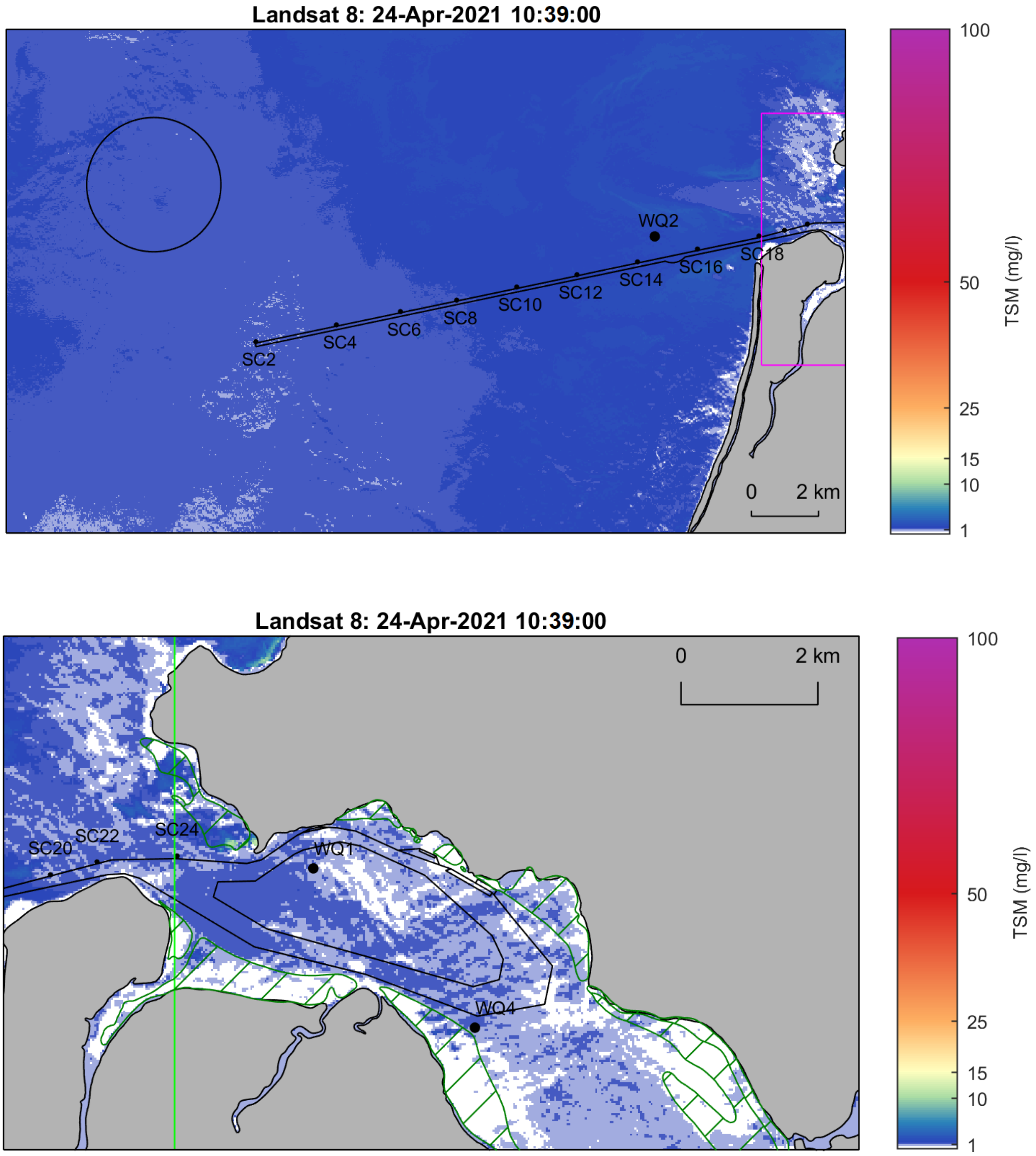


Figure 59. Satellite-derived turbidity from the Landsat-8 sensor for Albatross Bay on 24/04/2021 at 10:00 AEST (pre-dredging).

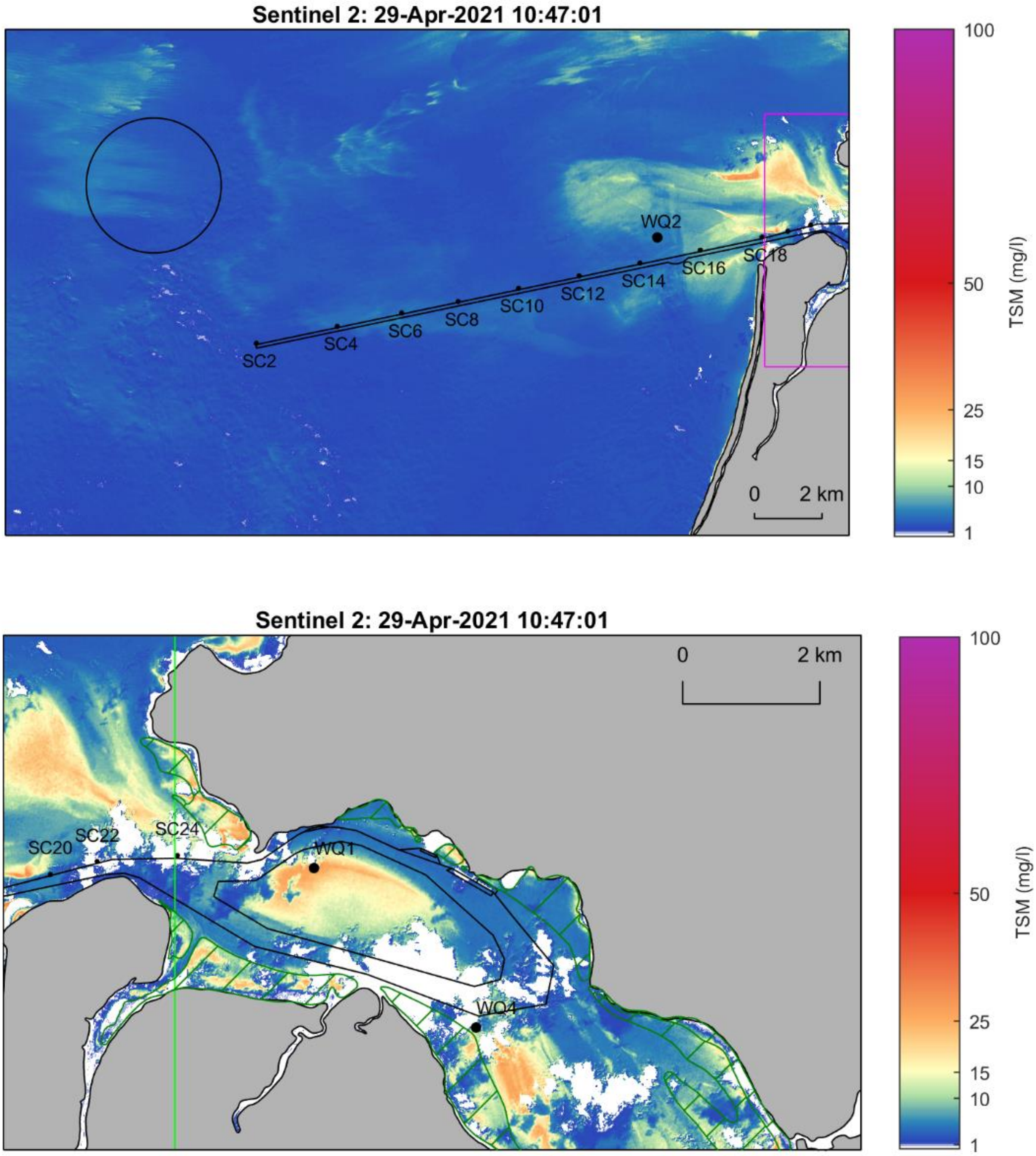


Figure 60. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 29/04/2021 at 10:47 AEST (dredging).

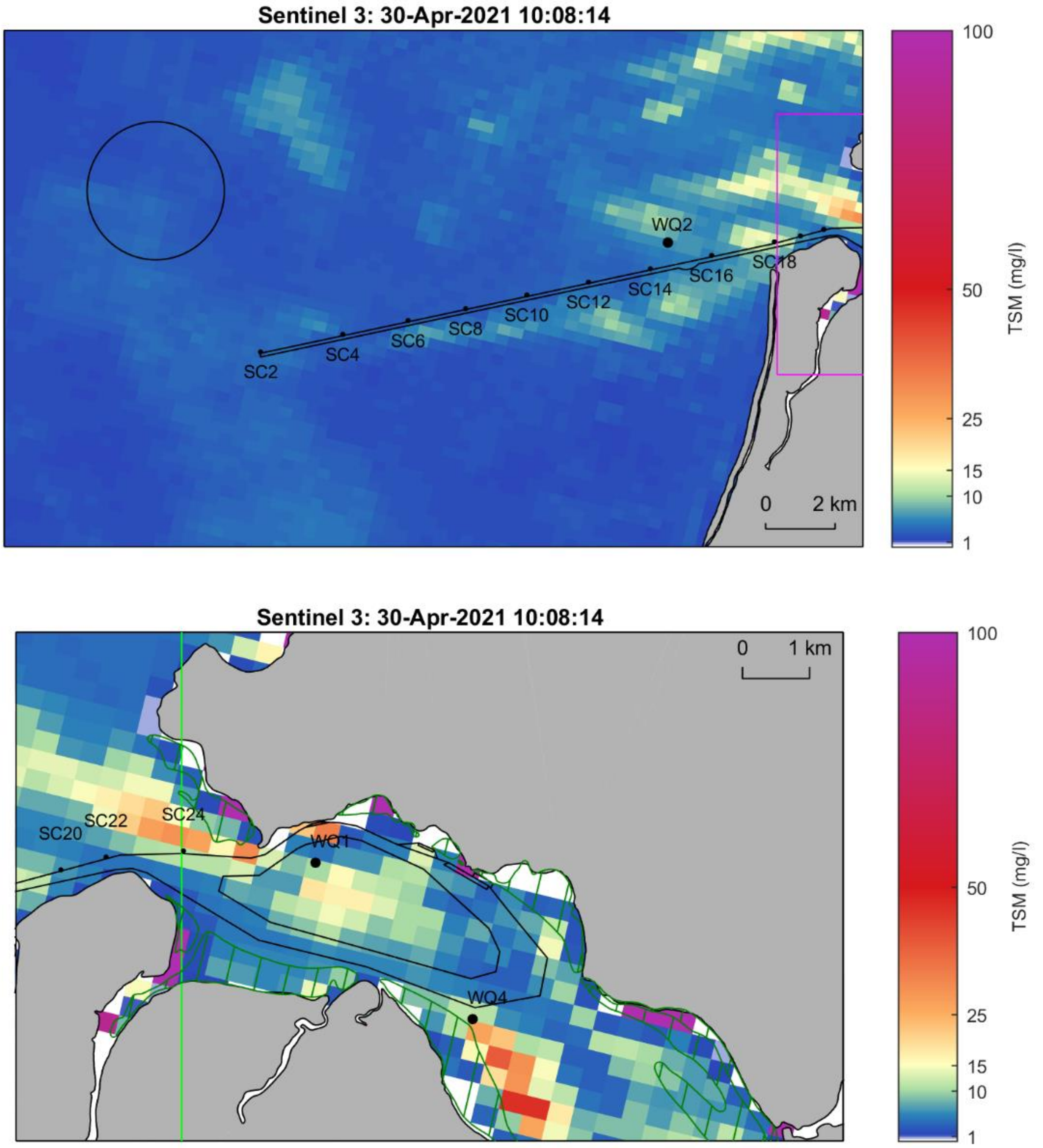


Figure 61. **Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 30/04/2021 at 10:08 AEST (dredging).**

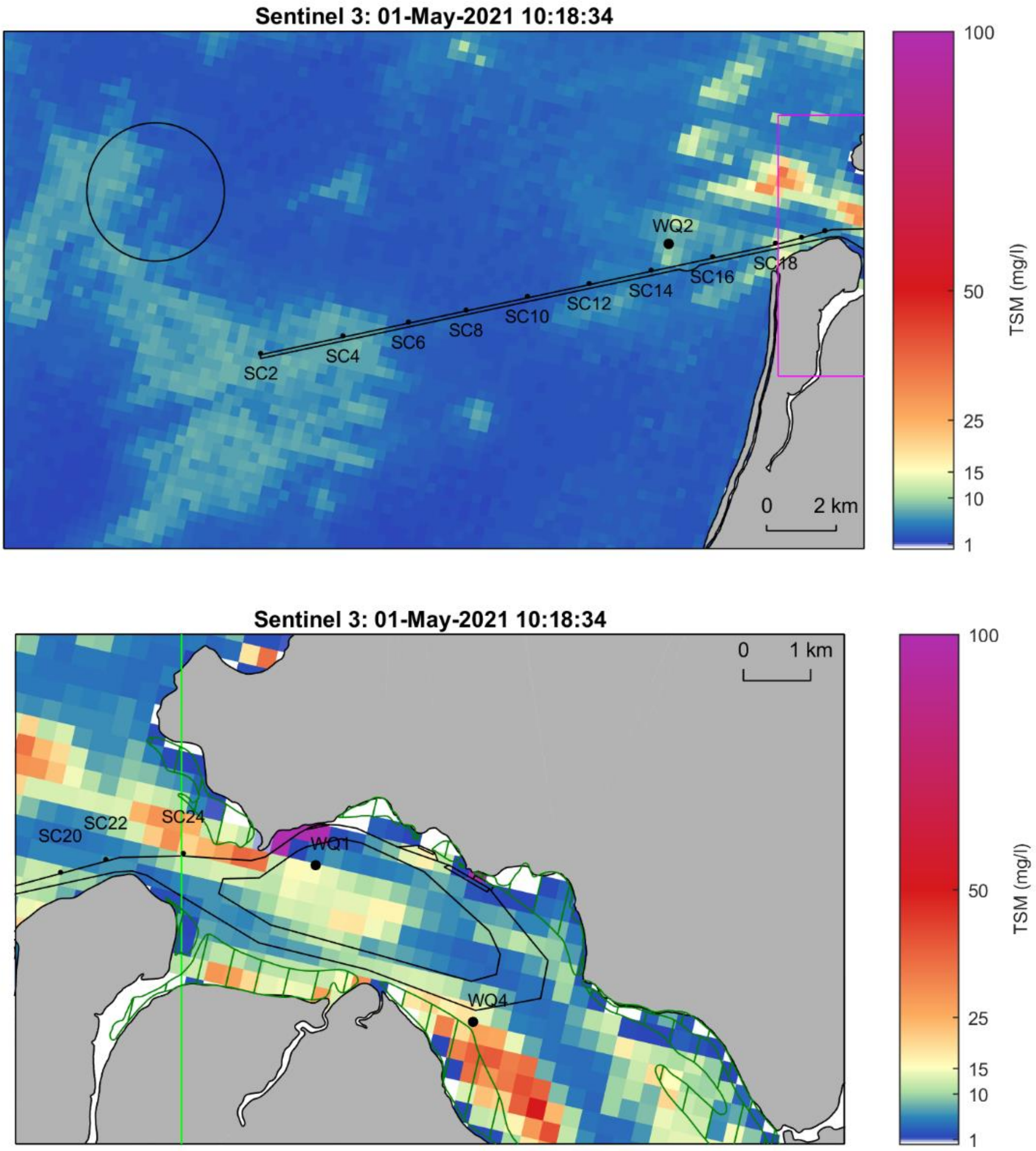


Figure 62. **Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 01/05/2021 at 10:18 AEST (dredging).**

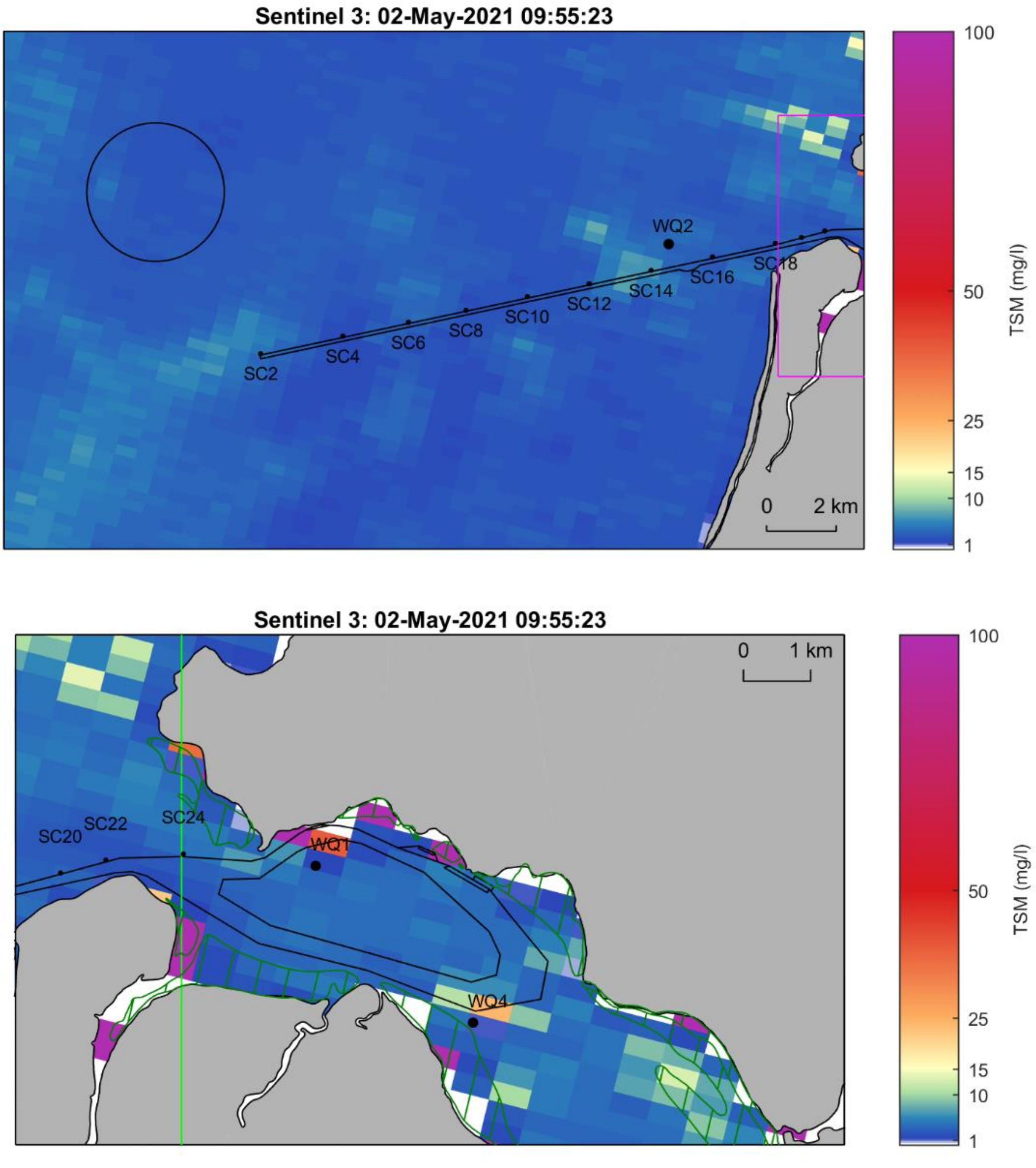


Figure 63. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 02/05/2021 at 9:55 AEST (dredging).

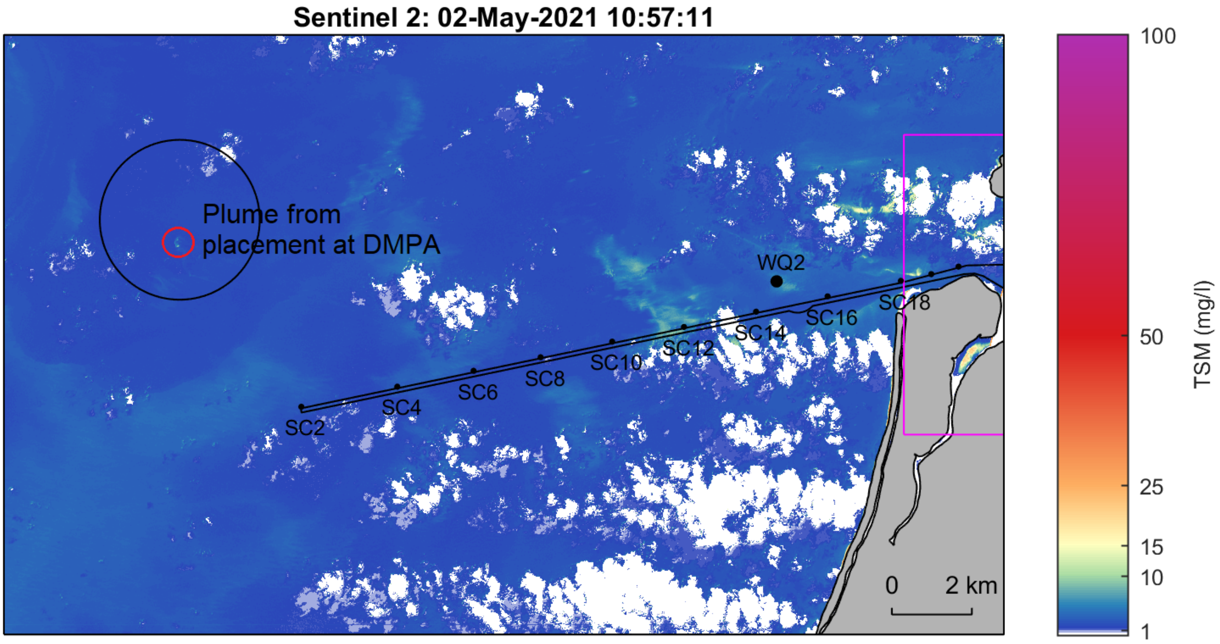
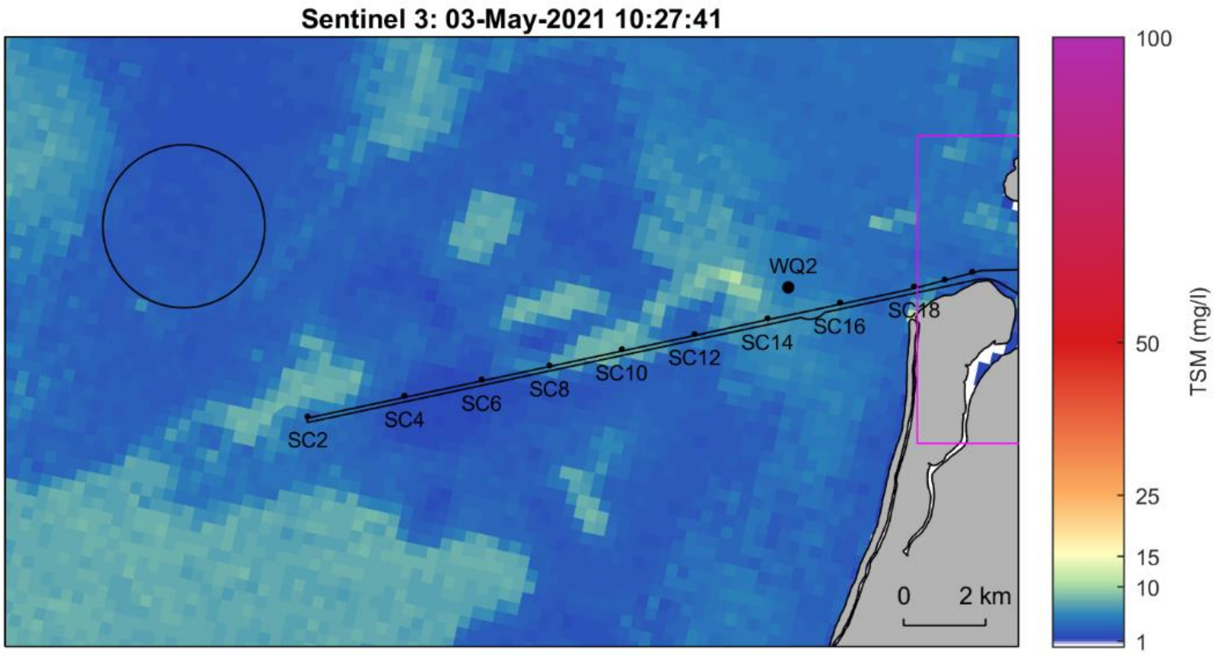


Figure 64. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 02/05/2021 at 10:57 AEST (dredging). *Image does not cover Inner Harbour.*



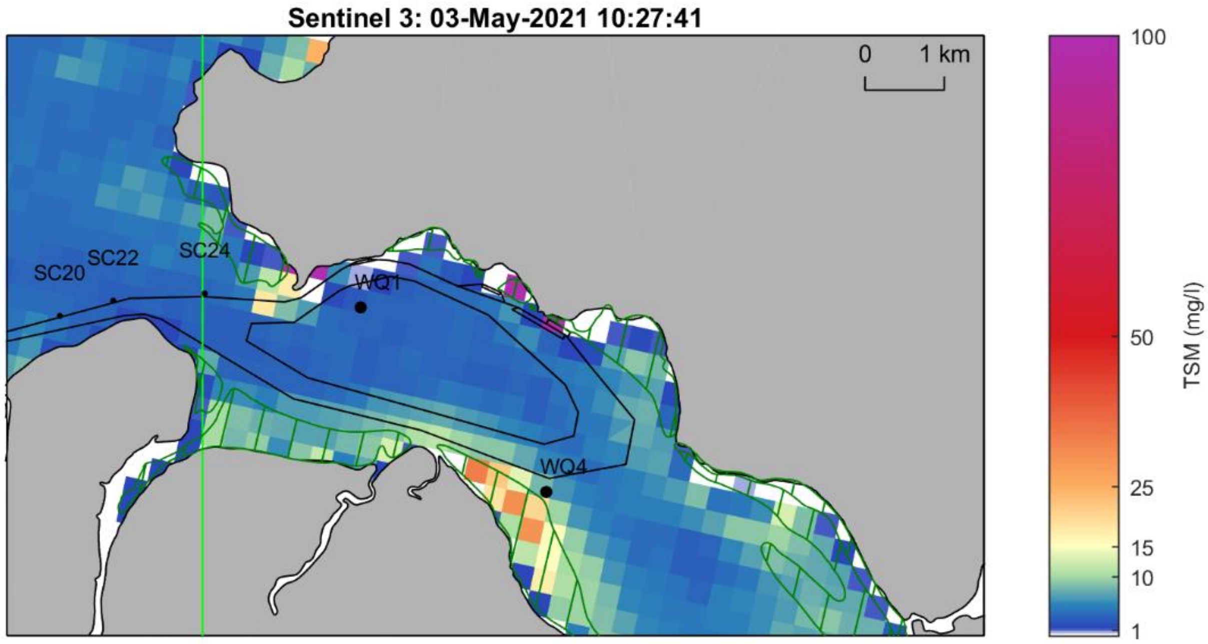


Figure 65. **Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 03/05/2021 at 10:27 AEST (dredging).**

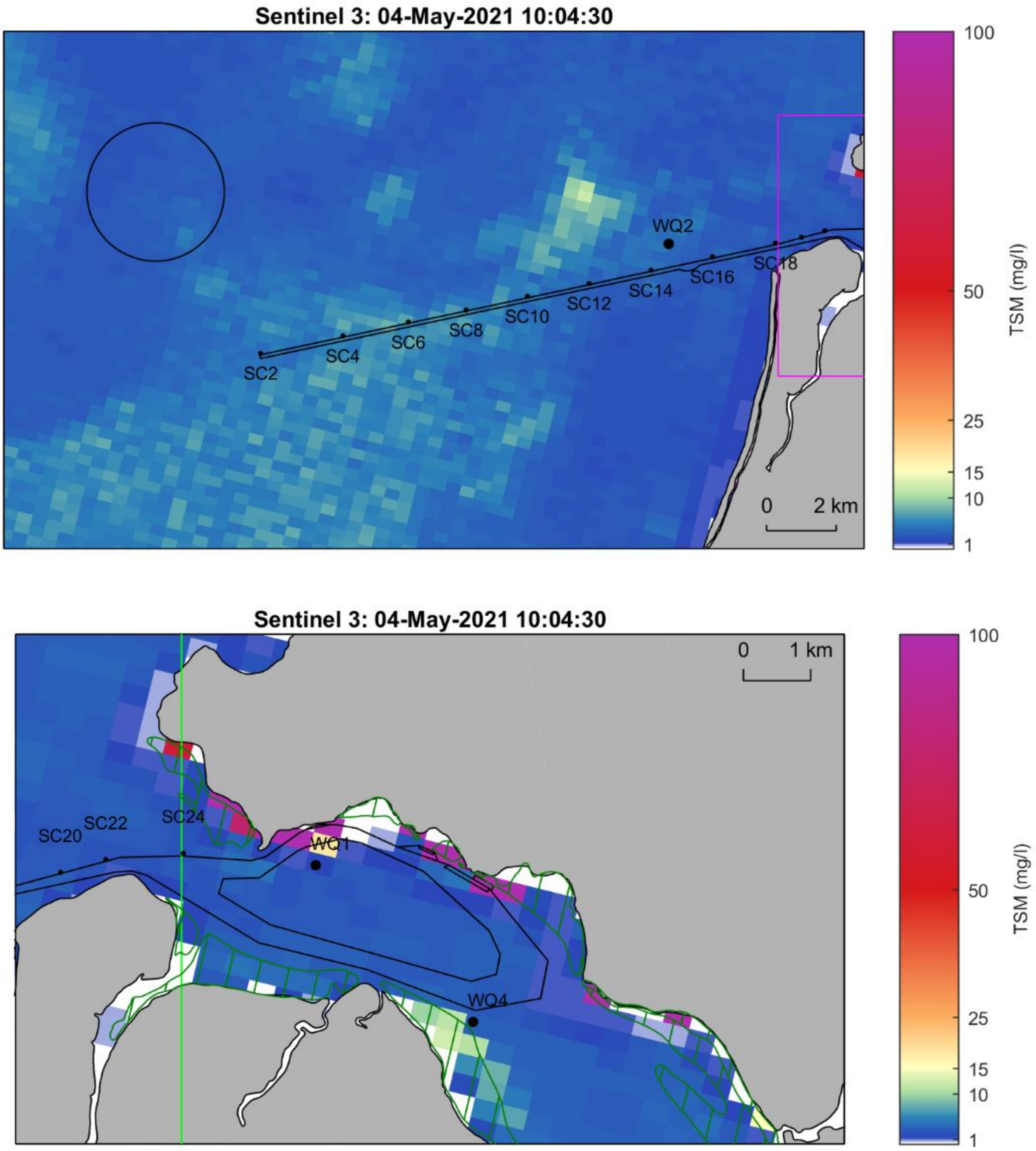


Figure 66. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 04/05/2021 at 10:05 AEST (dredging).

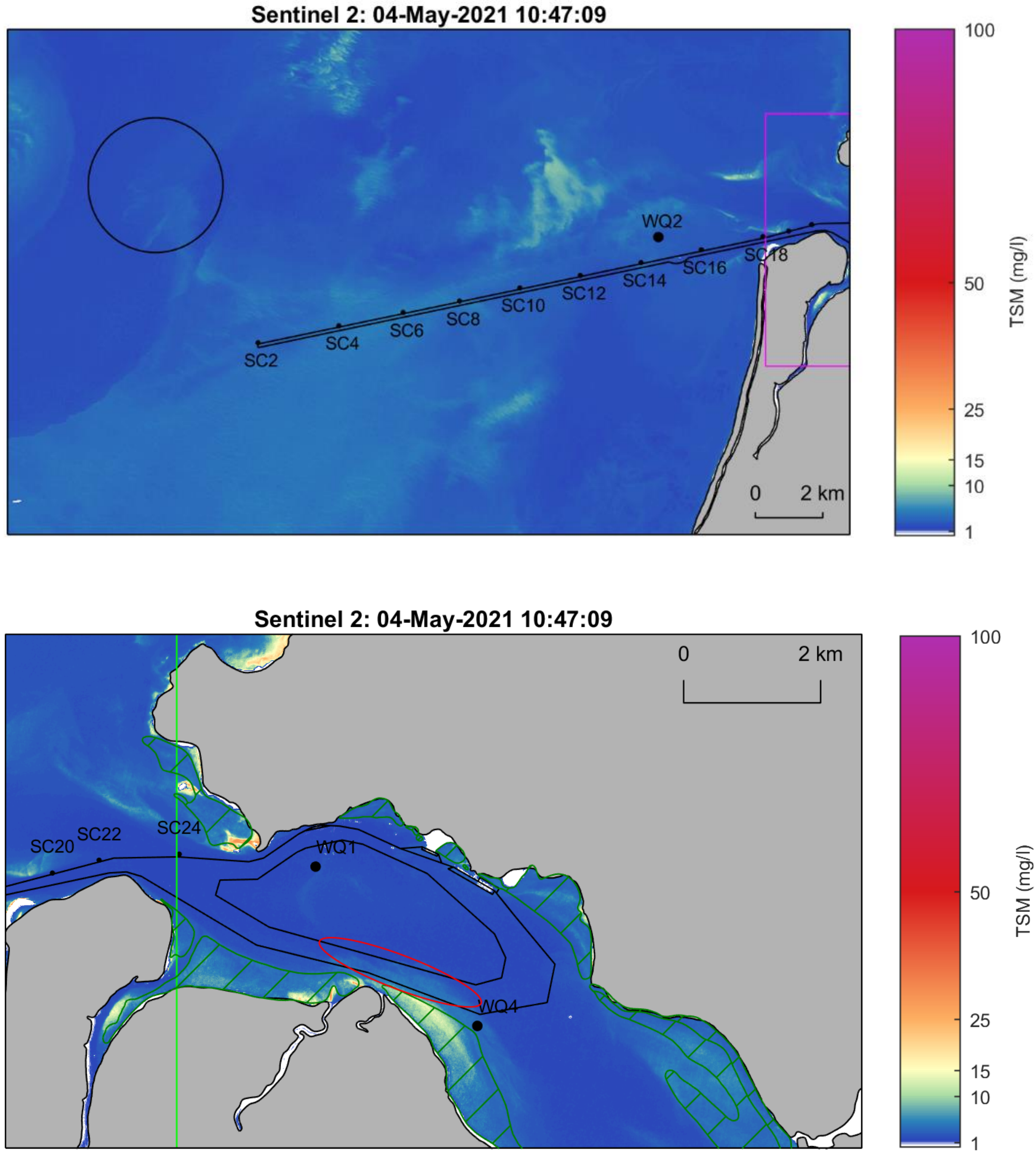


Figure 67. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 04/05/2021 at 10:47 AEST (dredging).

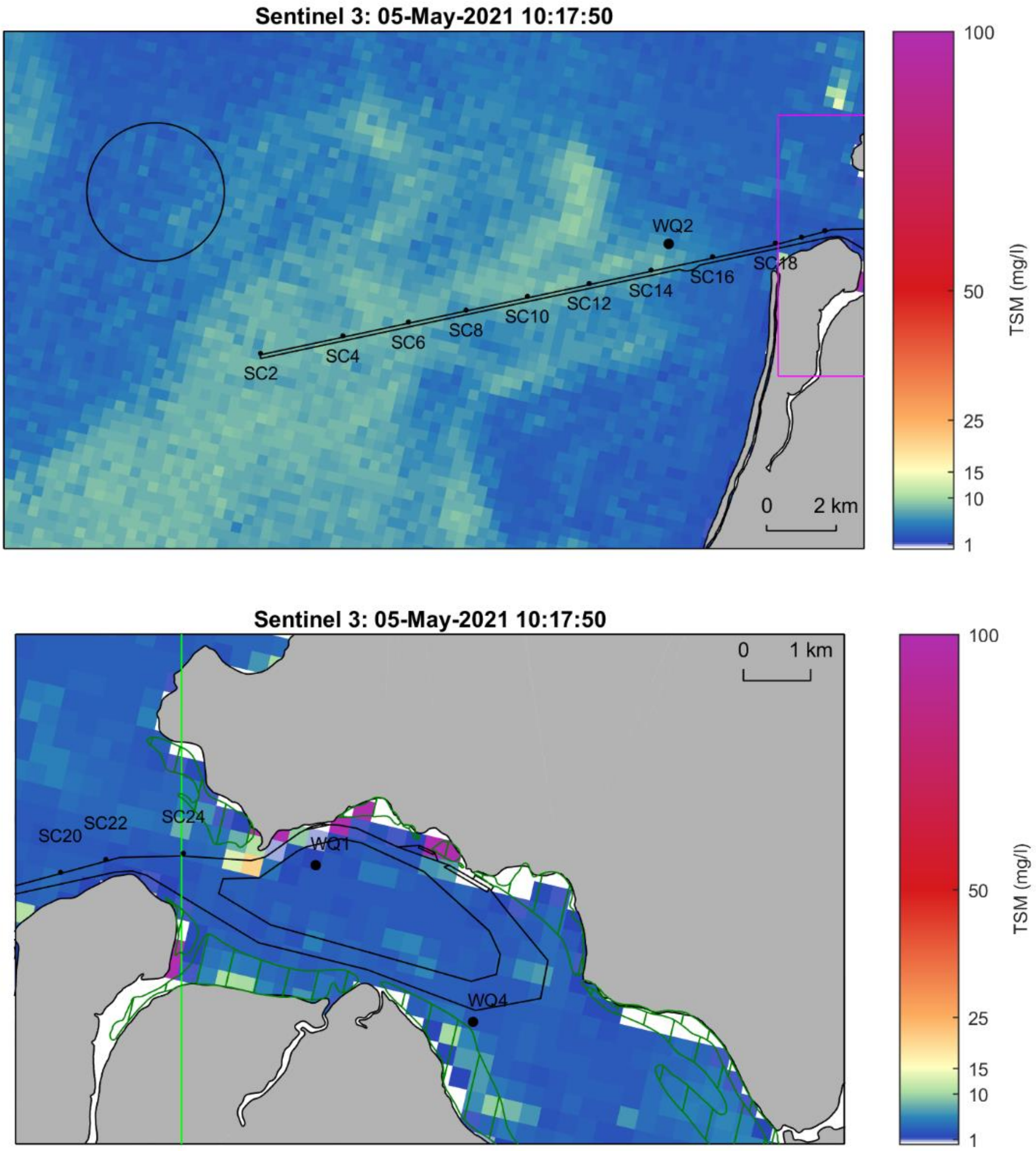


Figure 68. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 05/05/2021 at 10:17 AEST (dredging).

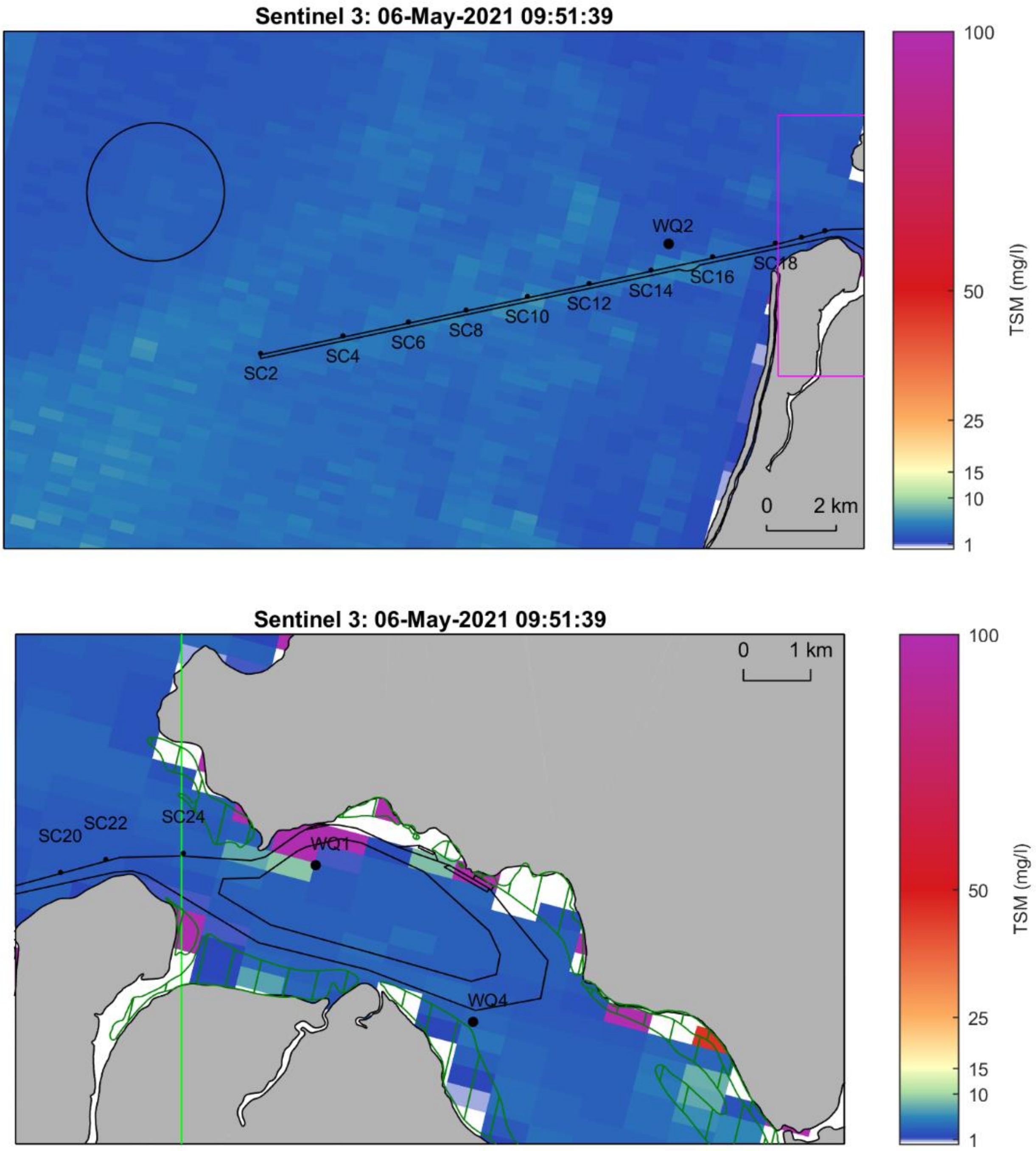


Figure 69. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 06/05/2021 at 9:51 AEST (dredging).

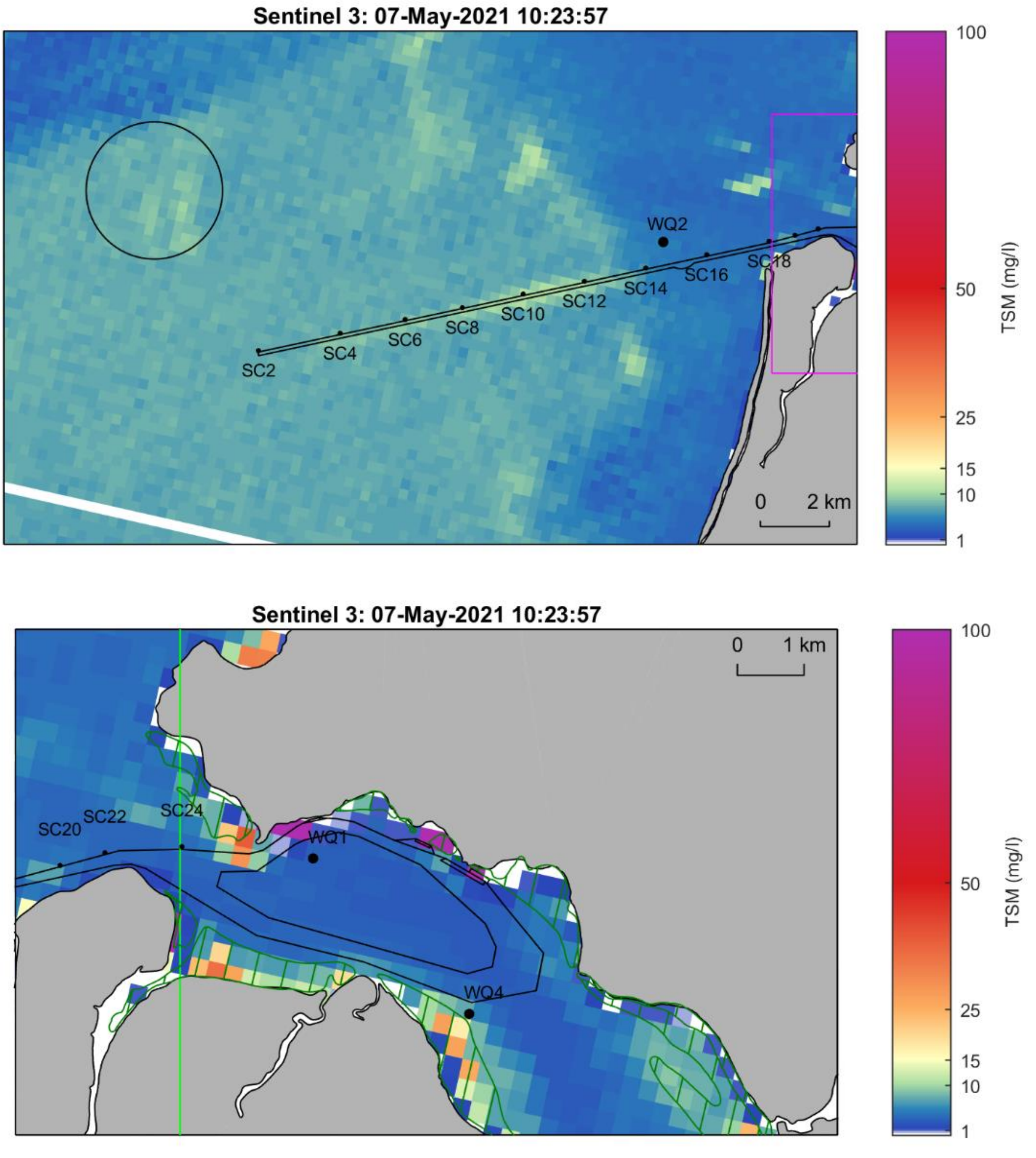


Figure 70. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 07/05/2021 at 10:23 AEST (dredging).

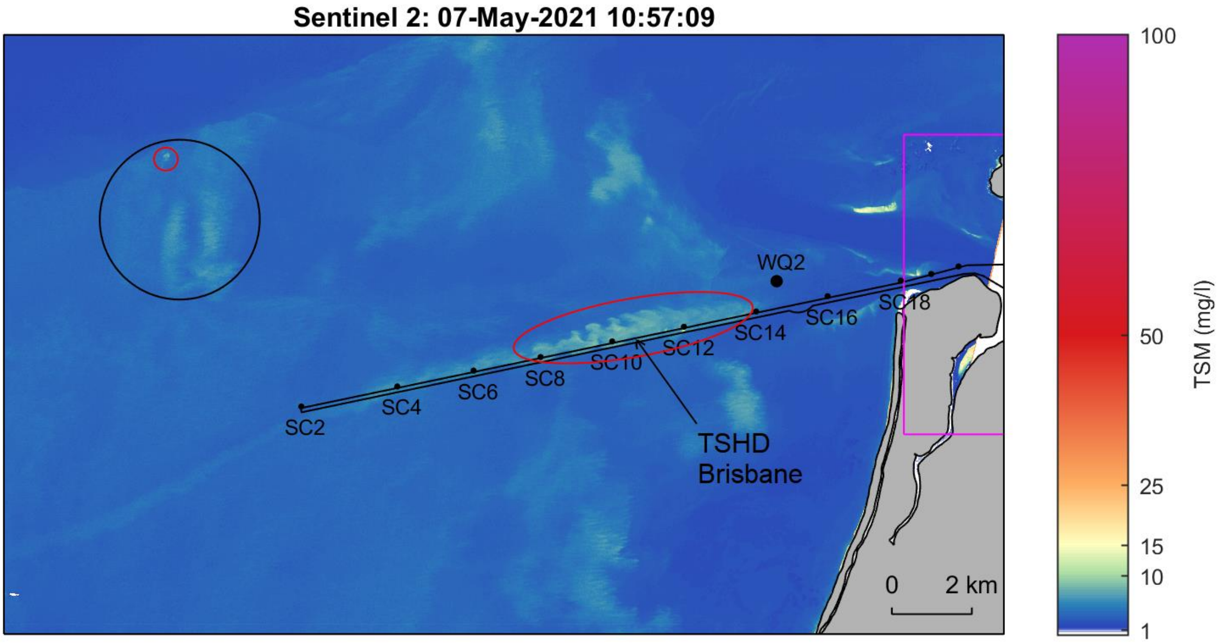


Figure 71. **Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 07/05/2021 at 10:57 AEST (dredging).** *Image does not cover Inner Harbour.*

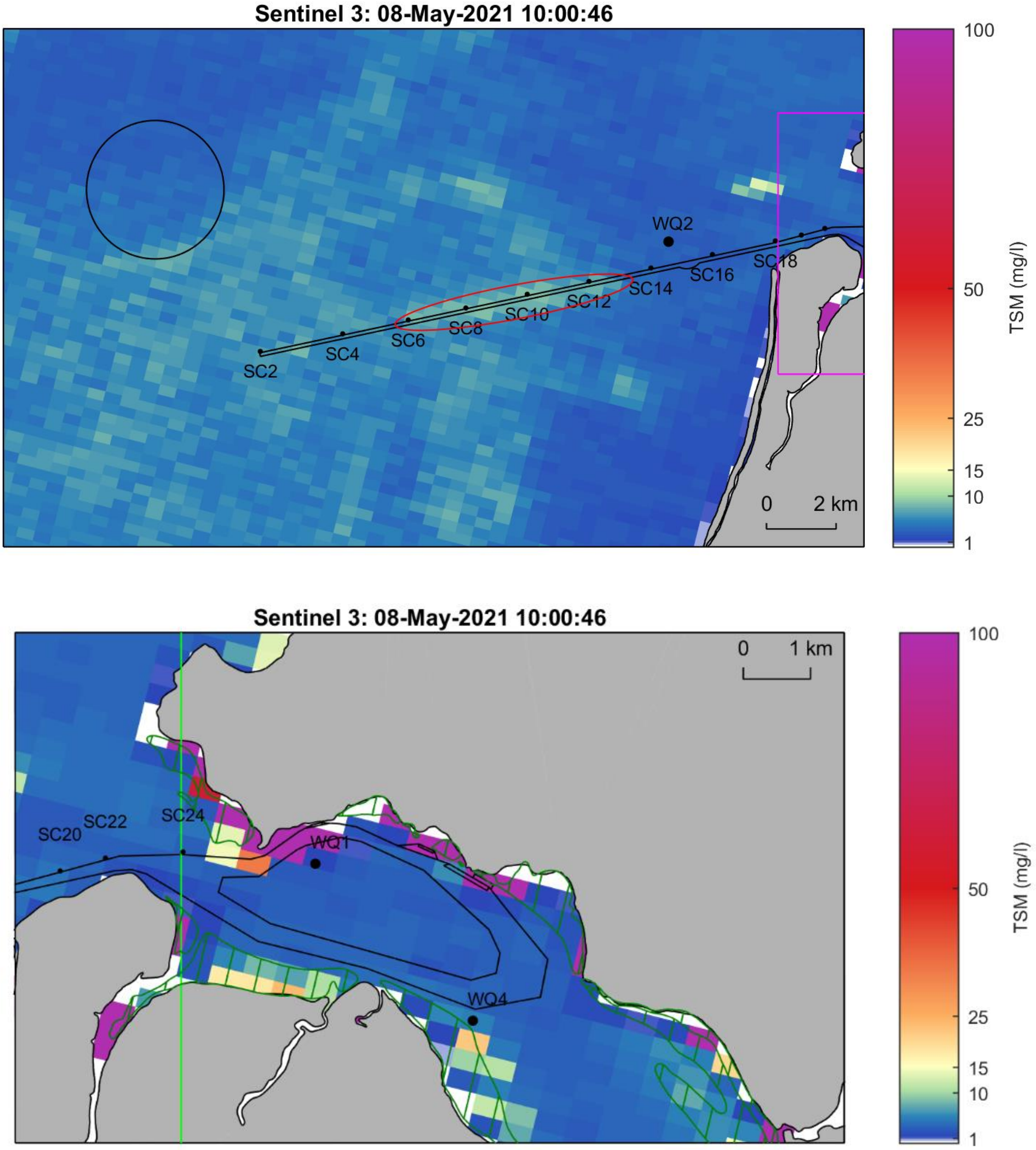


Figure 72. **Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 08/05/2021 at 10:00 AEST (dredging).**

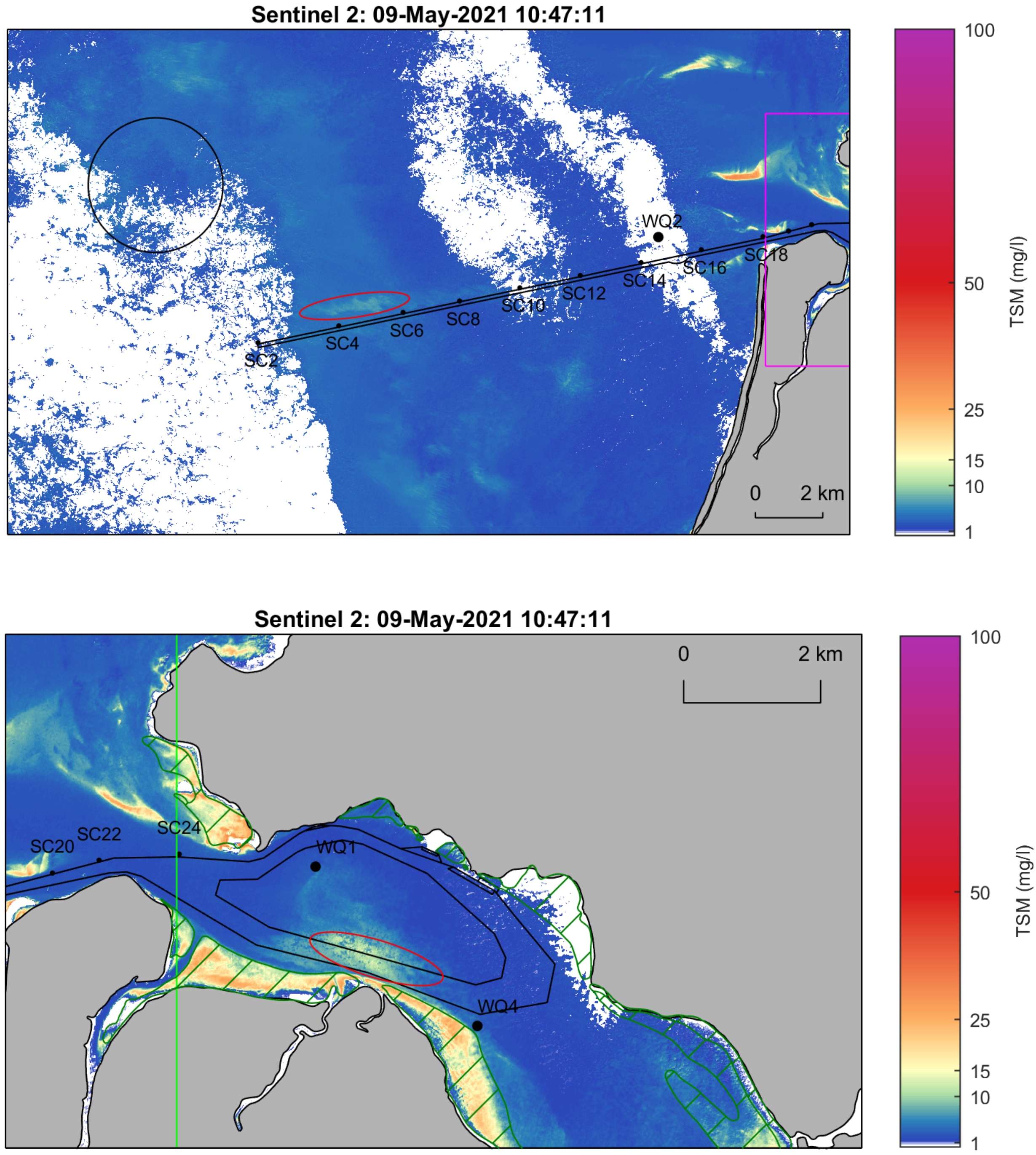


Figure 73. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 09/05/2021 at 10:47 AEST (dredging).

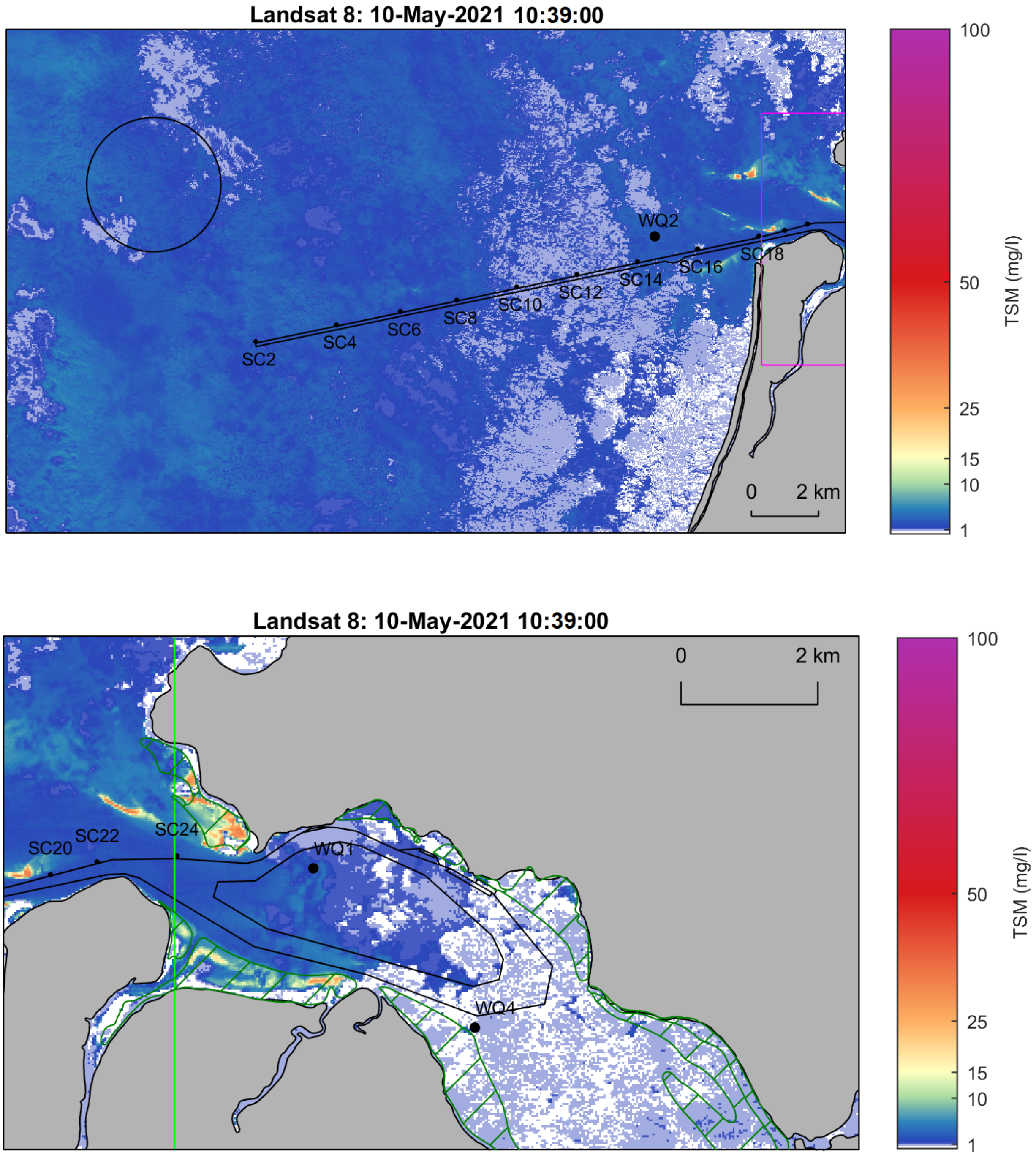


Figure 74. **Satellite-derived turbidity from the Landsat 8 sensor for Albatross Bay on 10/05/2021 at 10:00 AEST (dredging).**

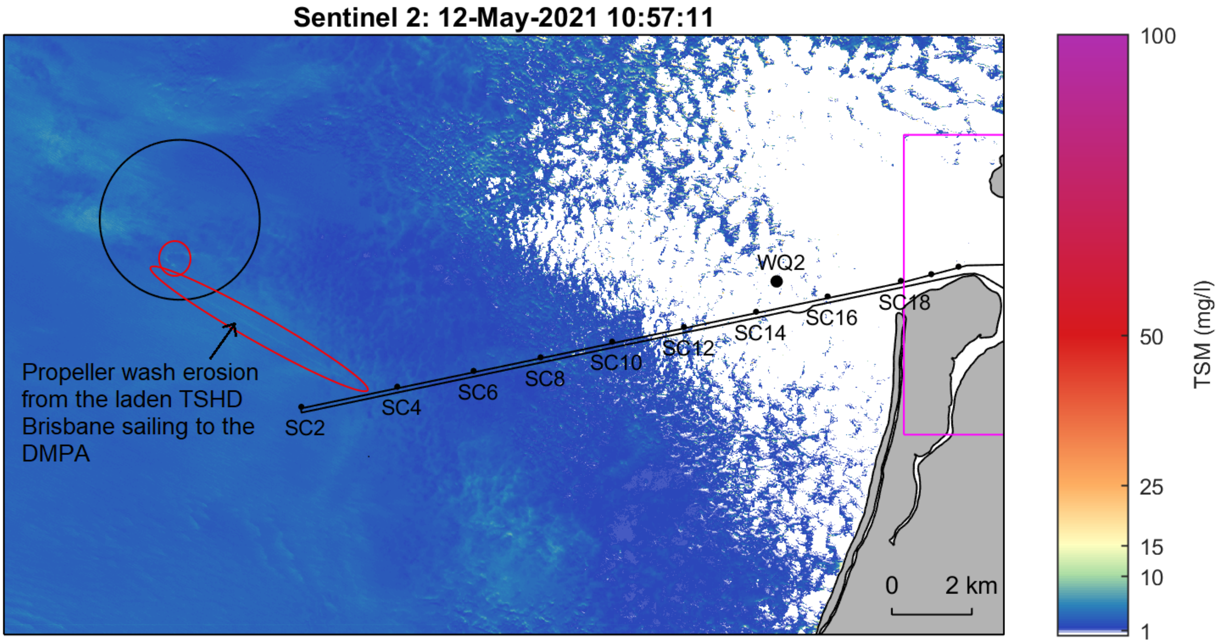


Figure 75. **Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 12/05/2021 at 10:57 AEST (dredging).** *Image does not cover Inner Harbour.*

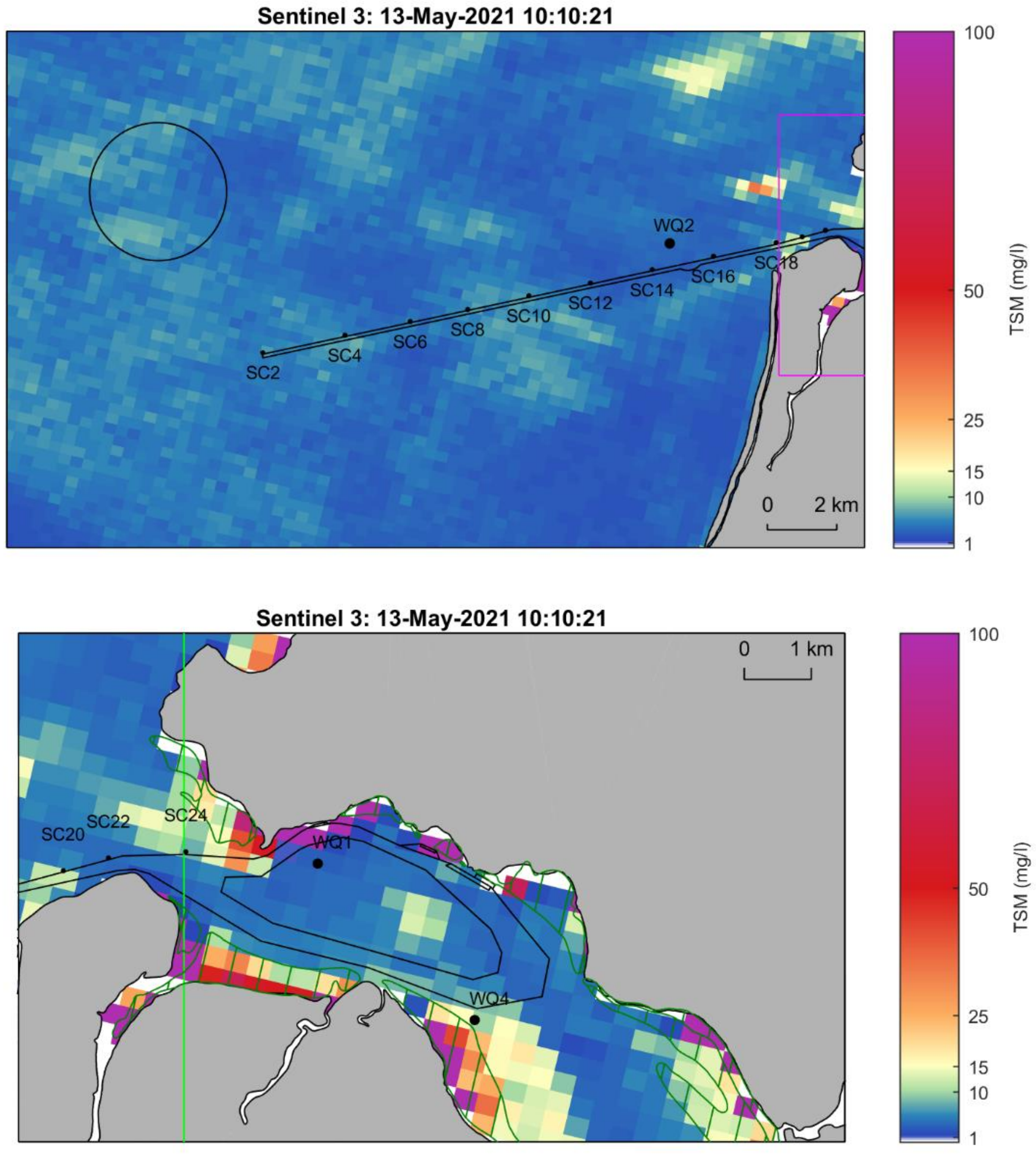


Figure 76. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 13/05/2021 at 10:10 AEST (dredging).

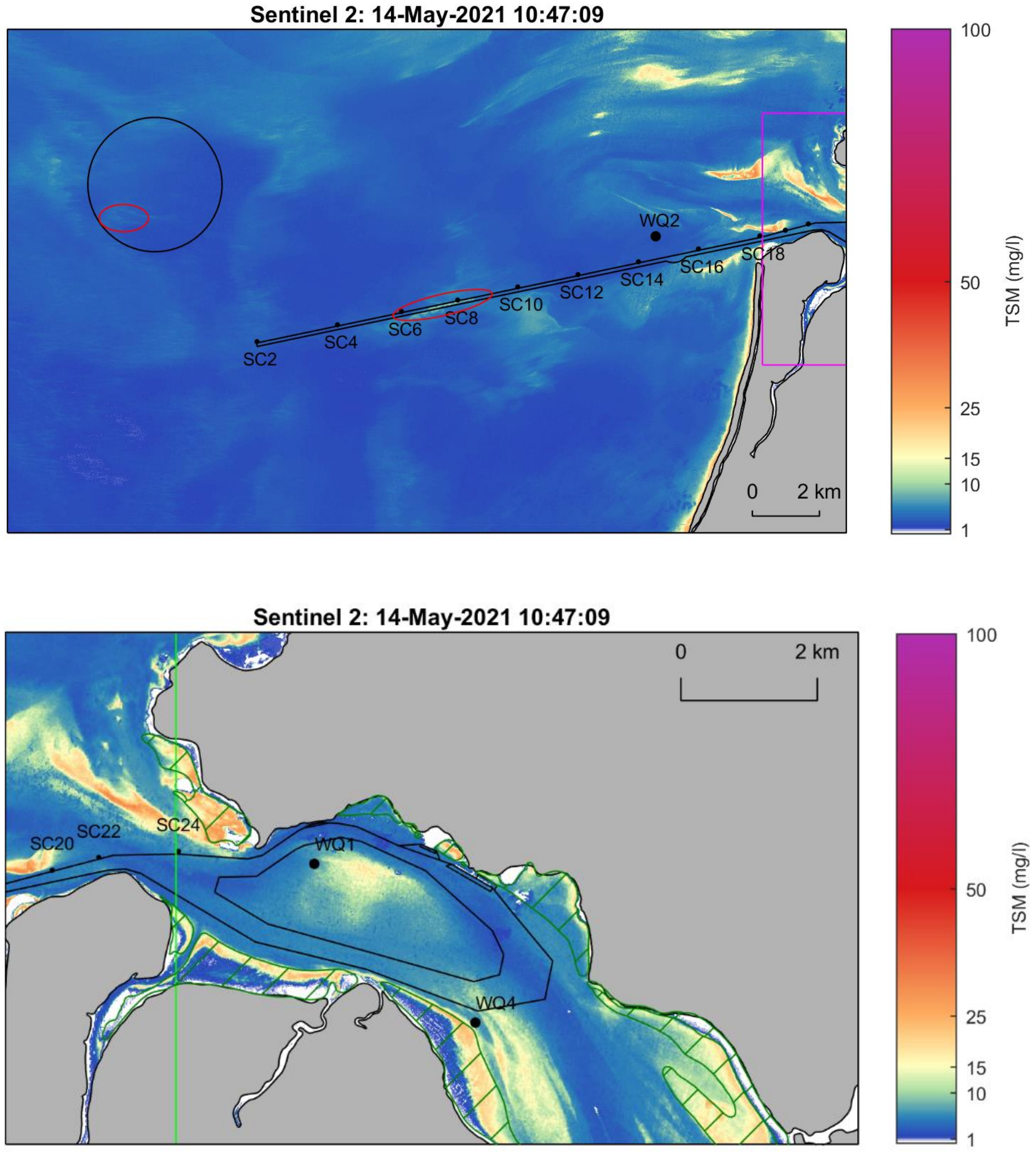


Figure 77. **Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 14/05/2021 at 10:47 AEST (dredging).**

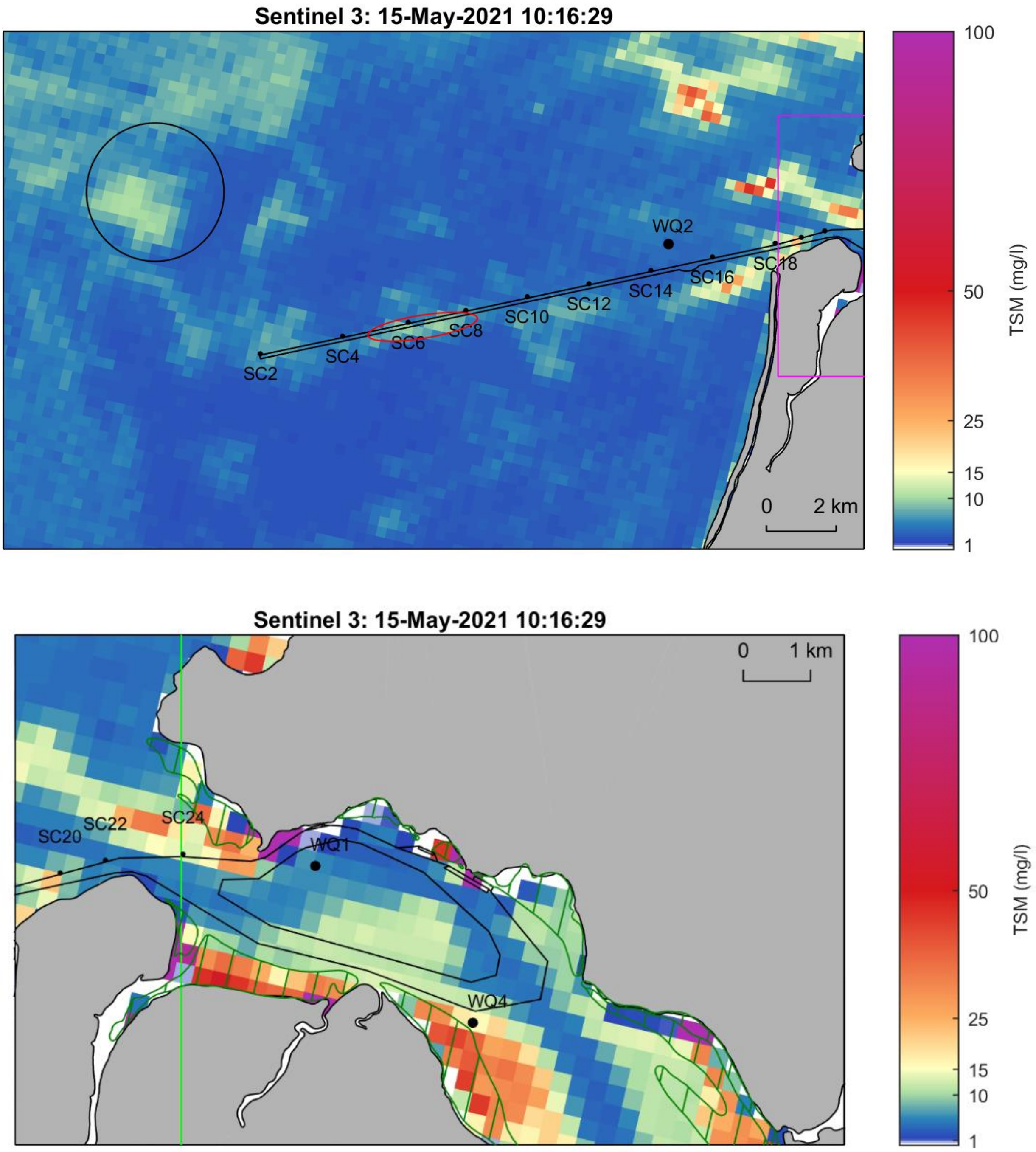
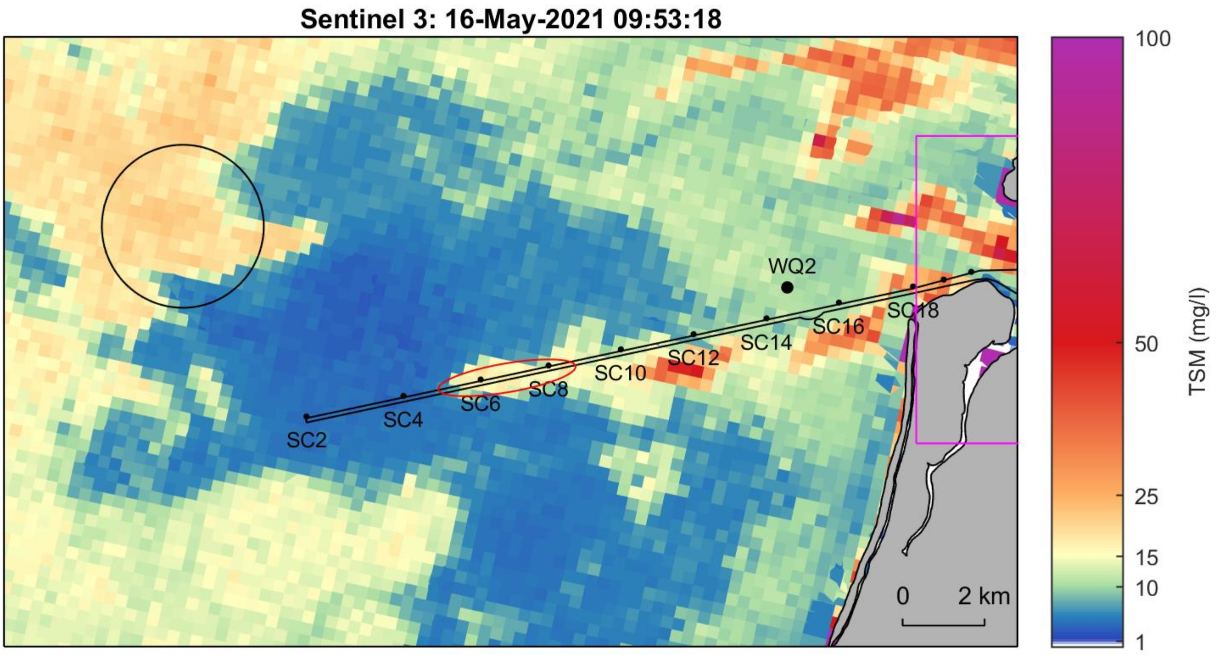


Figure 78. **Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 15/05/2021 at 10:16 AEST (dredging).**



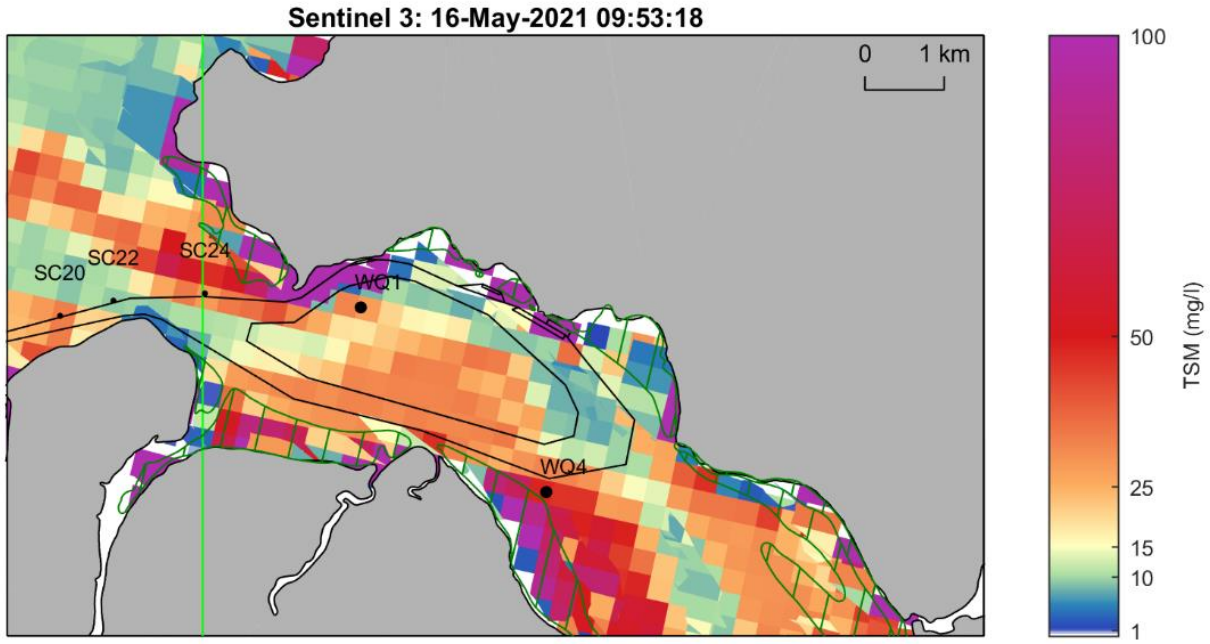
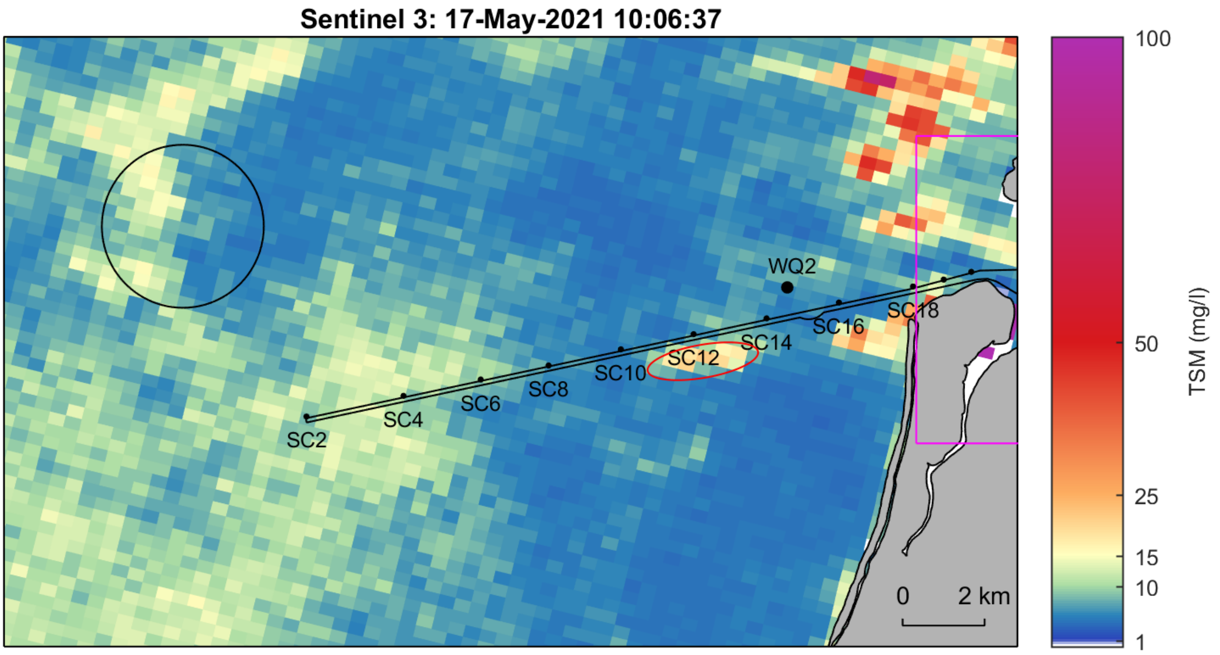


Figure 79. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 16/05/2021 at 9:53 AEST (dredging).



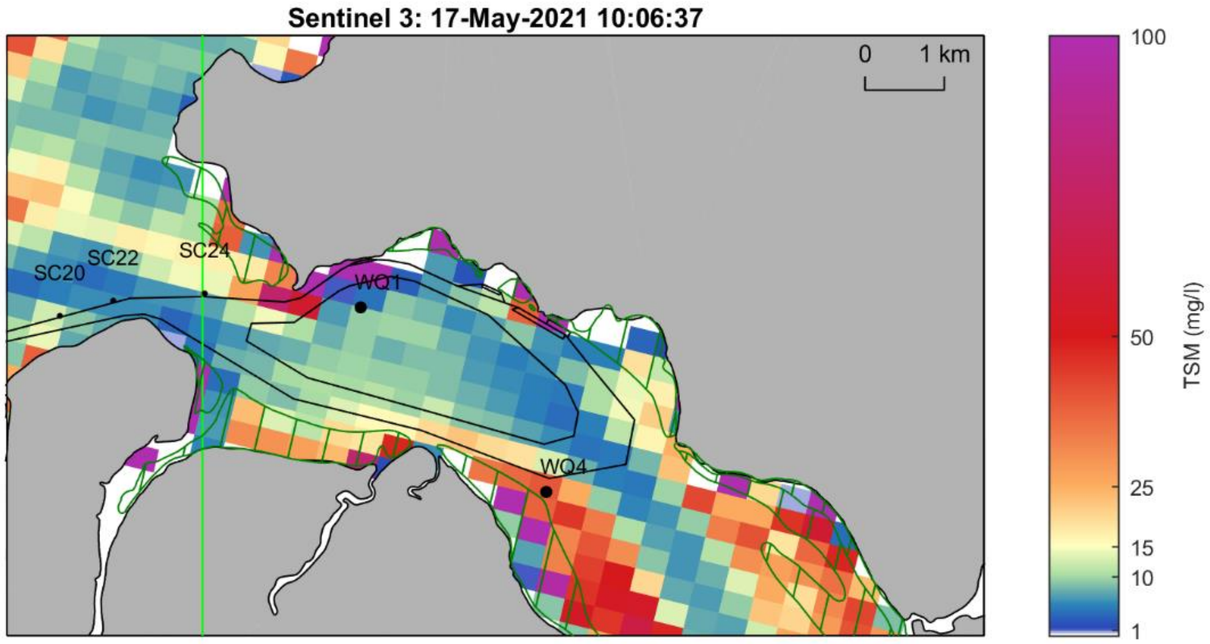


Figure 80. **Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 17/05/2021 at 10:07 AEST (dredging).**

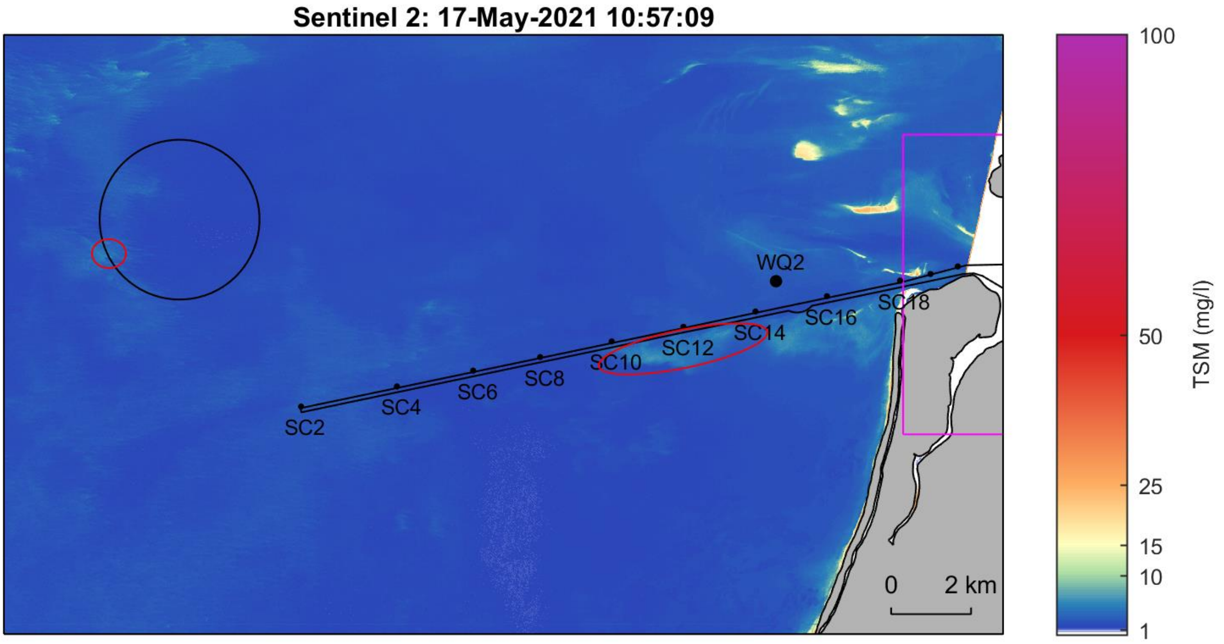


Figure 81. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 17/05/2021 at 10:57 AEST (dredging). *Image does not cover Inner Harbour.*

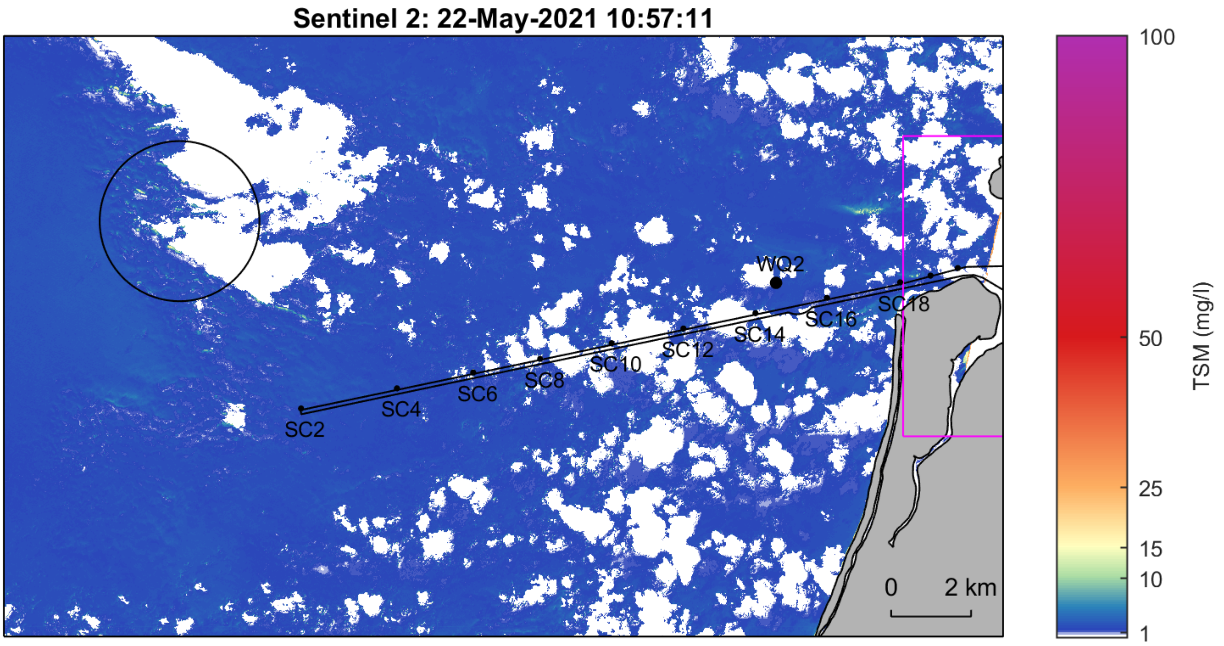


Figure 82. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 22/05/2021 at 10:57 AEST (post-dredging). *Image does not cover Inner Harbour.*

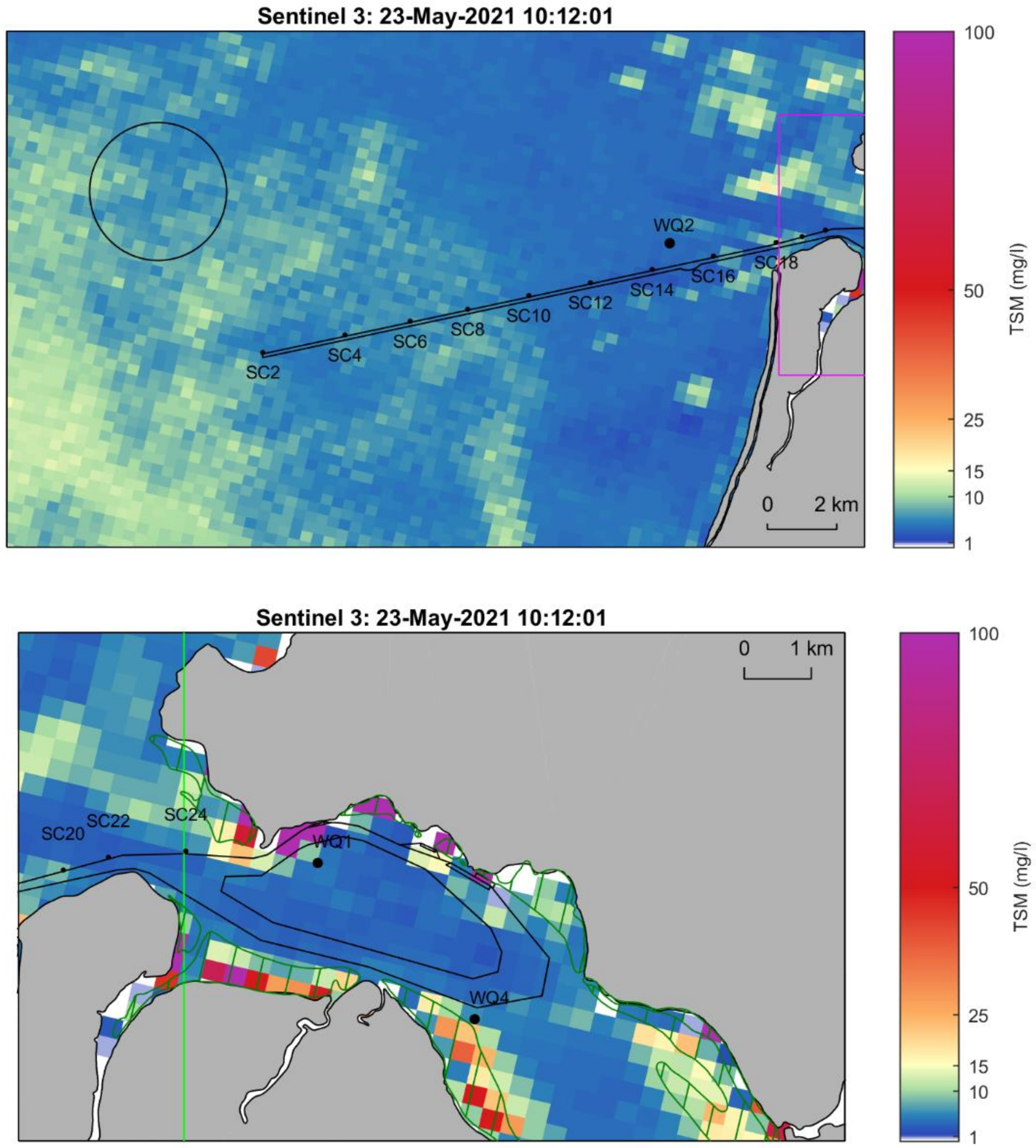
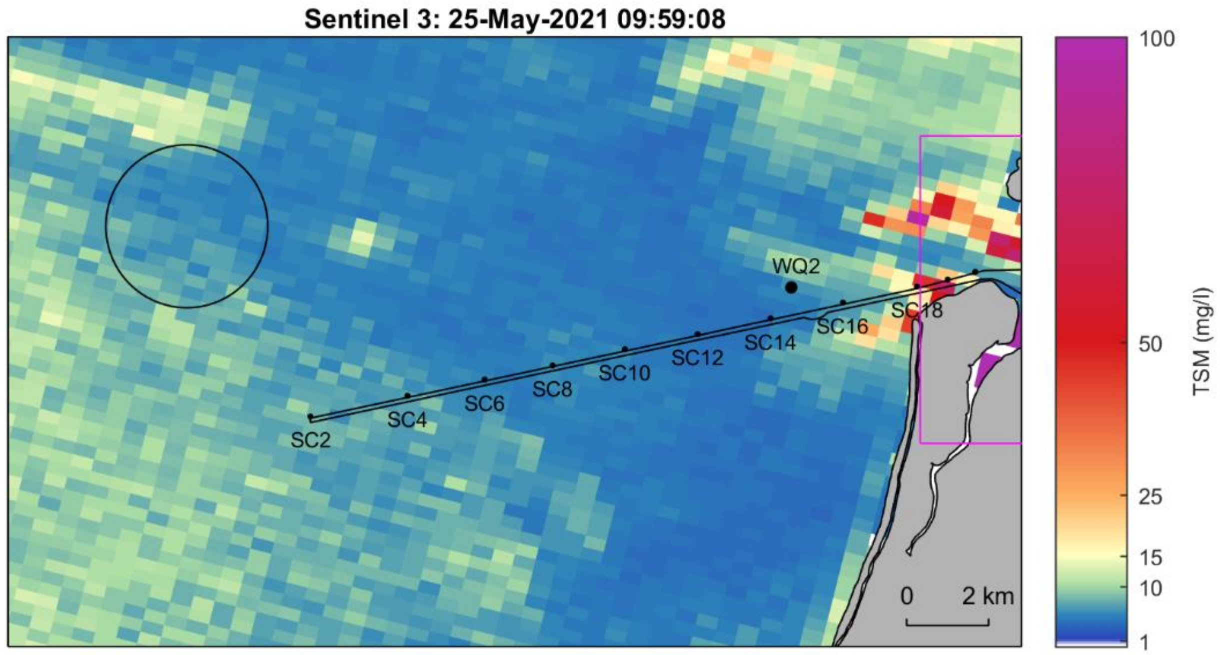


Figure 83. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 23/05/2021 at 10:12 AEST (post-dredging).



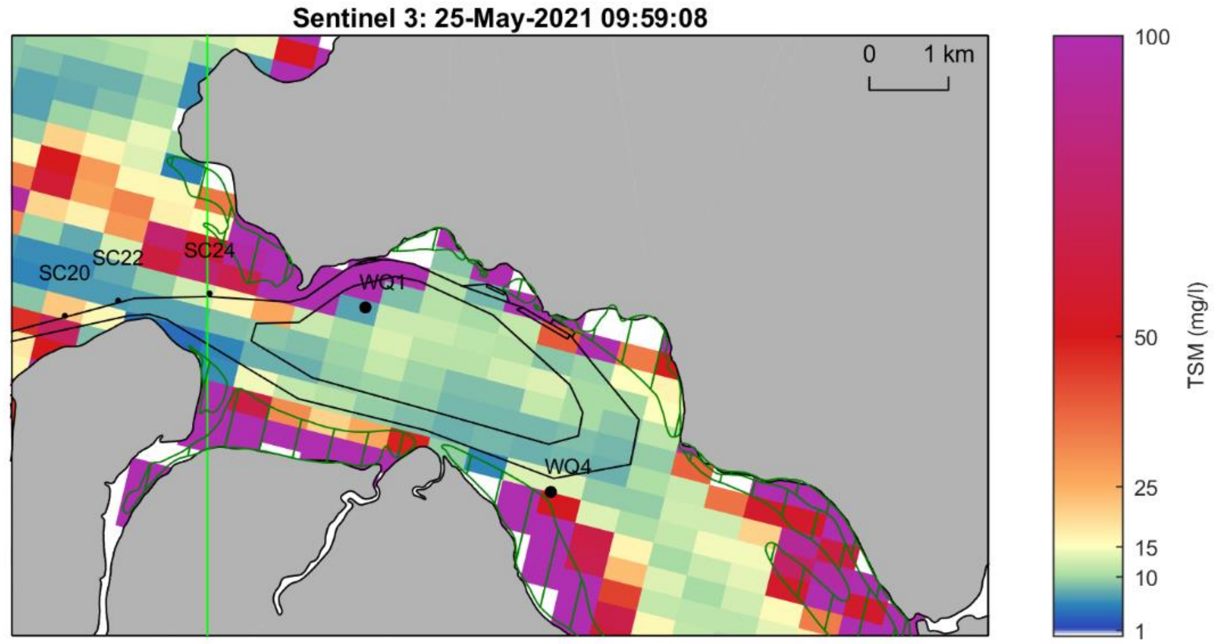


Figure 84. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 25/05/2021 at 9:59 AEST (post-dredging).

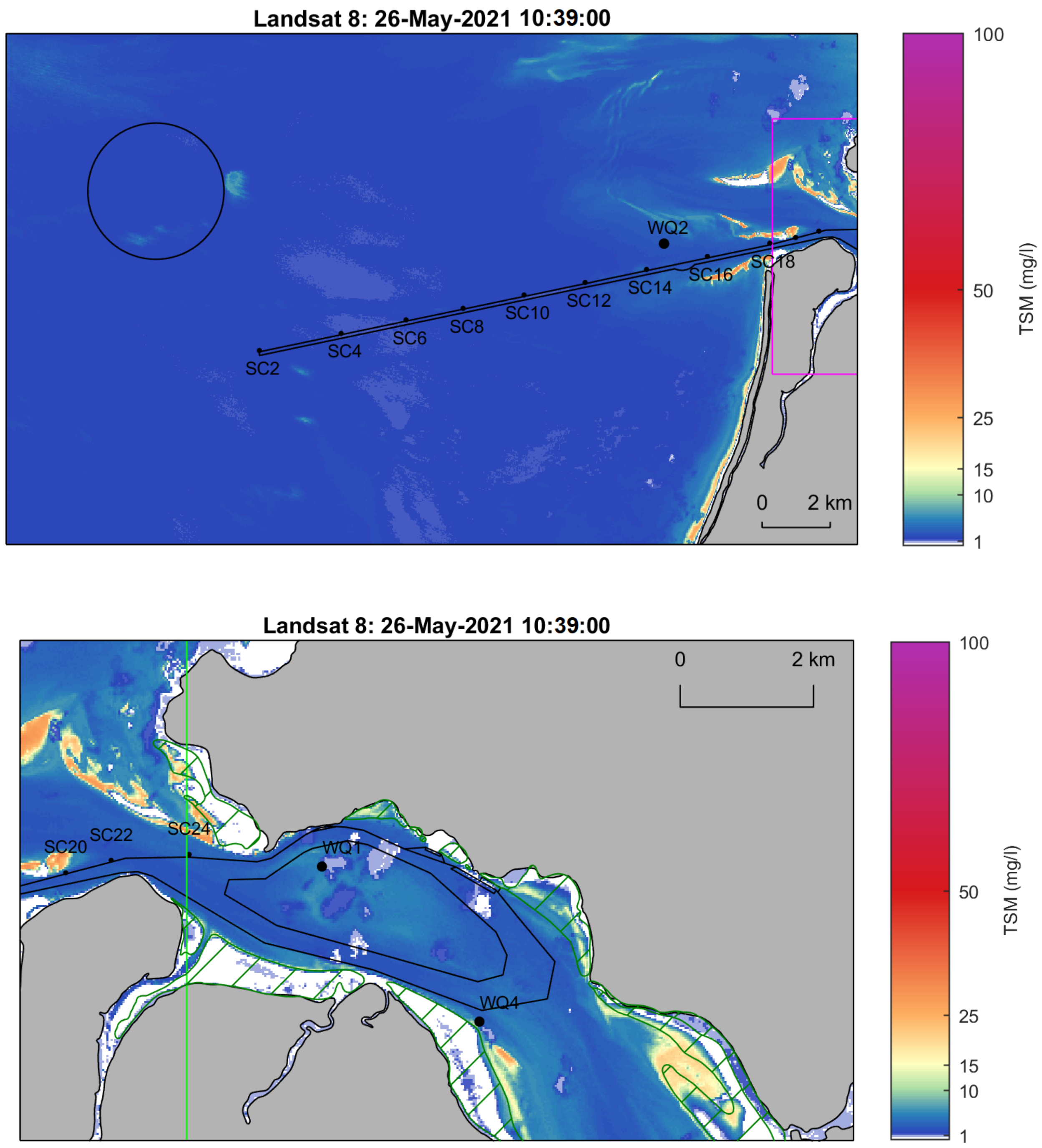


Figure 85. **Satellite-derived turbidity from the Landsat 8 sensor for Albatross Bay on 26/05/2021 at 10:00 AEST (post-dredging).**

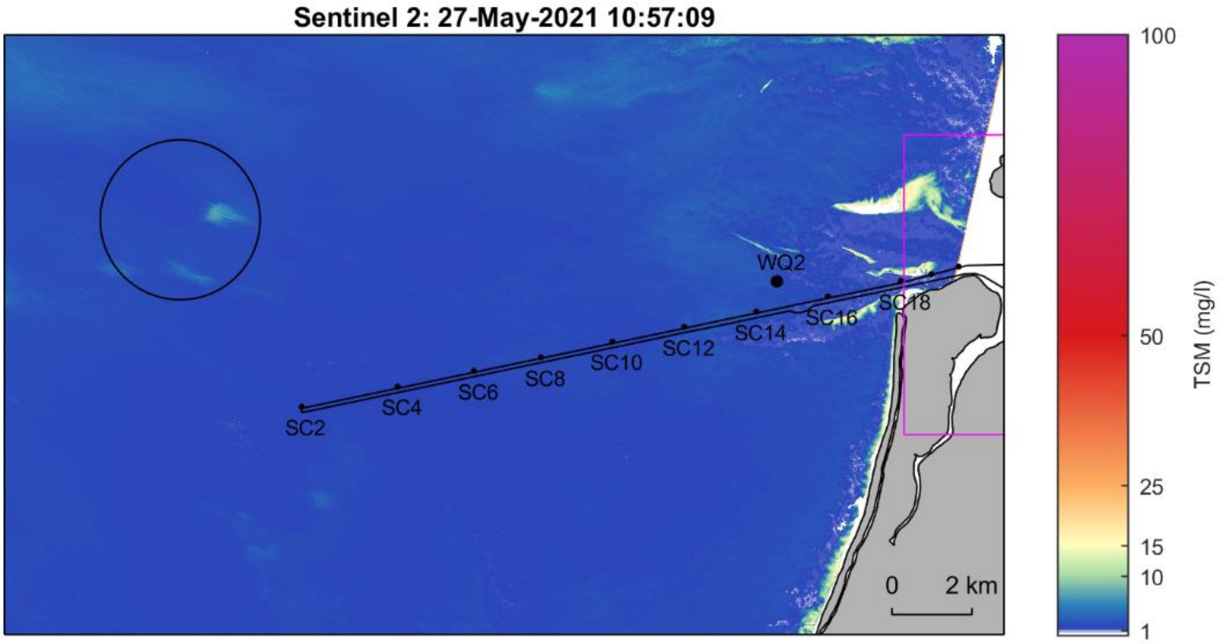


Figure 86. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 27/05/2021 at 10:57 AEST (post-dredging). *Image does not cover Inner Harbour.*

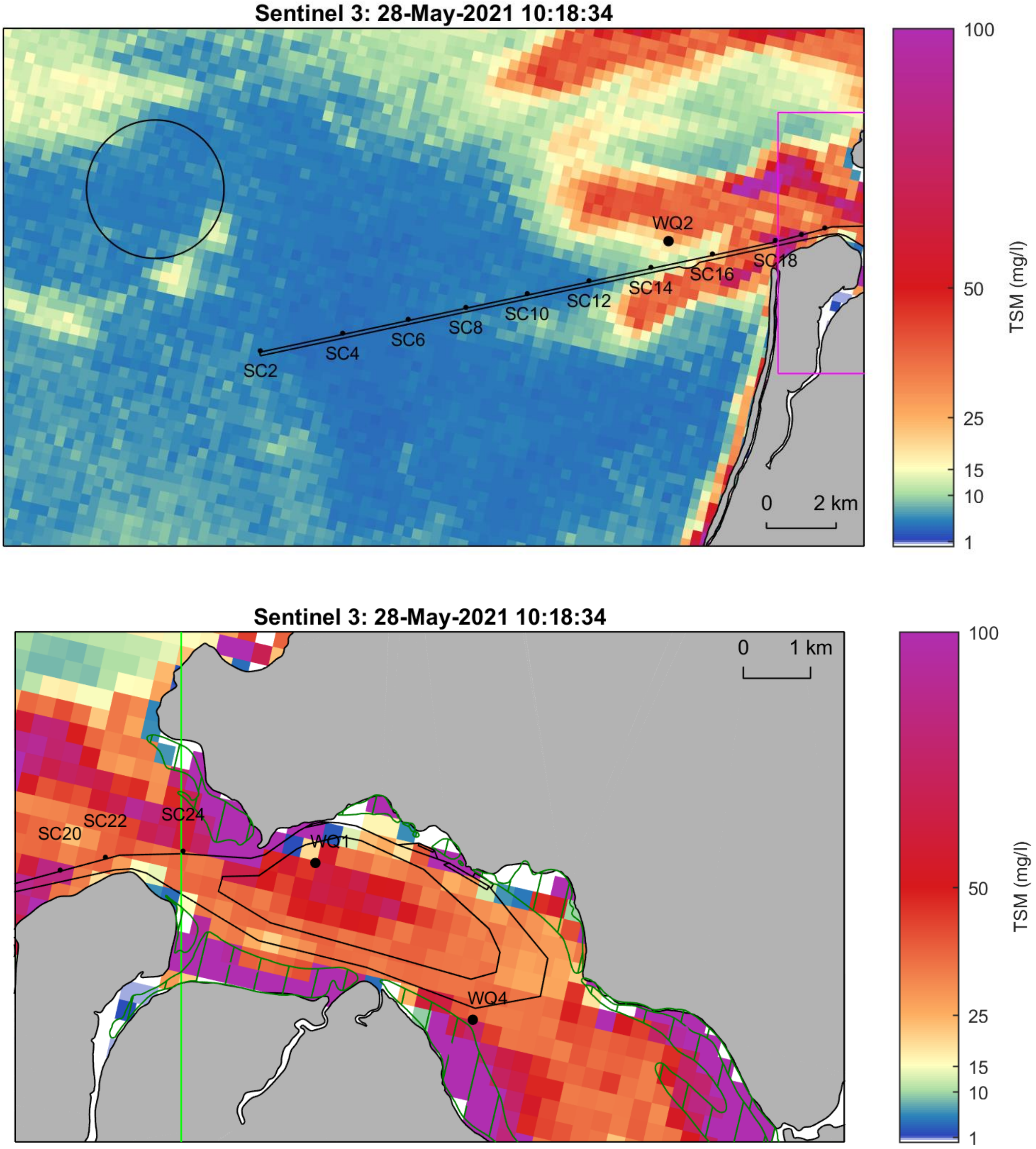


Figure 87. **Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 28/05/2021 at 9:59 AEST (post-dredging).**

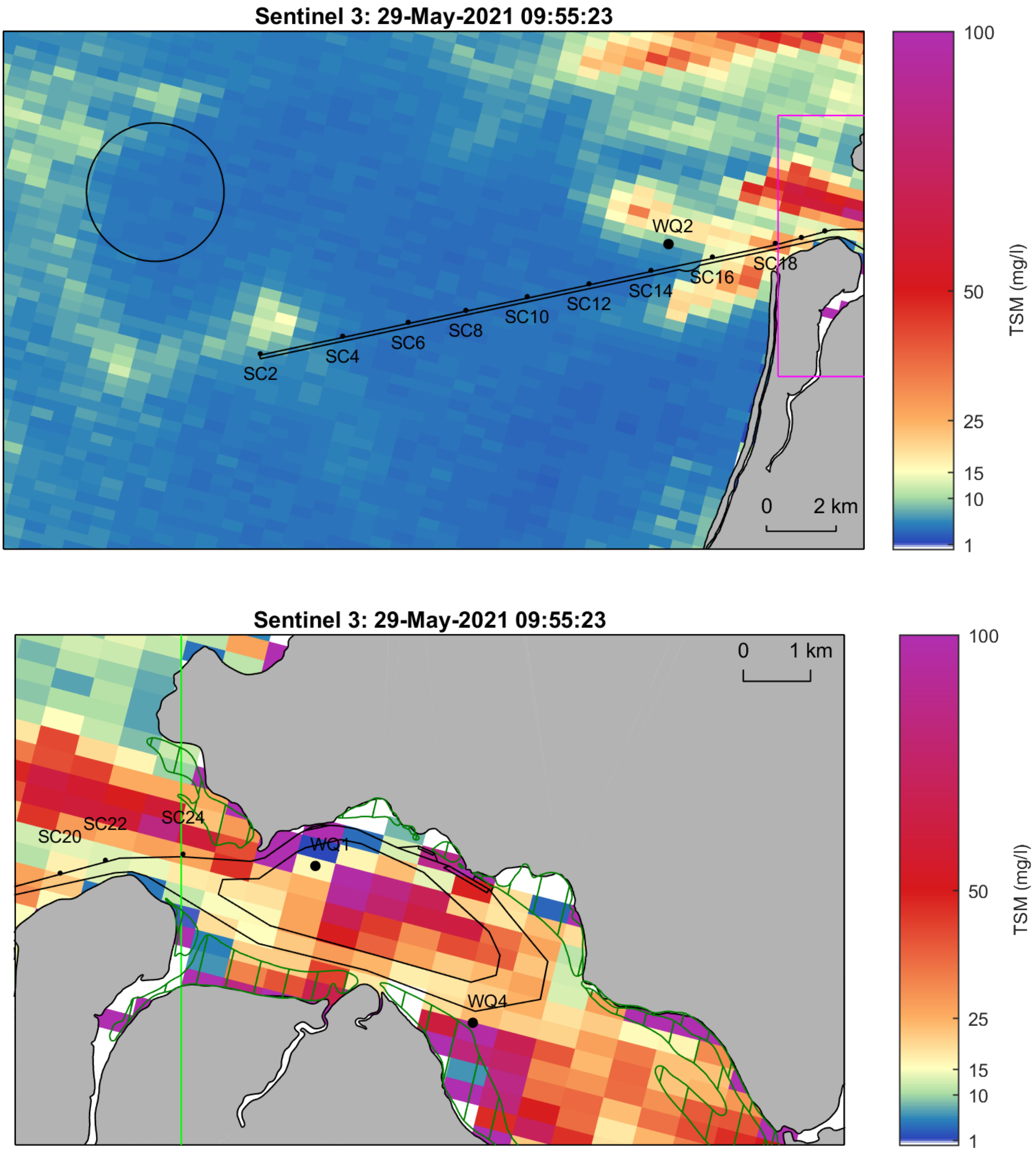


Figure 88. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 29/05/2021 at 9:59 AEST (post-dredging).

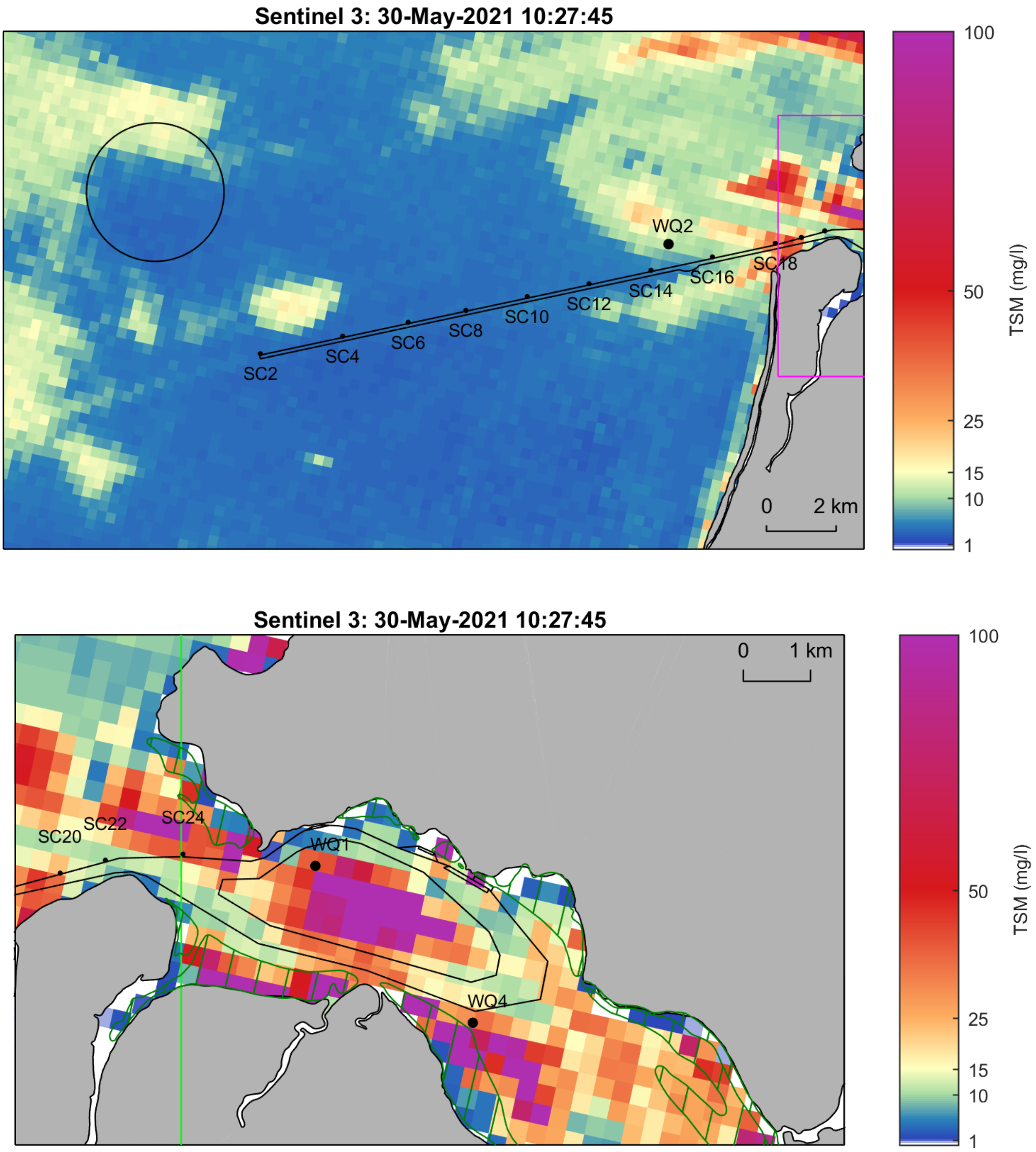


Figure 89. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 30/05/2021 at 9:59 AEST (post-dredging).

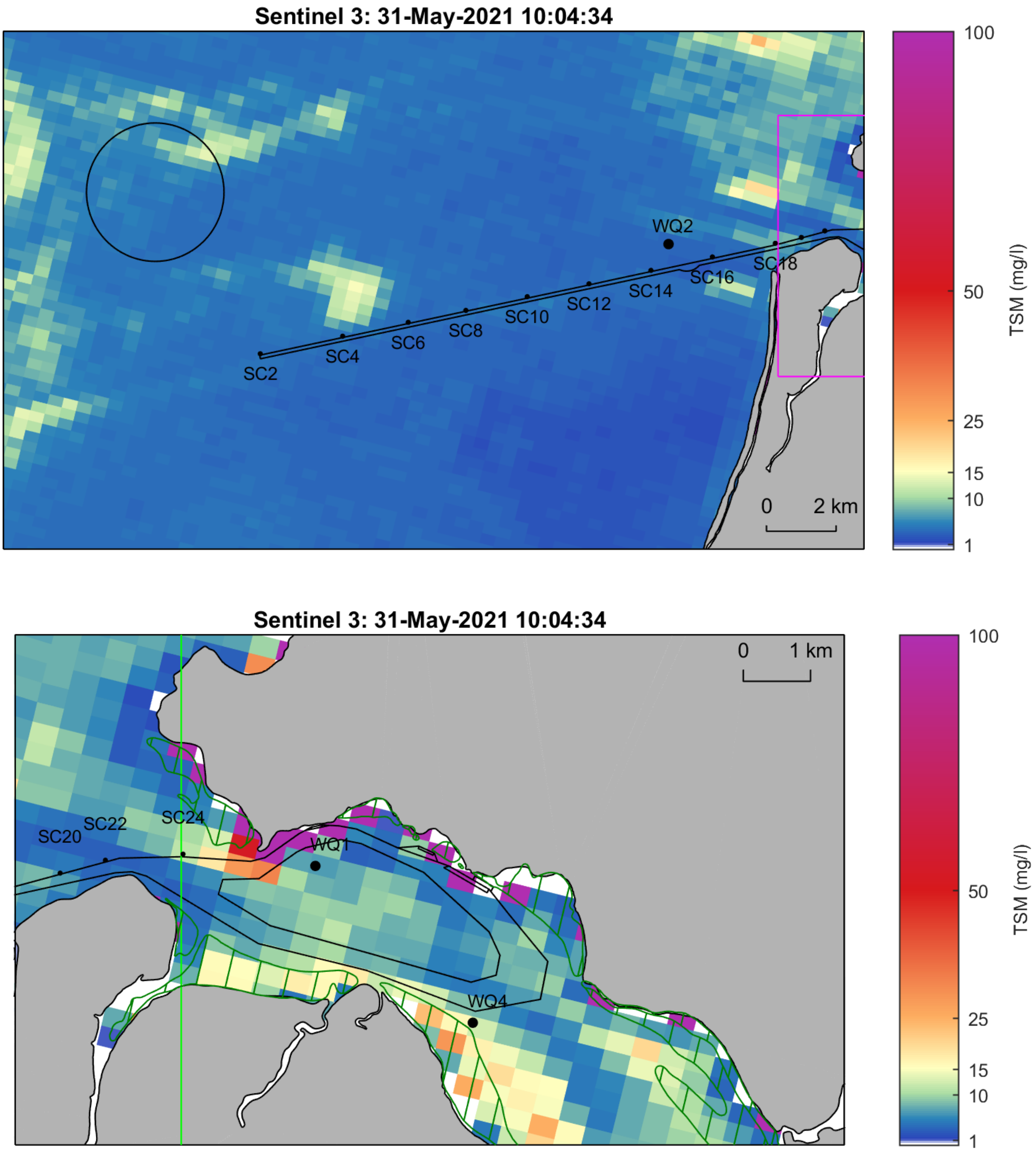


Figure 90. Satellite-derived turbidity from the Sentinel-3 sensor for Albatross Bay on 31/05/2021 at 9:59 AEST (post-dredging).

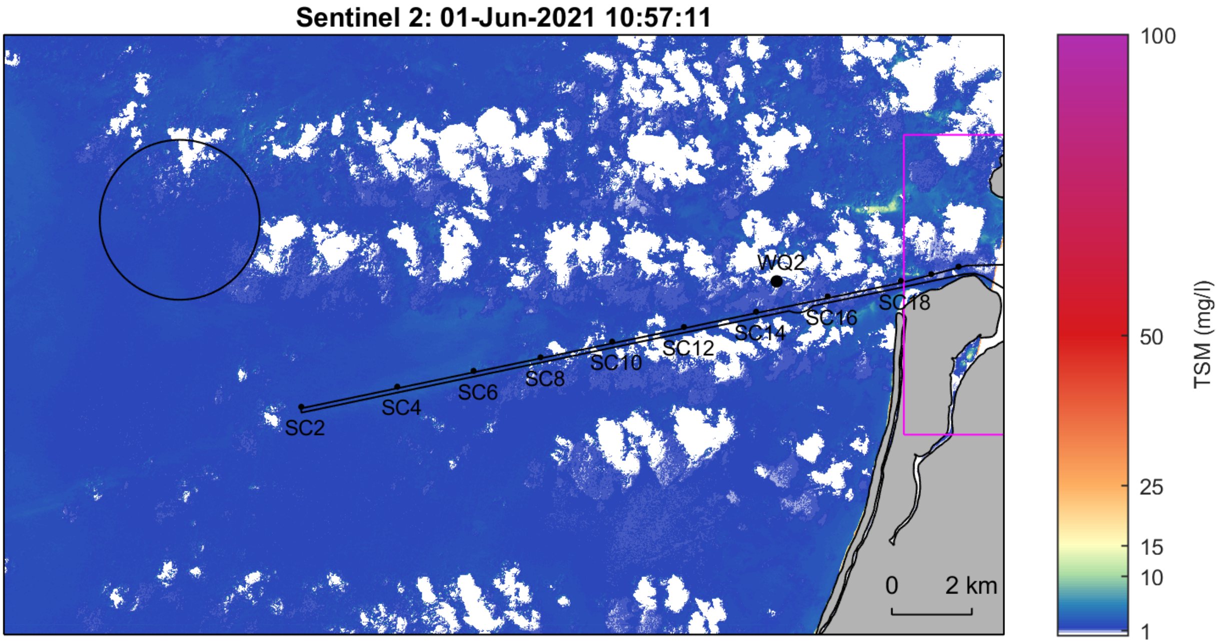


Figure 91. Satellite-derived turbidity from the Sentinel-2 sensor for Albatross Bay on 01/06/2021 at 10:57 AEST (post-dredging). *Image does not cover Inner Harbour.*

4.2.2.3. Dredge Vessel Scale

To further analyse the satellite-derived turbidity for potential increases in turbidity due to the maintenance dredging activity, zoomed in plots of high resolution imagery during periods when the TSHD Brisbane was dredging are shown for the following images:

- 7th May 2021 (Figure 92): the TSHD Brisbane was dredging load 92 (silt from SC10 to SC12) with dredging have started 10 mins before the time of image capture; and
- 12th May 2021 (Figure 93): the TSHD Brisbane was dredging load 133 (silt and sand from SC4 to SC6) with dredging having started 7 minutes before the time of image capture.

The image from the 7th May 2021 shows a localised plume with a TSM concentration of around 10 to 15 mg/l extending approximately 6 km in length and 1 km in width to the north of the South Channel and the TSHD Brisbane (the dredger is travelling from SC10 to SC12). This image was taken 11 minutes after dredging commenced and so the hopper would still be filling (i.e. it is unlikely there was any overflow at the time of the image). It is therefore likely that the plume identified is either from previous dredge cycles (with this being the fifth consecutive load in this part of the South Channel), natural processes or due to disturbance by laden tankers transiting the channel, with the low tidal mixing on neap tides limiting the mixing and dispersion of the plume.

The image from 12th May 2021 did not show a plume which is likely due to the fact that overflow had not yet started, resulting in very limited sediment disturbance from the dredging at this time.

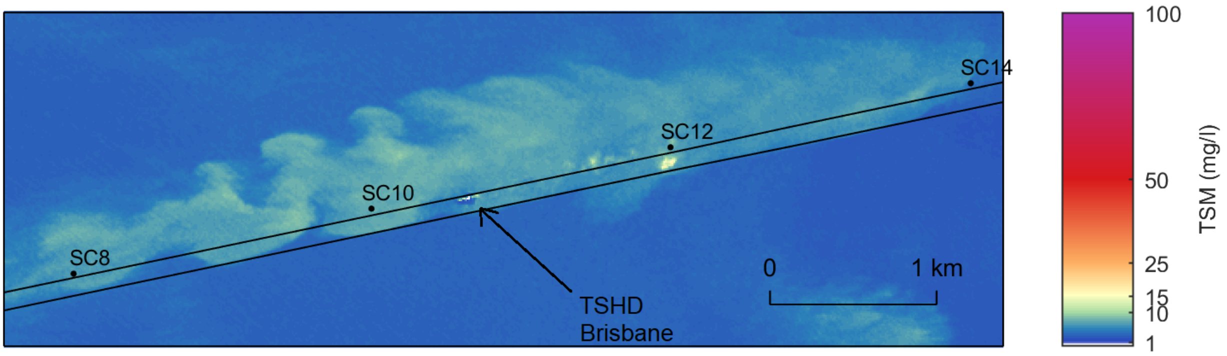


Figure 92. **Satellite derived turbidity from the Sentinel-2 sensor showing the location of the TSHD Brisbane on 07/07/2021 at 10:57 AEST.**

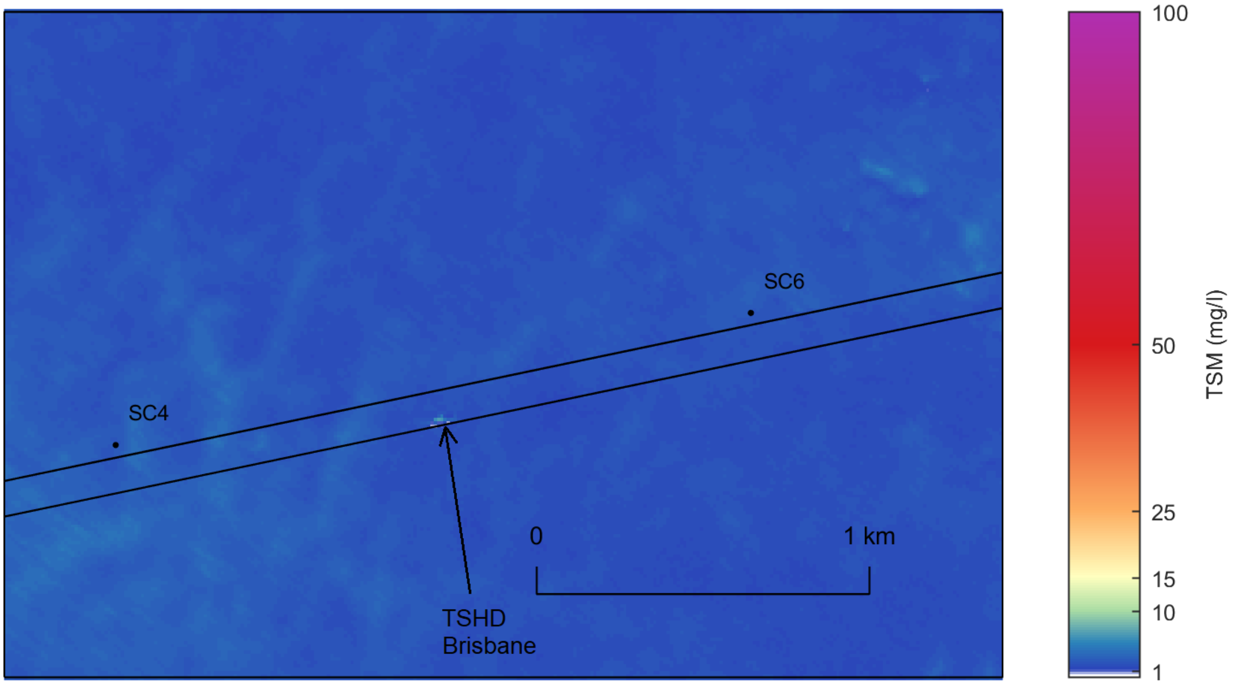


Figure 93. **Satellite derived turbidity from the Sentinel-2 sensor showing the location of the TSHD Brisbane on 12/07/2021 at 10:57 AEST.**

5. Summary

This report has analysed and interpreted turbidity data collected pre-, during and post the Port of Weipa 2021 maintenance dredging program. The 2021 maintenance dredging program was undertaken by the TSHD Brisbane and involved the relocation of approximately 320,000 m^3 of sediment from the dredged areas of the Port to the Albatross Bay DMPA. Following the 2020 maintenance dredging program the DMPA was moved to the west, by the distance of its radius (1.1 nautical miles), to provide additional capacity for the future. The data showed that during the dredging program the turbidity around the Port of Weipa was generally driven by the natural conditions (predominantly the astronomical tide), with higher turbidity occurring during periods of larger range spring tides. The key findings from the turbidity data analysis are detailed below:

- the exceedance analysis of the in-situ measured benthic turbidity data shows increased duration exceedances over the dredging period of the 2021 maintenance dredging program at WQ4. However, based on the available information this is not expected to be a result of the dredging activity, but rather a change in the natural turbidity at this site (i.e. it is now naturally more turbid) since the turbidity threshold was defined. Based on this it is suggested that the benthic turbidity data at WQ4 are reviewed and the reason for the change in natural turbidity is investigated. Based on the findings of this the benthic turbidity threshold should be redefined at WQ4 to ensure it is representative of the natural turbidity which occurs at the site. The turbidity during the dredging period was well within the range of natural variability at WQ1 and WQ2;
- as expected, the dredging and placement activities associated with the Port of Weipa 2021 maintenance dredging program were found to result in visible plumes. Plumes were observed close to the dredger when dredging, adjacent to the South Channel, in the Approach Channel of the Inner Harbour and within the Albatross Bay DMPA. The size and concentration of the plumes was variable;
  - the largest plume was up to 6 km in length and 1 km in width with a concentration of around 15 mg/l, occurring adjacent to the South Channel due to ongoing dredging in the area during a period of neap tides. Satellite imagery indicated that this plume persisted for several days (although it is possible that natural processes and laden tankers in transit in the South Channel could also have contributed to this plume). A similar plume was also identified during a period of spring tides, although this plume was more elongate as a result of the faster spring tidal currents and was found to be due to natural processes as no dredging or bed levelling was undertaken in the South Channel at the time;
  - plumes in the Inner Harbour were approximately 1 to 2 km in length by 200 m in width with concentrations of up to around 15 mg/l; and
  - plumes in the DMPA from the placement of dredged sediment were typically less than 0.5 km in extent following placement on neap tides and less than 2 km in extent on spring tides and only persisted for short durations (of the order of hours). The observed plumes were consistent with placement by the TSHD Brisbane during previous annual maintenance dredging programs prior to the Albatross Bay DMPA being moved.
- all of the plumes resulting from maintenance dredging (including those from both dredging and placement) were found to remain close to where they were created. This shows that little net residual transport occurs in the region, this was also noted during the 2019 and 2020 maintenance dredging programs and as part of the Port of Weipa Sustainable Sediment Management assessment (PCS, 2019b, 2020b and 2020c). Based on this, it can be assumed that the majority of the sediment suspended by the maintenance dredging is subsequently redeposited close to where it was either dredged or placed;
- the Port of Weipa 2021 maintenance dredging program did not influence the regional turbidity in the area. The dredging only influenced the local turbidity close to where

dredging was undertaken in the Port and in the Albatross Bay DMPA. Natural variations in turbidity driven by the tide and wave conditions over the monitoring period were larger than the variations in turbidity due to the maintenance dredging; and

- due to high levels of cloud cover following the completion of the 2021 maintenance dredge program, it was not possible to determine how quickly the turbidity returned to natural conditions. However, based on information from the 2020 maintenance dredge program (PCS, 2020b), and imagery available four days post dredging, it is expected that the turbidity had returned to natural conditions within one to four days with no remaining areas with elevated turbidity due to the maintenance dredging and placement activities.

6. References

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