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DEPARTMENT OF PLANNING, INDUSTRY & ENVIRONMENT

# Towards safer swimming – Terrigal region

## Understanding turbidity and discolouration in Terrigal Bay

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**Authorship and citation**

This document was prepared by Peter Scanes.

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Cover photo: Deploying turbidity loggers in Terrigal Bay. Mick Orr/DPIE

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# Summary

The turbidity observed in Terrigal Bay cannot be attributed to one cause as there are multiple processes that can and do affect water clarity in the bay. Turbidity is affected by the presence of biotic (phytoplankton, organic detritus) and abiotic (sediment) factors. The primary factor is sediment, resulting from local causes such as sediment inputs from stormwater and lagoon discharges during rainfall events and sediment resuspension when wave heights exceed 1.5 metres. Elevated turbidity in Terrigal Bay can also be driven by larger-scale phenomena such as large sediment discharges from the Hawkesbury River, coastal algal blooms and upwelling events.

Water circulation modelling (Rao 2020) showed that the Haven retains about 10–20% of suspended sediments that come in from drains, the lagoon and other sources. The sediments at the Haven were found to have a higher proportion of fine particles (Johnson et al. 2020) which are readily resuspended by wave energy. Fine particles can stay in suspension for a day or two, but very fine particles may remain in suspension for up to a week.

Over the 2019–2020 summer the entire NSW mid-coast from Manning to south of Sydney was subject to naturally high chlorophyll levels. After the early February storms, a plume of sediment from the Hawkesbury River was evident all the way to Terrigal. Both these factors led to reductions in water clarity.

The available data do not support the idea that the Haven is an area of relatively high algal growth. Average chlorophyll concentrations in Terrigal Bay were below national guideline levels in May and June 2019, except for one site near the shore in front of the Marine Rescue building in the Haven.

There is no practical way to manage turbidity from resuspension of sediments already in Terrigal Bay. Reduction of the sediments in rainfall runoff could assist in managing future inputs, but this is an infrequent contribution in comparison to wave resuspension.

# Background

Central Coast Council, in partnership with Beachwatch, monitors and reports on recreational water quality along the NSW Central Coast in accordance with the National Health and Medical Research Council's *Guidelines for Managing Risks in Recreational Waters* (NHMRC 2008). Waters are tested for enterococci bacteria as an indicator of faecal contamination and graded to provide a guide to potential risk to human health from swimming.

During the past decade, Terrigal Beach has been routinely graded as Poor in the annual NSW State of the Beaches Report (DPIE 2019). This has led to considerable concern by local and state governments as well as beach goers, recreational swimmers, surfers, fishers and the broader community.

In January 2019, Central Coast Council commenced a water quality audit, expanding Beachwatch enterococci sampling at a single site (Terrigal Surf Club) to include 10 additional sites along Terrigal Beach from the Terrigal Lagoon mouth to the Haven, as well as sites at Forresters Beach to the north and North Avoca Beach to the south. Enterococci sampling was also undertaken at the major stormwater drain outlets discharging to Terrigal Beach and the Haven to assess their potential as sources of enterococci.

In February 2019, the NSW Government committed $500,000 to address water quality issues at Terrigal Beach and the Central Coast lagoons by undertaking a detailed, scientific audit and analysis of the microbial pollution sources to find solutions to improve water quality.

In April 2019, scientists from the NSW Department of Planning, Industry and Environment (DPIE) and Central Coast Council developed a detailed work program to expand council's water quality audit. Specific objectives of the NSW Government and council's joint water quality audit were to:

- determine if microbial contamination in nearshore waters and stormwater outlets along Terrigal Beach and the Haven and in Terrigal Lagoon was from human sewage or other animal (e.g. bird, dog) faeces
- determine if microbial contamination of Terrigal Beach and the Haven nearshore waters extended into deeper waters of Terrigal Bay
- determine how long contaminated stormwater remained in the bay
- assess pollutants in sediments at Terrigal Beach and the Haven
- assess the spatial extent and temporal persistence of water quality issues in Central Coast lagoons
- identify and prioritise major microbial source locations in Terrigal Beach, the Haven, Terrigal Lagoon and Avoca Lagoon catchments.

Extensive field work has been done by the NSW Government and Central Coast Council in conjunction with University of Technology Sydney. This is Report #6 and is one of nine technical reports that describe the results of the NSW Government's Terrigal Water Quality Audit research.

This research has led to the identification of the major biological sources of faecal bacteria and indicates regions in the sewage/stormwater drainage system where likely cross contamination occurs. Council can now focus on remediation of these priority areas, and has commenced works in Terrigal Beach, the Haven and lagoon catchments to improve water quality.

Due to the size and complexity of the task the entire work program could take up to six years to complete. If routine monitoring continues to detect unacceptable contamination, further investigation and remediation works may be required.

## Objectives

From commencement of the audit in January 2019, members of the public have expressed concern about the level of turbidity observed from time to time in Terrigal Bay.

The purpose of this report is to:

- determine the principal causes of observed turbidity in Terrigal Bay
- describe the mechanisms of turbidity increase relevant to Terrigal Bay and the Haven.

# What is 'turbidity'?

Turbidity is a measure of the scattering of light by particles suspended in the water. Those particles can be anything, but most commonly they are algal cells or sediment (dirt) particles. When particles are suspended in water, they immediately start to settle out again, but continued disturbance can keep particles suspended. Large dense particles settle quickly but very fine particles can remain suspended for days or weeks. Algal cells can maintain buoyancy through the presence of oils in the cells that reduce their density.

In real life, turbidity is perceived as cloudiness in the water and a lack of ability to see through the water. We use a 'nephelometer' to measure turbidity (which is why the units are 'ntu' – nephelometric turbidity units), but it can be measured just as well with a secchi disk, a simple device that provides a standardised means of measuring how far you can see through water (Figure 1).

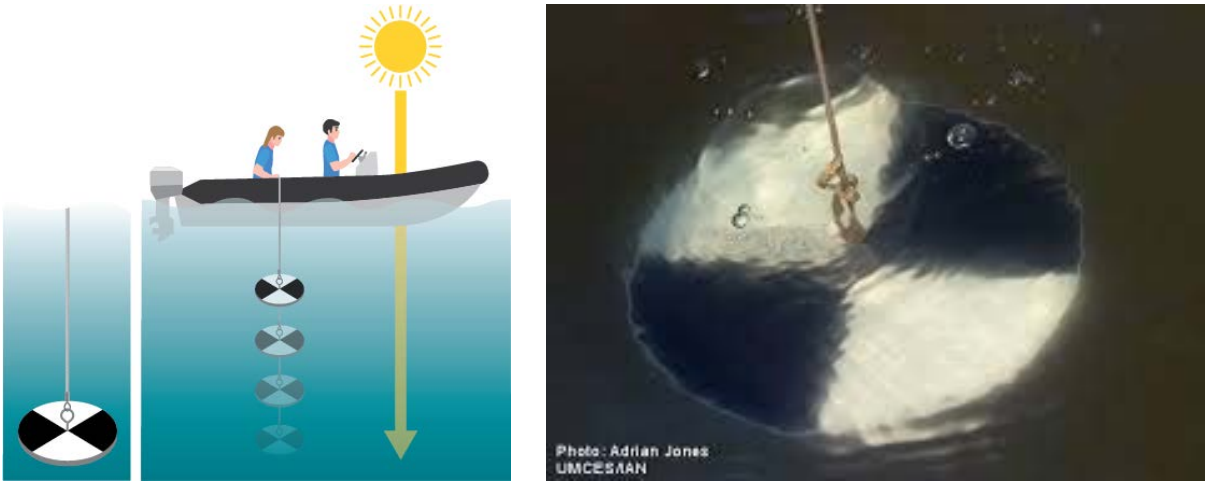



**Figure 1** **Secchi disk for measuring water clarity.**
The disk is lowered until it ceases to be visible. The depth where it is no longer visible is recorded. Photo on right: Adrian Jones/UMCESAAN

# What might be causing turbidity in Terrigal Bay?

As mentioned above, turbidity is the presence of particles in water. The particles can come from an outside source (drains, currents) or be generated locally (resuspension of particles from the seafloor). In this section we present the results of our limited research on possible sources of suspended particles in Terrigal Bay.

## Local causes (drains, waves, local sediments)

### Chlorophyll

Locally stimulated algal growth has been proposed as part of the reason why waters are not clear. Chlorophyll concentration in water is used as a measure of the abundance of algae. Chlorophyll was measured five times from 20 May to 11 June 2019 at the surf edge and at 5 metre and 10 metre water depths at sites between Forresters Beach and North Avoca Beach. The average chlorophyll concentration was found to be below national guideline values at all sites except one, and that site exceeded the guidelines by only a small amount in three out of five samples (Figure 2, left).

Chlorophyll concentrations (May and June 2019) tended to be higher and more variable in samples from the surf edge, highest at the Haven (H), and lowest at ‘7 drains’ (D) (top panel), but at 5 metre and 10 metre depths, concentrations at the Haven do not differ from other sites (Figure 2, right).

### Sediment characteristics

As part of the pollution investigations, we measured the size of the sediment particles on the seafloor.

We measured the percentage (by volume) of each sample that was in a range of size classes. Silt, muds, very fine and fine sands are all more easily resuspended by wave action. This can be seen in the wave zone at the Haven, which is often turbid, even with small waves.

Fine to very fine sediments dominated the seafloor from Terrigal surf club south to the Haven (Figure 3).

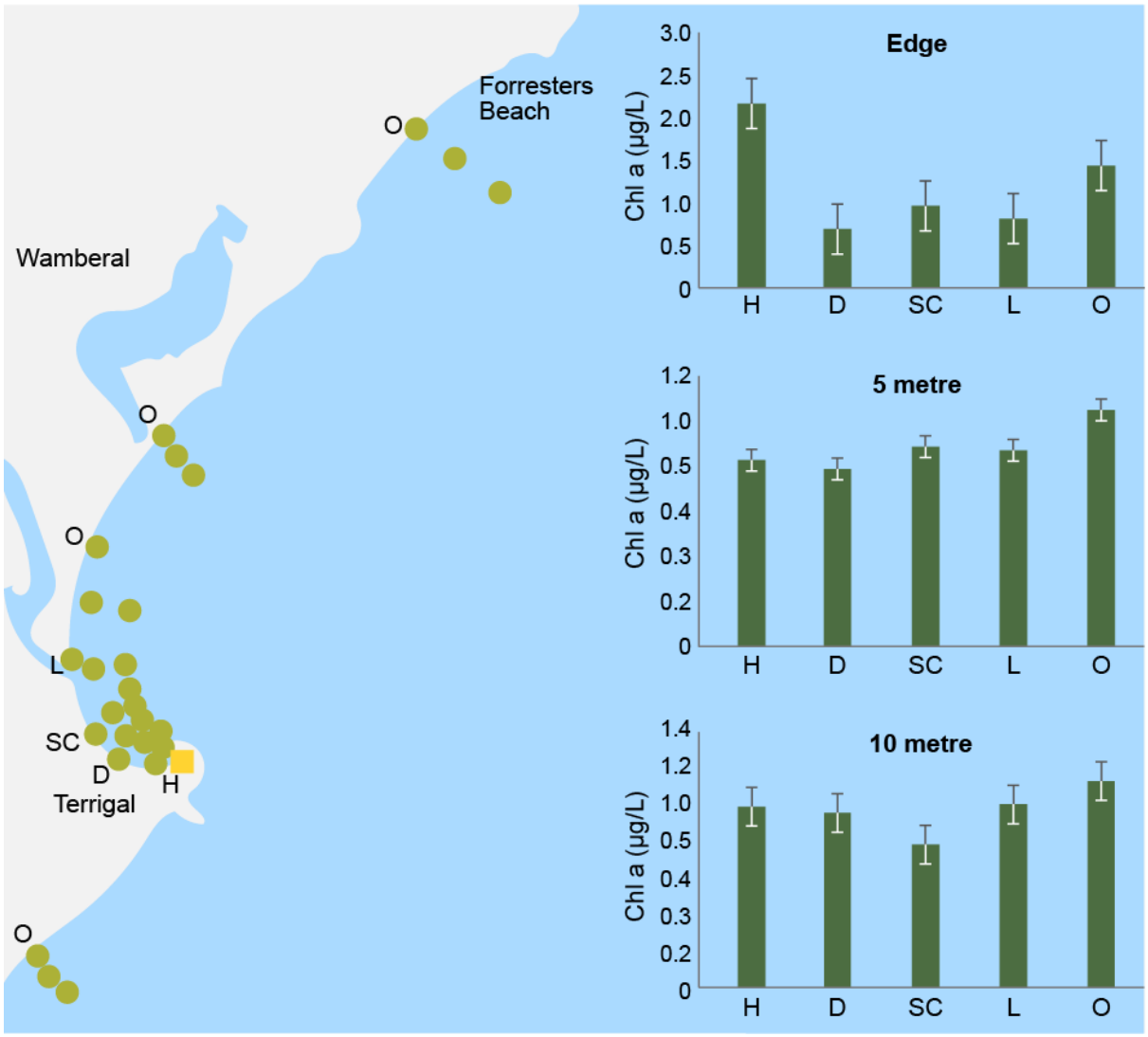



**Figure 2** **Left: Average chlorophyll concentrations were less than guideline values (green circles) in May and June 2019, except for one shoreline site in the Haven (yellow circle). Right: Chlorophyll concentrations (mg/L) in May and June 2019 in samples from the surf edge, 5 and 10 m depths**

Key: H – Haven; D – 7 drains; SC – surf club; L – beach near lagoon entrance; O – control sites (North Avoca, Wamberal, Forresters beaches).

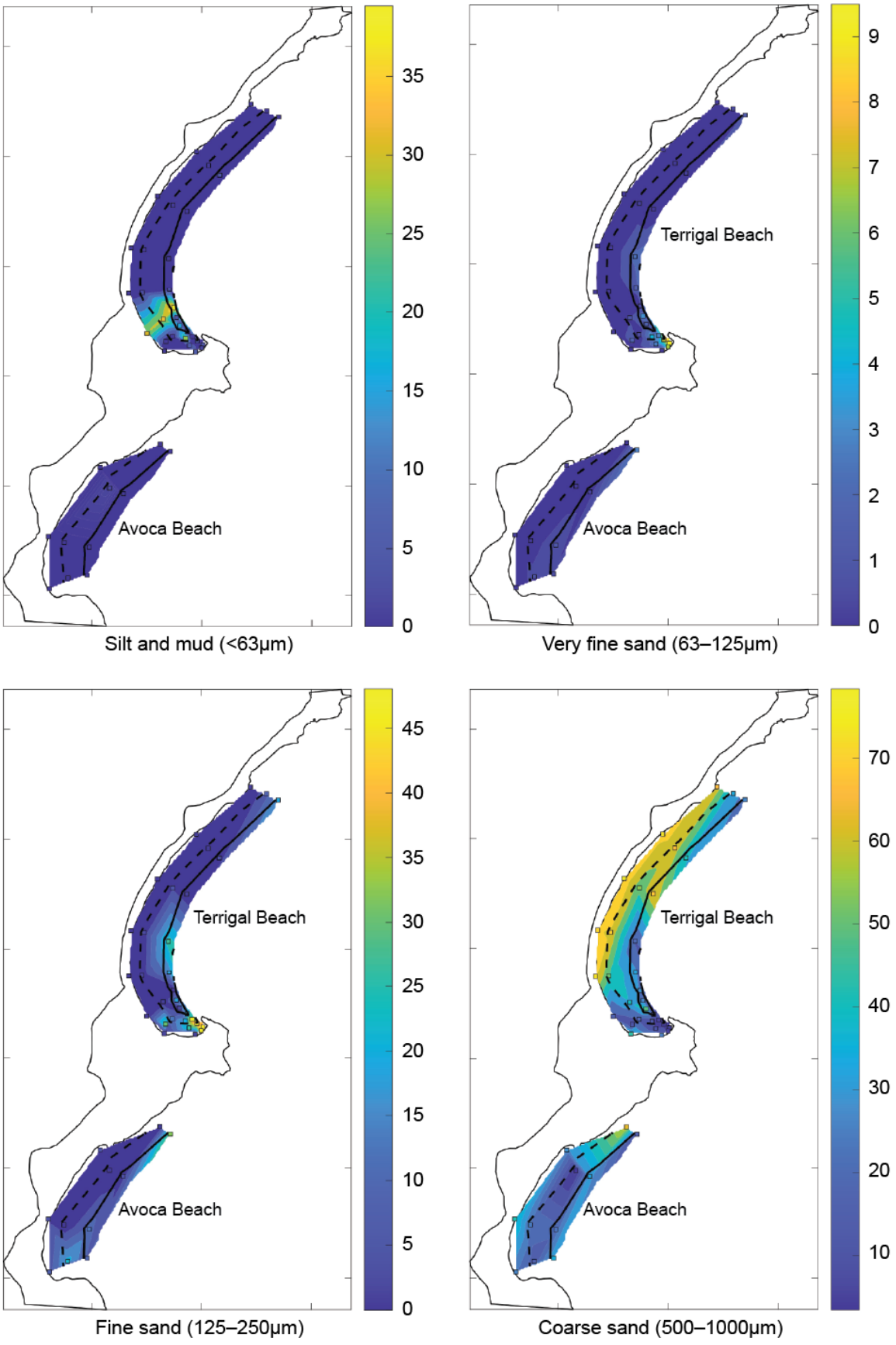



**Figure 3** **Silt, mud and fine sands accumulate in and near the Haven (light colours mean a high percentage of the sample was composed of that type of sediment), with coarse sands in high energy wave zones further north on the beach**

## Linking water clarity observations from Terrigal Haven Supporters group to physical drivers

There is no evidence that the drains (e.g. 7 drains) discharge turbid water other than after rainstorms, but observations from swimmers show that turbidity occurs in dry as well as wet periods. We have used observations from deployed instruments, swimmers (courtesy of Terrigal Haven Supporters group (THS)) and modelling outputs to investigate what natural processes are occurring when turbidity is observed. This work shows that most of the time the turbidity in Terrigal Bay is driven by local factors such as elevated wave heights and directions, lagoon entrance opening and water residence times (Figure 4).

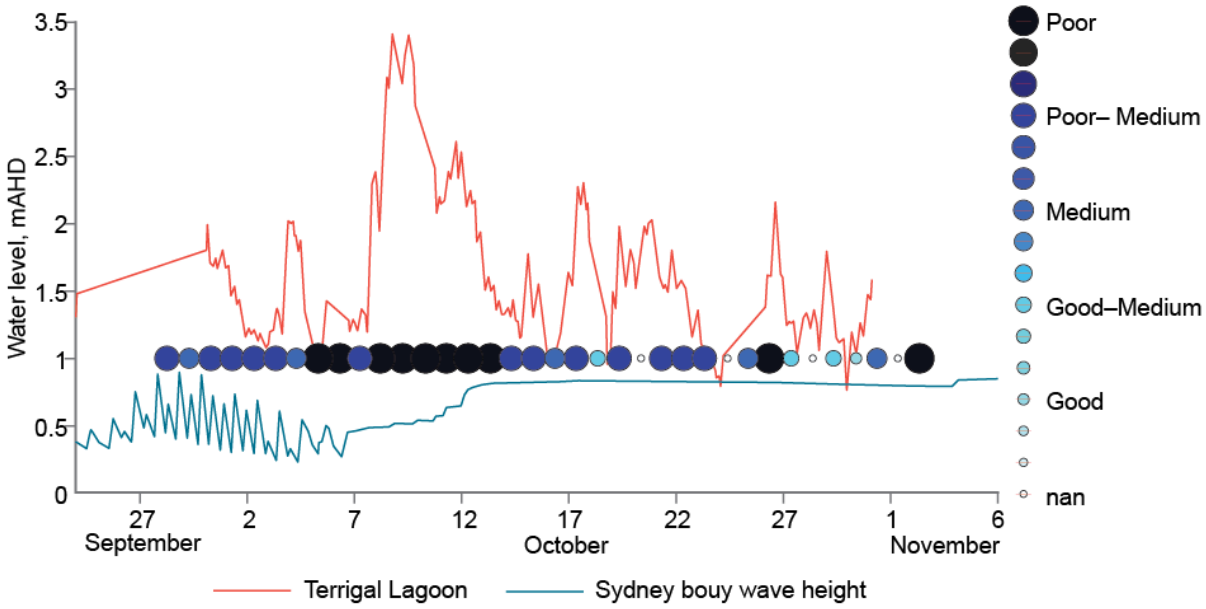



**Figure 4** **Comparison between lagoon water levels (Terrigal Bridge), significant wave heights (Sydney Buoy) and water clarity observations by THS swimmers (poor, medium or good) over the October 2019 period**

## Wave heights and lagoon openings

Swimmer observations of poor water clarity appear to be linked to periods when the lagoon was open (prior to 7 October) and/or the wave height at the Sydney wave buoy was greater than 1.5 metres. Both processes, for different reasons, can elevate the turbidity of the bay. Lagoons discharge fine sediment loads that had accumulated in the lagoon, while elevated waves can resuspend fine sediments from the seafloor. All the poor and medium/poor THS water clarity observations occurred while the entrance was opened, or after high waves. Sometimes poor visibility will linger after high waves because very fine particles can remain in suspension until high waves occur again.

The intermittent peaks of turbidity that increase quickly (red arrows in Figure 5) and then decline more slowly (green arrows) can clearly be seen in the data collected to validate the ocean processes model built by DPIE. On 11 November 2019 turbidity rose quickly, but then declined slowly, until an event on 12 November brought another rapid increase. The greater turbidity measured near the seafloor demonstrates that turbidity originates there and only a fraction of it is observed at the surface.

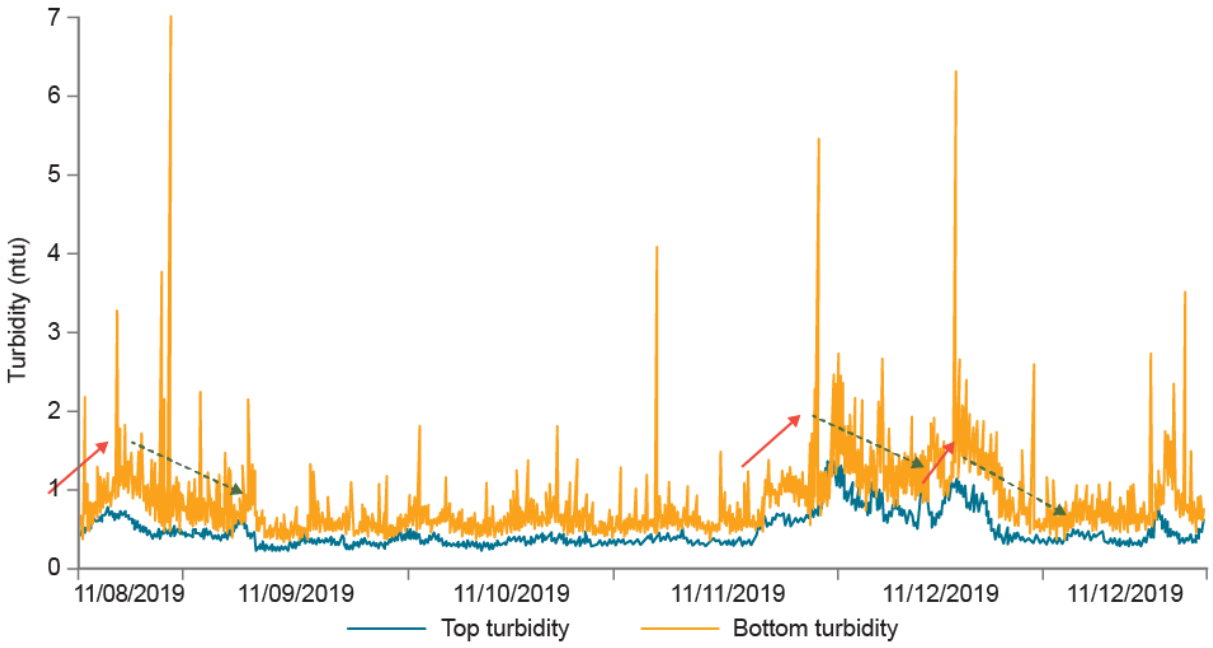



**Figure 5** **Turbidity in the Haven near the seafloor (orange) and 0.5 m below the surface (blue)**

Red arrows show rapid increases in turbidity and green arrows the slower reductions.

## Swell direction

The swell direction governs the residence time of particles inside the Terrigal Haven (Figure 6):

- Southern swell – The Broken Head headland breaks this swell, which creates a calm shadow from Broken Head to Northern Wamberal Beach (Spoon Bay). Further to this, inside the Haven, the current speeds are very calm and in eddy circulation. This results in the gradual release of trapped particles from inside the Haven.
- South-eastern swell – The swell refracts around Broken Head and into the bay region. This creates a smaller shadow compared to the southern swell. There is a transient eddy formation that is forced by the current around Broken Head and similar wave-driven currents from North Wamberal. The transient formation and decay of the eddy results in a step-like release of particles trapped inside the Haven.
- North-eastern swell – The swell is broken by Bateau Bay, which creates a shadow from Wamberal to Yumbool point. This also drives a strong southward current along the beach that flows into the Haven and returns northward, driven by the northward current around Broken Head. The current around Broken Head is strong and drives a secondary current along the Haven beach, which results in an eddy flow. The Haven becomes a bit isolated and particles tend to reside longer after an initial exodus.

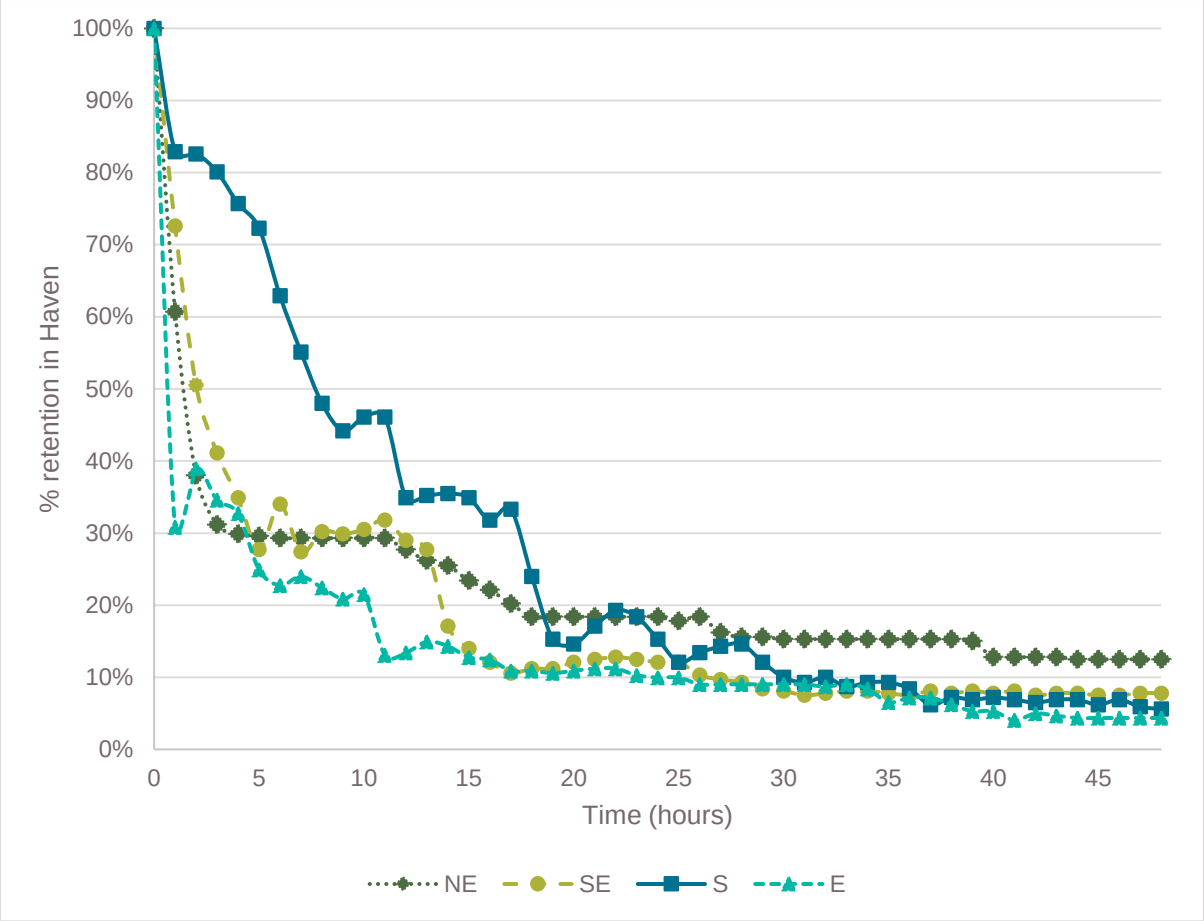



**Figure 6** **A time series of the residence of particles as a function of swell direction**
The vertical axis is the fraction of particles that are in the initial release area.

The swells that create strong eddies in the Haven tend to release particles in bursts, followed by periods of retention; however, in any case, about 80% of the released particles are flushed out of the Haven within 24 hours. There is a background level of retained particles in all cases, that remained at the 10–20% level (Rao 2020).

If after a storm, the significant wave heights drop, there is the chance that the circulation inside the Haven will be very slow and the residence times would increase. Further, winds from the easterly directions can push particles released back towards the shore, where the return current can drive the particles back into the Haven.

# External causes of turbidity

As well as locally generated sources of turbidity from the lagoon and sediment resuspension, turbidity can be influenced by regional-scale processes such as upwelling-driven algal blooms and flood flows from the Hawkesbury River.

## Regionally elevated chlorophyll

The MODIS satellite is operated by NASA and the Australian Integrated Marine Observing System (IMOS) uses information from MODIS to map the concentrations of chlorophyll in Australia's oceans (see IMOS OceanCurrent maps). MODIS only provides clear images when the skies are clear. The few clear images over the summer period indicate there was a persistent elevated chlorophyll bloom along the Central Coast (Figure 7).

## Flood plume

Satellite imagery also shows the flood plume from the Hawkesbury River reached well past Terrigal and persisted until at least mid-March 2020 (Figure 8).

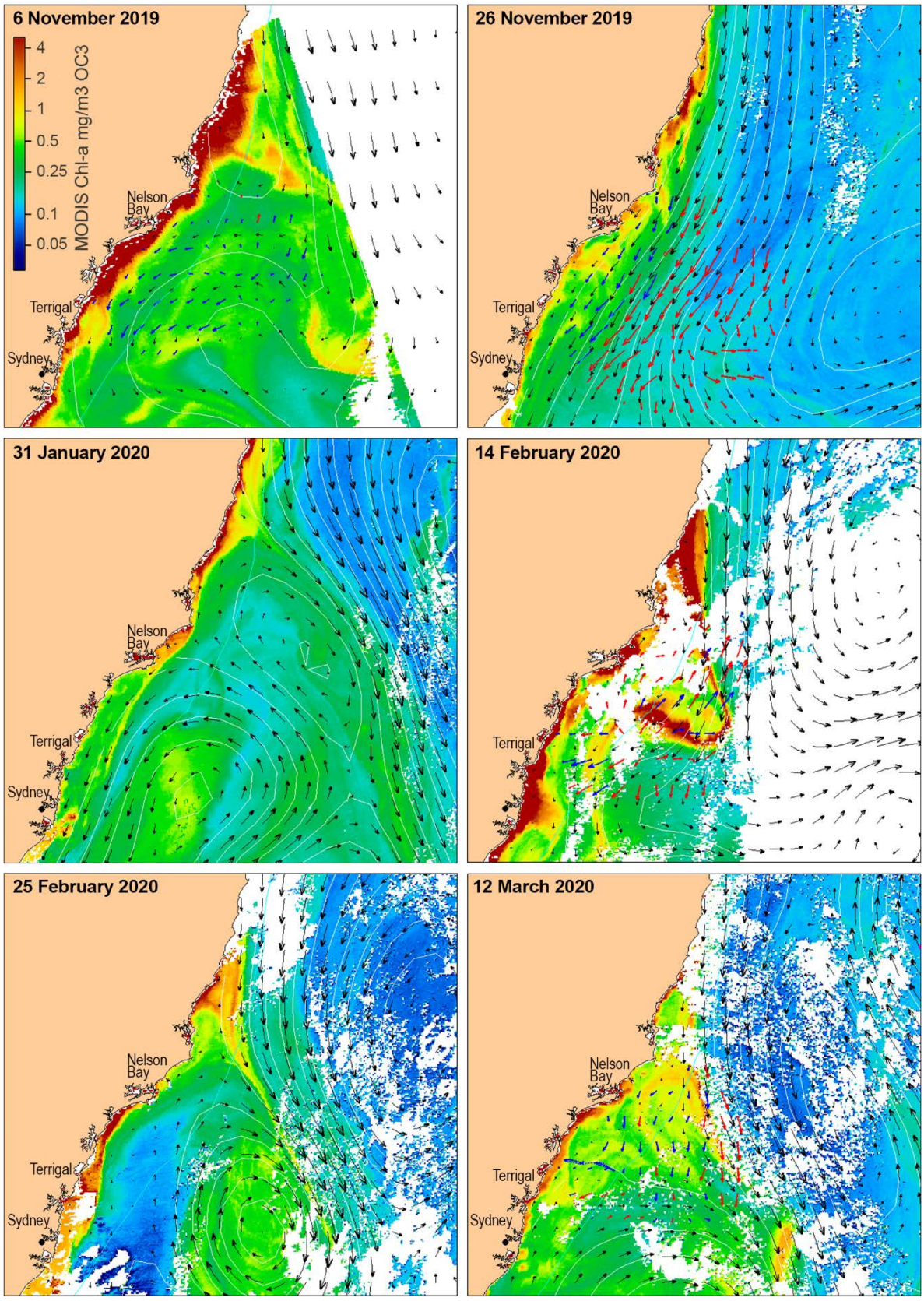
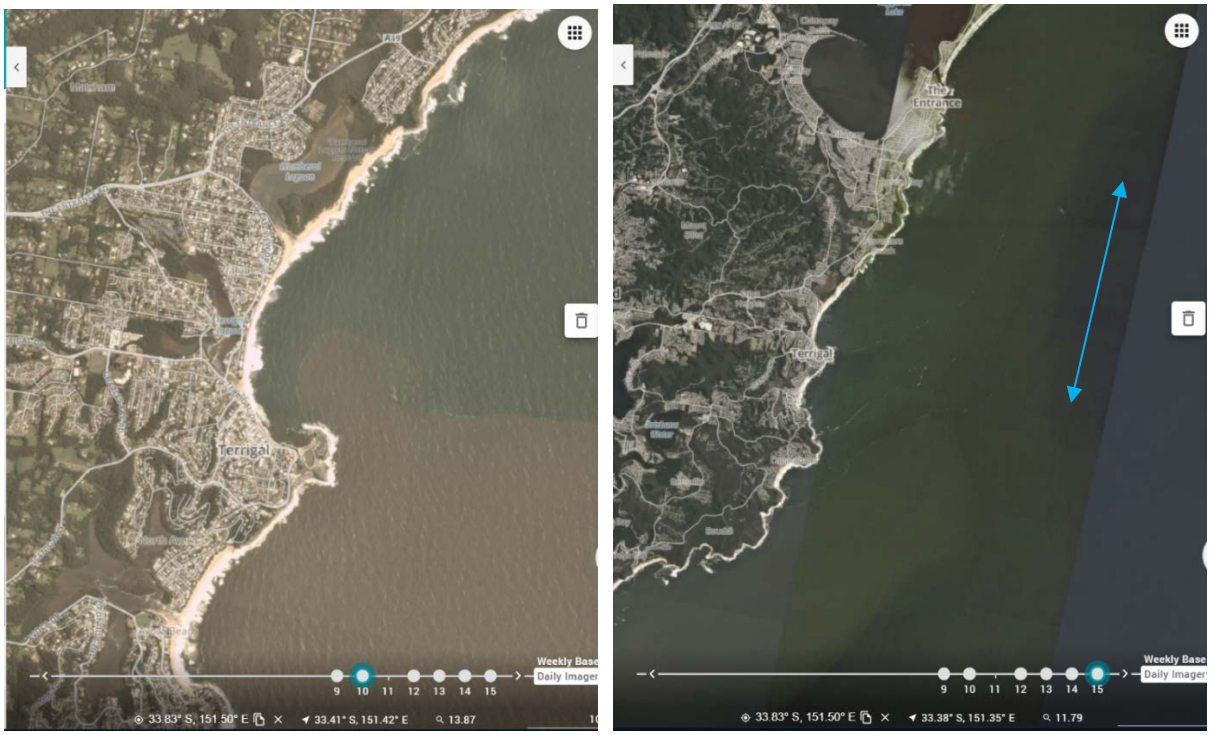
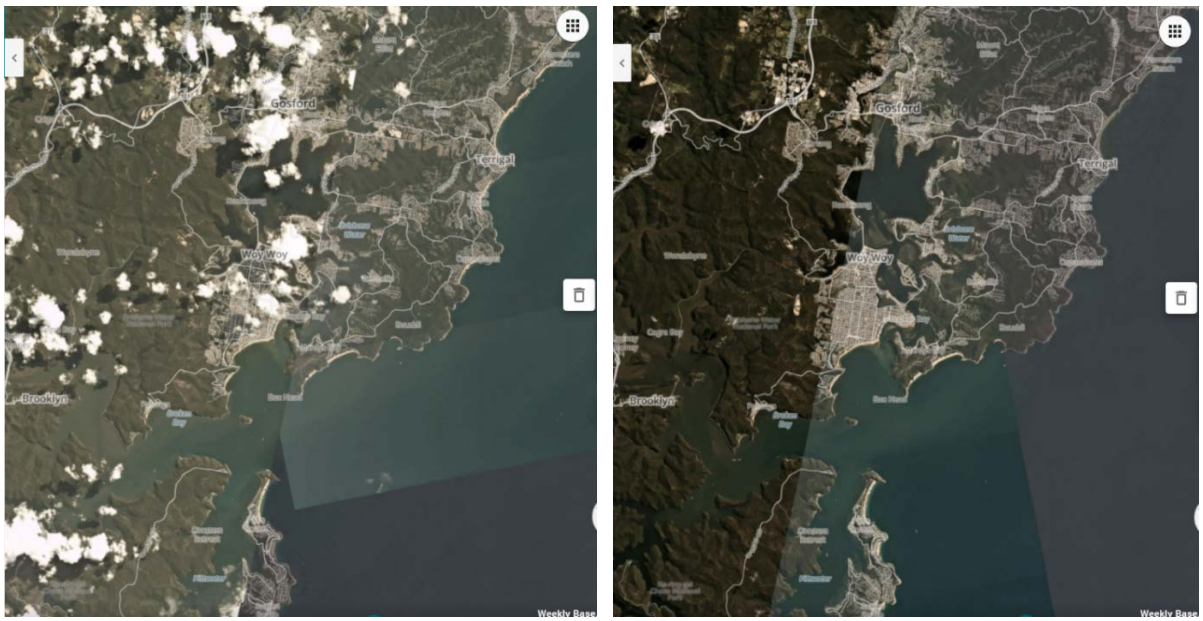



**Figure 7 IMOS ocean chlorophyll images summer 2019–2020**




10 February 2020 15 February 2020




11 March 2020 13 March 2020

**Figure 8** **True colour satellite images show turbid plume from Hawkesbury extends past Terrigal for over 5 weeks from the rains on 7 February 2020**

Note the clear ocean water many kilometres offshore (blue arrow) in the 15 February image.

# Is it possible to manage turbidity in Terrigal Bay?

In the past year, which is the only one we have data for, it is clear the turbidity that has been experienced is mainly a consequence of frequent resuspension of fine sand from the seafloor plus occasional wet weather inputs from Terrigal Lagoon and 7 drains, and in summer, regional-wide algal blooms and the flood plume from the Hawkesbury River.

All of these sources are part of normal processes (rainfall runoff and ocean processes), though the amount of sediment in the Hawkesbury flood plume and from Terrigal Lagoon and drains is more than natural due to past poor land management practices. This could influence the amount of fine sediment on the seafloor. Creation of the Haven boat harbour, with the resultant reduction in wave energy, also contributes to accumulation of fine sediments in the Haven.

Given the majority of turbidity in the Haven results from natural processes resuspending sediment from previous large-scale events, albeit there may be more to disturb, there is no practical way to manage turbidity from resuspension of sediments already in Terrigal Bay. Reduction of sediments in rainfall runoff could assist in managing future inputs, but this is an infrequent contribution in comparison to wave resuspension.

There is no evidence in the data from May to June 2019 of persistent algal enrichment in the Haven, except for three occasions in the immediate vicinity of a single nearshore site at the eastern end of the Haven Beach. These appear to be isolated events rather than a persistent problem.

# References

Johnson C, Potts J and Giardina M 2020, *Towards safer swimming – Terrigal region: Terrigal Bay sediment contaminants report*, NSW Department of Planning, Industry and Environment, Parramatta, NSW.

Rao 2020, *Towards safer swimming – Terrigal region: Calibration and verification of a 2D hydrodynamic model for Terrigal Bay*, NSW Department of Planning, Industry and Environment, Parramatta, NSW.